Building evidence for conservation globally

Journal of Threatened Taxa

Open Access

10.11609/jott.2023.15.12.24291-24450
www.threatenedtaxa.org

26 December 2023 (Online & Print)
15(12): 24291–24450
ISSN 0974-79t07 (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

43/2 Varadarajulu Nagar, 5th Street West, Ganapathy, Coimbatore, Tamil Nadu 641006, India
Registered Office: 3A2 Varadarajulu Nagar, FCI Road, Ganapathy, Coimbatore, Tamil Nadu 641006, India
Ph: +91 9385339863 | www.threatenedtaxa.org
Email: sanjay@threatenedtaxa.org

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: The critically endangered *Lilium polyphyllum* in watercolour and acrylics. © Aishwarya S Kumar.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 December 2023 | 15(12): 24291–24298

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

https://doi.org/10.11609/jott.8073.15.12.24291-24298

#8073 | Received 25 June 2022 | Final received 17 November 2023 | Finally accepted 29 November 2023

OPEN ACCESS

ARTICLE

Patterns of livestock depredation by carnivores: Leopard *Panthera pardus* (Linnaeus, 1758) and Grey Wolf *Canis lupus* (Linnaeus, 1758) in and around Mahuadanr Wolf Sanctuary, Jharkhand, India

Shahzada Iqbal [1] & **Orus Ilyas** [2]

[1,2] Department of Wildlife Sciences, Aligarh Muslim University, Aligarh, Uttar Pradesh 202002, India.
[1] shahzada90@yahoo.com (corresponding author), [2] orus16@gmail.com

Abstract: Large predator attacks on livestock play a significant role in fuelling conflicts between stakeholders. Effectively managing these conflicts requires a thorough comprehension of locations susceptible to livestock depredation, and the underlying factors influencing such incidents. The recent spread of Grey Wolf *Canis lupus* and Leopard *Panthera pardus* into agriculturally dominated areas in Mahuadanr has resulted in increased proximity between these predators and livestock. We investigated the patterns of livestock depredation in and around Mahuadanr Wolf Sanctuary in the Indian state of Jharkhand using Leopard and Grey Wolf depredation data collected from 2019 to 2021 by the wildlife authorities of the sanctuary. A total of 74 heads of livestock were reportedly killed by Leopard and Grey Wolf in the study area between 2019 and 2021. The Mahuadanr forest beat experienced most of the livestock depredation incidents in 2021, while the maximum depredation incidents happened in Belwar and Lodh sub-beats by Leopard and Grey Wolf, respectively. Livestock depredation incidents varied temporally. Depredation by Leopard occurred more often during evenings (n = 22) and by night (n = 14), but less often during mornings (n = 4). Seasonal livestock depredation by both predators was not statistically significant in our study area. Around Mahuadanr Wolf Sanctuary, hotspots for livestock depredation were identified. The utilization of these findings can facilitate a comprehensive understanding of various aspects related to livestock depredation, while also supporting the design and implementation of effective, long-term conservation strategies for both species.

Keywords: Compensation data, depredation hotspots, financial benefits, large predators, livestock enclosures, poverty, red corridor, temporary relief.

Editor: Angie Appel, Wild Cat Network, Bad Marienberg, Germany.

Date of publication: 26 December 2023 (online & print)

Citation: Iqbal, S. & O. Ilyas (2023). Patterns of livestock depredation by carnivores: Leopard *Panthera pardus* (Linnaeus, 1758) and Grey Wolf *Canis lupus* (Linnaeus, 1758) in and around Mahuadanr Wolf Sanctuary, Jharkhand, India. *Journal of Threatened Taxa* 15(12): 24291–24298. https://doi.org/10.11609/jott.8073.15.12.24291-24298

Funding: There was no funding for this research project.

Competing interests: The authors declare no competing interests.

Author details: Shahzada Iqbal (SI)—research scholar, currently enrolled in the PhD programme at Aligarh Muslim University in the Department of Wildlife Sciences. Primary academic interests are Political ecology and Human-Wolf interaction. Current project is in the Mahuadanr Wolf Sanctuary in Jharkhand. Orus Ilyas (OI)—associate professor in the Department of Wildlife Sciences at Aligarh Muslim University, India. She has studied mammals in India since 1995 and has worked in the high-altitude Himalayas for more than 25 years.

Author contributions: Concept & Design: SI & OI; Supervision: OI; Data collection: SI; Analysis: SI & OI; Manuscript writing: SI; Manuscript review & comments: SI & OI.

Acknowledgements: We thank all staff members of Palamau Tiger Reserve, Palamau, Jharkhand for their support throughout the course of field work. We thank Jharkhand Forest Department for permission and for facilitating this work. We are grateful to Shri Mukesh Kumar, IFS, Deputy Director, Palamau Tiger Reserve (South Division) for his valuable inputs and continuous support. We are also thankful to Shri Manish Kumar Bakshi and Devanshu Arun Agarwal for useful discussions which helped considerably in improving the manuscript.

INTRODUCTION

Livestock depredation by large carnivores and the resulting retaliatory killing represent pressing conservation concerns on a global scale (Madhusudan & Mishra 2003; Thirgood et al. 2005; Treves et al. 2006). Large predators can have significant economic implications at the local level, particularly in impoverished rural areas where households are least equipped to bear such expenses. These costs can hinder the efforts of local communities, particularly traditional pastoralists, to alleviate poverty (Dickman et al. 2011). Negative human-carnivore interactions significantly contribute to large predator reductions, and reducing these interactions is critical to sustain sustainable carnivore populations (LeFlore et al. 2019). Livestock predation is a significant element influencing the effective coexistence of large carnivores and humans from pastoral villages (Decker et al. 2002; Habib et al. 2015).

The Leopard *Panthera pardus* has been assessed as 'Vulnerable' on the IUCN Red List of Threatened Species, and there is evidence for a decline of the global population (Stein et al. 2020). Currently, the Leopard occupies just around 25% of its historical range (Jacobson et al. 2016). Additionally, it demonstrates high adaptability and lives in diverse habitats such as tropical rainforests, deserts, and temperate regions (Kitchener 1991).

The Indian Leopard subspecies *P. p. fusca* exhibits a wide distribution across various habitats throughout India, with the exception of the arid Thar desert and Sundarban mangroves (Prater 1980; Daniel 1996). Within forested landscapes in India, it plays a crucial role as a major predator and coexists with other apex predators such as the Tiger *P. tigris*, Lion *P. leo,* and Dhole *Cuon alpinus* (Jhala et al. 2021). The Leopard is remarkably adaptable when compared to other large carnivores in terms of its habitat preferences and dietary requirements, as it can survive in agro-pastoral landscapes, plantations, and even in close proximity to human settlements, both rural and urban (Nowell & Jackson 1996). In areas where it coexists with humans in a shared landscape, it is likely that some predation on domestic animals occurs (Athreya & Belsare 2007).

Furthermore, in India, the Grey Wolf *Canis lupus* inhabits the dry and semi-arid plains and some forested parts of central India and the Terai plains (Jhala 2003; Dey et al. 2010; Sharma et al. 2019). It also occurs in open grasslands, shrub regions, and rocky slopes, as well as moist forested habitats in Odisha, Bihar, Jharkhand, and portions of West Bengal (Shahi 1982). It thrives on somewhat rocky, undulating terrain with minimal foliage cover (Jhala & Giles 1991; Mahajan & Khandal 2021).

The predation on livestock is a primary factor driving human-wolf interaction worldwide, especially concerning the Grey Wolf (Treves et al. 2002; Kaczensky et al. 2008; Ambarlı 2019; Hamid et al. 2019). The interaction between wolves and livestock poses a significant challenge in wildlife management, particularly in Asia, where Grey Wolf populations extensively overlap with livestock husbandry (Reading et al. 1998; Dou et al. 2014; Ekernas et al. 2017; Mahajan et al. 2021). To ensure the conservation of large carnivores, the government has started many compensation schemes for local people for the depredation of their livestock. The majority of large carnivore population lives within protected areas (PAs) (Bargali & Ahmad 2018). PAs act as sources, whereas adjoining forests and corridors outside PAs aid in the spread of large as well as other predators towards sinks (Bargali & Ahmad 2018). As a result, habitat outside protected areas ensures long-term demographic and genetic heterogeneity (Jhala et al. 2015; Bargali & Ahmad 2018).

Communities living near PAs, on the other hand, face restricted historical rights, constraints on traditional livelihoods, and a minor participation in maintaining and safeguarding such protected places (Maikhuri et al. 2002; Negi & Nautiya1 2003; Chan et al. 2007; Miller et al. 2011). Livestock depredation by both Grey Wolf and Leopard in and around the Mahuadanr Wolf Sanctuary can have significant implications for the tribal villagers residing in the area, who heavily depend on their livestock as a major source of livelihood (Mahaling & Kumar 2021). These incidents of predation may result in a negative perception among the villagers, as the loss of livestock not only leads to economic hardships but also generates tensions and conflicts between humans and wildlife (Mekonen 2020). It is imperative to acknowledge the consequences of depredation patterns against the inhabitants in and around the PAs to balance conservation goals (Terborgh & Peres 2002; Naughton-Treves et al. 2005; Bruyere et al. 2009; Karanth & DeFries 2010).

The objective of this study is to understand the livestock depredation patterns by Grey Wolf and Leopard in and around Mahuadanr Wolf Sanctuary. The landscape sustains a substantial population of Grey Wolves, estimated to be 55 individuals in the year 2010 (Mahaling & Kumar 2021). Furthermore, the Leopard population in the landscape was estimated at approximately 36±9 individuals in 2018 (Jhala et al. 2021). Hence, proper carnivore management initiatives are necessary in and outside Mahuadanr Wolf Sanctuary, and in adjoining territorial forest divisions facilitating large carnivore movement across the landscape. Moreover, wildlife conservation is a difficult challenge in India's red corridor, i.e., the eastern, central, and southern regions of the country where the Naxalite-Maoist insurgency is most active (Prasad 2015). Mahuadanr Wolf Sanctuary falls within the jurisdiction of the Latehar district of Jharkhand, which is also part of the red corridor (Press Information Bureau 2019). The Red Corridor region of India is often perceived as one of the most underdeveloped areas in the country. The socio-economic progress in this region has been highly unsatisfactory since independence, contributing to the Maoists' ability to gain support from the marginalized communities residing there (Mukhopadhyay & Banik 2013). Livestock depredation by the large carnivores contributes to poverty (Dickman et al. 2011). It is critical to understand every detail about the causes of poverty, as this will ultimately aid in wildlife conservation.

Study area

Mahuadanr Wolf Sanctuary is located in Mahuadanr Block of Latehar district in the state of Jharkhand and it is administered under Palamau Tiger Reserve Circle (Mahaling & Kumar 2021). The sanctuary was declared in 1976 vide Government of Bihar (Mahaling & Kumar 2021). The smallest administrative unit in the study area is sub-beat (Mahaling & Kumar 2021). The sanctuary falls mainly into two beats, namely Aksi and Mahuadanr of the Mahuadanr range (Mahaling & Kumar 2021). A small forest area of the Baresanr range of Chetna sub-beat is also included in the sanctuary (Rawat 2013). The Aksi beat consists of five sub-beats, namely Sarnadih, Aksi, Lodh, Parewa, and Pakardih, encompassing 18 protected forest areas (Mahaling & Kumar 2021). The Mahuadanr beat consists of three sub-beats covering six protected forest areas. The total forest area in the sanctuary is 63.256 km^2 in size (Mahaling & Kumar 2021). The sanctuary borders hill ranges of various elevations, and the western hilltops are flat with an elevation of 1,170 m (Rawat 2013). The major parts are Chiro Pat, Orsa Pat, and Kukud Pat (Rawat 2013). The isolated hills are also nearer to valleys (Rawat 2013). Burha River is the major river draining the Mahuadanr valley (Mahaling & Kumar 2021). The drainage system follows south to north and forms tributaries of the Son river (Mahaling & Kumar 2021).

There are 25 villages adjacent to the sanctuary, and the remaining 72 villages are in the sanctuary's buffer zone (Mahaling & Kumar 2021) with approximately 14,000 households (Census of India 2011). The population constitutes 78.68% of scheduled tribes and 3.2% of scheduled castes population (Census of India 2011).

The climate in the region is characterized as humid and subtropical, featuring three distinct seasons: a hot and dry summer, a cold winter, and a rainy season (Mahaling & Kumar 2021). The cold season typically spans from November–March, followed by the summer season from April–mid-June, and the rainy season from mid-June–mid-October (Rawat 2013). The topography of the area, a cup-shaped valley surrounded by hills, contributes to high precipitation of 1,300 mm annually, of which about 90% occurs during the monsoon season from June–October (Rawat 2013).

MATERIAL AND METHODS

We examined the Leopard and Grey Wolf depredation data collected from 2019 to 2021 by the wildlife authorities of the Mahuandanr Wolf Sanctuary. Depredations on livestock such as Water Buffalo *Bubalus bubalis*, Cattle *Bos taurus*, Goat *Capra hircus* were included in the data. We examined the Mahuandanr Wolf Sanctuary's wildlife section records on livestock in the sanctuary area. The wildlife section conducts annual wildlife surveys twice in a year on various species (Mahaling & Kumar 2021).

We examined the applications and compensation payments for livestock losses to better understand the Mahuandanr Wolf Sanctuary's wildlife section acceptance and denial trends and cross-check figures. To avoid inflated allegations, the sanctuary's officials went to the depredation scene within 24 hours of the incident to determine whether a Leopard or a Grey Wolf killed the livestock or whether it died naturally. We also checked the maximum number of depredations, both by village and community-wise.

Our data is completely based on records of compensation paid to local people by the wildlife section of Mahuandanr Wolf Sanctuary. Chi-square test was used to determine the seasonal difference in livestock depredation. Statistical analysis was done using SPSS version 24 and MS Excel version 2021. The spatial analyst tool of QGIS (Version 2.18.25- Pisa, QGIS Development Team 2018) was used to map the kill sites in and around Mahuadanr Wolf Sanctuary.

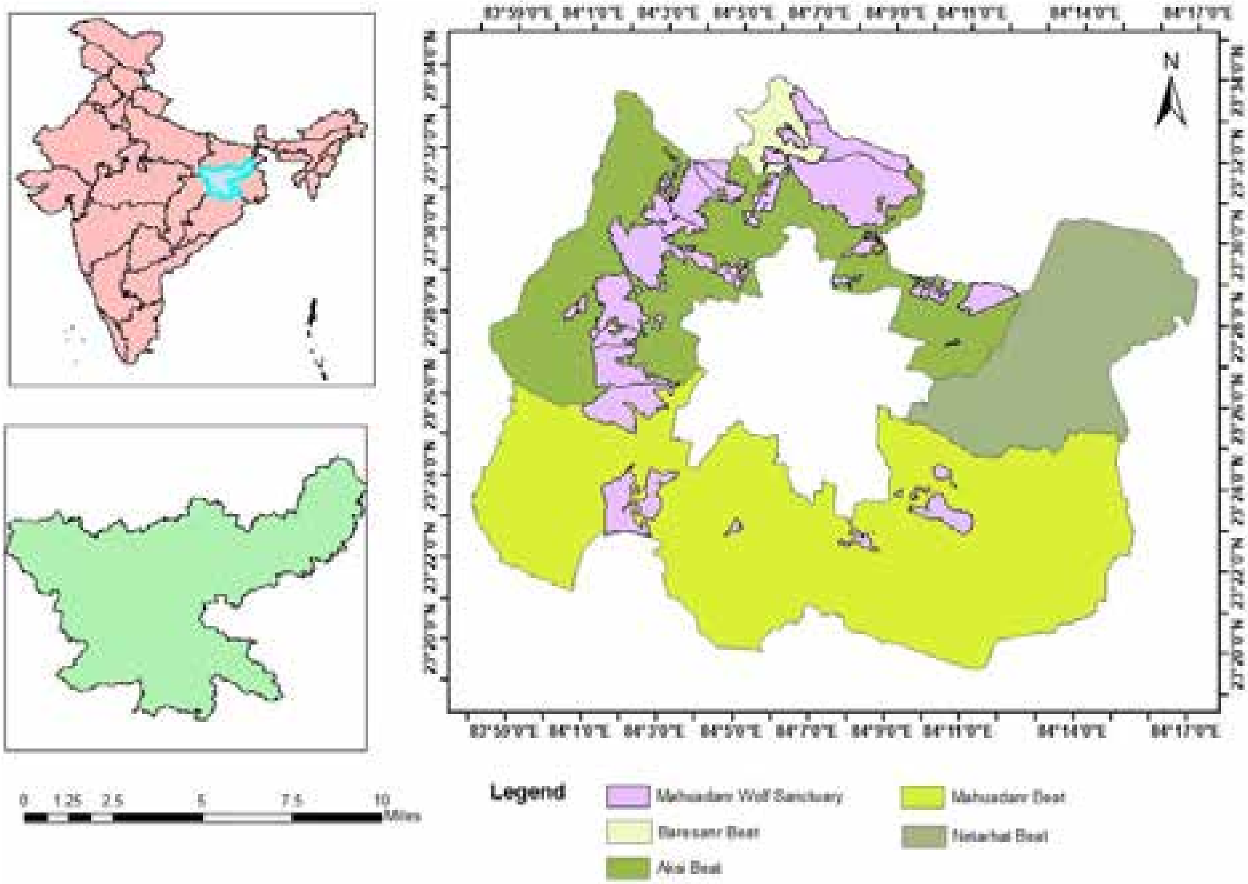

Figure 1. Map of the study area Mahuadanr Wolf Sanctuary and beats of Mahuadanr Range.

RESULTS

Between January 2019 and November 2021, 74 livestock depredation incidents were reported in the villages surrounding Mahuadanr Wolf Sanctuary. These encompassed 21 incidents in 2019, 13 in 2020, and 40 in 2021. The Leopard was responsible for 40 incidents, and the Grey Wolf for 34 incidents.

A higher number of livestock depredation incidents were reported in Mahuandanr beat (n = 49), followed by Netarhat (n = 14) and Aksi (n = 11). At the same time, the Belwar sub beat (n = 25), followed by the Lodh sub beat (n = 19) of the Mahuadanr beat experienced the maximum number of incidents. Livestock depredation incidents around Mahuadanr Wolf Sanctuary indicated that Leopards were the main predator in the Belwar sub-beat (n = 17) and Grey Wolf (n = 16) in the Lodh sub-beat. In contrast, the Aksi sub-beat found a minimum number of incidents. A comparison of livestock depredation incidents across the seasons revealed that depredation by Leopards and Grey Wolves was more during the winter season (n = 57) than the summer season (n = 9), and very few incidents in the monsoon season (n = 8). There was no statistical significance between the predators with respect to seasonal livestock depredation.

Livestock depredation incidents by Leopards and Grey Wolves differed temporally. Leopards preyed on livestock more often during the evenings (n = 22) than by night (n = 14) and in the mornings (n = 4). Grey Wolves preyed on livestock more often in the mornings (n = 14) than during the evenings (n = 11) and at night (n = 9). There was a significant difference in livestock depredation by Leopard and wolf among various temporal durations (χ^2= 9.88, df = 6, P<0.05).

The pattern of livestock depredation differed between the Leopard and Grey Wolf. Leopards mainly preyed upon Cows (n = 23; 57.5% of all), followed by Water Buffalo (n = 9 ; 22.5%), and others (Goat and Ox, n = 8; 20%), whereas Grey Wolf preyed mostly on Goats (n = 34; 100%).

Dujardin and Chutia villages of Belwar sub-beat recorded the maximum cases of Leopard depredation. In contrast, the Lodh, Tewahi, and Mirgi villages of Lodh sub-beat have a maximum of Grey Wolf depredation

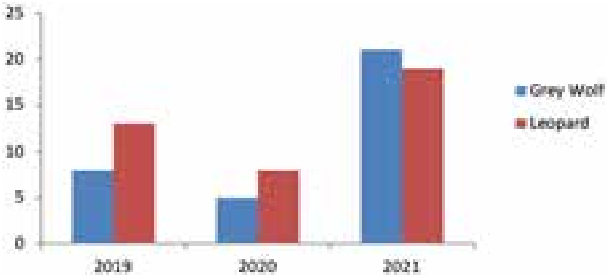

Figure 2. Livestock depredation by Leopard and Grey Wolf between 2019 and 2021.

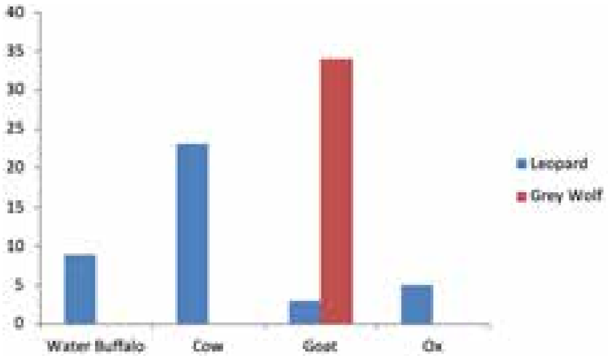

Figure 3 Livestock killed in and around Mahuadanr Wolf Sanctuary between 2019 and 2021.

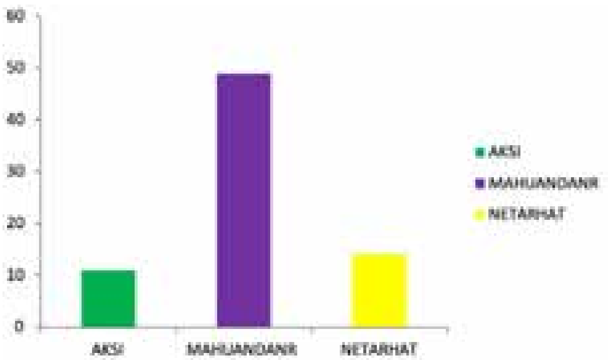

Figure 4. Beat-wise livestock depredation incidents in and around Mahuadanr Wolf Sanctuary between 2019 and 2021.

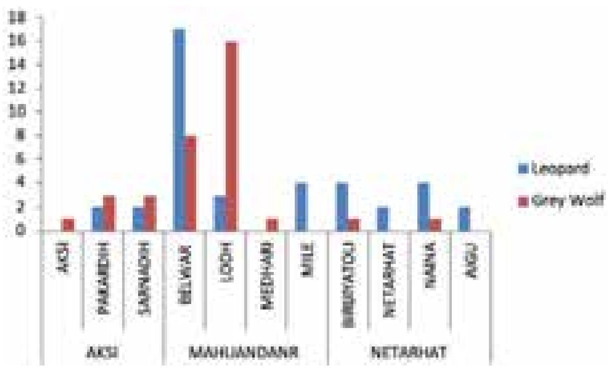

Figure 5. Sub-beat wise livestock depredation incidents in and around Mahuadanr Wolf Sanctuary between 2019 and 2021.

incidents.

DISCUSSION

Our results show that livestock loss around Mahuadanr Wolf Sanctuary was more often attributed to the Leopard than to the Grey Wolf. The Leopard is thought to prefer small-sized livestock prey (Patterson et al. 2004). However, in our study area, the majority of compensation for Leopard kills was paid for loss of Cattle and Water Buffalo. On the contrary, the primary cause of Goat kills was attributed to predation by the Grey Wolf, which seems to rely entirely on Goats as a food source. However, it is important to consider that the data available is derived from government compensation schemes, which exclusively focus on livestock and may not encompass wild species. Therefore, conducting further studies is necessary to determine the extent of the Grey Wolves prey dependency within the Mahuadanr Wolf Sanctuary.

Altogether, livestock depredation was higher in the winter season than in the monsoon and summer seasons. This may be due to the fact that Grey Wolves usually leave the region once their breeding season is over, as well as due to less human mobility in the area during the winter (Mahaling & Kumar 2021). Leopards prey mostly in the evening and night hours, which may be owing to the Leopard's nature as a nocturnal animal that is more active in the latter half of the day (Athreys et al. 2015; Chaudhari et al. 2020). Villagers usually return to their homes in the evening with their livestock from the forest after grazing them, which might lead to the predation by Leopards during the second half of the day (Mahaling & Kumar 2021).

The maximum cases of livestock depredation were reported from the Mahuadanr forest beat. Moreover, the Leopard was the major livestock predator in Belwar sub-beat while the Grey Wolf in the Lodh sub-beat of Mahuadanr forest beat. A relation could be drawn to the topography of Mahuadanr Wolf Sanctuary, Lodh sub-beat is rockier and hillier, which is the most suitable site for Grey Wolf dens (Rajpurohit 1999; Saren et al. 2019).

According to the 20th Livestock Census (Department of Animal Husbandry & Dairying 2019), the density of livestock in the Latehar district is expanding, providing easy prey for predators (Mahaling & Kumar 2021). Carnivores are frequently perceived as hazardous and incongruous within landscapes predominantly influenced by humans (Athreya et al. 2020). In light of the growing instances of livestock depredation by large carnivores in the vicinity of the Mahuadanr Wolf

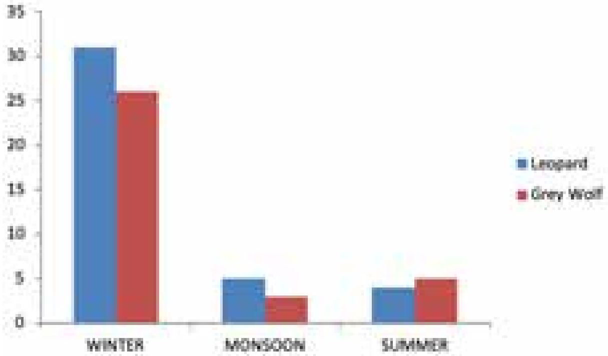

Figure 6. Seasonal variation in livestock depredation incidents in and around Mahuadanr Wolf Sanctuary between 2019 and 2021.

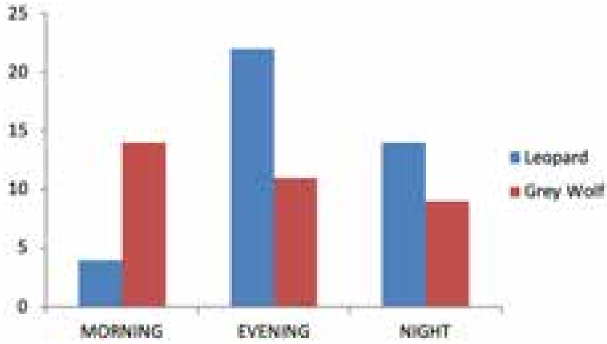

Figure 7. Temporal variation in livestock depredation in and around Mahuadanr Wolf Sanctuary between 2019 and 2021.

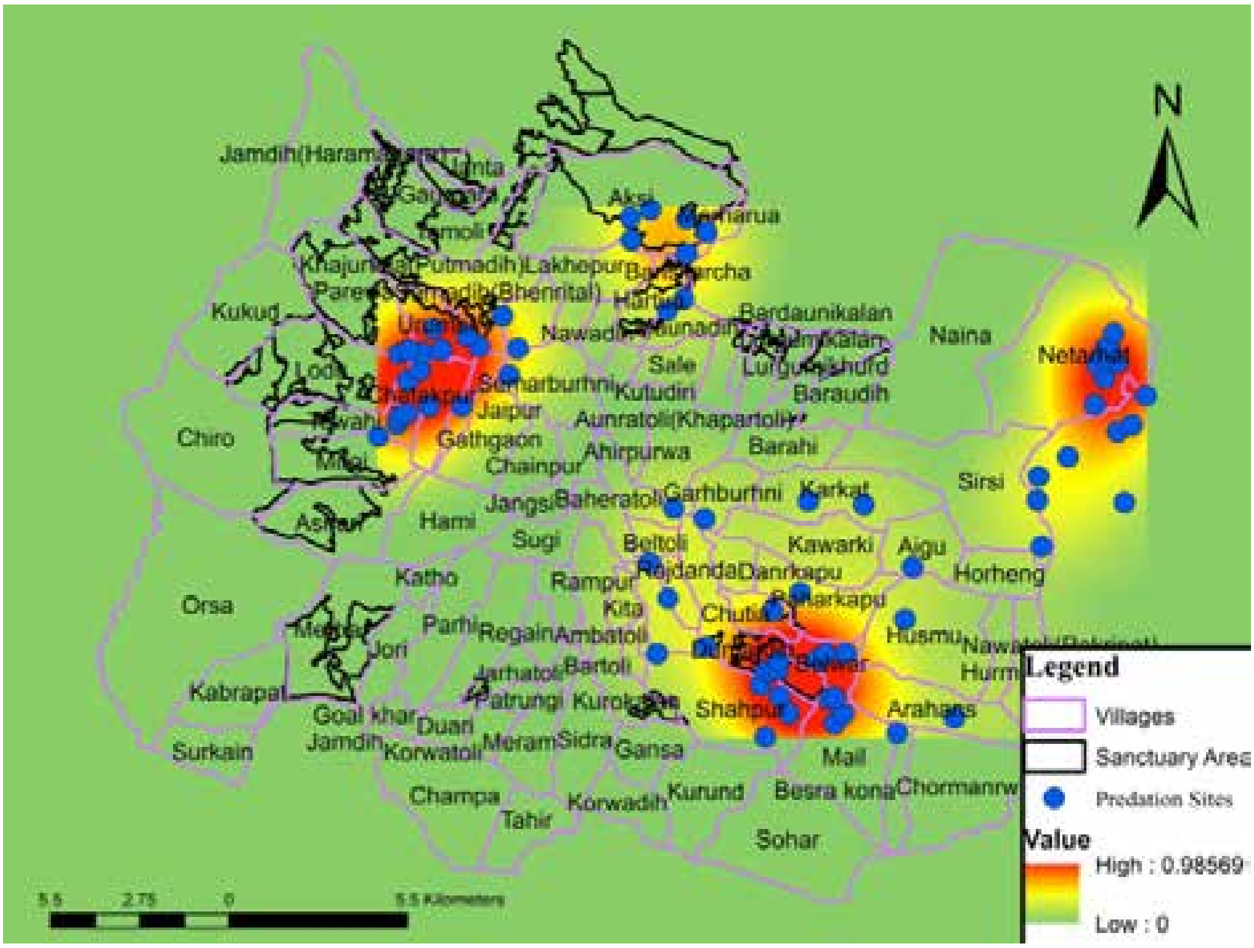

Figure 8. Locations and hotspots of livestock depredation around Mahuadanr Wolf Sanctuary's villages with green colour depicting low interaction and red high interaction areas.

Sanctuary, the impact on the local communities is concerning, potentially leading to economic hardships and an increased risk of poverty among the villagers. In order to formulate practical recommendations aimed at mitigating this situation, it is crucial to thoroughly understand the underlying circumstances surrounding the incidents of predation (Donikar et al. 2011; Mahajan et al. 2022). Through an exploration of circumstantial evidence, it has been revealed that incidents of livestock depredation by both predators are more prevalent during the winter season. Additionally, variations in temporal patterns indicate that Leopards tend to engage in livestock depredation more frequently during the evening hours, while the Grey Wolf exhibits higher activity in predation during the morning hours. In light of these findings, it is imperative for villagers to enhance their guarding measures while grazing their livestock during these specific seasons and times. Moreover, the Forest Department should exercise heightened vigilance and bolster patrolling efforts during these critical hours.

Sustaining this proactive approach is essential to effectively prevent livestock predation (Suryawanshi et al. 2013). While compensation provides temporary relief, it cannot compensate for the financial benefits that would have been obtained had the livestock remained alive. Therefore, it is crucial for the Forest Department to take proactive measures to establish trust within the community. One potential strategy could involve implementing a program to subsidize the strengthening of livestock enclosures, thereby providing additional support to villagers in protecting their livestock from carnivore predation.

REFERENCES

Ambarlı, H. (2019). Analysis of Wolf–human conflicts: Implications for damage mitigation measures. *European Journal of Wildlife Research* 65: 81. https://doi.org/10.1007/s10344-019-1320-4

Athreya, V. & A.V. Belsare (2007). Human-Leopard conflict management guidelines. Kaati Trust, Pune. India, 63 pp.

Athreya, V., A. Srivathsa, M. Puri, K.K. Karanth, N.S. Kumar & K.U. Karanth (2015). Spotted in the news: using media reports to examine Leopard distribution, depredation, and management practices outside protected areas in Southern India. *PLoS One* 10(11): e0142647. https://doi.org/10.1371/journal.pone.0142647

Athreya, V., K. Isvaran, M. Odden, J.D. Linnell, A. Kshettry, J. Krishnaswamy & U.K. Karanth (2020). The impact of Leopards (*Panthera pardus*) on livestock losses and human injuries in a human-use landscape in Maharashtra, India. *PeerJ* 8: e8405. https://doi.org/10.7717/peerj.8405

Bargali, H.S. & T. Ahmed (2018). Patterns of livestock depredation by Tiger (*Panthera tigris*) and Leopard (*Panthera pardus*) in and around Corbett Tiger Reserve, Uttarakhand, India. *Plos One* 13(5): e0195612. https://doi.org/10.1371/journal.pone.0195612

Bruyere, B.L., A.W. Beh & G. Lelengula (2009). Differences in perceptions of communication, tourism benefits, and management issues in a protected area of rural Kenya. *Environmental Management* 43(1): 49–59.

Census of India (2011). Primary Census Abstract, Registrar General of India, Ministry of Home Affairs. Government of India, New Delhi. https://censusindia.gov.in/census.website/data/data-visualizations/PopulationSearch_PCA_Indicators Accessed 16 April 2022.

Chan, K.M., R.M. Pringle, J.A.I. Ranganathan, C.L. Boggs, Y.L. Chan, P.R. Ehrlich, P.K. Haff, N.E. Heller, K. Al-khafaji & D.P. Macmynowski (2007). When agendas collide: human welfare and biological conservation. *Conservation Biology* 21(1): 59–68. https://doi.org/10.1111/j.1523-1739.2006.00570.x

Chaudhary, R., N. Zehra, A. Musavi & J.A. Khan (2020). Spatio-temporal partitioning and coexistence between Leopard (*Panthera pardus fusca*) and Asiatic Lion (*Panthera leo persica*) in Gir protected area, Gujarat, India. *PloS One* 15(3): e0229045. https://doi.org/10.1371/journal.pone.0229045

Daniel, J.C. (1996). *The Leopard in India – A Natural History*. Natraj Publishers, Dehradun, 228 pp.

Decker, D.J., T.B. Lauber & W.F. Siemer (2002). *Human-wildlife Conflict Management*. Siemer Human Dimensions Research Unit, Cornell University Ithaca, New York, 47 pp.

Department of Animal Husbandry & Dairying (2019). *20th Livestock Census***.** All India report. Ministry of Agriculture, Department of Animal Husbandry, Dairying & Fisheries, Krishi Bhawan, New Delhi, India, 55 pp.

Dey, S., V. Sagar, S. Dey & S.K. Choudhary (2010). Sight record of the Indian Wolf *Canis lupus pallipes* in the river Gandak floodplains. *Journal of the Bombay Natural History Society* 107(1): 51–53.

Dickman, A.J., E.A. Macdonald & D.W. Macdonald (2011). A review of financial instruments to pay for predator conservation and encourage human–carnivore coexistence. *Proceedings of the National Academy of Sciences* 108(34): 13937–13944. https://doi.org/10.1073/pnas.1012972108

Donikar, R.P., V.K. Patil, S.S. Narkhede, A.D. Rane, D.N. Mokat & S.G. Bhave (2011). Circumstantial and response attitudes of people affected with livestock depredation by Leopards *Panthera pardus* Linnaeus in Ratnagiri District, Maharashtra, India. *Journal of the Bombay Natural History Society* 108(1): 18.

Dou, H.S., H.H. Zhang, M.R. Wu & M.Q. Gui (2014). Wolf Predation on livestock around the Dalai Lake National Nature Reserve, Inner Mongolia, pp. 25–27. In: Buuveibaatar, B., J.K. Smith, A. Edwards & L. Ochirkhuyag (eds.). *Proceedings of the International Conference for the 20th Anniversary of China-Mongolia-Russia Daurian International Protected Area*. Wildlife Conservation Society Mongolia, Ulaanbaatar, 99 pp.

Ekernas, L.S., W.M. Sarmento, H.S. Davie, R.P. Reading, J. Murdoch, G.J. Wingard, S. Amgalanbaatar & J. Berger (2017). Desert pastoralists' negative and positive effects on rare wildlife in the Gobi. *Conservation Biology* 31(2): 269–277. https://doi.org/10.1111/cobi.12881

Habib, B., A. Saxena, I. Mondal, A. Rajvanshi, V.B. Mathur & H.S. Negi (2015). Proposed mitigation measures for maintaining habitat contiguity and reducing wild animal mortality on NH 6 & 7 in the Central Indian Landscape. Technical Report, Wildlife Institute of India, Dehradun and National Tiger Conservation Authority, Govt. of India, New Delhi, 101 pp.

Hamid, A., T. Mahmood, H. Fatima, L. M. Hennelly, F. Akrim, A. Hussain & M. Waseem (2019). Origin, ecology and human conflict of Gray Wolf (*Canis lupus*) in Suleman Range, South Waziristan, Pakistan. *Mammalia* 83(6): 539–551. https://doi.org/10.1515/mammalia-2018-0167

Jacobson, A.P., P. Gerngross, J.R. Lemeris, R.F. Schoonover, C. Anco, C. Breitenmoser-Würsten, S.M. Durant, M.S. Farhadinia, P. Henschel, J.F. Kamler & A. Laguardia (2016). Leopard (*Panthera pardus*) status, distribution, and the research efforts across its range. *PeerJ* 4: e1974. https://doi.org/10.7717/peerj.1974

Jhala, Y.V. & R.H. Giles (1991). The status and conservation of the Wolf in Gujarat and Rajasthan, India. *Conservation Biology* 5(4): 476–483.

Jhala, Y.V. (2003). Status, ecology and conservation of the Indian Wolf *Canis lupus pallipes* Sykes. *Journal of the Bombay Natural History Society* 100(2&3): 293–307.

Jhala, Y.V., Q. Qureshi & R. Gopal (2015). The status of Tigers in India 2014. National Tiger Conservation Authority, New Delhi and Wildlife Institute of India, Dehradun.

Jhala, Y.V., Q. Qureshi & S.P. Yadav (2021). Status of Leopards, co-predators, and megaherbivores in India, 2018. National Tiger Conservation Authority, Government of India, New Delhi, and Wildlife Institute of India, Dehradun, 301 pp.

Kaczensky, P., N. Enkhsaikhan, O. Ganbaatar & C. Walzer (2008). The Great Gobi B Strictly Protected Area in Mongolia – refuge or sink for Wolves *Canis lupus* in the Gobi. *Wildlife Biology* 14(4): 444–456.

Karanth, K.K. & R. DeFries (2010). Conservation and management in human-dominated landscapes: case studies from India. *Biological*

Conservation 143(12): 2865–2964.

Kitchener, A. (1991). *Natural History of Wild Cats*. Comstock Publishing Associates, Ithaca, New York, xxi + 280 pp.

LeFlore, E.G., T.K. Fuller, M. Tomeletso & A.B. Stein (2019). Livestock depredation by large carnivores in northern Botswana. *Global Ecology and Conservation* 18: e00592. https://doi.org/10.1016/j.gecco.2019.e00592

Madhusudan, M.D. & C. Mishra (2003). Why big, fierce animals are threatened: conserving large mammals in densely populated landscapes, pp. 31–55. In: Saberwal, V.K. & M. Rangajaran (Eds.). *Battles over Nature: Science and the Politics of Wildlife Conservation.* Orient Blackswan, 412 pp.

Mahajan, P. & D. Khandal (2021). Preliminary status of the Indian Grey Wolf in Kailadevi Wildlife Sanctuary. *Canid Biology & Conservation* 23: 8–14.

Mahajan, P., R. Chaudhary, A. Kazi & D. Khandal (2022). 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 (2021). Factors Influencing habitat-use of Indian Grey Wolf in the semiarid landscape of western India. *Mammal Study* 47: 1–15. https://doi.org/10.3106/ms2021-0029

Mahaling, M.K. & M. Kumar (2021). Management Plan of Mahuadanr Wolf Sanctuary 2016–2017 to 2025–2026. Palamau Tiger Reserve, Government of Jharkhand, Medninagar, 302 pp.

Maikhuri, R.K., K.S. Rao, S. Nautiyal, A. Purohit, R.L. Sennwal & K.G. Saxena (2002). Management options for Nanda Devi Biosphere Reserve, pp. 49–70. *Traditional Ecological Knowledge for Manging Biosphere Reserves in South and Central Asia.* Oxford & IBH Publishing, New Delhi.

Mekonen, S. (2020). Coexistence between human and wildlife: the nature, causes and mitigations of human wildlife conflict around Bale Mountains National Park, Southeast Ethiopia. *BMC Ecology* 20(1): 51. https://doi.org/10.1186/s12898-020-00319-1

Miller, T.R., B.A. Minteer & L.C. Malan (2011). The new conservation debate: the view from practical ethics. *Biological Conservation* 144(3): 948–957.

Mukhopadhyay, J.P. & N. Banik (2013). *The Red Corridor Region of India: What Do the Data Tell Us?* Institute for Financial Management and Research, Hyderabad, India, 41 pp.

Naughton-Treves, L., M.B. Holland & K. Brandon (2005). The role of protected areas in conserving biodiversity and sustaining local livelihoods. *Annual Review of Environment and Resources* 30: 219–252. https://doi.org/10.1146/annurev.energy.30.050504.164507

Negi, C.S. & S. Nautiyal (2003). Indigenous peoples, biological diversity and protected area management – policy framework towards resolving conflicts. *International Journal of Sustainable Development & World Ecology* 10(2): 169–179. https://doi.org/10.1080/13504500309469795

Nowell, K. & P. Jackson (1996). *Wild Cats: Status Survey and Conservation Action Plan*. IUCN, Gland, Switzerland, 382 pp.

Patterson, B.D., S.M. Kasiki, E. Selempo & R.W. Kays (2004). Livestock predation by lions (*Panthera leo*) and other carnivores on ranches neighbouring Tsavo National Parks, Kenya. *Biological Conservation* 119(4): 507–516. https://doi.org/10.1016/j.biocon.2004.01.013

Prasad, D.Y. (2015). A perspective on the Naxalite insurgency in Jharkhand and Bihar: going beyond the grievance argument. Master's Thesis. The Faculty of Graduate and Post Graduate Studies, University of British Columbia, 55 pp.

Prater, S.H. (1980). *The Book of Indian Animals (3rd edition)*. Bombay Natural History Society, Bombay, xxii+324 pp.

Press Information Bureau (2019). Naxal affected Districts, Ministry of Home Affairs [Press release]. Retrieved on 12 April 2022 at https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1562724

QGIS Development Team (2018). QGIS Geographic Information System. Open Source Geospatial Foundation Project, Austin, Texas. https://www.qgis.org/en/site/. Accessed on 05 June 2022.

Rajpurohit, K.S. (1999). Child lifting: Wolves in Hazaribagh, India. *Ambio* 28(2): 162–166.

Rawat, A.S. (2013). Tiger Conservation Plan. Palamau Tiger Reserve, Department of Forest, Environment and Climate Change, Government of Jharkhand, Ranchi, 423 pp.

Reading, R.P., H. Mix, B. Lhagvasuren & N. Tseveenmyadag (1998). The commercial harvest of wildlife in Dornod Aimag, Mongolia. *The Journal of Wildlife Management* 62(1): 59–71. https://doi.org/10.2307/3802264

Saren, P.C., D. Basu & T. Mukherjee (2019). Status survey of Indian Grey Wolf (*Canis lupus pallipes*) in West Bengal and some part of Jharkhand. *Records of the Zoological Survey of India* 119(2): 103–110.

Shahi, S.P. (1982). Report of Grey Wolf (*Canis lupus pallipes* Sykes) in India-a preliminary survey. *Journal of the Bombay Natural History Society* 79(3): 493–502.

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 Planes: A species with differential management needs. *PloS One* 14(4): e0215019. https://doi.org/10.1371/journal.pone.0215019

Stein, A.B., V. Athreya, P. Gerngross, G. Balme, P. Henschel, U. Karanth, D. Miquelle, S. Rostro-Garcia, J.F. Kamler, A. Laguardia, I. Khorozyan & A. Ghoddousi (2020). *Panthera pardus* (Amended Version of 2019 Assessment). The IUCN Red List of Threatened Species: e.T15954A163991139. Accessed on 06 April 2022. https://doi.org/10.2305/IUCN.UK.2016-1.RLTS.T15954A50659089.en

Suryawanshi, K.R., Y.V. Bhatnagar, S. Redpath & C. Mishra (2013). People, predators and perceptions: patterns of livestock depredation by Snow Leopards and Wolves. *Journal of Applied Ecology* 50(3): 550–560. https://doi.org/10.1111/1365-2664.12061

Terborgh, J. & C.A. Peres (2002). The problem of people in parks, pp. 307–318. In: *Making Parks Work: Strategies for Preserving Tropical Nature*. Island Press, Washington DC.

Thirgood, S., R. Woodroffe & A. Rabinowitz (2005). The Impact of Human Wildlife Conflict on Human Lives and Livelihoods, pp. 13–26. In: Woodroffe, R., S. Thirgood, & A. Rabinowitz (eds.). People and Wildlife: Conflict or Coexistence? Cambridge University Press, Cambridge, UK, 477 pp. http://doi.org/10.1017/CBO9780511614774.003

Treves, A., R.R. Jurewicz, L. Naughton-Treves, R.A. Rose, R.C. Willging & A.P. Wydeven (2002). Wolf depredation on domestic animals in Wisconsin, 1976-2000. *Wildlife Society Bulletin* 30(1): 231–241.

Treves, A., R. Wallace, L. Naughton-Treves & A. Morales (2006). Co-managing human–wildlife conflicts: a review. *Human Dimensions of Wildlife* 11: 383–396. https://doi.org/10.1080/10871200600984265

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 December 2023 | 15(12): 24299–24320
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.7918.15.12.24299-24320
#7918 | Received 13 March 2023 | Final received 30 October 2023 | Finally accepted 13 November 2023

ARTICLE

Wetland biodiversity of Ramaroshan Lake complex: a need for conservation

Ram Devi Tachamo-Shah [1], Deep Narayan Shah [2], Subodh Sharma [3], Lila Sharma [4], Jagan Nath Adhikari [5] & Deepak Rijal [6]

[1] Department of Life Sciences, School of Science, Kathmandu University, Dhulikhel 45200, Nepal.
[1,3] Aquatic Ecology Centre, School of Science, Kathmandu University, Dhulikhel 45200, Nepal.
[2] Central Department of Environmental Science, Tribhuvan University, Kirtipur, Kathmandu 44618, Nepal.
[3] Department of Hydro and Renewable Energy, Indian Institute of Technology Roorkee (IITR), India.
[4] Forest Action Nepal, Lalitpur 44700, Nepal.
[5] Department of Zoology, Birendra Multiple Campus, Tribhuvan University, Bharatpur, Chitwan, Nepal.
[6] USAID Paani Program, Baluwatar, Kathmandu 44616, Nepal.
[1] ramdevi.shah@ku.edu.np, [2] dnshah@cdes.edu.np (corresponding author), [3] subodh.sharma@hre.iitr.ac.in,
[4] lilanathsharma@gmail.com, [5] jnnadhikari@gmail.com, [6] rijal.deepak@gmail.com

Abstract: The Ramaroshan Lake Complex, situated in the mid-hills of Sudurpaschim Province, is renowned for its scenic beauty, yet there is a notable dearth of information regarding its biodiversity and ecological status. This study represents the first systematic examination of seasonal variations in water quality parameters and biodiversity encompassing aquatic macroinvertebrates, fishes, birds, herpetofauna, mammals, and macrophytes, as well as the surrounding vegetation within the complex, spanning the winters and summers of 2018 and 2019. Among the twenty water quality parameters investigated, thirteen displayed significant seasonal differences across the lakes ($p < 0.05$), with Batula and Ramaroshan lakes exhibiting elevated nutrient levels. Lamadaya Lake stood out with a highly diverse macroinvertebrate community compared to other lakes, while overall, the study recorded 45 aquatic macroinvertebrate families, three fish species, 79 bird species, 12 herpetofauna species, 12 mammal species, and 26 macrophyte species within the complex. Additionally, the surrounding vegetation comprised 193 distinct plant species. Notably, the complex currently hosts 14 IUCN Red List species, including Near Threatened (5), Vulnerable (5), Critically Endangered (1), and Endangered (3) species, as well as five migratory wetland bird species, underscoring its significance for wildlife conservation. Given the diverse and cross-cutting nature of wetlands, the development of science-based policies and coordinated efforts among central, provincial, and local governments are essential for the preservation and sustainable management of these vital ecosystems.

Keywords: Avian diversity, Batula Lake, biodiversity, conservation, critical habitat, herpetofauna, Jingale Lake, Lamadaya Lake, macroinvertebrates, Ramsar Site, water quality.

Editor: Channa Bambaradeniya, Ellicott City, MD, USA. **Date of publication:** 26 December 2023 (online & print)

Citation: Tachamo-Shah, R.D., D.N. Shah, S. Sharma, L. Sharma, J.N. Adhikari & D. Rijal (2023). Wetland biodiversity of Ramaroshan Lake complex: a need for conservation. *Journal of Threatened Taxa* 15(12): 24299–24320. https://doi.org/10.11609/jott.7918.15.12.24299-24320

Funding: This research was funded by the USAID-Paani Program - Grant no. G-KAT-013 and G-KAT-041

Competing interests: The authors declare no competing interests.

Author details: Ram Devi Tachamo Shah, Ph.D. is an assistant professor. She is interested in the assessment of freshwater ecosystems at spatial and temporal scales in particular macroinvertebrates, microbiota, and fish under changing environments. Deep Narayan Shah, Ph.D. is an assistant professor. His research and professional interests are freshwater ecology, wetland restorations, species distribution, and the development of bio-assessment tools. He has significantly contributed to wetland-related policy documents including management plans, strategy, and action plans. Subodh Sharma, Ph.D. is a professor. His interest lies in water quality assessment and freshwater ecology. Lilanath Sharma, Ph.D. is a vegetation ecologist and botanist. He is interested in biodiversity conservation, forest restoration, and invasive species management. Jagan Nath Adhikari, Ph.D. is an assistant professor of zoology and has a keen interest in the landscape ecology, conservation of birds, large mammals, and herpetofauna. Deepak Rijal, Ph.D. was affiliated with DAI Inc. and heads AGON Nepal. He is interested in biodiversity conservation.

Author contributions: RDTS: Conceptualization, designed the ecological field methods, led the field study, data curation, formal analysis, original draft, review and editing. DNS: Conceptualization, designed the ecological field methods, led the field study, formal analysis, original draft, review and editing. SS: Conceptualization, review and editing. LS: Conceptualization and review. JNA: Conceptualization, field study, data analysis, original draft, review and editing. DR: Conceptualization and review. All authors read and approved the manuscript.

Acknowledgements: We would like to acknowledge the financial support of the American people for this study through the United States Agency for International Development (USAID). The contents of this study are the sole responsibility of the authors and do not necessarily reflect the views of USAID or the United States Government. We also thank Dipendra Adhikari, Subarna Ghimire, Amrit Adhikari, and Suman Sapakota for their assistance in data collection. We thank Junu Maharjan for her involvement in data collection and the production of location maps used in this manuscript.

INTRODUCTION

Over 5% of Nepal's land surface area is covered by natural and man-made wetlands, of which nearly 97% are contributed by rivers and irrigated paddy fields, and only 3% of the wetlands belong to marshy lands and lakes, including reservoirs and ponds (DoFD 2012). These lakes are disproportionally distributed across the varying altitudes: 51% of the lakes are situated in the high mountains above 3,000 m, 42% are located in the Tarai below 500 m, and only 7% of lakes are located in the mid-hills between 500 m and 5,000 m (Bhuju et al. 2010). Wetland ecosystems provide critical habitats to a wide range of wildlife, support livelihoods, regulate ecosystem functions, and are a source of renewable energy (Zedler & Kercher 2005; Baral 2009; Shah et al. 2011; Lamsal et al. 2014; Regmi et al. 2021a; Shrestha et al. 2021). These wetlands support critical habitats for globally threatened species (BLI 2010). Many endemic species, including two mammals (ASM 2018), one bird (BLI 2020), 10 reptiles (Uetz et al. 2018), 11 amphibians (Web 2018), 15 fish (Eschmeyer 2015), and eight flowering species, are endemic to the wetlands of Nepal. Similarly, the majority of the wetlands have socio-economic and cultural values, and riparian communities are highly dependent on wetland products (Khatri et al. 2010; Lamsal et al. 2014).

Due to the high significance of wetlands for wildlife and society, they need to be preserved and maintained. The Convention on Wetlands of International Importance is an international treaty that was signed in the city of Ramsar, Iran, on 02 February 1971, for protecting and maintaining the wetlands of ecological, botanical, limnological, hydrological, and zoological significance across the globe and designate as Ramsar Sites. The Koshi Tappu wetland was the first Ramsar Site in Nepal, designated in 1979, due to its importance for migratory birds. Since then, the government of Nepal has successfully designated a total of 10 wetlands of international importance. Among the 10 Ramsar Sites, eight are situated either in the high mountains or lowland Tarai, while only two are located in the mid-hills though the region covers over 40% of the total land surface.

Most of the wetlands, particularly in lowland Tarai, are highly threatened due to the high dependency of people on wetland products to sustain their livelihood (Sah & Heinen 2001), while wetlands situated in the inaccessible areas of mid-hills and high-mountain areas are nearly free from human pressures, hence serving as biodiversity reservoirs for many native and/or endemic species.

Ramaroshan Lake complex, located in a unique geographic location in the mid-hills of Sudurpaschim Province of Nepal, may serve as a critical habitat for wide ranges of wildlife (DoF 2017). The lake complex is one of the major habitats of Nepal's national bird, the Himalayan Monal *Lophophorus impejanus*, and a new record of a breeding site of a wetland-dependent migratory species, the Mallard *Anas platyrhynchos* (Aditiya Pal pers. comm. June 2019). The inlets and outlets of the lake complex are also important habitats for a globally 'Near Threatened' species, *Epiophlebia laidlawi* (Nesemann et al. 2011; Shah et al. 2012; Deep Narayan Shah pers. comm. June 2019). Moreover, the lake complex is the source of the Kailash River, which sustains hundreds of thousands of downstream communities in the province. Many river systems of the province have been recently explored for their biodiversity across disturbance scales (Shah et al. 2020a), spatial scale along the longitudinal gradient (Shah et al. 2020b), stressor types (Sharma & Shah 2020), and microhabitats (Bhandari et al. 2018), but the lake complex has not yet been studied from the wider aspects of wetland biodiversity except for water quality and bathymetry (Chalaune et al. 2020). Therefore, a detailed scientific study of the wetland complex was felt necessary. The present study was carried out to assess and document the water quality and the extent and distribution of wetland floral and faunal diversity in the lake complex.

MATERIALS AND METHODS

Study area

The study was carried out in the four lakes of the Ramaroshan Lake complex, i.e., Ramaroshan, Batula, Jingale, and Lamadaya lakes (Figure 1; Image 1). The lake complex lies in Ramaroshan Rural Municipality in the Achham District of Sudurpaschim Province in Nepal. The rural municipality has 4,832 total households with a total population of 23,600, including 11,092 males and 12,508 females, respectively (CBS 2021). Ramaroshan is a proposed protected forest in Nepal that covers an area of 3051.29 ha for the conservation of its unique wetland ecosystem and biodiversity (DoF 2017). The ecosystems of the Ramaroshan protected forest consist of dense forest (96.95%), grassland (1.50%), lakes (1.09%), and rivers and streams (0.46%) (DFO 2019). The lake complex is the union of 12 lakes that cover an area of 30 ha (1.09%), but water remains throughout the year only in four lakes (Ramaroshan, Batula, Lamadaya, and Jingale).

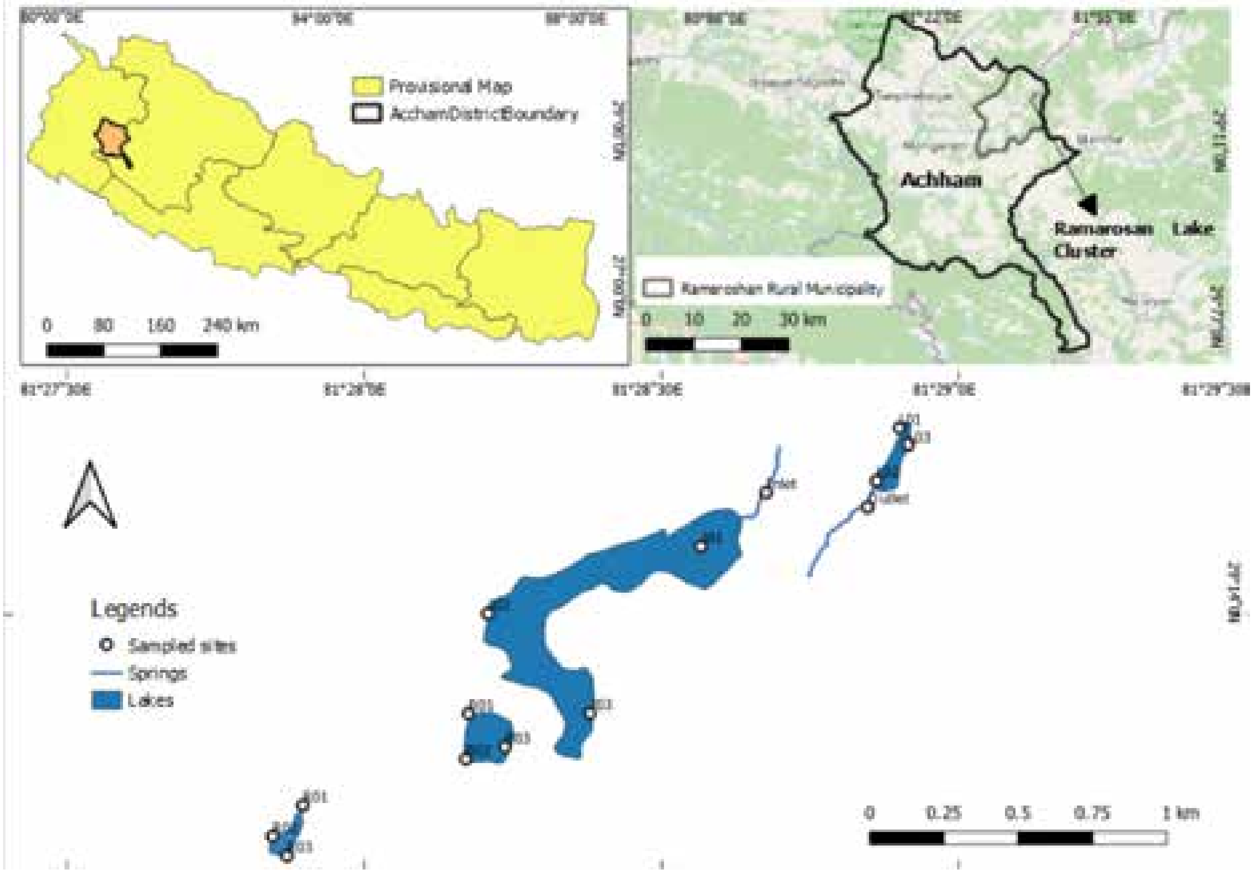

Figure 1. Location of study lakes in Ramaroshan Lake Complex in Sudurpaschim Province of Nepal. Only four major lakes from left to right: namely Ramaroshan (R01, R02, R03), Batula (B01, B02, B03); Jingale (J01, J02, J03); Lamadaya (L01, L02, L03) and the inlet of Jingale and outlet of Lamadaya are included in the study.

Sampling sites

The sampling sites were distributed in all the study lakes namely Ramaroshan, Batula, Jingale, and Lamadaya (Table 1). Jingale is the largest lake among the four lakes studied. In each lake, three littoral sections were selected for the sampling of aquatic macroinvertebrates and measurements of water quality parameters. The study was conducted during the winter (November–February) and summer (May-–June) seasons of 2018 and 2019.)

METHODS

Water quality parameters

Water quality parameters such as pH, water temperature, turbidity, dissolved oxygen (DO), electrical conductivity (EC), and total dissolved solids (TDS) were measured at three sites in each lake using a Hanna multi-parameter probe (Model: HI9829) and turbidity meter. Composite water samples were collected for the determination of total hardness, calcium hardness, magnesium hardness, total alkalinity, chloride, free carbon dioxide (CO_2), calcium cations (Ca^{2+}), magnesium cations (Mg^{2+}), sodium cations (Na^{+}), sulphate anions (SO_4^{2-}) and analysed following APHA guidelines (APHA 2017) at the Aquatic Ecology Centre (AEC), Kathmandu University (KU). Ammonia (NH_4^{+}), ortho-phosphate (PO_4^{2-}), and nitrate (NO_3^{-}) were analysed on-site using the portable HANNA photometers (Hannah Instruments HI96715C, HI96728C, and HI96717, respectively).

Aquatic macroinvertebrates

Aquatic macroinvertebrates were sampled from littoral sections of the lakes following Shah et al. (2015). The samples were collected from three littoral sections of each lake studied. In total, 15 macroinvertebrate samples, including one sample each from the inlet and outlet of the lake complex were collected during field visits. The samples were taken using a standard circular metallic framed hand net of mesh size 500 µm and preserved on site in 95% ethanol for further laboratory

Image 1. Study lakes: A—Ramaroshan Lake. © Deep Narayan Shah | B—Batula Lake. © Ravi Ram | C—Jingale Lake. © Ravi Ram | D—Lamadayal Lake. © Ravi Ram.

Table 1. Geographical locations and morphometric features of the study lakes.

Lakes	Latitude	Longitude	Altitude (m)	Core area (ha)	Maximum Length & depth (m)
Ramaroshan	29.230936	81.461270	2,340	2.18	120 m and 2 m
Batula	29.230451	81.467531	2,405	3.20	130 m and 8 m
Jingale	29.233852	81.468570	2,430	21.50	300 m and 12 m
Lamadaya	29.238693	81.481549	2,545	1.12	100 m and 6 m

processing. The samples were processed at the Aquatic Ecology Centre (AEC) at Kathmandu University (KU). The macroinvertebrates were identified at the family level (Nesemann et al. 2007, 2011; Shah et al. 2015, 2020). The identified samples were preserved in 90% ethanol and stored at AEC, KU.

Fish

The passive entanglement gear technique was used for fish sampling. The fish samples were collected through gill nets placed at different parts of the lake.

Three lake sections — left bank, right bank, and center— were selected in each lake for fish sampling. At each site, two-gill nets were placed and removed every two hours. All captured individuals were taken to a nearby dry place, identified to species level (Shrestha 2019), measured, photographed, and then released back into their original habitats. Specimens that could not be identified in the field were fixed in 10% formalin for 24 hours and subsequently preserved in 70% ethanol. Voucher specimens were deposited at the National Fishery Research Centre, Godavari, Lalitpur, Nepal.

Bird survey

Bird surveys were conducted using the open-width point count method along transects near the lake's shoreline, following the protocol outlined by Bibby et al. (2000). Additionally, we employed the area search method during the field study, as described by Slater (1994), Dieni and Jones (2002), and Adhikari et al. (2022). The length of each transect was determined based on the specific characteristics of the habitat and landscape, following principles outlined by Hanowski et al. (1990). Within each transect, we established a minimum of five vantage points at 100-meter intervals, where we used binoculars (Nikon 20x50) to count bird species. At each point, we conducted five-minute counts of bird species. We documented all observed species, aided by both visual and auditory observations, including relevant habitat and environmental variables. To ensure data accuracy, each transect was surveyed by two observers. Subsequently, we combined the recorded bird species lists from various vantage points within each transect. Survey periods included mornings from 600 h to 1200 h and evenings from 1500 h to 1800 h. Bird species were identified using the field guidebook for birds of Nepal authored by Grimmett et al. (2016a, b).

Herpetofauna

Both amphibians and reptiles were surveyed using nocturnal and diurnal and transects respectively in a time-constrained visual encounter survey (Khatiwada 2012; Khatiwada et al. 2016; Khatiwada et al. 2019). Transects were searched by four people for two hours using torches, walking at a slow pace at night (700 h – 900 h) and during the day (1000 h– 1300 h). The number of species and individuals encountered in each transect was recorded along with all habitat and environmental variables. Apart from nocturnal and diurnal transects, opportunistic random surveys were also carried out to document the occurrence of herpetofauna species in the area. All individuals encountered were captured and stored in a 15 L plastic bucket with small holes in the lid. Some uncaptured individuals were also counted. All captured individuals were taken to a nearby dry place where the animals were measured and identified at the species level based on guide books: Schleich & Kästle (2002) and Shah & Tiwari (2004), and then released back into their original habitats. Male frogs were identified based on secondary sexual characteristics in the presence of black pigment on the throat (vocal sac) and nuptial pads, and females by the enlargement of the coelomic cavity in gravid individuals. Specimens that were difficult to identify based on morphological traits in the field were euthanized in a chlorobutanol solution, fixed in formalin for 24 hours, and subsequently preserved in 75% ethanol. The morphological parameters (e.g., body length, fin length, and eye diameter) were measured and compared with identification keys. The species nomenclature follows Frost (2019). Voucher specimens were stored at the Central Department of Zoology, Tribhuvan University, Kathmandu, Nepal.

Mammal survey

Five systematic transects (varying from 0.42 to 1.5 km) were laid in the riparian areas. The transect line was searched by 2-3 people, and all the animals sighted and indirect signs of mammals such as scats, pellets, droppings, dung, pugmarks, scrapings, carcasses, quills, and burrows were recorded. Apart from these, an opportunistic survey was also conducted around the lake to record mammals.

Macrophytes and vegetation survey

Macrophytes and vegetation were surveyed in and around the lake to enumerate the checklist of plant species. Surveying along line transects starting from shore to the lake interior is a flexible method to document macrophytes in small lakes (Titus 1993). We used two 25 m long-line transects from Lake Shore to the centre and noted the macrophytes at different distances. A floating tube was used to swim, and a rake was used to collect submerged macrophytes.

A vegetation survey in the surrounding forests (about 100 m from the lake shore) was carried out to prepare the checklist of plants occurring in the lake complex area. Transect walks along the trails and through the forest were performed to collect plant specimens.

Collected specimens were identified on-site, while unidentified specimens were preserved following standard herbarium methods (Bridson & Forman 1999). Herbarium specimens prepared for further identification were deposited at the National Herbarium and Plant Laboratory in Kathmandu. Plants were identified using relevant identification keys (Polunin & Stainton 1984; Grierson & Long 1983, 2001).

Data analysis

The Nepal Lake Biotic Index (NLBI) for lakes and the Biotic Index (Shah et al. 2020c) for running waters (inlet and outlet) were calculated by assigning tolerance scores to macroinvertebrates identified at the family level (Shah et al. 2011, 2020c). In these methods, the index value is the sum of the tolerance scores divided by the number of scored taxa for a site, which then translates to the lake water quality class (LWQC) for indicating the degree of degradation).

Non-metric Multidimensional Scaling (NMDS): Non-metric multidimensional scaling (NMDS) was performed to cluster sites based on macroinvertebrate abundance data. Prior to analysis, macroinvertebrate abundance data were transformed to log (x+1). The Bray-Curtis distance measure was employed in NMDS, and the analysis was conducted using the R package (R Core Team 2019).

Shannon diversity index (H) The Shannon diversity index (H) was used to assess species diversity within a community (Shannon 1948):

Shannon Index (H) = $-\sum p_i \, ln \, p_i$

Where p_i is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N),

ln is the natural log,

Σ is the sum of the calculations,

Community Diversity Measurement - Simpson Index (D): The Simpson index was determined to measure community diversity in relation to habitats (Simpson 1949).

$$\text{Simpson Index (D)} = 1 - \left(\frac{\sum n(n-1)}{N(N-1)}\right)$$

Where n is the number of individuals of one particular species,

N is the total number of individuals found.

Σ is the sum of the calculations.

D values range between 0 and 1.

Evenness and Equitability: Evenness (e) was used to determine the distribution of individuals of a taxon in a community. It is constrained between 0 and 1.0:

Evenness = H'/Hmax

Where H' is the Shannon diversity index

H_{max} is the maximum taxon recorded at a site.

Jacob's Equitability index: Jacob's Equitability (J) was used to measure the evenness with which individuals are divided among the taxa present.

Equitability (J) = H'/lnS

Where H' is Shannon's index of diversity,

S is the number of taxa

Fisher's Diversity Index: Fisher's index describes the mathematical relationship between the number of species and the number of individuals in those species (Fisher & Yates, 1943). The Fisher diversity index is defined implicitly by the formula below:

Fisher's diversity index $(S) = a \times ln\,(1 + \frac{n}{a})$

Where n is the number of individuals and a is Fisher's alpha).

RESULTS

Water quality parameters

Most of the water quality parameters except pH, free CO_2, Mg hardness, Ca hardness, potassium cations, and sulphate anions significantly varied between seasons across lakes (Table 2). For each lake, the water temperature was the single parameter that varied significantly in each study lake between seasons. Seasonal variation was recorded for electrical conductivity (86.86±4.93|75.23±5.53, p <0.001), ammonia (0.17±0.01|0.30±0.02, p <0.01), total alkalinity (64±4.93|55.66±4.91, p <0.01), chloride (14.33±1.45|16.67±1.45, p <0.01) and sodium cations (5.2±0.26|4.46±0.12, p <0.05) in Ramaroshan lake. Dissolved oxygen (7.36±0.42|5.35±0.05, p <0.05), nitrate (6.18±0.18|7.51±0.55, p <0.05), phosphate (1.19±0.09|1.64±0.12**, p <0.01) and total hardness (101±2.08|135.33±3.17, p <0.01) were different between seasons for Batula lake. Ammonia (0.28±0.03|0.34±0.03, p <0.05) and Mg hardness (18±2.64|18±1.52, P <0.001) were different between seasons for Jingale lake. TDS (49±7|36±3, p <0.01), turbidity (2.3±0.49|2.7±0.41, p <0.01), DO (2.3±0.49|2.7±0.41, p <0.01), Mg hardness (15±1.52|14±2, p <0.05) and sodium cations (5.33±0.14|4.3±0.20, p <0.01) were significantly different between seasons for Lamadaya lake.

Biodiversity survey

Aquatic macroinvertebrates

A total of 45 families belonging to 14 orders of macroinvertebrates were recorded in the study lakes including the inlet and outlet of the Ramaroshan Lake complex (Supplementary 1). Diptera was the most dominant and diverse order followed by Odonata and Mollusca in the lakes, while Trichoptera was the most dominant and diverse order followed by Diptera and Ephemeroptera in running waterbodies (inlet and outlet streams) of the lakes (Figure 2). Plecoptera was found only in Lamadaya Lake and running water bodies. Among lakes, Lamadaya was found to be highly diverse in terms of taxa composition, while Ramaroshan was the least diverse. Family richness ranged from 10 to 25 in the lakes, and 14 to 30 in running waterbodies. Family

Table 2. Mean and standard values of physico-chemical parameters for each study lake for the winter and summer seasons of year 2018 and 2019. Values indicated in bold digits are significant between seasons. The symbols (Asterisks) "*", "" and "***" represent significance levels at 0.05, 0.01, and <0.001.**

	Parameters/Lakes	Across lakes Winter| Summer	Lamadaya Winter| Summer	Jingale Winter| Summer	Batula Winter| Summer	Ramaroshan Winter| Summer
1	pH	8.36±0.42| 8.57±0.48	8.66±0.26| 8.77±0.35	8.68±0.14| 8.69±0.32	8.82±0.15| 8.46±0.21	8.03±0.27| 8.36±0.31
2	Temperature (°C)	**16.08±1.76| 23.98±2.11*** **	**13.86±0.20| 22.27±0.56** **	**15.23±0.26| 21.92±0.36** **	**17.16±0.40| 25.35±0.43** **	**18.06±0.26| 26.37±0.39*** **
3	TDS	**47.08±9.23| 38.75±10.64***	**49±7| 36±3** **	56.33±5.48| 43.66±12.12	36.66±0.88| 37.33±2.02	46.33±3.17| 38±5.50
4	Turbidity (NTU)	**2.97±1.06| 3.62±1.28** **	**2.3±0.49| 2.7±0.41** **	4.06±0.29| 5.36±0.46	2.93±0.42| 3.02±0.32	2.6±0.81| 3.4±0.62
5	DO	**7.49±0.67| 80.37±13.73*** **	**8.13±0.17| 6.36±0.33** **	7.73±0.12| 6.80±0.50	**7.36±0.42| 5.35±0.05***	6.73±0.29| 5.82±0.33
6	EC (µS/cm)	**88.49±14.86| 80.37±13.73***	88.03±4.23| 71.33±2.58	107.06±7.03| 98.41±5.95	72±1.89| 76.52±6.97	**86.86±4.93| 75.23±5.53** **
7	Free CO2	3.43±1.32| 3.14±0.85	4.06±0.98| 3.8±0.20	3.56±0.81| 3.06±0.18	3.83±0.75| 3.66±0.47	2.26±0.24| 2.03±0.23
8	Nitrate (mg/L)	**2.87±2.83| 3.42±3.49** **	0.12±0.02| 0.10±0.3	0.28±0.08| 0.21±0.06	**6.18±0.18| 7.51±0.55***	4.9±0.13| 5.86±0.23
9	Ortho-phosphate (mg/L)	**1.27±0.19| 1.48±0.21*** **	1.41±0.12| 1.36±0.14	1.12±0.01| 1.41±0.08	**1.19±0.09| 1.64±0.12** **	1.35±0.13| 1.53±0.14
10	Ammonia (mg/L)	**0.19±0.11| 0.27±0.14***	0.21±0.11| 0.36±0.11	**0.28±0.03| 0.34±0.03***	0.08±0.02| 0.09±0.02	**0.17±0.01| 0.30±0.02** **
11	Total Alkalinity (mg/L)	**55.08±17.93| 48.05±16.09** **	27.66±2.40| 24.33±4.33	59±2.3| 57±5.50	69.66±3.28| 55.22±5.07	**64±4.93| 55.66±4.91** **
12	Mg Hardness	19.58±7.93| 20.08±8.36	**15±1.52| 14±2***	**18±2.64| 18±1.52*** **	29.33±4.91| 31.22±3.84	16±4.04| 17±4.58
13	Ca Hardness	**57.83±13.75| 74.66±20.06** **	42.33±1.20| 55.33±2.40	53.33±4.63| 73.33±2.90	71.66±6.93| 104±7	64±5.56| 66±4.35
14	Total Hardness (mg/L)	**77.41±16.83| 94.75±26.15*** **	57.33±2.02| 69.33±3.52	71.33±2.02| 91.33±1.85	**101±2.08| 135.33±3.17** **	80±2.30| 83±2.64
15	Chloride (mg/L)	**11.75±4.82| 13.5±5.16*** **	5±0.57| 6.33±1.20	16.33±1.45| 18±3	11.33±1.20| 13±2	**14.33±1.45| 16.67±1.45** **
16	Calcium cations (mg/L)	15.64±3.87| 15.79±3.51	9.98±0.89| 10.74±0.89	18.36±1.94| 17.47±0.77	17.53±0.55| 18.61±1.24	16.7±0.75| 16.33±1.20
17	Magnesium cations (mg/L)	3.13±0.88| 3.25±0.90	1.89±0.11| 1.96±0.23	3.33±0.34| 3.60±0.36	3.56±0.43| 3.66±0.14	3.76±0.17| 3.76±0.42
18	Potassium cations (mg/L)	1.80±0.60| 1.72±0.53	1.73±0.35| 1.5±0.30	1.63±0.08| 1.6±0.11	2.6±0.25| 2.43±0.20	1.26±0.08| 1.36±0.17
19	Sodium cations (mg/L)	**5.16±0.46| 4.36±0.42*** **	**5.33±0.14| 4.3±0.20** **	4.7±0.34| 3.93±0.18	5.43±0.14| 4.76±0.24	**5.2±0.26| 4.46±0.12***
20	Sulphate anions (mg/L)	0.80±0.67| 0.63±0.53	0.13±0.01| 0.12±0.02	1.6±0.40| 1.2±0.36	1.02±0.14| 0.90±0.11	0.46±0.12| 0.3±0.05

richness was low for the winter season compared to the summer season in the lakes and running water bodies (Figure 2)

The lakes were categorized into a 'fair' LWQC for both seasons while the water quality class for running water bodies was categorized into a 'good' status for winter and a 'fair' status for the summer season in the outlet (Figure 3).

Non-metric multidimensional scaling (NMDS) disentangled sites into three clusters- Cluster 1 representing sites of running water bodies, Cluster 2 for sites of Lamadaya, and Cluster 3 for sites of the remaining three lakes (Figure 4).

Fish

Altogether, three species of fish, namely *Schizothorax nepalensis*, *S. richardsonii,* and *Garra gotyla,* belonging to the Cyprinidae family, were recorded in the lakes of Ramaroshan Lake Complex. Among these reported species, *S. nepalensis* listed as Critically Endangered, which is endemic to northwest Nepal (Regmi et al., 2021b), and *S. richardsonii which is* common to major river systems (Koshi, Gandaki, and Karnali), is listed as a vulnerable category in the IUCN Red List.

Bird survey

In total, 1018 individuals (winter = 611 and summer = 423) of birds from 79 species belonging to 33 families and 15 orders were documented in the lake complex

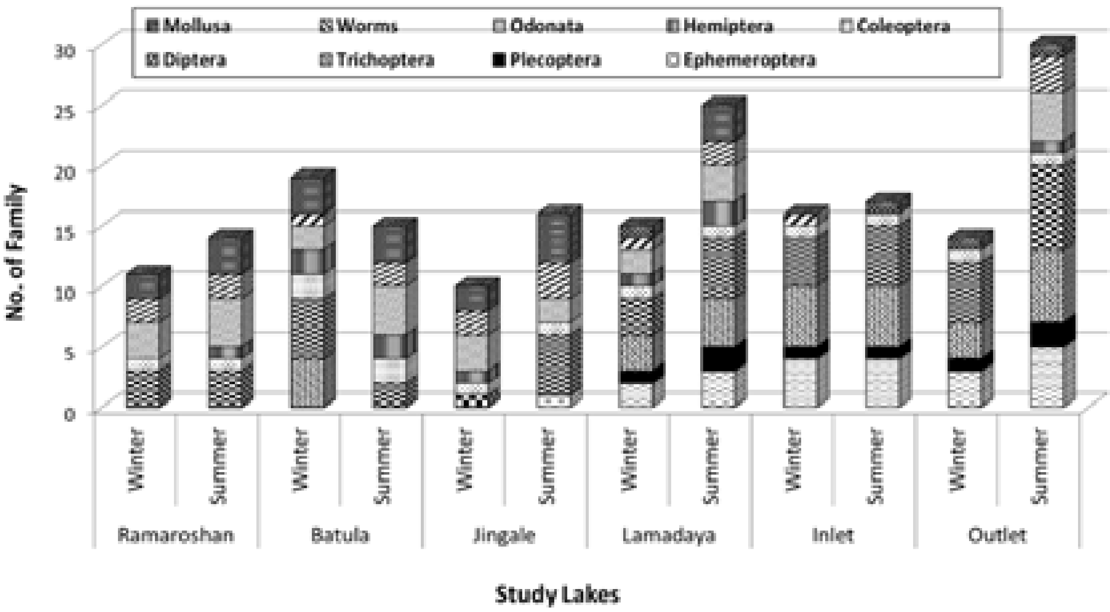

Figure 2. The family richness of aquatic macroinvertebrates was recorded in the winter and summer seasons of the year 2018 and 2019 in the study sites of the Ramaroshan Lake Complex. Inlets and outlets are running streams coming to the lake and leaving the lake.

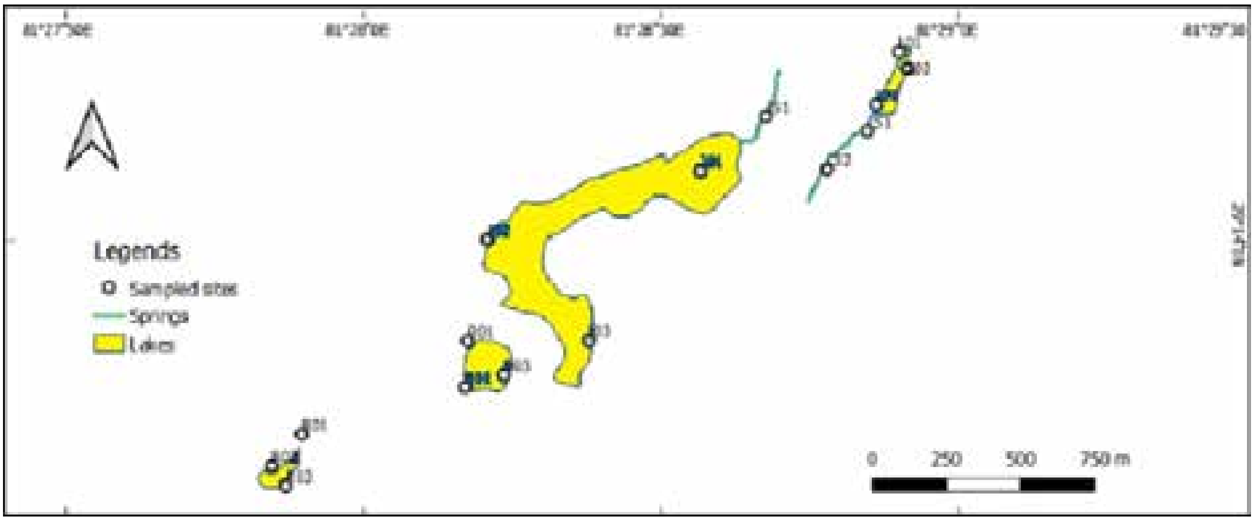

Figure 3. Lake water quality classes of four study lakes and water quality classes for running water bodies. Yellow color indicates fair water quality while green indicates good water quality.

(Supplementary 2). The abundance of birds was significantly higher in the winter season than in the summer season ($t = 2.81$, $p < 0.01$), but the species richness was higher in summer ($n = 73$) than in winter ($n = 67$). Of them, four species: *Neophron percnopterus* (Egyptian Vulture), *Ciconia episcopus* (Asian Wollyneck), *Catreus wallichii* (Cheer Pheasant), and *Vanellus vanellus* (Northern Lapwing) have been listed as Endangered, Vulnerable and Near Threatened, respectively in the IUCN Red List. The most abundant species were from the order Passeriformes for the summer (66.90%) and winter (64.84%) seasons (Figure 5).

A total of 15 species of wetland birds (winter – 14, and summer - 15) were recorded from the lakes of the Ramaroshan complex, followed by 37 forest birds (winter - 30, summer - 35), 16 open area and grassland-dependent birds (winter -14, summer -13), and 9 bush birds (winter - 9, summer - 10) (Figure 6). The study reported winter migratory birds such as the Eurasian Coot (*Fulica atra*), Little Grebe (*Tachybaptus ruficollis*), Mallard (*Anas platyrhynchos*), Eurasian Wigeon (*Anas Penelope*) and Common Teal (*Anas crecca*).

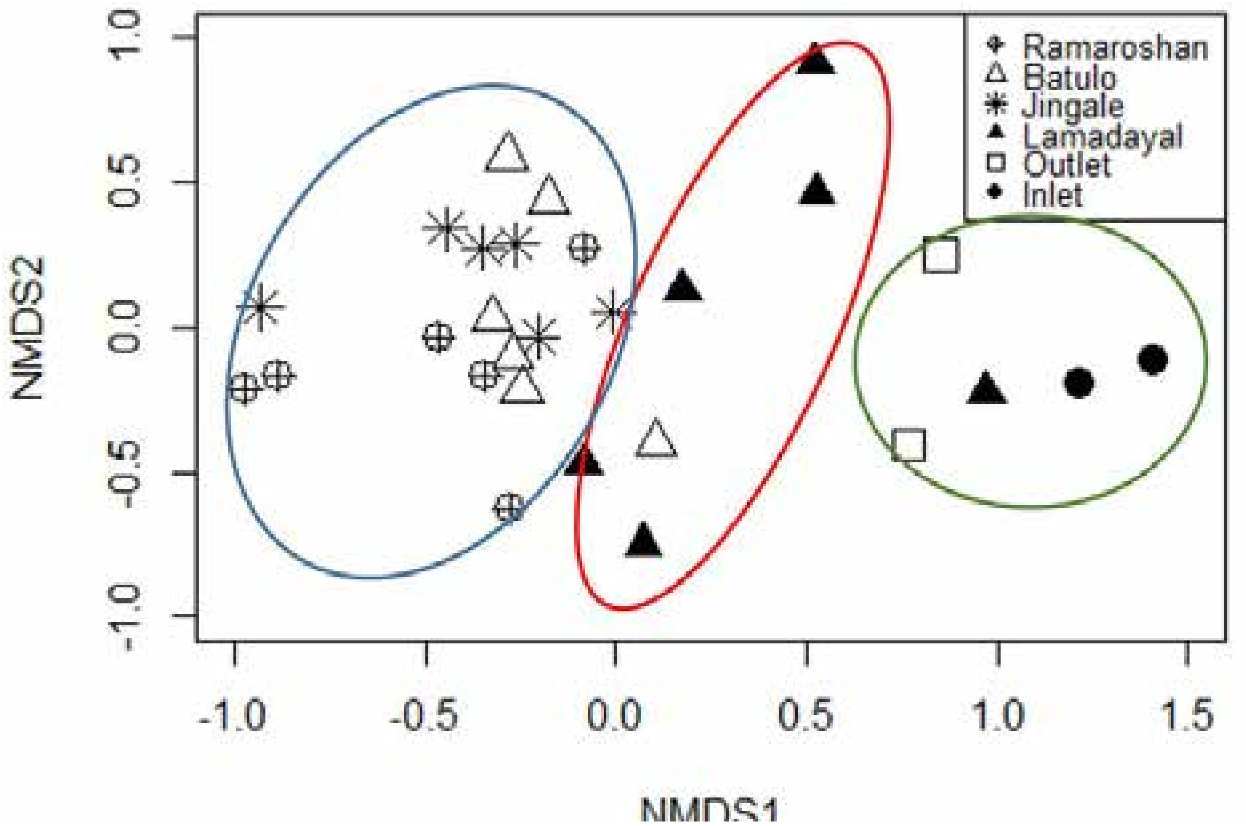

Figure 4. Non-metric multidimensional scaling based on aquatic macroinvertebrate abundance data. Each symbol type represents sites of a particular lake or inlet and outlet. Symbols: closed circle: Inlet sites; open square: outlet sites; closed triangle: Lamadaya sites; open triangle: Batula lake; Asterisk: Jingale lake; crossed circle: Ramaroshan lake. Stress value: 0.17.

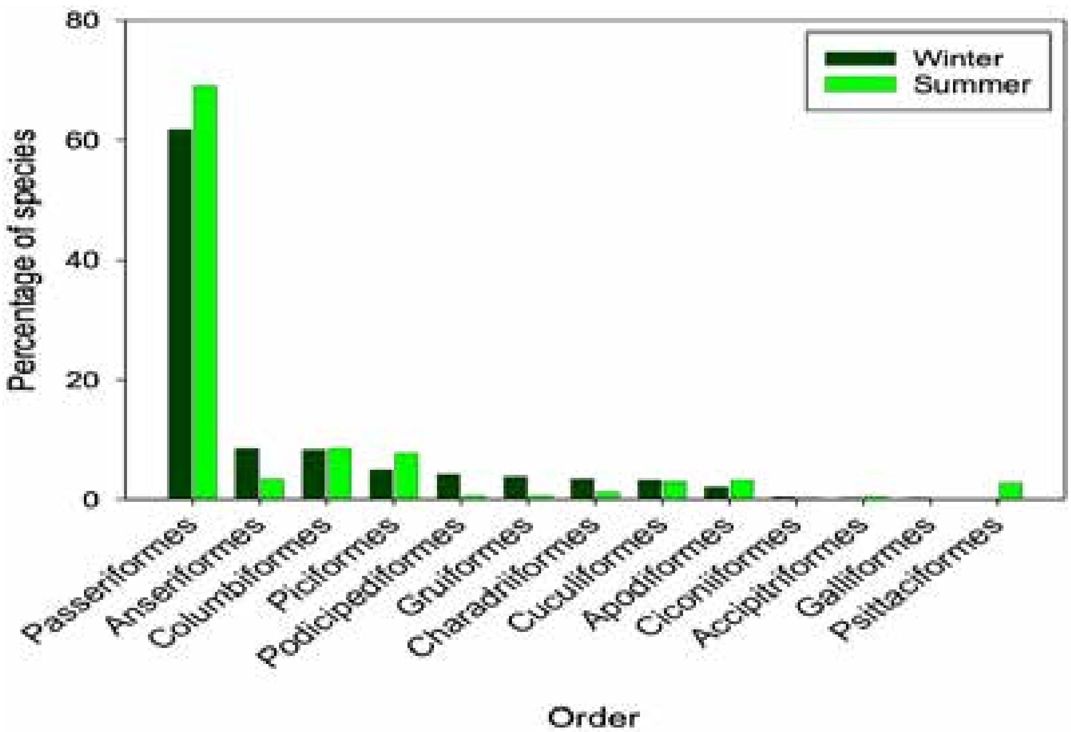

Figure 5. Number of bird species recorded with respect to order for winter and summer seasons in the Ramaroshan Lake Complex.

Table 3. Bird's diversity and dominance indices in Ramaroshan Lake Complex.

Metrics/Seasons	Winter			Summer		
	Average	Lower	Upper	Average	Lower	Upper
Shannon diversity index (H)	4.01	3.93	4.01	4.06	3.96	4.07
Species dominance index (D)	0.02	0.02	0.02	0.02	0.02	0.02
Simpson index of diversity (1-D)	0.98	0.98	0.98	0.98	0.98	0.98
Evenness (E)	0.82	0.76	0.82	0.80	0.72	0.80
Equitability (J)	0.95	0.93	0.95	0.95	0.92	0.95
Fisher diversity index (S)	19.19	19.19	19.19	25.44	25.44	25.44

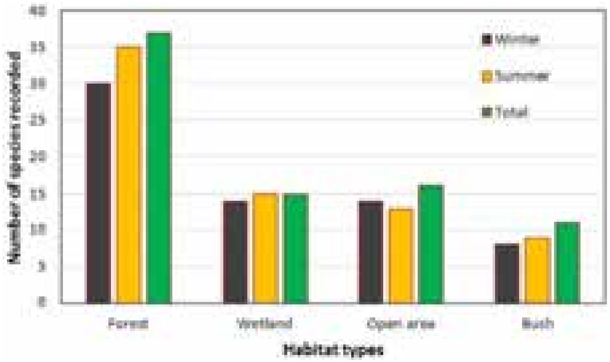

Figure 6. Number of bird species across habitat types recorded in and around Ramaroshan Lake Complex.

There was no significant variation in the Shannon diversity index, Species dominance index, and Simpson index of diversity for birds between winter and summer seasons (Table 3; p = 0.79). The species' evenness of birds (0.82) and Jacob's coefficient of equality (0.95) were lower in winter than in the summer season (evenness = 0. 80, Jacob's coefficient of equality = 0.95).

Herpetofauna

Within the lake complex, a comprehensive survey documented a total of 121 amphibians, representing 7 distinct species distributed across 5 families. Notably, *Nanorana legibii* dominated the population at 50.4%, followed by *Duttaphrynus himalayanus* at 32.2% and *Hoplobatrachus tigerinus* at 5.8% (Figure 7). Two endemic amphibian species, *Nanorana minica* and *Amolops marmoratus*, were also identified at the study sites (Table 4). It is worth highlighting that both Liebiegi's Paa Frog *Nanorana legibii* and Small Paa Frog *Nanorana minica* are categorized as globally Vulnerable on the IUCN Red List. Furthermore, the Indian Bull Frog *Hoplobatrachus tigerinus*, classified as globally Near Threatened by the IUCN in 2021, was also observed within the lake complex.

A total of five species of reptiles were recorded during the field survey. Among them, *Laudakia tuberculata* (48%) was the most abundant species in the study area, followed by *Calotes versicolor* (25%), and *Eutropis carinata* (21.4%), respectively (Table 4).

Mammals

This study documented a total of 12 mammal species. Notably, four of these species enjoy legal protection under the DNPWC Act of 1973, enforced by the government of Nepal. These protected species include the Leopard *Panthera pardus*, the Red Panda *Ailurus fulgens*, the Asiatic Black Bear *Ursus thibetanus*, and the Himalayan Goral *Naemorhedus goral*. The Red Panda is of particular concern as it holds the classification as being 'Endangered' according to the IUCN Red List. Similarly, the Himalayan Black Bear and Leopard are categorized as 'Vulnerable' under the IUCN Red List, while the Assam Macaque and Himalayan Goral fall within the 'Near Threatened' category (Table 5).

Macrophytes and Vegetation Survey

In total, the lakes of the Ramaroshan Lake complex harbored 25 species, encompassing 14 families of macrophytes (Table 6). Predominantly, *Scirpus compressus*, *Scirpus sinensis*, and *Polygonum hydropier* thrived as major emergent plants along the shores and in marshy areas. Among submerged vegetation, *Ceratophyllum demersum* and *Potamogeton nutans* prevailed. The complex featured *Nelumbo nucifera* as the sole-rooted floating macrophyte species. Additionally, the region supported two wetland-dependent plants, *Allium waalichina* and *Ophioglossum nudicaule*, esteemed for their medicinal attributes and utilized as vegetables by the local populace.

Expanding the scope, the Ramaroshan Lake complex area showcased an impressive biodiversity of 167 plant species, spanning 70 families (Supplementary 3).

Table 4. List of the herpetofauna recorded in the study transect. LC—Least Concern | NT—Near Threatened | VU—Vulnerable.

Types	Common name	Scientific name	Habitat type	IUCN Red List status
Amphibian	Marbled Cascade Frog	*Amolops marmoratus* (Blyth,1855)	River bank	LC
	Himalayan Toad	*Duttaphrynus himalayanus* (Gunther, 1864)	Lake edge	LC
	Indian Bull Frog	*Hoplobatrachus tigerinus* (Daudin, 1802)	Lake edge	NT
	Myanmar Pelobatid Toad	*Megophyrus parva* (Boulenger, 1893)	Grassland	LC
	Liebiegi's Paa Frog	*Nanorana legibii* (Gunther, 1860)	River bank	VU
	Small Paa Frog	*Nanorana minica* (Dubois, 1975)	Lake edge	VU
	Common Indian Tree Frog	*Polypedates maculatus* (Gray, 1830)	Lake edge	LC
Reptile	Common Garden Lizard	*Calotes versicolor versicolor* (Daudin, 1802)	River bank	LC
	Himalayan Rock Lizard	*Laudakia tuberculata* (Hardwicke & Gray, 1827)	Lake edge	LC
	Bengal Monitor	*Varanus bengalensis* (Daudin, 1802)	Lake edge	LC
	Common Indian Skink	*Eutropis carinata* (Schneider, 1801)	Lake edge	LC
	Mountain Keelback	*Amphiesma platyceps* (Blyth, 1854)	Lake edge	LC

Notably, Rosaceae stood out as the largest family with 17 species, followed closely by Asteraceae with 14 species and Poaceae with 13 species. *Taxus wallichiana*, a valuable medicinal plant, flourished abundantly within the complex area. It's worth mentioning that this species holds a spot on the IUCN Red List as endangered and is also listed in CITES Appendix III.

DISCUSSION

Ramaroshan Lake complex is known for its unique landscape and high biodiversity. The lake complex provides forest resources such as fodder for livestock and bamboo and firewood for household consumption in adjacent communities. The complex is an excellent area for livestock grazing. Local inhabitants obtain water for drinking purposes, domestic consumption, and irrigation. Like other wetlands in Nepal, the lake complex is also affected by land encroachment. In 30 years, the wetland area of the complex has shrunk by 16% due to land use and land cover changes (Paudel et al. 2022).

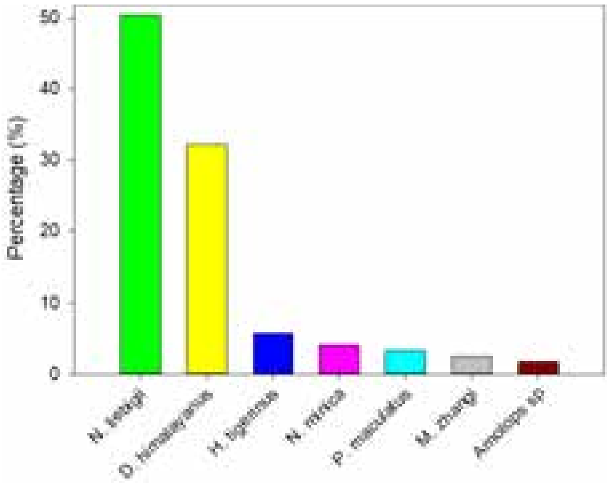

Figure 7. The relative percentage of amphibian species recorded in the Ramaroshan Lake Complex.

Water quality status

Ramaroshan Lake complex, being situated in the remote mid-hills of the country, has water quality parameter values for all four lakes within the permissible limit for the winter and summer seasons (see Table 2). Dissolved oxygen (DO) for all four lakes was greater than 5 mg/L, indicating good status for maintaining higher forms of aquatic life in water (Bozorg-Haddad et al. 2021). DO was highest in Lamadaya lake (6.35 mg/L) and lowest in Batula lake (5.26 mg/L). Similar DO values were also reported from the lake complex for the winter season in 2020 (Chalaune et al. 2020) and were comparable with the DO values recorded in other lakes of the region (Gurung et al. 2018). DO greater than 4 mg/L is suitable for bathing, aquaculture, and irrigation (Bozorg-Haddad et al. 2021).

Lamadaya Lake unlike other lakes, had many physical parameters that were significantly different. This might be due to its smaller size, being relatively shallow, and being surrounded by dense forest. Hydrological fluctuation between seasons might have played a major role in making it different (Regmi et al. 2021a). Similarly, Ramaroshan Lake and Batula Lake being situated in the lower region of the lake complex, the nutrient parameters such as nitrate and phosphate; hardness, and alkalinity were found to be high compared to Jingale and Lamadaya lakes.

Table 5. List of threatened mammals recorded from the Ramaroshan Lake Complex. LC—Least Concern | NT—Near Threatened | VU—Vulnerable | EN—Endangered.

	Order	Family	Common name	Scientific name	IUCN Red List status
1	Rodentia	Hystricidae	Indian Crested Porcupine	*Hystrix indica*	LC
2	Lagomorpha	Ochotonidae	Royle's Pika	*Ochotona roylei*	LC
3	Carnivora	Canidae	Golden Jackal	*Canis aureus*	LC
4	Rodentia	Hystricidae	Malayan Porcupine	*Hystrix brachyura*	LC
5	Primates	Cercopithecidae	Assam Macaque	*Macaca assamensis*	NT
6	Primates	Cercopithecidae	Rhesus Macaque	*Macaca mulatta*	LC
7	Cetartiodactyla	Cervidae	Northern Red Muntjac	*Muntiacus vaginalis*	LC
8	Cetartiodactyla	Bovidae	Himalayan Goral	*Naemorhedus goral*	NT
9	Carnivora	Felidae	Leopard	*Panthera pardus*	VU
10	Primates	Cercopithecidae	Nepal Grey Langur	*Semnopithecus schistaceus*	LC
11	Carnivora	Ursidae	Himalayan Black Bear	*Ursus thibetanus*	VU
12	Carnivora	Ailuridae	Red Panda	*Ailurus fulgens*	EN

Table 6. List of macrophytes species according to their types in the lakes of Ramaroshan Lake Complex for summer 2019.

	Family	Scientific name	Types
1	Brassicaceae	*Barbarea intermedia*	Amphibious
2	Caryophyllaceae	*Stellaria aquatica*	Emergent
3	Ceratophyllaceae	*Ceratophyllum demersum*	Submerged
4	Characeae	*Chara* sp.	Submerged
5	Cyperaceae	*Cyperus compressus*	Amphibious
6	Cyperaceae	*Scirpus sinensis*	Emergent
7	Hydrocharitaceae	*Hydrilla verticillata*	Submerged
8	Juncaceae	*Juncus articulates*	Amphibious
9	Juncaceae	*Juncus leucanthus*	Amphibious
10	Plantaginaceae	*Plantago aquatica*	Emergent
11	Poaceae	*Alopecurus geniculatus*	Amphibious
12	Poaceae	*Echinochloa crus-galli*	Amphibious
13	Poaceae	*Eleocharis congesta*	Amphibious
14	Poaceae	*Eragrostis* sp.	Amphibious
15	Polygonaceae	*Persicaria barbata*	Emergent
16	Polygonaceae	*Persicaria capitata*	Emergent
17	Polygonaceae	*Persicaria posumbu*	Emergent
18	Polygonaceae	*Polygonum hydropiper*	Emergent
19	Potamogetonaceae	*Potamogeton filiformis*	Submerged
20	Potamogetonaceae	*Potamogeton nutans*	Submerged
21	Potamogetonaceae	*Potamogeton crispus*	Submerged
22	Ranunculaceae	*Caltha scapose*	Emergent
23	Ranunculaceae	*Ranunculus trichophyllus*	Submerged
24	Typhaceae	*Typha angustifolia*	Emergent
25	Zygnemataceae	*Spirogyra* sp.	Submerged

Biodiversity

Ramaroshan Lake complex is situated in the temperate zone, low species richness can be expected in comparison to lowland Tarai because species richness declines with increasing elevation in the Himalayas (Shah et al. 2015; Basnet et al. 2016; Araneda et al. 2018).

Aquatic macroinvertebrates

Water quality is a crucial parameter that determines biotic community composition in lake environments. We observed significant changes in water quality parameters across the lakes (Table 2), and this could be a key factor for the differences in the composition of macroinvertebrates between Lamadaya and the other lakes (Figure 3, 4). Warm water-adapted macroinvertebrates of insect orders Odonata, Coleoptera, and Hemiptera, together with annelid worms and Mollusca were diverse and abundant in lakes during the summer season (Figure 3). These findings are similar to the findings for tropical lakes (Shah et al. 2011; Shrestha et al. 2021). Diverse macroinvertebrates were recorded in Lamadaya Lake which might be due to the occurrence of mosaic habitats mainly comprised of soft substrates like leaf litters, twigs, and macrophytes. Soft substrates not only provide suitable habitats for macroinvertebrate colonization but also prevent predation (sensu Shah et al. 2011).

Fishes

The lake complex highlights its importance as a critical habitat for critically endangered fish species: Snow Trout *Schizothorax nepalensis* and vulnerable fish species (*Schizothorax richardsonii*).

Birds

The Ramaroshan Lake Complex plays a pivotal role in providing a crucial habitat for bird diversity, as evident from Supplementary 2. A notable highlight is the documented presence of the globally endangered vulture species *Neophron percnopterus*, the Egyptian Vulture, underscoring the complex's significance. This mountainous ecosystem serves as a sanctuary for globally threatened vulture species, with a majority (7 out of 9) choosing mountain cliffs and towering trees for nesting (DeCandido et al. 2012). Notably, this study reveals that 8.9% of the bird species documented in Nepal, amounting to 891 species according to DNPWC and BCN 2019, find a habitat in the Ramaroshan Lake complex. In Nepal, approximately 200 wetland bird species have been recorded (BCN 2018), with 15 of them (7.5%) also making their presence known in the Ramaroshan Lake complex. It's worth noting that the winter season sees a decline in the sighting of wetland birds, likely attributed to the sub-zero temperatures during this period (DFO 2019).

Herpetofauna

Ramaroshan Lake complex is rich in herpetofauna diversity. A total of 7 species of frogs and 5 species of reptiles were recorded during this study, which is 12.5% (out of 56) and 4.5% (out of 117 species) of the total species recorded from Nepal, respectively (Shah & Tiwari 2004a). High altitude supports a low number of herpetofauna as they are cold-blooded animals (Khatiwada et al. 2019).

Among the recorded amphibian species, Liebiegi's Paa Frog *Nanorana legibii* and Small Paa Frog *Nanorana minica* are listed under the globally vulnerable category, while the Indian Bullfrog *Hoplobatrachus tigerinus* is listed as a globally near threatened species. Studies have shown that frogs are an important source of livelihood for many people (Khatiwada & Haugaasen 2015) and remain an integral part of local medicinal heritage (Mohneke et al. 2011; Lynch et al. 2023). Amphibians and reptiles have long been used by humans as food and medicine (Gonwouo & Rödel 2008; Khatiwada & Haugaasen 2015). Local people in the Ramaroshan areas use Paha frogs (*Nanorana* and *Amolops* species) as food and medicines. Over-collection of the species may lead to local extinctions or severe population declines. As many amphibian species predictably aggregate for reproduction or hibernation, this makes them particularly vulnerable to intensive collecting efforts. Recent studies have indicated that commercial or subsistence harvesting has contributed to a decline in many reptile species (Webb et al. 2002). Khatiwada & Haugaasen (2015) revealed that *Paa* and *Amolops* are the most exploited frog species by the local people for food and medicinal purposes in mountainous parts of Nepal. This heavy exploitation may also lead to local or global declines and even extinctions through unsustainable collection (Warkentin et al. 2009).

Mammals

The mammals in the Ramaroshan lakes area were reported based on signs and direct sightings, and 12 species of mammals were reported during the field study. Among the reported species, one is endangered, two are vulnerable, and two are near threatened mammals, according to the IUCN Red List. Nepal supports 212 species of mammals (Amin et al. 2018), but this small area alone supports 12 species of mammals thus highlighting the importance of the Ramaroshan Lake complex for mammal conservation.

Macrophytes and Vegetation

This study significantly expanded upon the existing knowledge of the area's flora by documenting a total of 26 macrophyte species, thus surpassing the previously reported count of 10 wetland species (Paudel & Pandey 2016). Furthermore, compared to an earlier study (DoF 2017) that documented only 124 plant species within the lake complex (see Supplementary 3), our research uncovered additional plant species. It's worth noting that there is a limited body of research assessing macrophytes in the mid-hills (Basnet et al. 2016), Churia, and Tarai regions of Nepal (Regmi et al. 2021a). For instance, Basnet et al. (2016) identified fewer than 10 macrophytes in Rara Lake, located in the High Mountain region. In contrast, the wetlands of the Tarai-Plain, as highlighted by Regmi et al. (2021a) and Burlakoti & Karmacharya (2006), hosted over 50 macrophyte species. This observation suggests a pattern of increasing macrophyte species richness from the high mountain to the lowland Tarai regions. Despite its location in the mid-hill region, the Ramaroshan Lake Complex exhibited a modest richness of macrophytes. Additionally, the presence of terrestrial flora, including endangered species like *Taxus wallichiana*, contributes to the overall biodiversity of the lake ecosystem. It's important to note that our vegetation survey was exploratory, and further extensive sampling in both forests and lakes may reveal more plant species.

Threats to the Ramaroshan Lake Complex

The lake complex is a tourist destination for local people in the district. However, the area is not as well visited by domestic or international tourists as other lakes in Nepal, such as Gosaikunda, Rara Taal, Pokhara Lake Clusters, etc., due to poor road and air connectivity despite its beautiful landscape. Therefore, minimum tourist influences and minimum activities can be seen. However local people visit the areas frequently for fodder collection, and they use the lake complex for grazing their livestock. Some of the local people are often sighted poaching birds such as the Kalij Pheasant *Lophura leucomelanos* for meat consumption (Aditiya Pal pers. comm. June 2019). Local people harvest Paha frogs (*Nanorana* and *Amolops* species) in large quantities for food and medicinal purposes, which may affect the population of the species in the near future. Plastic pollution is increasing in the littoral sections of the lakes

Conservation value of Ramaroshan Lake Complex

The Ramaroshan Lake Complex and its surrounding catchment area are home to a multitude of species with significant conservation value. These include various aquatic macroinvertebrates such as the Relict Himalayan Dragonfly *Epiophlebia laidlawi*, fish species like *Schizothorax nepalensis* and *Schizothorax richardsonii*, bird species including the Egyptian Vulture *Neophron percnopterus*, Asian Woolly-necked *Ciconia episcopus*, Cheer Pheasant *Catreus wallichii*, and Northern Lapwing *Vanellus vanellus*, frog species such as Liebiegi's Paa Frog *Nanorana legibii*, Small Paa Frog *Nanorana minica*, and Indian Bull Frog *Hoplobatrachus tigerinus*, as well as mammal species including Royle's Pika *Ochotona roylei*, Assam Macaque *Macaca assamensis*, Himalayan Goral *Naemorhedus goral*, Leopard *Panthera pardus*, Himalayan Black Bear *Ursus thibetanus*, and Red Panda *Ailurus fulgens*. The lake systems are encompassed by pasturelands, expansive grasslands, and dense forests that further support a diverse range of wetland-dependent and forest birds. Given its unique geographical location, suitable wetland habitat, native biodiversity, and essential ecosystem services, the Ramaroshan Lake Complex meets the criteria for designation as wetlands of international importance (Ramsar Site). It is imperative that the Ramsar focal agency for Nepal actively pursue this designation.

With the country's adoption of a federal structure, there exist opportunities to integrate wetland management considerations by formulating regulatory frameworks at the central, provincial, and local levels. To ensure the sustainable management of these wetlands, it is crucial to engage and incorporate local communities into this regulatory framework. This approach will facilitate timely monitoring, restoration efforts, and the judicious utilisation of wetland resources.

REFERENCES

Adhikari, J.N., B.P. Bhattarai & T.B. Thapa (2018). Diversity and conservation threats of water birds in and around Barandabhar corridor forest, Chitwan, Nepal. *Journal of Natural History Museum* 30: 164–179. https://doi.org/10.3126/jnhm.v30i0.27553

Adhikari, J.N., J.R. Khatiwada, D. Adhikari, S. Sapkota, B.P. Bhattarai, D. Rijal & L.N. Sharma (2022). Comparison of bird diversity in protected and non-protected wetlands of western lowland of Nepal. *Journal of Threatened Taxa* 14(1): 20371–20386. https://doi.org/10.11609/jott.7452.14.1.20371-20386

American Society of Mammalogists (2018). Mammal Diversity Database. Living National Treasures. https://www.mammaldiversity.org/.

Amin, R., H.S. Baral, B.R. Lamichhane, L.P. Poudyal, S. Lee, S.R. Jnawali, K.P. Acharya, G.P. Upadhyaya, M.B. Pandey, R. Shrestha, D. Joshi, J. Griffiths, A.P. Khatiwada & N. Subedi (2018). The status of Nepal's mammals. *Journal of Threatened Taxa* 10(3): 11361–11378. https://doi.org/10.11609/jott.3712.10.3.11361-11378

APHA (2017). *Standard Method for the Examination of Water and Waste Water, 24th Edition*. American Public Health Association. New York, 1516 pp.

Araneda, P., W. Sielfeld, C. Bonacic & J.T. Ibarra (2018). Bird diversity along elevational gradients in the Dry Tropical Andes of northern Chile: The potential role of Aymara indigenous traditional agriculture. *PLoS ONE* 13(12): e0207544. https://doi.org/10.1371/journal.pone.0207544

Baral, H. (2009). Updated status of Nepal's wetland birds. *Banko Janakari* 19(3): 30–35. https://doi.org/10.3126/banko.v19i3.2209.

Basnet, R., D. Luintel, K. Bhattarai, M. Joshi & K. Sapkota (2020). Wetland flora of Betkot lake, far western Nepal. *Journal of Natural History Museum* 30: 2016–18. https://doi.org/10.3126/jnhm.v30i0.27558

Basnet, T.B., M.B. Rokaya, B.P. Bhattarai & Z. Munzbergova (2016). Heterogeneous landscapes on steep slopes at low altitudes as hotspots of bird diversity in a hilly region of Nepal in the Central Himalayas. *PLoS ONE* 11: e0150498. https://doi.org/10.1371/journal.pone.0150498

BCN (2018). Status of Birds of Nepal. Bird Conservation Nepal, Kathmandu. Retrieved from https://www.birdconservationnepal.org/

BCN (2020). Birds of Nepal. Retrieved from https://www.birdlifenepal.org/birds/status-of-birds

Bhandari, A.R., U.R. Khadka & K.R. Kanel (2018). Ecosystem services in the mid-hill forest of western Nepal: a case of Panchase Protected Forest. *Journal of Institute of Science and Technology* 23(1): 10–17. https://doi.org/10.3126/jist.v23i1.22146

Bhandari, B., R.D.T. Shah & S. Sharma (2018). Status, distribution and habitat specificity of benthic macro-invertebrates: a case study in five tributaries of Buddhiganga river in western Nepal. *Journal of Institute of Science and Technology* 23(1): 69–75. https://doi.org/10.3126/jist.v23i1.22198

Bhuju, U.R., M. Khadka, P.K. Neupane, & R. Adhikari (2011). A Map based inventory of lakes in Nepal. *Nepal Journal of Science and Technology* 11: 173–180. https://doi.org/10.3126/njst.v11i0.4141

Bibby, C.J., N.D. Burgess, D.A. Hill & S. Mustoe (2000). Bird census techniques. Elsevier.

BirdLife International (2010). Lists of Globally Threatened and Near-Threatened Species in Nepal.

BirdLife International (2020). Handbook of the Birds of the World and BirdLife International digital checklist of the birds of the world. Version 5. Available at: http://datazone.birdlife.org/userfiles/file/Species/Taxonomy/HBW-BirdLife_Checklist_v5_Dec20.zip.

BirdLife International (2021). Species factsheet: *Neophron percnopterus*. Downloaded from http://www.birdlife.org on 31/12/2021.

Bozorg-Haddad, O., M. Delpasand & H.A. Loáiciga (2021). Water quality, hygiene, and health. *Economical, Political, and Social Issues* *in Water Resources*. 217-257. https://doi.org/10.1016/B978-0-323-90567-1.00008-5

Bridson, D. & L. Forman (1999). *IUCN Redlist Data Book (3rd edition),* IUCN. http://www.iucnredlist.org.

Burlakoti, C. & S.B. Karmacharya (2006). Quantitative analysis of macrophytes of Beeshazar Tal, Chitwan, Nepal. *Himalayan Journal of Sciences* 2(3): 37–41. https://doi.org/10.3126/hjs.v2i3.229

CBS (2021). National Population and Housing Census 2021 (National Report), 01, NPHC 2021.

Chalaune, T.B., A. Dangol, J. Sharma, & C.M. Sharma (2020). First results on physico-chemical status and bathymetry of lakes in Ramaroshan Wetland, Far-West Nepal. *Nepal Journal of Environmental Science* 8(1): 17–27. https://doi.org/10.3126/njes.v8i1.34464

Colwell, R.K., C. Rahbek & N. Gotelli (2004). The mid-domain effect and species richness patterns: what have we learned so far? *The American Naturalist* 163: 3–23. https://doi.org/10.1086/382056

DeCandido, R., T. Subedi & D. Allen (2012). Jatayu: the vulture restaurants of Nepal. *Birding Asia* 17: 49–56.

Del Hoyo, J., N.J., C. and International, B. (2016). Illustrated Checklist of the Birds of the World. Living National Treasures 2.

DFO (2019). Ramaroshan: A brief Introduction. In A. Division Forest Office (eds.), Division Forest Office Achham and Ramaroshan rural municipality 4 pp.

DoF (2017). Wetlands of Western Nepal: A brief profile of Selected Lakes. Department of Forests, Babarmahal, Kathmandu, Nepal, Babarmahal, Kathmandu, Nepal.

Directorate of Fisheries Development (2012). Annual Progress Report 2011. Kathmandu, Nepal: DoFD

Dieni, J.S. & S.L.J. Jones (2002). A Field Test of the Area Search Method for Measuring Breeding Bird Populations (Una prueba de campo del metodo de" búsqueda de. *Journal of Field Ornithology* 73(3): 253–257. https://www.jstor.org/stable/4131101

DNPWC & BCN (2019). An official checklist of the birds. Department of National Parks and Wildlife Conservation, Bird Conservation Nepal.

DNPWC (2020). Sukla Phanta National Park. Retrieved from www.dnpwc.gov.np

Eschmeyer, W.N., R. Fricke, & R. van der Laan (eds.) (2015). Catalog of Fishes: Genera, Species, References. The freshwater fish lists are based on an electronic version Living National. http://lntreasures.com/nepalff.html.

Fisher, R.A. & F. Yates (1943). Statistical tables: For biological, agricultural and medical research. Second edition. Oliver and Boyd Ltd, London.

Frost, D.R. (2019). Amphibian Species of the World: an Online Reference. Version 6.0. Retrieved from http://research.amnh.org/herpetology/amphibia/index.html

Gonwouo, L. & M. Rödel (2008). The importance of frogs to the livelihood of the Bakossi people around Mount Manengouba, Cameroon, with special consideration of the Hairy Frog, Trichobatrachus robustus. *Salamandra* 44(1): 23–34.

Grierson, A.J.C. & D.G. Long (eds.) (1983–2001). Flora of Bhutan. Royal Botanic Garden Edinburgh and Royal Taxus wallichiana

Grimmett, R., C. Inskipp & T. Inskipp (2016 a). Birds of the Indian Subcontinent: India, Pakistan, Sri Lanka, Nepal, Bhutan, Bangladesh and the Maldives. Bloomsbury Publishing.

Grimmett, R., C. Inskipp, T. Inskipp & H.S. Baral (2016b). Birds of Nepal: Revised Edition. Bloomsbury Publishing.

Gurung, S., A. Gurung, C.M. Sharma, I. Jüttner, L. Tripathee, R.M. Bajracharya, N. Raut, P. Pradhananga, B.K. Sitaula, Y. Zhang, S. Kang & J. Guo (2018). Hydrochemistry of Lake Rara: A high mountain lake in western Nepal. *Lakes & Reservoirs: Science, Policy and Management for Sustainable Use* 23(2): 87–97. https://doi.org/10.1111/lre.12218

Hanowski, J.M., Niemi, G.J., & Blake, J.G. (1990). Statistical Perspectives and Experimental Design When Counting Birds on Line Transects. *The Condor* 92(2): 326–335. https://doi.org/10.2307/1368230

IUCN (2004). A Review of the Status and Threats to Wetlands in Nepal, IUCN Nepal. Kathmandu, Nepal

Khatiwada, J.R. & T. Haugaasen (2015). Anuran species richness and abundance along an elevational gradient in Chitwan, Nepal. *Zoology and ecology* 25: 110–119. https://doi.org/10.1080/21658005.2015.1016775

Khatiwada, J.R. (2012). Amphibian species richness and composition along an elevational gradient in Chitwan, Nepal. (Master Thesis), Norwegian University of Life Sciences, Aas, Norway.

Khatiwada, J.R., S. Ghimire, S. Paudel Khatiwada, B. Paudel, R. Bischof, J.P. Jiang & T. Haugaasen (2016). Frogs as potential biological control agents in the rice fields of Chitwan, Nepal. *Agriculture, Ecosystems & Environment* 230: 307–314. https://doi.org/10.1016/j.agee.2016.06.025

Khatiwada, J.R., T. Zhao, Y. Chen, B. Wang, F. Xie, D.C. Cannatella & J. Jiang, J. (2019). Amphibian community structure along elevation gradients in eastern Nepal Himalaya. *BMC Ecology* 19(1): 19. https://doi.org/10.1186/s12898-019-0234-z

Khatri, T.B., D.N. Shah, R.D.T. Shah & N. Mishra (2010). Biodiversity of Koshi Tappu Wildlife Reserve: a post flood assessment. J*ournal of Wetlands Ecology* 4: 69–82.

Lamsal, P., K.P. Pant, L. Kumar & K. Atreya (2014). Diversity, Uses, and Threats in the Ghodaghodi Lake Complex, a Ramsar Site in Western Lowland Nepal. *Hindawi* 680102. https://doi.org/10.1155/2014/680102

Lynch, A. J., S. J. Cooke, A.H. Arthington, C. Baigun, L. Bossenbroek, C. Dickens, I. Harrison, I. Kimirei, S.D. Langhans, K.J. Murchie, J.D. Olden, S.J. Ormerod, M. Owuor, R. Raghavan, M.J. Samways, R. Schinegger, S. Sharma, R.-D. Tachamo-Shah, D. Tickner & S.C. Jähnig (2023). People need freshwater biodiversity. *WIREs Water* 10(3): e1633; https://doi.org/10.1002/wat2.1633

Mammalogists, A. S. O. (2018). Mammal Diversity Database. Living National Treasures.

Mohneke, M., A.B. Onadeko & M.O. Rödel (2011). Medicinal and dietary uses of amphibians in Burkina Faso. *African Journal of Herpetology* 60: 78–83 78-83.

Nesemann, H., R.D.T. Shah & D.N. Shah (2011). Key to the larval stages of common Odonata of Hindu Kush Himalaya, with short notes on habitats and ecology. *Journal of Threatened Taxa* 3: 2045–2060

Nesemann N., S. Sharma, G. Sharma, S.N. Khanal, B. Pradhan, D.N. Shah & R.D. Tachamo (2007). Aquatic Invertebrates of the Ganga River System (Mollusca, Annelida, Crustacea [in part]), Volume 1.

Paudel, H.R. & T.R. Pandey (2017). Documentation of the Flora of Ramaroshan Wetland Complex, Achham, West Nepal. Bul. Dept. Pl. Res. N. 38. Department of Plant Resources, Kathmandu, Nepal, 16–21p.

Paudel, J., L. Khanal, N. Pandey, L.P. Upadhyaya, C.B. Sunar, B. Thapa, C.R. Bhatta, R.R. Pant & R.C. Kyes (2022). Determinants of Herpetofaunal Diversity in a Threatened Wetland Ecosystem: A Case Stdy of the Ramaroshan Wetland Complex, Western Nepal. *Animals 13*: 135; https://doi.org/10.3390/ani13010135

Polunin, O. & A. Stainton (1984). Flowers of the Himalaya. Oxford University Press, New Delhi.

Poupkou, A., P. Zanis, P. Nastos, D. Papanastasiou, D. Melas, K. Tourpali & C. Zerefos (2011). Present climate trend analysis of the Etesian winds in the Aegean Sea. *Theoretical and Applied Climatology* 106(3): 459-472; https://doi.org/10.1007/s00704-011-0443-7

R Core Team (2019). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Regmi, T., D.N. Shah, T.M. Doody, S. Cuddy & R.D. Tachamo Shah (2021a). Hydrological alteration induced changes on macrophyte community composition in sub-tropical floodplain wetlands of Nepal. *Aquatic Botany* 173: 103413. https://doi.org/10.1016/j.aquabot.2021.103413

Regmi, B., M.R. Douglas, D.R. Edds & M.E. Douglas (2021). Geometric morphometric analyses define riverine and lacustrine species flocks of Himalayan snowtrout (Cyprinidae: Schizothorax) in Nepal. *Aquatic Biology* 30: 19–31.

Sah, J.P. & J.T. Heinen (2001). Wetland resource use and conservation attitudes among indigenous and migrant peoples in Ghodaghodi Lake area, Nepal. *Environmental Conservation* 28(4): 345–356. 345-356 345–356. https://doi.org/10.1017/S0376892901000376

Schleich, H.H. & W. Kästle (2002). *Amphibians and reptiles of Nepal: Biology, Systematics, Field Guide.* Gantner Verlag K. G, Koenigstein, Germany. 1211 pp.

Shah D.N., R.D. Tachamo Shah & B.K. Pradhan (2011). Diversity and Community Assemblage of Littoral Zone Benthic Macroinvertebrates in Jagadishpur Reservoir. *Nepal Journal of Science and Technology* 12: 211–219.

Shah D. N., S. Sharma & R.D. Tachamo-Shah (2015). Rapid assessment of biodiversity, benthic macroinvertebrates. In Gopal, B. (eds) Guidelines for Rapid Assessment of Biodiversity and Ecosystem Services of Wetlands, Version 1.0. Asia-Pacific Network for Global Change Research (APN-GCR), Kobe, Japan, and National Institute of Ecology, New Delhi. 134 pp.

Shah, K.B. & S. Tiwari (2004). *Herpetofauna of Nepal*. The World Conservation Union (IUCN), Kathmandu, Nepal, 237 pp.

Shannon, C.E. (1948). Mathematical Theory of Communication. *The Bell System Technical Journal* 27: 379–424.

Sharma S., & R.D.Tachamo-Shah (2020). Major stressors influencing the river ecosystems of Far and Mid-Western Development Regions of Nepal. *Current World Environment* 14 (2): 231.

Shrestha S., R.D. Tachamo Shah, T.M. Doody, S. Cuddy & D.N. Shah (2021). Establishing the relationship between benthic macroinvertebrates and water level fluctuation in subtropical shallow wetlands. *Environmental Monitoring and Assessment* 193 (534).

Shrestha, T.K. (2019). Ichthyology of Nepal (Second ed.). Kathmandu: Binita Shreatha Publiation.

Simpson, E.H. (1949). Measurement of diversity. *Nature*163, 688 (1949). https://doi.org/10.1038/163688a0

Slater, P.J. (1994). Factors affecting the efficiency of the area search method of censusing birds in open forests and woodlands. *Emu-Austral Ornithology* 94(1): 9–16.

Smith, F.A., A.G. Boyer, J.H. Brown, D.P. Costa, T. Dayan, S.K. Ernest & M.D. Uhen (2010). The evolution of maximum body size of terrestrial mammals. *Science* 330(6008): 1216–1219; https://doi.org/10.1126/science.1194830

Shah, R.D.T., S. Sharma & L. Bharati (2020a). Water diversion induced changes in aquatic biodiversity in monsoon-dominated rivers of Western Himalayas in Nepal: Implications for environmental flows. *Ecological Indicators* 108: 105735. https://doi.org/10.1016/j.ecolind.2019.105735

Shah, R.D.T., S. Sharma, D.N. Shah & D. Rijal (2020b). Structure of Benthic Macroinvertebrate Communities in the Rivers of Western Himalaya, Nepal. *Geosciences* 10 (4).

Shah, R.D.T., S. Sharma, P. Haase, S. Jähnig & S. Pauls (2015). The climate sensitive zone along an altitudinal gradient in central Himalayan rivers: a useful concept to monitor climate change impacts in mountain regions. *Climatic Change*. DOI: 10.1007/s10584-015-1417-z.

Shah, R.D.T., D.N. Shah & S. Domisch (2012). Range shifts of a relict Himalayan dragonfly in the Hindu Kush Himalayan region under climate change scenarios. *International Journal of Odonatology*. doi: 10.1080/13887890.2012.697399.

Shah, R.D.T., D.N. Shah & H. Nesemann (2011). Development of a macroinvertebrate-based Nepal Lake Biotic Index (NLBI): an applied method for assessing the ecological quality of lakes and reservoirs in Nepal. *International Journal of Hydrology Science and Technology* 1:125–146.

Shah, R.D.T., D.N. Shah & S. Sharma (2020). *Rivers Handbook-A guide to the health of rivers in the Hindu-Kush Himalaya*. Aquatic Ecology Centre, School of Science, Katmandu University. 130 pp.

Titus, J.E. (1993). Submersed Macrophyte Vegetation and Distribution Within Lakes: Line Transect Sampling, *Lake and Reservoir Management* 7(2): 155–164. https://doi.org/10.1080/07438149309354267

Uetz, P., P. Freed & J. Hošek (2018). The Reptile Database. Living National Treasures.

USAID (2010). A Climate Trend Analysis of Kenya—August 2010. USGS and USAID.

Warkentin, I.G., D. Bickford, N.S. Sodhi & C.J. Bradshaw (2009). Eating frogs to extinction. *Conservation Biology* 23: 1056–1059; 1056-1059; https://www.jstor.org/stable/29738845.

Web, A. (2018). Amphibian web. Living National Treaures.

Webb, J.K., B.W. Brook & R. Shine (2002). Collectors endanger Australia's most threatened snake, the broad-headed snake *Hoplocephalus bungaroides*. *Oryx* 36: 170–181.

Wikipedia (2020). District Profile: Achham. Retrieved from https://en.wikipedia.org/wiki/Achham_District.

Zedler, J.B. & S. Kercher (2005) Wetland resources: status, trends, ecosystem services, and restorability. *Annual Review of Environmental Resources* 30: 39–74: https://doi.org/10.1146/annurev.energy.30.050504.144248

Supplementary 1. List of aquatic macroinvertebrates recorded in the Ramaroshan Lake Complex. Symbol (√) represents the presence of the taxon in the waterbodies with respect to the season.

Order/Class	Lakes/ waterbodies	Ramaroshan		Batula		Jingale		Lamadaya		Inlet		Outlet	
	Family/season	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
Ephemeroptera	Baetidae						√	√	√	√	√	√	√
Ephemeroptera	Caenidae							√				√	√
Ephemeroptera	Ephemerellidae								√	√	√		√
Ephemeroptera	Ephemeridae								√	√	√		√
Ephemeroptera	Heptageniidae									√	√	√	√
Plecoptera	Perlidae							√	√				√
Plecoptera	Perlodidae								√	√	√	√	√
Trichoptera	Brachycentridae									√	√		
Trichoptera	Hydropsychidae			√				√	√	√			√
Trichoptera	Leptoceridae			√				√	√	√	√	√	√
Trichoptera	Molannidae			√					√				
Trichoptera	Philopotamidae									√	√	√	√
Trichoptera	Polycentropodidae									√	√		√
Trichoptera	Psychomyiidae			√				√	√				√
Trichoptera	Rhyacophilidae										√	√	
Trichoptera	Uenoidae												√
Coleoptera	Dytiscidae	√	√	√	√	√	√		√				√
Coleoptera	Elmidae				√			√		√	√	√	
Coleoptera	Psephenidae			√									
Hemiptera	Mesoveliidae			√					√				
Hemiptera	Micronectidae				√				√				√
Hemiptera	Notonectidae		√	√	√	√		√					
Odonata	Aeshnidae		√	√	√								√
Odonata	Coenagrionidae	√	√		√	√	√		√				√
Odonata	Gomphidae	√	√		√	√		√	√				√
Odonata	Libellulidae	√	√	√	√	√	√	√	√				√
Diptera	Athericidae											√	
Diptera	Ceratopogonidae	√	√	√				√		√	√	√	√
Diptera	Chironomidae	√	√	√	√	√	√	√	√	√	√	√	√
Diptera	Culicidae	√	√	√	√		√	√	√				√
Diptera	Dixidae												√
Diptera	Dolicopodidae								√			√	
Diptera	Empididae						√				√		
Diptera	Psychodidae_									√	√		√
Diptera	Simulidae								√	√	√	√	√
Diptera	Tabanidae			√			√		√				
Diptera	Tipulidae			√			√						√
Acari	Hydracarina								√		√		
Haplotaxids	Megascolecidae	√	√	√	√	√	√	√	√				√
Haplotaxids	Naididae	√	√		√		√		√				√
Haplotaxids	Glossiphoniidae					√	√			√	√		√
Gastropoda	Lymnaeidae	√	√	√	√	√	√		√				√
Gastropoda	Planorbidae	√	√	√	√	√	√	√	√			√	
Gastropoda	Thiaridae						√						
Bivalvia	Sphaeriidae		√	√	√		√		√				√

Supplementary 2. Bird species with their number of individuals observed in the Ramaroshan Lake Complex area. Abundance (%) refers to the total percentage contribution of each species to the total sample for both seasons. EN = Endangered, VU = Vulnerable, NT= Near threatened and LC= Least concerned.

	Common Name	Species	Order	Family	Winter (%)	Summer (%)	Total	IUCN Red List status
1	Egyptian Vulture	*Neophron percnopterus* (Linnaeus 1758)	Accipitriformes	Accipitridae	0.16	0.47	0.29	EN
2	Common Teal	*Anas crecca* (Linnaeus 1758)	Anseriformes	Anatidae	2.62	1.18	2.03	LC
3	Mallard	*Anas platyrhynchos* Linnaeus 1758	Anseriformes	Anatidae	3.6	1.65	2.8	LC
4	Eurasian Wigeon	*Mareca penelope* (Linnaeus 1758)	Anseriformes	Anatidae	0.98	0.95	0.97	LC
5	Pacific Swift	*Apus pacificus* (Latham 1802)	Apodiformes	Apodidae	1.96	1.65	1.84	LC
6	Alpine Swift	*Tachymarptis melba* (Linnaeus 1758)	Apodiformes	Apodidae	0.65	0.95	0.77	LC
7	Northern Lapwing	*Vanellus vanellus* (Linnaeus 1758)	Charadriiformes	Charadriidae	0	0.16	0.1	NT
8	Common Sandpiper	*Actitis hypoleucos* (Linnaeus 1758)	Charadriiformes	Scolopacidae	1.96	0.95	1.55	LC
9	Asian Wolly necked	*Ciconia episcopus* (Boddaert 1783)	Ciconiiformes	Ciconiidae	0.33	0.24	0.29	VU
10	Common Pigeon	*Columba livia* (Gmelin 1789)	Columbiformes	Columbidae	2.29	0.47	1.55	LC
11	Spotted Dove	*Spilopelia chinensis* (Scopoli 1786)	Columbiformes	Columbidae	2.78	2.13	2.51	LC
12	Snow Pigeon	*Columba leuconota (*Vigors 1831)	Columbiformes	Columbidae	0.98	1.89	1.35	LC
13	Oriental Turtle Dove	*Streptopelia orientalis* (Latham 1790)	Columbiformes	Columbidae	3.11	3.31	3.19	LC
14	Common Cuckoo	*Cuculus canorus (*Linnaeus 1758)	Cuculiformes	Cuculidae	1.96	2.36	2.13	LC
15	Indian Cuckoo	*Cuculus micropterus* (Gould 1837)	Cuculiformes	Cuculidae	0.98	0.95	0.97	LC
16	Cheer Pheasant	*Catreus wallichii* (Hardwicke 1827)	Galliformes	Phasianidae	0.16	0	0.1	VU
17	Common Coot	*Fulica atra* (Linnaeus 1758)	Gruiformes	Rallidae	3.11	0.71	2.13	LC
18	Jungle Babbler	*Turdoides striata* (Dumont 1823)	Passeriformes	Leiotrichidae	0	0.24	0.1	LC
19	Long-tailed Minivet	*Pericrocotus ethologus* Bangs & Phillips 1914	Passeriformes	Campephagidae	1.15	2.13	1.55	LC
20	Large-billed Crow	*Corvus macrorhynchos* (Wagler 1827)	Passeriformes	Corvidae	2.13	3.55	2.71	LC
21	Grey Treepie	*Dendrocitta formosae* (Swinhoe 1863)	Passeriformes	Corvidae	2.29	1.89	2.13	LC
22	Yellow-billed Blue Magpie	*Urocissa flavirostris* (Blyth 1846)	Passeriformes	Corvidae	2.13	0.95	1.64	LC
23	Red-billed Blue Magpie	*Urocissa erythroryncha* (Boddaert 1783)	Passeriformes	Corvidae	3.11	1.65	2.51	LC
24	Ashy Drongo	*Dicrurus leucophaeus* (Vieillot 1817)	Passeriformes	Dicruridae	0.82	0	0.48	LC
25	Black Drongo	*Dicrurus macrocercus* (Vieillot 1817)	Passeriformes	Dicruridae	0.82	0	0.48	LC
26	Red-headed Bullfinch	*Pyrrhula erythrocephala (*Vigors 1832)	Passeriformes	Fringillidae	0.98	0.47	0.77	LC
27	Collared Grosbeak	*Mycerobas affinis (Blyth 1855)*	Passeriformes	Fringillidae	0.65	1.18	0.87	LC
28	Nepal House Martin	*Delichon nipalense* (Horsfield & Moore 1854)	Passeriformes	Hirundinidae	1.15	0.71	0.97	LC
29	Red-rumped Swallow	*Cecropis daurica (*Linnaeus 1771)	Passeriformes	Hirundinidae	1.96	1.65	1.84	LC
30	Long-tailed Shrike	*Lanius schach* (Linnaeus 1758)	Passeriformes	Laniidae	1.64	0.71	1.26	LC
31	Grey-backed Shrike	*Lanius tephronotus* (Vigors 1831)	Passeriformes	Laniidae	0.65	0.24	0.48	LC
32	White- throated Laughingthrush	*Garrulax albogularis* (Gould 1836)	Passeriformes	Leiothrichidae	0	2.36	0.97	LC
33	Streaked Laughingthrush	*Trochalopteron lineatum (Vigors 1831)*	Passeriformes	Leiothrichidae	1.96	1.65	1.84	LC

	Common Name	Species	Order	Family	Winter (%)	Summer (%)	Total	IUCN Red List status
34	Striated Laughingthrush	*Grammatoptila striata* (Vigors 1831)	Passeriformes	Leiothrichidae	2.78	2.13	2.51	LC
35	Rufous Sibia	*Heterophasia capistrata* (Vigors 1831)	Passeriformes	Leiothrichidae	2.29	4.02	3	LC
36	Grey Wagtail	*Motacilla cinerea* (Tunstall 1771)	Passeriformes	Motacillidae	0.65	0.71	0.68	LC
37	White Wagtail	*Motacilla alba (Linnaeus 1758)*	Passeriformes	Motacillidae	1.64	0.95	1.35	LC
38	Spotted Forktail	*Enicurus maculatus* (Vigors 1831)	Passeriformes	Muscicapidae	0	0.71	0.29	LC
39	Verditer Flycatcher	*Eumyias thalassinus* (Swainson 1838)	Passeriformes	Muscicapidae	0	0.47	0.19	LC
40	Plumbeous Water Redstart	*Phoenicurus fuliginosus* (Vigors 1831)	Passeriformes	Muscicapidae	0.16	0.95	0.48	LC
41	White-capped Redstart	*Phoenicurus leucocephalus* (Vigors 1831)	Passeriformes	Muscicapidae	0.16	0	0.1	LC
42	Blue Whistling Thrush	*Myophonus caeruleus* (Scopoli 1786)	Passeriformes	Muscicapidae	2.62	3.31	2.9	LC
43	Little Forktail	*Enicurus scouleri (*Vigors 1832)	Passeriformes	Muscicapidae	0.49	0.71	0.58	LC
44	Grey-headed Canary-flycatcher	*Culicicapa ceylonensis (Swainson 1820)*	Passeriformes	Muscicapidae	1.15	0.95	1.06	LC
45	Verditer Flycatcher	*Eumyias thalassinus Swainson, 1838*	Passeriformes	Muscicapidae	0.82	1.18	0.97	LC
46	Blue Whistling Thrush	*Myophonus caeruleus* (Scopoli 1786)	Passeriformes	Muscicapidae	1.8	1.89	1.84	LC
47	Blue-capped Redstart	*Phoenicurus coeruleocephala (Vigors 1831)*	Passeriformes	Muscicapidae	0.95	0	54	LC
48	Black Redstart	*Phoenicurus ochruros* (Gmelin 1774)	Passeriformes	Muscicapidae	1.15	0.47	0.87	LC
49	Pied Bushchat	*Saxicola caprata* (Linnaeus 1766)	Passeriformes	Muscicapidae	1.96	0.95	1.55	LC
50	Grey Bushchat	*Saxicola ferreus* (Gray 1846)	Passeriformes	Muscicapidae	1.15	2.36	1.64	LC
51	Green-tailed Sunbird	*Aethopyga nipalensis* (Hodgson 1837)	Passeriformes	Nectariniidae	0.49	0.95	0.68	LC
52	Indian Golden Oriole	*Oriolus kundoo* (Sykes 1832)	Passeriformes	Oriolidae	1.47	1.89	1.64	LC
53	Green-backed Tit	*Parus monticolus* Vigors 1831)	Passeriformes	Paridae	2.29	3.07	2.61	LC
54	Russet Sparrow	*Passer cinnamomeus* (Temminck 1836)	Passeriformes	Passeridae	2.29	2.13	2.22	LC
55	Grey-hooded Warbler	*Phylloscopus xanthoschistos* (Gray 1846)	Passeriformes	Phylloscopidae	0.49	0	0.29	LC
56	Oriental White-eye	*Zosterops palpebrosus (Temminck 1824)*	Passeriformes	Phylloscopidae	1.64	2.36	1.93	LC
57	Altai Accentor	*Prunella himalayana* (Blyth 1842)	Passeriformes	Prunellidae	0.33	1.18	0.68	LC
58	Brown Accentor	*Prunella fulvescens* (Severtsov 1873)	Passeriformes	Prunellidae	1.15	0.95	1.06	LC
59	Himalayan Bulbul	*Pycnonotus leucogenys* (Gray 1835)	Passeriformes	Pycnonotidae	0.82	0	0.48	LC
60	Red-vented Bulbul	*Pycnonotus cafer* (Linnaeus 1766)	Passeriformes	Pycnonotidae	2.95	4.02	3.38	LC
61	Black Bulbul	*Pycnonotus flaviventris* (Tickell 1833)	Passeriformes	Pycnonotidae	1.47	0.47	1.06	LC
62	Pycnonotidae	*Ixos mcclellandii* (Horsfield 1840)	Passeriformes	Pycnonotidae	4.26	4.02	4.16	LC
63	Velvet-fronted Nuthatch	*Sitta frontalis* (Swainson 1820)	Passeriformes	Sittidae	0	0.47	0.19	LC
64	Common Myna	*Acridotheres tristis* (Linnaeus 1766)	Passeriformes	Sturnidae	1.15	1.42	1.26	LC
65	Jungle Myna	*Acridotheres fuscus* (Wagler 1827)	Passeriformes	Sturnidae	0	0.71	0.29	LC
66	Grey-winged Blackbird	*Turdus boulboul* (Latham 1790)	Passeriformes	Turdidae	0	0.47	0.19	LC
67	White-collared Blackbird	*Turdus albocinctus* (Royle 1840)	Passeriformes	Turdidae	0.98	0.47	0.77	LC

	Common Name	Species	Order	Family	Winter (%)	Summer (%)	Total	IUCN Red List status
68	Mistle Thrush	*Turdus viscivorus* Linnaeus 1758	Passeriformes	Turdidae	0.75	0	0.56	LC
69	Blue Throated Barbet	*Psilopogon asiaticus* (Latham 1790)	Piciformes	Megalaimidae	0	0.47	0.19	LC
70	Fulvous-breasted Woodpecker	*Dendrocopos macei* (Vieillot 1818)	Piciformes	Picidae	0.65	1.89	1.16	LC
71	Great Barbet	*Psilopogon virens* (Boddaert 1783)	Piciformes	Megalaimidae	1.8	2.6	2.13	LC
72	Himalayan Woodpecker	*Dendrocopos himalayensis* (Jardine & Selby 1835)	Piciformes	Picidae	0	0.47	0.19	LC
73	Brown-fronted Woodpecker	*Leiopicus auriceps* (Vigors 1831)	Piciformes	Picidae	0.65	0.71	0.68	LC
74	Rufous-bellied Woodpecker	*Dendrocopos hyperythrus* (Vigors 1831)	Piciformes	Picidae	0.49	1.18	0.77	LC
75	Grey-headed Woodpecker	*Dendropicos spodocephalus* (Bonaparte 1850)	Piciformes	Picidae	0.82	1.18	0.97	LC
76	Scaly-bellied Woodpecker	*Picus squamatus* (Vigors 1831)	Piciformes	Picidae	0	0.47	0.19	LC
77	Little Grebe	*Tachybaptus ruficollis* (Pallas 1764)	Podicipediformes	Podicipedidae	2.62	0.71	1.84	LC
78	Rose-ringed Parakeet	*Psittacula krameri* (Scopoli 1769)	Psittaciformes	Psittacidae	0	2.13	0.87	LC
79	Plum-headed Parakeet	*Psittacula cyanocephala* (Linnaeus 1766)	Psittaciformes	Psittacidae	0	0.95	0.39	LC

Supplementary 3. Records of terrestrial plant species with respect to family in the surrounding forest of Ramaroshan Lake Complex.

	Species	Family
1	*Pteracanthus lachenensis* (C. B. Clarke) Bremek	Acanthaceae
2	*Strobilanthes species*	Acanthaceae
3	*Acer campbelli*	Aceraceae
4	*Cythula capitata* Moq.	Amaranthaceae
5	*Heracleum* sp.	Apiaceae
6	*Ilex dyprena* Wall.	Aquifoliaceae
7	*Arisaema propinqum* Schott	Araceae
8	*Hedera nepalensis* K. Koch	Araceae
9	*Asplenium ensiforme*	Aspleniaceae
10	*Ageratina adenophora*	Asteraceae
11	*Anaphalis busua* (Buch- Ham. ex D. Don.)	Asteraceae
12	*Anaphalis contorta* (D.Don) Hook.f.	Asteraceae
13	*Anaphalis triplinervis* (Sims) C. B. Clarke	Asteraceae
14	*Bidens tripartia* L.	Asteraceae
15	*Carpesium cernum* L.	Asteraceae
16	*Crassosephalum crepidoides*	Asteraceae
17	*Dicrocephala benthamii* C.B.Clarke	Asteraceae
18	*Erigeron karvinskianus*	Asteraceae
19	*Galinsoga parviflora* Cav.	Asteraceae
20	*Galinsuga ciliata* (Raf.) Blake	Asteraceae
21	*Myriactis nepalensis* Less	Asteraceae
22	*Senecio alatus* Wall.	Asteraceae
23	*Tanacetum dolichophyllum* Kitam.	Asteraceae
24	*Balanophora species*	Balanophoraceae
25	*Impatiens racemosa* DC.	Balsaminaceae
26	*Impatiens serrata* Benth.	Balsaminaceae
27	*Berberis aristata* DC.	Berberidaceae
28	*Berberis asiatica* Roxb.ex DC.	Berberidaceae
29	*Mahonia nepaulensis* DC.	Berberidaceae
30	*Cynoglossum zelanicum* (Vahl) Thunb. Ex Lehm.	Boraginaceae
31	*Barbaria intermedia* Boreau	Brassicaceae
32	*Rorippa* Sp	Brassicaceae
33	*Sarcococca hookeriana* Baill.	Buxaceae
34	*Viburnum erubescens* Wall.	Caprifoliaceae
35	*Arenaria debilis* Hook. f. ex Edgew. & Hook. F.	Caryophyllaceae
36	*Arenaria depauperata* (Edgew.)	Caryophyllaceae
37	*Stellaria media*	Caryophyllaceae
38	*Stellaria monosperma* Buch -Ham ex D. Don	Caryophyllaceae
39	*Stellaria nepalensis*	Caryophyllaceae
40	*Euonymus tingens* Wall.	Celastraceae
41	*Carex baccans* Nees	Cyperaceae
42	*Carex* species	Cyperaceae
43	*Cyperus species*	Cyperaceae
44	*Eleocharis congesta* D. Don	Cyperaceae
45	*Kyllinga brevifolia* Rottb.	Cyperaceae
46	*Daphniphyllum himalense* (Benth.) Mull. Arg.	Daphniphyllaceae
47	Dryopteris zayuensis	Dryopteridaceae

	Species	Family
48	*Elaegnus parvifolia* Wall.	Elaegnaceae
49	*Equisetum arvense*	Equisetaceae
50	*Gaultheria nummularioides* D. Don	Ericaceae
51	*Lyonia villosa* (Hook. f.) Hand- Mazz.	Ericaceae
52	*Rhododendron arboretum* Sm.	Ericaceae
53	*Parochetus communis* Buch -Ham ex D. Don	Fabaceae
54	*Parochetus communis* Buch-Ham.	Fabaceae
55	*Piptanthus nepalensis* (Hook.) D. Don	Fabaceae
56	*Quercus semicarpifolia* Sm.	Fagaceae
57	*Corydalis hookeri* Prain	Fumaricaceae
58	*Swertia aungustifolia*	Gentianaceae
59	*Swertia chirayita* (Roxb. ex-Fleming) Karsten	Gentianaceae
60	*Geranium nepalense* Sweet	Geraniaceae
61	*Ribes griffithii* Hook. f. & Thomson	Grossulariaceae
62	*Aesculus indica* (Colebr.ex Cambess.) Hook.	Hippocastanaceae
63	*Hydrangea anomala* D. Don	Hydrangeaceae
64	*Hydrangea aspera Buch* -Ham ex D. Don	Hydrangeaceae
65	*Hypericum elodeoides* Choisy	Hydrangeaceae
66	*Iris kemaonensis* D.Don	Iridaceae
67	*Juncus articulatus* L.	Juncaceae
68	*Clinopodium umbrosum* (M. Bieb.) C. Koch	Lamiaceae
69	*Elsholtzia fruiticosa* (D. Don) Rehder	Lamiaceae
70	*Eltsholtzia strobilifera* Benth.	Lamiaceae
71	*Leucosceptrum canum* Sm.	Lamiaceae
72	*Origanum vulgare* L.	Lamiaceae
73	*Salvia lanata*	Lamiaceae
74	*Thymus linearis*	Lamiaceae
75	*Dodecadenia grandiflora* Nees	Lauraceae
76	*Lindera pulcherrima* (Nees) Benth.ex Hook.f.	Lauraceae
77	*Persea odoratissima* (Nees) Kosterm.	Lauraceae
78	*Utricularia australis* R.Br.	Lentibulariaceae
79	*Allium tuberosum* Rottl.ex Sprengel	Liliaceae
80	*Allium wallichii* Kunth.	Liliaceae
81	*Cardiocrinum giganteum* (Wall.) Makino	Liliaceae
82	*Fritillaria cirrhosa* D. Don	Liliaceae
83	*Frittelaria royeli*	Liliaceae
84	*Paris polyphylla* Smith.	Liliaceae
85	*Lobelia pyramidalis* Wall.	Lobeliaceae
86	*Lyonia ovalifolia* (Wall.) Drude	Lobeliaceae
87	*Unknown parasite*	Loranthaceae
88	*Stephania gracilenta* Miers	Menispermaceae
89	*Boerhavia diffusa* L.	Nyctaginaceae
90	*Jasminum humile* L.	Oleaceae
91	*Oleandra wallichi*	Oleandraceae
92	*Epilobium palustre* L.	Onagraceae
93	*Ophioglossum nudicaule*	Ophioglossaceae
94	*Calanthe tricarinata* Lindl.	Orchidaceae
95	*Cephalanthera longifolia* (L.) Fritsch	Orchidaceae
96	*Malaxis muscifera* (Lindl.) Kuntze	Orchidaceae
97	*Platanthera species*	Orchidaceae
98	*Satyrium nepalense*	Orchidaceae
99	*Spiranthes sinensis*	Orchidaceae
100	*Oxalis corniculata* L.	Oxalidaceae
101	*Plantago erosa* Wall.	Plantaginaceae
102	*Arundinella hookeri* Munro	Poaceae
103	*Cynodon dactylon* (L.) Pers.	Poaceae
104	*Danthonia cumminsii* Hook .f.	Poaceae
105	*Digitaria cruciata* (Nees ex Steudel)	Poaceae
106	*Microstegium nodum* (Trin.) A. Camus	Poaceae
107	*Poa annua* L.	Poaceae
108	*Pogonantherum paniceum* (Lam.) Hackel	Poaceae
109	*Polypogon fugax* Nees ex Steudel	Poaceae
110	*Aconogonum molle* (D.Don) Hara	Polygonaceae
111	*Bistorta amplexicaulis* (D.Don) Greene	Polygonaceae
112	*Bistorta milletii* H. Lev.	Polygonaceae
113	*Fagopyrum tataricum* (L.) Gaertn.	Polygonaceae
114	*Persicaria capitata* Buch -Ham ex D. Don	Polygonaceae
115	*Persicaria posumbo* Buch -Ham ex D. Don	Polygonaceae
116	*Rumex nepaulensis* Spreng.	Polygonaceae
117	*Potamogeton crispus* L.	Potamogetonaceae
118	*Potamogeton lucens* L.	Potamogetonaceae
119	*Cheilanthes dalhousie* Hook.	Pteridaceae
120	*Lepisorus mehre* Fraser-Jenks	Pteridaceae
121	*Onychium species*	Pteridaceae
122	*Aconitum spicatum* (Bruhl) stapf	Ranunculaceae
123	*Thalictrum virgatum* Hook. f. Thoms.	Ranunculaceae
124	*Berchemia flavescens* (Wall.) Brongn.	Rhamnaceae
125	*Cotoneaster acuminatus* Lindl	Rosaceae
126	*Cotoneaster bacialláris* Wall.	Rosaceae
127	*Cotoneaster microphyllus* Wall.ex Lindl.	Rosaceae
128	*Fragaria nubicola* Lindl.	Rosaceae
129	*Gaultheria fragratissima*	Rosaceae
130	*Geum elatum* Wall. ex G. Don	Rosaceae
131	*Prinsepia utilis* Royle	Rosaceae
132	*Prunus cornuta* (Wall. ex-Royle) Steud.	Rosaceae
133	*Pyracantha crenulata* (D. Don) M. Roem.	Rosaceae
134	Ribes gracillis	Rosaceae
135	*Rosa brunonianum*	Rosaceae

	Species	Family
136	Rosa macrocarpa	Rosaceae
137	*Rosa microphylla* Lindl.	Rosaceae
138	Rosa serecia	Rosaceae
139	*Rubus ellipticus* Sm.	Rosaceae
140	*Rubus nepalensis* (Hook.f.) Kuntze	Rosaceae
141	*Rubus* Sp	Rosaceae
142	*Galium elegans* Wall.ex Roxb.	Rubiaceae
143	*Rubia manjith* Roxb. ex-Fleming	Rubiaceae
144	*Skimmia alatus* Wall.	Rutaceae
145	*Skimmia anquetilia*	Rutaceae
146	*Zanthoxylum nepalense* Babu	Rutaceae
147	*Salix babylonica* L.	Salicaceae
148	*Viburnum mullaha* Buch.-Ham. ex D. Don	Sambucaceae
149	*Schissandra species*	Schisandraceae
150	*Hemiphragma heterophyllum* Wall.	Scrophulariaceae
151	*Mazus surculosus* D.Don	Scrophulariaceae
152	*Schrophularia species*	Scrophulariaceae
153	*Smilax elegans* Wall. ex Kunth	Smilacaceae
154	*Solanum nigrum* L.	Solanaceae
155	*Symplocos paniculata* (Thunb.) Miq.	Symplocaceae
156	*Symplocos ramosissima* Wall. ex G. Don	Symplocaceae
157	*Taxus wallichiana* Zucc., Abh. Akad. Muench.	Taxaceae
158	*Daphne papyracea* Wall. ex Steud.	Thymelaeaceae
159	*Elatostema monandrum* (Buch.- Ham. ex D. Don.)	Urticaceae
160	*Elatostema obtusum* Wedd.	Urticaceae
161	*Elatostema sessile* J.R. and G.Forst.	Urticaceae
162	*Lecanthus peduncularis* (Royle) Wedd	Urticaceae
163	*Pilea symmerica* Wedd.	Urticaceae
164	*Pilea umbrosa* Blume	Urticaceae
165	*Valeriana hardwiki* Wall.	Valerianaceae
166	*Viola betonicifolia* Sm.	Violaceae
167	*Roscoea purpurea* Smith	Zingiberaceae

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 December 2023 | 15(12): 24321–24330
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.7647.15.12.24321-24330
#7647 | Received 04 September 2021 | Final received 31 August 2023 | Finally accepted 23 September 2023
OPEN ACCESS
ARTICLE

Diversity of wintering avifauna throughout the heterogeneous aquatic habitats of Bankura District, West Bengal, India

Biplob Kumar Modak [1], Subha Shankar Mukherjee [2], Susobhan Mondal [3], Mainak Sarkar [4] & Asif Hossain [5]

[1,2,3,4] Department of Zoology, SKB University, Purulia, West Bengal 723104, India.
[2,5] Department of Zoology, The University of Burdwan, Golapbag, Burdwan, West Bengal 713104, India.
[1] bkmodak09@gmail.com, [2] msubhashankar@gmail.com, [3] mainakbios@gmail.com, [4] susobhan.sm@gmail.com,
[5] asifhossain.bu@gmail.com (corresponding author)

Abstract: Birds play various crucial roles in the ecosystem including pollination, seed dispersal, and pest control. Assemblages of bird species in a particular landscape are useful predictors in various ecosystem services, this is evident from studies of forest bird assemblages, aquatic bodies and agro ecosystems. For developing conservation strategies, information on bird species assemblages in a particular geographical area is important. Diversity in aquatic ecosystem support a diversity of water bird species. In the present study, around 45 bird species were recorded in 21 aquatic bodies in Bankura, West Bengal, India, in which two species, namely, *Leptoptilos javanicus* and *Aythya ferina* declared 'Vulnerable' and three species such as *Mareca falcata, Threskiornis melanocephalus*, and *Limosa limosa* considered as 'Near Threatened' according to the IUCN Red list. *Dendrocygna javanica* and *Nettapus coromandelianus* were found to be the most abundant. In those 21 study areas, site6 has the highest species richness and site2 has the lowest. The dominance index was highest for site2 and lowest for site6. Pielou's index of evenness was highest for site20. The rarefaction curve showed species abundance was highest for site1. Classical cluster analysis for species abundance showsthat site20, site21, site3, site8, site4, site19, site5, site14, site12, site15, site7, site 10 site11, and site13 are closely related. This paper is aimed to generate interest among people to conserve aquatic birds and their habitats and to document baseline information for further study.

Keywords: Abundance, conservation, diversity, evenness, winter birds, Near Threatened, richness, Vulnerable.

Editor: S. Balachandran, Bombay Natural History Society, Mumbai, India. **Date of publication:** 26 December 2023 (online & print)

Citation: Modak, B.K., S.S. Mukherjee, S. Mondal, M. Sarkar & A. Hossain (2023). Diversity of wintering avifauna throughout the heterogeneous aquatic habitats of Bankura District, West Bengal, India. *Journal of Threatened Taxa* 15(12): 24321–24330. https://doi.org/10.11609/jott.7647.15.12.24321-24330

Funding: Financial assistance provided by WBBB (Memo no. 51./5k(Bio)-3/2018 dt 09/01/2019).

Competing interests: The authors declare no competing interests.

Author details: Biplob Kumar Modak is a professor in Department of Zoology, Sidho-Kanho-Birsha University, Purulia. Subha Shankar Mukherjee is a senior research fellow (UGC) in Department of Zoology, The University of Burdwan. Susobhan Mondal is a research scholar in Department of Zoology, Sidho-Kanho-Birsha University. Mainak Sarkar is a research scholar in Department of Zoology, Sidho-Kanho-Birsha University. Asif Hossain is an assistant professor in Department of Zoology, The University of Burdwan.

Author contributions: BKM conceptualised the idea, helped in data collection and drafting the manuscript. SSM contributed in data collection and analyses. SM helped in field survey and data analyses. MS helped in field survey and data analyses. AH helped data collection, analyses and drafting manuscript.

Acknowledgements: The authors thankfully acknowledge the head, Department of Zoology, SKB University, Purulia, India, and Head, Department of Zoology, The University of Burdwan, Golapbag, Burdwan, India, for the facilities provided. The authors thankfully acknowledge the critical comments of the anonymous reviewers and the suggestions of the respected chief editor that helped in transforming the manuscript into the present form. Financial assistance provided by WBBB (Memo no. 51./5k(Bio)-3/2018 dt 09/01/2019) is thankfully acknowledged.

INTRODUCTION

Birds are one of the most popular life forms on the planet and their diversity contributes to life's richness and beauty. Birds are important components of the ecosystem contributing substantively toecosystem function, especially pollination, seed dispersal, pest control, nutrient cycling, and others (Whelan et al. 2008; Sekercioglu 2012). Information on bird assemblages in forests (Aich & Mukhopadhyay 2008; Roy et al. 2011; Chatterjee et al. 2013), aquatic bodies (Kumar et al. 2006; Kumar & Gupta 2013), agricultural and otherlandscapes are useful tools in understanding the various ecosystem health (Dhindsa & Saini 1994; Borad et al. 2001; Basavarajappa 2006; Gopi Sundar 2011; Gopi Sundar & Kittur 2013; Hossain & Aditya 2014) and to develop strategies for conservation and further monitoring of ecosystem conditions and functions (Bradford et al. 1998; Browder et al. 2002). Millions of people rely on aquatic ecosystems for a better living through fishing, agricultural irrigation and other purposes. Birds can be found almost everywhere on the planet, in almost every climatic condition and at nearly every altitude. Birds are excellent environmental indicators because they respond quickly to changes in habitat structure, composition and other environmental factors (Hossain & Aditya 2014). Besides their aesthetic role, they also hold a unique position in the food chain. Aquatic ecosystems are highly productive ecosystems on Earth and provide people a source of food, animal farming, fisheries, aquaculture and also as a refuge for rare and endangered plant and animal species. The assemblage of foraging bird species is dependent on habitat type and stable condition of food resources. Migratory birds also play an important role in maintaining ecosystem health by influencing nutrient cycling during the migratory season. The present study deals with the documentation of avifauna in Bankura and similar areas in the Chota Nagpur Plateau. The study sites are heterogeneous in habitat structure as some of the aquatic bodies are in plains area while others are from hilly terrains, and forested areas while some from agricultural areas and a few of them are within the human settlements. The climate of the Bankura District is characterized by excessive heat in summer and highly humid throughout the year. The average daily maximum temperature varies 26–39 ^{0}C during summer and during winter temperature ranges 12–25 ^{0}C. The relative humidity is high throughout the year. Damodar, Dwarakeswar, Silabati, and Kangsabati are the four major rivers of Bankura District. These rivers constitute the main drainage system of this district. The Kangsabati dam is a major dam constructed on the river at Mukutmanipur of Bankura District to arrest flood and to provide irrigation facilities. There are many threats to the water bodies of Bankura that include pollution due to domestic sewage, pesticides, fertilizers, farming agriculture along the exposing periphery, eutrophication/blooms of surface water, partial reclamation of wetland, residential & commercial development, and sedimentation that are the primary factors for reducing species diversity including birds.

The current study's goal was to assess the diversity of wintering aquatic birds and create an avifauna checklist for the district of Bankura, West Bengal, India, which will aid in future aquatic bird management with appropriate conservation strategies.

MATERIALS AND METHODS

Study Area

The survey was carried out at 21 water bodies and adjoining landscapes in Bankura, West Bengal, India, namely Mukutmanipur Dam (Site 1), Lal Bandh (Site 2), Jamuna Bandh (Site 3), Krishna Bandh (Site 4), Kulaijurir Bandh (Site 5), Sal Bandh (Site 6), Kadam Deuli Dam (Site 7), Sutan Dam (Site 8), Gangdua Dam (Site 9), Bonkati Bandh (Site10), Bagjobra Bandh (Site11), Kesiakol Bandh (Site 12), Talberia Dam (Site 13), Kakila Daha (Site 14), Jhilimili Bandh (Site 15), Poabagan Bandh (Site 16), Chattna Bandh (Site 17), Nityanandapur Dam (Site 18), AmbikanagarBandh (Site 19), Saheb Bandh (Site 20), and Ranir Bandh (Site 21). All of the sites' coordinates are plotted in a raster plot (Figure 1a,b,c). The following are the specific characteristics of these aquatic bodies:

Mukutmanipur dam: This is a reservoir type of aquatic body, with rain water and streams as the primary sources of water. This body of water covers approximately 38.4 ha and has a maximum depth of 11 m. Vegetation covered 5% of the area, including submerged Hydrilla as well as shrubs and reeds in the bank.

Lal Bandh: Fresh water lake with 30% vegetation cover, including shrubs, reeds, Hydrilla, water hyacinth, and water lilies. The lake has a surface area of about 12 ha and a maximum depth of about 9 m.

Jamuna Bandh: This freshwater lake covers an area of 22 ha, with vegetation covering 90% of the area. This aquatic body has a maximum depth of approximately 8 m.

Krishna Bandh: Relying completely on rainfall and local streams, this freshwater lake spans 10 ha in surface area with a maximum depth of 5 m. Notably, 30% of the area hosts vegetation, including submerged Hydrilla,

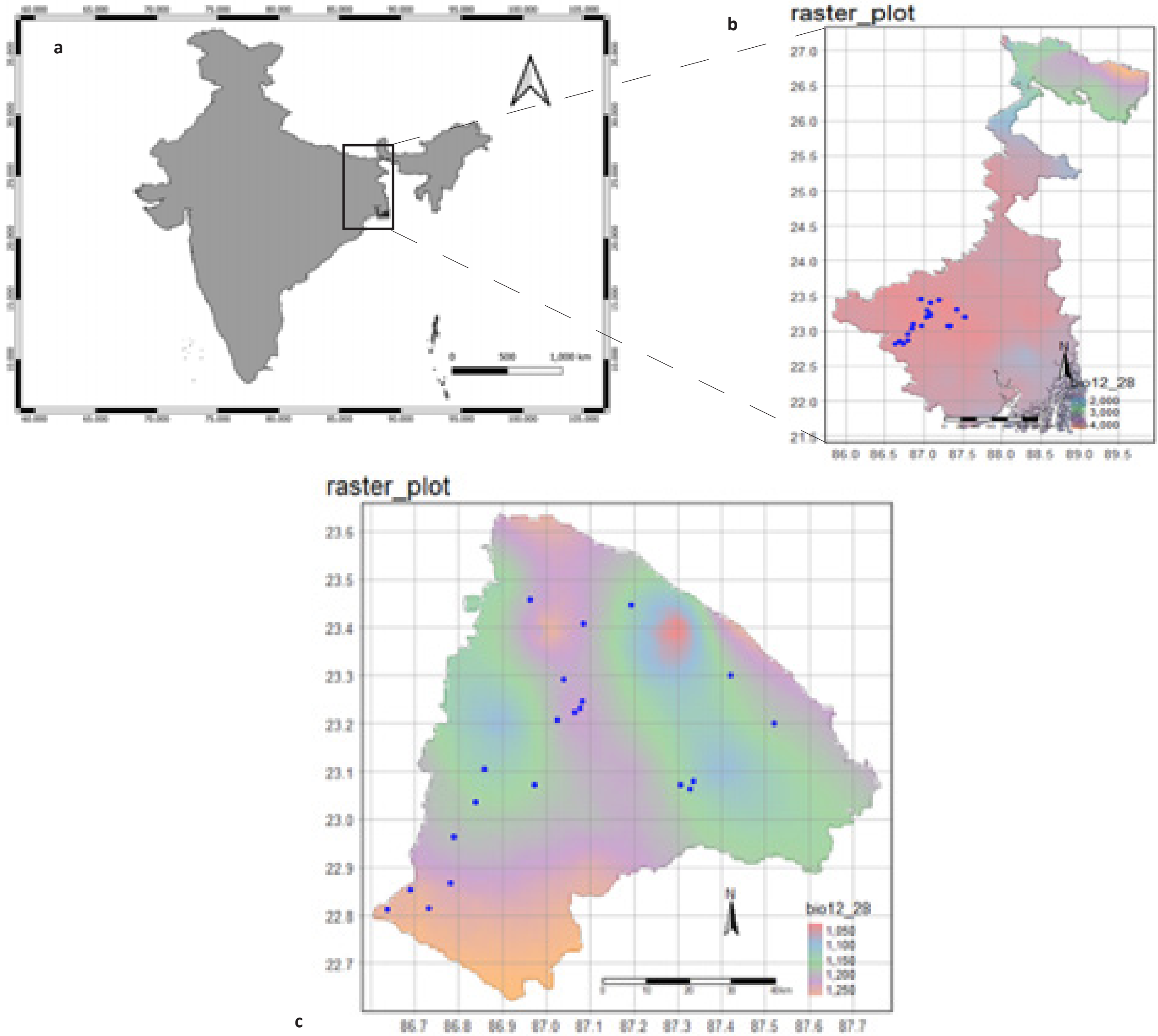

Figure 1. a—Coordinates of study area plotted in India State map | b—Raster plot of West Bengal | c—Raster plot of Bankura District.

free-floating water hyacinth, shrubs, and reeds along the banks.

Kulaijurir bandh: This freshwater pond covers an area of 18 ha and has a maximum depth of about 5 m; 56% of the area is covered by vegetation, which includes various shrubs on the bank, free-floating water hyacinth, and submerged Hydrilla.

Sal bandh: Sal bandh is a 3.5-ha reservoir with a maximum depth of 3 m. It is dependent on local rain and is only temporary in nature. Vegetation covered 20% of this area.

Kadam Deuli dam: Featuring a 7 m maximum depth, this rainwater and stream-fed freshwater pond spans a total area of 14.94 ha. Impressively, 86% of this expanse is veiled by vegetation.

Sutan dam: This reservoir has a surface area of 6.5 ha and a maximum depth of 4 m. It is primarily dependent on rainfall and streams. Vegetation such as *Hydrilla* and various shrubs covered 15% of the area.

Gangdua dam: This lake's main source of water is local rainfall and streams. This body of water has an area of about 18 ha and a maximum depth of 7.5 m. Hydrilla and water lily vegetation covered 35% of the area.

Bonkati bandh: The main sources of water for this freshwater lake are local rainand streams. This water body covers an area of11.92 ha and has a maximum depth o-f about 5 m. The vegetation covered 66% of the land area.

Bagjobra bandh: This lake covers 5 ha, and 86% of it is covered by vegetation such as shrubs and reeds growing on the bank, free floating water hyacinth, submerged Hydrilla, and floating, leaved-rooted water lilies.

Kesiakol bandh: This freshwater lake covers 10.26 ha and has a maximum depth of 4.5 m. The lake is 10.26 ha in size, with vegetation covering 38% of the area.

Talberia dam: Talberia dam is a freshwater lake with a surface area of 12.30 ha and a maximum depth of 5 m. It is reliant on rainwater and streams, and vegetation covers 53% of the area, including various shrubs in the bank, Hydrilla*,* water hyacinth, and water lilies.

Kakila Daha: Local rainwater and streams are the primary sources of water for this lake, which has a maximum depth of 5 m. This lake took up 4.94 ha of land, accounting for 39% of the total vegetation area.

Jhilimili bandh: This freshwater lake has a surface area of 12.37 ha and a maximum depth of 5.5 m. It is entirely dependent on rainwater and streams for its survival. The vegetation covered 66% of the land area.

Poabagan bandh: Spanning an area of 4.514 ha, this site relies on local rainfall and streams for sustained existence. Vegetation, encompassing shrubs, reeds, Hydrilla, and water hyacinth, blankets 46% of the area.

Chattna bandh: This freshwater lake has an area of 11.30 ha, with vegetation covering 69% of it. Its long-term survival is dependent on local rains and streams.

Nityanandapur dam: With a surface area of 24 ha and a maximum depth of 7 m, this reservoir relies on rainfall and local streams. About 90% of its area features vegetation, including various shrubs, Hydrilla, and water lilies.

Ambikanagar bandh: This freshwater lake, fed by local rain and streams, spans an area of 18 ha with a maximum depth of 12 m. Approximately 90% of the area is covered by vegetation

Saheb bandh: A freshwater lake with a surface area of 9.2 ha and a depth of 6 m. It is mainly dependent on local rainfall and stream flow. The area is covered by vegetation, accounting for 49% of the total area. This vegetation includes primarily shrubs growing along the banks, as well as submerged and free-floating aquatic plants.

Ranir bandh: This lake is seasonal in nature and relies on water from streams. It spans an area of 3 ha and has a maximum depth of 5 m. Vegetation covers 20% of the total area surrounding the lake.

Data Collection

The survey spanned from November to January in both 2018 and 2019, involving monthly visits to study sites from 0700 h to 1200 h and 1230 h to 1700 h with the participation of nine individuals. Transportation primarily relied on bicycles and motorcycles to cover the extensive distances. Executed through the point count method, the survey focused on cataloging bird species around water bodies and their environs. Birds were observed using Olympus 7 X 21 PS III binoculars and documented via Nikon Coolpix P600 camera. Identification of avian species utilized relevant keys from Grimmett et al. (1998), Kazmierczak & van Perlo (2000), and Ali (2002)

Statistical Analyses

Three biological indices are employed to compute species richness, species dominance, and evenness: the Shannon-Wiener index (Shannon & Wiener 1963), the Berger-Parker index (Berger & Parker 1970), and Pielou's index (Pielou 1969; Biswas et al. 2019; Mukherjee et al. 2021). The Shannon-Wiener index (Shannon & Wiener 1963) serves as a valuable statistical metric for determining the species richness within a community. This index can yield low values due to the contribution of rare species with small populations. The calculation is expressed as $Hs = -\Sigma pi \ln pi$, where Hs represents the Shannon index value and pi signifies the proportion of the ith species within the community. The Berger-Parker index (Berger & Parker 1970) is derived as $d = \max(pi)$, where d indicates dominance and pi denotes the proportion of the i^{th} species in the community. Higher values of the Berger-Parker index imply greater dominance by one or a few species. Pielou's index of species evenness (Pielou 1969) gauges how evenly species are distributed numerically within the community. The following formula quantifies it: $E = Hs / Hmax$, where E signifies evenness, Hs signifies the Shannon index value, and Hmax represents ln(S), where S signifies the number of species in the community. Pielou's evenness index ranges from 0 to 1, with values closer to 1 indicating higher species evenness in the community. All three indices underwent one-way ANOVA to assess the significance of differences in their means. Subsequently, the species-habitat-evenness (SHE) analysis was employed to interpret the relationship between species richness (H) and evenness (E) of the samples. This analysis was carried out to understand the log series distribution of species in the community. Furthermore, principal component analysis (PCA) was performed on the Shannon-Wiener index of species richness, Pielou's index of evenness, and the Berger-Parker index of dominance to elucidate the relationships between these three variables. For the species abundance across all 21 sites, classical clustering using the UPGMA algorithm (based on the Brey-Curtis index) was executed (Mukherjee & Mondal 2020). All analyses were conducted using PAST 3.14 (Hammer et al. 2001) and R-Studio 3.6.3 (R Studio Team 2020).

RESULTS

In Bankura, 45 species of aquatic birds were recorded during winter in 21 different locations (Table 1). The results of one-way ANOVA for the Shannon-Wiener index ($F = 11.06$, $p < 0.001$) (Table 2), Berger-Parker index of dominance ($F = 6.519$, $p < 0.001$) (Table 2) and Pielou's index of evenness ($F = 27.92$, $p < 0.001$) (Table 2) demonstrated that there was a significant difference in the mean of all the indices present in all of the study sites. The Shannon-Wiener index, or species richness, was highest at site 6 (2.280±0.10) and lowest at site 2 (0.82±0.015) (Figure 2). These findings indicate that the community at site 6 is a natural one with high species richness. As the dominance index increases, species richness decreases because the highest dominance index recommends the predominance of one or a few species in an ecosystem. Site 2 has the highest dominance index (0.84±0.13) and Site 6 has the lowest (0.32±0.04) (Figure 3). The highest species evenness (0.91±0.06) is found at Site 20 (Figure 4). The results of SHE analysis show a log-series distribution of bird species in the studied area (Figure 5). Individual rarefaction analysis of taxa plotted at the 95 percent confidence level shows that the highest specimen is more likely to be found in site 1, followed by site 2 (Figure 6). PCA results show that dimension 1 has an Eigen value of 2.04390180, followed by dimension 2 with a value of 0.92147965; in terms of percent variance, dimensions 1 and 2 contribute 68.130060 and 30.715988, respectively (Table 3). The PCA scree plot shows that dimensions 1 and 2 contribute the majority of the percent variance (Figure 7). In terms of species abundance, classical cluster analysis using the Brey-Curtis index reveals that sites 20-site 21, site 3, site 8, site 4, site 19, site 5, site 14, site 12, site15, site7, site 10 and site 11, site 13 are closely related (Figure 8).

DISCUSSION

During the current study, 45 bird Species of 13 families such as Accipitridae, Alcedinidae, Anatidae, Ardeidae, Charadriidae, Ciconiidae, Jacanidae, Motacillidae, Phalacrocoracidae, Podicipedidae, Rallidae, Scolopacidae, and Threskiornithidae were recorded in aquatic bodies in the Bankura district, including two 'Vulnerable' species *Leptoptilos javanicus*and *Aythya farina*, three

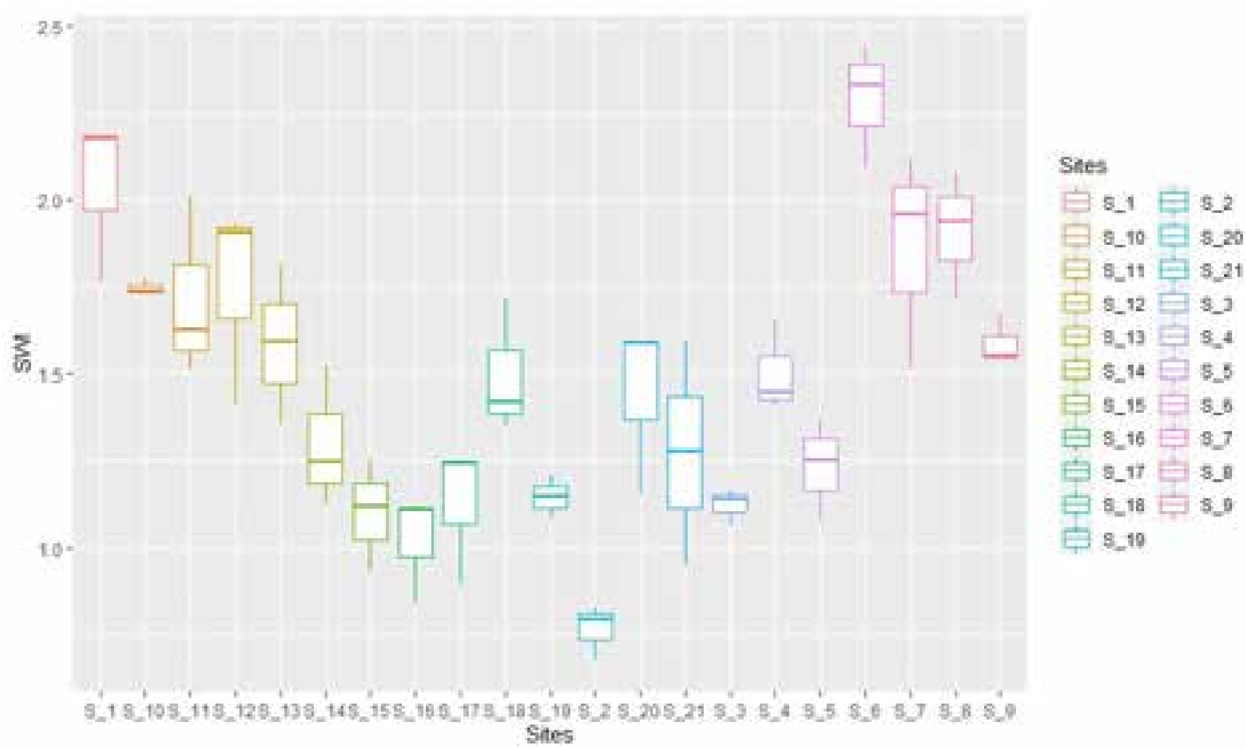

Figure 2. Ggplot of Shannon-Wiener index showing Site 6 has the highest and Site 2 has the lowest species richness.

Table 1. List of aquatic and migratory birds observed in Bankura district during thestudy period, 2018–2019. W —Winter Migratory | R—Resident | L—Local migratory | VU—Vulnerable | LC—Least Concern | NT–Near Threatened.

Common name	Scientific name	Family	IUCN Red List status	Migratory status	Abundance
Lesser Whistling-Duck	*Dendrocygna javanica*	Anatidae	LC	W	2125
Cotton Pygmy-Goose	*Nettapus coromandelianus*	Anatidae	LC	W	3351
Common Teal	*Anas crecca*	Anatidae	LC	L	62
Northern Pintail	*Anas acuta*	Anatidae	LC	W	62
Falcated Duck	*Mareca falcata*	Anatidae	NT	W	19
Garganey	*Spatula querquedula*	Anatidae	LC	W	12
Tufted Duck	*Aythya fuligula*	Anatidae	LC	L	7
Common Pochard	*Aythya ferina*	Anatidae	VU	L	85
Gadwall	*Mareca strepera*	Anatidae	LC	W	60
Red-crested Pochard	*Netta rufina*	Anatidae	LC	W	34
Indian PondHeron	*Ardeola grayii*	Ardeidae	LC	R	209
Cattle Egret	*Bubulcus ibis*	Ardeidae	LC	R	182
Purple Heron	*Ardea purpurea*	Ardeidae	LC	R	23
Great Egret	*Ardea alba*	Ardeidae	LC	R	38
Little Egret	*Egretta garzetta*	Ardeidae	LC	R	47
Yellow Bittern	*Ixobrychus sinensis*	Ardeidae	LC	L	32
Cinnamon Bittern	*Ixobrychus cinnamomeus*	Ardeidae	LC	R	18
Little Cormorant	*Microcarbo niger*	Phalacrocoracidae	LC	R	283
Great Cormorant	*Phalacrocorax carbo*	Phalacrocoracidae	LC	R	41
Pheasant-tailed Jacana	*Hydrophasianus chirurgus*	Jacanidae	LC	R	35
Bronze-winged Jacana	*Metopidius indicus*	Jacanidae	LC	R	48
Asian Openbill	*Anastomus oscitans*	Ciconiidae	LC	R	31
Lesser Adjutant	*Leptoptilos javanicus*	Ciconiidae	VU	L	28
White-brested Kingfisher	*Halcyon smyrnensis*	Alcedinidae	LC	R	17
Common Kingfisher	*Alcedo atthis*	Alcedinidae	LC	R	91
Pied Kingfisher	*Ceryle rudis*	Alcedinidae	LC	R	18
Stork-billed Kingfisher	*Pelargopsis capensis*	Alcedinidae	LC	R	21
Common Sandpiper	*Actitis hypoleucos*	Scolopacidae	LC	W	55
Green Sandpiper	*Tringa ochropus*	Scolopacidae	LC	W	11
Common Greenshank	*Tringa nebularia*	Scolopacidae	LC	W	15
Common Redshank	*Tringa totanus*	Scolopacidae	LC	W	2
Black-tailed Godwit	*Limosa limosa*	Scolopacidae	NT	W	9
Little Grebe	*Tachybaptus ruficollis*	Podicipedidae	LC	L	316
Ruddy-breasted Crake	*Zapornia fusca*	Rallidae	LC	R	4
Purple Swamphen	*Porphyrio poliocephalus*	Rallidae	LC	R	8
Common Moorhen	*Gallinula chloropus*	Rallidae	LC	R	105
Common Coot	*Fulica atra*	Rallidae	LC	L	19
White-breasted Waterhen	*Amaurornis phoenicurus*	Rallidae	LC	R	86
Western Marsh-Harrier (Eurasian Marsh-Harrier)	*Circus aeruginosus*	Accipitridae	LC	R	25
Yellow-wattled Lapwing	*Vanellus malabaricus*	Charadriidae	LC	R	4
White Wagtail	*Motacilla alba*	Motacillidae	LC	W	2
Western Yellow Wagtail	*Motacilla flava*	Motacillidae	LC	W	9
Citrine Wagtail	*Motacilla citreola*	Motacillidae	LC	W	12
Black-headed Ibis	*Threskiornis melanocephalus*	Threskiornithidae	NT	L	41
Red-naped Ibis	*Pseudibis papillosa*	Threskiornithidae	LC	L	8

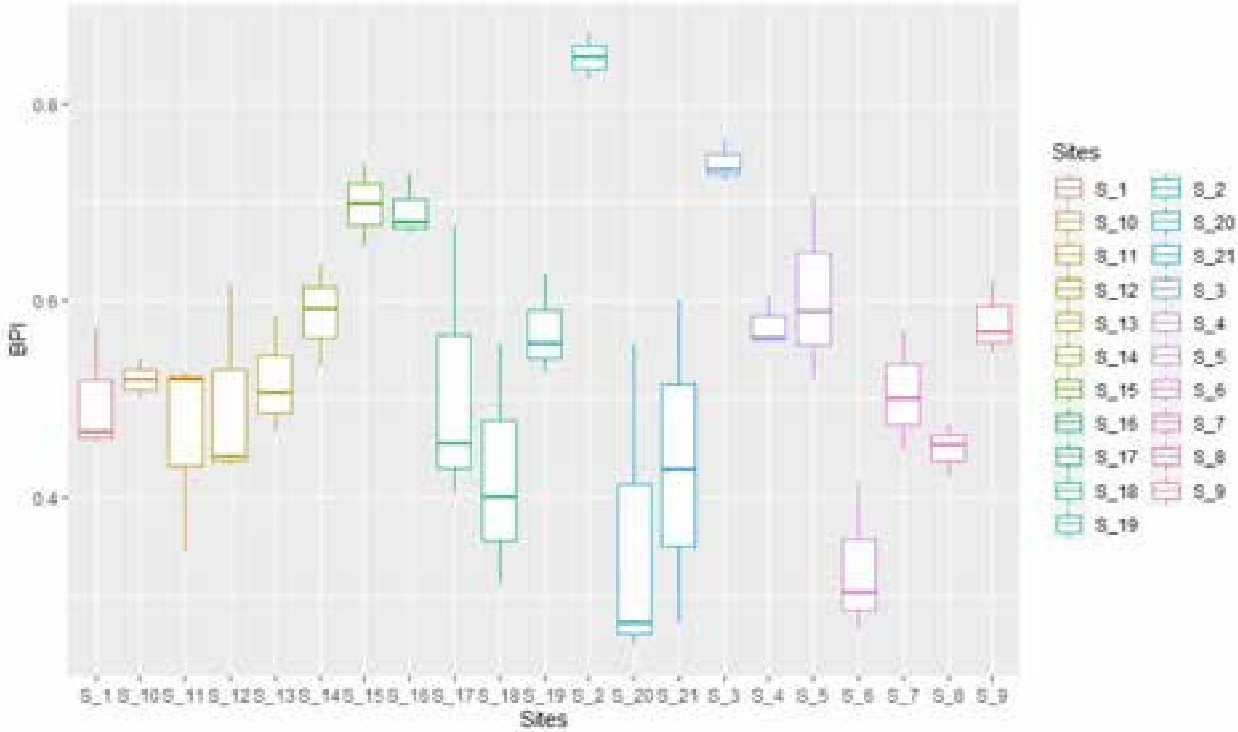

Figure 3. Ggplot of Berger-Parker index of dominance showing Site 2 has the highest and Site 6 has the lowest dominance.

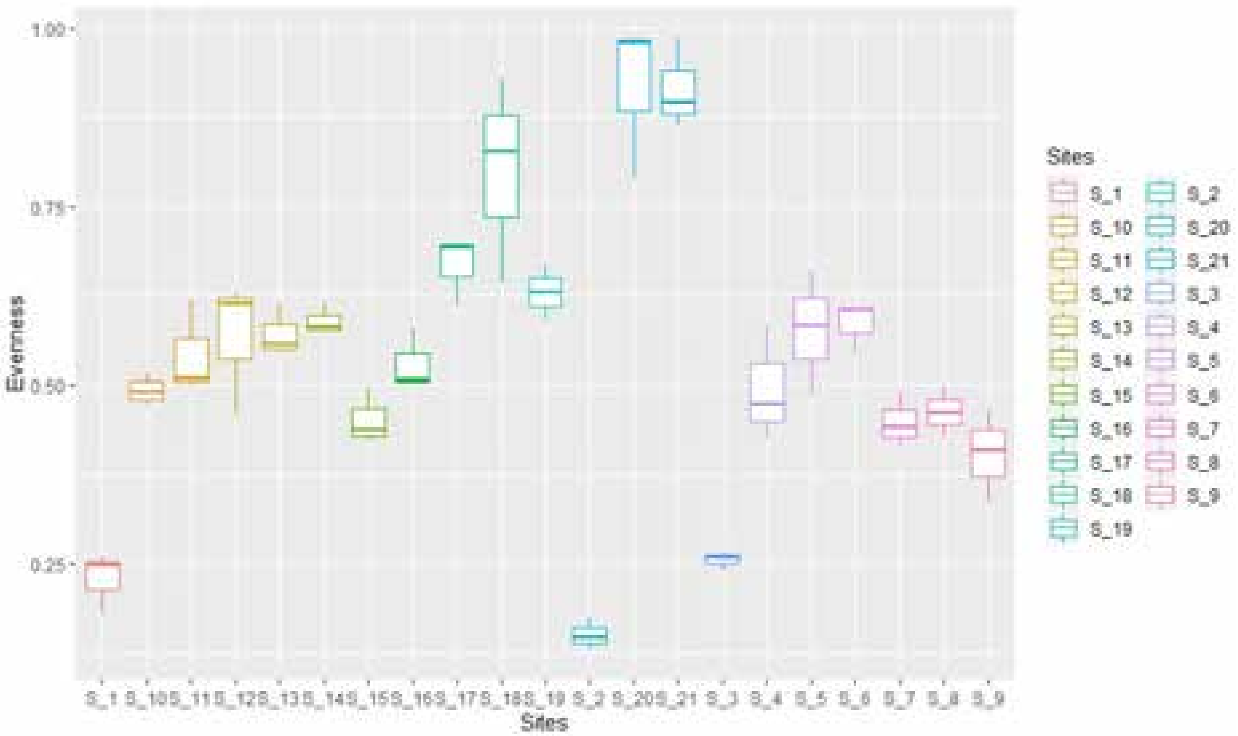

Figure 4. Ggplot of Pielou's index of evenness showing site 20 has the highest species evenness.

Table 2. Result of one-way ANOVA of Shannon-Wiener index, Berger-Parker index and Pielou's index of evenness of 21 sampling sites. F values are significant at p <0.001 level.

Index		D_f	Sum Sq	Mean Sq	F value	Pr (>F)
Shannon-Wiener index	Sites	20	8.712	0.4536	11.06	<0.001
	Residuals	42	1.655	0.0394		
Berger- Parker index	Sites	20	0.9414	0.04707	6.519	<0.001
	Residuals	42	0.3033	0.00722		
Pielou's index of evenness	Sites	20	2.2621	0.11311	27.92	<0.001
	Residuals	42	0.1701	0.00405		

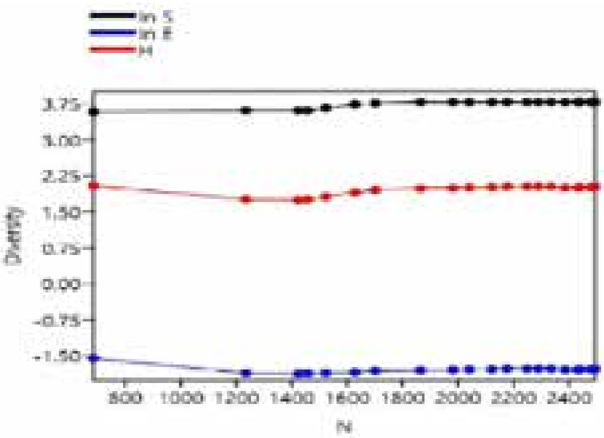

Figure 5. Graphical representation of SHE analysis.

Table 3. Results of Principal component analysis showing that dimension 1 has the highest eigenvalue and percent variance followed by dimension 2.

Dimensions	Eigen value	Percent variance	Cumulative percent variance
Dim.1	2.04390180	68.130060	68.13006
Dim.2	0.92147965	30.715988	98.84605
Dim.3	0.03461855	1.153952	100.00000

'Near Threatened' species *Mareca falcata, Threskiornis melanocephalus* and *Limosa limosa* as listed under *Dendrocygna javanica* and *Nettapus coromandelianus* are the most abundant. This is the first report of its kind on birds in 21 aquatic bodies and their surroundings in Bankura. Birds are vulnerable to changes in the landscape, pollution, hunting and other factors, so proper precautions must be taken to protect them. The Shannon-Wiener index is highest at site 6 and lowest at site 2, and the Berger-Parker index is highest at site 2 and lowest at site 6. Site 20 has the highest level of evenness. The results of SHE analysis show that the distribution of bird species in the studied area is a log series. The rarefaction curve depicts the likelihood of finding the most specimens at site 1, followed by site 2. The richness value observed during the current survey is higher than the values reported in 2000 for Purulia Saheb bandh (24 species) (Nandi et al. 2004), Santragachi lake in Howrah District, West Bengal (22 species) (Roy et al. 2011), Bakreswar and Hinglo reservoirs and Adra Saheb bandh lake (24 species) (Khan et al. 2016), but lower than the Kolkata surroundings (48 species) (Sengupta et al. 2013), Purulia town and its outskirts (115 species) (Mahato et al. 2021), agricultural landscape in Burdwan (Hossain & Aditya 2014). The Shannon index (2.28) in Sal Bandh (Site 6), which was the highest during the current survey, was lower than the Mukkali moist deciduous forest (3.45) and Purulia town and its outskirts (3.66) (Jayson & Mathew 2000; Mahato et al. 2021). In 2018 it was reported that the species richness of Mukutmanipur dam (81 species) (Singh et al. 2018) was much higher than the richness value in this dam during the present survey (36 species). The richness value for Jamuna bandh (12 species), Krishna bandh (11 species), and Kulaijurir bandh (6 species) was lower, but the Lal bandh (15 species) richness value was higher than the previous survey that was conducted in 2000 (Nandi et al. 2007). Apart from this, it was also found during the present survey Sal bandh (site 6), Kadam Deuli Dam (Site 7), Sutan Dam (Site 8), Gangdua Dam (Site 9), Bonkati Bandh (Site 10), Bagjobra Bandh (Site 11), Kesiakol Bandh (Site 12), Talberia Dam (Site 13), Kakila Daha (Site 14), Jhilimili Bandh (Site 15), Poabagan Bandh (Site 16), Chattna Bandh (Site 17), Nityanandapur Dam (Site 18), Ambikanagar Bandh (Site 19), Saheb Bandh (Site 20) and Ranir Bandh (Site 21) contain 19, 16, 15, 14, 12, 12, 10, 10, 8, 6, 6, 5, 6, 5, 5, and 5 species, respectively. The present study investigates that the reduction in richness value may be due to pollution by domestic sewage, pesticides, fertilizers, eutrophication and residential & commercial development in the bank of these aquatic bodies. The loss of avian diversity can have a significant impact on species

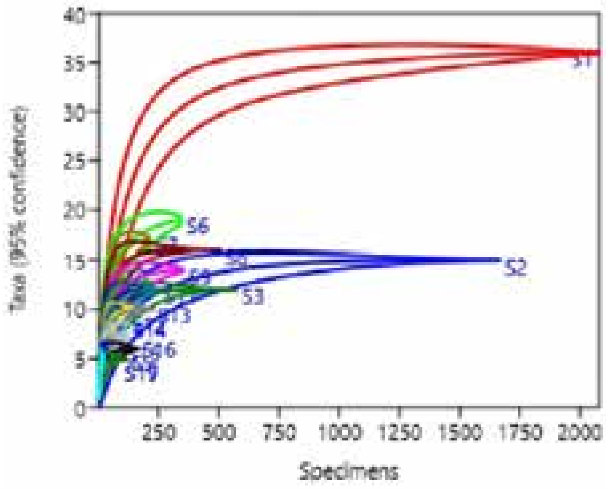

Figure 6. Rarefaction curve indicating site1 has the probability of finding the highest specimen in site1 followed by site 2.

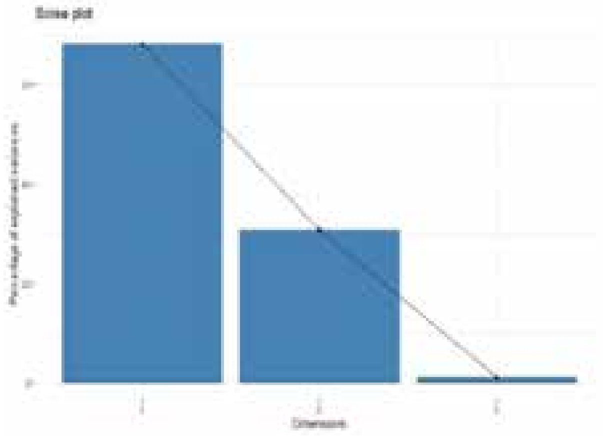

Figure 7. PCA scree plot indicates dimension 1 and dimension 2 contribute most of the percent variance.

interactions and ecosystem functions. Changes in avian diversity have an impact on the food chain (Hossain & Aditya 2014). Assessing avifauna assemblages to govern foraging behaviour and habitat preferences is critical for determining their importance in ecosystem services (Lawton et al. 1998; Sekercioglu 2006). It was observed that species richness values were lower for the Mukutmanipur dam, Jamuna bandh, Krishna bandh, and Kulaijurir bandhbut richness value was higher for Lal bandh than the previous survey (Nandi et al. 2004). A survey of sixteen new aquatic bodies was conducted that had not previously been done (Nandi et al. 2004). So, to begin the assessment of ecological services in a specific landscape, a document of species richness and composition of birds must be created and maintained as present study. This document aids in the comparison of aquatic bird diversity for future research. The primary step in the conservation of bird species and the maintenance of ecosystem services is the species-specific ecological role, which is far from complete in the Indian context (Dhindsa & Saini 1994; Singh &Banyal 2013; Sengupta et al. 2013; Sundar & Kittur 2013). This report can pique people's interest in conserving aquatic birds and their habitats and conservation of this avifauna is necessary for long-term development.

REFERENCES

Ali, S., (2002). *The Book of Indian Birds*. Oxford University Press, New Delhi, 486 pp.

Aich, A. & S.K. Mukhopadhyay (2008). Comparison of avifauna at the edges of contrasting forest patches in Western Ghat Hills of India. *Ring* 30(1/2): 71–79. https://doi.org/10.2478/v10050-008-0001-6

Basavarajappa, S. (2006). Avifauna of agro-ecosystems of Maidan area of Karnataka. *Zoos' Print Journal* 21(7): 2217–2219. https://doi.org/10.11609/JoTT.ZPJ.1277.2217-9

Basu, P., S. Sao & R. Singh (2018). Diversity, seasonal, variation, abundance and migratory behavior of local and migratory water birds of Mukutmanipur Dam, Bankura, West Bengal, India. *World Journal of Pharmaceutical Research* 7(11): 855–869.

Berger, W.H., & F.L. Parker (1970). Diversity of Planktonic foraminifera in deep- sea sediments. *Science* 168: 1345–1347. https://doi.org/10.1126/science.168.3937.1345

Biswas, S.J.B., D. Patra, S. Roy, S.K. Giri, S. Paul & A. Hossain (2019). Butterfly diversity throughout Midnapore urban area in West Bengal, India *Journal of Threatened Taxa* 11(4): 14816-14826. https://doi.org/10.11609/jott.4587.11.14.14816-14826

Borad, C.K., A. Mukherjee & B.M. Parasharya (2001). Damage potential of Indian Sarus Crane in paddy crop agro-ecosystems in Kheda district, Gujarat, India. *Agriculture, Ecosystems and Environment* 86: 211–215. https://doi.org/10.1016/S0167-8809(00)00275-9

Bradford, D.F., S.E. Franson, A.C. Neale, D.T. Heggem, G.R. Miller & G.E. Canterbury (1998). Bird species assemblages as indicators of biological integrity in Great Basin Rangeland. *Environmental Monitoring and Assessment* 49: 1–22. https://doi.org/10.1023/A:1005712405487

Browder, S.F., D.H. Johnson & I.J. Ball (2002). Assemblages of breeding birds as indicators of grassland condition. *Ecological Indicators* 2: 257–270. https://doi.org/10.1016/S1470-160X(02)00060-2

Chatterjee, A., S. Adhikari, A. Barik & S.K. Mukhopadhyay (2013). The mid-winter assemblage and diversity of bird populations at Patlakhawa Protected Forest, Coochbehar, West Bengal, India. *Ring* 35: 31–53. https://doi.org/10.2478/ring-2013-0002

Dhindsa, M.S. & H.K. Saini (1994). Agricultural ornithology: An Indian perspective. *Journal of Biosciences* 19(4): 391–402. https://doi.org/10.1007/BF02703176

Grimmett, R., C. Inskipp & T. Inskipp (1998). *Birds of the Indian Subcontinent*. Oxford University Press, New Delhi, 528 pp.

Hammer, Ø., D.A.T. Harper & P.D. Ryan (2001). PAST: paleontological statistics software package for education and data analysis. *Palaeontology* 4(1): 9.

Hossain, A. & G. Aditya (2014). Avian Diversity in Agricultural Landscape: Records from Burdwan, West Bengal, India. *Proceedings of the Zoological Society* 69(1): 38–51. https://doi.org/10.1007/s12595-014-0118-3

Jayson, E. & D.N. Mathew (2000). Diversity and species abundance distribution of birds in the tropical forests of Silent Valley, Kerala. *Journal of the Bombay Natural History Society* 97: 390–400.

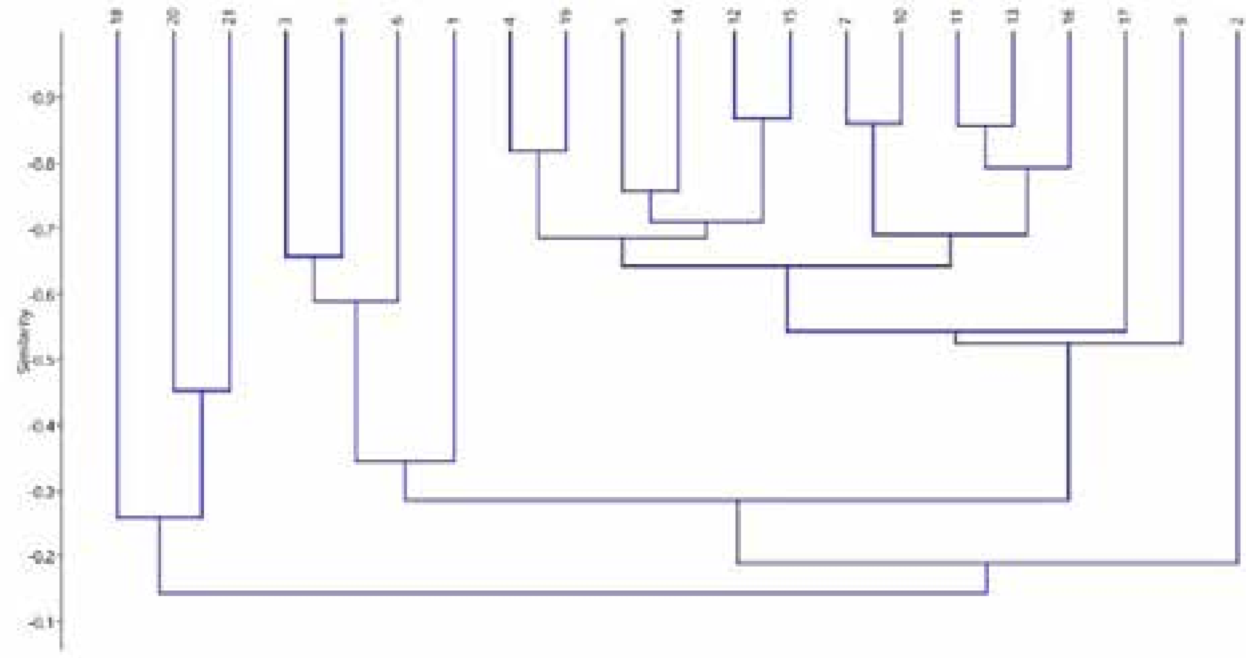

Figure 8. Results of classical cluster analysis by using algorithm UPGMA (Brey-Curtis index) showing similarity between all 21 study sites.

Kazmierczak, K. & B. van Perlo (2000). *Birds of India*. Om Books International, New Delhi.

Khan, T.N., A. Sinha & P. Hazra (2016). Population trends and community composition of migratory waterbirds in three emerging wetlands of global significance in southwestern Bengal, India. *Journal of Threatened Taxa* 8(3): 8541–8555. https://doi.org/10.11609/jott.2652.8.3.8541-8555

Kumar, A., P.C. Tak & J.P. Sati (2006). Residential, population and conservation status of Indian wetland birds. In: Boere, G.C., C.A. Galbraith & D.A. Stroud (eds.). *Waterbirds Around the World* ed. The Stationery Office, Edinburgh, UK.

Kumar, P. & S.K. Gupta (2013). Status of wetland birds of Chhilchhila Wildlife Sanctuary, Haryana, India. *Journal of Threatened Taxa* 5(5): 3969–3976. https://doi.org/10.11609/JoTT.o3158.3969-76

Lawton, J.H., D.E. Bignell, B. Bolton, G.F. Bloemers, P. Eggleton, P.M. Hammond, M. Hodda, R.D. Holt, T.B. Larsen, N.A. Mawdsley, N.E. Stork, D.S. Srivastava & A.D. Watt (1998). Biodiversity inventories, indicator taxa, and effects of habitat modification in tropical forest. *Nature* 391: 72–76. https://doi.org/10.1038/34166

Mahato, S., S. Mandal & D. Das (2021). An appraisal of avian species diversity in and around Purulia Town, West Bengal, India. *Journal of Threatened Taxa* 13(3): 17906–17917. https://doi.org/10.11609/jott.4733

Mukherjee, K. & A. Mondal (2020). Butterfly diversity in heterogeneous habitat of Bankura, West Bengal, India. *Journal of Threatened Taxa* 12(8): 15804–15816. https://doi.org/10.11609/jot.5136.12.8.15804-15816

Mukherjee, S.S., M.T. Ahmed & A. Hossain (2021). Role of a Global Invasive Species (GIS), *Lantana camara* in conservation and sustenance of local butterfly community. *Acta Ecologica Sinica* 42(6): 600–604. https://doi.org/10.1016/j.chnaes.2021.02.008

Nandi, N.C., K. Bhenkataraman, S.R. Das & S.K. Das (2007). Notes on mid-winter water bird population of some selected wetlands of Bankura and Purulia districts, West Bengal. *Records of the Zoological Survey of India* 107(Part 2): 61–91.

Nandi, N.C., S. Bhuinya & S.R. Das (2004). Notes on mid-winter water bird population of some selected wetlands of Bankura and Purulia districts, West Bengal. *Records of the Zoological Survey of India* 102(Part 1–2): 47–51.

Pielou, E.C. (1969). *An Introduction to Mathematical Ecology*. John Wiley, New York, 286 pp.

Roy, U.S., A.R. Goswami, A. Aich & S.K. Mukhopadhyay (2011). Changes in densities of water bird species in Santragachi Lake, India: potential effects on limnochemical variables. *Zoological Studies* 50(1): 76–84.

RStudio Team (2020). RStudio: Integrated Development for R. RStudio, PBC, Boston, MA. http://www.rstudio.com/.

Sekercioglu, C.H. (2006). Increasing awareness of avian ecological function. *Trends in Ecology and Evolution* 21(8): 464–471.

Sekercioglu, C.H. (2012). Bird functional diversity and ecosystem services in tropical forests, agroforests and agricultural areas. *Journal of Ornithology* 153(Suppl 1): 153–S161.

Sengupta, S., M. Mondal & P. Basu (2013). Bird species assemblages across a rural urban gradient around Kolkata. *Urban Ecosystems* 17: 585–596. https://doi.org/10.1007/s11252-013-0335-y

Shannon., C.E. & W. Wiener (1963). *The Mathematical Theory of Communications*. University of Illinois Press, Urbana, Illinois, 117 pp.

Singh, V. & H.S. Banyal (2013). Avian fauna of Khajjar Lake, district Chamba, Himachal Pradesh, India. *Proceedings of the Zoological Society* 66(2): 130–136. https://doi.org/10.1007/s12595-012-0049-9

Sundar, K.G.G. (2011). Agricultural intensification, rainfall patterns, and large waterbird breeding success in the extensively cultivated landscape of Uttar Pradesh, India. *Biological Conservation* 144: 3055–3063. https://doi.org/10.1016/j.biocon.2011.09.012

Sundar, K.G.G. & S. Kittur (2013). Can wetlands maintained for human use also help conserve biodiversity? Landscape-scale patterns of bird use of wetlands in an agricultural landscape in north India. *Biological Conservation* 168: 49–56. https://doi.org/10.1016/j.biocon.2013.09.016

Whelan, C.J., D.G. Wenny, & R.J. Marquis (2008). Ecosystem services provided by birds. *Annals of the New York Academy of Sciences* 1134: 25–60.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 December 2023 | 15(12): 24331–24344

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

https://doi.org/10.11609/jott.8357.15.12.24331-24344

#8357 | Received 06 January 2023 | Final received 16 October 2023 | Finally accepted 08 December 2023

ARTICLE

Assessing and understanding diversity and foraging guilds of bird community structure in Gautam Buddha Wildlife Sanctuary, Bihar and Jharkhand, India

Umar Saeed [1], Mujahid Ahamad [2], Vivek Ranjan [3], Syed Ainul Hussain [4] & Ruchi Badola [5]

[1–5] Department of Eco-Development Planning and Participatory Management, Wildlife Institute of India, Dehradun, Uttrakhand 248001, India.
[1] umar2673@gmail.com, [2] syedmujahidahmad@gmail.com (corresponding author), [3] vivek.nil@gmail.com, [4] ainul.hussain@gmail.com, [5] ruchi@wii.gov.in

Abstract: This study was conducted between June 2017 and December 2018 to assess the bird community structure, diversity, feeding guilds, and the residential status of birds in Gautam Buddha Wildlife Sanctuary (GBWS). Avian diversity and guild organization in five different habitat types were classified according to the forest type present in the landscape. The results indicated a total of 99 avifauna that belongs to 48 families, distributed in 16 orders. Among the 99 species, 77 were residents, 17 were winter visitors, four were summer visitors, and only one was a passage migrant. Based on the feeding guild evaluation, the majority were insectivorous (47%), followed by omnivorous (24%), carnivorous (14%), granivorous (8%), frugivorous (4%), insectivorous (1%), and piscivorous (1%). The scrubland, among other forest types, represented the highest diversity value for the Shannon-Weiner diversity index (3.2), evenness was recorded highest in riverine habitat (0.63), whereas utmost Simpson's dominance (0.98) and Fisher's index value (41) were in human settlement. These findings of our study illustrate the outstanding potential of GBWS as an important protected site for mixed bird diversity and specific feeding guilds, precisely in terms of the insectivorous and omnivorous communities. Hence, the study outcomes set a notable landmark for understanding birds and their habitats.

Keywords: Avifauna, evenness, Fisher's index, habitat types, protected site, residential status, Simpson's dominance, Shannon-Weiner diversity index.

Editor: H. Byju, Coimbatore, Tamil Nadu, India. **Date of publication:** 26 December 2023 (online & print)

Citation: Saeed, U., M. Ahamad, V. Ranjan, S.A. Hussain & R. Badola (2023). Assessing and understanding diversity and foraging guilds of bird community structure in Gautam Buddha Wildlife Sanctuary, Bihar and Jharkhand, India. *Journal of Threatened Taxa* 15(12): 24331–24344. https://doi.org/10.11609/jott.8357.15.12.24331-24344

Funding: The study is funded by the Dedicated Freight Corridor Corporation of India Limited (DFCCIL) [Permission no. CPM/DFCCIL/KKK wildlife – 186 dated 22 December 2015].

Competing interests: The authors declare no competing interests.

Author details: Umar Saeed is a senior research fellow at the Wildlife Institute of India and currently pursuing PhD from Graphic Era University and perceives a field of interest in grassland management and conservation ecology. Mujahid Ahamad is a PhD scholar and currently working as a senior project biologist at the Wildlife Institute of India, Dehradun. He specialized in animal ecology and human-wildlife interaction. Vivek Ranjan is a PhD scholar at the Wildlife Institute of India working on human-wildlife interaction in human-dominated landscapes. He has been actively supporting Uttarakhand State Forest Department in the management and mitigation of negative human-wildlife interaction and encouraging coexistence through technical advisory. Syed Ainul Hussain is the project manager (NMCG) and former scientist-G at the Wildlife Institute of India. Ruchi Badola is dean and scientist-G at the Wildlife Institute of India.

Author contributions: US—conceptualization, data collection, data analysis & visualization, methodology, writing the original draft. MA—conceptualization, writing original draft, data collection. VR—data collection. SAH—conceptualization, funding acquisition, investigation, supervision, writing - review & editing. RB—conceptualization, writing - review & editing.

Acknowledgements: We express our thanks for the financial support from the DFCCIL (Dedicated Freight Corridors Corporation Limited) for this study. The study permission no. CPM/DFCCIL/KKK wildlife – 186 dated 22 December 2015. We take this opportunity to express a deep sense of gratitude for the constant support received from Mr. A.K. Dwivedi CF, Gaya forest circle, and Mr. Arvind Kumar Singh DFO Gaya forest circle (Environment and Forests Department, Government of Bihar) and D.K. Yadav Singh DFO Hazaribagh forest division Jharkhand for providing the necessary support during the fieldwork and assure the good environment around us. We also thank our colleagues Rashmi Das and Kumar Ankit for their valuable suggestions and comments for the improvement of the Manuscript.

भारतीय वन्यजीव संस्थान Wildlife Institute of India

INTRODUCTION

Bird communities are considered to provide excellent model structures for studying biodiversity due to their occurrence in all habitat types and climatic zones (McCain & Grytnes 2010; Panda et al. 2021). Mixed habitats such as woodland, cropland, scrubland, riverine, and grasslands ensure the existence of habitat-restricted taxa and amplify community diversity (Berg 2002; Stein et al. 2014; Stein & Kreft 2015). Additionally, the diverse characteristics within natural environments and species diversity are pivotal in upholding essential traits that contribute significantly to biodiversity. (Manhães & Loures-Ribeiro 2005). Species diversity and richness in a particular area are determined by habitat heterogeneity and may also impact habitat resources (Lorenzón et al. 2016). At the same time, the absence of a natural environment leads to species homogenization with low species richness (Pickett et al. 2011; Lepczyk & Warren 2012; Aronson et al. 2014; Beninde et al. 2015) and high similarity (Blair 2001a,b). Bird diversity is always correlated with specific habitat types (Brawn et al. 2001; Seymour & Simmons 2008; Harisha & Hosetti 2009). Changes in their vegetation structure are affected by bird community structure and composition (Caziani & Derlindati 2000; Gabbe 2002; Earnst & Holmes 2012; Nsor et al. 2018), population trends, behaviour patterns, and reproductive ability (Harisha & Hosetti 2009). Vegetation structure is essential in structuring bird communities (Gabbe et al. 2002; Earnst & Holmes 2012); thus, the relative abundance of birds is often linked to vegetation community (Caziani & Derlindati 2000). For example, MacArthur & MacArthur (1961) pointed out the importance of vegetation structure for local bird species diversity. Williams (1964) highlighted that various environmental conditions and habitat types increase with an increase in the study area.

Feeding guild is a fundamental concept in avian ecology and is shaped when a community of birds uses the same class of environmental resources (Balestrieri et al. 2015). Katuwal et al. (2016) stated that all guilds have different resource requirements and tolerance capacities depending on ecological conditions, which are influenced by various environmental factors such as vegetation cover, food supply, predatory availability, and various other ecological factors reflecting different temporal variations and diversity gradients (O'Connell et al. 2000; Kissling et al. 2012). Studies of avian feeding guilds help to understand complex ecosystem structures and improve knowledge about the habitats of a particular ecosystem (Rathod & Padate 2017).

The distribution and feeding guild of the birds is associated with their habitat type and structural complexity, which influence species diversity and the inter-relationship between vegetation and the avian population (MacArthur & MacArthur 1961). Many studies have been conducted to determine relationships between bird species diversity and habitat attributes such as heterogeneity and vegetation structure (Chettri et al. 2005; Corbett 2006; Yeany 2009; Beasley 2013; Stirnemann et al. 2015). Bird populations in fragmented landscapes respond resiliently to complex environmental combinations and are an indicator of habitat change, and they also show a wide range of feeding guilds (Azman et al. 2011). Protected areas with substantial anthropogenic disturbance causes habitat fragmentation and degradation (Haddad et al. 2015; Wilson et al. 2016; Pardini et al. 2017).

In the Gautam Buddha Wildlife Sanctuary (GBWS), over the past few years, the widening of the National Highway (NH-2) has split the sanctuary into two halves. Moreover, anthropogenic pressures, selective hunting, and the expansion of villages in and around the sanctuary have been significant causes of biodiversity decline (Kumar 2016). The study of bird diversity and feeding guilds is crucial for understanding the complexity of ecosystem structure and for providing up-to-date knowledge on each habitat type in the ecosystem. In addition, we have also assessed the abundance of birds in the various habitat types. Thus, the present study aimed to understand the diversity of birds and feeding guilds with different habitat types, such as woodland, scrubland, human settlement, riverine, and cultivation lands. The study will also provide baseline information on the bird community's species richness, which will help design management plans and conservation strategies for the sanctuary.

Study area

The GBWS lies between 24.379°–24.425° N and 85.136°–85.213° E and is situated in the southeast part of the sacred city of Gaya district, Bihar. The sanctuary spreads over an area of 259.47 km^2 in the states of Bihar and Jharkhand under three forest divisions: the Gaya Forest Division (138.33 km^2) in Bihar and the Hazaribagh and Chatra Forest Division (121.24 km^2) in Jharkhand (Figure 1). The Bihar government notified the sanctuary in 1976. Before becoming a sanctuary, it used to be the hunting ground of the Tikri king. The terrain of the sanctuary is undulating, with an elevation ranging 213–529 m. The sanctuary is drained by the perennial river Mohane, a sink for all the streams and rivulets flowing in

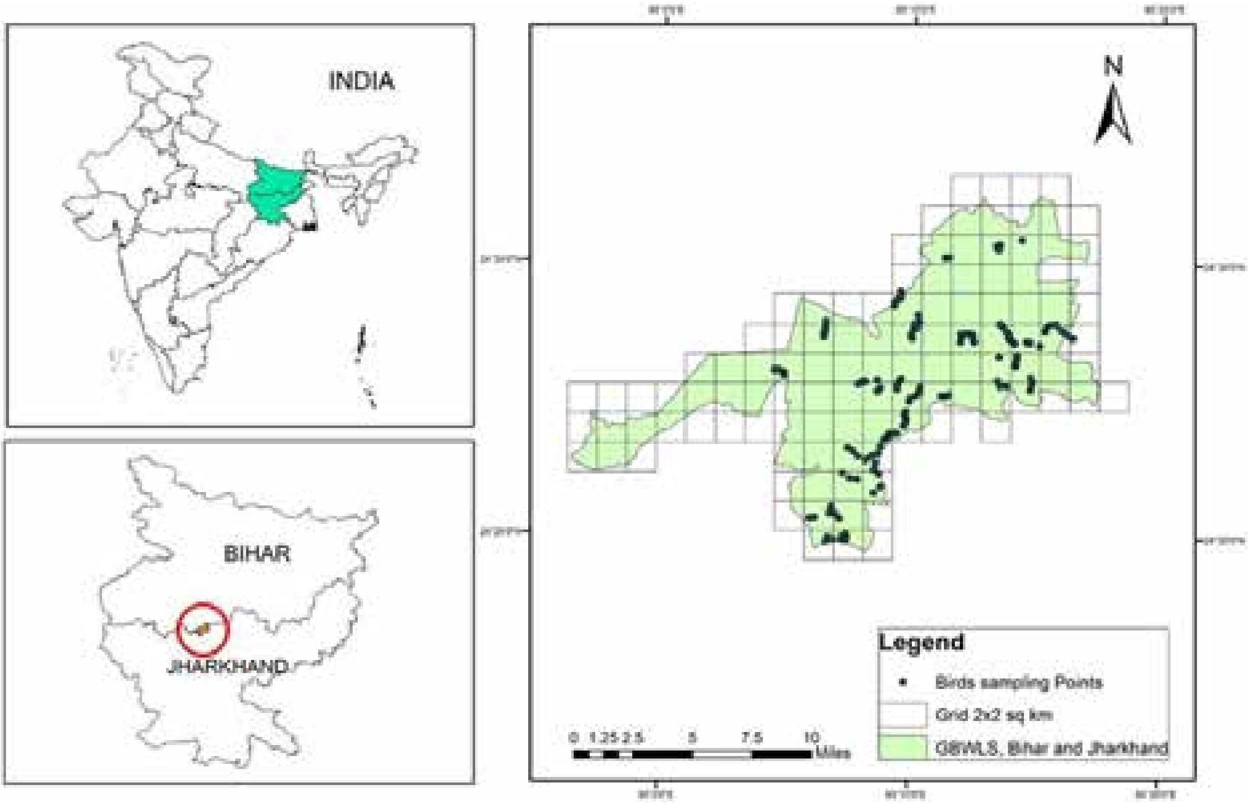

Figure 1. The study area of Gautam Buddha Wildlife Sanctuary Bihar and Jharkhand.

the sanctuary (Kumar 2016). The south-west monsoon starts in June and lasts until September. Rainfall is highest between June and July, with an average rainfall of 159 mm. The average temperature varies $26–9^0$C during the winter season, which commences from November to February (Nirbhay & Singh 2009). The average summer temperature ranges around 40^0C maximum, even touching 47^0C, and is usually characterized by dry and hot weather conditions from March to June.

The sanctuary falls in the lower Gangetic Plains and Chota Nagpur biogeographical regions of India and shares wildlife species from both regions. Making it a unique ecosystem that supports a wide diversity of floral and faunal species (Rodgers & Panwar 1988; Kumar 2016; Kumar et al. 2021). The sanctuary is characterized by moist and dry deciduous forests (Kumar et al. 2021). Forest communities are further divided into dry peninsular sal forest, northern dry mixed deciduous forest, dry deciduous scrub forest, ravine thorn forest, and tropical dry riverine forest (Kumar 2016; Kumar & Sahu 2020). More than 100 species of plants and 75 species of birds enrich the biodiversity of the sanctuary (Kumar et al. 2021). Various dominant flora of the sanctuary comprises *Shorea robusta*, *Pterocarpus marsupium*, *Diospyros melanoxylon*, *Lagerstroemia parviflora*, *Buchanania lanzan*, *Butea monosperma*, *Madhuca indica*, *Acacia catechu*, and *Boswellia serrata*. It also supports various wild animal species, such as *Axis axis*, *Rusa unicolor*, *Melursus ursinus*, *Boselaphus tragocamelus*, *Vulpes bengalensis*, and *Felis chaus*, among others (Kumar 2016).

METHODS AND MATERIALS

Data collection

The avifaunal status, habitat characteristics, and community structure were assessed using the point count transect method during summer (June–August 2017) and winter (November–December 2018). Bird observations occurred from 0700 h to 1000 h, avoiding adverse weather conditions (Ding et al. 2019). A 1-km trail transect with five observation points at 250 m intervals was used, involving two observers. Within a 50-m radius during a 15-minute duration, bird species, distances, and individual numbers were recorded. Birds flying overhead of the observer were not recorded to avoid the double count. The birds were observed with the help of Nikon (8x10) binoculars, and photographs were taken using a Cannon 80D camera for further identification. The birds were identified with the help of Grimmett et al. (2016).

Guild classification

In this study, birds were systematically categorized into distinct feeding guilds based on their primary diet and foraging habitats, following the classification outlined by Ding et al. (2019) and Panda et al. (2021). The seven identified guild categories are as follows: insectivores (species consuming insects, earthworms, small crustaceans, and arthropods), carnivores (species preying on large animals or scavenging their carcasses), omnivores (species with a mixed diet of both animals and plants), granivores (species primarily feeding on seeds and grains), nectarivores (species relying on nectar as a primary food source), frugivores (species mainly consuming fruits), and piscivores (species specialized in a fish-based diet). This classification scheme provides a comprehensive framework for understanding the diverse dietary preferences and foraging behaviors exhibited by avian species within the studied ecosystem.

Data analysis

In the data analysis phase, various species diversity indices were computed using the Paleontological Statistics (Past 2001 version 3.2) program (Hammer & Harper 2001). Shannon's diversity index (H) was employed to assess community diversity, calculated using the formula $H = -\sum(p_i \ln p_i)$, where pi represents the proportion of individuals of a particular species with the total number of individuals (n/N), and s is the number of species. Simpson's index (D), a dominance measure, was also utilized, given by the formula $1/(\sum(p_i^2))$, where pi is as defined for Shannon's index. Fisher alpha (S) was employed to mathematically describe the relationship between species and individuals, expressed as $S = \alpha \times \ln(1 + n/a)$, with S denoting the number of taxa, n representing the number of individuals, and α as Fisher's alpha (Fisher & Yates 1953)**.** Evenness (e), comparing actual diversity to maximum potential diversity, was determined using $e = H'/H_{max}$, with E constrained between 0 and 1. Relative abundance (RA) of each bird species was calculated as $n_i/N \times 100$, with ni being the number of individuals of the ith species and N being the total number of individuals. Abundance categories were assigned based on sightings, from rare (1–5) to very abundant (>50). The Sorensen similarity index (Cs) gauged species association between habitats using $Cs = 2j/(a + b)$, where j is the number of common species, a is the number of species in habitat A, and b is the number of species in habitat B. Bird residential status categories (resident, summer visitor, winter visitor influx) were determined using the presence and absence method (Sorensen 1948). Statistical analyses were conducted in SPSS, with significance at $p = 0.01$. Pearson's correlation (r) explored relationships between guilds, residential status, and habitat types, and post-hoc Wald tests with Bonferroni adjustments were performed for identified significant differences. Additionally, a one-way analysis of variance (ANOVA) examined significant differences in habitat-related species richness concerning feeding guilds and residential status.

RESULTS

The present study recorded 99 avifaunal species belonging to 16 orders and 48 families in GBWS. Amongst the habitats, the highest species richness was recorded in woodland (53.52%), and the lowest species richness was recorded in cultivation land (20.20%) (Table 1). The highest number of species belongs to the order Passeriformes (52.52%), followed by Accipitriformes and Charadriiformes (Figure 2). The species diversity of birds in five different habitats of the study area revealed that the highest Shannon diversity was recorded in scrubland (H = 3.186), followed by woodland (H = 3.181) and human settlement (H = 3.136). In contrast, the lowest Shannon diversity was recorded in cultivation land (H = 2.527). The Simpson diversity index value was maximum in human settlement (1-D = 0.978) and minimum in woodland (1-D = 0.926). The Evenness of bird species was highest in the riverine (0.629) and lowest in the woodland forest (0.454) (Table 1). At a 95% confidence interval level, we found that scrubland possesses the highest holding capacity of diversity compared to the other habitats. The Fisher alpha diversity index was highest in human settlement (α = 41.12). The lowest Fisher alpha diversity profile was recorded in cultivation land (α = 16.47) (Figure 3).

According to the frequency of sightings, 68.68% of bird species were rare, and 1.01% were abundant in GBWS (Figure 4). The relative abundance of Red-vented Bulbul *Pycnonotus cafer* was highest in the study area, followed by Jungle Babbler *Turdoides striata* and Grey-breasted Prinia *Prinia hodgsonii* (Appendix 1). Results of Sorenson's similarity index indicate that woodland and scrubland (0.31) were ecologically the most similar habitats, followed by the similarity between woodland and human settlement (0.30). However, riverine and

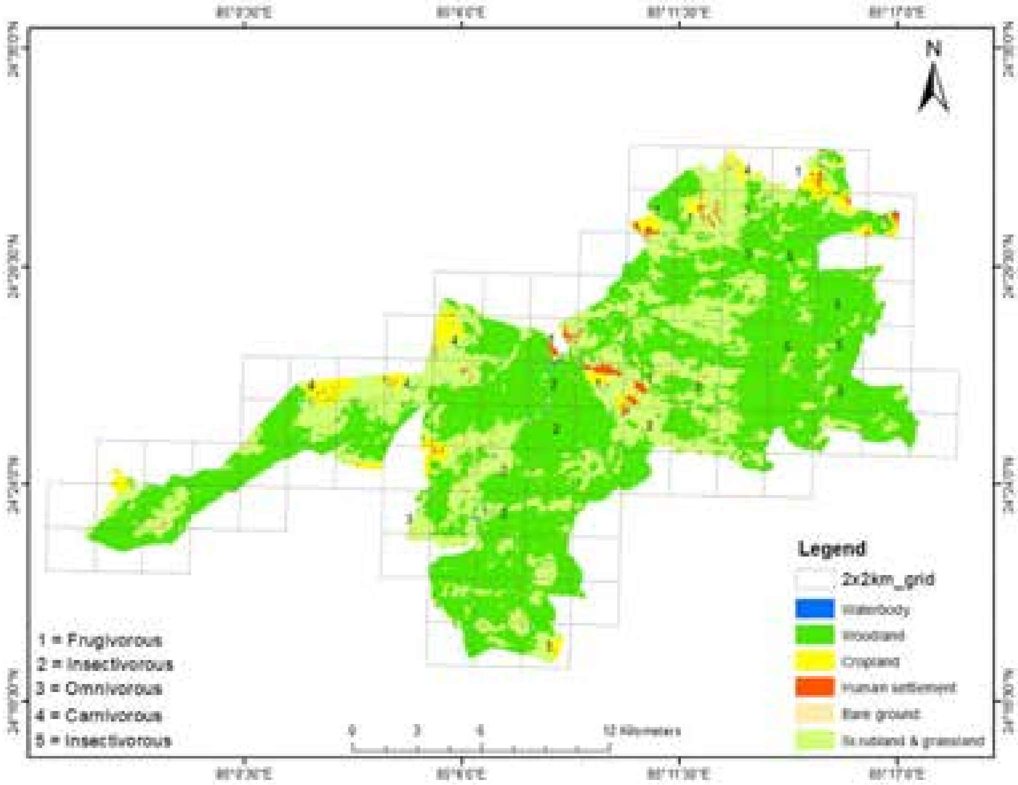

Figure 2. Land use Land cover of Gautam Buddha Wildlife Sanctuary Bihar and Jharkhand.

Table 1. Percentage, feeding guild, diversity, and dominance of birds in different habitats in GBWS Bihar and Jharkhand.

	Habitat	Number of species	Percentage	Feeding guild	Shannon diversity	Simpson (1-D)	Evenness	Fisher alpha
1	Woodland	53	53.53	6	3.181	0.926	0.454	17.26
2	Scrubland	47	47.47	7	3.186	0.950	0.514	24.83
3	Riverine	32	32.32	5	3.003	0.960	0.629	19.77
4	Human settlement	37	37.37	6	3.136	0.978	0.621	41.12
5	Cultivation land	20	20.20	5	2.527	0.947	0.625	16.47

woodland had the most negligible ecological similarity value (0.14) (Table 3).

Further, the bird species were categorized according to their feeding guild. Among the feeding guilds, the insectivorous guild recorded a maximum percentage of species (47.47%), and nectarivores and piscivorous guild recorded a minimum percentage of species (1.01%) (Figure 5). Regardless of the habitats, the dominant guild remained the insectivorous among all the guilds. The comparison of the abundance of species from all habitats within every feeding guild is shown in Table 2.

The Pearson correlation coefficient provided visions of the specific preference of the bird species under different foraging guild towards some particular habitats. The frugivorous guild was most positively correlated with human settlement ($r = 0.282$, $t = 0.320$ $p < 0.01$), and negatively with cultivation ($r = -0.29$, $t = 1.988$, $p > 0.01$), riverine ($r = -0.102$, $t = 2.267$, $p > 0.01$), and scrubland ($r = -0.045$, $t = 2.021$, $p > 0.01$). Insectivorous bird species were only positively correlated with the riverine habitat ($r = 0.127$, $t = 8.037$ $p < 0.01$) and negatively correlated with the remaining habitats. Omnivores were most positively correlated with scrubland habitat ($r = 0.156$, $t = 4.459$ $p < 0.01$) and a negative correlation with riverine habitat ($r = -0.150$, $t = 1.9885$, $p < 0.01$). On the other hand, the carnivorous guild was strongly associated with cultivation habitat ($r = 0.128$, $t = 3.295$ $p < 0.01$). Granivores showed a positive association with only scrubland habitat ($r = 0.105$, $t = 2.038$ $p < 0.01$).

Further, the residential status of the species revealed

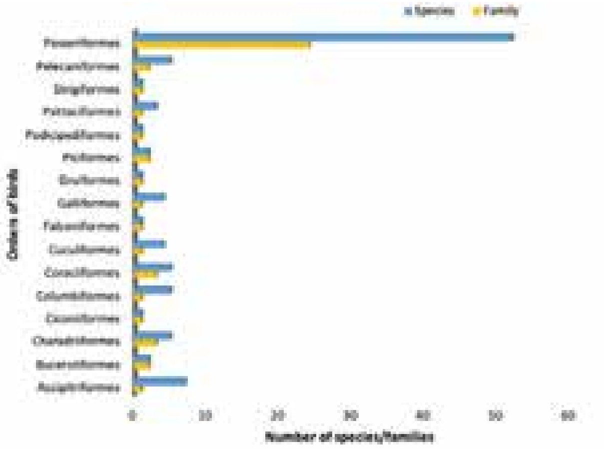

Figure 3. Composition of avian community in Gautam Buddha Wildlife Sanctuary Bihar & Jharkhand.

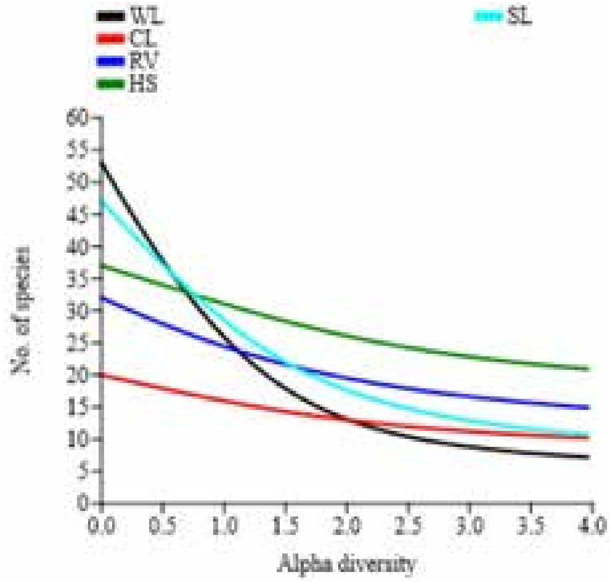

Figure 4. Species diversity profile of bird species in different habitats of Gautam Buddha Wildlife Sanctuary.
WL—woodland | CL—cultivation land | RV—riverine | HS—human settlement | SL—scrubland.

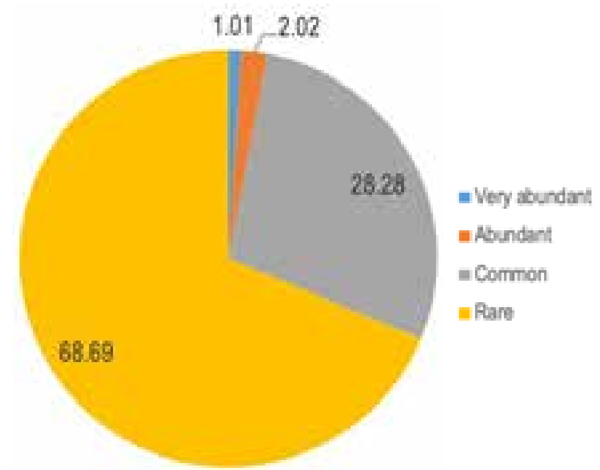

Figure 5. The pie chart shows the percentage of bird species in different abundance categories in Gautam Buddha Wildlife Sanctuary Bihar and Jharkhand.

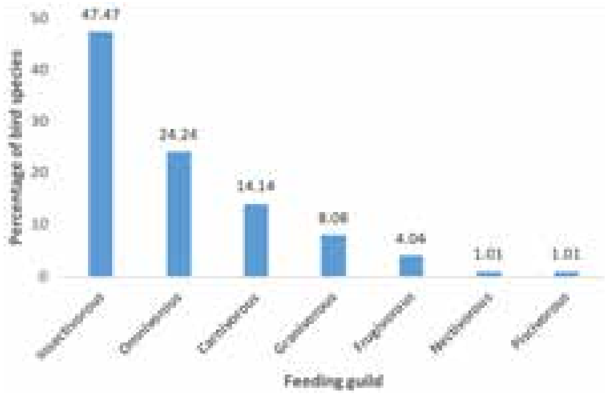

Figure 6. Percentage of the bird community in different feeding guilds observed in Gautam Buddha Wildlife Sanctuary Bihar and Jharkhand.

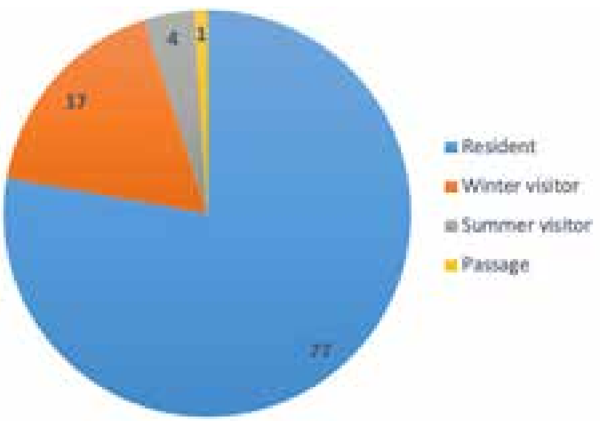

Figure 7. The pie chart shows the number of birds under different residential statuses in Gautam Buddha Wildlife Sanctuary Bihar and Jharkhand.

that 77 birds were residents, whereas the remaining 17 were winter visitors, four were summer visitors, and one species was a passage migrant (Figure 6). While analyzing the association of different habitats according to their residential status, we found that resident bird species were positively correlated with all the habitat types, but the association was highest with scrubland ($r = 0.177$, $t = 16.226$ $p < 0.01$). It was discovered that there was no significant correlation between any of the habitat categories and summer visitors, winter visitors, or passage migrants.

DISCUSSION

The bird diversity and their distribution concerning habitat types characterize the importance of GBWS as an essential bird habitat. The present study revealed that Passeriformes was the dominant order comprising the highest number of bird species. Two species represented the order Bucerotiformes and Piciformes; besides the order Ciconiiformes, Falconiformes, Gruiformes, Podicipediformes, and Strigiformes were represented by single species. This study agrees with the prior result that order Passeriformes is the leading avian taxon in India (Praveen et al. 2016; Kumar & Sahu 2020; Singh 2022). Data analysis on relative abundance shows that the Accipitridae family is the most dominant one. A similar pattern of dominance of Accipitridae was recorded by different authors from different protected areas in India, for example, from the Araku Valley of Ananthagiri Hills of the Eastern Ghats in Visakhapatnam, Andhra Pradesh (Kumar et al. 2010), a scrub forest of Sri Lankamalleswara Wildlife Sanctuary, Andhra Pradesh (Mali et al. 2017), Tamhini Wildlife Sanctuary, the northern Western Ghats, Maharashtra (Vinayak & Mali 2018), and Bhimbandh Wildlife Sanctuary, Bihar (Khan & Pant 2017).

The GBWS comprises a mosaic habitat, which supports a significant diversity of bird species. Habitat heterogeneity favors habitat specialists (through niche partitioning) for birds with broad niches (Surasinghe et al. 2010; Chakdar et al. 2016). The overall Shannon diversity index (H = 3.935) of GBWS is high. Therefore, the Shannon diversity in all habitats was good except in cultivation land (H = 2.527). The habitat heterogeneity hypothesis suggests that a landscape's species diversity increases with the number of habitats because of an expansion in the number of partitionable niche dimensions (Cramer & Willing 2005; Chakdar et al. 2016). Numerous studies have revealed that the distribution and diversities of bird species were highly dependent on habitat heterogeneity (Hettiarachchi & Wijesundara 2017; Chandrasiri et al. 2018; Panda et al. 2021; Thilakarathne et al. 2021).

As the Simpson diversity index has swift convergence to limit diversity value for a minor sample size, it is principally suitable for rapidly estimating regions for conservation (Lande et al. 2000). Analysis of data on the Simpson dominance index revealed that human settlement (1-D = 0.978) was the most dominated habitat in the sanctuary followed by riverine habitat (1-D = 0.960). The high value of Simpson's index of diversity is an indication of the richness of bird diversity in the GBWS. The result revealed that bird species' Evenness varied in the sanctuary's different habitats. The highest evenness index value was recorded in the riverine habitat. Several reasons, including food availability, breeding, migration, and change in vegetation cover, could be attributed to this pattern (Harisha & Hosetti 2009). However, the lowest evenness index value recorded in woodland habitat expresses that the species-rich site may result from the occurrence of rare species or two or three species being hyper-abundant in the area compared to the other sites (Symonds & Johnson 2008).

However, the Fisher alpha diversity index was highest in human settlement (α = 41.12), as the number of individuals was low compared to the species number. In woodland habitats, the species diversity is highest, but due to the presence of more individuals of the bird species, Fisher's alpha was lower (α = 17.26) than in human settlement. The lowest Fisher alpha diversity profile was recorded in cultivation land (α = 16.47) (Figure 3). The diversity, which compares the similarity between habitats, is measured by Sorensen's similarity index between the five selected habitats. The result revealed that woodland and scrubland had the highest similarity value (0.31), while the lowest species similarity (0.14)

Table 2. Species presence at all habitats of each feeding guild.

Feeding guild	Habitat					Number of species
	WL	RV	H	CL	SL	
Carnivorous	7	5	3	4	3	15
Frugivorous	4	0	2	1	2	4
Granivorous	3	1	3	0	6	7
Insectivorous	27	20	16	9	19	47
Nectivorous	1	0	1	1	1	1
Omnivorous	11	5	12	5	15	24
Piscivorous	0	1	0	0	1	1
Number of species	53	32	37	20	47	

WL—woodland | CL—cultivation land | RV—riverine | HS—human settlement | SL—scrubland.

Table 3. Sorenson's similarity index value between different habitats.

	Habitat	WL	CL	RV	HS	SL
1	SL	0.31	0.22	0.17	0.26	
2	HS	0.30	0.17	0.20		
3	WB	0.14	0.21			
4	RV	0.21				
5	WL					

WL—woodland | CL—cultivation land | RV—riverine | HS—human settlement | SL—scrubland.

Image 1. Dhodiya village situated inside the Gautam Buddha Wildlife Sanctuary.

Image 2. Livestock rearing and grazing in the Gautam Buddha Wildlife Sanctuary.

Image 3. Cutting of trees in Gautam Buddha Wildlife Sanctuary.

was recorded between woodland and riverine habitats. The highest value of Sorensen's similarity indices documented between woodland and scrubland habitats might be attributed to landscape characteristics. Better habitat structural similarity tended to support more similar bird communities (Tubelis & Cavalcanti 2001; Andrade et al. 2018; Kumar & Sahu 2020).

Correlation values between different feeding guilds and habitat preferences displayed that the frugivorous bird population flourished well in the area with human settlement due to the sufficient availability of food sources. Gomes et al. (2008) have shown that resilient frugivores that increased in densities have occurred under all habitat disturbance regimes of the forest area, which markedly supports our study. In another study (Pejchar et al. 2008), frugivore abundance and richness were found to strongly account for a positive relationship with the human-dominated landscape. These results account for the fact that frugivores can tolerate moderate to intermediate levels of disturbance.

The significant positive correlation of insectivores was highest with riverine habitat. Other studies supporting the observation state that in wetlands, aquatic insects classically dominate the macroinvertebrate communities (Maher 1984; Euliss & Grodhaus 1987; Batzer & Resh 1992; Mukhopadhyay & Mazumdar 2019) and are an integral part of various aquatic ecosystems (Sivaramakrishnan et al. 2000). Omnivores and granivores were most favorable and significantly correlated with the scrubland habitat due to the mosaic structure of the habitat of GBWS. This contrasts with the findings of Mukhopadhyay & Mazumdar (2019), in a suburban landscape of the lower Gangetic plains of West Bengal, where the omnivores mostly dominated the residential and plantation forest area. Panda (2021) has also found a significant close association between human habitation with omnivores.

Additionally, granivores are positively related to the scrubland area, Poulin et al. (1993), support and validate our outcomes as they found a peak number of granivores interactions in the scrubland of the Guarapo region on the Araya Peninsula. In contrast, other studies support the preference of granivores for low-stratification crops (Henderson et al. 2000) and the positive relation with orchards due to the protection these areas offer from predation by birds of prey (Figueroa & Corales 2005). Furthermore, our study revealed that carnivorous species were primarily observed in cultivated forest areas due to the enormous presence of small size of frogs, fishes, molluscs, and small vertebrate species. Likewise, Tanalgo et al. (2015) agree with our study that carnivorous species were primarily observed in the rice fields. Stafford et al. (2010) indicated that the abundance of carnivorous bird species in rice fields is due to the availability of a large number of food resources, such as polychaetes, crustaceans, and molluscs. Besides, King et al. (2010) also noted that the rice fields in many countries support large numbers of migratory water birds and are essential for many species.

A significant positive correlation of the resident bird species with all the habitat types shows that these species are well distributed in the GBWS, but they mostly prefer the scrubland area. A study by Daily et al. (2001) also suggests that bird species mainly were correlated with the forest fragments. The migratory bird species do not possess any significant positive correlation with the different habitats. This is because migrants distribute themselves spatially and temporally relative to available fruit resources at different intervals (Wolfe et al. 2014).

Moreover, human interference and livestock pressure significantly threatened bird species in the sanctuary (Image 1,2). The presence of livestock in bird habitats caused a significant negative impact on the abundance and species richness of bird species ($r = -0.308$, $p = <0.01$). After agriculture, local inhabitants also depend on the sanctuary for livestock grazing. Overgrazing led to the destruction of plant seedlings and restricted forest regeneration. Studies by Adhikari et al. (2019) support our finding as they have also found that livestock pressure and human disturbances were the major threats to birds in Chitwan National Park. The presence of local people in the forested land caused a non-significant negative impact on bird species richness and abundance in the sanctuary ($r = -0.091$, $p = >0.01$). Another major cause of disturbance in bird habitat is the cutting of trees for fodder and fuelwood collection (Image 3). The Pearson correlation coefficient value of tree cutting was negatively not significant to habitat ($r = -0.064$, $p = >0.01$). These pragmatic findings suggest a negative impact of livestock and human interference on the bird species richness and abundance.

CONCLUSION

The present study is the first documentation of the bird diversity, richness, and feeding guilds found in GBWS. Our study concludes with evidence that GBWS is an essential habitat for birds with high conservation status.

The diversity of bird species recorded is highest in the scrubland habitat and lowest in the cultivation habitat. However, these habitats are under constant threat of high risk for immense anthropogenic pressure. Also, if human disturbance increases at the same pace, there would be the threat of homogenization of avian species, as these generalist species have the advantage over the specialists in disturbed ecosystems. Consequently, the study suggests that maintaining heterogeneous habitats could be a better strategy for the long-term survival of resident and migratory birds in GBWS.

REFERENCES

Adhikari, J.N., B.P. Bhattarai & T.B. Thapa (2019). Factors affecting diversity and distribution of threatened birds in Chitwan National Park, Nepal. *Journal of Threatened Taxa* 11(5): 13511–13522. https://doi.org/10.11609/jot.4137.11.5.13511-13522

Andrade, R., H.L. Bateman, J. Franklin & D. Allen (2018). Waterbird community composition, abundance, and diversity along an urban gradient. *Landscape and Urban Planning* 170: 103–111. https://doi.org/10.1016/j.landurbplan.2017.11.003

Aronson, M.F., F.A. la Sorte, C.H. Nilon, M. Katti, M.A. Goddard, C.A. Lepczyk, P.S. Warren, N.S. Williams, S. Cilliers, B. Clarkson, C. Dobbs, R. Dolan, M. Hedblom, S. Klotz, J.L. Kooijmans, I. Kühn, I. Macgregor-Fors, M. McDonnell, U. Mörtberg, P. Petr, S. Stefan, S. Jessica, W. Peter & W. Marten (2014). A global analysis of the impacts of urbanization on bird and plant diversity reveals key anthropogenic drivers. *Proceedings of the Royal Society B: Biological Sciences* 281(1780): 2013-3330. https://doi.org/10.1098/rspb.2013.3330

Azman, N.M., N.S.A. Latip, S.A.M. Sah, M.A.M.M Akil, N.J. Shafie & N.L. Khairuddin (2011). Avian diversity and feeding guilds in a secondary forest, an oil palm plantation and a paddy field in Riparian areas of the Kerian River Basin, Perak, Malaysia. *Tropical Life Sciences Research* 22(2): 45.

Balestrieri, R., M. Basile, M. Posillico, T. Altea, B. De Cinti & G. Matteucci (2015). A guild-based approach to assessing the influence of beech forest structure on bird communities. *Forest Ecology and Management* 356: 216–223. https://doi.org/10.1016/j.foreco.2015.07.011

Batzer, D.P. & V.H. Resh (1992). Macroinvertebrates of a California seasonal wetland and responses to experimental habitat manipulation. *Wetlands* 12(1): 1–7. https://doi.org/10.1007/BF03160538

Beasley, C.J. (2013). Avian communities in suspended development: disentangling mechanistic effects of changing habitat structure versus human habitation (Doctoral dissertation, University of Georgia).

Beninde, J., M. Veith & A. Hochkirch (2015). Biodiversity in cities needs space: a meta-analysis of factors determining intra-urban biodiversity variation. *Ecology Letters* 18(6): 581–592. https://doi.org/10.1111/ele.12427

Berg, Å. (2002). Composition and diversity of bird communities in Swedish farmland–forest mosaic landscapes. *Bird Study* 49(2): 153–165. https://doi.org/10.1080/00063650209461260

Bibby, C.J. (2000). *Bird census techniques*. Elsevier, 40 pp.

Blair, R.B. (2001a). Birds and butterflies along urban gradients in two ecoregions of the United States: is urbanization creating a homogeneous fauna? pp. 33–56. In: *Biotic Homogenization*. Springer, Boston, MA.

Blair, R.B. (2001b). Creating a homogeneous avifauna. *Avian Ecology and Conservation in an Urbanizing World*: 459–486. https://doi.org/10.1007/978-1-4615-1531-9_22

Brawn, J.D., S.K. Robinson & F.R. Thompson III (2001). The role of disturbance in the ecology and conservation of birds. *Annual Review of Ecology and Systematics*: 251–276. https://doi.org/10.1146/annurev.ecolsys.32.081501.114031

Caziani, S.M. & E. Derlindati (2000). Abundance and habitat of high Andes flamingos in northwestern Argentina. *Waterbirds*: 121–133. https://doi.org/10.2307/1522157

Chakdar, B., P. Choudhury & H. Singha (2016). Avifaunal diversity in Assam University Campus, Silchar, India. *Journal of Threatened Taxa* 8(1): 8369–8378. https://doi.org/10.11609/jott.2524.8.1.8369-8378

Chandrasiri, P.H.S.P., W.D.S.C. Dharmarathne & W.A.D. Mahaulpatha (2018). Diversity and Distribution of Avifauna at the Tropical Montane Cloud Forests of Horton Plains National Park. *Journal of Tropical Forestry and Environment* 8(1): 36–49. https://doi.org/10.31357/jtfe.v8i1.3481

Chettri, N., D.C. Deb, E. Sharma & R. Jackson (2005). The relationship between bird communities and habitat. *Mountain Research and Development* 25(3): 235–243. https://doi.org/10.1659/0276-4741(2005)025[0235:TRBBCA]2.0.CO;2

Corbett, J. (2006). Measuring wildlife habitat: What to measure and how to measure it. Wildlife-Habitat Relationships: *Concepts and Applications* 151. University of Wisconsin Press, 416 pp.

Cramer, M.J. & M.R. Willig (2005). Habitat heterogeneity, species diversity and null models. *Oikos* 108(2): 209–218; It was discovered that there was no significant correlation between any of the habitat categories and summer visits, winter visitors, or passage migrants. https://doi.org/10.1111/j.0030-1299.2005.12944.x

Daily, G.C., P.R. Ehrlich & G.A. Sanchez-Azofeifa (2001). Countryside biogeography: use of human-dominated habitats by the avifauna of southern Costa Rica. *Ecological Applications* 11(1): 1–13. https://doi.org/10.1890/1051-0761(2001)011[0001:CBUOHD]2.0.CO;2

Ding, Z., J. Liang, Y. Hu, Z. Zhou, H. Sun, L. Liu & X. Si (2019). Different responses of avian feeding guilds to spatial and environmental factors across an elevation gradient in the central Himalaya. *Ecology and Evolution* 9(7): 4116–4128. https://doi.org/10.1002/ece3.5040

Earnst, S.L. & A.L. Holmes (2012). Bird—habitat relationships in interior Columbia basin shrub steppe. *The Condor* 114(1): 15–29. https://doi.org/10.1525/cond.2012.100176

Euliss Jr, N.H. & G. Grodhaus (1987). Management of midges and other invertebrates for waterfowl wintering in California. *California Fish and Game* 73(4): 238–243.

Evans, K.L., S.E. Newson & K.J. Gaston (2009). Habitat influences on urban avian assemblages. *Ibis* 151(1): 19–39. https://doi.org/10.1111/j.1474-919X.2008.00898.x

Figueroa, R.A. & E.S. Corales (2005). Seasonal diet of the Aplomado Falcon (*Falco femoralis*) in an agricultural area of Araucanía, southern Chile. *Journal of Raptor Research* 39(1): 55–60.

Fisher, R.A. & F. Yates (1953). Statistical Tables for Biological, Agricultural and Medical Research. *Hafner Publishing Company*.

Gabbe, A.P., S.K. Robinson & J.D. Brawn (2002). Tree-species preferences of foraging insectivorous birds: implications for floodplain forest restoration. *Conservation Biology* 16(2): 462–470. https://doi.org/10.1046/j.1523-1739.2002.00460.x

Gomes, L.G., V. Oostra, V. Nijman, A.M. Cleef & M. Kappelle (2008). Tolerance of frugivorous birds to habitat disturbance in a tropical cloud forest. *Biological Conservation* 141(3): 860–871. https://doi.org/10.1016/j.biocon.2008.01.007

Grimmett, R., C. Inskipp & T. Inskipp (2016). *Birds of the Indian Subcontinent: India, Pakistan, Sri Lanka, Nepal, Bhutan, Bangladesh and the Maldives*. Bloomsbury India, 448 pp.

Haddad, N.M., L.A. Brudvig, J. Clobert, K.F. Davies, A. Gonzalez, R.D. Holt & J.R. Townshend (2015). Habitat fragmentation and its lasting impact on Earth's ecosystems. *Science Advances* 1(2): e1500052. https://doi.org:10.1126/sciadv.1500052

Hammer, Ø., & D.A. Harper (2001). PAST: Paleontological statistics software package for education and data analysis. *Palaeontologia Electronica* 4(1): 9.

Harisha, M.N. & B.B. Hosetti (2009). Diversity and distribution of avifauna of Lakkavalli range forest, Bhadra wildlife sanctuary, western ghat, India. *Ecoprint: An International Journal of Ecology* 16: 21–27. https://doi.org:10.3126/eco.v16i0.3469

Henderson, I.G., J. Cooper, R.J. Fuller & J. Vickery (2000). The relative abundance of birds on set-aside and neighbouring fields in summer. *Journal of Applied Ecology* 37(2): 335–347. https://doi.org/10.1046/j.1365-2664.2000.00497.x

Hettiarachchi, T. & C.S. Wijesundara (2017). Conservational significance of Dunumadalawa Forest Reserve in Central Sri Lanka based on the endemism of its avifauna. *Ceylon Journal of Science* 46(3): 21–30. https://doi.org:10.4038/cjs.v46i3.7439

Katuwal, H.B., K. Basnet, B. Khanal, S. Devkota, S.K. Rai, J.P. Gajurel & M.P. Nobis (2016). Seasonal changes in bird species and feeding guilds along elevational gradients of the Central Himalayas, Nepal. *PLoS One* 11(7): e0158362. https://doi.org/10.1371/journal.pone.0158362

Khan, M.S. & A. Pant (2017). Conservation status, species composition, and distribution of Avian Community in Bhimbandh Wildlife Sanctuary, India. Journal of Asia-Pacific Biodiversity 10(1): 20–26. https://doi.org/10.1016/j.japb.2016.07.004

King, S., C.S. Elphick, D. Guadagnin, O. Taft & T. Amano (2010). Effects of landscape features on waterbird use of rice fields. *Waterbirds* 33(sp1): 151–159. https://doi.org/10.1675/063.033.s111

Kissling, W.D., F. Carsten, Dormann, G. Ju¨rgen, H. Thomas, I. Ku¨hn, G.J. McInerny, J.M. Montoya, C. Ro¨mermann, K. Schiffers, F.M. Schurr, A. Singer, J. Svenning, N.E. Zimmermann & R.B. O'Hara (2012). Towards novel approaches to modelling biotic interactions in multispecies assemblages at large spatial extents. *Journal of Biogeography* 39(12): 2163–2178. https://doi.org/10.1111/j.1365-2699.2011.02663.x

Kumar, A. (2016). Forest ecology of Gautam Buddha Wildlife Sanctuary of Bihar, India. *Flora* 22(1): 93–96.

Kumar, G., A. Alam, M. Maaz, M.S.D. Kumari & A. Kumar (2021). First Record of Occurrence of Indian Tree Shrew (*Anathana ellioti*) in Gautam Buddha Wildlife Sanctuary, Gaya, Bihar (India). *Indian Journal of Ecology* 48(5): 1566–1568.

Kumar, P. & S. Sahu (2020). Composition, diversity and foraging guilds of avifauna in agricultural landscapes in Panipat, Haryana, India. *Journal of Threatened Taxa* 12(1): 15140–15153. https://doi.org/10.11609/jott.5267.12.1.15140-15153

Kumar, T.S., R. Chandra & P.A. Azeez (2010). The birds of Araku, Visakhapatnam, Andhra Pradesh, India. *Journal of Threatened Taxa* 2(1): 662–665. https://doi.org/10.11609/JoTT.o2108.662-5

Lande, R., P.J. DeVries & T.R. Walla (2000). When species accumulation curves intersect: implications for ranking diversity using small samples. *Oikos* 89(3): 601–605. https://doi.org/10.1034/j.1600-0706.2000.890320.x

Lepczyk, C.A. & P.S. Warren (2012). *Urban Bird Ecology and Conservation*. Studies in Avian Biology No. 45. University of California Press, Berkeley, CA. xiv + 326 pp.

Lorenzón, R.E., A.H. Beltzer, P.F. Olguin & A.L. Ronchi-Virgolini (2016). Habitat heterogeneity drives bird species richness, nestedness and habitat selection by individual species in fluvial wetlands of the Paraná River, Argentina. *Austral Ecology* 41(7): 829–841. https://doi.org/10.1111/aec.12375

MacArthur, R.H. & J.W. MacArthur (1961). On bird species diversity. *Ecology* 42(3): 594–598.

Maher, M. (1984). Benthic studies of waterfowl breeding habitat in south-western New South Wales. I. The fauna. *Marine and Freshwater Research* 35(1): 85–96. https://doi.org/10.1071/MF9840085

Mali, S., C. Srinivasulu & A.R. Rahmani (2017). Avifaunal diversity in the scrub forest of Sri Lankamalleswara Wildlife Sanctuary, Andhra Pradesh, India. *Journal of Threatened Taxa* 9(9): 10679–10691. http://doi.org/10.11609/jott.2720.9.9.10679-10691

Manhães, M.A. & A. Loures-Ribeiro (2005). Spatial distribution and diversity of bird community in an urban area of Southeast Brazil. *Brazilian Archives of Biology and Technology* 48: 285–294. https://doi.org/10.1590/S1516-89132005000200016

McCain, C.M. & J.A. Grytnes (2010). Elevational gradients in species richness. *Encyclopedia of Life Sciences*. https://doi.org/10.1002/9780470015902.a0022548

McKinney, M.L. (2006). Urbanization as a major cause of biotic homogenization. *Biological Conservation* 127(3): 247–260. https://doi.org/10.1016/j.biocon.2005.09.005

Mukhopadhyay, S. & S. Mazumdar (2019). Habitat-wise composition and foraging guilds of avian community in a suburban landscape of lower Gangetic plains, West Bengal, India. *Biologia* 74(8): 1001–1010. https://doi.org/10.2478/s11756-019-00226-x

Nirbhay, A. & C.T.N. Singh (2009). Summer grasses of Gautam Buddha wild life sanctuary, Hazaribagh. *Advances in Plant Sciences* 22(2): 575–576.

Nsor, C.A., E. Acquah, G. Mensah, V. Kusi-Kyei & S. Boadi (2018). Avian Community Structure as a Function of Season, Habitat

Type, and Disturbance, in Mole National Park, Northern Region (Ghana). *International Journal of Ecology* 2018: 2045629. https://doi.org/10.1155/2018/2045629

O'Connell, T.J., L.E. Jackson & R.P. Brooks (2000). Bird guilds as indicators of ecological condition in the central Appalachians. *Ecological Applications* 10(6): 1706–1721. https://doi.org/10.1890/1051-0761(2000)010[1706:BGAIOE]2.0.CO;2

Panda, B.P., B. Prusty, B. Panda, A. Pradhan & S.P. Parida (2021). Habitat heterogeneity influences avian feeding guild composition in urban landscapes: evidence from Bhubaneswar, India. *Ecological Processes* 10(1): 1–10. https://doi.org/10.1186/s13717-021-00304-6

Pardini, R., E. Nichols & T. Püttker (2017). Biodiversity response to habitat loss and fragmentation. *Encyclopedia of the Anthropocene* 3: 229–239. https://doi.org/10.1016/B978-0-12-809665-9.09824-4

Pejchar, L., R.M. Pringle, J. Ranganathan, J.R. Zook, G. Duran, F. Oviedo & G.C. Daily (2008). Birds as agents of seed dispersal in a human-dominated landscape in southern Costa Rica. *Biological Conservation* 141(2): 536–544. https://doi.org/10.1016/j.biocon.2007.11.008

Pickett, S.T., M.L. Cadenasso, J.M. Grove, C.G. Boone, P.M. Groffman, E. Irwin, S.S. Kaushal, V. Marshall, B.P. McGrath, C.H. Nilon, R.V. Pouyat, K. Szlavecz, A. Troy & P. Warren (2011). Urban ecological systems: Scientific foundations and a decade of progress. *Journal of Environmental Management* 92(3): 331–362. https://doi.org/10.1016/j.jenvman.2010.08.022

Poulin, B., G. Lefebvre & R.A.Y.M.O.N.D. McNeil (1993). Variations in bird abundance in tropical arid and semi-arid habitats. *Ibis* 135(4): 432–441. https://doi.org/10.1111/j.1474-919X.1993.tb02116.x

Praveen, J., R. Jayapal & A. Pittie (2016). A Checklist of the birds of India. *Indian Birds* 11(5&6): 113–172.

Rathod, J. & G. Padate (2017). Feeding guilds of urban birds of Vadodara city. *International Journal of Fauna Biological Studies* 4: 78–85.

Rodgers, W.A. & H.S. Panwar (1988). Planning a Wildlife Protected area Network in India. 2 Volumes. Project FO: IND/82/003, FAO, Dehradun, 339 pp, 267 pp.

Seymour, C.L. & R.E. Simmons (2008). Can severely fragmented patches of riparian vegetation still be important for arid-land bird diversity? *Journal of Arid Environments* 72(12): 2275–2281. https://doi.org/10.1016/j.jaridenv.2008.07.014

Shannon, C.E. (1948). A mathematical theory of communication. *The Bell system technical journal* 27(3): 379–423. https://doi.org/10.1002/j.1538-7305.1948.tb01338.x

Simpson, E.H. (1949). Measurement of diversity. *Nature* 163(4148): 688–688. https://doi.org/10.1038/163688a0

Singh, M. (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

Sivaramakrishnan, K. (2000). Crafting the public sphere in the forests of West Bengal: Democracy, development, and political action. *American Ethnologist* 27(2): 431–461. https://doi.org/10.1525/ae.2000.27.2.431

Sorensen, T.A. (1948). A method of establishing groups of equal amplitude in plant sociology based on similarity of species content and its application to analyses of the vegetation on Danish commons. *Biological Sarkar* 5: 1–34.

Stafford, J.D., R.M. Kaminski & K.J. Reinecke (2010). Avian foods, foraging and habitat conservation in world rice fields. *Waterbirds* 33(sp1): 133–150. https://doi.org/10.1675/063.033.s110

Statsoft (2001). Statistica (data analysis software system), ver.6. - StatSoft, <www.statsoft.com>.

Stein, A. & H. Kreft (2015). Terminology and quantification of environmental heterogeneity in species-richness research. *Biological Reviews* 90(3): 815–836. https://doi.org/10.1111/brv.12135

Stein, A., K. Gerstner & H. Kreft (2014). Environmental heterogeneity as a universal driver of species richness across taxa, biomes and spatial scales. *Ecology letters* 17(7): 866–880. https://doi.org/10.1111/ele.12277

Stirnemann, I.A., K. Ikin, P. Gibbons, W. Blanchard & D.B. Lindenmayer (2015). Measuring habitat heterogeneity reveals new insights into bird community composition. *Oecologia* 177(3): 733–746. https://doi.org/10.1007/s00442-014-3134-0

Surasinghe, T.D. & C. De Alwis (2010). Birds of Sabaragamuwa University campus, Buttala, Sri Lanka. *Journal of Threatened Taxa* 2(5): 876–888. https://doi.org/10.11609/JoTT.o2113.876-88

Symonds, M.R. & C.N. Johnson (2008). Species richness and evenness in Australian birds. *The American Naturalist* 171(4): 480–490. https://doi.org/10.1086/528960

Tanalgo, K.C., J.A.F. Pineda, M.E. Agravante & Z.M. Amerol (2015). Bird diversity and structure in different land-use types in lowland south-central Mindanao, Philippines. *Tropical Life Sciences Research* 26(2): 85.

Tanveer, A., H.S. Bargali & K. Afifullah (2019). Status and distribution of avifauna in Ramnagar Forest Division, Western Terai-Arc Landscape, Uttarakhand. *Indian Forester* 145(10): 935–945.

Thakur, M.L. & V.K. Mattu (2011). Avifauna of Kaza area of Spiti (Himachal Pradesh), India. *International Journal of Science and Nature* 2(3): 483–487.

Thilakarathne, D., T. Lakkana, G. Hirimuthugoda, C. Wijesundara & S. Kumburegama (2021). Diversity and distribution of avifauna at Warathenna-Hakkinda Environmental Protection Area in Kandy, Sri Lanka. *Journal of Threatened Taxa* 13(12): 19689–19701. https://doi.org/10.11609/jott.7447.13.12.19689-19701

Tubelis, D.P. & R.B. Cavalcanti (2001). Community similarity and abundance of bird species in open habitats of a central Brazilian Cerrado. *Ornitologia Neotropical* 12(1): 57–73.

Vinayak, D.C. & S.V. Mali (2018). A checklist of bird communities In Tamhini Wildlife Sanctuary, the northern Western Ghats, Maharashtra, India. *Journal of Threatened Taxa* 10(3): 11399–11409. https://doi.org/10.11609/jot.3377.10.3.11399-11409

Williams, C.B. (1964). Patterns in the balance of nature and related problems of quantitative ecology. *Journal of Ecology* 54(2): 549–550. https://doi.org/10.2307/2257968

Wilson, M.C., X.Y. Chen, R.T. Corlett, R.K. Didham, P. Ding, R.D. Holt & M. Yu (2016). Habitat fragmentation and biodiversity conservation: key findings and future challenges. *Landscape Ecology* 31(2): 219–227. https://doi.org/10.1007/s10980-015-0312-3

Wolfe, J.D., M.D. Johnson & C.J. Ralph (2014). Do birds select habitat or food resources? Nearctic-Neotropic migrants in northeastern Costa Rica. *PloS One* 9(1): e86221. https://doi.org/10.1371/journal.pone.0086221

Yeany II, D. (2009). Avian Community Analysis and Habitat Relationships at Finzel Swamp, Maryland. Master Thesis, xi + 153 pp. https://doi.org/10.13140/RG.2.1.4669.9283

Appendix 1. Systematic checklist and status of birds recorded in Gautam Buddha Wildlife Sanctuary Bihar and Jharkhand, India.
LC—Least Concern | EN—Endangered | NT—Near Threatened | WV—Winter visitor | R—Resident | SV—Summer visitor | PM—Passage migrant.

	Order	Family	Common name	Scientific name	IUCN Red List status	Relative abundance	Residential status	Feeding guild
1	Accipitriformes	Accipitridae	Black Eagle	*Ictinaetus malaiensis*	LC	0.61	WV	Carnivores
2			Black Kite	*Milvus migrans*	LC	0.15	R	Carnivores
3			Black-winged Kite	*Elanus caeruleus*	LC	0.61	R	Carnivores
4			Booted Eagle	*Hieraaetus pennatus*	LC	0.30	WV	Carnivores
5			Egyptian Vulture	*Neophron percnopterus*	EN	0.46	R	Carnivores
6			Oriental Honey-buzzard	*Pernis ptilorhynchus*	LC	0.30	R	Carnivores
7			Shikra	*Accipiter badius*	LC	0.46	R	Carnivores
8	Bucerotiformes	Bucerotidae	Indian Grey Hornbill	*Ocyceros birostris*	LC	0.46	R	Frugivores
9		Upupidae	Common Hoopoe	*Upupa epops*	LC	0.46	R	Insectivores
10	Charadriiformes	Turnicidae	Barred Buttonquail	*Turnix suscitator*	LC	2.44	R	Omnivores
11		Recurvirostridae	Black-winged Stilt	*Himantopus himantopus*	LC	1.07	WV	Insectivores
12		Charadriidae	Little-ringed Plover	*Charadrius dubius*	LC	0.46	R	Insectivores
13			Red-wattled Lapwing	*Vanellus indicus*	LC	0.30	R	Insectivores
14			Yellow-wattled Lapwing	*Vanellus malabaricus*	LC	0.61	R	Insectivores
15	Ciconiiformes	Ciconiidae	Asian Openbill	*Anastomus oscitans*	LC	0.30	R	Carnivores
16	Columbiformes	Columbidae	Rock Pigeon	*Columba livia*	LC	0.30	R	Granivores
17			Spotted Dove	*Streptopelia chinensis*	LC	2.74	R	Granivores
18			Eurasian Collared Dove	*Streptopelia decaocto*	LC	0.30	R	Granivores
19			Laughing Dove	*Streptopelia senegalensis*	LC	0.30	R	Granivores
20			Orange-breasted Green Pigeon	*Treron bicinctus*	LC	0.76	R	Granivores
21	Coraciiformes	Coraciidae	Indian Roller	*Coracias benghalensis*	LC	0.91	R	Insectivores
22		Alcedinidae	White-throated Kingfisher	*Halcyon smyrnensis*	LC	0.91	R	Piscivores
23		Meropidae	Chestnut-headed Bee-eater	*Merops leschenaulti*	LC	1.37	R	Insectivores
24			Green Bee-eater	*Merops orientalis*	LC	2.74	R	Insectivores
25			Blue-tailed Bee-eater	*Merops philippinus*	LC	0.91	SV	Insectivores
26	Cuculiformes	Cuculidae	Greater Coucal	*Centropus sinensis*	LC	0.61	R	Omnivores
27			Jacobin Cuckoo	*Clamator jacobinus*	LC	0.30	SV	Insectivores
28			Asian Koel	*Eudynamys scolopaceus*	LC	0.46	R	Omnivores
29			Common Hawk-cuckoo	*Hierococcyx varius*	LC	0.76	R	Omnivores
30	Falconiformes	Falconidae	Common Kestrel	*Falco tinnunculus*	LC	0.15	WV	Carnivores
31	Galliformes	Phasianidae	Grey Francolin	*Francolinus pondicerianus*	LC	0.91	R	Omnivores
32			Painted Spurfowl	*Galloperdix lunulata*	LC	0.61	R	Omnivores
33			Red Junglefowl	*Gallus gallus*	LC	0.61	R	Omnivores
34			Indian Peafowl	*Pavo cristatus*	LC	0.15	R	Omnivores
35	Gruiformes	Rallidae	White-breasted Waterhen	*Amaurornis phoenicurus*	LC	0.30	R	Insectivores
36	Passeriformes	Sturnidae	Jungle Myna	*Acridotheres fuscus*	LC	0.61	R	Omnivores
37		Sturnidae	Common Myna	*Acridotheres tristis*	LC	3.50	R	Omnivores
38		Aegithinidae	Common Iora	*Aegithina tiphia*	LC	0.15	R	Insectivores
39		Motacillidae	Paddyfield Pipit	*Anthus rufulus*	LC	0.15	R	Insectivores

	Order	Family	Common name	Scientific name	IUCN Red List status	Relative abundance	Residential status	Feeding guild
40	Passeriformes	Motacillidae	Tree Pipit	*Anthus trivialis*	LC	0.15	WV	Insectivores
41		Chloropseidae	Golden-fronted Leafbird	*Chloropsis aurifrons*	LC	0.46	R	Omnivores
42		Sylviidae	Yellow-eyed Babbler	*Chrysomma sinense*	LC	1.37	R	Insectivores
43		Nectariniidae	Purple Sunbird	*Cinnyris asiaticus*	LC	2.28	R	Nectivores
44		Muscicapidae	Indian Robin	*Copsychus fulicatus*	LC	2.59	R	Insectivores
45		Muscicapidae	Oriental Magpie Robin	*Copsychus saularis*	LC	2.13	R	Insectivores
46		Campephagidae	Large Cuckooshrike	*Coracina macei*	LC	0.61	R	Insectivores
47		Corvidae	Large-billed Crow	*Corvus macrorhynchos*	LC	0.46	R	Omnivores
48		Corvidae	House Crow	*Corvus splendens*	LC	0.30	R	Omnivores
49		Muscicapidae	Tickell's Blue Flycatcher	*Cyornis tickelliae*	LC	0.15	WV	Insectivores
50		Corvidae	Rufous Treepie	*Dendrocitta vagabunda*	LC	1.67	R	Omnivores
51		Dicaeidae	Thick-billed Flowerpecker	*Dicaeum agile*	LC	0.61	R	Omnivores
52		Dicruridae	White-bellied Drongo	*Dicrurus caerulescens*	LC	0.30	R	Insectivores
53		Dicruridae	Ashy Drongo	*Dicrurus leucophaeus*	LC	0.30	WV	Insectivores
54		Dicruridae	Black Drongo	*Dicrurus macrocercus*	LC	2.74	R	Insectivores
55		Alaudidae	Ashy-crowned Sparrow-lark	*Eremopterix griseus*	LC	0.46	R	Omnivores
56		Estrildidae	Indian Silverbill	*Euodice malabarica*	LC	0.46	R	Granivores
57		Muscicapidae	Taiga Flycatcher	*Ficedula albicilla*	LC	0.15	WV	Insectivores
58		Sturnidae	Asian Pied Starling	*Gracupica contra*	LC	1.37	R	Omnivores
59		Laniidae	Brown Shrike	*Lanius cristatus*	LC	0.30	WV	Insectivores
60		Laniidae	Long-tailed Shrike	*Lanius schach*	LC	0.91	WV	Insectivores
61		Laniidae	Bay-backed Shrike	*Lanius vittatus*	LC	0.15	R	Insectivores
62		Estrildidae	Scaly-breasted Munia	*Lonchura punctulata*	LC	0.91	R	Granivores
63		Alaudidae	Indian Bush Lark	*Mirafra erythroptera*	LC	0.30	R	Omnivores
64		Motacillidae	White Wagtail	*Motacilla alba*	LC	0.30	WV	Insectivores
65		Motacillidae	Grey Wagtail	*Motacilla cinerea*	LC	0.15	WV	Insectivores
66		Muscicapidae	Brown Rock Chat	*Oenanthe fusca*	LC	0.30	R	Insectivores
67		Oriolidae	Indian Golden Oriole	*Oriolus kundoo*	LC	0.61	R	Insectivores
68		Cisticolidae	Common Tailorbird	*Orthotomus sutorius*	LC	0.46	R	Insectivores
69		Sturnidae	Rosy Starling	Pastor roseus	LC	0.15	PM	Omnivores
70		Campephagidae	Small Minivet	*Pericrocotus cinnamomeus*	LC	0.76	R	Insectivores
71		Muscicapidae	Black Redstart	*Phoenicurus ochruros*	LC	0.15	WV	Insectivores
72		Phylloscopidae	Tickell's Leaf Warbler	*Phylloscopus affinis*	LC	0.15	WV	Insectivores
73		Phylloscopidae	Hume's Leaf Warbler	*Phylloscopus humei*	LC	0.15	WV	Insectivores
74		Phylloscopidae	Greenish Warbler	*Phylloscopus trochiloides*	LC	0.76	WV	Insectivores
75		Pittidae	Indian Pitta	*Pitta brachyura*	LC	0.30	SV	Insectivores
76		Cisticolidae	Grey-breasted Prinia	*Prinia hodgsonii*	LC	4.41	R	Insectivores
77		Cisticolidae	Plain Prinia	*Prinia inornata*	LC	0.46	R	Insectivores
78		Cisticolidae	Ashy Prinia	*Prinia socialis*	LC	0.15	R	Insectivores
79		Pycnonotidae	Red-vented Bulbul	*Pycnonotus cafer*	LC	16.74	R	Omnivores
80		Pycnonotidae	Red-whiskered Bulbul	*Pycnonotus jocosus*	LC	0.30	R	Omnivores
81		Rhipiduridae	White-browed Fantail	*Rhipidura aureola*	LC	0.61	R	Insectivores
82		Sturnidae	Brahminy Starling	*Sturnia pagodarum*	LC	0.15	R	Omnivores

	Order	Family	Common name	Scientific name	IUCN Red List status	Relative abundance	Residential status	Feeding guild
83	Passeriformes	Vangidae	Common Woodshrike	*Tephrodornis pondicerianus*	LC	1.22	R	Insectivores
84		Vangidae	Large Woodshrike	*Tephrodornis virgatus*	LC	0.30	R	Insectivores
85		Monarchidae	Indian Paradise Flycatcher	*Terpsiphone paradisi*	LC	1.07	SV	Insectivores
86		Leiothrichidae	Jungle Babbler	*Turdoides striata*	LC	5.94	R	Insectivores
87		Zosteropidae	Oriental White-eye	*Zosterops palpebrosus*	LC	1.83	R	Insectivores
88	Pelecaniformes	Ardeidae	Great Egret	*Ardea alba*	LC	0.15	R	Carnivores
89			Indian Pond Heron	*Ardeola grayii*	LC	0.76	R	Carnivores
90			Cattle Egret	*Bubulcus ibis*	LC	0.91	R	Carnivores
91			Little Egret	*Egretta garzetta*	LC	1.37	R	Carnivores
92		Threskiornithidae	Red-naped Ibis	*Pseudibis papillosa*	LC	0.61	WV	Omnivores
93	Piciformes	Picidae	Lesser-goldenbacked Woodpecker	*Dinopium benghalensis*	LC	1.98	R	Insectivores
94		Megalaimidae	Brown-headed Barbet	*Psilopogon zeylanicus*	LC	0.30	R	Omnivores
95	Podicipediformes	Podicipedidae	Little Grebe	*Tachybaptus ruficollis*	LC	0.91	R	Insectivores
96	Psittaciformes	Psittaculidae	Plum-headed Parakeet	*Psittacula cyanocephala*	LC	0.15	R	Frugivores
97			Alexandrine Parakeet	*Psittacula eupatria*	NT	1.98	R	Frugivores
98			Rose-ringed Parakeet	*Psittacula krameri*	LC	2.28	R	Frugivores
99	Strigiformes	Strigidae	Jungle Owlet	*Glaucidium radiatum*	LC	0.46	R	Carnivores

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 December 2023 | 15(12): 24345–24351
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.8635.15.12.24345-24351
#8635 | Received 14 July 2023 | Final received 21 November 2023 | Finally accepted 01 December 2023
OPEN ACCESS
COMMUNICATION

Identifying potential habitats of Himalayan Red Panda *Ailurus fulgens* (Cuvier, 1825) (Mammalia: Carnivora: Ailuridae) in Neora Valley National Park, West Bengal, India

Sangay W. Bhutia [1], Asim Giri [2], Pranita Gupta [3] & Basavaraj S. Holeyachi [4]

[1,2,3,4] Padmaja Naidu Himalayan Zoological Park, Darjeeling, West Bengal 734101, India.
[1] bhutiasangay0018@gmail.com, [2] giriasim2013@gmail.com (corresponding author), [3] pranita.gupta.subba@gmail.com,
[4] basavifs@gmail.com

Abstract: The Himalayan Red Panda *Ailurus fulgens* (Cuvier, 1825) is a globally Endangered species whose population is reported to be declining in the wild. It is a priority species for the Neora Valley National Park (NVNP) since it is the flagship species of this ecosystem. Moreover, this landscape functions as an important connecting link of the Himalayan Red Panda habitat between the state of West Bengal and Sikkim. The spatial habitat of the Himalayan Red Panda in this National Park is little known. Our study attempts to identify the spatial distribution of potential habitats for the Himalayan Red Panda using the maximum entropy algorithm (MaxEnt 3.4.1). The model predicted a 55 km^2 of potential habitat with the current climate scenario. With climate change, predicted potential habitats are likely to experience significant loss and upward shift to a relatively higher elevation. Hence, the management of the NVNP should identify the potential habitats and accomplish realistic goals to help conserve the Red Pandas.

Keywords: Climate change, conservation, habitat ecology, habitat modelling, Himalaya, maximum entropy, reintroduction.

Editor: Honnavalli N. Kumara, Salim Ali Centre for Ornithology and Natural History, Coimbatore India. **Date of publication:** 26 December 2023 (online & print)

Citation: Bhutia, S.W., A. Giri, P. Gupta & B.S. Holeyachi (2023). Identifying potential habitats of Himalayan Red Panda *Ailurus fulgens* (Cuvier, 1825) (Mammalia: Carnivora: Ailuridae) in Neora Valley National Park, West Bengal, India. *Journal of Threatened Taxa* 15(12): 24345–24351. https://doi.org/10.11609/jott.8635.15.12.24345-24351

Funding: West Bengal Zoo Authority (WBZA)

Competing interests: The authors declare no competing interests.

Author details: Sangay W. Bhutia has completed his masters' degree in Wildlife Science and has previously worked in Snow Leopard project at Ladakh. Now he has just completed this Red Panda project as a junior research fellow from Padmaja Naidu Himalayan Zoological Park. Asim Giri has completed his masters' degree in Zoology and currently is a field assistant at the Padmaja Naidu Himalayan Zoological Park on the research of the behaviour and conservation of the endangered Red Panda. He also does scientific works on the bird, butterfly, odonata, etc. and has a few publications also. Pranita Gupta is a wildlife biologist having almost ten years of experience. She is now the zoo biologist at Padmaja Naidu Himalayan Zoological Pak. She has master' degree in medical microbiology. She also worked on research projects studying on various aspects and reintroduction of Red Panda and Himalayan Goral. Dr Basavaraj S. Holeyachi is an IFS officer with more than 15 years of work experience with some prestigious awards in his name. He completed PhD in genetics from Indian Agricultural Research Institute with gold medal. He is currently appointed as the director of Padmaja Naidu Himalayan Zoological Park, Darjeeling.

Author contributions: SWB—field data collection, analysis and article writing. AG—field data collection, photographic documentation and article writing. PG—conceptualise & designed the research work. BSH—conceptualise the research work & overall supervision.

Acknowledgements: The authors would like to thank the Member Secretary of the West Bengal Zoo Authority (WBZA) Saurabh Chaudhuri for funding the project. We would like to thank the Principal Chief Conservator of Forest (PCCF) & the Chief Wildlife Warden (CWLW) of West Bengal, DFO Gorumara Wildlife Division, Range Officer, Beat officers and staff of Neora Valley National Park for their support.

INTRODUCTION

The Himalayan Red Panda *Ailurus fulgens* (Cuvier, 1825) belongs to the Ailuridae family of the order Carnivora, in which *Ailurus* represents the only genus (Roberts & Gittleman 1984). Although taxonomically considered as a carnivore, the species has evolved as a specialized herbivore (Roberts & Gittleman 1984). Almost 80% of its diet consists of bamboo leaves and shoots (e.g., *Arundinaria maling, A. aristata*) and reported to feed on bird eggs, insects, and grubs occasionally (Choudhury 2001; Pradhan et al. 2001). This flagship species is found exclusively in the moist, temperate, and sub-alpine forests of the Himalaya, at 2,100–4,800 m, stretching from Nepal, India, Bhutan, and southeastern China to Myanmar (Roberts & Gittleman 1984; Choudhury 2001; Mallick 2010a,b; Ghose & Dutta 2011; Dorji et al. 2012; Glatston et al. 2015; Bista et al. 2019; Hu et al. 2020). However, a recent genomic study shows that there are two species of *Ailurus fulgens*, the Himalayan Red Panda (*A. fulgens*) and the Chinese Red Panda (*A. styani*) known today rather than subspecies as considered earlier (Hu et al. 2020; Joshi et al. 2021; Lyon et al. 2022). Among the two species, *A. fulgens* is the nominate species in India (Roberts & Gittleman 1984; Choudhury 2001; Ghose et al. 2011; Dorji et al. 2012) and it is only found to the west of the Siang River of Arunachal Pradesh in India, and on southern Tibet; whereas, the Chinese Red Panda *A. styani* is found only to the east of Siang River, in eastern Arunachal Pradesh, India, and in southwestern China (Wei et al. 1999; Hu et al. 2020; Joshi et al. 2021). In West Bengal, they are only found in the Singalila National Park (SNP) of Darjeeling district and in the Neora Valley National Park (NVNP) of Kalimpong district (Choudhury 2001; Mallick 2010a,b). Red Pandas are selective in forest use; usually, the good density of bamboo, presence of water sources, well canopy covering accompanied with other important elements like a fallen log, and tree stump, make their perfect habitat (Image 1) (Dorji et al. 2012; Bista et al. 2019).

However, the shrinking habitat, livestock farming, trafficking, poaching, and road construction put their population at risk (Pradhan et al. 2001; Ghose et al. 2011; Dorji et al. 2012; Glatston et al. 2015). As a result, it is categorized as an 'Endangered' on the IUCN Red List of Threatened Species (Glatston et al. 2015), and listed under Schedule I in the Wildlife (Protection) Act of India, 1972, and as Appendix I species under the CITES (CITES 2010). This study was aimed to find out and analyze the most-used patches of Red Pandas in the NVNP, which will help in further studies and future reintroduction programs.

MATERIALS AND METHODS

Study Area

The Neora Valley National Park (NVNP) is located between latitudes 26.88417–27.12639 ^{0}N and longitudes 88.75000–88.83333 ^{0}E located in Kalimpong district which forms the ecological trijunction with Sikkim and Bhutan, is the last wilderness in West Bengal (Mallick 2010a,b) (Figure 1). The park, spreading over 88 km^2 is one of the oldest reserve forests in India. NVNP is also considered an integral part of the Kanchenjunga landscape (Sharma & Chettri 2005; Chettri et al. 2007) and is considered West Bengal's crowning glory because of its vast environment gradients (183–3,200 m) and climatic conditions, supporting a unique and ecologically important undisturbed patch of late succession forest (Mallick 2010a).

Occurrence records and predictor variables

The occurrence coordinates were collected using a handheld GPS (Garmin eTrex 10) for six months (January–June of 2022) long study from the NVNP. Those locations include the occurrence of droppings, trap camera footages (Image 2) (Cuddeback H20 MP IR-Model H-1453 & Y24 32MP IR), and direct sighting coordinates of a Red Pandas by forest officials of the NVNP as a proxy to denote their presence.

For modeling the potential habitats, 19 bioclimatic variables were downloaded from WorldClim (www.worldclim.org) with 1 km spatial resolution (Hijamans et al. 2005; Su et al. 2021). The bioclimatic variables included annual trends (mean annual precipitation and temperature), seasonality (annual range in precipitation and temperature), and extreme environmental factors (temperature of the coldest and warmest month and precipitation of the wet and dry quarters).

Modeling

MaxEnt (Maximum entropy algorithm) model in one of the most utilized modeling tools for presence-only records (Elith et al. 2011) where collinearity does not affect the performance of this model (DeMarco & Nóbrega 2018). For the creation of the model, 19 bioclimatic variables (Image 3) along with slope, altitude, aspect, and landcover were used as the predictor variables (Pradhan et al. 2001; Thapa et al. 2020; Su et al. 2021). A 30 m resolution digital elevation model

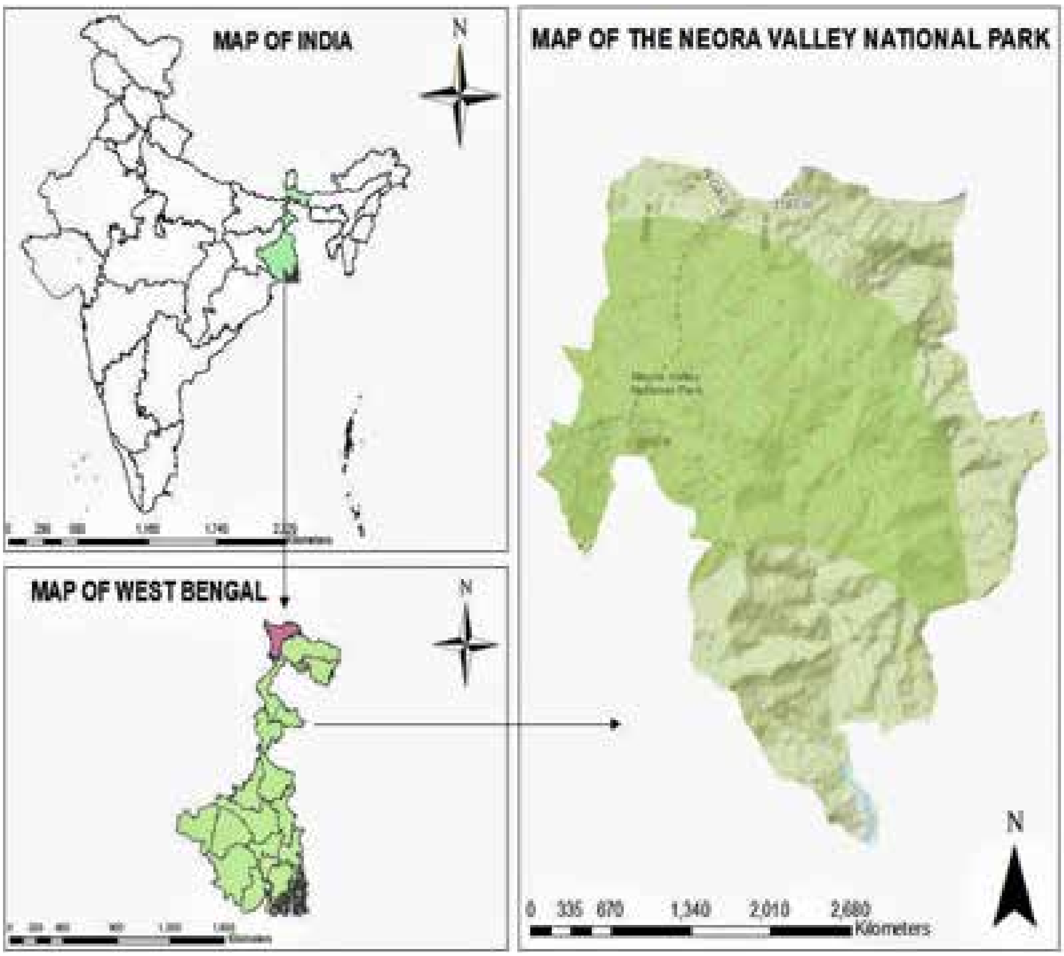

Figure 1. Study area: The Neora Valley National Park.

(DEM) was used here to calculate the slope and aspect (Su et al. 2021). This model has been run with the given settings: 5-fold cross-validation, regularization multiplier = 2.5, feature = linear, quadratic and hinge, and output type = logistic, where 70% of the occurrence data was used for training and the remaining 30% for testing the model.

The accuracy of the species distribution model was evaluated on the area under curve (AUC) by measuring the area under the receiver operating characteristic (ROC) curve which is widely used for comparing the performance of this model. The AUC value ranges from 0 to 1 where the higher value suggests better performance with better discriminatory capability than the randomly generated model (Phillips et al. 2006).

To generate a suitable habitat map for the Himalayan Red Panda, above 10% training presence logistic threshold was selected. The Jackknife test has been used here to evaluate the relative importance of each environmental predictor variable (Su et al. 2021).

RESULTS

The NVNP comprises of a large variety of habitats and niches, comprising the catchment and watershed of the Neora River which is fed by nine main streams and 16 subsidiary streams (Mallick 2010a). The main habitat types where we found the sign of the Himalayan Red Pandas, over 2,000 m altitude were mostly Oak *Quercus* and *Rhododendron* Forest along with dense bamboo *Malingo* thickets. Most of the pallets were found on those trees. The total count of direct sighting and pallet occurrence data along with indirect sighting data (questioner survey) were taken for the modeling. The MaxEnt model with the mean AUC value of 0.999 predicted that the NVNP is highly suitable habitat area for the Himalayan Red Panda under the current climate scenario (Figure 2). The mean AUC = 0.999 suggest that model performance is relatively better than random predictions.

Amongst the 21 predictor variables (19 bioclimatic,

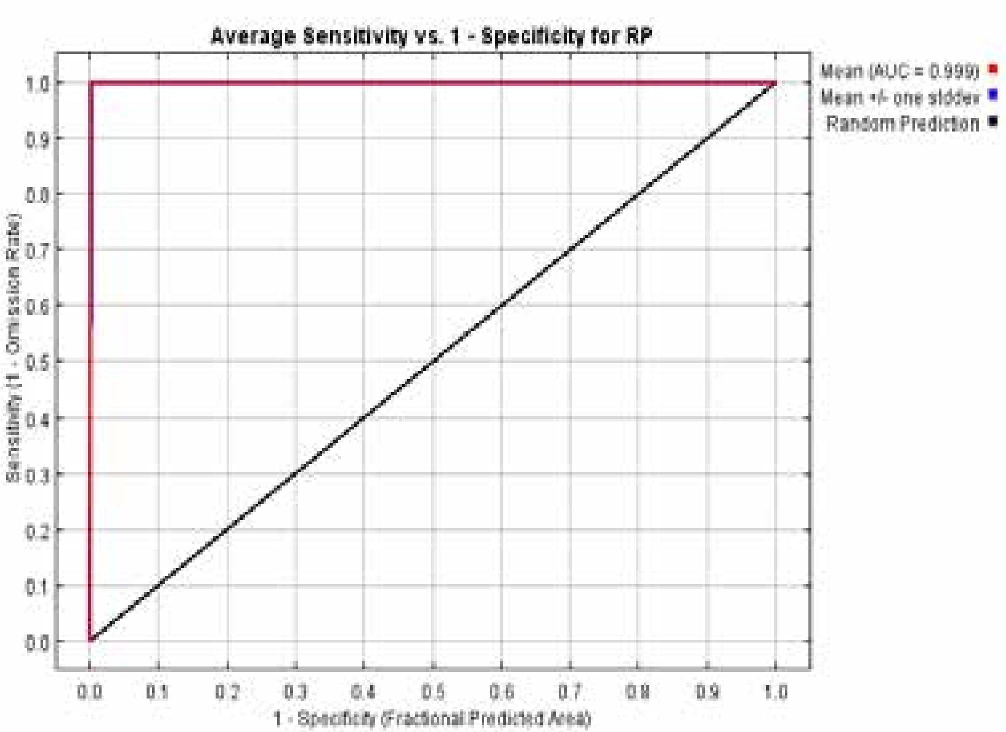

Figure 2. High value (0.999) of this Area Under ROC Curve (AUC) model of the species distribution map (SDM) shows that the NVNP is highly suitable for the Himalayan Red Panda *Ailurus fulgens*.

Image 1. Habitat of the Himalayan Red Panda *Ailurus fulgens*, Neora Valley National Park. © Asim Giri.

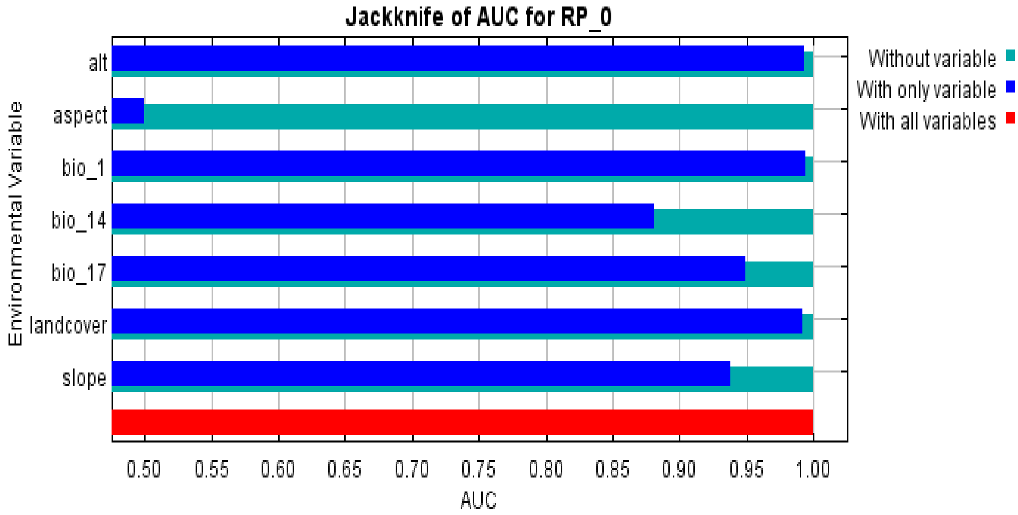

Figure 3. The individual environmental predictor variables (in blue) in this Jackknife test shows the relative dependance to all variables (in red). (alt—altitude | bio_1—annual mean temperature | bio_14—precipitation of driest month | bio_17—precipitation of driest quarter)

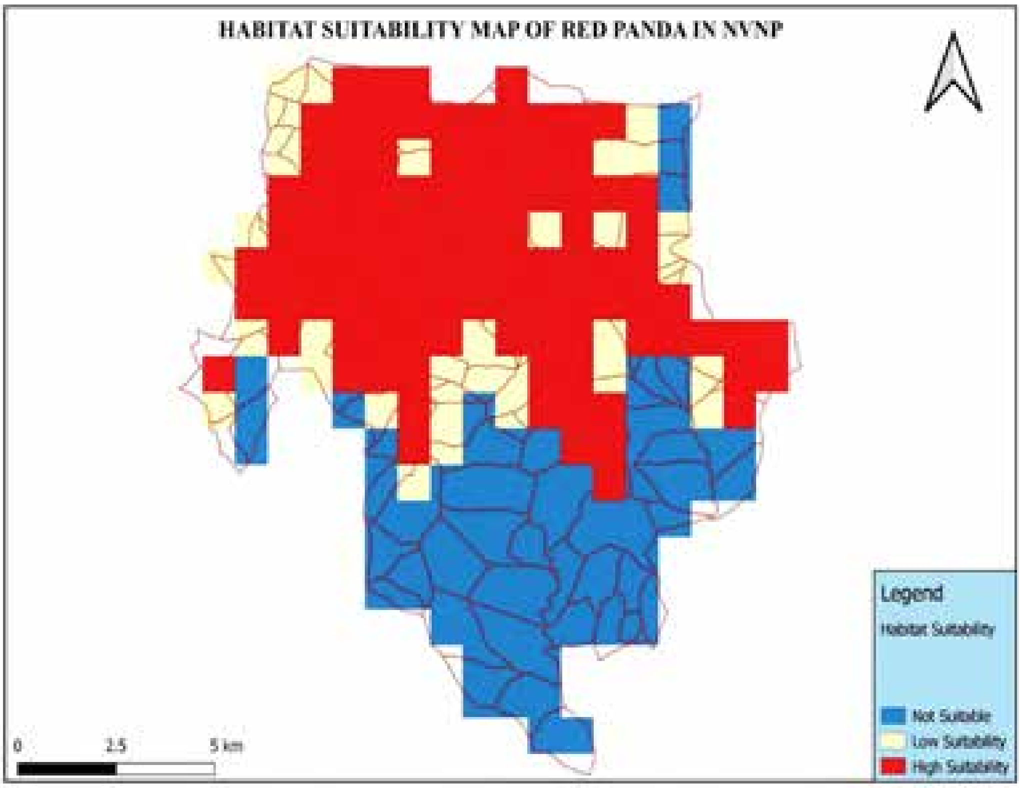

Figure 4. Potential habitat area for the Himalayan Red Panda *Ailurus fulgens*.

slope, and aspect) with approximately 1 km spatial data (30 seconds), annual mean temperature (Bio1), altitude, precipitation of driest month (Bio14), precipitation of driest quarter (Bio17), landcover and slope were the main contributing factors (Figure 3).

From these factors, a habitat suitability map was created using MaxEnt, which predicts that approximately 55 km^2 of area inside the NVNP is a potential conservation zone for the Himalayan Red Pandas (Figure 4).

Image 2. A—droppings of the Himalayan Red Panda | B—camera-trap photograph of the Himalayan Red Panda captured during our survey in Neora Valley National Park.

DISCUSSION

The IUCN conservation status of the Himalayan Red Panda has changed from 'Vulnerable' to 'Endangered', which indicates that the species has been experiencing a decrease in population over the years and facing significant threats. Understanding the spatial distribution of the potential habitat of species with the help of a model enables to assess the existing threats and planning for future uncertainties.

The model predicted approximately 55 km^2 of potential habitat consisting the areas above 2,000 m elevation with slope more than 30°, the aspect facing south-east and west, areas with dense bamboo *Malingo* and canopy cover, and water sources are the important habitat factors for the Himalayan Red Panda under the current climatic scenario, but the actual habitat is likely to be less since the correlative species distribution model predicts a fundamental niche that is larger than the realized niche (Polechova & Storch 2008). Further, the species can be limited by other environmental factors like land use, edaphic and anthropogenic disturbances that are not incorporated in the model (Ranjitkar et al. 2014).

The Himalayan ecosystem is rapidly changing under the influence of current global and regional warming and is expected to exacerbate with the predicted increase in mean temperature by 3.0–4.8°C by 2100 (Stocker 2014). Anthropogenic threats are the primary causes of changing climate which is expected to affect

Bioclimatic variables are coded as follows:

BIO1 = Annual Mean Temperature

BIO2 = Mean Diurnal Range (Mean of monthly (max temp - min temp))

BIO3 = Isothermality (BIO2/BIO7) (×100)

BIO4 = Temperature Seasonality (standard deviation ×100)

BIO5 = Max Temperature of Warmest Month

BIO6 = Min Temperature of Coldest Month

BIO7 = Temperature Annual Range (BIO5-BIO6)

BIO8 = Mean Temperature of Wettest Quarter

BIO9 = Mean Temperature of Driest Quarter

BIO10 = Mean Temperature of Warmest Quarter

BIO11 = Mean Temperature of Coldest Quarter

BIO12 = Annual Precipitation

BIO13 = Precipitation of Wettest Month

BIO14 = Precipitation of Driest Month

BIO15 = Precipitation Seasonality (Coefficient of Variation)

BIO16 = Precipitation of Wettest Quarter

BIO17 = Precipitation of Driest Quarter

BIO18 = Precipitation of Warmest Quarter

BIO19 = Precipitation of Coldest Quarter

Image 3. List of 19 coded bioclimatic variables available at worldclim.org.

vegetation patterns and will significantly influence the disturbance, structure, and ecology of forests (Sharma et al. 2009; Lyon et al. 2022). Upward range expansion is widely documented as a response of vegetation to a warming climate (Kullman 2002). The phenomenon of such range expansion will alter the availability of food and shelter in the current habitat, influencing the future upward distribution of the Himalayan Red Panda.

CONCLUSION

In this study, we used the presence-only species distribution modeling tool, MaxEnt to model the potential habitat distribution of the Endangered Himalayan Red Panda in NVNP. The information generated through the MaxEnt model can help conservation planners to be informed and decisive for making action plans in the future. The conservation management of NVNP should set priorities for the identification and accomplishment of realistic goals that would help preserve the habitat of the Himalayan Red Pandas.

REFERENCES

Bista, D., P.K. Paudel, S.R. Jnawali, A.P. Sherpa, S. Shrestha & K.P. Acharya (2019). Red panda fine-scale habitat selection along a Central Himalayan longitudinal gradient. *Ecology and Evolution* 9(9): 5260–5269. https://doi.org/10.1002/ece3.5116

CITES (2010). Convention on International Trade in Endangered Species of Wild Fauna and Flora: The CITES Appendices. UN Environment Programme, Geneva, Switzerland. http://www.cites.org. Accessed on 19 June 2023.

Chettri, N., E. Sharma, B. Shakya & B. Bajracharya (2007). Developing Forested Conservation Corridors in the Kangchenjunga Landscape, Eastern Himalaya. *Mountain Research and Development* 27(3): 211–214. https://doi.org/10.1659/mrd.0923

Choudhury, A. (2001). An overview of the status and conservation of the Red Panda *Ailurus fulgens* in India, with reference to its global status. *Oryx* 35(3): 250–259. https://doi.org/10.1046/j.1365-3008.2001.00181.x

DeMarco, P.J. & C.C. Nóbrega (2018). Evaluating collinearity effects on species distribution models: An approach based on virtual species simulation. *PLoS ONE* 13(9): e0202403–e0202403. https://doi.org/10.1371/journal.pone.0202403

Dorji, S., R. Rajaratnam & K. Vernes (2012). The Vulnerable Red Panda *Ailurus fulgens* in Bhutan: distribution, conservation status and management recommendations. *Oryx* 46(4): 536–543. https://doi.org/10.1017/S0030605311000780

Elith, J., S.J. Phillips, T. Hastie, M. Dudík, Y.E. Chee & C.J. Yates (2011). A statistical explanation of MaxEnt for ecologists. *Diversity and Distributions* 17(1): 43–57. https://doi.org/10.1111/j.1472-4642.2010.00725.x

Ghose, D. & P.K. Dutta (2011). Status and distribution of Red Panda, *Ailurus fulgens fulgens*, in India, pp. 357–374. In: Glatston, A.R. (ed.). *Red Panda: Biology and Conservation of the First Panda.* Academic Press, London, UK, 488 pp. https://doi.org/10.1016/B978-1-4377-7813-7.00020-3

Glatston, A., F. Wei, Z. Than & A. Sherpa (2015). *Ailurus fulgens* (errata version published in 2017). The IUCN Red List of Threatened Species 2015: e.T714A110023718. https://dx.doi.org/10.2305/IUCN.UK.2015-4.RLTS.T714A45195924.en. Accessed on 19 June 2023.

Hijmans, R.J., S.E. Cameron, J.L. Parra, P.G. Jones & A. Jarvis (2005). Very high- resolution interpolated climate surfaces for global land areas. *International Journal of Climatology* 25(15): 1965–1978. https://doi.org/10.1002/joc.1276

Hu, Y., A. Thapa, H. Fan, T. Ma, Q. Wu, S. Ma, D. Zhang, B. Wang, M. Li, L. Yan & F. Wei (2020). Genomic evidence for two phylogenetic species and long-term population bottlenecks in red pandas. *Science Advances* 6(9): 1–10. https://doi.org/10.1126/sciadv.aax5751

Joshi, B.D., S. Dalui, S.K. Singh, T. Mukherjee, K. Chandra, L.K. Sharma & M. Thakur (2021). Siang river in Arunachal Pradesh splits red panda into two phylogenetic species. *Mammalian Biology* 101: 121–124. https://doi.org/10.1007/s42991-020-00094-y

Kullman, L. (2002). Rapid recent range-margin rise of tree and shrub species in the Swedish Scandes. *Journal of Ecology* 90(1): 68–77. https://doi.org/10.1046/j.0022-0477.2001.00630.x

Lyon, L.M., S.C. Wallace & T.A. Joyner (2022). Impacts of climate change on extant Ailurids, pp. 369–392. In: Glatston, A.R. (eds.). *Red Panda (Second Edition): Biology and Conservation of the First Panda*. Academic Press, London, UK, 577 pp. https://doi.org/10.1016/B978-0-12-823753-3.00006-5

Mallick, J. (2010a). Neora Valley—A new short-listed World Heritage Site. *Tigerpaper* 37: 12–16.

Mallick, J.K. (2010b). Status of Red Panda *Ailurus fulgens* in Neora Valley National Park, Darjeeling District, West Bengal, India. *Small Carnivore Conservation* 43: 30–36.

Phillips, S. J., R.P. Anderson & R.E. Schapire (2006). Maximum entropy modeling of species geographic distributions. *Ecological Modelling* 190(3–4): 231–259. https://doi.org/10.1016/j.ecolmodel.2005.03.026

Polechová, J. & D. Storch (2008). Ecological Niche, pp.1088–1097. In: Jørgensen, S.E. & B.D. Fath (eds.). *Encyclopedia of Ecology*. Academic Press, 4122 pp.

Pradhan, S., G.K. Saha & J.A. Khan (2001). Food Habits of the Red Panda, *Ailurus Fulgens* in the Singhalila National Park, Darjeeling, India. *Journal of the Bombay Natural History Society* 98(2): 224–230.

Ranjitkar, S., R. Kindt, N.M. Sujakhu, R. Hart, W. Guo, X. Yang, K.K. Shrestha, J. Xu & E. Luedeling (2014). Separation of the bioclimatic spaces of Himalayan tree *Rhododendron* species predicted by ensemble suitability models. *Global Ecology and Conservation* 1: 2–12. https://doi.org/10.1016/j.gecco.2014.07.001

Roberts, M.S. & J.L. Gittleman (1984). *Ailurus fulgens*. *Mammalian Species* 222: 1–8. https://doi.org/10.2307/3503840

Sharma, E. & N. Chettri (2005). ICIMOD's Transboundary Biodiversity Management Initiative in the Hindu Kush–Himalayas. *Mountain Research and Development* 25(3): 278–281. https://doi.org/10.1659/0276-4741(2005)025[0278:ITBMII]2.0.CO;2

Stocker, T. (2014). *Climate Change 2013: The Physical Science Basis. Working Group I Contribution to the Fifth assessment report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, 1535 pp. https://doi.org/10.1017/CBO9781107415324

Thapa, A., Y. Hu, P.C. Aryal, P.B. Singh, K.B. Shah & F. Wei (2020). The endangered red panda in Himalayas: Potential distribution and ecological habitat associates. *Global Ecology and Conservation* 21(2020): p. e00890. https://doi.org/10.1016/j.gecco.2019.e00890

Su, H., M. Bista & M. Li (2021). Mapping habitat suitability for Asiatic black bear and red panda in Makalu Barun National Park of Nepal from Maxent and GARP models. *Science Report* 11: 14135. https://doi.org/10.1038/s41598-021-93540-x

Wei, F., Z. Feng, Z. Wang & J. Hu (1999). Current distribution, status and conservation of wild red pandas Ailurus fulgens in China. *Biological Conservation* 89(3): 285–291. https://doi.org/10.1016/S0006-3207(98)00156-6

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 December 2023 | 15(12): 24352–24356

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

https://doi.org/10.11609/jott.8505.15.12.24352-24356

OPEN ACCESS

#8505 | Received 04 May 2023 | Final received 06 November 2023 | Finally accepted 28 November 2023

COMMUNICATION

Recent record of Eurasian Otter *Lutra lutra* (Linnaeus, 1758) (Mammalia: Carnivora: Mustellidae) from Kerala part of the Western Ghats, India and an insight into the behaviour and habitat preferences

Sreehari K. Mohan [1], Lathish R. Nath [2], K.S. Subin [3], Sreekumar K. Govindankutty [4] & P.O. Nameer [5]

[1–5] Centre for Wildlife Studies, College of Forestry, Kerala Agricultural University, Vellanikkara, Thrissur, Kerala 680656, India.
[1] Rebuild Kerala Development Programme, Forest Headquarters, Vazhuthakkad, Thiruvananthapuram, Kerala 695014, India.
[2] Government Vocational Higher Secondary School Wadakkanchery, Thrissur,Kerala, 680582, India.
[1] sreeharikmohan007@gmail.com, [2] lathishrnath@gmail.com, [3] subinmanakody@gmail.com, [4] sreenomad123@gmail.com,
[5] nameer.po@kau.in (corresponding author)

Abstract: We report a recent record of the elusive Eurasian Otter *Lutra lutra* from Kerala, through a direct observation in the higher reaches of the Chinnar Wildlife Sanctuary within the Western Ghats, southern India. Field observation involved the sighting of two Eurasian Otters in a rocky-torrential stream in March 2020. The otters displayed a hyperactive foraging behaviour, searching among submerged rocks and crevices, followed by occasional dives. They seemed particularly interested in areas where water rushed with force, avoiding locations with low water flow or shallow pools. The observation site, at 1,275 m altitude in Chinnar Wildlife Sanctuary, located in the Western Ghats of Kerala region, featured wet evergreen vegetation, transitional sholas (stunted evergreen forests), and riparian patches along a stream characterised by rapid water flow, boulders, and fallen trees. This habitat, as observed by others, was also indicative of Asian Small-clawed Otter *Aonyx cinereus* suitability, suggesting potential resource partitioning between the two otter species. This discovery challenges previous assumptions about the preferred habitat of Eurasian Otters in the Western Ghats and emphasizes the need for comprehensive research on the taxonomy, distribution, population status, and behaviour of these possibly sympatric species of otters, the Asian Small-clawed Otter and the Eurasian Otter. Such studies are crucial for the conservation of both these species, which face threats from habitat loss, sand mining, hunting, and population decline. Preserving and restoring riparian vegetation in the higher reaches of the Western Ghats is essential for their protection within this biodiversity hotspot.

Keywords: Chinnar, conservation, small carnivores, montane forest, population decline, shola forests, riparian forests, Small-clawed Otter.

Malayalam: സംഗ്രഹം: അത്യപൂർവമായ യുറേഷ്യൻ നീർനായയുടെ കേരളത്തിലെ സാന്നിധ്യം ഔദ്യോഗികമായി സ്ഥിരീകരിച്ചു കൊണ്ടുള്ള ആദ്യരേഖപ്പെടുത്തലാണിത്. തെക്കൻ പശ്ചിമഘട്ടത്തിന്റെ ഭാഗമായ ചിന്നാർ വന്യജീവി സങ്കേതത്തിലെ ഉയർന്ന പ്രദേശത്താണ് ഇവയെ കണ്ടെത്തിയത്. ചിന്നാർ നദിയുടെ ഉത്ഭവപ്രദേശത്തു നിന്നും 2020 മാർച്ച് മാസം രണ്ട് നീർനായകളെയാണ് കണ്ടെത്താൻ സാധിച്ചത്. ഫീൽഡ് നിരീക്ഷണത്തിൽ കൃശഗാത്രരും ഊർജസ്വലരുമായ ഇവ കാട്ടരുവിയിലെ കല്ലുകൾക്കിടയിൽ ഇരതേടുന്നതായാണ് കാണാൻ സാധിച്ചത്. അതേ സമയം, അരുവിയുടെ നീരൊഴുക്ക് കുറഞ്ഞ പ്രദേശങ്ങൾ ഇവ ഒഴിവാക്കുന്നതാണ് ശ്രദ്ധയിൽപ്പെട്ടത്. സമുദ്രനിരപ്പിൽ നിന്ന് 1275 മീറ്റർ ഉയരത്തിൽ സ്ഥിതി ചെയ്യുന്നതും ശക്തമായ നീരൊഴുക്കും അങ്ങിങ്ങായി മരങ്ങളും വീണുകിടക്കുന്ന ഈ അരുവിയുടെ ചുറ്റുമായി ആർദ്ര-നിത്യഹരിതവനങ്ങൾ, ചോലക്കാടുകൾ, പുൽമേടുകൾ, പുഴയോരക്കാടുകൾ എന്നീ ആവാസവ്യവസ്ഥകൾ കാണപ്പെടുന്നു. മറ്റു ഗവേഷണങ്ങളിൽ നിന്നുള്ള വിവരങ്ങൾ അനുസരിച്ച് ഈ പ്രദേശം മലനീർനായയുടെ കൂടി ആവാസവ്യവസ്ഥയായതിനാൽ ഈ രണ്ട് നീർനായകൾ തമ്മിൽ പരസ്പരധാരണയോടുകൂടിയ വിഭവവിനിയോഗവും നടക്കുന്നുണ്ട് എന്ന് വേണം കരുതാൻ. യൂറേഷ്യൻ നീർനായയുടെ ഈ കണ്ടെത്തൽ പശ്ചിമഘട്ടത്തിലെ അവയുടെ സ്വാഭാവിക ആവാസവ്യവസ്ഥയെ കുറിച്ചുള്ള നിലവിലെ ശാസ്ത്രനിലപാടിനെ ചോദ്യം ചെയ്യുന്നു എന്നതുകൂടി ശ്രദ്ധേയമാണ്. അതുകൊണ്ടു തന്നെ ഒരേ ആവാസവ്യവസ്ഥ പങ്കിടുന്ന യൂറേഷ്യൻ നീർനായയെയും മലനീർനായയെയും കുറിച്ചുള്ള ഗവേഷണ-നിരീക്ഷണങ്ങളും അവയുടെ വർഗീകരണം, എണ്ണം, വിന്യാസം, സ്വഭാവശാസ്ത്രം എന്നിവയെക്കുറിച്ചുള്ള വിശദമായ പഠനങ്ങളും ആവശ്യമാണ്. ആവാസവ്യവസ്ഥശോഷണം, മണൽഖനനം, വേട്ടയാടൽ എന്നിവ മൂലമുണ്ടാകുന്ന നാശങ്ങളിൽ നിന്നും ഇവയെ സംരക്ഷിക്കുവാനായി ഇത്തരം പഠനങ്ങൾ അനിവാര്യമാണ്. ഇതിനു പുറമെ, പശ്ചിമഘട്ടത്തിലെ ഉയർന്ന വിതാനങ്ങളിലെ പുഴയോരക്കാടുകളെ പുനരുജ്ജീവിപ്പിക്കേണ്ടതും സംരക്ഷിക്കേണ്ടതും ഇവയുടെ നിലനിൽപ്പിന് അത്യന്താപേക്ഷിതമാണ്.

Editor: Nicole Duplaix, Oregon State University, Corvallis, USA. **Date of publication:** 26 December 2023 (online & print)

Citation: Mohan, S.K., L.R. Nath, K.S. Subin, S.K. Govindankutty & P.O. Nameer (2023). Recent record of Eurasian Otter *Lutra lutra* (Linnaeus, 1758) (Mammalia: Carnivora: Mustellidae) from Kerala part of the Western Ghats, India and an insight into the behaviour and habitat preferences. *Journal of Threatened Taxa* 15(12): 24352–24356. https://doi.org/10.11609/jott.8505.15.12.24352-24356

Funding: Kerala Agricultural University.

Competing interests: The authors declare no competing interests.

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

Acknowledgements: We thank the Chief Wildlife Warden, Kerala Forest Department, for the study permit (BDC1-15371/2018). We thank the Wildlife Warden, Munnar WL Division, Divisional Forest Officer, Marayoor, Range Forest Officer, Marayoor, Assistant Wildlife Warden, Chinnar for the logistical support that enabled us to conduct hassle-free fieldwork in the remote forests of the sanctuary. We would like to extend our gratitude to the dedicated team of forest watchers who accompanied us throughout the trek, without whom the collection of data and observations would not have been possible. The critical reviews provided by the reviewers have been of immense help in improving the quality of the manuscript, and we are grateful to the reviewers.

Eurasian Otter *Lutra lutra* has been described as having *one of the widest distributions of all Palearctic mammals* (Conroy et al. 1998). They are opportunistic and have high foraging plasticity (Smiroldo et al. 2009) and their diets are mainly composed of aquatic invertebrates, crabs, fishes, and tetrapods (Almeida et al. 2012). In India, the species is restricted to the Himalayan foothills up to Sikkim, north of the Ganges, Assam in the north-east and to southern India (Wroughton 1920; Pocock 1941). They are considered to be absent from central India until photographic records appeared from Madhya Pradesh and Chhattisgarh (Joshi et al. 2016; Suraj et al. 2022). Despite extensive research on otters in the Western Ghats (Basnet et al. 2020), including many recent sightings and observations of Smooth-coated and Small-clawed Otters, there was no documented evidence, such as photographs or genetic studies, of Eurasian Otters in the region until recently. This could probably be because of the shy, often nocturnal and elusive habit of the Eurasian Otters, making it difficult to study in the wild by direct observations. Historical records indicate that Eurasian Otters were previously documented in the Coorg hills of Karnataka, Ooty in the Nilgiris, Palani hills, Pambar river in Kodaikanal, Tamil Nadu within the Western Ghats (Ryley 1913; Wroughton & Davidson 1920; Lindsay 1926; Pocock 1941; Prater 1971). Blanford (1888) examined a specimen that came from Pondicherry, southern India while *Lutra indica* Gray was originally described from Madras (Hinton & Fry 1923). Museum specimens in the British Museum of Natural History (BMNH) were misidentified in the past, making it extremely difficult to identify the *Lutra lutra* to the subspecies (Nicole Duplaix in litt. September, 2023). Molecular analysis has now made this straightforward, as evidenced by Mudappa et al. (2018), who made a significant rediscovery of this species in the Western Ghats, specifically in the Anamalai hills of Tamil Nadu, after an absence of nearly seven decades. Their identification was based on detailed morphological and molecular analyses of a carcass found as roadkill.

Three species of otters—Eurasian *Lutra lutra,* Smooth-coated *Lutrogale perspicillata* and Asian Small-clawed *Aonyx cinereus*—are known to occur in Western Ghats mountain ranges (Hussain 1999), Eurasian Otter is mostly confined to small rivers in elevations ranging 450–950 m (Raha & Hussain 2016). The Smooth-coated Otter occurs in large water bodies (Anoop & Hussain 2005). The Asian Small-clawed Otter is the smallest of the otters and seems to prefer lower-order streams above 500 m altitude in the Western Ghats (Perinchery et al. 2011; Mudappa et al. 2018).

Previous records of Eurasian Otters in the Western Ghats were primarily based on surveys that relied on identifying spraints and tracks, conducted by Raha & Hussain (2015) in five protected areas within the southern Western Ghats. In their study, Eurasian Otters were identified in Periyar Tiger Reserve, Kerala based on track signs. However, it is important to note that precisely distinguishing between Smooth-coated Otters and Eurasian Otters based solely on tracks can be challenging, and confirmation through camera trap images is recommended (Conroy et al. 1998; Mudappa et al. 2018). This was further validated by Nameer (2015) where Eurasian Otter was not included in the checklist of mammals of Kerala. Some earlier studies mistakenly identified Smooth-coated Otters as Eurasian Otters in the coastal plains, leading to incorrect records of the species in peninsular India (Umapathy & Durairaj 1995; Umapathy 2000; Mudappa et al. 2018).

Previous research concentrating on small carnivores within Western Ghats' protected areas consistently documented the presence of Asian Small-clawed Otters in Eravikulam National Park (Perinchery et al. 2011; Nikhil & Nameer 2017), Silent Valley National Park (Sanghamitra & Nameer 2018), and Wayanad Wildlife Sanctuary (Sreekumar & Nameer 2018); and despite extensive camera trap sampling, none of these studies reported any Eurasian Otters in the region. However, in this paper, we present a remarkable observation of live Eurasian Otters from Chinnar Wildlife Sanctuary, southern Western Ghats of Kerala. This observation marks the first-ever direct sighting of live Eurasian Otters in the Western Ghats after an absence of nearly 70 years and represents an unmatched record for the state of Kerala.

During the 'Kerala Bird Atlas' project (Praveen et al. 2022) fieldwork near Olikkudy (10.3318^{0}N, 77.1400^{0}E) in Chinnar Wildlife Sanctuary, Idukki district, Kerala, on 07 March 2020, at 1800 h we observed a remarkable behavior of Eurasian Otters in the rocky-torrential streams of the Chinnar river. Two otters, one female and one of unidentified sex, were actively searching for food, demonstrating heightened activity among submerged rocks and crevices. Their dives lasted between 5–20 seconds, and they exhibited a clear preference for areas with strong water flow. While we did not witness them feeding above the water's surface, they consistently chewed on smaller prey-items after each dive, suggesting they obtained their food directly from underwater. After approximately 8–10 minutes of feeding, they left spraints on a nearby rock (Image 1) before resting on another rock located about half a meter away. This entire behavior was also captured on video (Video 1 & Video 2).

The individuals were confirmed as Eurasian Otter *Lutra lutra* after careful examination by the experts from the

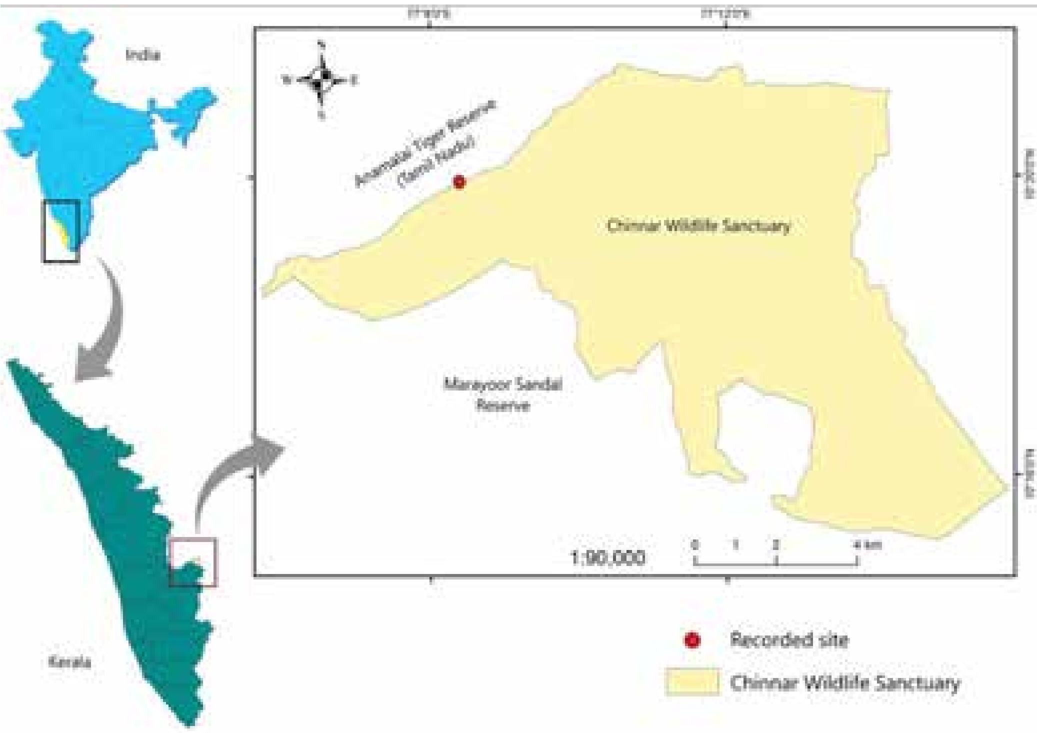

Figure 1. Recorded site of Eurasian Otter *Lutra lutra* from Chinnar Wildlife Sanctuary.

Image 1. Eurasian Otter *Lutra lutra* depositing spraints.

Image 2. Eurasian Otter *Lutra lutra* resting on a rock.

IUCN Otter Specialist Group (Jason Palmer in litt. September 2023; Nicole Duplaix in litt. September 2023; Anna Loy in litt. September 2023) and referring Hwang & Lariviere (2005), Larivière & Jennings (2009), Hung & Law (2016) and Menon (2023). The morphological features such as the flattened head shape, nasal arrangement with double ridged rhinarium, webbed feet with visible claws and structure of the tail are definite for *Lutra lutra*. According to Larivière & Jennings (2009) and Hung & Law (2016), the morphometric details are as follows, head-to-body length: 50–82 cm, tail length: 33–50 cm, weight: 5–14 kg.

During the sighting, the otters were spotted at an altitude of 1,275 m on the western slopes of Chinnar Wildlife Sanctuary, amid wet evergreen vegetation, transitional sholas, and riparian patches (Image 4). The stream, ranging 0.2–1.2 m in depth, was nestled between two hill ranges adorned with montane sub-tropical forests and grasslands. Riparian vegetation included various tree species such as *Elaeocarpus tuberculatus, Elaeocarpus munronii, Litsea* spp., *Acronychia pedunculata, Actinodaphne* spp., *Meliosma simplicifolia, Oreocnide integrifolia*, and *Schefflera* spp., along with dominant ferns of the *Cyathea* genus. The swiftly flowing stream was characterized by boulders and fallen trees (Image 4). Perinchery et al. (2011) noted this habitat as suitable for Asian Small-clawed Otters, suggesting potential resource partitioning between these two otter species in the area. It is worth noting here that these observations are counter-intuitive to the previously suggested idea by Raha & Hussain (2015), where it has been claimed that the species prefers moderate to slow-flowing rivers or dams in the Western Ghats. We could also find multiple spraints of the otters upstream in the subsequent days. The spraints dominated with finely macerated crabs, fishes and other fresh-water crustaceans laid over rocks or sand bars.

The Eurasian Otter has been listed in Appendix-I of CITES, Near Threatened as per IUCN Red list of Threatened Species (Loy et al. 2022) and largely depleted as per the IUCN Green status due to a decline in population (Loy et al. 2021). Within the Western Ghats, there is a notable lack of data regarding both the distribution and population status of the Eurasian Otter. Hung & Law (2016) reports 12 subspecies of *Lutra lutra* and the subspecies seen in southern India is *Lutra lutra nair*. Phylogenetic studies

Image 3. Eurasian Otter *Lutra lutra*.

Image 4. Habitat of Eurasian Otter in Chinnar Wildlife Sanctuary.

Video 1. Euresian Otter *Lutra lutra* actively foraging. © Sreehari K Mohan.

Video 2. Eurasian Otter *Lutra lutra* depositing spraints. © Sreehari K Mohan

are needed to find out the exact taxonomic status of this otherwise wide-ranging species in the Western Ghats.

Conserving this otter species necessitates prioritizing efforts like preserving and restoring riparian vegetation, and mitigating threats such as habitat loss, sand mining, and hunting (Yoxon & Yoxon 2019; Basnet et al. 2020; Suraj et al. 2022). This observation highlights the need for comprehensive research on Eurasian Otters and other small carnivores in the Western Ghats, focusing on taxonomy, distribution, population status, habitat characterization, resource partitioning, and behavior. Such studies are integral to the conservation of these lesser-known mammal species in the biodiverse Western Ghats region.

REFERENCES

Almeida, D., G.H. Copp, L. Masson, R. Miranda, M. Murai & C.D. Sayer (2012). Changes in the diet of a recovering Eurasian otter population between the 1970s and 2010. *Aquatic Conservation: Marine and Freshwater Ecosystems* 22(1): 26–35. https://doi.org/10.1002/aqc.1241

Anoop, K.R. & S.A. Hussain (2005). Food and feeding habits of smooth coated otters *(Lutra perspicillata)* and their significance to the fish population of Kerala, India. *Journal of Zoology* 266: 15–23.

Basnet, A., P. Ghimire, Y.P. Timilsina & B.S. Bist (2020). Otter research in Asia: Trends, biases and future directions. *Global Ecology and Conservation* 24: e01391. https://doi.org/10.1016/j.gecco.2020.e01391

Blanford, W.T. (1888). *The Fauna of British India including Ceylon and Burma.* Taylor and Francis, London, U.K. 617 pp.

Conroy, J., R. Melisch & P. Chanin (1998). The Distribution and Status of the Eurasian Otter (*Lutra lutra*) in Asia - a Preliminary Review. *IUCN Otter Specialist Group Bulletin* 15(1): 15– 30

Hung, N. & C.J. Law (2014). *Lutra lutra* (Carnivora: Mustelidae). *Mammalian Species* 48(940): 109–122.

Hinton, M.A.C. & T.B. Fry (1923). Report No. 37: Nepal. Bombay Natural History Society's Mammal Survey of India, Burma, and Ceylon. *Journal of the Bombay Natural History Society* 29: 399–428.

Hussain S.A. (1999). Status of otter conservation in India. *Environmental Information System Bulletin*: *Wildlife and Protected Areas, Mustelids, Viverrids and Herpestids of India* 2: 92–97.

Hwang, Y.T. & S. Lariviere (2005). *Lutrogale perspicillata*. *Mammalian Species* 786: 1–4.

Joshi, A., V.M. Tumsare, A.K. Nagar, A.K. Mishra & M.P. Pariwakam (2016). Photographic records of Eurasian Otter *Lutra lutra* from the central Indian landscape. *IUCN Otter Specialist Group Bulletin* 33(2): 73–78.

Larivière, S. & A.P. Jennings (2009). Family Mustelidae (Weasels & relatives), pp. 564–658. In: Wilson, D.E. & R.A. Mittermeier (eds.). *Handbook of Mammals of the World. Vol. I. Carnivores.* Lynx Edicions. Barcelona.

Lindsay, H.M. (1926). Bombay Natural History Society's Mammal Survey of India: Report 43. *Journal of the Bombay Natural History Society* 31(3): 591–597.

Loy, A., P.S. Jamwal & S.A. Hussain (2021). *Lutra lutra* (Green Status assessment). The IUCN Red List of Threatened Species 2021: e.T12419A1241920221. Accessed on 10 September 2023.

Loy, A., A. Kranz, A. Oleynikov, A. Roos, M. Savage & N. Duplaix (2022). *Lutra lutra* (amended version of 2021 assessment). The IUCN Red List of Threatened Species 2022: e.T12419A218069689. https://doi.org/10.2305/IUCN.UK.2022-2.RLTS.T12419A218069689.en. Accessed on 10 September 2023.

Menon, V. (2023). *Indian Mammals: A Field Guide.* Hachette Book Publishing India, 328 pp.

Mudappa, D., N. Prakash, P. Pawar, K. Srinivasan, M.S. Ram, S. Kittur & G. Umapathy (2018). First record of Eurasian Otter *Lutra lutra* in the Anamalai Hills, southern Western Ghats, India. *IUCN Otter Specialist Group Bulletin* 35(1): 47–56

Nameer, P.O. (2015). A checklist of mammals of Kerala, India. *Journal of Threatened Taxa* 7(13): 7971–7982. https://doi.org/10.11609/jott.2000.7.13.7971-7982

Nikhil, S. & P.O. Nameer (2017). Small carnivores of the montane forests of Eravikulam National Park in the Western Ghats, India. *Journal of Threatened Taxa* 9(11): 10880–10885. https://doi.org/10.11609/jott.2211.9.11.10880-10885

Perinchery, A., D. Jathanna & A. Kumar (2011). Factors determining occupancy and habitat use by Asian small-clawed otters in the Western Ghats, India. *Journal of Mammalogy* 92: 796–802. https://doi.org/10.1644/10-MAMM-A-323.1

Pocock, R.I. (1941). *The Fauna of British India including Ceylon and Burma, Mammalia,* Vol. 2. Carnivora, Taylor and Francis, London, 503 pp.

Prater, S.H. (1971). *The Book of Indian Animals.* Bombay Natural History Society, India, 348 pp.

Praveen, J., P.O. Nameer, A. Jha, A. Aravind, K.G. Dilip, D. Karuthedathu, G. Tom, H. Mavelikara, H. Mannar, J. Palot, J. Johnson, R. Jishnu, K.M. Rodrigues, P.M. Mujeeb, L. Namassivayan, N.l Payyeri, P.P. Nesrudheen, S.P. Narayanan, S.S. Prasanth, M.C.P. Krishna, E.S. Praveen, P. Velayudhan, P. Reghuvaran, R. Kidoor, R.L. Rathish, R. Roshnath, C. Sashikumar, S. Meppayur, A.K. Sivakumar, A. Sreedevi, B. Sreekumar, E.R. Sreekumar, P. B. Sumesh, R. Venugopal, V. Venugopal, C.K. Vishnudas, V. Kartha, V. Puliyeri, S. Quader, A. Reddy, A.R. Puthiyeri, K.A. Riyas, R.S. Abhijith, A. Surendran, A.M. Sunil, A. Chandran, C. Abhirami, A.M. Jayakumar, A.S. Peter, N.V.A. Muhammed, A.F. Katakath, P. Ajai, A.K. Raju, P.M. Akhil, U.S. Akhil, U.S. Amal, A. Menon, A.I. Ansari, K.S. Aneesh, S. Aneesh, C.A. Hari, R. Anjitha, P.N.A. Raj, A. John, A. Varma, S.S. Anushreedha, C.K. Aravind, A. Ramachandran, B. Arun, A. George, A.P. Gopi, A. Varghese, A. Vinod, A. Shaji, V.M.A. Raj, A. Viswanathan, A. Mohammed, A. Aswin, K.S. Aswin, A.A. Ali, P.B. Balaji, M.B. Paul, J.C. Shree, C. Venkatraman, K. Charutha, C.T. Jose, C.P. Jose, D. Singh, D. Sanghamithra, D.S. Sikarwar, D. Murukesh, V. Divin, F. Arief, J. Mandal, P.J. Sarlin, A.A. Nafar, K.H.A. Bachan, V. Rejitha, R.S.V. Dev, B. E. Rowther, F. Raja, G. Iyer, G. George, T.U. Gireesan, P.K.G Mohan, G.P. Dsouza, G. Govind, P. Greeshma, P.M.H. Prasad, T.V. Hariharan, A. Harith, C. Harith, B. Hemanth, I. Mohamed, J. P. David, P.K. Jain, P. Jameela, G. Jayakrishnan, K. Jishnu, M.O. Jismi, J. Johnson, C.J. Soniya, J.R. Babu, J. Roy, J. Nelson, M.J. Krishnan, K.P. Bhandary, K.M. Jamaludheen, K. Ravi, K. Thrikkadeeri, K.K. Nair, B.S. Kiran, K.S. Kumar, D.K. Raj, K.K. Panaganti, M.K. Moorthy, R. K. Murthy, M.R. Krishnanunni, L. Prabhakaran, K.K. Lathika, L. Abraham, G.H. Narayanan, M. Panigrahi, S. Manav, M. Karingamadathil, T.R. Manoj, M. Thomas, P.P. Manuel, M.G. Varghese, P.M. Chandran, M.M. Sulaiman, M.A. Madathil, V.K.M. Hirash, K.M. Ramees, M.S. Thirunnavaya, A.P.M. Niyas, C.T. Muhasin, M. Kizhakkemadham, N.A. Azeez, P.V. Nikhil, C. Niranjana, N. Mundekad, N. Mohan, A. Pavithra, P. Viswanathan, P. Pramod, G. Prakash, S. Prasath, P. Prakash, N. Preethi, R. Rajeevan, M. Rajaguru, V. Rajarajan, R. Sankaran, K. Ratheesh, R.P. Crasta, R. Mohan, Renju, R.C. Koshy, R. Rai, R. Tom, S. Chandran, M.V. Sachinkrishna, M.V.S.A. Ali, S. Siril, D.D.S. Bharadwaj, S. George, S. Morris, S. Augustine, S.K. Das, S.Morris, P.R. Sandra, T.K. Sanuraj, S. Sawant, S. Morris, K. Selvaganesh, K. Shahil, N.N. Shahina, S. Valasy, P.K. Siji, S. Joseph, R. Sivashankar, S.A. Karim, S.K. Mohan, S.M. Pillai, M.S. Sowmiya, K.T. Srinila, K.S. Subin, V.G. Sujith, S. Sukumaran, M.S. Syamili, T. Menon, T Praveen, S.A. Thilak, T. Antony, U.R. Ullas, V.O. Sivaji, V. Narayanan, M.V. Sreejith, A.V. Chandran, V. Sudhakaran, R. Vridhi, W.I. Humam, Y.J. Uchummal & M. A. Yathumon (2022). Kerala Bird Atlas 2015–20: features, outcomes and implications of a citizen-science project. *Current Science* 122: 298– 309.

Raha, A. & S.A. Hussain (2016). Factors affecting habitat selection by three sympatric otter species in the southern Western Ghats, India. *Acta Ecologica Sinica* 36(1): 45–49. https://doi.org/10.1016/j.chnaes.2015.12.002

Ryley, K.V. (1913). Bombay Natural History Society's Mammal Survey of India: Report 11. *Journal of the Bombay Natural History Society* 22(3): 486–513.

Sanghamithra, D. & P.O. Nameer (2018). Small carnivores of Silent Valley National Park, Kerala, India. *Journal of Threatened Taxa* 10(8): 12091–12097. https://doi.org/10.11609/jott.2992.10.8.12091-12097

Smiroldo, G., A. Balestrieri, L. Remonti & C. Prigioni (2009). Seasonal and habitat-related variation of otter *Lutra lutra* diet in a Mediterranean river catchment (Italy). *Folia Zoologica* 58: 87–97.

Sreekumar, E.R. & P.O. Nameer (2018). Small carnivores of Wayanad Wildlife Sanctuary, the southern Western Ghats, India. *Journal of Threatened Taxa* 10(1): 11218–11225. https://doi.org/10.11609/jott.3651.10.1.11218- 11225

Suraj, M., M. Ahmed, K. Basak, J. Sarathi, P. Pandey & A. Khelwar (2022). First Record of Eurasian Otter (*Lutra lutra*) from Chhattisgarh, Central India. *IUCN Otter Specialist Group Bulletin* 39(4): 229–235.

Umapathy, G. & G. Durairaj (1995). Preliminary Studies on the Feeding Ecology of the Otter *Lutra lutra* at Pitchavaram, East Coast of India. IUCN Otter Specialist Group Bulletin 11: 24–26.

Umapathy, G. (2000). Food habits and activity pattern of the Common Otter *Lutra Lutra* Nair (F. Cuvier) at Pichavaram, Tamil Nadu, South India. Journal of Bombay Natural History Society 97: 367–69.

Wroughton, R.C. (1919). Summary of the results from the Indian mammal survey of Bombay Natural History Society, Part III. *Journal of the Bombay Natural History Society* 26(2): 338–378.

Wroughton, R.C. & W.M. Davidson (1920). Bombay Natural History Society's Mammal Survey of India: Report 31. *Journal of the Bombay Natural History Society* 26(4): 1031–1035.

Yoxon, P. & B. Yoxon (2019). Eurasian Otter (*Lutra lutra*): a review of the current world status. *Otter* 5: 53–73.

Author details: Sreehari K. Mohan is a wildlife biologist who completed Masters in Forestry with specialization in Wildlife Science, Kerala Agricultural University, Thrissur. His interest lies in studying the ecology of mammals, trees, and birds. He is the co-founder of 'Myristika' that aims to promote nature education and sustainable resource sharing. He currently works as Project Manager of Rebuild Kerala Development Programme, Kerala Forest Department, Thiruvananthapuram. Lathish R. Nath is a passionate teacher with fervent enthusiasm for birdwatching, wildlife photography, and curiosity to explore the wonders of nature. Beyond the classroom, he proudly serves as a contributor for travel magazines, sharing compelling articles focused on birds. Subin, K.S. is a wildlife enthusiast who enjoys studying birds, mammals, and odonates. His interest goes beyond observation, as he actively contributes to conservation efforts and engages in citizen science projects to gather data on these creatures, emphasizing the importance of preserving their habitats. Sreekumar K. Govindankutty is not just a businessman; he finds solace and inspiration in birdwatching and bird photography. His curious and nature-loving spirit drives him to explore the wonders of the natural world, blending his entrepreneurial pursuits with a deep appreciation for the beauty and diversity of birds. P.O. Nameer is a professor of Wildlife Science at Kerala Agricultural University. He is a passionate researcher and academician with a keen interest in documenting biodiversity and strives to understand the ecology and biogeography of various taxa and communities, mainly in the Western Ghats region, with a motive to assist with the long-term conservation of the species and the habitats. He is also interested in the socio-economic dimensions of ecology.

Author contributions: SKM—field observation and data collection, manuscript writing, proof reading and referencing. LRN—field observation and data collection. KSS—field observation and data collection. SKG—field observation and data collection. PON—manuscript writing, editing, proof reading and referencing.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 December 2023 | 15(12): 24357–24367
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.8260.15.12.24357-24367
#8260 | Received 06 November 2022 | Final received 05 December 2023 | Finally accepted 12 December 2023
OPEN ACCESS
COMMUNICATION

A review of Baya Weaver *Ploceus philippinus* (Linnaeus, 1766) (Aves: Passeriformes: Ploceidae): ecological and conservation status

Yusufkhan Pathan [1] & **Arvindgiri Goswami** [2]

[1,2] Biology Department, M.V.M. Science & Home Science College, Saurashtra University, Rajkot, Gujarat 360005, India.
[1] pathanyn4@gmail.com (corresponding author), [2] arvindgirigoswami@gmail.com

Abstract: Baya Weaver *Ploceus philippinus* is a highly social and gregarious bird of the family Ploceidae that has been recently listed as 'Least Concern' by the IUCN Red List of Threatened Species. In India, four species of genus *Ploceus* are reported to date. This study focused on the appearance, distribution, diet specificity, nesting ecology, mating behaviour, and physiological responses to seasonal changes of *P. philippinus*. Populations have declined due to poor cultivation practices by farmers, rapid urbanization, and industrialization that have resulted in habitat loss. Weaver birds also face threats due to natural predators such as birds, and from insect damage to chicks, eggs, and nests.

Keywords: Diet specificity, Least Concern, mating behaviour, nesting ecology, threats, Weaver Bird.

Editor: H. Byju, Coimbatore, Tamil Nadu, India. **Date of publication:** 26 December 2023 (online & print)

Citation: Pathan, Y. & A. Goswami (2023). A review of Baya Weaver *Ploceus philippinus* (Linnaeus, 1766) (Aves: Passeriformes: Ploceidae): ecological and conservation status. *Journal of Threatened Taxa* 15(12): 24357–24367. https://doi.org/10.11609/jott.8260.15.12.24357-24367

Funding: SHODH- ScHeme Of Developing High Quality Research, Education Department, Gujarat State.

Competing interests: The authors declare no competing interests.

Author details: Pathan, Y. is a research scholar at Saurashtra university, Rajkot. He has been working on the avian diversity and ecology of Baya Weaver for the last five years and has an interest in study of ornithology and conservation of birds. Dr. A. Goswami is associate professor of Zoology at Biology Department, M.V.M Science and home science college, Rajkot. His area of specialization includes fisheries ecology, avifaunal ecology and aquatic biodiversity.

Author contributions: YP explore the research articles and draft the manuscript. A. Goswami supervised and finalized a manuscript.

Acknowledgements: YP was supported by SHODH fellowship, Govt. Of Gujarat. The authors are thankful to Dr. K.J. Ganatra, Principal of the M.V.M Science & Home Science College, Rajkot for providing necessary permissions and support during research work.

INTRODUCTION

Baya Weaver *Ploceus philippinus* is a docile, intelligent, and gregarious sparrow-sized bird that is popularly known for excellent nest-weaving skills (Quader 2006). In 1760, the French zoologist Mathurin Jacques Brisson included a description of the Baya Weaver in his book of ornithology that was based on a specimen that he believed had been collected in the Philippines. Linnaeus (1766) provided a brief description of the Baya Weaver, citing the elongated description of Brisson, and repeated the locality as the Philippines. More than a century later, Hartert (1902) realized that the Baya Weaver does not occur in the Philippines and suggested the type locality should be Ceylon (Sri Lanka). This species is now placed in the genus *Ploceus* that was introduced by the French naturalist Georges Cuvier in 1816. India is home to four *Ploceus* (Lack 1954, 1968; Grewal et al. 2016; Grimmett et al. 2016): Black-breasted Weaver *P.* benghalensis, Streaked Weaver *P. manyar*, Finn's Weaver *P. megarhynchus*, and Baya Weaver *P. philippinus*. There are many works on nesting and population ecology (Quader 2005, 2006; Borges et al. 2002; Raju 2009; Pandian & Ahimas 2018; Kumar et al. 2018; Pandian 2022), but a combined review has not been prepared to date. This review provides baseline information about the nesting, mating, and population ecology, in addition to conservation status.

MATERIAL AND METHODS

Available literature was scrutinised for the ecological and conservation studies of Baya Weaver *P. philippinus*. Old articles were obtained from the Biodiversity Library and open source/online publications. References were collected from various institute libraries and recognised web-based literature. For the present study, 78 articles and books were screened for Baya Weaver studies including aspects such as nesting, mating, population ecology, and conservation status.

Appearance

Female and nonbreeding male: A male and female looks similar in nonbreeding season males exhibit brighter and more vibrant colours during the breeding season (Inskipp et al. 2011). The non-breeding male Baya Weaver boasts a yellow head cap, adorned with fine darker shaft streaks, while its mantle feathers exhibit a central brown hue complemented by distinct yellow margins. The tail and wings are dark brown with lighter margins. On the tertials, margins of the outer vanes are buffy to rusty while they are yellow-olive on the secondaries forming an unobtrusive wing panel. The throat is light brown, the breast yellow and the belly is light yellowish to whitish while the flanks are rather buffy. In addition, tarsi and toes are horn-coloured (Stiels & Schidelko 2013).

Breeding male: The males assumed bright golden yellow plumage on the crown, nape, breast, and sides of the neck. The bill was pale yellow in the non-breeding season but turned blackish in April and became black between May and October (Narasimhacharya et al. 1988).

Distribution in India: Andhra Pradesh, Bihar, Chhattisgarh, Goa, Jharkhand, Karnataka, Madhya Pradesh, Maharashtra, Rajasthan, Tamil Nadu, Telangana, Uttar Pradesh, and West Bengal, Gujarat (Arigela et al. 2021).

Wider distribution: Java & Sumatra (Indonesia) (Wood 1926), Pakistan, Bangladesh, Thailand, Malaysia, and Sri Lanka (Ali & Ripley 1999), and Afghanistan (Stiels & Schidelko 2013).

Food preference: *P. philippinus* feeds on wider varieties of herbs as annotated in the Table 1. These birds forage in flocks for grains in cultivated fields and sometimes this bird is considered an agricultural pest (Sengupta 1974; Kale et al. 2014) but, in contrast, they also feed on different insects which are causing damage to the cultivated crops (Arigela et al. 2021).

Nesting ecology of *P. philippinus*

Nest construction pattern and its stages: The Baya Weaver *P. philippinus*, has been considered an architectural genius for the delicate craftsmanship of building intricate pendant nests. The nest of *P. philippinus* is pendulous, suspended to leaf tips, mono-storied, stalked, and retort shaped with a central nesting chamber and long vertical tube that leads to a side entrance to the chamber (Venkataramani 1981). Wood (1926) mentioned that weaver birds instead of building a nest once or twice in a year they reuse the old nest by repairing it, Raju (2009) reported that male Weaver birds constructed a new nest because of old ones may fall along with the leaf during an annual leaf fall. The Weaver bird rarely constructs a stalk-less nest because such nests are hardly ever excepted by the female weaver bird (Sharma 1995). There are five stages in the construction of a nest initial attachment, roof and egg/brood chamber, antechamber, entrance, and entrance tube (Raju 2009). Nest building was initiated by winding strands of grass around a selected twig until

Table 1. Details about the food specificity of *Ploceus philippinus*.

	Plant type	Family	Scientific name
1	Herb	Poaceae	*Acrachne racemosa* (B. Heyne ex Roth) Ohwi
2	Herb	Poaceae	*Alloteropsis cimicina* (L.) Stapf
3	Herb	Poaceae	*Arundinella pumila* (Hochst. ex A. Rich.) Steud.
4	Herb	Poaceae	*Arundinella setosa* Trin.
5	Herb	Poaceae	*Brachiaria eruciformis* (Sm.) Griseb.
6	Herb	Poaceae	*Brachiaria remota* (Retz.) Haines
7	Herb	Poaceae	*Brachiaria semiundulata* (Hochst. ex A. Rich.) Stapf
8	Herb	Poaceae	*Cyrtococcum trigonum* (Retz.) A. Camus
9	Herb	Poaceae	*Dactyloctenium aegyptium* (L.) Willd.
10	Herb	Poaceae	*Diplachne fusca* (L.) P. Beauv. ex Roem. & Schult.
11	Herb	Poaceae	*Echinochloa colona* (L.) Link
12	Herb	Poaceae	*Echinochloa crus-galli* (L.) P. Beauv.
13	Herb	Poaceae	*Echinochloa esculenta* (A. Braun) H. Scholz
14	Herb	Poaceae	*Echinochloa frumentacea* Link
15	Herb	Poaceae	*Echinochloa oryzoides* (Ard.) Fritsch
16	Herb	Poaceae	*Echinochloa picta* (J. Koenig) P.W. Michael
17	Herb	Poaceae	*Echinochloa stagnina* (Retz.) P. Beauv.
18	Herb	Cyperaceae	*Eleocharis dulcis* (Burm. f.) Trin. ex Hensch.
19	Herb	Poaceae	*Eleusine coracana* (L.) Gaertn.
20	Herb	Poaceae	*Eleusine indica* (L.) Gaertn.
21	Herb	Poaceae	*Eriochloa fatmensis* (Hochst. & Steud.) Clayton
22	Herb	Poaceae	*Eriochloa procera* (Retz.) C.E. Hubb.
23	Herb	Poaceae	*Hymenachne amplexicaulis* (Rudge) Nees
24	Herb	Juncaceae	*Juncus bufonius* L.
25	Herb	Juncaceae	*Juncus effusus* L.
26	Herb	Juncaceae	*Juncus inflexus* L.
27	Herb	Juncaceae	*Juncus prismatocarpus* R.Br.
28	Herb	Poaceae	*Leptochloa chinensis* (L.) Nees
29	Herb	Poaceae	*Leptochloa panicea* (Retz.) Ohwi
30	Herb	Poaceae	*Leptochloa uniflora* Hochst. ex A. Rich.
31	Herb	Poaceae	*Oryza rufipogon* Griff.
32	Herb	Poaceae	*Oryza sativa* L.
33	Herb	Poaceae	*Panicum brevifolium* L.
34	Herb	Poaceae	*Panicum curviflorum* Hornem.
35	Herb	Poaceae	*Panicum humile* Steud.
36	Herb	Poaceae	*Panicum miliaceum* L.
37	Herb	Poaceae	*Panicum notatum* Retz.
38	Herb	Poaceae	*Panicum paludosum* Roxb.
39	Herb	Poaceae	*Panicum repens* L.
40	Herb	Poaceae	*Panicum sparsicomum* Nees ex Steud.,
41	Herb	Poaceae	*Panicum sumatrense* Roth
42	Herb	Poaceae	*Paspalum distichum* L.
43	Herb	Poaceae	*Paspalum scrobiculatum* L.
44	Herb	Poaceae	*Pennisetum glaucum* (L.) R. Br.
45	Herb	Poaceae	*Sacciolepis indica* (L.) Chase
46	Herb	Poaceae	*Sacciolepis myosuroides* (R. Br.) Chase ex E.G. Camus & A. Camus
47	Herb	Poaceae	*Setaria geminata* (Forssk.) Veldkamp
48	Herb	Poaceae	*Setaria intermedia* Roem. & Schult.
49	Herb	Poaceae	*Setaria italica* (L.) P. Beauv.
50	Herb	Poaceae	*Setaria pumila* (Poir.) Roem. & Schult.
51	Herb	Poaceae	*Setaria punctata* (Burm. f.) Veldkamp
52	Herb	Poaceae	*Setaria verticillata* (L.) P. Beauv.
53	Subshrub	Solanaceae	*Solanum diphyllum* L.
54	Herb	Poaceae	*Sorghum bicolor* (L.) Moench
55	Herb	Poaceae	*Sorghum halepense* (L.) Pers.
56	Herb	Poaceae	*Sporobolus coromandelianus* (Retz.) Kunth
57	Herb	Poaceae	*Sporobolus diandrus* (Retz.) P. Beauv.
58	Herb	Poaceae	*Triticum aestivum* L.
59	Herb	Poaceae	*Triticum turgidum* L. subsp. *dicoccum* (Schrank ex Schübl.) Thell.
60	Herb	Poaceae	*Urochloa deflexa* (Schumach.) H. Scholz
61	Herb	Poaceae	*Urochloa distachya* (L.) T.Q. Nguyen
62	Herb	Poaceae	*Urochloa kurzii* (Hook. f.) T.Q. Nguyen
63	Herb	Poaceae	*Urochloa maxima* (Jacq.) R.D. Webster
64	Herb	Poaceae	*Urochloa mutica* (Forssk.) T.Q. Nguyen
65	Herb	Poaceae	*Urochloa panicoides* P. Beauv.
66	Herb	Poaceae	*Urochloa ramosa* (L.) T.Q. Nguyen
67	Herb	Poaceae	*Urochloa reptans* (L.) Stapf
68	Herb	Poaceae	*Urochloa setigera* (Retz.) Stapf
69	Herb	Poaceae	*Urochloa trichopus* (Hochst.) Stapf

Subramanyam (2017), Surender et al. (2018), Arigela (2021), Pandian (2022).

firm support was secured. A bunch of strands was then woven to form a 'wad' which was further expanded into an initial ring. The initial ring was then built up to form a helmet-shaped nest. Gradually, an egg chamber was added to the helmet and, at this stage, the bird's nest-building activity slowed down. Nest building only continued if the partially completed nest was accepted by the female weaver bird, Once the nest was accepted, a long entrance tube was added marking the completion of nest construction (Narasimhacharya et al. 1987).

Nest building material: The nest-building material used by this bird may vary according to the locality in India. Most often they use herbs of the family Poaceae as a nest-building material (Table 2). Baya weaver also preferred to build nests close to the power cable, roads and human dwellings (Pandian 2022).

Nest orientation: Borges et al. (2002) reported that the orientation of most of the nests is towards the east, while very few nests are oriented towards the south and north direction and no single nest oriented to west direction. Mean nest-entrance orientation was generally opposite to wind direction so as to be least affected by the south-west monsoon wind (Davis 1971; Pandian 2021a). It was reported that 40% of nest colonies in Rajasthan (Sharma 1990) and 89% of nests in Tindivanam taluka (Pandian & Ahimas 2018), 70% nests towards the east in Villupuram district and 81% of nests in Arakkonam taluka, Tamil Nadu (Pandian 2022) were oriented towards the east probably to protect their nests from the battering south-west monsoon winds.

Nesting platforms: In India, there is a wide variety of plants available to serve the purpose of nesting platforms for the *P. philippinus* (Ali & Ambedkar 1957; Ambedkar 1958). Availability of nesting materials, surrounding biological environment, temperature, light intensity, humidity, etc., restrict the nest selection of birds (Asokan et al. 2008). Psychic factor such as photoperiodic sensitivity also influence the nest site selection (Welty 1982). A regional bias seems to exist in the choice of certain plant species for nesting by the weaver bird, one of the reasons proposed for such a choice is the protection against intruders provided by the different plant species (Borges et al. 2002). A taking priority over the availability of food and nesting fibres has considered as a primitive factor for selection of nesting site. (Davis 1974). The nesting sites in the fields were always located near a water supply such as irrigation wells, rivers, lakes, ponds, and sewage stagnant water, and in urban areas underneath shady trees (Kumar et al. 2018; Pandian 2022). The apparent bias in the selection of plant species observed in various regions of the subcontinent raises the question of whether this reflects a genuine preference or is simply a consequence of their widespread occurrence in the region. The bird's selection criteria for nesting plants may involve choosing those with tall, sturdy, unbranched trunks, and a crown of swaying fronds. This choice not only provides protection against intruders, rain, and wind but also serves as a means of seeking attention from female weaver birds (Davis 1974). Among the various preferred nesting platforms (Table 3), some of them are also used for roosting and foraging. These birds move in flock to the sugarcane crops and *Prosopis juliflora* for roosting and foraging purposes (Pandian 2021b).

Mating Behaviour

Mate and nest choice: In many species of weaverbirds, males display their nests to females, suggesting that females may use nests for mate choice (Quader 2005). After the completion of the nest up to the wad stage, females arrive and visit several nests before pairing. Female choice of mates has been presumed to be based largely on the color; material and quality of the available nest (Collias & Collias 1964b, 1984; Crook 1960; Narasimhacharya et al. 1987). Female choice of the site may be influenced by both wind direction and safety from predation (Quader 2003). Most helmets were never made into complete nests and hence nest completion is a good indicator of female choice (Quader 2006). Ambedkar (1964) and Crook (1964) reported that the nest at a higher height is safer from predation than lower-heightened nests. Nest height is believed to be an important influence on nesting success in birds (Martin 1993) within tree nesting species, predation tends to decrease with height (Cresswell 1997; Schmidt & Whelan 1999). Both males and females are polygamous. Males usually build partial nests and complete them only after courting females (Ali et al. 1956). The male may build another helmet to attract another female. If a helmet is not accepted by any female the male often tears it down and builds a new one in its place (Abdar 2013). Quader (2006) found that several aspects of nest location (tree type, diameter of branch, nest height) and nest architecture (fibre thickness) predict direct benefit to females when nesting date and year are statistically controlled.

Breeding season: The Baya Weaver breeds during the rainy season (monsoon) in the Indian subcontinent (Ali & Ripley 1987). The breeding period of the Baya Weaver is largely based on seasonal changes and the availability of the diet. Food availability is preferably dependent on environmental factors such as temperature and rainfall and its ultimate cause to control seasonal breeding (Baker 1938; Immelmann 1971).

Physiological Responses to seasonal changes: The reproductive activity stimulates responses to the photoperiod (Thapliyal & Saxena 1964; Singh & Chandola 1981) as increasing day length during the pre-monsoon season. The stimulation of gonadotropic hormones in *P. phillipinus* such as leutinizing hormone (LH) and testosterone level varies in response to day length (Thapliyal & Saxena 1964; Stokkan & Sharp 1980)

Table 2. Annotated list of the nest building material used by *P. philippinus*.

	Habit	Family	Scientific Name
1	Subshrub	Poaceae	*Arundo donax* L.
2	Shrub	Poaceae	*Bambusa bambos* (L.) Voss
3	Tree	Arecaceae	*Borassus flabellifer* L.
4	Tree	Arecaceae	*Caryota urens* L.
5	Herb	Poaceae	*Chrysopogon zizanioides* (L.) Roberty
6	Tree	Arecaceae	*Cocos nucifera* L.
7	Herb	Cyperaceae	*Cyperus alopecuroides* Rottb.
8	Herb	Cyperaceae	*Cyperus articulatus* L.
9	Herb	Cyperaceae	*Cyperus corymbosus* Rottb.
10	Herb	Cyperaceae	*Cyperus digitatus* Roxb.
11	Herb	Cyperaceae	*Cyperus exaltatus* Retz.
12	Herb	Cyperaceae	*Cyperus pangorei* Rottb.
13		Arecaceae	*Dypsis lutescens* (H.Wendl.) Beentje & J. Dransf.
14	Herb	Poaceae	*Echinochloa crus-galli* (L.) P. Beauv.
15	Herb	Poaceae	*Echinochloa esculenta* (A. Braun) H. Scholz
16	Herb	Poaceae	*Echinochloa frumentacea* Link
17	Herb	Poaceae	*Echinochloa oryzoides* (Ard.) Fritsch
18	Herb	Poaceae	*Echinochloa picta* (J. Koenig) P.W. Michael
19	Herb	Poaceae	*Echinochloa stagnina* (Retz.) P. Beauv.
20	Herb	Cyperaceae	*Eleocharis dulcis* (Burm. f.) Trin. ex Hensch.
21	Herb	Poaceae	*Eleusine coracana* (L.) Gaertn.
22	Herb	Poaceae	*Eleusine indica* (L.) Gaertn.
23	Herb	Poaceae	*Eragrostis atrovirens* (Desf.) Trin. ex Steud.
24	Herb	Poaceae	*Eragrostis gangetica* (Roxb.) Steud.
25	Herb	Poaceae	*Eragrostis japonica* (Thunb.) Trin.
26	Herb	Poaceae	*Eragrostis nutans* (Retz.) Nees ex Steud.
27	Herb	Poaceae	*Eragrostis riparia* (Willd.) Nees
28	Herb	Poaceae	*Eragrostis tenuifolia* (A. Rich.) Hochst. ex Steud.
29	Herb	Poaceae	*Eriochloa fatmensis* (Hochst. & Steud.) Clayton
30	Herb	Poaceae	*Eriochloa procera* (Retz.) C.E. Hubb.
31	Herb	Poaceae	*Ischaemum afrum* (J.F. Gmel.) Dandy
32	Herb	Poaceae	*Oryza sativa* L.
33	Herb	Poaceae	*Pennisetum glaucum* (L.) R. Br.
34	Tree	Arecaceae	*Phoenix sylvestris* (L.) Roxb.
35	Herb	Poaceae	*Phragmites karka* (Retz.) Trin. ex Steud.
36	Herb	Poaceae	*Pogonatherum paniceum* (Lam.) Hack.
37	Tree	Arecaceae	*Roystonea regia* O.F.Cook
38	Herb	Poaceae	*Saccharum spontaneum* L.
39	Herb	Poaceae	*Saccharum officinarum* L.
40	Herb	Poaceae	*Sacciolepis interrupta* (Willd.) Stapf
41	Herb	Poaceae	*Setaria verticillata* (L.) P. Beauv.
42	Herb	Poaceae	*Sorghum bicolor* (L.) Moench
43	Herb	Poaceae	*Sorghum halepense* (L.) Pers.
44	Herb	Poaceae	*Sorghum nitidum* (Vahl) Pers.
45	Herb	Poaceae	*Sporobolus diandrus* (Retz.) P. Beauv.
46	Herb	Poaceae	*Thysanolaena latifolia* (Roxb. ex Hornem.) Honda
47	Herb	Poaceae	*Triticum aestivum* L.
48	Herb	Poaceae	*Triticum turgidum* L. subsp. *dicoccum* (Schrank ex Schübl.) Thell.
49	Herb	Typhaceae	*Typha angustifolia* L.
50	Herb	Typhaceae	*Typha domingensis* Pers.
51		Typhaceae	*Typha elephantina* Roxb.
52	Herb	Poaceae	*Urochloa maxima* (Jacq.) R.D. Webster
53	Herb	Poaceae	*Urochloa mutica* (Forssk.) T.Q. Nguyen
54	Herb	Poaceae	*Urochloa panicoides* P. Beauv.
55	Herb	Poaceae	*Urochloa trichopus* (Hochst.) Stapf
56	Tree	Arecaceae	*Wodyetia bifurcata* A.K. Irvine

Borges et al. (2002), Arigela (2021), Pandian (2022).

as its concentration increases during the month of April and May and highest between June and September (Narasimhacharya et al. 1987). The expression of gonadotropin inhibiting hormone is high on short days when the duration of nocturnal melatonin is increased, and low on long days when the duration of nocturnal melatonin is decreased (Ubuka et al. 2005). The environmental factors also contributed to the ecological significance via accompanying pre-breeding sexual changes and behaviour (Morley 1943; Sharp et al. 1986). A pre-nuptial molt occurred between March and June and a post-nuptial molt between October and November (Narasimhacharya et al. 1987). The lightning of the bill color starts to cause in August and its turns to a complete straw color in November and depigmented their plumage to the non-breeding type (Rani et al. 2007; Pandey & Bhardwaj 2015). The alteration in night light as a bright light during the night alters the resting pattern

Table 3. Detail about the nesting platforms preferred by the *P. philippinus* among the various part of the countries.

	Type of plant	Host plant	No. of nest	Locality	Reference
1	Unbranched Trees	*Borassus flabellifer*	247	Tindivanam Taluk, Villupuram District, Tamil Nadu, India	Pandian (2018)
2		*Cocos nucifera*			
3		*Phoenix sylvestris*			
4	Branched trees	*Casuarina equisetifolia*	12		
5		*Ficus benghalensis*			
6		*Azadirachta indica*			
7		*Morinda tinctoria*			
8		*Prosopis juliflora*			
9		*Pithecellobium dulce*			
10	Shrubs	*Phyllanthus reticulatus*	7		
11		*Securinega leucopyrus*			
12	Twiner	*Cissampelos pareira*	3		
13	Herb	*Ruellia prostrata*	1		
14	Power cables		4		
15	Unbranched Trees	*Acacia nilotica*	--	Western ghat, Maharashtra, India	Abdar (2013)
16		*Cycas sphaerica*	--	Jalantrakota reserve forest	Raju (2009)
17		*Cocos nucifera*	244	Agricultural study plot at Chorao an island in the Mandovi estuary in Goa, India.	Borges et al. (2002)
18		*Eucalyptus sp.*	136		
19		*Careya arborea*	2		
20		*Saccharum sp.*	3		
21		*Bambusa sp*	3		
22		*Borassus flabellifer*	--	Nagapattinam and Tiruvarur District of Tamil Nadu, India.	Asokan et al (2008)
23		*Cocos nucifera*	--		
24		*Phoneix psuilla*	--		
25		*Acacia Nilotica*	286	Nanded, Maharashtra, India	
26		*Prosopis Juliflora*	14		
27		*Azadirachta Indica*	18		
28		*Ziziphus mauritiana*	41		
29		*Acacia Karroo*	39		
30		*Mgifera Indica*	1		
31		*Dalbergia Sisooroxh*	13		
32		*Cocos Nucifera*	6		
33		*Ficus Religiosa*	17		
34		*Borassus fabellife*	8304	Tindivanam, Tamil Nadu, India	Pandian (2022)
35		*Phoenix sylvestris* (Arecaceae)	1083		
36		*Cocos nucifera* (Arecaceae)	1277		
37		*Prosopis julifora* (Fabaceae)	186		
38		*Morinda tnctoria* (Rubiaceae)	64		
39		*Casuarina equisetfolia*	102		
40		*Phyllanthus retculatu*	31		
41		*Vachellia nilotca* (Fabaceae)	41		
42		*Azadirachta indica* (Meliaceae)	39		
43		*Flueggea leucopyrus*	38		
44		*Ficus benghalensis (Fabaceae)*	58		

	Type of plant	Host plant	No. of nest	Locality	Reference
45	Unbranched Trees	*Lantana camara (Verbanaceae)*	113	Tindivanam, Tamil Nadu, India	Pandian (2022)
46		*Pithecellobium dulce (Fabaceae)*	12		
47		*Senna siamea*	10		
48		*Chromolaena odorata (Asteraceae)*	8		
49		*Ficus religios*	3		
50		*Leucaena leucocephela (Fabaceae)*	8		
51		*Albizia lebbeck (Fabaceae)*	21		
52		*Cortaderia selloana (Poaceae)*	12		
53		*Passifora foetda (Passiforaceae)*	1		
54		*Tamarindus indica (Tamarindus)*	1		
55		*Ehereta pubescens (Boraginaceae)*	3		
56		*Ziziphus oenopolia (Ramnaceae)*	1		
57		*Cocculus carolinu*	1		
58		*Solanum trilobatum (Solanaceae)*	1		
59		*Musa paradisiaca (Musaceae)*	1		
60		*Moringa oleifera (Moringaceae)*	4		
61	Crop	*Cereal grain crop*	7477		Pandian (2022)
62		*Sugarcane*	1641		
63		*Pulses & oil seeds*	767		
64		*Fallow lands*	381		
65		*Casuarina groves*	568		
66		*Residental area*	173		
67		*Flower crops*	106		
68		*Other groves*	273		
69	Abnormal nest supporting plant	*Borassus fabellifer- female*	3682		Pandian (2022)
70		*Borassus fabellifer- male*	2272		
71		*Cocos nucifera*	776		
72		*Phoenix sylvestris*	452		
73		*Morinda tnctoria*	43		
74		*Prosopis julifora*	73		
75		*Vachellia nilotica*	11		
76		*Azadirachta indica*	15		
77		*Ficus benghalensis*	90		
78		*Flueggea leucopyrus*	10		
79		*Lantana camara*	7		

Arigela (2021), Abdar (2012), Pandian (2018), Abdar (2013), Raju (2009), Borges et al. (2002), Asokan et al. (2008), Pandian (2022).

of this bird it induced a fragmented activity in the early phase of night and enhancement at late night instead of the actual onset of the day (Raap et al. 2015; Touitou et al. 2017; Kumar et al. 2018). The midnight activity increases in presence of bright light due to advancement in the endogenous clock function as the suppression level of melatonin and increased body temperature (Kumar et al. 2002; Jong et al. 2015; Kumar et al. 2018). An endogenous clock system sensitive to light enables the bird to synchronize its physiological activities at the appropriate time of the day and time of the year (Kumar & Follett 1993a; Kumar et al. 1996).

Clutch size and coloration: The female lay 2–4 white eggs and incubates them for 14–17 days. (Ali & Ambedkar 1957). Two eggs per nest were observed by Venkatramani (1981) and Sharma (1995).

Image 1. Sexual dimorphism and nesting of *Ploceus philippinus*. A—Flock of male and female | B—Male with host plant | C—Nesting over irrigation well | D & E—Nesting on host plant | F—Nest weaving by male bird. © Authors.

Threats

Pandian (2021b) reported that farmers are the prime reason behind the declining population of the *Ploceus philippinus* in India. They burn herbs and shrubs under nest supporting trees and by clearing grasses around irrigation wells which may cause the scarcity of the nesting substrata for the *P. philippinus*. Individuals of *Rufous treepie* damage the nest of the weaver birds by driving a circular hole over the nest and predating the egg and chicks and it is also damaged by other bird species such as *Corvus splendens*, *Corvus macrorhynchos*, *Dicrurus macrocercus*, and *Eudynamys scolopaceus* (Ali 1931; Pandian 2021a, 2022). Ali et al. (1957) observed that the predation by House Crow *Corvus splendens* (Passeriformes: Corvidae) is very common. Pandian (2022) reported that 1,050 nests had fallen during their study period among various sites in Tamil Nadu, it has been found that total of 25 eggs and 18 dead chicks were spread near fallen nests may due to various biotic and abiotic factors as suggested by Ali et al. (1957), Collias & Collias (1959, 1962), and Pandian (2021b). Rapid urbanization and industrialization have resulted in declining areas of cultivation up to 20%, particularly cereal crops, thus causing lack of food grains and insect fauna to *P. philippinus* (Pandian 2018). The presence of heavy metal contamination in excreta has indicated that it might have a negative impact on the abundance of Baya Weaver in Punjab state (Sidhu & Kler 2021). *Ploceus philippinus* has most recently been assessed for The IUCN Red List of Threatened Species in 2016 as 'Least Concern' (Birdlife International 2016).

CONCLUSION

This study provides information about appearance, food specificity, nesting ecology, and mating behaviour of the *P. philippinus*. It is found that a small sparrow sized weaver bird shows sexual dimorphism in appearance. They mostly prefer a wider variety of herbs species in their diet as it perennially found during all seasons but highly flourish during cold season. Along with the food availability some physiological changes bring a seasonal breeding bird. These birds are famous for their nest weaving practices, it can be considered as a nidificate architect. Species specific studies and detailed knowledge of local bird population can greatly help in effective management measures, as several scientific aspects covered by the many initiators among diverse countries. It can help to bridge gaps in knowledge and benefit the future survival of a population of *P. philippinus* in the threatened environment. However, this review could act as a baseline for further research on ecology of *P. philippinus*.

REFERENCES

Abdar, M.R. (2013). Nesting Ecology of Baya Weaver *Ploceus Philippinus* (Linnaeus): Passeriformes pp 75–80. In: Jadhav, B., U. Jadhav & U. Bagde. *Current Trends in Life Sciences*. Lambert Academy Publishing, Saarbrücken, Germany, 209 pp.

Ali, S. & S.D. Ripley (1987). *Birds of India and Pakistan.* Oxford University Press, New Delhi, 737 pp.

Ali, S. & V.C. Ambedkar (1957). Further notes on Baya, *Ploceus philippinus* (Linn.). *Journal of the Bombay Natural History Society* 54(3): 491–502.

Ali, S. (1931). The nesting habits of the Baya (*Ploceus philippinus*). *Journal of the Bombay Natural History Society* 4(4): 947–964.

Ali, S., Vijayakumar & V.C. Ambedkar (1956). Notes on the Baya weaver Bird. *Journal of the Bombay Natural History Society* 53: 381–389.

Ambedkar, V.C. (1958). Notes on the Baya breeding season. *Journal of the Bombay Natural History Society* 55(1): 100–106.

Ambedkar, V.C. (1964). *Some Indian Weaver Birds: A Contribution to their Breeding Biology.* University of Bombay, Bombay, 75 pp.

Arigela, R.K., R.K. Singh, N. Siddabathula, K. Prasad & B.S. Yadav (2021). Botanical view of the Baya Weaver's choices in India. *Species* 22(70): 420–430.

Asokan, S., M.S. Ali & R. Nagarajan (2008). Studies on nest construction and nest microclimate of the Baya Weaver, *Ploceus philippinus* (Linn.). *Journal of Environmental Biology* 29: 393–396.

Baker, J.R. (1938). The relation between latitude and breeding seasons in birds. Proceedings of the *Zoological Society of London* 108: 557–582.

BirdLife International (2016). *Ploceus philippinus*. The IUCN Red List of Threatened Species 2016: e.T22719005A94606190. Accessed on 08 July 2022. https://doi.org/10.2305/IUCN.UK.2016-3.RLTS.T22719005A96006190.en

Borges, S.D., M. Desai & A.B. Shanbhang (2002). Selection of nest platforms and the differential use of nest building fibers by the Baya Weaver *Ploceus philippinus* Linn. *Tropical Biology* 15: 17–25. https://doi.org/10.1080/03946975.2002.10531164

Brisson, M.J. (1760). *Ornithology, or a methodical synopsis showing the division of birds into orders*. Vol. 3. Joannes-Baptista Bauche, Paris, 734 pp.

Brisson, M.J. (1st ed.) (1760). *Ornithology, or method containing the division of birds into orders, sections, genera, species and their varieties. To which has been added an exact description of each species, with the citations of the authors who have dealt with them, the names they have given them, those given to them by different nations, and the common names*. Cl. Jean-Baptiste Bauche, Paris, 4: 576 pp.

Collias, N.E. & E.C. Collias (1962). An experimental study of the mechanisms of nest building in a weaver bird. *The Auk* 79: 568–595.

Collias, N.E. & E.C. Collias (1964). The development of nest building behavior in a weaver bird. *The Auk* 81: 42–52.

Collias, N.E & E.C. Collias (1964b). Evolution of nest-building in the weaverbirds. *University of California Publications in Zoology* 73: 1–162.

Collias, N.E. & E.C. Collias (1959). Breeding behaviours of the Black-headed Weaver bird, *Textor cucullatus graueri* (Hartert), in the Belgian Congo. Proceedings of the First Pan-African Ornithological Congress, Ostrich, Suppl. No. 3: 233–241.

Collias, N.E. & E.C. Collias (1984). Nest building and bird behaviour. Princeton, NJ: Princeton University Press, 358 pp.

Cresswell, W. (1997). Nest predation: the relative effects of nest characteristics, clutch size and parental behaviour. *Animal Behaviour*

53(1): 93–103.

Crook, J.H. (1960). Studies on the reproductive behavior of the Baya Weaver bird *Ploceus philippinus* (Linn.). *Journal of the Bombay Natural History Society* 57(1): 1–44.

Crook, J.H. (1964). *The evolution of social Organisation and visual communication in the weaver birds (Ploceinae)*. Brill – book. 178 pp.

Cuvier, G. (1816). *The Animal Kingdom distributed according to its organization: to serve as a basis for the natural history of animals and an introduction to comparative anatomy (in French), 3rd edition, Vol. 1*. Déterville, Paris, 383 pp.

Davis, T.A. (1971). Variation in nest structure of the common weaver birds *P. philippinus* of India. *Forma et functio* 4: 225–239.

Davis, T.A. (1974). Selection of nesting trees and the frequency of nest visits by Baya weaver bird. *Journal of the Bombay Natural History Society* 71(3): 356–366.

Grewal, B., S. Sen., S. Singh., N. Devasar & G. Bhatia (2016). *A pictorial field guide to birds of India, Pakistan, Nepal, Bhutan, Sri Lanka and Bangladesh*. Om Book International, Noida, 792 pp.

Grimmett, R., C. Inskipp & T. Inskipp (1998). *Birds of the Indian Subcontinent, 1st edition*. Christopher Helm, A & C Black, London, 888 pp.

Grimmett, R., C. Inskipp & T. Inskipp (2016). *Birds of the Indian Subcontinent: India, Pakistan, Sri Lanka, Nepal, Bhutan, Bangladesh and the Maldives*. Bloomsbury Publishing, India, 448 pp.

Hartert, E. (1902). On birds from Pahang, eastern Malay Peninsula. *Novitates Zoologicae* 9: 537–580. https://doi.org/10.2305/IUCN.UK.2016-3.RLTS.T22719005A94606190.en

Immelmann, K. (1971). Ecological aspects of periodic reproduction. *Avian biology* 1: 341–389.

Inskipp, C., R. Allen., T. Inskipp & R. Grimmett (2011). *Birds of the Indian Subcontinent*. United Kindom: Christopher Helm, 528 pp.

Jong, M., L. Jeninga, J.Q. Ouyang, K. Oers, K. Spoelstra & M.E. Visser (2015). Dose-dependent responses of avian daily rhythms to artificial light at night. *Physiology and Behavior* 155: 172–179.

Kale, M.A., N. Dudhe, R. Kasambe & P. Bhattacharya (2014). Crop Depredation by Birds in Deccan Plateau, India. *International Journal of Biodiversity* 2014: 8. https://doi.org/10.1155/2014/947683

Kumar, J., S. Malik., S.K. Bhardwaj & S. Rani (2018). Bright light at night alters the perception of daylength in Indian weaver bird (*Ploceus philippinus*). *Journal of Experimental Zoology Part A: Ecological and Integrative Physiology* 329(8–9): 488–496.

Kumar, V. & B.K. Follett (1993a). The nature of photoperiodic clock in vertebrates. Proceeding Zoological Society of Calcutta, J.B.S. Haldane Commemoration Volume: 217–227.

Kumar, V., S. Singh, M. Misra, S. Malik & S. Rani (2002). Role of melatonin in photoperiodic time measurement in the migratory redheaded bunting (*Emberiza bruniceps*) and the nonmigratory Indian weaver bird (*Ploceus philippinus*). *Journal of Experimental Zoology* 292: 277–286.

Lack, D. (1954). *The natural regulation of animal numbers*. Oxford University Press, Oxford, 343 pp.

Lack, D. (1968). *Ecological adaptations for breeding in birds*. Methuen and Co., London, 409 pp.

Linnaeus, C. (1766). *The system of nature through the three kingdoms of nature, according to classes, orders, genera, species, with characters, differences, synonyms, places, Vol 1,* 12th edition reformed. Lawrence Salvius, Holmiae, 532 pp.

Martin, T.E. (1993). Nest predation among vegetation layers and habitat types: revising the dogmas. *The American Naturalist* 141(6): 897–913.

Mohanathan, P. & A. Preston (2018). Nesting behavior of the Baya weaver bird, *Ploceus philippinus* (Linnaeus) (Passeriformes: Ploceidae) in rural Tamil Nadu, India. *International Journal of Ecology and Environmental Sciences* 44(1): 33–42.

Morley, A. (1943). Sexual behaviour in British birds from October to January. *IBIS International journal of avian science* 85: 132–158.

Narasimhacharya, A.V.R.L. (1987). Investigations on hormonal factors integument and certain aspects of breeding biology of the male Indian baya weaver bird *Ploceus philippinus* l. Ph.D. thesis, Department of Bio Science, Sardar Patel University, 215 pp.

Narasimhacharya, A.V.R.L., V.C. Kotak & P.J. Sharp (1988). Environmental and hormonal interactions in the regulation of seasonal breeding in free-living male Indian baya weaver birds (*Ploceus philippinus*). *Journal of Zoology* 215(2): 239–248.

Pandey, R.K. & S.K. Bhardwaj (2015). Photoperiodic regulation of seasonal responses in Indian weaver bird (*Ploceus philippinus*). *Biological Rhythm Research* 46(4): 483–495.

Pandian, M. & P. Ahimaz (2018). Nesting behavior of the Baya Weaver Bird, *Ploceus philippinus* (Linnaeus) (Passeriformes: Ploceidae) in rural Tamil Nadu, India. *International Journal of Ecology and Environmental Sciences* 44(1): 33–42.

Pandian, M. (2018). Baya Weaver Bird: Nest colonies and abnormal nests of *Ploceus philippinus* in Tindivanam Taluk, Tamil Nadu, India. Bird-o-soar. In: *Zoo's Print* 33(12): 15–27.

Pandian, M. (2021a). Nesting habits of Baya Weaver *Ploceus philippinus* (Linnaeus, 1776) in rural Arakkonam Taluk, Vellore district, Tamil Nadu, India. *Journal of the Bombay Natural History Society* 118: 03–17.

Pandian, M. (2021b). Incidences of White-rumped Munia occupying the nest of Baya Weaver in Villupuram District, Tamil Nadu. Bird-o-soar 65, In: *Zoo's Print* 36(1): 07–09.

Pandian, M. (2022). Nesting habits of the Baya Weaver *Ploceus philippinus* (Linnaeus, 1766) in the agricultural landscape of Tindivanam, Tamil Nadu, India. *Journal of Threatened Taxa* 14(5): 20970–20987. https://doi.org/10.11609/jott.7762.14.5.20970-20987

Quader, S. (2003). Nesting and mating decisions and their consequences in the Baya Weaverbird *Ploceus philippinus*. PhD Thesis. Graduate School, University of Florida, 116 pp.

Quader, S. (2005). Elaborate Nests in a Weaver birds: Arole for female choice? *Ethology* 111: 1073–1088.

Quader, S. (2006). Sequential settlement by nesting male and female Baya weaverbirds *Ploceus philippinus*: the role of monsoon winds. *Journal of Avian Biology* 37:396–404.

Raap, T., R. Pinxten & M. Eens (2015). Light pollution disrupts sleep-in free-living animals. *Science Reports* 5(8): 13557.

Raju, A.J.S. (2009). Nesting behaviourof the Baya Weaver bird, *Ploceus philippinus* (Ploceidae) and the life-cycle of the Plains Cupidbutterfly, *Chilades pandava* (Lycaenidae) with thered-listed *Cycas sphaerica* and *C. beddomei* (Cycadaceae). *Journal of Threatened Taxa* 1(8): 429–433. https://doi.org/10.11609/JoTT.o21735.429-33

Rani, S., S. Singh & V. Kumar (2007). Photoperiodism, pineal clock and seasonal reproduction in the Indian weaver bird (*Ploceus philippinus*). *Journal of Ornithology* 148(2): 601–610.

Schmidt, K.A. & C.J. Whelan (1999). Nest placement and mortality: is nest predation a random event in space and time? *The Condor* 101(4): 916–920. https://doi.org/10.2307/1370089

Sengupta, S. (1974). The Common Baya (*Ploceus philippinus*) - a serious pest of agriculture. *Current Science* 43: 24–125.

Sharma, S.K. (1990). Orientation of nest colonies by Baya Weaver Birds. *Journal of the Bombay Natural History Society* 87(3): 454–455.

Sharma, S.K. (1995). A study of abnormal nests of Baya weaver bird *Ploceus philippinus* (Linn.) in Rajasthan. *Journal of the Bombay Natural History Society* 92(1): 67–76.

Sharp, P.J., R. Massa, L. Bottoni, V. Lucini, R.W. Lea, I.C. Dunn & V. Trocchi (1986). Photoperiodic and endocrine control of seasonal breeding in grey partridge (Perdix perdix). *Journal of Zoology* 209(2): 187–200. https://doi.org/10.1111/j.1469-7998.1986.tb03575.x

Sidhu, S.K. & T.K. Kler (2021). Assessment of Heavy Metal Contamination in Excreta of Baya Weaver Bird (*Ploceus philippinus*) from Three Districts of Different Zones of Punjab. *Bulletin of Environmental Contamination and Toxicology* 106(5): 799–804.

Singh, S. & A. Chandola (1981). Photoperiodic control of seasonal reproduction in a tropical weaver bird. *Journal of Experimental Zoology* 216: 293–298.

Stiels, D. & K. Schidelko (2013). Records of Indian' Baya Weaver *Ploceus philippinus* (Linnaeus, 1766) and Hooded Wheatear *Oenanthe monacha* (Temminck, 1825) from Afghanistan (Aves:

Passeriformes). *Bonn Zoological bulletin* 62(2): 171–176.

Stokkan, K.A. & P.J. Sharp (1980). Seasonal changes in the concentrations of plasma luteinizing hormone and testosterone in willow ptarmigan (*Lagopus lagopus lagopus*) with observations on the effects of permanent short days. *General and Comparative Endocrinology* 40: 109–115.

Surender G., R.V. Vasudeva, S.S Mahesh, R.S. Tripati & K. Swamy (2018). Unusual Depredatory Birds in Sunflower and Sorghum. *Entomology Ornithology Herpetology: Current research* 7: 291. https://doi.org/10.4172/2161-0983.1000291

Thapliyal, J.P. & R.N. Saxena (1964). Absence of a refractory period in the common Weaver bird. *The Condor* 66: 199–208.

Touitou, Y., A. Reinberg & D. Touitou (2017). Association between light at night, melatonin secretion, sleep deprivation, and the internal clock: Health impacts and mechanisms of circadian disruption. *Life Sciences* 173: 94–106.

Ubuka, T., G.E. Bentley, K. Ukena, J.C. Wingfield & K. Tsutsui (2005). Melatonin induces the expression of gonadotropin-inhibitory hormone in the avian brain. *Proceedings of the National Academy of Sciences of the United States of America* 102: 3052–3057.

Kumar, V., N. Jain & B.K. Follett (1996). The photoperiodic clock in black headed buntings (Emberizamelanocephala) is mediated by a self-sustaining circadian system. *Journal of Comparative Physiology* A 179: 59–64.

Venkataramani, K. (1981). Nests of weaver birds on telegraph wires. *Newsletter for Birdwatchers* 21: 18.

Welty, C.J. (1982). *The Life of Birds*. W.B. Saunders Co., New York, 754 pp.

Wood, C.A. (1926). The nest of the Baya Weaver bird. *The Auk* 43(3): 295–302. https://doi.org/10.2307/4075422

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 December 2023 | 15(12): 24368–24395

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

https://doi.org/10.11609/jott.8516.15.12.24368-24395

#8516 | Received 08 May 2023 | Final received 11 November 2023 | Finally accepted 08 December 2023

COMMUNICATION

An updated checklist of non-marine molluscs of the western Himalaya

Hilal Ahmed [1], Imtiaz Ahmed [2] & Neelavar Ananthram Aravind [3]

[1,2] Fish Nutrition Research Laboratory, Department of Zoology, University of Kashmir, Hazratbal, Srinagar, Jammu & Kashmir 190006, India.
[3] SM Sehgal Foundation Centre for Biodiversity and Conservation, Ashoka Trust for Research in Ecology and the Environment (ATREE), Royal Enclave, Srirampura, Bengaluru, Karnataka 560064, India.
[1] hilalahmed1991@gmail.com, [2] imtiazamu1@yahoo.com (corresponding author), [3] aravind@atree.org

Abstract: This paper presents the first comprehensive checklist of the non-marine molluscs from the western Himalaya, a region of high biodiversity and endemism. Based on faunistic surveys during 2019-2023 and published records, the paper reports 242 species belonging to 101 genera and 45 families of gastropods and bivalves, of which 168 species are endemic to the region. The paper also provides new distribution records and taxonomic notes for some species. Among the notable findings are the first records of *Limax mayae, Oxyloma* sp.*, Odhneripisidium kuiperi, Thiara aspera* from India, and *Bensonies jamuensis, Euaustenia cassida, Stagnicola* sp. from the western Himalaya. The paper presents some species with substitutional illustrations and literature from the region for the past two centuries. Additionally, the paper also discusses the threats that non-marine molluscs face in the western Himalaya and suggests some conservation measures to protect them. The authors hope this paper will serve as a baseline for future studies on the diversity, distribution, ecology, and conservation of non-marine molluscs in the western Himalaya.

Keywords: Biodiversity, conservation, endemic, gastropods, India, *Limax mayae,* malacofauna*,* non-marine, Pir Panjal range.

Editor: Prem Budha, Tribhuvan University, Kathmandu, Nepal. **Date of publication:** 26 December 2023 (online & print)

Citation: Ahmed, H., I. Ahmed & N.A. Aravind (2023). An updated checklist of non-marine molluscs of the western Himalaya. *Journal of Threatened Taxa* 15(12): 24368–24395. https://doi.org/10.11609/jott.8516.15.12.24368-24395

Funding: The work was supported by Council of Scientific and Industrial Research (CSIR), Government of India, New Delhi with the reference to file number 09/251(0137)/2019-EMR-I for awarding fellowship to Hilal Ahmed, a Senior Research Fellow, Department of Zoology, University of Kashmir.

Competing interests: The authors declare no competing interests.

Author details: Mr. Hilal Ahmed, a senior research fellow at the Department of Zoology, University of Kashmir has been engaged in fisheries and molluscan studies since 2019. Dr. Imtiaz Ahmed, an associate professor at the Department of Zoology, University of Kashmir focuses his teaching and research efforts on fish diversity, nutrition, physiology and molluscan biodiversity since 2006. Dr. Neelavar Ananthram Aravind, an associate professor at ATREE, Bengaluru brings 25 years of expertise in land and freshwater molluscs in India, focusing on ecology, systematics, biogeography, and conservation. His research employs molecular, spatial and citizen science tools to address pertinent questions in molluscan studies.

Author contributions: HA led the entire field sampling, data collection and preparation of the manuscript. IA and NAA gave study conceptualization, design, manuscript review, editing and supervision. Their significant contributions were crucial for the improvement of the overall quality of the manuscript.

Acknowledgements: The authors express gratitude to the Head, Department of Zoology, University of Kashmir for providing required laboratory facilities. Special appreciation to the Freshwater Ecology and Conservation Lab, ATREE Bangaluru for offering access to various equipments for enhancing our practical work. The authors would also like to extend their sincere appreciation to CSIR, New Delhi for providing financial support to Hilal Ahmed, senior research fellow, Department of Zoology, University of Kashmir in advancing the research goals.

INTRODUCTION

Molluscs are the second largest phylum after arthropods in terms of the number of species described. To date, close to 100,000 species have been reported in marine, freshwater, and terrestrial ecosystems (Molluscabase 2023). Molluscs are widely distributed in a variety of habitats and have diverse ecological roles and functions (Strong et al. 2008). They are also indicators of environmental quality and health (von Rintelen & Hauser 2017). However, the identification and systematic positioning of many non-marine molluscs is challenging due to their morphological similarity and high variability. Despite this, a regional checklist is a significant first step towards understanding the region's rich biodiversity. The present study aimed to compile a list of non-marine molluscs in the western Himalayan region. For this study, we have covered the west of the Kali Gandaki River of Nepal, the northwestern Indian Himalaya, and northern Pakistan. We considered the northern limit of western Himalaya from south of the Hindukush-Kunlun Mountain ranges and Kali Gandaki River as the southernmost limit. Thus, the western Himalaya includes the region south of Hindukush, Karakoram, Ladakh, Zanskar Range, Pir Panjal Range, Dhauladhar Range, western parts of Great Himalaya, and Shivalik Ranges (Ramakrishna & Mitra 2002) (Figure 1).

In the western Himalaya, variations in altitude and climatic conditions create diverse habitats that include alluvial grasslands, subtropical forests, conifer mountain forests and alpine meadows. This biodiversity hotspot contains a rich and diverse assemblage of non-marine molluscs. The region has a long history of human exploration, scientific research, and conservation in four major biomes: alpine, temperate, subtropical, and arid. The alpine biome covers the highest elevations, where vegetation is sparse and adapted to cold and dry conditions. The temperate biome covers the middle elevations, where coniferous, and broadleaf forests dominate. The subtropical biome covers the lower elevations, where moist and evergreen forests thrive. The arid biome covers the northwestern parts of the region, where desert and shrub-steppe vegetation prevail. The region hosts many endemic and threatened species of animals.

The study conducted a comprehensive review of existing literature spanning the past two centuries, critically analysing each species with original descriptions from the region (see Table 2) and meticulously recording details such as type localities and distribution. In addition to previously published records, the research compiled a list of non-marine molluscs collected from Pir Panjal Range in Jammu & Kashmir, India, between 2019 and 2023. To maintain systematic consistency, the work followed the classification system established by Bouchet et al. (2017) for gastropods and Bouchet et al. (2010) for bivalves, ensuring that species were accurately placed within their respective genera and families whenever possible.

The history of molluscan studies*:* The history of malacological research in the western Himalaya is quite rich and fascinating but also fragmented and incomplete. The early explorers and collectors of non-marine molluscs faced many challenges and hardships in their expeditions to the remote and rugged terrain of the region. Despite these challenges, they contributed immensely to the knowledge of the diversity and distribution of molluscs, which are often overlooked and neglected in conservation efforts. The rich diversity of non-marine molluscs of the western Himalaya was explored mostly by pioneering 19th Century European malacologists. As per available literature, the first species of terrestrial mollusc from the western Himalaya was *Macrochlamys vesicula* (Benson, 1838) and *Clausilia elegans* Hutton, 1837, collected by Captain Thomas Hutton to the Burenda pass (Burzil pass) in 1836 (Hutton 1837; Hutton & Benson 1838). The first comprehensive inventory of non-marine molluscs from the region was made by Thomas Thomson (Woodward 1856), and later, an exhaustive collection reported by Ferdinand Stoliczka (Nevill 1878b) during his several Yarkand expeditions. Apart from these major expeditions, there are several scattered literatures available from the region on the molluscs (Benson 1837; Hutton & Benson 1838; Theobald 1862, 1878, 1881; Nevill 1878a; Hora 1928; Hora et al. 1955; Rajagopal & Rao 1968, 1972; Agarwal 1976; Kaul et al. 1980; Dutta & Malhotra 1986; Sajan et al. 2019, 2020, 2021). Some of the works are part of large compilations of literature from adjoining regions as well (Benson 1857; Benson 1863; Nevill 1878b; Godwin-Austen 1899; Rao 1989; Dey & Mitra 2000; Tripathy & Mukhopadhayay 2015; Tripathy et al. 2018). Recent work on the survey of malacofauna diversity from the region is at a much smaller scale and very site-specific (Sharma et al. 2009, 2015; Mir & Bakhtiyar 2022; Uttam et al. 2022) and records of molluscs are mainly concerned on ecological studies especially of freshwater molluscs. Several systematic checklists were compiled and published by Ramakrishna & Mitra (2002), Mitra et al. (2004), Ramakrishna et al. (2010), and Tripathy et al. (2018) for malacofauna of the whole of India with passing reference to the western Himalaya. No major publications on terrestrial snails appeared in the past century until 13 species reported from the Kashmir valley by Rajagopal & Rao (1972) and thereafter Biswas et al. (2015) appeared on non-marine molluscs after a gap of about 40 years. Recently, Sajan et al. (2021) redescribed *Carychium indicum* from the hills surrounding the Great Himalayan National Park in the Kullu District of Himachal Pradesh, India. Even though the study of the western Himalaya terrestrial gastropods is still in its infancy, there is a need for at least a provisional checklist as a starting point for further study.

The main objective of this study is to compile an updated list of malacofauna of the western Himalayan region. Such documentation and compilation are important for the assessment of the ecological status of the region as it is undergoing unprecedented changes due to unplanned development in infrastructure, extensive exploitation of natural resources, increased population and climate change (Saad et al. 2019).

MATERIAL AND METHODS

The western Himalaya, a region with a rich biodiversity, complex topography and climate, is the focus of this study. It spans India, Nepal, Pakistan, and Afghanistan. This study reviewed the literature on the diversity and distribution of non-marine molluscs in this region for the last two centuries recording the distribution, habits, and habitats of each mollusc species from the literature. The study also conducted monthly field surveys in the Poonch and the Rajouri districts of the Pir Panjal range of western Himalaya from March 2019 to February 2023. The surveys collected molluscs from various aquatic and terrestrial habitats using different methods such as hand-picking, sieving, netting and trapping. The specimens were preserved in ethanol and stored at the Freshwater Ecology and Conservation Laboratory, ATREE Bengaluru. The specimens were identified based on their morphological charactes using the most recent literature and online databases such as MolluscaBase and WoRMS. This study aimed to collect and present distribution data of different species in the region, especially for hard-to-distinguish species, to facilitate accurate identification of species from a specific area and to compare current and past diversity for conservation purposes.

RESULTS

This compilation from primary field surveys and the published literature reports 242 species of non-marine molluscs from western Himalaya belonging

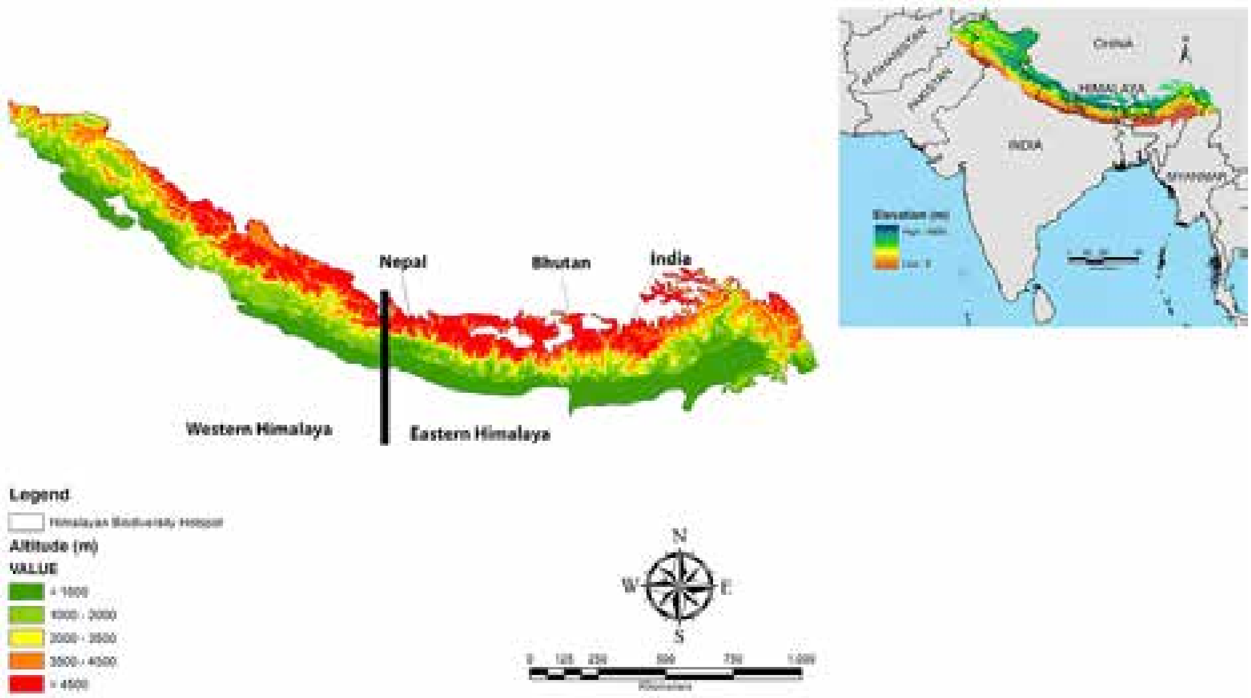

Figure 1. Digital elevation map of the Himalayan biodiversity hotspot showing eastern and western Himalaya. Inset: The Himalayan biodiversity hotspot.

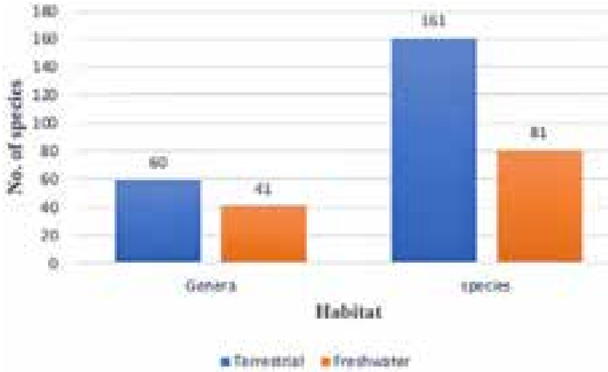

Figure 2. The number of genera and species reported from land and freshwater molluscs from the western Himalayan region.

to 101 genera and 45 families (Figure 2). Of these, 81 species are freshwater molluscs and 161 are terrestrial molluscs. Among non-marine molluscs, 217 species are gastropods and 25 are bivalves. The four families, namely, Ariophantidae, Enidae, Planorbidae, and Lymnaeidae, contribute 45 percent of all the species reported from the western Himalayan region (Table 1). The endemism in molluscan fauna in the western Himalayan region is around 70 percent. The complete list of species with distribution in the western Himalaya is given below. The introduced species forms a small proportion of the total molluscan fauna in the western Himalaya, e.g., *Deroceras laeve*, *Euconulus fulvus*, *Lissachatina fulica,* and *Physella acuta* (Table 4).

DISCUSSION

The estimated number of non-marine molluscs in southern Asia is around 1,705 species, of which around 1,500 terrestrial species in 140 genera and 210 freshwater species in 53 genera, including 150 species of gastropods and 67 species of bivalves (Chandra et al. 2017). Our compilation lists a total of 45 families, 101 genera, and 242 native species, belonging to 81 freshwater and 161 land molluscs species. The western Himalaya, part of the Palaearctic realm, the largest biogeographic realm of the Earth, is home to rich temperate coniferous, broadleaf, and mixed forests. This region has molluscan fauna of both Palaearctic and Indo-Malayan, making the fauna very interesting in terms of biogeography. The malacofauna from the region present unique species like *Helisoma* sp., *Biomphalaria* sp. from Jammu (Uttam et al. 2022), *Segmentina* sp., *Pseudosuccinea columella* from Kashmir (Mir & Bakhtiyar 2022) *Limax mayae*, *Oxyloma* sp., *Thiara aspera*, and *Stagnicola* sp. reported in this

Table 1. List of terrestrial and freshwater molluscs of western Himalaya.

	Family	No. of genera	No. of species	Percentage
Terrestrial				
1	Achatinidae	5	8	3.30
2	Agriolimacidae	1	1	0.41
3	Alycaeidae	1	1	0.41
4	Anadenidae	1	4	1.65
5	Ariophantidae	9	45	18.59
6	Camaenidae	5	8	3.30
7	Cerastidae	1	1	0.41
8	Chronidae	1	5	2.06
9	Clausiliidae	1	4	1.65
10	Cochlicopidae	1	1	0.41
11	Cyclophoridae	1	1	0.41
12	Diplommatinidae	1	3	1.23
13	Ellobiidae	2	2	0.82
14	Enidae	6	30	12.3
15	Euconulidae	1	1	0.41
16	Ferussaciidae	1	1	0.41
17	Gastrocoptidae	4	5	2.06
18	Helicarionidae	2	2	0.82
19	Limacidae	1	2	0.82
20	Parmacellidae	1	1	0.41
21	Plectopylidae	1	1	0.41
22	Pupillidae	2	10	4.13
23	Pyramidulidae	1	2	0.82
24	Streptaxidae	1	1	0.41
25	Succineidae	3	6	2.47
26	Truncatellinidae	2	3	1.23
27	Valloniidae	1	6	2.47
28	Veronicellidae	1	1	0.41
29	Vertiginidae	1	4	1.65
30	Vitrinidae	1	1	0.41
Freshwater				
31	Ampullariidae	1	1	0.41
32	Cyrenidae	1	3	1.23
33	Erhaiidae	1	1	0.41
34	Sphaeriidae	5	11	4.54
35	Unionidae	3	11	4.54
36	Bithyniidae	2	10	4.13
37	Pomatiopsidae	1	1	0.41
38	Bulinidae	1	1	0.41
39	Lymnaeidae	9	16	6.61
40	Pachychilidae	1	1	0.41
41	Physidae	1	1	0.41
42	Planorbidae	9	17	7.02
43	Thiaridae	3	4	1.65
44	Valvatidae	1	1	0.41
45	Viviparidae	2	2	0.82

Table 2. List of old names used in the literature with its new name and country.

Old names	New names, City, State, Country
Adampur	Udhampur, Jammu & Kashmir, India
Avantipura	Awantipora, Pulwama, Jammu & Kashmir, India
Badakshan	Badakhshan, Baltistan, Afghanistan
Bagh Punch	Bagh, Poonch Division, Pakistan
Bagie	Bagi Village, Himachal Pradesh, India
Dudh lekh, Nepal	Dudh lekh, Suderpashchim, Nepal
Burenda Pass	Burzil pass, Gilgit-Baltistan, Pakistan
Cashmire	Kashmir, Jammu & Kashmir, India
Chandanwari	Chandanwari, Pahalgam, Jammu & Kashmir, India
Changligali	Changli Gali, Abbottabad, Pakistan
Chillianwalla	Chillianwala, Punjab province, Pakistan
Dakhinkhund	Dainkund, Dalhousie, Himachal Pradesh, India
Dras	Drass, Ladakh, India
Faggu	Fagu, Himachal Pradesh, India
Gunji,	Gunji, Uttarakhand, India
Gurwal	Garhwal, Uttarakhand, India
Hattu	Hatu, Himachal Pradesh, India
Iskardo	Skardo, Gilgit-Baltistan, Pakistan
Islamabad	Islamabad town, Jammu & Kashmir, India
Jamu Hills	Jammu (Trikuta) Hills, Jammu & Kashmir, India
Jawi valley	Tawi valley, Jammu & Kashmir, India
Jhilum	Jhelum River, Jammu & Kashmir, India
Jummoo; Jamu	Jammu, Jammu & Kashmir, India
Karimabad	Karimabad, Gilgit-Baltistan, Pakistan
Kemaon	Kumaon, Uttarakhand, India
Khilanmarg	Khilanmarg, Jammu & Kashmir, India
Kulu	Kullu, Himachal Pradesh, India
Kunawur	Kunawur, Himachal Pradesh, India
Landor	Landour, Uttarakhand, India
Liti pass	Liti pass, Uttarakhand, India
Mahassu	Mahasu, Himachal Pradesh, India
Masuri	Mussoorie, Uttarakhand, India
Mataian	Matayen, Kargil, Ladakh, India
Mohu pass	Banihal pass, Jammu & Kashmir, India
Muri; Mari	Murree, Rawalpindi, Pakistan
Nag Tiba	Nag Tibba, Uttarakhand, India
Nagkunda	Narkanda, Himachal Pradesh, India
Naukuchia Tal	Naukuchiatal, Uttarakhand, India
Nayni Tal; Nynee Thai	Nainital, Uttarakhand, India
Nubra	Nubra, Ladakh, India
Pakli Valley	Pakhli Valley, Punjab province, Pakistan
Pankong	Pangong Tso (Lake), Ladakh, India
Panjal valley	Pir Panjal range, Jammu and Kashmir, India
Rampur, Barmula	Rampur, Baramulla, Jammu & Kashmir, India
Salt range	Pothohar Plateau, Punjab province, Pakistan
Sariya Tal	Sariyatal, Uttarkhand, India
Shypion	Shopian, Jammu & Kashmir, India
Simla	Shimla, Himachal Pradesh, India
Sonmarg	Sonamarg, Jammu & Kashmir, India
Soper	Sopore, Jammu & Kashmir, India
Tajwas marg	Thajiwas Glacier, Jammu & Kashmir, India
Takht-i-Suleiman	Shankaracharya Hill, Jammu & Kashmir, India
Tandāli	Tandali, Tikra, Himachal Pradesh, India
Tandiani	Thandiani, Abbottabad, Pakistan
Tangitar	Tangdhar, Jammu & Kashmir, India
Tsoral lake	Tsokar lake, Ladakh, India
Wakha	Wakhan, Kargil district, India
Whartu; Hattu	Hatu, Himachal Pradesh, India
Tribeni Ghat	Triveni Ghat, Rishikesh, Uttarakhand or Triveni Ghat, Hoogly, West Bengal, India

work for the first time from the Pir Panjal region shows the rich diversity of molluscs from the western Himalaya (Table 3). Thus, there is a high probability of finding new species or new records in this region if extensive surveys are undertaken.

According to the recent IUCN Red List (2019), molluscs represent 34 percent of all species and 40 percent of animal species extinction globally. Despite this, a small proportion of non-marine molluscs have been evaluated. In India, only 200 and odd freshwater molluscs were evaluated for the Red List status (Budha et al. 2010; Aravind et al. 2011). There is a need to assess the conservation status of land molluscs from this region. However, the main knowledge gaps that hindered the conservation assessment were a lack of taxonomic inventory, especially in unexplored areas, information about current and historical distributions and population sizes, and basic ecological information. Implementation of integrative taxonomy, ecological and distributional studies, exploration of areas and groups are yet largely ignored, development of researcher networks and improvement of public and political awareness and concern about these important and diverse animals are necessary actions for the conservation of non-marine molluscs in the region to have any chance of success.

Threats and conservation challenges

The western Himalayan region faces a myriad of

Table 3. Number of families, genera, and species reported by different studies.

References	No. of family	No. of genera	No. of species
Present work	13	27	39
Agrawal (1976)	9	12	15
Annandale & Prashad (1920)	1	1	1
Annandale & Rao (1925)	7	8	11
Auffenberg & Fakhri (1995)	1	1	1
Battish & Sharma (2002)	1	1	3
Benson (1849)	2	2	2
Benson (1857)	1	1	2
Benson (1863)	2	2	2
Benson (1864)	3	3	3
Bhat (2020)	1	1	1
Biswas et al. (2015)	6	8	8
Bößneck et al. (2016)	1	1	1
Budha (2016)	11	21	29
Budha et al. (2015)	11	14	19
Budha et al. (2017a)	1	1	1
Budha et al (2017b)	1	1	1
Budha & Naggs (2005)	1	1	1
Budha & Naggs (2008)	1	1	1
Chaudhary (2017)	10	14	16
Davis & Rao (1997)	1	1	1
Gerber & Bössneck (2009)	1	4	4
Glöer & Bössneck (2013)	2	2	5
Godwin-Austen (1899)	2	2	3
Godwin-Austen (1914)	2	2	2
Gude (1914)	15	30	47
Hanley & Theobald (1876)	14	17	29
Heynemann (1863)	1	1	1
Hlaváč (2004)	1	1	1
Hora (1928)	1	1	1
Hutton & Benson (1838a)	6	12	15
Hutton & Benson (1838b)	6	9	13
Hutton (1834)	4	4	4
Hutton (1837)	2	2	2
Kuzminykh & Schileyko (2005)	1	1	2
Kuznetsov & Schileyko (1997)	3	3	3
Kuznetsov & Schileyko (1999)	1	1	2
Mir & Bakhtiyar (2022)	7	12	12
Nesemann & Sharma (2005)	1	2	2
Nevill (1878a)	13	16	20
Nevill (1878b)	15	25	41
Nevill (1885)	4	4	6
Nordsieck (1973)	1	1	1
Odhner (1963)	1	1	1
Páll-Gergely et al. (2015)	1	1	1
Pfeiffer (1846a)	4	4	5
Pfeiffer (1849)	1	1	2
Pfeiffer (1854)	1	1	1
Pokryszko et al. (2009)	4	5	13
Prashad (1922)	5	9	9
Prashad (1928)	1	1	1
Preston (1915)	6	10	13
Rajagopal & Rao (1972)	6	10	12
Rajagopal (1973)	1	1	1
Ramakrishna et al. (2010)	20	34	81
Reeve (1848)	1	1	2
Reeve (1849)	4	4	7
Reeve (1862)	2	2	2
Sajan et al. (2019)	1	1	1
Sajan et al. (2020)	1	1	1
Sajan et al. (2021)	1	1	1
Schileyko & Balashov (2012)	1	1	1
Schileyko & Kuznetsov (1998a)	1	1	2
Schileyko & Kuznetsov (1998b)	1	1	1
Schileyko & Frank (1994)	2	2	2
Rao (1989)	10	17	23
Subba & Ghosh (2001)	3	6	6
Subba & Ghosh (2008)	1	1	1
Theobald (1862)	1	1	1
Theobald (1878)	23	35	51
Theobald (1881)	8	14	23
Uttam et al. (2022)	7	8	8
Wiktor (2001b)	1	1	1
Wiktor (2001a)	1	1	3
Wiktor & Auffenberg (2002)	3	3	3
Wiktor & Bössneck (2004)	1	1	1
Woodward (1856)	10	17	19

pressing threats and conservation challenges, including rapid population growth, uncontrolled development, unplanned urbanisation, agricultural expansion and climate change-induced alterations in land use and land cover (LULC) (Mondal & Zhang 2018), as well as the construction of dams (Sati et al. 2020). While previous studies have observed plant species migrating to higher altitudes due to global warming, snails as model systems to assess climate change impacts remain largely unexplored. The Himalayan region's vulnerability to climate change is particularly pronounced (Tewari et al. 2017), with estimates indicating a potential warming

Table 4. List of introduced species reported from the western Himalayan region from various studies.

	Family	Species	References
1	Euconulidae	*Euconulus fulvus* (Müller, 1774)	Theobald 1878: p. 141
2	Agriolimacidae	*Deroceras laeve* (Müller, 1774)	Wiktor & Auffenberg 2002: p. 12
3	Thiaridae	*Mieniplotia scabra* (Müller, 1774)	Rao 1989: p. 96
4	Physinae	*Physella acuta* (Draparnaud, 1805)	Uttam et al. 2022: p. 356
5	Achatinidae	*Lissachatina fulica* (Bowdich, 1822)	Budha & Naggs 2005: p. 19

rate of 0.5°C by the end of the 21st Century (Sabin et al. 2020). Additionally, changes in land use and land cover, exemplified by significant natural forest reductions, threaten biodiversity. Urbanisation, pollution, and habitat loss are compounding concerns with potential repercussions for non-marine molluscs. The invasion of aquatic species, such as plants, further imperils aquatic ecosystems, as evidenced by declines in native species in Dal Lake due to pollution, urbanisation and the proliferation of invasive aquatic species, including fish and macrophytes (Kumar et al. 2022). These complex challenges underscore the urgent need for research and conservation efforts to safeguard the fragile ecosystems of the western Himalayan region.

Future direction

In the realm of mollusc research in the western Himalayan region, recent studies have been notably localised, with a scarcity of large-scale landscape-level investigations. Given the ongoing transformations in the Himalayan region, it is crucial to explore molluscan diversity, considering their heightened vulnerability to climate variations and changes in land use and land cover, as emphasised by Kardong et al. (2016). To address these pressing concerns, comprehensive transboundary surveys, increased funding for local institutions, and the development of human resources are imperative. Strikingly, none of the terrestrial mollusc species in the western Himalaya have undergone IUCN Red List assessments. In contrast, the freshwater molluscs have been evaluated as part of the Biological Surveys and Assessment Program (BSAP) and the rapid bioassessment methods for freshwater molluscs assessment program, with none of the species falling under the categories of critically endangered, endangered or vulnerable from this region. However, to gain a precise understanding of habitat utilisation and population status, it is essential to embark on ecological and long-term studies. Many species necessitate internal examinations or molecular analysis for accurate identification and species delimitation, as highlighted in the past (Wiktor & Auffenberg 2002). Furthermore, some species exhibit endemism to specific small regions (as noted by Godwin-Austin in 1899, p. 242), and whether this pattern reflects reality or is a sampling artefact requires scrutiny. Habitat loss and degradation pose potential threats to many species, underscoring the significance of a comprehensive understanding of natural resources and their diversity before scientific exploitation and conservation efforts, as emphasised by the United Nations in 2022. This study seeks to establish foundational data on the malacofauna of the region through both morphological and molecular methodologies, aiming to assess distribution patterns, phylogenetic relationships, and conservation statuses. The existing literature on this subject is antiquated, incomplete, and dispersed, highlighting the pressing need for a comprehensive taxonomic revision, as well as an exploration of the distribution and ecology of freshwater and terrestrial molluscs in this region.

Species List
Terrestrial Molluscs

Phylum Mollusca
Class Gastropoda
Subclass Caenogastropoda
Order Architaenioglossa
Superfamily Cyclophoroidea
Family Cyclophoridae
Subfamily Cyclophorinae
Genus *Cyclophorus* Montfort, 1810

***1. Cyclophorus fulguratus* (Pfeiffer, 1854)**

Distribution: Gulmi District, Nepal (Subba & Ghosh 2001: p. 60), Philippines, Thailand, and Vietnam.

Family Diplommatinidae
Genus *Diplommatina* Benson, 1849

***2. Diplommatina costulata* Benson, 1849**

Distribution: Sub-western Himalaya, India (Benson 1849b: p. 194; Gude 1921: p. 307); Landour, Uttarakhand, India (Hanley & Theobald 1876: p. 49), southern and southeastern Asia.

***3. Diplommatina folliculus* (Pfeiffer, 1846)**

Distribution: Shimla, Himachal Pradesh, India (Pfeiffer 1846b; p. 83), Landour, Himachal Pradesh, India (Hanley & Theobald 1876: p. 56); Nainital, Uttarakhand, India (Ramakrishna et al. 2010: p. 86), Philippines, and Nepal.

***4. Diplommatina huttoni* Pfeiffer, 1854**

Distribution: Western Himalaya, India (Pfeiffer 1854: p. 157); Mussoorie, Uttarakhand, India (Hanley & Theobald 1876: p. 55; Gude 1921: p. 319; Ramakrishna et al. 2010: p. 88).

Family Alycaeidae

Genus *Dicharax* Kobelt & Möllendorff, 1900

***5. Dicharax strangulatus* (Pfeiffer, 1846)**

Distribution: Landour, Uttarakhand, India (Hanley & Theobald 1876: p. 38); Mussoorie, Uttarakhand, India (Godwin-Austen 1914: p. 337); The Great Himalayan National Park, Manali, Uttarakhand, India (Sajan et al. 2020: p. 523), Shivapuri-Nagarjun National Park, Nepal (Budha et al. 2015: p. 5).

Subclass Heterobranchia

Order Stylommatophora

Superfamily Plectopyloidea

Family Plectopylidae

Genus *Endothyrella* Zilch, 1960

***6. Endothyrella nepalica* Budha & Páll-Gergely, 2015**

Distribution: Dhaulagiri zone, Baglung and Myagdi Districts, Nepal (Páll-Gergely et al. 2015: p. 47).

Superfamily Streptaxoidea

Family Streptaxidae

Subfamily Enneinae

Genus *Gulella* Pfeiffer, 1856

***7. Gulella bicolor* (Hutton, 1834)**

Distribution: Kumaon, Uttarakhand, India (Hutton 1834: p. 86), Kashmir, India (Theobald, 1878: p. 147), Angola, Botswana, Lesotho, Mozambique, Namibia, South Africa, Caribbean, South America, Seychelles, Australia, Nicaragua, Brazil, Dominica, and Nepal (Budha et al. 2015: p. 17).

Superfamily Achatinoidea

Family Achatinidae

Subfamily Achatininae

***Genus Lissachatina* Bequaert, 1950**

***8. Lissachatina fulica* (Bowdich, 1822)**

Distribution: Baglung and Myagdi Districts, Nepal (Budha & Naggs 2008: p. 19); Gulmi District, Nepal (Budha & Naggs 2005: p. 19), eastern Africa, Brazil, Cuba, Ecuador, western Africa, Argentina, South America, Venezuela, Philippines, China, Taiwan, West Indies, Florida, Bhutan, Nepal, Italy, Salvador, Indonesia, Sri Lanka, Caribbean, Thailand, and India.

Remark: One of the worst invasive species with pan-tropical distribution.

Subfamily Glessulinae

Genus *Glessula* Martens, 1860

***9. Glessula huegeli* (Pfeiffer, 1842)**

Distribution: Kashmir, India (Hanley & Theobald 1876: p. 33; Gude 1914: p. 38; Ramakrishna et al. 2010: p. 162).

***10. Glessula paupercula* (Blanford & Blanford, 1861)**

Distribution: Solan District, Himachal Pradesh, India (Agrawal 1976: p. 139), India: Tamil Nadu, Madhya Pradesh, Kerala.

Subfamily Rishetiinae

Genus *Rishetia* Godwin-Austen, 1920

***11. Rishetia rishikeshi* Budha & Naggs, 2017**

Distribution: Jhawalepakho Community Forest, Ridi, Gulmi District, Nepal (Budha et al. 2017a: p. 146).

Subfamily Subulininae

Genus *Allopeas* Baker, 1935

***12. Allopeas gracile* (Hutton, 1834)**

Distribution: Jhelum valley, India (Theobald 1878: p. 146); Bilaspur District, Himachal Pradesh, India (Agrawal 1976: p. 139); Kashmir, India (Gude 1914: p. 356); Jhelum District, Salt range, Pakistan (Annandale & Rao 1925: p. 394), Myanmar, America, Tanzania, Malaysia, Sri Lanka, Indonesia, Borneo, Brazil, Malaysia, Vietnam, Cambodia, Indonesia, Tanzania, Iraq, Florida, Nepal, and India: Assam, Arunachal Pradesh, West Bengal, Andaman & Nicobar.

***13. Allopeas latebricola* (Reeve, 1849)**

Distribution: Landour, Uttarakhand, India (Reeve 1849: pl. 80, no 572; Hanley & Theobald 1876: p. 34; Gude 1914: p. 358; Ramakrishna et al. 2010: p. 181).

Genus *Zootecus* Westerlund 1887

***14. Zootecus chion* (Pfeiffer, 1857)**

Distribution: Chandak, Pir Panjal range, Jammu & Kashmir, India (Present study), Pakistan, Afghanistan, and India: Maharashtra, Uttar Pradesh.

Remarks: First time reported from the region.

15. Zootecus insularis **(Ehrenberg, 1831)**

Distribution: Outer hills, Kashmir, India (Theobald 1878: p; 146; Gude 1914: p. 368; Ramakrishna et al. 2010: p. 184); Salt range, Pakistan (Annandale & Rao 1925: p. 394); Chandak, Pir Panjal range, Jammu and Kashmir, India (Present study), Pakistan, Qatar, Israel, Sudan, Egypt, and Oman.

Remarks: Found in an agriculture field under a shady swamp area.

Family Ferussaciidae

Genus *Cecilioides* Férussac, 1814

16. Cecilioides balanus **(Reeve, 1850)**

Distribution: Kashmir, India (Nevill 1878a: p; 162; Gude 1914: p. 374; Ramakrishna et al. 2010: p. 146).

Superfamily Arionoidea

Family Anadenidae

Genus *Anadenus* Heynemann, 1863

17. Anadenus altivagus **(Theobald, 1862)**

Distribution: Narkanda, Himachal Pradesh, India (Theobald 1862: p. 489); Changla Gali, Abbottabad District, Pakistan (Nevill 1878b: p. 21; Gude 1914: p. 473). Thandiani & Murree, Pir Panjal range, Pakistan (Theobald 1881: p. 47); Shimla, Himachal Pradesh, India (Godwin-Austen 1882: p. 48); Dalhousie, Himachal Pradesh, India (Hora 1928: p. 357; Wiktor 2001a: p. 26); Khilanmarg, Jammu and Kashmir (Rajagopal and Rao 1972: p. 213); Bagh, Poonch Division, Pakistan (Wiktor & Auffenberg 2002: p. 10); Dunga Gali, Abbottabad District, Pakistan (Wiktor 2001a: p. 5), China, and India.

18. Anadenus banerjeei **Rajagopal, 1973**

Distribution: Kumaon, Uttarakhand, India (Rajagopal 1973: p. 416); Gunji village, Pithoragarh District, Uttarakhand, India (Ramakrishna et al. 2010: p. 342).

19. ***Anadenus giganteus*** **Heynemann, 1863**

Distribution: Shimpti village, Uttarakhand, India (Heynemann 1863: p. 140); Kumaon, Uttarakhand, India (Godwin-Austen 1882: p. 48; Gude 1914: p. 474); western Himalaya, India (Ramakrishna et al. 2010: p. 343); Garhwal, Uttarakhand, India (Wiktor 2001a: p. 24); western Nepal, Nepal (Kuzminykh & Schileyko 2005: p. 113), India and Nepal.

20. Anadenus nepalensis **Wiktor, 2001**

Distribution: Hills of Darchula and Dolpa Districts, Nepal (Budha et al. 2015: p. 28); Ghundruk, Kaski District, Nepal (Wiktor 2001a: p. 14; Kuzminykh & Schileyko 2005: p. 113).

Superfamily Chondrinoidea

Family Truncatellinidae

Genus *Columella* Westerlund, 1878

21. Columella nymphaepratensis **Hlaváč & Pokryszko, 2009**

Distribution: Raikhot Gah, Diamir, and Skardu districts, Gilgit-Baltistan, Pakistan (Pokryszko et al. 2009: p. 425).

Genus *Truncatellina* Lowe 1852

22. Truncatellina babusarica **Auffenberg & Pokryszko, 2009**

Distribution: Babusar Pass, Gilgit District, Gilgit-Baltistan, Pakistan (Pokryszko et al. 2009: p. 428).

23. Truncatellina himalayana **(Benson, 1863)**

Distribution: Shimla, Himachal Pradesh and Mussoorie, Uttarakhand, India (Benson 1863: p. 428; Hanley & Theobald 1876: p. 41; Gude 1914: p. 41); Pir Panjal range, Kashmir, India (Theobald 1878: p. 146); Kashmir, India (Ramakrishna et al. 2010: p. 125); Khobang, Annapurna range, Nepal (Kuznetsov & Schileyko 1997: p. 429); Gilgit District, Gilgit-Baltistan, Pakistan (Pokryszko et al. 2009: p. 429).

Superfamily Clausilioidea

Family Clausiliidae

Subfamily Phaedusinae

Genus *Cylindrophaedusa* Boettger, 1877

24. *Cylindrophaedusa cylindrica* (Pfeiffer, 1846)

Distribution: Tandiani, Khyber Pakhtunkhwa, Pakistan (Theobald 1881: p. 48); Landour, Uttarakhand, India (Hanley & Theobald 1876: p. 12; Ramakrishna et al. 2010: p. 143); Murree, Pir Panjal Range, Pakistan (Nevill 1878b: p. 19); Dharamshala, Himachal Pradesh, India (Theobald 1878: p. 147); Nainital, Uttarakhand and Shimla, Himachal Pradesh, India (Gude 1914: 338); Dadeldhura District, Nepal (Budha et al. 2015: p. 14).

25. Cylindrophaedusa farooqi **(Auffenberg & Fakhri, 1995)**

Distribution: Malam Jabba, Northwest Frontier Province, Pakistan (Auffenberg & Fakhri, 1995: p. 89).

26. Cylindrophaedusa martensiana **(Nordsieck, 1973)**

Distribution: Lamjung, Myagdi and Mustang Districts, Nepal (Nordsieck 1973: p. 67).

27. Cylindrophaedusa waageni **(Stoliczka 1872)**

Distribution: Murree, Pir Panjal range, Pakistan

(Nevill 1878b: p. 19); Rampur, Baramulla, India (Theobald 1878: p. 147); Tandiani, Khyber Pakhtunkhwa, Pakistan (Theobald 1881: p. 48); Changla Gali, Pir Panjal range, Pakistan (Gude 1914: p. 307); western Himalaya, India (Ramakrishna et al. 2010: p. 143).

Order Ellobiida
Superfamily Ellobioidea
Family Ellobiidae
Subfamily Carychiinae
Genus *Carychium* Müller, 1773

28. *Carychium indicum* Benson, 1849

Distribution: Lower western Himalaya of Shimla, Himachal Pradesh, India (Benson 1849b: p. 194); Shakti Village, Uttarakhand, India (Sajan et al. 2021: p. 38), Pakistan, and Bhutan.

Genus *Coilostele* Benson, 1864

29. *Coilostele scalaris* Benson, 1864

Distribution: Western Himalaya, India (Benson 1863: p. 136; Hanley & Theobald 1876: p. 156); Kashmir, India (Theobald 1878: p. 147; Gude 1914: p. 376; Ramakrishna et al. 2010: p. 145; Nevill 1878a: p. 162).

Order Stylommatophora
Superfamily Gastrodontoidea
Family Gastrodontidae
Genus *Zonitoides* Lehmann, 1862

30. *Zonitoides nitidus* (Müller, 1774)

Distribution: Skardu, Gilgit-Baltistan, Pakistan (Woodward 1856: p. 186), Slovakia, Hungary, Romania, Poland, Latvia, Russia, Uzbekistan, Türkiye, and Italy.

Superfamily Helicarionoidea
Family Ariophantidae
Subfamily Macrochlamydinae
Genus *Bensonies* Baker 1938

***31. Bensonies angelica* (Pfeiffer, 1856)**

Distribution: Uri, Jammu & Kashmir, India (Nevill 1878b: p. 18); southern Kashmir, India (Blandford & Godwin-Austen 1908: p. 173); Kashmir, India (Ramakrishna et al. 2010: p. 293).

***32. Bensonies convexa* (Reeve, 1852)**

Distribution: Himachal Pradesh, India (Ramakrishna et al. 2010: p. 294); Kumaon, Uttarakhand, India (Blandford & Godwin-Austen 1908: p. 174), Annapurna range, Nepal (Budha et al. 2015: p. 23).

***33. Bensonies jacquemontii* (Martens, 1869)**

Distribution: Murree, Pir Panjal range, Pakistan (Nevill 1878b: p. 18; Blandford & Godwin-Austen 1908: p. 174); western Himalaya, India (Ramakrishna et al. 2010: p. 294); Baitadi District, Nepal (Budha et al. 2015: p. 24).

34. *Bensonies jamuensis* (Theobald, 1878)

Distribution: Tawi valley, between Chenani and Udhampur, India (Theobald 1878: p. 142); Tirkuta hills, Jammu & Kashmir, India (Godwin Austen 1888: p. 251); Jammu, India (Ramakrishna et al. 2010: p. 294); Mandi area of Poonch and Shahdara area of Rajouri, Pir Panjal range, India (Present study).

35. *Bensonies monticola* (Benson, 1838)

Distribution: Hatu, Shimla District, Himachal Pradesh, India (Hutton & Benson 1838: p. 215); Landour, Uttarakhand, India (Hanley & Theobald 1876: p. 13 as *H. labiata*); Tandiani, Khyber Pakhtunkhwa, Pakistan (Theobald 1881: p. 46); Changli Gali near Murree, Pir Panjal range, Pakistan (Nevill 1878b: p. 17); Bichlari, Chenab River, India (Theobald 1878: p. 142); Mussoorie, Uttarakhand, India (Godwin-Austen 1888: p. 248); Kumaon & Mussoorie, Uttarakhand, India (Blandford & Godwin-Austen 1908: p. 172); Kashmir, India (Ramakrishna et al. 2010: p. 295); Khaptad National Park, Nepal (Budha et al. 2015: p. 24); Bufliaz area of Poonch and Narain area of Rajouri, Pir Panjal range (Present study).

***36. Bensonies nepalensis* (Blanford, 1904)**

Distribution: Syangjha, Parbat, and Myagdi Districts, Nepal (Budha et al. 2015: p. 24); Gulmi District, Nepal (Subba & Ghosh, 2001: p. 60), Kathmandu, Nepal (Blanford 1904: p. 441).

***37. Bensonies theobaldiana* (Godwin-Austen, 1888)**

Distribution: Narkanda, Himachal Pradesh, India (Blanford & Godwin-Austen 1908: p. 173); Bilaspur, Himachal Pradesh, India (Ramakrishna et al. 2010: p. 295); Khaptad National Park, Nepal (Budha et al. 2015: p. 24).

***38. Bensonies wynnei* (Blanford, 1881)**

Distribution: Murree near river Jhelum, Pir Panjal range, Pakistan (Theobald 1881: no 11, p. 197); Kashmir, India (Ramakrishna et al. 2010: p. 296).

Subfamily Macrochlamydinae

Genus *Himalodiscus* Kuznetsov, 1996

***39. Himalodiscus echinatus* Schileyko & Kuznetsov, 1998**

Distribution: Lete-Khola valley, Nepal (Schileyko & Kuznetsov, 1998b: p. 86).

Genus *Euaustenia* Cockerell, 1891

40. *Euaustenia cassida* (Benson, 1838)

Distribution: Sabathu, Solan District, Himachal Pradesh, India (Hutton & Benson 1838: p. 214); Landour, Uttarakhand, India (Pfeiffer 1849: p. 107); Hatu and Mahasu, Himachal Pradesh, India (Hanley & Theobald 1876: p. 24); Murree, Pir Panjal range, Pakistan (Nevill 1878b: p. 16); Nainital, Uttarakhand, India (Blandford & Godwin-Austen 1876: p. 148); Dharmshala, Chenab valley, India (Theobald 1878: p. 142); Kashmir, India (Godwin Austen 1888: p. 214); Chandanwari, Pahalgam, Jammu & Kashmir, India (Rajagopal & Rao 1972: p. 209; Ramakrishna et al. 2010: p. 290); Kangra fort, Himachal Pradesh, India (Biswas et al. 2015: p. 22); Dadeldhura District, Nepal (Budha et al. 2015: p. 23); Loran village, Poonch District and Dangri village, Rajouri District, Pir Panjal range, India (Present study), Bangladesh, India, Pakistan, Shivapuri-Nagarjun National Park (Budha et al. 2015: p. 23).

Genus *Macrochlamys* Gray, 1847

41. *Macrochlamys flemingi* (Pfeiffer, 1857)

Distribution: Tandali, Pir Panjal range, Pakistan (Nevill 1878b: p. 14; Theobald 1881: p. 45); Murree, Pir Panjal range, Pakistan (Theobald 1878: p. 142; Godwin-Austen 1888: p. 212); western Himalaya, India (Ramakrishna et al. 2010: p. 290).

***42. Macrochlamys fragilis* (Hutton, 1838)**

Distribution: Hatu, Himachal Pradesh, India (Hutton & Benson, 1838: no. 6, p. 216),

43. *Macrochlamys glauca* (Pfeiffer, 1846)

Distribution: Mussoorie, Uttarakhand, India (Blanford & Godwin-Austen 1908: 80); Kangra valley, Himachal Pradesh, India (Rao 1927: p. 53); Kotgarh, Himachal Pradesh, India (Ramakrishna et al. 2010: p. 269); Kuniyan village, Poonch District and Saaj village, Rajouri District, Pir Panjal range, India (Present study).

***44. Macrochlamys gurhwalensis* (Godwin-Austen, 1899)**

Distribution: Garhwal, Uttarakhand, India (Godwin-Austen 1899: p. 180; Ramakrishna et al. 2010: p. 290).

***45. Macrochlamys indica* Godwin-Austen, 1883**

Distribution: Kashmir valley, India (Theobald 1878: p. 141); Chamba Bridge, Himachal Pradesh, India (Biswas et al. 2015: p. 22); Kanchanpur District, Nepal (Budha et al. 2015: p. 21); Gulmi District, Nepal (Subba & Ghosh, 2001: p. 60); Azmatabad, Poonch District and Budhal, Rajouri District, Pir Panjal range, India (Present study), Saudi Arabia, Pakistan, Bangladesh, Nepal, Myanmar, India, Thailand, Sri Lanka, Brazil, Singapore, and Malaysia.

46. ***Macrochlamys kashmirensis* (Nevill, 1878)**

Distribution: Sonamarg, Jammu & Kashmir, India (Nevill 1878b: p. 16; Blandford & Godwin-Austen 1908: p. 165; Ramakrishna et al. 2010: p. 298).

***47. Macrochlamys kuluensis* Blanford, 1904**

Distribution: Kullu, Himachal Pradesh, India (Blanford 1904: p. 442; Blanford & Godwin-Austen 1908: p. 81; Godwin-Austin 1910: p. 246; Gude 1914: p. 255; Ramakrishna et al. 2010: p. 272).

***48. Macrochlamys leggeae* Sajan, Tripathy, Chandra & Sivakumar, 2019**

Distribution: Valley of Flowers National Park, Uttarakhand, India (Sajan et al. 2019: p. 800).

***49. Macrochlamys nuda* (Reeve, 1852)**

Distribution: Mussoorie, Uttarakhand, India (Blanford & Godwin-Austen 1908: p. 81); Kumaon, Uttarakhand, India (Ramakrishna et al. 2010: p. 276), Annapurna range, Nepal (Budha et al. 2015: p. 22).

***50. Macrochlamys patane* (Benson, 1859)**

Distribution: Uri, Jammu & Kashmir, India (Theobald 1878: p. 141).

***51. Macrochlamys paurhiensis* (Godwin-Austen, 1899)**

Distribution: Western Himalaya, India (Godwin-Austen 1899: p. 109).

***52. Macrochlamys petrosa* (Hutton, 1834)**

Distribution: Mohu pass, Jammu & Kashmir, India (Theobald 1878: p. 141).

***53. Macrochlamys planiuscula* (Benson, 1838)**

Distribution: Shimla, Himachal Pradesh, India (Hutton & Benson 1838: p. 218); Mussoorie, Uttarakhand, India (Blandford & Godwin Austen 1908: p. 302).

***54. Macrochlamys theobaldi* (Godwin-Austen, 1888)**

Distribution: Bichlari River, Chenab valley, Himachal Pradesh, India (Godwin Austen 1888: p. 236).

***55. Macrochlamys tugurium* (Benson, 1852)**

Distribution: Khaptad National Park, Nepal (Budha et al. 2015: p. 23); Gulmi District, Nepal (Subba & Ghosh 2001: p. 60), Darjeeling, West Bengal, and India (Ramakrishna et al. 2010: p. 288).

***56. Macrochlamys vesicula* (Benson, 1838)**

Distribution: Shimla, Himachal Pradesh, India (Hutton 1937: p. 931; Godwin-Austen 1883: p. 83; Blandford & Godwin-Austen 1908: p. 80); Burzil pass, Astore District, Gilgit-Baltistan, Pakistan (Hutton & Benson 1838: p. 216); Landour, Uttarakhand, India (Godwin-Austen 1897: p. 243); Kashmir, India (Ramakrishna et al. 2010: p. 290).

***57. Macrochlamys vitrinoides* (Deshayes, 1831)**

Distribution: Sabathu, Solan district, Himachal Pradesh, India (Hutton & Benson 1838: no. 5, p. 216); Mohu pass, Jammu & Kashmir, India (Theobald 1878: p. 141).

Genus *Oxytesta* Zilch, 1956

***58. Oxytesta sylvicola* (Blanford, 1881)**

Distribution: Gulmi and Rupandehi Districts, Nepal (Subba & Ghosh 2001: p. 60).

Genus *Parvatella* Blanford & Godwin-Austen, 1908

***59. Parvatella altivaga* (Theobald, 1878)**

Distribution: Uri, Jhelum valley, India (Godwin-Austen 1888: p, 213; Blandford & Godwin-Austen 1908: p. 148); Kashmir, India (Theobald 1878: p. 143; Ramakrishna et al. 2010: p. 291).

***60. Parvatella austeniana* (Nevill, 1878)**

Distribution: Sonamarg, Jammu & Kashmir, India (Nevill 1878b: p. 14; Godwin-Austen 1888: p. 215) Tandiani, Khyber Pakhtunkhwa, Pakistan (Theobald 1881: p. 45) Kashmir, India (Ramakrishna et al. 2010: p. 292).

***61. Parvatella magnifica* (Reeve, 1862)**

Distribution: Northwestern Himalaya, India (Reeve 1862: p. 3; Ramakrishna et al. 2010: p. 22).

***62. Parvatella stoliczkanus* (Nevill, 1878)**

Distribution: Tandali, Tikra, Himachal Pradesh, India (Nevill 1878b: p. 14); Sirban hill, Damtour near Abbottabad, Pakistan (Theobald 1881: p. 45).

Genus *Syama* Blanford & Godwin-Austen, 1908

***63. Syama annandalei* Godwin-Austen, 1908**

Distribution: Western Himalaya, India (Ramakrishna et al. 2010: p. 305).

***64. Syama masuriensis* (Godwin-Austen, 1883)**

Distribution: Mussoorie, Uttarakhand, India (Blandford & Godwin-Austen 1908: p. 156; Ramakrishna et al. 2010: p. 305).

***65. Syama promiscua* (Godwin-Austen, 1908)**

Distribution: Tandiani, Khyber Pakhtunkhwa, Pakistan (Blandford & Godwin-Austen 1908: p. 156); Murree, Pir Panjal range, Pakistan (Ramakrishna et al. 2010: p. 305).

***66. Syama prona* (Nevill, 1878)**

Distribution: Murree, Pir Panjal range, Pakistan (Nevill 1878b: p. 17); Tandiani, Khyber Pakhtunkhwa, Pakistan, (Theobald 1881: p. 46); Mussoorie, Uttarakhand, India (Godwin Austen 1883: p. 103); Shimla, Himachal Pradesh, India (Blandford & Godwin-Austen 1908: p. 155); Garhwal, Uttarakhand, India (Ramakrishna et al. 2010: p. 306), Shivapuri-Nagarjun National Park, Nepal (Budha et al. 2015: p. 26).

***67. Syama splendens* (Benson, 1838)**

Distribution: Fagu and Narkunda, Himachal Pradesh, India (Hutton & Benson 1838: no. 4, p. 216); Tandali, Tikra, Himachal Pradesh, India (Nevill 1878b: p. 18); Uri, Jammu & Kashmir, India (Theobald 1878: p. 141); Murree, Pir Panjal range, Pakistan (Theobald 1881: p. 46); Nag-Tiba ridge near Mussoorie, Uttarakhand, India (Godwin-Austen 1883: p. 100); Mahasu, near Shimla, Himachal Pradesh, India (Blandford & Godwin-Austen 1908: p. 153); Thajiwas near Sonamarg, Jammu and Kashmir, India (Rajagopal & Rao 1972: p. 207); Kashmir, India (Ramakrishna et al. 2010: p. 306); Sawajian, Poonch District and Siot, Rajouri District, Pir Panjal range (Present study).

***68. Syama theobaldi* Blanford & Godwin-Austen, 1908**

Distribution: Jhelum valley, India (Blanford & Godwin-Austen 1908: p. 157); Gulmarg, Jammu and Kashmir, India (Rajagopal & Rao 1972: p. 210); Murree, Pir Panjal range, Pakistan (Ramakrishna et al. 2010: p. 306).

Subfamily Ariophantinae

Genus *Ariophanta* Moulins, 1829

***69. Ariophanta himalana* (Lea, 1834)**

Distribution: Himalaya mountains, India (Lea 1834: p. 55); Kangra fort, Himachal Pradesh, India (Biswas et al. 2015: p. 23); Samote, Poonch District and Kalakot, Rajouri District, Pir Panjal range, India (Present study).

Genus *Khasiella* Godwin-Austen, 1899

***70. Khasiella chloroplax* (Benson, 1865)**

Distribution: Shimla, Himachal Pradesh, India (Benson 1865: p. 14; Blandford & Godwin-Austen 1908: p. 165); Murree, Pir Panjal range, Pakistan (Nevill 1878b: p. 16); western Himalaya, India (Ramakrishna et al. 2010: p. 296).

***71. Khasiella hyba* (Benson, 1861)**

Distribution: Wular Lake, Jammu & Kashmir, India (Theobald 1878: p. 142); Dainkund, Dalhousie, Himachal Pradesh, India (Blandford & Godwin-Austen 1908: p. 164); Tangmarg, Jammu and Kashmir, India (Rajagopal & Rao 1972: p. 208); Kashmir, India (Ramakrishna et al. 2010: p. 298); Samote, Poonch District and Kalakot, Rajouri District, Pir Panjal range, India (Present study).

***72. Khasiella kashmirensis* (Nevill, 1878)**

Distribution: Sonamarg, Jammu & Kashmir, India (Nevill 1878b: p. 16); Kashmir, India (Ramakrishna et al. 2010: p. 298).

***73. Khasiella ornatissima* (Benson, 1859)**

Distribution: Nawalparasi District, Nepal (Budha et al. 2015: p. 25).

74. ***Khasiella sonamurgensis* (Nevill, 1878)**

Distribution: Sonamarg, Jammu & Kashmir, India (Godwin-Austen 1908: 166; Ramakrishna et al. 2010: p. 299).

***75. Khasiella tandianensis* (Theobald, 1881)**

Distribution: Tandiani, Khyber Pakhtunkhwa, Pakistan (Theobald 1881: p. 46; Blandford & Godwin-Austen 1908: p. 166; Gude 1914: p. 255; Ramakrishna et al. 2010: p. 299).

Family Camaenidae

Subfamily Bradybaeninae

Genus *Bradybaena* Beck, 1837

***76. Bradybaena radicicola* (Benson, 1848)**

Distribution: Landour, Uttarakhand, India (Benson 1848: p. 161); Shimla, Himachal Pradesh, India (Hunley & Theobald 1876: pl. 62); Mussoorie, Uttarakhand, India (Gude 1914: p. 205); western Himalaya, India (Ramakrishna et al. 2010: p. 336), Nepal, and India: Sikkim.

Genus *Pseudiberus* Ancey, 1887

***77. Pseudiberus chitralensis* (Odhner, 1963)**

Distribution: Chitral District, Khyber Pakhtunkhwa, Pakistan (Odhner, 1963: p. 151).

Family Helicarionidae

Subfamily Durgellinae

Genus *Girasia* Gray, 1855

***78. Girasia dalhousiae* Godwin-Austen, 1888**

Distribution: Dalhousie, Chamba Hills, Himachal Pradesh, India (Godwin-Austen 1888: p. 224; Blandford & Godwin-Austen 1908: p. 202; Ramakrishna et al. 2010: p. 252).

Genus *Sitala* H. Adams, 1865

***79. Sitala rimicola* (Benson, 1859)**

Distribution: Landour, Uttarakhand, India (Benson 1859: p. 161); Mussoorie, Uttarakhand, India (Godwin Austen 1882: p. 36; Ramakrishna et al. 2010: p. 316); Nag Tiba range near Mussoorie, Uttarakhand, India (Blanford & Godwin-Austen 1908: p. 236).

Superfamily Helicoidea

Family Camaenidae

Subfamily Bradybaeninae

Genus *Cathaica* Möllendorff, 1884

***80. Cathaica fasciola* (Draparnaud, 1801)**

Distribution: Kashmir, India (Gude 1914: p. 207) and China.

***81. Cathaica mataianensis* (Nevill, 1878)**

Distribution: Mataian, Drass Valley, India (Nevill 1878b: p. 3; Gude 1914: p. 208); Kashmir, India (Ramakrishna et al. 2010: p. 341).

***82. Cathaica phaeozona* (Martens, 1874)**

Distribution: Tangdhar, Jammu & Kashmir, India (Nevill 1878b: p. 3); Hunza, Gilgit-Baltistan, Pakistan (Nevill 1878a: p. 92; Gude 1914: p. 208; Ramakrishna et al. 2010: p. 341).

Genus *Fruticicola* Held, 1838

***83. Fruticicola stoliczkana* (Nevill, 1878)**

Distribution: Sasak Taka, Badakshan Province, Afghanistan (Nevill 1878b: p. 3).

Genus *Landouria* Godwin-Austen, 1918

***84. Landouria huttonii* (Pfeiffer, 1842)**

Distribution: Shimla and Mahasu, Himachal Pradesh, India (Hutton & Benson 1838: p. 217); Shimla and Landour, Uttarakhand, India (Nevill 1878a: p. 73); Kashmir, India (Theobald 1878: p. 144; Gude 1914: p. 211); Kaski and Myagdi Districts, Nepal (Kuznetsov & Schileyko 1997; Schileyko & Kuznetsov 1998a: p. 44).

***85. Landouria rhododendronis* Schileyko & Kuznetsov, 1998**

Distribution: Gorepani, Parbat District, Nepal (Schileyko & Kuznetsov 1998a: p. 49).

Superfamily Limacoidea

Family Limacidae

Subfamily Limacinae

Genus *Limax* Linnaeus, 1758

***86. Limax mayae* Godwin-Austen, 1914**

Distribution: Thajiwas, Sonamarg, Jammu & Kashmir, India (Wiktor 2001b: p. 38; Godwin-Austen 1914: p. 312); Kashmir, India (Ramakrishna et al. 2010: p. 320); Loran, Poonch Loran area of Poonch, Pir Panjal range, India (Present study).

***87. Limax seticus* Wiktor & Bössneck, 2004**

Distribution: Dudh lekh, Nepal (Wiktor & Bössneck 2004: p. 183); Bajura District, Nepal (Budha et al. 2015: p. 27).

Family Agriolimacidae

Subfamily Agriolimacinae

Genus *Deroceras* Rafinesque, 1820

88. *Deroceras laeve* (Müller, 1774)

Distribution: Karimabad and Duikar village, Gilgit District, Gilgit-Baltistan, Pakistan (Wiktor & Auffenberg 2002: p. 12; Hlaváč, 2004: p. 182); Kashmir valley, India (Bhat 2020: p. 25), Argentina, Pakistan, Bhutan, Nepal, eastern Himalaya, and Sri Lanka.

Remarks: Introduced species.

Family Vitrinidae

Subfamily Vitrininae

Genus *Vitrina* Draparnaud, 1801

***89. Vitrina pellucida* (Müller, 1774)**

Distribution: Mataian, near Drass Valley, India (Nevill 1878b: p. 2); Loran village, Poonch District, Pir Panjal range, India (Present study), Spain, Bulgaria, Croatia, Czech Republic, Lithuania, Alaska, Poland, Ukraine, Germany, and Romania.

Superfamily Parmacelloidea

Family Parmacellidae

Genus *Candaharia* Godwin-Austen, 1888

***90. Candaharia rutellum* (Hutton, 1849)**

Distribution: Mingora, Swat District, North-West Frontier Province, Pakistan (Wiktor & Auffenberg 2002: p. 14), Afghanistan, and Uzbekistan.

Superfamily Pupilloidea

Family Cerastidae

Genus *Cerastus* Martens, 1860

91. *Cerastus segregatus* (Reeve, 1849)

Distribution: Shimla, Himachal Pradesh, India (Reeve 1849: pl. 83, no 619; Hanley & Theobald 1876: p. 34); Kashmir, India (Woodward 1856: p. 186; Ramakrishna et al. 2010: p. 135); Chenab valley, India (Theobald 1878: p. 145; Gude 1914: p. 268).

Family Cochlicopidae

Genus *Cochlicopa* Férussac, 1821

***92. Cochlicopa lubrica* (Müller, 1774)**

Distribution: Skardu, Gilgit-Baltistan, Pakistan (Woodward, 1856: p. 186), Bulgaria, Argentina, Slovakia, Ukraine, Spain, Hungary, Romania, Lithuania, Poland, Czech Republic, Siberia, and Great Britain.

Family Gastrocoptidae

Subfamily Gastrocoptinae

Genus *Gastrocopta* Wollaston, 1878

***93. Gastrocopta huttoniana* (Benson, 1849)**

Distribution: Shimla, Himachal Pradesh, India (Benson 1849a: p. 126; Hanley & Theobald 1876: p. 41); Skardu, Gilgit-Baltistan (Woodward 1856: p. 186); Panjal range, Kashmir, India (Nevill 1878a: p. 197; Theobald 1878: p. 146; Gude 1914: p. 291); Kashmir, India (Ramakrishna et al. 2010: p. 122), Nepal, and peninsular India.

***94. Gastrocopta thibetica* (Benson, 1864)**

Distribution: Skardu, Gilgit-Baltistan, Pakistan (Benson 1864: p. 138).

Family Enidae

Subfamily Eninae

Genus *Laevozebrinus* Lindholm, 1925

***95. Laevozebrinus mustangensis* Kuznetsov & Schileyko, 1997**

Distribution: Tukuche, Mustang District, Nepal (Kuznetzov & Schileyko, 1997: p. 137).

96. Laevozebrinus nepalensis **Schileyko & Frank, 1994**

Distribution: Annapurna range, Nepal (Schileyko & Frank, 1994: p. 130).

Genus *Mirus* Albers, 1850

97. Mirus smithei **(Benson, 1865)**

Distribution: Jhelum Valley, India (Theobald 1878: p. 146); Marree, Pir Panjal, Pakistan (Theobald 1881: p. 48; Gude 1914: p. 235); Kashmir, India (Nevill 1878a: p. 186; Ramakrishna et al. 2010: p. 127).

Genus *Nepaliena* Schileyko & Frank, 1994

98. Nepaliena ceratina **(Benson, 1849)**

Distribution: Kumaon, Uttarakhand, India (Reeve 1849: pl. 78; Ramakrishna et al. 2010: p. 126); Annapurna range, Nepal (Schileyko & Frank 1994: p. 14; Kuznetsov & Schileyko 1997: p. 20).

Genus *Pseudonapaeus* Westerlund, 1887

99. Pseudonapaeus arcuatus **(Küster, 1845)**

Distribution: Mahasu, Himachal Pradesh, India (Reeve 1849: pl. 67; Hanley & Theobald 1876: p. 10; Gude 1914 p. 239); Higher hills of Kashmir, India (Theobald 1878: p. 144; Ramakrishna et al. 2010: p. 130).

100. Pseudonapaeus boysianus **(Benson, 1849)**

Distribution: Kumaon, Uttarakhand, India (Reeve 1849: pl. 78, no. 575; Hanley & Theobald 1876: p. 11; Gude 1914: p. 238; Ramakrishna et al. 2010: p. 130).

101. Pseudonapaeus candelaris **(Pfeiffer, 1846)**

Distribution: Takht-i-Suleiman, Shankaracharya Hill, Srinagar, India (Woodward 1856: p. 186; Benson 1857, p. 327; Hanley & Theobald 1876: p. 10; Rajagopal & Rao 1972: p. 202); Tandali, Tikra, Himachal Pradesh, India (Nevill 1878b: p. 20); Higher hills Kashmir, India (Theobald 1878: p. 144); Fort Lockhart, Pakistan (Gude 1914: p. 243); Kashmir, India (Ramakrishna et al. 2010: p. 130); Chandak, Poonch District, Pir Panjal range, India (Present study).

Remarks: Found in red clay and moist soil.

102. Pseudonapaeus coelebs **(Pfeiffer, 1846)**

Distribution: Mussoorie, Uttarakhand, India (Pfeiffer 1846a; p. 83; Gude 1914: p. 249); Higher hills Kashmir, India (Theobald 1878: p. 145; Ramakrishna et al. 2010: p. 131); Nainital (Nevill 1878a: p. 134).

103. Pseudonapaeus dextrosinister **(Annandale & Rao, 1923)**

Distribution: Salt range, Pakistan (Annandale & Rao 1925: p. 390; Mitra & Ramakrishna 2004: p. 134); northwestern Himalaya (Ramakrishna et al. 2010: p. 131).

104. Pseudonapaeus domina **(Benson, 1857)**

Distribution: Kashmir, India (Benson 1857: no 1, p. 321; Hanley & Theobald 1876: p. 11; Ramakrishna et al. 2010: p. 131); Murree, Pir Panjal range, Pakistan (Nevill 1878b: p. 20); Tandiani, Khyber Pakhtunkhwa and Abbottabad, Pakistan (Theobald 1881: p. 47; Gude 1914: p. 246).

105. Pseudonapaeus eremita **(Reeve, 1849)**

Distribution: Bolan pass, Gilgit-Baltistan, Pakistan (Hanley & Theobald 1876: p. 12); Subathor, near Shimla, Himachal Pradesh, India (Gude 1914: p. 247); northwestern Himalaya (Dey & Mitra 2000: p. 25; Ramakrishna et al. 2010: p. 131).

106. Pseudonapaeus kunawurensis **(Reeve, 1849)**

Distribution: Landour, Uttarakhand, India (Hanley & Theobald 1876: p. 10; Nevill 1878: p. 136; Ramakrishna et al. 2010: p. 132); Kunawur, Himachal Pradesh, India (Gude 1914: p. 242).

107. Pseudonapaeus linterae **(Kobelt, 1899)**

Distribution: Western Himalaya, India (Gude 1914: p. 237; Ramakrishna et al. 2010: p. 133).

108. Pseudonapaeus mainwaringiana **(Nevill, 1878)**

Distribution: Murree, Pir Panjal range, Pakistan (Nevill 1878b: p. 19) Pakli Valley, Tandiani Hills, Khyber Pakhtunkhwa, Pakistan (Theobald 1881: p. 47; Gude 1914: p 251); Chakua nullah, Batote (Rajagopal & Rao 1972: p. 204); Kashmir, India (Ramakrishna et al. 2010: p. 133).

109. Pseudonapaeus nivicola **(Reeve, 1849)**

Distribution: Liti pass, Bageshwar District, Uttarakhand, India (Reeve 1849: pl. 69, 496; Hanley & Theobald 1876: p. 11; Gude 1914 p. 230; Ramakrishna et al. 2010: p. 133).

110. Pseudonapaeus pretiosus **(Reeve, 1849)**

Distribution: Kashmir, India (Reeve 1849: pl. 83; Ramakrishna et al. 2010: p. 134); Murree, Pir Panjal range, Pakistan (Nevill 1878b: p. 20); Chilianwalla, Jhelum, Pakistan (Theobald 1878: p. 146; Hanley &

Theobald 1876: p. 12; Gude 1914: p. 250).

111. Pseudonapaeus rufistrigatus **(Reeve, 1849)**
Distribution: Western Himalaya, India (Reeve 149: pl. 78); Jhelum Valley (Nevill 1878b: p. 20; Theobald 1878: p. 146; Rajagopal & Rao 1972: p. 205); Jumna to the Indus, Himachal Pradesh, India (Gude 1914: p. 253); Kashmir, India (Ramakrishna et al. 2010: p. 134); Rogumba, Mugu District, Nepal (Budha et al. 2015: p. 13).

112. Pseudonapaeus salsicola **(Benson, 1857)**
Distribution: Salsicola, Salt range, Pakistan (Benson 1857: p. 327; Annandale & Rao 1925: p. 390); Northwestern Himalaya (Ramakrishna et al. 2010: p. 134).

113. Pseudonapaeus sindicus **(Reeve, 1848)**
Distribution: Sindh, Pakistan (Reeve 1848: pl. 47, no. 303; Gude 1914: p. 245); Jhelum valley, Kashmir, India (Theobald 1878: p. 145); Mandi, Himachal Pradesh, India (Nevill 1878a: p. 134); Kashmir, India (Ramakrishna et al. 2010: p. 135).

114. Pseudonapaeus stoliczkanus **(Nevill, 1878)**
Distribution: Sonamarg, Jammu & Kashmir, India (Nevill 1878b: p. 19); Banihal, Jammu & Kashmir, India (Rajagopal & Rao 1972: p. 203).

115. Pseudonapaeus vibex **(Küster, 1845)**
Distribution: Shimla, Himachal Pradesh, India (Reeve 1848: pl. 47, no. 299; Hanley & Theobald 1876: p. 12; Nevill 1878a: p. 136); Landour, Uttarakhand, India (Gude 1914: p. 237; Ramakrishna et al. 2010: p. 135).

Genus *Pupinidius* Möllendorff, 1901
116. Pupinidius himalayanus **Kuznetsov & Schlieyko, 1999**
Distribution: Tukuche, Mustang District, Nepal (Kuznetsov & Schileyko, 1999: p. 119).
117. Pupinidius siniayevi **Kuznetsov & Schlieyko, 1999**
Distribution: Tukuche, Mustang District, Nepal (Kuznetsov & Schileyko, 1999: p. 16).
118. Pupinidius tukuchensis **Kuznetzov & Schileyko, 1997**
Distribution: Tukuche, Mustang District, Nepal (Kuznetzov & Schileyko, 1997: p. 133).

Genus *Serina* Gredler, 1898
119. Serina beddomeana **(Nevill, 1878)**
Distribution: Murree, Pir Panjal range, Pakistan (Nevill 1878b: p. 20), Tandiani, Khyber Pakhtunkhwa, Pakistan (Theobald 1881: p. 47; Gude 1914: p. 257); northwestern Himalaya (Ramakrishna et al. 2010: p. 128).

120. Serina hazarica **(Gude, 1914)**
Distribution: Hazara, Khyber Pakhtunkhwa, Pakistan (Gude 1914: p. 257); Tandiana, Khyber Pakhtunkhwa, Pakistan (Ramakrishna et al. 2010: p. 128).

121. Serina kuluensis **(Kobelt, 1902)**
Distribution: Kullu, Himachal Pradesh, India (Ramakrishna et al. 2010: p. 129).

122. Serina nevilliana **(Theobald, 1881)**
Distribution: Hazara, Khyber Pakhtunkhwa, Pakistan (Theobald 1881: p. 48); Murree, Pir Panjal range, Pakistan (Gude 1914: p. 258).

123. Serina tandianiensis **(Kobelt, 1902)**
Distribution: Western Himalaya, India (Ramakrishna et al. 2010: p. 129).

Family Gastrocoptidae
Subfamily Hypselostomatinae
Genus *Bensonella* Pilsbry & Vanatta, 1900
124. Bensonella plicidens **(Benson, 1849)**
Distribution: Landour and Mussoorie, Uttarakhand, India (Benson 1849a: p. 126; Hanley & Theobald 1876: p. 40; Gude 1914: p. 294; Ramakrishna et al. 2010: p. 123); Higher hill ranges, Kashmir, India (Theobald 1878: p. 146).

Genus *Boysidia* Ancey, 1881
125. Boysidia tamtouriana **Pokryszko & Auffenberg, 2009**
Distribution: Tamtour village, Abbottabad District, Pakistan (Pokryszko et al. 2009: p. 436).

Family Pupillidae
Genus *Pupilla* J. Fleming, 1828
126. Pupilla annandalei **Pilsbry, 1921**
Distribution: Skardu, Gilgit, and Hunza districts, Gilgit-Baltistan, Pakistan (Pokryszko et al. 2009: p. 444).

127. Pupilla eurina **(Benson, 1864)**
Distribution: Triveni Ghat, Rishikesh, Uttarakhand, India (Benson 1864: p. 139); Tukuche, Annapurna range, Nepal (Budha et al. 2015: p. 10), Gosainkund, Langtang National Park, Nepal (Budha et al. 2015: p. 10).

128. Pupilla gutta **(Benson, 1864)**
Distribution: Spiti valley, Himachal Pradesh, India (Benson 1864: p. 138; Hanley & Theobald 1876: p. 41); Higher hill ranges, Kashmir, India (Theobald 1878: p. 146).

129. Pupilla khunjerabica **Auffenberg & Pokryszko, 2009**
Distribution: Khunjerab Pass, Hunza District, Gilgit-Baltistan, Pakistan (Pokryszko et al. 2009: p. 438).

130. Pupilla muscorum **(Linnaeus, 1758)**
Distribution: Pangong Lake, Ladakh, India (Nevill 1878b: p. 4); Kashmir, India (Theobald 1878: p. 146; Gude 1914: p. 283; Ramakrishna et al. 2010: p. 118); Mastuj River, Chitral District, Pakistan (Pokryszko et al. 2009: p. 440), China, Sweden, and Germany.

131. Pupilla paraturcmenica **Hlaváč & Pokryszko, 2009**
Distribution: Apo Brukh valley, Skardu District, Gilgit-Baltistan, Pakistan (Pokryszko et al. 2009: p. 440).

132. Pupilla satparanica **Pokryszko & Auffenberg, 2009**
Distribution: Satpara Lake, Skardu District, Gilgit-Baltistan, Pakistan (Pokryszko et al. 2009: p. 440).

133. Pupilla riplicate **(Studer, 1820)**
Distribution: Tukuche, Annapurna range, Nepal (Budha et al. 2015: p. 10).

Genus *Pupoides* Pfeiffer, 1854

134. Pupoides coenopictus **(Hutton, 1834)**
Distribution: Salt range, Pakistan (Nevill 1878a: p. 193; Theobald 1878, p. 144; Gude 1914: p. 259; Annandale & Rao 1925: p. 393), Israel, Egypt, Tanzania, Sudan, Sri Lanka, India, Pakistan, Malawi, Mozambique, and South Africa.

135. Pupoides lardeus **(Pfeiffer, 1854)**
Distribution: Salt range, Pakistan (Annandale & Rao 1925: p. 393); western Himalaya, India (Ramakrishna et al. 2010: p. 120).

Family Pyramidulidae

Genus *Pyramidula* Fitzinger, 1833

136. Pyramidula humilis **(Benson, 1838)**
Distribution: Shimla, Himachal Pradesh, India (Hutton & Benson 1838: no. 7, p. 217); Murree, Pir Panjal range, Pakistan (Nevill 1878a: p. 66; Nevill 1878b: p. 18); Tandiani, Khyber Pakhtunkhwa, Pakistan (Theobald 1881: p. 47); Landour, Himachal Pradesh, India (Gude 1914: p. 43).

137. Pyramidula kuznetsovi **Schileyko & Balashov, 2012**
Distribution: Dhaulagiri zone, Mustang District, Nepal (Schileyko & Balashov 2012: p. 41).

Family Valloniidae

Genus *Vallonia* Risso, 1826

138. Vallonia costata **(Müller, 1774)**
Distribution: Skardu, Gilgit-Baltistan, Pakistan (Woodward 1856: p. 186); Sasak Taka and Wakhan Badakshan Province, Afghanistan (Nevill 1878b: p. 4); Kashmir, India (Theobald 1878: p. 142; Gude 1914: p. 225; Ramakrishna et al. 2010: p. 120), North America, North Africa, Europe, Norway, Poland, Hungary, Italy, Bulgaria, Ukraine, Croatia, Latvia, France, Czech Republic, Türkiye, Poland, Spain, Romania, Siberia, Republic of Moldova, Germany, and Uzbekistan.

139. Vallonia costohimala **Gerber & Bössneck, 2009**
Distribution: Darchula District, Nepal (Gerber & Bössneck 2009: p. 45).

140. Vallonia himalaevis **Gerber & Bössneck, 2009**
Distribution: Chala, Karnali zone, India (Gerber & Bössneck 2009: p. 47).

141. Vallonia kathrinae **Gerber & Bössneck, 2009**
Distribution: Khobang, Dhaulagiri zone, Nepal (Gerber & Bössneck 2009: p. 47).

142. Vallonia ladacensis **(Nevill, 1878)**
Distribution: Leh, Ladakh, India (Nevill 1878a: p. 70); Mataian, Drass valley, India (Nevill 1878b: p. 70; Gude 1914: p. 224); Liddar River, Pahalgam (Rajagopal & Rao 1972: p. 200); Kashmir, India (Ramakrishna et al. 2010: p. 121); Mustang District, Nepal (Budha et al. 2015: p. 11); Khobang, Dhaulagiri Zone, India (Gerber & Bössneck 2009: p. 44).

143. Vallonia pulchella **(Müller, 1774)**
Distribution: Skardu, Gilgit-Baltistan, Pakistan (Woodward 1856: p. 186); Kashmir, India (Theobald 1878: p. 144; Gude 1914: p. 224; Ramakrishna et al. 2010: p. 121); Shalimar Garden, Jammu and Kashmir, India (Rajagopal & Rao 1972: p. 200); Surankote, Poonch, Pir Panjal range, India (Present study), Great Britain, Ireland, Czech Republic, Slovakia, Poland, Ukraine,

Germany, Netherlands, Argentina, Bulgaria, Hungary, France, Republic of Moldova, Albania, South Africa, Slovakia, Croatia, Latvia, Siberia, Türkiye, Lithuania, Romania, Caucasus, and Spain.

Family Vertiginidae
Subfamily Vertigininae
Genus *Vertigo* Müller, 1773

***144. Vertigo antivertigo* (Draparnaud, 1801)**

Distribution: Gilgit District, Gilgit-Baltistan, Pakistan (Pokryszko et al. 2009: p. 430).

***145. Vertigo nangaparbatensis* Pokryszko & Hlaváč, 2009**

Distribution: Raikhot Gah, Diamir District, Gilgit-Baltistan, Pakistan (Pokryszko et al. 2009: p. 430).

***146. Vertigo pseudosubstriata* Ložek, 1954**

Distribution: Gilgit District, Gilgit-Baltistan, Pakistan (Pokryszko et al. 2009: p. 432).

***147. Vertigo superstriata* Pokryszko & Auffenberg, 2009**

Distribution: Thandiani, Abbottabad, Khyber Pakhtunkhwa, Pakistan (Pokryszko et al. 2009: p. 432).

Superfamily Succineoidea
Family Succineidae
Subfamily Succineinae
Genus *Novisuccinea* Schileyko & Likharev, 1986

***148. Novisuccinea martensiana* (Nevill, 1878)**

Distribution: Sasa Taka, Badakshan Province, Afghanistan (Nevill 1878a: p. 211); Western Himalaya, India (Ramakrishna et al. 2010: p. 210).

Genus *Succinea* Draparnaud, 1801

***149. Succinea crassinuclea* Pfeiffer, 1849**

Distribution: Shimla, Himachal Pradesh, India (Hutton & Benson 1838: p. 212; Ramakrishna et al. 2010: p. 210); Salt range, Pakistan (Gude 1914: p. 453; Annandale & Rao 1925: p. 394); Kangra valley, Himachal Pradesh, India (Rao 1927: p. 50).

***150. Succinea indica* Pfeiffer, 1849**

Distribution: Nainital, Uttarakhand, India (Pfeiffer 1849: p. 133); Bhimtal, Uttarakhand, India (Hanley & Theobald 1876: pl. 29; Nevill 1878a: p. 212); Kashmir, India (Gude 1914: p. 447); Western Himalaya, India **(**Rao 1924: p. 378; Ramakrishna et al. 2010: p. 212).

***151. Succinea putris* (Linnaeus, 1758)**

Distribution: Sasak Taka, Badakshan Province, Afghanistan (Nevill 1878b: p. 6).

Subfamily Oxylomatinae
Genus *Oxyloma* Westerlund, 1885

***152. Oxyloma elegans* (Risso, 1826)**

Distribution: Kashmir, India (Woodward 1856: p. 186); Srinagar District, Jammu & Kashmir, India (Nevill 1878b: p. 18), Malta, Russia, Türkiye, Italy, Romania, Bulgaria, Uzbekistan, Lithuania, Albania, Ukraine, France, Siberia, and Finland.

***153. Oxyloma* sp.**

Distribution: Tantary Gam, Loran, Poonch district, Pir Panjal Range, India (Present study).

Remarks: Single sample was collected at a distance of 64 Km. from both type locations (Woodward, 1856: p. 186 as *Succinea pfeifferi* var. (*longiscata* Morillet?) and Srinagar (Nevill, 1878b: p. 18, fig. 32-33).

Superfamily Trochomorphoidea
Family Euconulidae
Genus *Euconulus* Reinhardt, 1883

***154. Euconulus fulvus* (Müller, 1774)**

Distribution: Wakha and Mataian villages of Kargil, Ladakh, India (Nevill 1878b: p. 2); Panjal range, India (Theobald 1878: p. 141), New South Wales, North America, Eurasia, Spain, New Zealand, Croatia, Hungary, Italy, Alaska, Poland, Spain, Türkiye, and Nepal.

Remarks: Introduced species.

Family Chronidae
Genus *Kaliella* Blanford, 1863

***155. Kaliella barrakporensis* (Pfeiffer, 1853)**

Distribution: Kashmir, India (Theobald 1878: p. 142), Equatorial Guinea, Malaysia, Indonesia, Tibet, Sri Lanka, Congo, Rwanda, Vietnam, Borneo, Nepal, and India: West Bengal, Western Ghat, Manipur, Uttar Pradesh.

***156. Kaliella bhasini* Rajagopalaingar, 1953**

Distribution: Shimla Hills, Himachal Pradesh, India (Rajagopalaingar 1953: p. 20); Ramakrishna et al. 2010: p. 222).

***157. Kaliella bullula* (Benson, 1838)**

Distribution: Shimla, Himachal Pradesh, India (Hutton & Benson 1838: no. 10, p. 218; Hanley & Theobald 1876: p. 28; Blandford & Godwin-Austen 1908: p. 267); Nainital, Kullu, and Mussoorie, Uttarakhand, India (Nevill 1878a: 27); Nag-Tiba range, near Mussoorie (Godwin

Austen 1882: p. 23).

***158. Kaliella fastigiata* (Hutton, 1838)**

Distribution: Shimla, Himachal Pradesh, India (Hutton & Benson 1838: p. 217; Hanley & Theobald 1876: p. 8; Blandford & Godwin-Austen 1908: p. 263); Landour, Uttarakhand, India (Nevill 1878a: 40); Tandiani, Khyber Pakhtunkhwa, Pakistan (Theobald 1881: p. 46); Mussoorie, Uttarakhand, India (Godwin-Austen 1889: p. 8); Western Himalaya, India (Ramakrishna et al. 2010: p. 225), Lalitpur District-Phulchowki Hill, Nepal (Budha et al. 2015: p. 19).

***159. Kaliella nana* (Benson, 1838)**

Distribution: Shimla, Himachal Pradesh, India (Hutton & Benson 1838: no. 11, p. 218; Nevill 1878a: p. 38); Mussoorie (Godwin Austen 1882: p. 22); Kullu and Mussoorie, Uttarakhand, India (Blandford & Godwin-Austen 1908: p. 266); Loran, Poonch District, Pir Panjal range, India (Present study), Lalitpur District-Phulchowki Hill, Nepal (Budha et al. 2015: p. 19).

***160. Kaliella* sp.**

Distribution: Loran village, Poonch District, Pir Panjal range, India (Present study).

Remarks: Found in moist soil under the tree.

Order Systellommatophora
Superfamily Veronicelloidea
Family Veronicellidae
Genus *Laevicaulis* Simroth, 1913

***161. Laevicaulis alte* (Férussac, 1822)**

Distribution: Dang District, Nepal (Subba & Ghosh 2008: p. 70); Sunderbani, Rajouri District, Pir Panjal range, India (Present study)**,** Cosmopolitan.

Remarks: Found in the grass on the lawn of the house. First time record from the region.

Freshwater Molluscs
Class Bivalvia
Subclass Heterobranchia
Order Venerida
Superfamily Cyrenoidea
Family Cyrenidae
Genus *Corbicula* Mühlfeld, 1811

***162. Corbicula cashmiriensis* Deshayes, 1855**

Distribution: Awantipora, Jammu & Kashmir, India (Woodward 1856: p. 186); Sopore, Jammu & Kashmir, India (Theobald 1878; p. 147); Kashmir, India (Rao 1989: p. 202); Ghou-Manhasan stream, Jammu & Kashmir, India (Uttam et al. 2022: p. 356); Mid and downstream of Aripal stream, Jammu & Kashmir, India (Mir & Bakhtiyar 2022: p. 10571); Poonch and Rajouri Rivers, Pir Panjal range, Jammu & Kashmir, India (Present study).

Remarks: Found in the sand of rivers and lakes of high-altitude Himalaya, inhibits at a depth of 3 m and can tolerate severe cold. Endemic to Kashmir.

***163. Corbicula fluminalis* (Müller, 1774)**

Distribution: Awantipora, Jammu & Kashmir, India (Woodward 1856: p. 186), Poland, Germany, France, Portugal, Hungary, the European part of Russia, Azerbaijan, Georgia, and the Czech Republic.

***164. Corbicula striatella* Deshayes, 1855**

Distribution: Lower Jhelum, Jammu & Kashmir, India (Theobald 1878; p. 147); Bilaspur District, Himachal Pradesh (Agrawal 1976: p. 140); Ghaila khola, Kailali District, Nepal (Budha 2016: p. 53) and Pakistan.

Subclass Autobranchia
Order Sphaeriida
Superfamily Sphaerioidea
Family Sphaeriidae
Subfamily Sphaeriinae
Genus *Afropisidium* Kuiper, 1962

***165. Afropisidium clarkeanum* (Nevill & Nevill, 1871)**

Distribution: Terai, Western region, Nepal (Nesemann & Sharma 2005: p. 59), Nepal, Myanmar, Hong Kong, Thailand, Laos, and India.

Genus *Musculium* Link, 1807

***166. Musculium indicum* (Deshayes, 1854)**

Distribution: Jhelum, Jammu & Kashmir, India (Theobald 1878: p. 147); Damyanti Tal, Uttarakhand, India (Prashad 1922: p. 17); Nakrodi, Kailali District, Nepal (Budha 2016: p. 54); Ghodaghodi Lake Area, Kailali District, Nepal (Chaudhary 2017: p. 24); Dargam, Poonch District and streams at Budhal area of Rajouri, Pir Panjal range, India (Present study), Nepal, and India: Assam.

***167. Musculium kashmirense* (Prashad, 1937)**

Distribution: Phashakuri wetland near Pompore**,** Kashmir, India (Prashad 1937: p. 276; Rao 1989: p. 213); Dargam, Poonch District and streams at Budhal, Rajouri District, Pir Panjal range, India (Present study).

Genus *Euglesa* Jenyns, 1832

***168. Euglesa casertana* (Poli, 1791)**

Distribution: Lower Jhelum, Baramulla, India (Theobald 1878; p. 147); Near Shopian, Kashmir, India

(Preston 1915: p. 225); Kashmir (Rao 1989: p. 215); Downstream of Aripal stream, Jammu & Kashmir, India (Mir & Bakhtiyar 2022: p. 10571); Loran, Poonch District and streams at Budhal area of Rajouri, Pir Panjal range, India (Present study), Europe, Armenia, Mongolia, Austria, Russia, France, Norway, Asia, Africa, North America, Australia, and New Zealand.

***169. Euglesa mitchelli* (Prashad, 1925)**

Distribution: Kashmir, India (Rao 1989: p. 220); Uttam et al. 2022: p. 356); Saklo, Poonch District and streams at Saaj area of Rajouri District, Pir Panjal range (Present study)

***170. Euglesa obtusalis* (Lamarck, 1818)**

Distribution: Pangong lake, Ladakh, India (Nevill 1878b: p.13), France, North America, and Vienna.

***171. Euglesa zugmayeri* (Weber, 1910)**

Distribution: Wular Lake, Kashmir, India (Preston 1915: p. 227).

Genus *Odhneripisidium* Kuiper, 1962

***172. Odhneripisidium kuiperi* (Dance, 1967)**

Distribution: Mustang District, Kali Gandak River, Nepal (Nesemann & Sharma 2005: p. 59); Streams of Poonch River and Rajouri River, Pir Panjal range, India (Present study).

***173. Odhneripisidium prasongi* (Kuiper, 1974)**

Distribution: Kaski District, Nepal (Nesemann & Sharma 2005: p. 59) and Thailand.

***174. Odhneripisidium stewarti* (Preston, 1909)**

Distribution: Chaka da Bagh, Poonch District and Budhal, Rajouri District, India (Present study), Tibet, China, and Bhutan.

Genus *Pisidium* Pfeiffer, 1821

***175. Pisidium alexeii* Bößneck, Clewing & Albrecht, 2016**

Distribution: Karnali River, western Nepal (Bößneck et al. 2016: p. 591).

Order Unionida

Superfamily Unionoidea

Family Unionidae

Subfamily Parreysiinae

Genus *Indonaia* Prashad, 1918

***176. Indonaia andersoniana* (Nevill, 1877)**

Distribution: Maghi khola, Kailali District, Nepal, (Budha 2016: p. 51), northeastern India, and Myanmar.

***177. Indonaia caerulea* (Lea, 1831)**

Distribution: Khundi river, Kailali District, Nepal, (Budha 2016: p. 51), Pakistan, India, Bhutan, and Bangladesh.

***178. Indonaia gratiosa* (Philippi, 1843)**

Distribution: Tikapur, Kailali District, Nepal, (Budha 2016: p. 52), India, and Myanmar.

***179. Indonaia rugosa* (Gmelin, 1791)**

Distribution: Badhariya, Kailali District, Nepal, (Budha 2016: p. 52) and India.

Genus *Lamellidens* Simpson, 1900

***180. Lamellidens corrianus* (Lea, 1834)**

Distribution: Western Himalaya, India (Rao 1989: p. 165); Gho-Manhasan stream, Jammu (Uttam et al. 2022: p. 356); Mohana river, Kailali District, Nepal (Budha 2016: p. 48), Bangladesh, Myanmar, Nepal, and India: Maharashtra, Assam, Madhya Pradesh, Karnataka, Punjab, Haryana.

***181. Lamellidens generosus* (Gould, 1847)**

Distribution: Renuka Lake, Nahan, Himachal Pradesh, India (Battish & Sharma 2002: p. 921).

***182. Lamellidens jammuensis* Prashad, 1928**

Distribution: Chenab River, Nagrota, India (Prashad 1928: p. 309).

***183. Lamellidens jenkinsianus* (Benson, 1862)**

Distribution: Dhongrahuwa Lake, Kailali District, Nepal (Budha 2016: p. 48); Renuka River, Nahan, Himachal Pradesh (Battish & Sharma 2002: p. 921), Bangladesh, and India.

***184. Lamellidens lamellatus* (Lea, 1838)**

Distribution: Renuka Lake, Nahan, Himachal Pradesh (Battish & Sharma 2002: p. 921), Sri Lanka, Myanmar, and India.

***185. Lamellidens marginalis* (Lamarck, 1819)**

Distribution: Khundi river, Kailali District, Nepal (Budha 2016: p. 49); Ghodaghodi Lake Area, Kailali District, Nepal (Chaudhary 2017: p. 25), Bangladesh, Pakistan, Nepal, and India: Uttar Pradesh, Maharashtra, West Bengal, Odisha, Kerala, Bihar.

Genus *Parreysia* Conrad, 1853

***186. Parreysia corrugata* (Müller, 1774)**

Distribution: Shimla District, Himachal Pradesh, India

(Agrawal 1976: p. 140); Bijuliya river, Kailali District, Nepal (Budha 2016: p. 50); Ghodaghodi Lake Area, Kailali District, Nepal (Chaudhary 2017: p. 25), Nepal, Pakistan, Bangladesh, Myanmar, Philippines, and India: Western Ghat, Kerala, Bihar, Odisha, Andhra Pradesh.

Class Gastropoda
Subclass Caenogastropoda
Order Littorinimorpha
Superfamily Truncatelloidea
Family Bithyniidae
Genus *Bithynia* Leach, 1818

***187. Bithynia cerameopoma* (Benson, 1830)**

Distribution: Ghodaghodi Tal, Kailali District, Nepal (Budha 2016: p. 37; Chaudhary 2017: p. 19) and throughout the plains.

***188. Bithynia kashmirense* Nevill, 1885**

Distribution: Srinagar, Jammu and Kashmir, India (Nevill 1885: p. 39; Rao 1989: p. 74).

***189. Bithynia pulchella* (Benson, 1836)**

Distribution: Nainital, Uttarakhand, India (Nevill 1885: p. 35); Kullu, Uttarakhand, India (Nevill 1878a: p. 35); Naukuchia Tal, Uttarakhand, India (Prashad 1922: p. 16); Sirmaur District, Himachal Pradesh, India (Agrawal 1976: p. 133); Pong Dam Lake, Himachal Pradesh, India (Biswas et al. 2015: p. 20); Saklo area of Poonch District and Dangri village of Rajouri District, Pir Panjal range, India (Present study), throughout India, Myanmar, and Thailand.

190. *Bithynia tentaculata* Linnaeus, 1758

Distribution: Srinagar District, Jammu & Kashmir, India (Preston 1915: p. 70); Ghou-Manhasan and Sehi streams, Jammu, India (Uttam et al. 2022: p. 356); Aripal stream, Jammu & Kashmir, India (Mir & Bakhtiyar 2022: p. 10571), Netherlands, North America, southeastern Europe, Ukraine, Turkiye, Bosnia and Herzegovina, Montenegro, Romania, Poland, Croatia, Bulgaria, Algeria, Russia, and Italy.

191. *Bithynia transsilvanica* (Bielz, 1853)

Distribution: Kashmir, India (Preston 1915: p. 77; Nevill 1885: p. 40; Rao 1989: p. 7), eastern Europe, Slovakia, Bulgaria, and Siberia.

Genus *Gabbia* Tryon, 1865

192. *Gabbia prestoni* (Glöer & Bössneck, 2013)

Distribution: Rapti river, Dang District, Nepal (Glöer & Bössneck 2013: p. 141).

***193. Gabbia orcula* (Frauenfeld, 1862)**

Distribution: Ghodaghodi Tal, Kailali District, Nepal (Budha 2016: p 38).

194. *Gabbia reharensis* (Glöer & Bössneck, 2013)

Distribution: Rapti river, Dang District, Nepal (Glöer & Bössneck 2013: p. 143).

195. *Gabbia raptiensis* (Glöer & Bössneck, 2013)

Distribution: Nepalgunj, Banke District, Nepal (Glöer & Bössneck 2013: p. 145); Rapti river, Nepal (Budha 2016: p. 38).

***196. Gabbia ghodaghodiensis* (Glöer & Bössneck, 2013)**

Distribution: Ghodaghodi Lake, District Kailali, Nepal (Glöer & Bössneck 2013: p. 145, Budha 2016: 37; Chaudhary 2017: p. 19).

Family Erhaiidae
Genus *Erhaia* Davis & Kuo, 1985

***197. Erhaia nainitalensis* Davis & Rao, 1997**

Distribution: Nainital District, Uttarakhand, India (Davis & Rao 1997: p. 276).

Family Pomatiopsidae
Subfamily Pomatiopsinae
Genus *Tricula* Benson, 1843

***198. Tricula montana* Benson 1843**

Distribution: Bhimtal, Uttarakhand, India (Benson 1843: p. 467; 1878a: p. 62; Nevill 1885: p. 62; Prashad 1922: p. 16; Davis et al 1986: p. 428); Bhimtal (Preston 1915: p. 68; Rao 1989: p. 68), Sri Lanka, Bhutan, Thailand, China, eastern Himalaya, and India: Uttar Pradesh, Andhra Pradesh.

Order Caenogastropoda
Superfamily Cerithioidea
Family Pachychilidae Fischer & Crosse, 1892
Genus *Brotia* Adams, 1866

***199. Brotia costula* (Rafinesque, 1833)**

Distribution: Karnali river, Kailali District, Nepal (Budha 2016: p. 41); Ghodaghodi Lake Area, Kailali District, Nepal (Chaudhary 2017: p. 20), Bhutan, Nepal, Bangladesh, India, Malaysia, Vietnam, and Philippines.

Family Thiaridae
Subfamily Thiarinae
Genus *Melanoides* Olivier, 1804

***200. Melanoides tuberculata* (Müller, 1774)**

Distribution: Mohu pass, Jammu, India (Theobald

1878: p. 141); Sirmaur District, Himachal Pradesh, India (Agrawal 1976: p. 133); Kangra District, Himachal Pradesh, India (Biswas et al. 2015: p. 20); Ghou-Manhasan and Sehi streams, Jammu, India (Uttam et al. 2022: p. 356); Kailali District, Nepal (Budha 2016: p. 39); Ghodaghodi Lake Area, Kailali District, Nepal (Chaudhary 2017: p. 20); Poonch river and streams at Munja Kot of Rajouri, Pir Panjal range, India (Present study).

Genus *Mieniplotia* Low & Tan, 2014

***201. Mieniplotia scabra* (Müller, 1774)**

Distribution: Western Himalaya, India (Rao 1989: p. 96) Kailali District, Nepal (Budha 2016: p. 39), Europe, Greece, Indonesia, Palestine, and Borneo.

Remarks: Introduced species.

Genus *Tarebia* Adams & Adams, 1854

***202. Tarebia granifera* (Lamarck, 1816)**

Distribution: Kailali District, Nepal (Budha 2016: p. 40), Africa, Brazil, Mexico, Taiwan, Sulawesi, Thailand, southeastern Asia, Israel, Indonesia, Philippines, Vietnam, Cuba, Australia, and India: Chhattisgarh, Assam, Odisha, Andaman & Nicobar.

Genus *Thiara* Röding 1798

***203. Thiara aspera* (Lesson, 1831)**

Distribution: Sunderbani, Rajouri District, Pir Panjal range, India (Present study), Myanmar, Thailand, Philippines, Indonesia, Malaysia, and India: Assam.

Order Architaenioglossa
Superfamily Viviparoidea
Family Viviparidae
Subfamily Bellamyinae
Genus *Filopaludina* Habe, 1964

***204. Filopaludina bengalensis* (Lamarck, 1822)**

Distribution: Jammu Hills, Jammu & Kashmir, India (Woodward 1856: p. 186); Northwestern Himalaya, India (Preston 1915: p. 83); Naini Tal and Khurpa Tal Lakes, Uttarakhand, India (Prashad 1922: p. 16); Sirmaur District, Himachal Pradesh, India (Agrawal 1976: p. 132); Ghou-Manhasan and Sehi streams, Jammu, India (Uttam et al. 2022: p. 356); Jagdishpur Tal, Kapilvastu District, Nepal (Budha 2016: p. 34); Ghodaghodi Lake, Nepal (Chaudhary 2017: p.18); Poonch District, Pir Panjal range, India (Present study), Bhutan, and throughout India.

Genus *Idiopoma* Pilsbry, 1901

***205. Idiopoma dissimilis* (Müller, 1774)**

Distribution: Naini Tal Lake, Uttarakhand, India (Nevill 1885: p. 27); Solan District, Himachal Pradesh, India (Agrawal 1976: p. 132); Ghodaghodi lake, Kailali District, Nepal (Budha 2016: p. 35; Chaudhary 2017: p. 19).

Subclass Heterobranchia
Superfamily Lymnaeoidea
Family Bulinidae
Subfamily Bulininae
Genus *Indoplanorbis* Annandale & Prashad, 1921

***206. Indoplanorbis exustus* (Deshayes, 1833)**

Distribution: Islamabad, Jammu & Kashmir, India (Woodward 1856: p. 186); Sirmaur District, Himachal Pradesh, India (Agrawal 1976: p. 135); Kashmir, India (Rao 1989: p. 142); Gho-Manhasan stream, Jammu (Uttam et al. 2022: p. 356); Pong Dam Lake, Himachal Pradesh, India (Biswas et al. 2015: p. 23); Pangong Lake, Ladakh, India, Kashmir valley, India (Theobald 1878; p. 147); Downstream of Aripal stream, Jammu & Kashmir, India (Mir & Bakhtiyar 2022: p. 10571); Kailali District, Nepal (Budha 2016: p. 47); Jammu hills, Jammu & Kashmir, India (Woodward 1856: p. 186); Ghodaghodi Lake Area, Kailali District, Nepal (Chaudhary 2017: p. 23); Dundak, Poonch District, Pir Panjal range, India (Present study).

Family Lymnaeidae
Subfamily Amphipepleinae
Genus *Ampullaceana* Servain, 1882

***207. Ampullaceana balthica* (Linnaeus, 1758)**

Distribution: Kashmir, India (Preston 1915: p. 110), Estonia, Canada, France, Germany, northern Iran, and Indonesia.

***208. Ampullaceana lagotis* (Schrank, 1803)**

Distribution: Pangong Lake, Ladakh, India (Nevill 1878b: p. 7), Tibet, Central Asia, Romania, Uzbekistan, Russia, China, Kyrgyzstan, and Georgia.

Genus *Pila* Röding, 1798

***209. Pila globosa* (Swainson, 1822)**

Distribution: Ghodaghodi lake, Kailali District, Nepal (Budha 2016: p. 36: Chaudhary 2017: p. 17), Nepal, Bangladesh, and India.

Subfamily Lymnaeinae
Genus *Galba* Schrank, 1803

***210. Galba truncatula* (Müller, 1774)**

Distribution: Skardu, Gilgit-Baltistan, Pakistan (Woodward 1856: p. 186); Spiti, Kullu, Kotegar, Himachal Pradesh, India (Nevill 1878b: p. 10); Kashmir valley, India (Theobald 1878; p. 149; Preston 1915: p. 114; Rao

1989: p. 133); Potha, Poonch District and Salani, Rajouri District, Pir Panjal range, India (Present study), Europe, Armenia, France, Poland, Bulgaria, France, Greece, Czech Republic, Austria, Romania, Germany, and Uzbekistan.

Genus *Lymnaea* Lamarck, 1799

***211. Lymnaea stagnalis* (Linnaeus, 1758)**

Distribution: Kashmir, India (Woodward 1856: p. 186; Theobald 1878: p. 149); Kashmir (Preston 1915: p. 106; Rao 1989: p. 135); Bilaspur District, Himachal Pradesh, India (Agrawal 1976: p. 137); Downstream of Aripal stream, Jammu & Kashmir, India (Mir & Bakhtiyar 2022: p. 20751); Rajouri District, Pir Panjal range, India (Present study), Türkiye, Mongolia, Kaliningrad, southern Siberia, Republic of Khakassia, and Ukraine.

***212. Lymnaea kashmirensis* Prashad, 1925**

Distribution: Wular Lake, Kashmir, India (Annandale & Rao 1925: p. 148).

Genus *Pseudosuccinea* Baker, 1908

***213. Pseudosuccinea columella* (Say, 1817)**

Distribution: Mid and downstream of Aripal stream, Jammu & Kashmir, India (Mir & Bakhtiyar 2022: p. 20751); Ghodaghodi, Kailali District, Nepal (Budha 2016: p. 41), France, Argentina, Republic of South Africa, Spain, Dominican Republic, North Carolina, New Zealand, Venezuela, Egypt, Cuba, and North America.

Genus *Stagnicola* Jeffreys, 1830

***214. Stagnicola* sp.**

Distribution: Poonch District and Salani village, Rajouri District, Pir Panjal range, India (Present study), Iran, Iraq, North America, and Mexico.

Subfamily Amphipepleinae

Genus *Peregriana* Servain, 1882

***215. Peregriana peregra* (Müller, 1774)**

Distribution: Kashmir, India (Woodward 1856: p. 186; Rao 1989: p. 135), Tibet, Ukraine, Berlin, Republic of Dagestan, Mongolia, Siberia, and Europe.

Genus *Racesina* Vinarski & Bolotov, 2018

***216. Racesina luteola* (Lamarck, 1822)**

Distribution: Islamabad, Jammu and Kashmir, India (Woodward 1856: p. 186); at Gho-Manhasan stream, Jammu (Uttam et al. 2022: p. 356); Naukuchia Tal, Uttarakhand, India (Prashad 1922; p. 14); Solan District, Himachal Pradesh, India (Agrawal 1976: p. 138); Kashmir valley, India (Theobald 1878; p. 149); Mid and downstream of Aripal stream, Jammu & Kashmir, India (Mir & Bakhtiyar 2022: p. 20751); Kailali District, Nepal (Budha 2016: p. 43); Saklo, Poonch, Pir Panjal range, India (Present study) and throughout Indian plains.

***217. Racesina ovalior* (Annandale & Prashad, 1921)**

Distribution: Bathanchamka lake, Kailali District, Nepal (Budha 2016: p. 44).

Genus *Radix* Montfort 1810

***218. Radix andersoniana* (Nevill, 1877)**

Distribution: Kangra Valley, Himachal Pradesh, India (Rao 1989: p. 132), China, Nepal, and Bhutan.

***219. Radix auricularia* (Linnaeus, 1758)**

Distribution: Skardu, Gilgit-Baltistan, Pakistan (Woodward 1856: p. 186); Shimshal village, Pamir, Pakistan (Nevill 1878b; p. 6); Kashmir valley, India (Theobald 1878; p. 149; Preston 1915: p. 111; Rao 1989: p. 134); Thogji Lake, Ladakh, India (Rajagopal & Rao 1969: p. 102); Sirmaur District, Himachal Pradesh, India (Agrawal 1976: p. 136); Ghou-Manhasan and Sehi streams, Jammu, India (Uttam et al. 2022: p. 356); Mid and downstream of Aripal stream, Jammu & Kashmir, India (Mir & Bakhtiyar 2022: p. 20751); Chakatro, Poonch District at Slani area of Rajouri District, Pir Panjal range, India (Present study), Austria, Bulgaria, Siberia, Russia, Iraq, Iran, Armenia, Slovakia, Turkiye, Algeria, and Montenegro.

***220. Radix brevicauda* (Sowerby 1872)**

Distribution: Kashmir, India (Hanley & Theobald 1876: p. 64; Preston 1915: p. 111; Rao 1989: p. 134); Pangong Lake, Ladakh, India.

***221. Radix rufescens* (Gray, 1822)**

Distribution: Jammu, Jammu & Kashmir, India (Woodward 1856: p. 286); Bhim Tal and Naukuchia Tal Lakes, Uttarakhand, India (Prashad 1922; p. 14); Solan District, Himachal Pradesh, India (Agrawal 1976: p. 138); Rajoy river, Kangra District, Himachal Pradesh, India (Biswas et al. 2015: p. 21); Ghodaghodi Lake Area, Kailali District, Nepal (Chaudhary 2017: p. 21); Poonch River at Bufliaz area of Poonch District, Pir Panjal range India (Present study), Indonesia, Berlin, Iran, Pakistan, and throughout the Indian plains.

***222. Radix tener* (Küster, 1862)**

Distribution: Bhim Tal Lake, Uttarakhand, India (Annandale & Rao 1925: p. 396); Kashmir, India (Rao 1989: p. 133); Ghodaghodi Lake Area, Kailali District, Nepal (Chaudhary 2017: p. 22) and Persia.

Genus *Tibetoradix* Bolotov, Vinarski & Aksenova, 2018

***223. Tibetoradix hookeri* (Reeve, 1850)**

Distribution: Skardu, Gilgit-Baltistan, Pakistan and Nubra, Leh District, India (Woodward 1856: p. 186), Tibetan Plateau (western China), Greece, and southern Asia.

Family Physidae

Subfamily Physinae

Genus *Physella* Haldeman, 1843

***224. Physella acuta* (Draparnaud, 1805)**

Distribution: Gho-Manhasan stream, Jammu, India (Uttam et al. 2022: p. 356); Rajoy river, Kangra District, Himachal Pradesh, India (Biswas et al. 2015: p. 21); Ghou-Manhasan and Sehi streams; Mid-stream of Aripal stream, Jammu & Kashmir, India (Mir & Bakhtiyar 2022: p. 20751); Poonch District, Pir Panjal range, India (Present study), Belarus, Lithuania, Vietnam, North America, Russia, Thailand, Laos, Europe, central Asia, Cuba, China, Morocco, Turkiye, South Korea, United Kingdom, Czech Republic, Brazil, Transcaucasia, South Carolina, and India: North Dinajpur, Kerala, West Bengal.

Remarks: Introduced species.

Family Planorbidae

Subfamily Ancylinae

Genus *Pettancylus* Iredale, 1943

***225. Pettancylus verruca* (Benson, 1855)**

Distribution: Dhongrahuwa Lake, Kailali District, Nepal (Budha 2016: p. 47).

Subfamily Planorbinae

Genus *Biomphalaria* Preston, 1910

***226. Biomphalaria* sp.**

Distribution: Gharana Wetland, Jammu & Kashmir, India (Uttam et al. 2022: p. 356).

Genus *Culmenella* Clench, 1927

***227. Culmenella subspinosa* (Annandale & Prashad, 1920)**

Distribution: Khanabal and Islamabad, Jammu and Kashmir, India (Annandale & Prashad 1920: p. 28); Kashmir, India (Rao 1989 p. 145).

Genus *Gyraulus* Charpentier, 1837

***228. Gyraulus albus* (Müller, 1774)**

Distribution: Panjah, Badakhshan Province, Afghanistan (Nevill 1878b: p. 10), Turkiye, France, Croatia, Hungary, Czech Republic, Morocco, Poland, Albania, Bulgaria, Russia, Iraq, Romania, Ukraine, and Germany.

229. *Gyraulus convexiusculus* (Hutton, 1849)

Distribution: Naini Tal, Sariya Tal, and Bhim Tal Lakes, Uttarakhand, India (Prashad 1922: p. 15); Solan District, Himachal Pradesh, India (Agrawal 1976: p. 136); Kailali District, Nepal (Budha 2016: p. 45), Pakistan, China, India, Nepal, Iran, Philippines, Thailand, Australia, Guinea, Korea, and India.

***230. Gyraulus euphraticus* (Mousson, 1874)**

Distribution: Salt range, Pakistan (Annandale & Rao 1925: p. 397); Salt Range (Rao 1989: p. 155); Kailali District, Nepal (Budha 2016: p. 45), Palaearctic, Iran, Iraq, Afghanistan, and India.

***231. Gyraulus kosiensis* Glöer & Bössneck, 2013**

Distribution: Karampani, Almora District, Uttarakhand, India (Glöer & Bössneck, 2013: p. 151).

***232. Gyraulus ladacensis* (Nevill, 1878)**

Distribution: Leh District, Ladakh, India (Nevill 1878b: p. 10; Rao 1989: p. 156); Gho-Manhasan stream, Jammu, India (Uttam et al. 2022: p. 356); Aripal stream, Jammu & Kashmir, India (Mir & Bakhtiyar 2022: p. 10571), Tibet, and Uzbekistan.

***233. Gyraulus parvus* (Say, 1817)**

Distribution: Salt range, Pakistan (Annandale & Rao 1925: p. 397), Netherlands, central Europe, North America, Myanmar, and throughout the plains of Inda.

Genus *Helicorbis* Benson, 1855

***234. Helicorbis cantori* (Benson, 1850)**

Distribution: Ghodaghodi Lake Area, Kailali District, Nepal (Chaudhary 2017: p. 23), China, Taiwan, Philippines, Sri Lanka, Nepal, Singapore, Korea, and India: Assam, Manipur.

***235. Helicorbis umbilicalis* (Benson, 1836)**

Distribution: Lakes of Bhimtal, Uttarakhand, India (Prashad 1922: p. 15); Kumaon, Uttarakhand, India (Rao 1989: p. 148); Kailali District, Nepal (Budha 2016: p. 46).

Genus *Helisoma* Swainson, 1840

***236. Helisoma* sp.**

Distribution: Gharana Wetland, Jammu & Kashmir, India (Uttam et al. 2022: p. 356).

Genus *Hippeutis* Charpentier, 1837

***237. Hippeutis complanatus* (Linnaeus, 1758)**

Distribution: Kashmir, India (Rao 1989: p. 146), Poland, Algeria, Russia, Poland, Iran, Slovakia, Türkiye, Republic of Moldova, Croatia, Czech Republic, Montenegro, Germany, Romania, and Latvia.

Genus *Planorbis* Müller, 1773

***238. Planorbis carinatus* Müller, 1774**

Distribution: Kashmir valley, India (Theobald 1878: p. 149), Poland, Lebanon, Bulgaria, Turkiye, Germany, Latvia, Albania, Ukraine, and Italy.

***239. Planorbis planorbis* (Linnaeus, 1758)**

Distribution: Pitak and Skardu, Gilgit-Baltistan, Pakistan (Woodward 1856: p. 186); Aripal stream, Jammu and Kashmir, India (Mir & Bakhtiyar 2022: p. 10571); Samote of Poonch District and Kalakote area of Rajouri District, Pir Panjal range, India (Present study), Armenia, Greece, Turkiye, Poland, Bulgaria, eastern Russia, Croatia, Uzbekistan, Germany, and India.

Genus *Polypylis* Pilsbry, 1906

***240. Polypylis calathus* (Benson, 1850)**

Distribution: Bhimtal Lake, Uttarakhand, India (Benson 1850: p. 348); Kashmir, India (Preston 1915: p. 127), Naini Tal, Uttarakhand, India (Prashad 1922: p. 16); Kailali District, Nepal (Budha 2016: p. 46); Ghodaghodi Lake Area, Kailali District, Nepal (Chaudhary 2017: p. 23), Sri Lanka, Myanmar, Nepal, India, and the plains of eastern India.

Genus *Segmentina* Fleming, 1818

***241. Segmentina* sp.**

Distribution: Downstream of Aripal stream, Jammu & Kashmir, India (Mir & Bakhtiyar 2022: p. 10571).

Superfamily Valvatoidea
Family Valvatidae
Genus *Valvata* Müller, 1773

***242. Valvata piscinalis* (Müller, 1774)**

Distribution: Tso Kar Lake, Rupshu valley, India (Woodward 1856: p. 186); Pangong Lake, Ladakh, India (Nevill 1878a: p. 15; Nevill 1878b: p. 12; Nevill 1885: p. 15; Sopore, Jammu & Kashmir, India (Theobald 1878: p. 141); Kashmir, India (Preston 1915: p. 95; Rao 1989: p. 56), Europe, Turkiye, Armenia, Poland, Croatia, Bulgaria, Siberia, Italy, Germany, Bulgaria, Romania, Estonia, and Latvia.

REFERENCES

Agrawal, H.P. (1976). Aquatic and Amphibious Molluscs of Himachal Pradesh, Pt. I. *Records of the Zoological Survey of India* 71: 129–142.

Annandale, T.N. & B. Prashad (1920). Further notes on the genus *Camptoceras* (*Mollusca Pulmonata*). *Journal and Proceedings of the Asiatic Society of Bengal* 16: 27–33.

Annandale, T.N. & H.S. Rao (1925). Further observations on the aquatic gastropods of the Inle watershed. *Records of the Indian Museum* 27: 101–127.

Aravind, N.A., N.A., Madhyastha, G.M. Rajendra & D. Anirudha (2011). The status and distribution of freshwater molluscs of the Western Ghats, pp. 21–42. In: Molur, S., K.G. Smith, B.A. Daniel & W.R.T. Darwall (Compilers). *The Status and Distribution of Freshwater Biodiversity in the Western Ghats, India*. IUCN, Cambridge, UK and Gland, Switzerland and Zoo Outreach Organisation, Coimbatore, India, 117 pp.

Auffenberg, K. & S.M.S. Fakhri (1995). A new species of land snail from Pakistan (Gastropoda: Pulmonata: Clausiliidae: Phaedusinae). *Archiv für Molluskenkunde* 124(1–2): 89–92. https://doi.org/10.1127/arch.moll/124/1995/89

Battish, S.K. & M. Sharma (2002). Some freshwater bivalves of Punjab, Haryana and Himachal Pradesh. *Zoos' Print Journal* 17(10): 921. https://doi.org/10.11609/JoTT.ZPJ.17.10.921

Benson, W.H. (1843). Description of *Camptoceras*, a new genus of the Lymnaeadae, allied to *Ancylus*, and of *Tricula*, a new type of form allied to *Melania*. *Calcutta Journal of Natural History, and Miscellany of the Arts and Sciences in India* 3(12): 465–468.

Benson, W.H. (1848). Characters of seven new species of *Helix*, with amended descriptions of some species previously described, and notes on others requiring remark. *Annals and Magazine of Natural History* 2(9): 158–164. https://doi.org/10.1080/03745485809494679

Benson, W.H. (1849a). Descriptions of four new Asiatic species of the genus *Pupa* of Draparnaud. *Annals and Magazine of Natural History* 4(20): 125–128. https://doi.org/10.1080/03745486009496158

Benson, W.H. (1849b). Characters of *Diplommatina*, a new genus of Terrestrial Mollusks belonging to the family of Carychiadæ, and of a second species contained in it; also of a new species of *Carychium* inhabiting the Western Himalaya. *Annals and Magazine of Natural History* 4(21): 193–195. https://doi.org/10.1080/03745486009494813

Benson, W.H. (1850). Characters of nine new or imperfectly described species of *Planorbis* inhabiting India and China. *Annals and Magazine of Natural History* 5(29): 348–352. https://doi.org/10.1080/03745486009494926

Benson, W.H. (1857). New species of *Bulimus* from India, Burma and the Mauritius. *The Annals and Magazine of Natural History* 19(2): 327–330. https://doi.org/10.1080/00222935708693934

Benson, W.H. (1859). Descriptions of new Helicidae contained in the Darjiling collections of Messrs. W. T and H. F. Blanford. *The Annals and Magazine of Natural History* 3(3): 265–273.

Benson, W.H. (1863). Characters of new operculate land-shells from the Andamans, and of Indian and Burmese species of *Pupa*. *Annals and Magazine of Natural History* 12(72): 425–429. https://doi.org/10.1080/00222936308681554

Benson, W.H. (1864). Characters of *Coilostele*, an undescribed genus of Auriculacea (?), and of species of *Helix*, *Pupa*, and *Ancylus*, from India, West Africa, and Ceylon. *Annals and Magazine of Natural History* 13(74): 136–140. https://doi.org/10.1080/00222936408681588

Benson, W.H. (1865). New land-shells from Travancore, western and northern India. *Annals and Magazine of Natural History* 15(85): 11–15. https://doi.org/10.1080/00222936508681753

Bhat, D.M. (2020). First report of *Deroceras* sp. (Gastropoda, Pulmonata, Agriolimacinae) as pest of agricultural crops in Kashmir valley (India). *Uttar Pradesh Journal of Zoology* 41(6): 24–28.

Biswas, T., B. Tripathy, K. Valarmathi & S.K. Sajan (2015). Taxonomy, distribution and conservation of Molluscs in Kangra district of Himachal Pradesh: three new records from the State. *Ambient Science* 2(2): 18–24. https://doi.org/10.21276/ambi.2015.02.2.ra02

Blanford, W.T. (1904). Descriptions of Indian and Burmese Land-Shells referred to the Genera *Macrochlamys, Bensonia, Taphrospira*, (gen. nov.), *Microcystina, Euplecta*, and *Polita*. *Proceedings of the Zoological Society of London* 74(4): 441–447. https://doi.

org/10.1111/j.1469-7998.1905.tb08348.x

Blanford, W.T & H.H. Godwin-Austen (1908). *The Fauna of British India, including Ceylon and Burma, Mollusca. Testacellidae and Zonitidae*, Taylor & Francis, London, 311 pp.

Boominathan, M. & T.V. Ramachandra (2010). Molluscs of Pangong Tso, A High-Altitude Brackish Water Lake in Ladakh. *In Symposium on Lake* 1–5.

Bößneck U., C. Clewing & C. Albrecht (2016). Exploring high-mountain limnic faunas: discovery of a novel endemic bivalve species (Sphaeriidae: *Pisidium*) in the Nepal Himalayas. *Invertebrate Systematics* 30(6): 588–597.

Bouchet, P., J.P. Rocroi, B. Hausdorf, A. Kaim, Y. Kano, A. Nützel, P. Parkhaev, M. Schrodl & E.E. Strong (2017). Revised classification, nomenclator and typification of gastropod and monoplacophoran families. *Malacologia* 61(1–2): 1–526. https://doi.org/10.4002/040.061.0201

Bouchet, P., J.P. Rocroi, R. Bieler, J.G. Carter & E.V. Coan (2010). Nomenclator of bivalve families with a classification of bivalve families. *Malacologia* 52(2): 1–184. https://doi.org/10.4002/040.052.0201

Budha, P. & F. Naggs (2008). The Giant African Land Snail *Lissachatina fulica* (Bowdich) in Nepal. *The Malacologist* 50: 19–21.

Budha, P.B., F. Naggs & T. Backeljau (2015). Annotated checklist of the terrestrial gastropods of Nepal. *ZooKeys* 492: 1–48. https://doi.org/10.3897/zookeys.492.9175

Budha, P.B., F. Naggs & T. Backeljau (2017a). Conchological differentiation and genital anatomy of Nepalese Glessulinae (Gastropoda, Stylommatophora, Subulinidae), with descriptions of six new species. *ZooKeys* 675: 129–156. https://doi.org/10.3897/zookeys.675.13252

Budha, P.B., F. Naggs & T. Backeljau (2017b). The genus *Diplommatina* Benson, 1849 (Gastropoda: Caenogastropoda: Diplommatinidae) in Nepal, with the description of seven new species. *European Journal of Taxonomy* 337: 1–30. https://doi.org/10.5852/ejt.2017.337

Budha, P.B. (2016). *A Field Guide to Freshwater Molluscs of Kailali, Far Western Nepal*. Central Department of Zoology, Tribhuvan University, Kathmandu, 83 pp.

Budha, P.B., N.A. Aravind & B.A. Daniel (2010). The status and distribution of freshwater molluscs of the eastern Himalaya pp. 42–53. In: Allen, D.J., S. Molur & B.A. Daniel (Compilers). *The Status and Distribution of Freshwater Biodiversity in the Eastern Himalaya*. IUCN, Cambridge, UK and Gland, Switzerland and Zoo Outreach Organization, Coimbatore, India, 88 pp.

Chandra, K., K.C. Gopi, D.V. Rao, K. Valarmathi & J.R.B. Alfred (Eds.) (2017). Current status of freshwater faunal diversity in India—-An overview pp. 1-25. In: Chandra, K., K.C. Gopi, D.V. Rao, K. Valarmathi & J.R.B. Alfred (Eds.). *Current Status of Freshwater Faunal Diversity in India*. Zoological Survey of India, Kolkata, India, 624 pp.

Chaudhary, P. (2017). Species Diversity, Consumption Trends and Conservation Status of Freshwater Molluscs in Ghodaghodi Lake Area, Kailali District, Nepal. PhD Thesis. Central Departmental of Zoology, Tribhuvan University, x+49 pp.

Cowie, R.H., B. Fontaine & P. Bouchet (2023). Non-marine molluscs. pp. 288-310. In: Maclean, N. (eds.). *The Living Planet: The State of the World's Wildlife*. Cambridge University Press, University of Cambridge, 408 pp. https://doi.org/10.1017/9781108758826

Davis, G.M. & S. Rao (1997). Discovery of *Erhaia* (Gastropoda: Pomatiopsidae) in northern India with description of a new genus of Erhaiini from China. *Proceedings of the Academy of Natural Sciences of Philadelphia* 148: 273–299.

Davis, G.M., N.V. Rao & K.E. Hoagland (1986). In search of *Tricula* (Gastropoda: Prosobranchia): *Tricula* defined, and a new genus described. *Proceedings of the Academy of Natural Sciences of Philadelphia* 138(2): 426–442.

Dey, A. & S.C. Mitra (2000). Molluscs of the Himalaya. *Records of the Zoological Survey of India* 98(2): 5–50.

Dutta, S.P.S & Y.R. Malhotra (1986). Seasonal variations in the macrobenthic fauna of Gadigarh stream (Miran Sahib) Jammu. *Indian Journal of Ecology* 13(1): 138–145.

Evans, D. (2006). The habitats of the European Union habitats directive. *Biology and Environment: Proceedings of the Royal Irish Academy* 106(3): 167–173.

Gerber, J. & U. Bössneck (2009). The genus Vallonia in Nepal:(Gastropoda: Pulmonata: Valloniidae). *Archiv für Molluskenkunde* 138(1): 43–52. https://doi.org/10.1127/arch.moll/0003-9284/138/043-052

Glöer, P. & U. Bössneck (2013). Freshwater molluscs from Nepal and North India with the description of seven new species. *Archiv für Molluskenkunde* 142(1): 137–156. https://doi.org/10.1127/arch.moll/1869-0963/142/137-156

Godwin-Austen, H.H. (1882). Land and freshwater Mollusca of India, including South Arabia, Baluchistan, Afghanistan, Kashmir, Nepal, Burmah, Pegu, Tenasserim, Malaya Peninsula, Ceylon, and other islands of the Indian Ocean. *Supplementary to Messrs. Theobald and Hanley's Conchologia Indica*. Taylor & Francis, London, 1(1): 19–66.

Godwin-Austen, H.H. (1899). Address of the president. *Proceedings of the Malacological Society of London* 3(5): 241–262.

Godwin-Austen, H.H. (1914). Land and freshwater Mollusca of India, including South Arabia, Baluchistan, Afghanistan, Kashmir, Nepal, Burmah, Pegu, Tenasserim, Malaya Peninsula, Ceylon, and other islands of the Indian Ocean. *Supplementary to Messrs. Theobald and Hanley's Conchologia Indica*. Taylor & Francis, London, 2(12): 311–442.

Gude, G.K. (1914). *The Fauna of British India including Ceylon and Burma. Mollusca II. (Trochomorphidae-Janellidae)*. *Today & Tomorrow's Printers and Publishers*, New Delhi, 534 pp.

Gude, G.K. (1921). *The Fauna of British India including Ceylon and Burma. Mollusca III. Land operculates*. Today & Tomorrow's Printers and Publishers, New Delhi, 406 pp.

Hanley, S.C.T & W. Theobald (eds.). (1876). *Conchologia Indica: illustrations of the land and freshwater shells of British India*. L. Reeve & Company, London, 416 pp.

Heynemann, F.D. (1863). Neue Nacktschnecken vom Himalaya. *Malakozoologische Blätter* 10: 137–143.

Hlaváč, J.Č. (2004). A new record of Deroceras laeve (O. F. Müller, 1774) from Pakistan (Gastropoda: Pulmonata: Agriolimacidae). *Folia Malacologica* 12(4): 181–182. https://doi.org/10.12657/folmal.012.016

Hora, S.L. (1928). Hibernation and Aestivation in Gastropod Molluscs-on the Habits of a Slug from Dalhousie (Western Himalayas), with Remarks on certain other Species of Gastropod Molluscs. *Records of the Zoological Survey of India* 30(3): 357–373.

Hora, S.L., G.M. Mulik & H. Khajuria (1955). Some interesting features of the aquatic fauna of the Kashmir Valley. *Journal of the Bombay Natural History Society* 53(1): 140–143.

Hutton, T. & W.H. Benson (1838). On land and fresh-water shells of the Western Himalaya. *The journal of the Asiatic Society of Bengal* 7: 211–218.

Hutton, T. (1834). On the land shells of India. *Journal of the Asiatic Society of Bengal* 3(26): 81–93.

Hutton, T. (1837). Journal of a trip to Burenda Pass in 1836. *Journal of the Asiatic Society of Bengal* 6: 901–938.

Kardong, D., M. Puzari & J. Sonowal (2016). Diversity of freshwater Mollusc in Maguri beel: A floodplain Wetland of Tinsukia District in Assam, India. *International Journal of Current Research* 8(4): 29169–-29176.

Kaul, V., A.K. Pandit & D.N. Fotedar (1980). Ecology of freshwater snails (gastropod molluscs) in Haigam--a typical wetland of Kashmir. *Tropical Ecology* 21(1): 32–46.

Kumar, R., S. Parvaze, M.B. Huda & S.P. Allaie (2022). The changing water quality of lakes—a case study of Dal Lake, Kashmir Valley. *Environment Environmental Monitoring and Assessment* 194(3): 228–246. https://doi.org/10.1007/s10661-022-09869-x

Kuzminykh, A.G. & A.A. Schileyko (2005). Slugs of the family Anadenidae Pilsbry, 1948, (Gastropoda: Pulmonata) with description of two new subgenera and three new species. *Ruthenica* 15(2): 109–118.

Kuznetsov, A.G. & A.A. Schileyko (1997). New data on Enidae

(Gastropoda, Pulmonata) of Nepal. *Ruthenica* 7(2): 133–140.

Kuznetsov, A.G. & A.A. Schileyko (1999). Two new species of the genus *Pupinidius* Moellendorff, 1901 (Enidae, Pulmonata), and the distribution of the genus in Nepal. *Ruthenica* 9(2): 117–121.

Lea, I. (1834). Observations on the Naïades; and descriptions of new species of that, and other families. *Transactions of the American Philosophical Society* 5: 23–119. https://doi.org/10.2307/1004939

Mir, Z.A. & Y. Bakhtiyar (2022). Spatial and temporal variation in the diversity of malacofauna from Aripal stream of Kashmir Himalaya, India. *Journal of Threatened Taxa* 14(3): 20747–20757. https://doi.org/10.11609/jott.7165.14.3.20747-20757

Mitra, S.C., A. Dey & Ramakrishna (2004). *Pictorial Handbook – Indian Land Snails*. Zoological Survey of India, Kolkata, 344 pp.

Molluscabase. (2023). Molluscabase. Retrieved from https://www.molluscabase.org/

Mondal, P.P & Y. Zhang (2018). Research progress on changes in land use and land cover in the western Himalayas (India) and effects on ecosystem services. *Sustainability* 10(12): 4504–4518. https://doi.org/10.3390/su10124504

Nevill, G. (1878a). *Hand list of Mollusca in the Indian Museum, Calcutta. Part I: Gastropoda: Pulmonata and Prosobranchia-Neurobranchia*. Printed by order of Trustees, Calcutta, 338 pp. https://doi.org/10.5962/bhl. title.11957

Nevill, G. (1878b). *Mollusca. Scientific Results of the Second Yarkand Mission; based upon the collections and notes of the late Ferdinand Stoliczka Ph.D*. Office of the Superintendent of Government Printing, Calcutta, 21 pp.

Nevill, G. (1885). *Hand List of Mollusca in the Indian Museum, Calcutta*. P*art II. Gastropoda. Prosobranchia-Neurobranchia*. Office of Superintendent of Government Printing, Calcutta, 306 pp.

Nordsieck, H. (1973). Zur Anatomie und Systematik der Clausilien, XII, Phaedusinae, I: Phae dusenaus Nepal und ihre systematische Stellung innerhalb der Unterfamilie. *Archiv für Molluskenkunde* 103: 63–85.

Odhner, N.H. (1963). *Cathaica* (*Pseudiberus*) *chitralensis* n. sp. *Proceedings of the Malacological Society of London* 35(4): 151–153. https://doi.org/10.1093/oxfordjournals.mollus.a064912

Padma, T.V. (2014). Himalayan plants seek cooler climes: Race is on to record mountain biodiversity before it is lost. *Nature* 512(7512): 359–360.

Páll-Gergely, B., P.B., Budha, F., Naggs, T. Backeljau & T. Asami (2015). Review of the genus *Endothyrella* Zilch, 1960 with description of five new species (Gastropoda, Pulmonata, Plectopylidae). *ZooKeys* 529: 1–70. https://doi.org/10.3897/zookeys.529.6139

Pfeiffer, L. (1846a). Descriptions of twenty new species of *Helicea*, collected by Hugh Cuming, Esq. *Proceedings of the Zoological Society of London* 14: 37–41.

Pfeiffer, L. (1846b). *Symbolae ad Historiam Heliceorum*. Sumptibus & typis Th. Fischeri, Germany, 348 pp. https://doi.org/10.5962/bhl.title.11903

Pfeiffer, L. (1849). Descriptions of twenty-three new species of *Vitrina*, from the collection of H. Cuming, Esq. *Proceedings of the Zoological Society of London* 21(1): 48–53. https://doi.org/10.1111/j.1469-7998.1853.tb07179.x

Pfeiffer, L. (1854). Descriptions of eighteen new land shells, from the collection of H. Cuming, Esq. *Proceedings of the Zoological Society of London* 20: 156–160.

Pokryszko, B.M., K. Auffenberg, J.Č. Hlaváč & F. Naggs (2009). Pupilloidea of Pakistan (Gastropoda: Pulmonata): Truncatellininae, Vertigininae, Gastrocoptinae, Pupillinae (In Part). *Annales Zoologici* 59(4): 423–458. https://doi.org/10.3161/000345409x484847

Prashad, B. (1922). Observations on the invertebrate fauna of the Kumoan lakes. III. The freshwater Mollusca. *Records of the Indian Museum* 24: 11–17.

Prashad, B. (1928). On some fossil Indian Unionidae. *Records of the Geological Survey of India* 60(3): 308–312.

Prashad, B. (1937). Scientific Results of the Yale North India Expedition. Biological Report (21). Aquatic and Amphibious Molluscs. *Records of the Indian Museum* 39(3): 261–280.

Preston, H.B. (1915). *The Fauna of British India including Ceylon and Burma, Mollusca (Freshwater Gastropoda and Pelecypoda)*, Tylor and Francis, London, 244 pp.

Rajagopal, A.S. & N.V.S. Rao (1968). Aquatic and amphibious molluscs of the Kashmir valley, India. In *Proceeding of Symposium on Mollusca, Part-1, Marine Biological Association of India* 94–120.

Rajagopal, A.S. & N.V.S. Rao (1972). Some land molluscs of Kashmir, India. *Records of the Zoological Survey of India* 66(1–4): 197–212.

Rajagopal, A.S. (1973). A new species of slug (Stylommatophora: Arionidae) from Kumaum Himalayan Range, Western Himalaya. *Zoologischer Anzeiger* 190: 416–420.

Rajagopalaiengar, A.S. (1954). On a new species of land shells of the genus *Kaliella* Blanford from the Simla Hills (Mollusca, Gastropoda: Family Zonitidae). *Records of the Zoological Survey of India* 51(1): 19–21.

Ramakrishna & S.C. Mitra (2002). *Endemic Land Molluscs of India*. Occasional Paper–-196, Records of the Zoological Survey of India, Kolkata, 65 pp.

Ramakrishna, S.C. Mitra & A. Dey (2010). Annotated checklist of Indian land molluscs. Occasional Paper–306, Records of the Zoological Survey of India, Kolkata, 359 pp.

Rao, H.S. (1927). Notes on two species of aestivating gastropod molluscs from the Kangra Valley. *Records of the Zoological Survey of India* 29: 50–56.

Rao, N.V.S. (1989). *Handbook: freshwater molluscs of India*. Zoological Survey of India, Calcutta, 411 pp.

Reeve, L.A. (1848). Monograph of the genus *Bulimus*, p. 47. In: Reeve, L.A. *Conchologia Iconica, or illustrations of the shells of molluscous animals,* L. Reeve & Co., London, 89 pp. https://doi.org/10.5962/bhl.title.8129

Reeve, L.A. (1849). Monograph of the genus *Bulimus*, pp. 62–89. In: Reeve, L.A. *Conchologia Iconica, or illustrations of the shells of molluscous animals,* L. Reeve & Co., London, 89 pp. https://doi.org/10.5962/bhl.title.8129

Reeve, L.A. (1862). Monograph of the genus *Vitrina*, 1–10. In: Reeve, L.A. *Conchologia Iconica, or illustrations of the shells of molluscous animals*, L. Reeve & Co., London, 89 pp. https://doi.org/10.5962/bhl.title.8129

Saad, L.D.O., C.M. Cunha & K.D. Colpo (2019). How mollusk assemblages respond to different urbanization levels: characterization of the malacofauna in subtropical Brazilian mangroves. *Marine Biodiversity* 49: 989–999. https://doi.org/10.1007/s12526-018-0883-8

Sabin, T.P., R. Krishnan, R. Vellore, P. Priya, H.P. Borgaonkar, B.S. Bhupendra & A. Sagar (2020). Climate Change Over the Himalayas. pp. 207-222. In: Krishnan, R., J. Sanjay, C. Gnanaseelan, M. Mujumdar, A. Kulkarni, S. Chakraborty (eds) *Assessment of Climate Change over the Indian Region*. Springer, Singapore, 226 pp. https://doi.org/10.1007/978-981-15-4327-2_11

Sajan, S., B. Páll-Gergely, B. Tripathy, P. Chatterjee & K. Chandra (2020). Redescription and ecological niche of a land snail *Dicharax strangulatus* (L. Pfeiffer, 1846) in the Himalaya (Gastropoda: Cyclophoroidea: Alycaeidae). *Journal of Conchology* 43(5): 521–530.

Sajan, S., B. Tripathy, K. Chandra & K. Sivakumar (2019). A new species of the genus Macrochlamys Gray, 1847 (Stylommatophora: Ariophantidae) from western Himalaya, India. *Journal of Natural History* 53(13–14): 797–813. https://doi.org/10.1080/00222933.2019.1615566

Sajan, S., B. Tripathy, K. Sivakumar & K. Chandra (2021). New record of *Carychium indicum* Benson, 1849 from Himachal Pradesh, India. *Spixiana* 44(1): 38.

Sati, S.P., S. Sharma, Y.P. Sundriyal, D. Rawat & M. Riyal (2020). Geo-environmental consequences of obstructing the Bhagirathi River, Uttarakhand Himalaya, India. *Geomatics, Natural Hazards and Risk* 11(1): 887–905. https://doi.org/10.1080/19475705.2020.1756464

Schileyko, A.A. & C. Frank (1994). Some terrestrial Mollusca of the Nepalesian fauna. *Archiv für Molluskenkunde* 123(1-6): 127–136. https://doi.org/10.1127/arch.moll/123/1994/127

Schileyko, A.A. & A.G. Kuznetsov (1998a). Land snails of the genus *Landouria* Godwin-Austen, 1918 and some other Bradybaenidae of

Nepal (Gastropoda, Pulmonata). *Ruthenica* 8(1): 43–54.

Schileyko, A.A. & A.G. Kuznetsov (1998b). On the taxonomic position of the genus *Himalodiscus* Kuznetsov, 1996 with a description of a new species. *Ruthenica* 8(1): 85–88.

Schileyko, A.A. & I.A. Balashov (2012). *Pyramidula kuznetsovi* sp. nov. – a new species of land molluscs from Nepal (Pulmonata, Pyramidulidae). *Ruthenica* 22(1): 41–45.

Sharma, K.K., S.P. Sharma & N. Sawhney (2009). Distribution and Ecology of Some Fresh Water Molluscs of the Jammu Division of J & K State. *Journal of Environmental and Biological Sciences* 23(2): 179–181.

Strong, E.E., O. Gargominy, W.F. Ponder & P. Bouchet (2008). Global diversity of gastropods (Gastropoda; Mollusca) in freshwater. *Hydrobiologia* 595: 149–166. https://doi.org/10.1007/978-1-4020-8259-7_17

Subba, B.R & T.K. Ghosh (2008). Report on some terrestrial molluscs from different regions of Nepal. *Journal of Natural History Museum* 23: 78–81.

Subba, B.R. & T.K. Ghosh (2001). Terrestrial molluscs from Nepal. *The journal of the Bombay Natural History Society* 98(1): 58–61.

Tewari, V.P., R.K. Verma & K. Von Gadow (2017). Climate change effects in the Western Himalayan ecosystems of India: evidence and strategies. *Forest Ecosystems* 4(1): 1–9. https://doi.org/10.1186/s40663-017-0100-4

Theobald, W. (1862). Notes of a trip from Shimla to the Spiti Valley and Chomoriri (Tshomoriri) Lake during the months of July, August and September, 1861. *Journal of the Asiatic Society of Bengal* 31: 480–527.

Theobald, W. (1878). Notes on the land and fresh-water shells of Kashmir, more particularly of the Jhelum valley below Srinagar and the hills North of Jammu. *Journal of the Asiatic Society of Bengal* 47(2): 141–149.

Theobald, W. (1881). List of Mollusca from the hills between Mari and Tandiani. *Journal and Proceedings of the Asiatic Society of Bengal* 50(1): 44–49.

Tripathy, B. & A. Mukhopadhayay (2015). Freshwater molluscs of India: an insight of into their diversity, distribution and conservation, pp. 163–195. In: Chandra, K., K.C. Gopi & D.V. Rao (eds.). *Current Status of Freshwater Biodiversity in India*. Zoological Survey of India, Kolkata, 306 pp. https://doi.org/10.1007/978-81-322-2178-4_11

Tripathy, B., S.K. Sajan & A. Mukhopadhyay (2018). Mollusca, pp. 785–796. In: Chandra, K., D. Gupta, K.C. Gopi, B. Tripathy & V. Kumar (eds.). *Faunal Diversity of Indian Himalaya*. Zoological Survey of India, Kolkata, 872 pp.

United Nations (2022). Sustainable Development Goal 15. Available online: https://sdgs.un.org/goals/goal15 Accessed on 12 March 2023.

Uttam, S., S. Langer, C. Gupta & M. Dhar (2022). Multivariate analysis showing impact of different environmental factors on species richness and species density of freshwater mollusc communities inhabiting waters of north-west Himalayas. *Pollution Research Journal* 41(1): 353–361. https://doi.org/10.53550/PR.2022.v41i01.052

von Rintelen, K., E. Arida & C. Häuser (2017). A review of biodiversity-related issues and challenges in megadiverse Indonesia and other Southeast Asian countries. *Research Ideas and Outcomes* 3: 1–16. https://doi.org/10.3897/rio.3.e20860

Wiktor, A. (2001a). A review of Anadenidae (Gastropoda: Pulmonata), with a description of a new species. *Folia Malacologica* 9(1): 3–26.

Wiktor, A. (2001b). Taxonomic position of *Kasperia* Godwin-Austen, 1914 (Gastropoda: Pulmonata: Limacidae). *Folia Malacologica* 9(1): 37–38.

Wiktor, A. & K. Auffenberg (2002). Contribution to the knowledge of the terrestrial slugs of Pakistan. *Folia Malacologica* 10(1): 9–15

Wiktor, A. & U. Bössneck (2004). *Limax (Limax) seticus* n. sp. from high mountains in Nepal (Gastropoda: Pulmonata: Limacidae). *Folia Malacologica* 12(4): 183–187.

Woodward, S.P. (1856). On the land and freshwater shells of Kashmir and Tibet, collected by Dr. T. Thomson. *Proceedings of the Zoological Society of London* 24: 185–187.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 December 2023 | 15(12): 24396–24401

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

https://doi.org/10.11609/jott.8765.15.12.24396-24401

#8765 | Received 04 October 2023 | Final received 21 November 2023 | Finally accepted 28 November 2023

COMMUNICATION

Nonessential elements (Al, As, Cd, & Pb) in shrimps and mussels from southeastern Brazil

Ana Paula Madeira Di Beneditto [1], Inácio Abreu Pestana [2], Dayvison Felismindo Lima [3] & Roberto Weider de Assis Franco [4]

[1–4] Universidade Estadual do Norte Fluminense Darcy Ribeiro, Laboratório de Ciências Ambientais and Laboratório de Ciências Físicas, Av. Alberto Lamego, 2000, Campos dos Goytacazes, RJ, 28013-602, Brazil.
[1] anapaula@uenf.br (corresponding author), [2] inacio@uenf.br, [3] lima@pq.uenf.br, [4] franco@uenf.br

Abstract: The bioaccumulation of nonessential elements (Al, As, Cd, & Pb) in shrimps and mussels from southeastern Brazil (21°S–23°S) were compared. The objective was to verify and confirm the differential responses of elemental assimilation at both the taxonomic and spatial level. Two hypotheses were predicted: i) shrimps have lower element concentrations than mussels, and ii) both shrimps and mussels from the highly polluted site have higher element concentrations. The results confirmed the first hypothesis. The intense filter feeding activity of mussels explains the taxonomic difference. The second hypothesis was not validated. Both shrimps and mussels from the highly polluted site (Guanabara Bay) have lower elemental concentrations than individuals from the less polluted site. This finding is explained by the large inputs of sewage that result in partially reducing conditions of the water and high sedimentation rates, maintaining elements buried in anoxic sediment and making them unavailable for biological uptake. To understand what drives the bioaccumulation of chemical elements in marine animals it is necessary to know the species feeding habits and physiology, and the habitat characteristics in each region.

Keywords: *Artemesia longinaris*, Atlantic Ocean, Brazilian coast, hazardous elements, *Penaeus brasiliensis, Penaeus paulensis, Perna perna*, pollution, Rio de Janeiro State, *Xiphopenaeus kroyeri*.

Portuguese abstract: A bioacumulação de elementos não essenciais (Al, As, Cd, e Pb) em camarões e mexilhões do Sudeste do Brasil (21°S–23°S) foi comparada. O objetivo foi verificar e confirmar as respostas diferenciais de assimilação elementar tanto em nível taxonômico quanto espacial. Duas hipóteses foram previstas: i) os camarões têm concentrações de elementos mais baixas do que os mexilhões, e ii) tanto os camarões como os mexilhões do local altamente poluído têm concentrações de elementos mais elevadas. Os resultados confirmaram a primeira hipótese. A intensa atividade de filtração dos mexilhões explica a diferença taxonômica. A segunda hipótese não foi validada. Tanto os camarões quanto os mexilhões do local altamente poluído (Baía de Guanabara) apresentam concentrações elementares mais baixas do que os indivíduos do local menos poluído. Esse achado é explicado pelos grandes aportes de esgoto que resultam na redução parcial das condições da água e nas altas taxas de sedimentação, mantendo elementos soterrados em sedimentos anóxicos e tornando-os indisponíveis para captação biológica. Para compreender o que impulsiona a bioacumulação de elementos químicos nos animais marinhos é necessário conhecer os hábitos alimentares e a fisiologia das espécies, e as características do habitat em cada região.

Editor: Anonymity requested.

Date of publication: 26 December 2023 (online & print)

Citation: Di Beneditto, A.P.M., I.A. Pestana, D.F. Lima & R.W.deA. Franco (2023). Nonessential elements (Al, As, Cd, & Pb) in shrimps and mussels from southeastern Brazil. *Journal of Threatened Taxa* 15(12): 24396–24401. https://doi.org/10.11609/jott.8765.15.12.24396-24401

Funding: Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) (grant no. 302.598/2021-9); Fundação Carlos Chagas Filho de Amparo à Pesquisa do Estado do Rio de Janeiro (FAPERJ) (grants no. E-26/210.498/2019, E-26/200.797/2021 and E-26/200.586/2022).

Competing interests: The authors declare no competing interests.

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

Acknowledgements: We are indebted to fishers who provided the shrimps for this study and to B.C.V. Oliveira for elements determination. This research was funded by Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) (grant no. 302.598/2021-9) and Fundação Carlos Chagas Filho de Amparo à Pesquisa do Estado do Rio de Janeiro (FAPERJ) (grants no. E-26/210.498/2019, E-26/200.797/2021 and E-26/200.586/2022).

INTRODUCTION

Fish and shellfish are important to food security because they are readily available sources of animal protein that people can self-harvest throughout the year (Henchion et al. 2017). Thus, it is important to determine if the target species are safe for consumption regarding the presence of harmful agents (bacteria, viruses, parasites) and / or the concentration of chemicals (nonessential elements and other pollutants) (WHO 2019). In the aquatic environment, nonessential elements can concentrate in all compartments (water, sediment, and biota), reaching consumers via trophic transfer (Ali et al. 2019). The concentrations of chemical elements tend to be higher in more industrialized and populous areas than in areas with lower anthropic influence (Wang et al. 2013; Delgado et al. 2023).

Aluminum (Al), arsenic (As), cadmium (Cd), and lead (Pb), for instance, are biologically nonessential elements with known adverse effects. Toxic effects of Al, for instance, induce oxidative stress, immunologic alterations, and other metabolic disorders (Igbokwe et al. 2019). Arsenic is responsible for several types of cancer, especially those affecting the skin (Palma-Lara et al. 2020). Cadmium and Pb are related to neurological and kidney damage (WHO 2019). The concentrations of these elements in the fishery resources are highly variable among species (Wang et al. 2013; Silva et al. 2021).

Shrimps of the Penaeidae family are targeted by marine fisheries worldwide (FAO 2020). In Brazil, they are key resources for the economy of coastal communities (Boos et al. 2016). In southeastern Brazil, *Xiphopenaeus kroyeri* Heller, 1862, *Artemesia longinaris* Bate, 1888, *Litopenaeus schmitti* Burkenroad, 1936, *Penaeus brasiliensis* Latreille, 1817, and *P. paulensis* Perez Farfante, 1967 are the main target species (Boos et al. 2016). Shrimps are omnivorous secondary consumers with high feeding plasticity, ingesting mainly other benthic invertebrates, particulate organic matter, and benthic algae (Albertoni et al. 2003; Di Beneditto et al. 2012; Willems et al. 2016). Shrimps accumulate chemical elements mainly from feeding, whether essential or nonessential for their metabolism (Boudet et al. 2019; Di Beneditto et al. 2023).

In Brazil, the mussel *Perna perna* (L.) (Mytilidae family) is a naturalized exotic species that has become the main species of Brazilian mussel farming (Resgalla et al. 2008; Silva et al. 2018). The high abundance of *P. perna* off the Brazilian coast has made it a key resource for traditional communities that practice extractive fishing (Antunes & Mesquita 2018). Mussels are suspension-feeding organisms that obtain nutrition by filtering particulate organic matter, comprising algae, detritus, and bacteria, out of the water column (Berry & Schleyer 1983). Due to their intense filtering activity, bivalve mollusks have a well-known capacity to accumulate chemical elements in different tissues, with overall higher concentrations than other marine organisms, such as fish, shrimp, crabs, and cephalopods, from the same area (Wang et al. 2013; Catry et al. 2021).

This study compares the concentrations of the nonessential elements Al, As, Cd and Pb in the edible portion of shrimps and mussels from southeastern Brazil (22^{0}S, 43^{0}W and 23^{0}S, 41^{0}W) to verify taxonomic and spatial patterns regarding element assimilation. We predicted two hypotheses: i) shrimps have lower element concentrations than mussels, and ii) shrimps and mussels from highly polluted sites have higher element concentrations.

METHODS

The samplings were performed between 2020–2022 in the coastal waters of Rio de Janeiro State, Southeast Brazil (Figure 1). The sampling sites were named sites I and II. Site I is less polluted, facing an open sandy beach in northern Rio de Janeiro State (Figure 1). At this site, we sampled the shrimps *X. kroyeri* and *A. longinaris* and the mussel *P. perna*. Site II is highly polluted, located inside the Guanabara Bay (Rio de Janeiro municipality), which is a semi enclosed oceanic bay with 400 km^2, densely populated (~12 million people live around it) and industrialized (~6,000 industries around it) (Figure 1). At this site, we sampled the shrimps *P. brasiliensis* and *P. paulensis* and the mussel *P. perna*. All shrimps were sampled from local fisheries, while mussels were sampled directly from rocky intertidal zones.

After sampling, the individuals were stored in clean plastic bags inside an icebox and transported to the laboratory. The abdominal muscle (edible portion) of each shrimp and the soft tissue of each mussel (edible portion) were removed, stored in a dry sterile bottle, frozen (-20 °C), freeze-dried and homogenized to a fine powder using a mortar and pestle. The nonessential elements Al, As, Cd, & Pb were determined in each individual using ICP–OES (Inductively Coupled Plasma-Optical Emission Spectrometry, Model 720 ES, Varian Liberty Series II, USA). Freeze-dried muscle (0.5 g) was solubilized in 10 mL of 65% HNO_3 and heated in a digester block. Subsequently, samples were resuspended in 5 mL

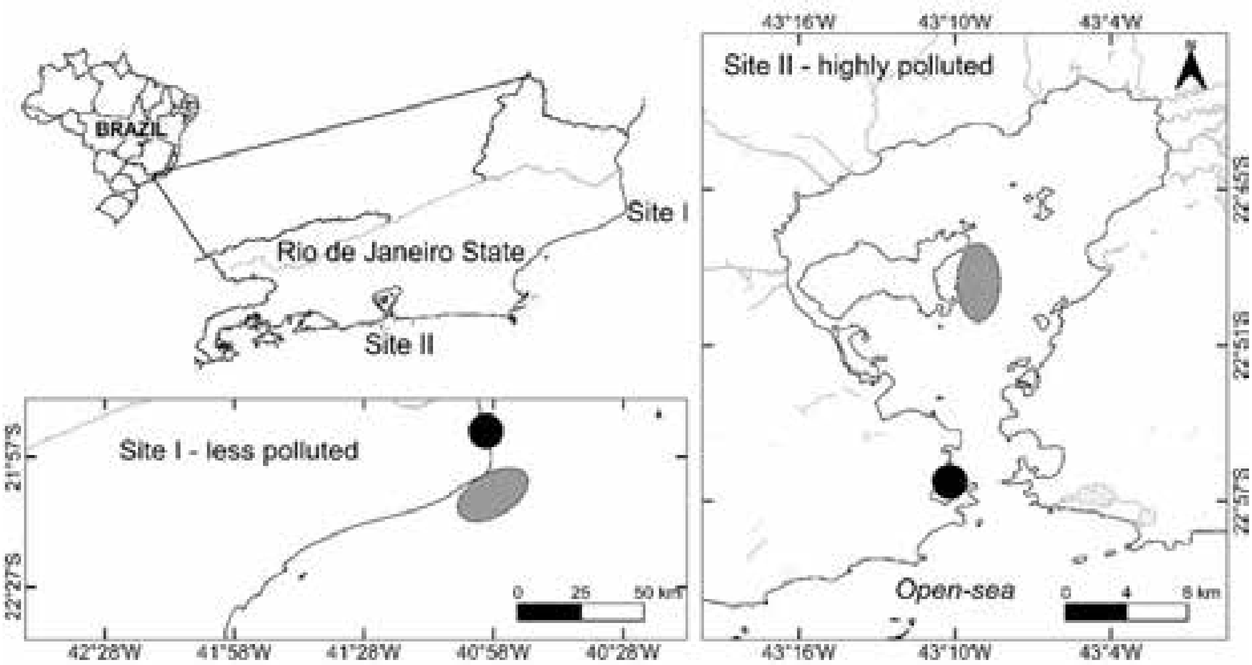

Figure 1. Map of Rio de Janeiro State, southeastern Brazil, with sites I (less polluted) and II (highly polluted) where shrimps (gray ellipses) and mussels (black circles) were sampled.

of 0.5% HNO_3 at 60 °C, filtered and brought to a final volume of 20 mL with 0.5% HNO_3. An analytical control solution was prepared to check for contamination, and a reference material (*DORM-4* fish protein, National Research Council of Canada) was analyzed to test the precision and accuracy (recovery values above 90%). The coefficients of variation among analytical replicates were <10%. All concentrations were determined in µg g^{-1} of dry weight.

Statistical analyses were performed using the R program (R Core Team 2023) considering a type I error of 5% ($\alpha = 0.05$). Descriptive statistics are reported as the median and interquartile range. An analysis of variance (ANOVA) followed by Tukey's test was used to evaluate the differences in the element concentrations regarding taxonomic groups and sampling sites. Mathematical transformations were used whenever necessary to meet the assumptions of normality, linearity, and homoscedasticity of residues using a maximum likelihood function (Venables & Ripley 2002). ANOVA assumptions were validated using diagnostic plots (Altman & Krzywinski 2016).

In addition to comparing each element separately, we also calculated and compared the normalized total load between taxonomic groups and sampling sites. It provides a holistic view of the elements' pathways, as detailed in Agostinho et al. (2021). The normalized total load represents the sum of element concentrations in each individual weighted by the number of elements detected in that individual (element load), as follow:

$$\text{Normalized total load } (\mu g \cdot g^{-1}) = \sum_{1}^{n=4} \frac{\text{Element concentration } (\mu g \cdot g^{-1})}{\text{N of Elements}}$$

RESULTS AND DISCUSSION

Samplings included two shrimp species from each site (site I: *A. longinaris* and *X. kroyeri*; and site II: *P. brasiliensis* and *P. paulensis*), and to avoid biased interpretation, we tested whether the element concentration was species dependent. The ANOVA results showed that in most cases (75%), the species from the same site did not show significant differences ($p > 0.05$) regarding element concentrations. Therefore, we grouped them only as 'shrimps' for further comparisons.

The results confirmed the first hypothesis that shrimps do have lower element concentrations than mussels, except for As at site I (Table 1 & Figure 2). This finding was corroborated by the normalized total load of nonessential elements, which was 13 times and 25 times lower in shrimp than in mussels at sites I and II, respectively (Table 1). The higher elemental concentration in the tissues of bivalve mollusks concerning other marine organisms (invertebrates and vertebrates) that share the environment is well documented elsewhere (e.g., Wang et al. 2013; Suami

Table 1. Concentration (µg·g⁻¹ dry weight) of nonessential elements (Al, As, Cd, & Pb) and normalized total load in the edible portion of shrimps and mussels from two sampling sites in Rio de Janeiro State, southeastern Brazil. Data are presented as the median ± interquartile range, and n values are the sample size.

Site I less polluted	*A. longinaris* (n = 58)	*X. kroyeri* (n = 57)	Shrimps grouped (n = 115)	*Perna perna* (n = 13)
Al	86.1 ± 35.6	84.4 ± 125.3	85.5 ± 58.5	1,781.5 ± 846.9
As	25.8 ± 9.6	20.3 ± 11.6	23.6 ± 12.4	14.4 ± 6.0
Cd	0.1 ± 0.1	0.2 ± 0.1	0.2 ± 0.1	0.5 ± 0.2
Pb	0.8 ± 0.4	0.7 ± 0.4	0.7 ± 0.4	1.0 ± 1.0
Normalized total load			35.4 ± 19.3	449.9 ± 212.8
Site II highly polluted	***P. brasiliensis* (n = 41)**	***P. paulensis* (n = 39)**	**Shrimps grouped (n = 80)**	***Perna perna* (n = 17)**
Al	13.3 ± 18	28.1 ± 29.6	16.8 ± 25.5	614.3 ± 345.7
As	3.8 ± 2.7	2.7 ± 1.8	3.1 ± 2.1	6.9 ± 2.1
Cd	0.1 ± 0.1	0.1 ± 0.1	0.1 ± 0.1	0.3 ± 0.1
Pb	0.1 ± 0.1	0.1 ± 0.1	0.1 ± 0.1	3.2 ± 2.1
Normalized total load			6.3 ± 7.5	157.1 ± 86.3

et al. 2019; Catry et al. 2021). The higher concentrations are explained by the suspension-feeding habit of bivalves, with intense filtering activity, the elements are transferred to the tissues through phytoplankton, which is at the base of the marine food chains (Santos & Boehs 2023).

Conversely, the results did not support the second hypothesis predicted in this study. Both shrimps and mussels from the highly polluted site (site II) had lower elemental concentrations than individuals from the less polluted site (site I) (Table 1 & Figure 2). The normalized total load of nonessential elements followed the same trend: six times lower in shrimps from site II and three times lower in mussels from site II (Table 1). The only exception was the Pb concentration in mussels, which was higher in individuals from site II.

Site II is Guanabara Bay (Figure 1). This semi-enclosed coastal bay suffers from several forms of anthropogenic impact threats. The edge and surroundings of this bay are heavily urbanized, receiving inputs from industrial and domestic sewage and residuals of crops (Soares-Gomes et al. 2016). Thus, a higher nonessential element concentration in organisms at site II would be expected. Site I, in turn, is an open coastal area of northern Rio de Janeiro State, sparsely populated, and whose only noteworthy anthropogenic activity in coastal waters is the Açu Harbor cargo handled (solid and liquid bulk, iron ore and oil) that began in 2014 (Zappes et al. 2016).

The unexpected result regarding the spatial pattern of element assimilation by the target species can be explained by the geochemistry of Guabanara Bay. Carvalho & Lacerda (1992) stated that element (Zn, Cu, Cd, Pb, Mn, & Ni) concentrations determined in the marine organisms (benthic algae, crustaceans, and mollusks) of Guanabara Bay were very low compared to those in other contaminated sites along Rio de Janeiro State, and they were even comparable with those in noncontaminated sites. The authors concluded that the large sewage inputs reduce conditions in the bay's water. These conditions, combined with high sedimentation rates, result in the immobilization of elements in the sediment. Consequently, these elements become unavailable for biological uptake. The same geochemistry pattern and its influence in the elements' bioavailability is reported elsewhere, as presented in the review done by Zhang et al. (2014).

The difference in the element concentrations was driven by the environment in which the target species (shrimp and mussel) belonged. The preliminary ANOVA that compared the elemental concentration in different shrimp species (site I: *A. longinaris* and *X. kroyeri*; and site II: *P. brasiliensis* and *P. paulensis*) showed that the difference in element concentrations is not species dependent, supporting this affirmation. The target species from a polluted site did not contain a necessarily high load of nonessential elements compared with those from a less polluted site due to spatial variation in the elements' bioavailability (Carvalho & Lacerda 1992; Zhang et al. 2014).

In conclusion, mussels had higher nonessential elements load than shrimps due to differences in their feeding habits and, consequently, bioaccumulation of these elements. The spatial approach showed that the geochemistry pattern of the sampling sites was probably

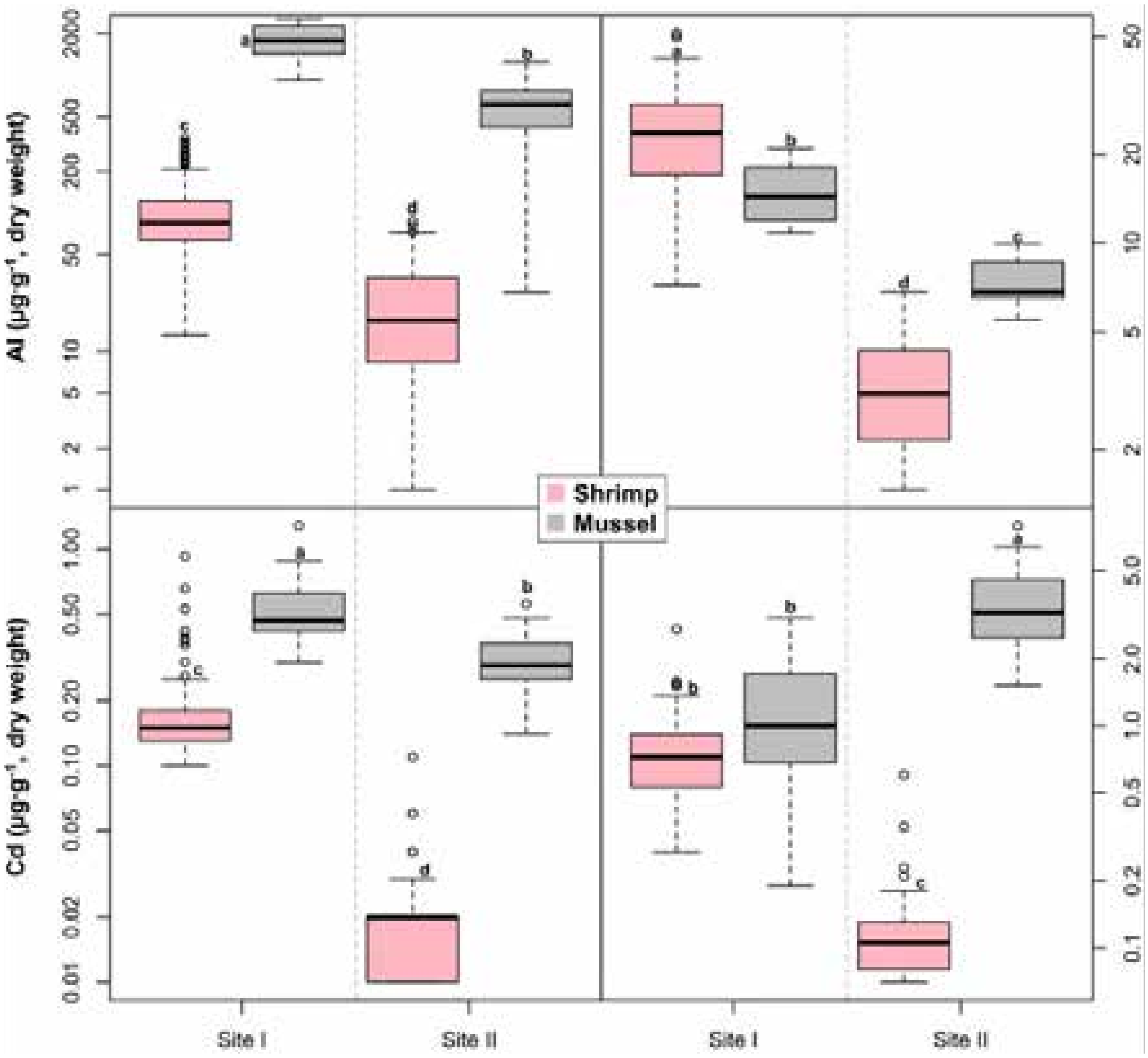

Figure 2. **Boxplots representing median (bar inside the box), interquartile range (box: 1st to 3rd quartile), minimum and maximum concentrations of the nonessential elements (Al, As, Cd, & Pb) in the edible portion of shrimps (grouped species) and mussels from two sampling sites in Rio de Janeiro State, southeastern Brazil. Lowercase letters differentiate the concentration of each element (p <0.05) between sampling sites and taxonomic groups. Open circles are outliers. The y-axis distances were log-transformed to optimize data visualization.**

the major influence for the elements' bioavailability, regardless of the target species. To understand what drives the bioaccumulation of chemical elements in marine organisms, it is necessary to know their feeding habits and physiology, besides the habitat characteristics in each region. This understanding of species for commercialization and human consumption, such as the shrimps and mussels analyzed in this study, is even more important since it affects both the local economy and public health.

REFERENCES

Agostinho, K.F.F., I.A. Pestana, C.E.V. Carvalho & A.P.M. Di Beneditto (2021). Trace elements and stable isotopes in egg yolk of green turtles on Rocas Atoll, Brazil. *Marine Pollution Bulletin* 162: 111821. https://doi.org/10.1016/j.marpolbul.2020.111821

Albertoni, E.F., C. Palma-Silva & F.D.A. Esteves (2003). Natural diet of three species of shrimp in a tropical coastal lagoon. *Brazilian Archives of Biology and Technology* 46(3): 395–403.

Ali, H., E. Khan. & I. Ilahi (2019). Environmental chemistry and ecotoxicology of hazardous heavy metals: environmental persistence, toxicity, and bioaccumulation. *Journal of Chemistry* 2019: 6730305. https://doi.org/10.1155/2019/6730305

Altman, N. & M. Krzywinski (2016). Regression diagnostics. *Nature Methods* 13: 385–386. https://doi.org/10.1038/nmeth.3854

Antunes, R.M. & E.F.M. Mesquita (2018). Exploração extrativa do mexilhão Perna perna (Mollusca: Bivalvia) no estado do Rio de Janeiro e suas questoes socioculturais, educacionais, governamentais, ambientais e de saúde coletiva: uma revisao de literatura. *Revista Vértices* 20(3): 304–316. https://doi.org/10.19180/1809-2667.v20n32018p304-316

Berry, P.F. & M.H. Schleyer (1983). The brown mussel *Perna perna* on the Natal coast, South Africa: utilization of available food and energy budget. *Marine Ecology Progress Series* 13(2-3): 201–210.

Boos, H., R.C. Costa, R.A.F. Santos, J. Dias-Neto,E. Severino-Rodrigues, L.F. Rodrigues, F. D'Incao, C.T.C. Ivo & P.A. Coelho (2016). Avaliação dos camarões peneídeos (Decapoda: Penaeidae), pp. 300-317. In: Pinheiro, M. & H. Boos (eds.). *Livro Vermelho dos Crustáceos do Brasil: Avaliação 2010-2014*. Sociedade Brasileira de Carcinologia, Porto Alegre, 466 pp.

Boudet, L.C., J. Mendieta, M.B. Romero, A.D. Carricavur, P. Polizzi & J.E. Marcovecchio (2019). Strategies for cadmium detoxification in the white shrimp *Palaemon argentines* from clean and polluted field locations. *Chemosphere* 236: 124–224. https://doi.org/10.1016/j.chemosphere.2019.06.194

Carvalho, C.E.V. & L.D. Lacerda (1992). Heavy metals in the Guanabara Bay biota: Why such low concentrations? *Ciência e Cultura* 44: 184–186.

Catry, T., C. Vale, P. Pedro, E. Pereira, M. Mil-Homens, J. Raimundo, D. Tavares & J.P. Granadeira (2021). Elemental composition of whole-body soft tissues in bivalves from the Bijagós Archipelago, Guinea-Bissau. *Environmental Pollution* 288: 117705. https://doi.org/10.1016/j.envpol.2021.117705

Delgado, J.F., R.M. Amorim, L.S. Lima,, C.C. Gaylarde, J.A.B. Neto, S.C.S. Pinto, B.F.S. Gonçalves & E.M. Fonseca (2023). Negative impacts of trace metal contamination on the macrobenthic communities along the Santos Port Complex-Brazil. *Eng* 4(2): 1210-1224. https://doi.org/10.3390/eng4020071

Di Beneditto, A.P.M., V.T. Bittar, P.B. Camargo, C.E. Rezende & H.A. Kehrig (2012). Mercury and nitrogen isotope in a marine species from a tropical coastal food web. *Archives of Environmental Contamination and Toxicology* 62: 264-271. https://doi.org/10.1007/s00244-011-9701-z

Di Beneditto, A.P.M., I.A. Pestana & C. de Carvalho (2023). Trace elements in *Penaeus* shrimp from two anthropized estuarine systems in Brazil. *Journal of Threatened Taxa* 15(6): 23403–23407. https://doi.org/10.11609/jott.8313.15.6.23403-23407

FAO (2020). The State of World Fisheries and Aquaculture 2020. Sustainability in Action. - Food and Aquaculture Organization of the United Nations, Rome. https://doi.org/10.4060/ca9229en. Electronic version accessed 21 May 2023.

Henchion, M., M. Hayes, A. Mullen, M. Fenelon & B. Tiwari (2017). Future protein supply and demand: strategies and factors influencing a sustainable equilibrium. *Foods* 6(7): 53. https://doi.org/10.3390/foods6070053

Igbokwe, I.O., E. Igwenagu & N.A. Igbokwe (2019). Aluminium toxicosis: a review of toxic actions and effects. *Interdisciplinary Toxicology* 12(2): 45-70. https://doi.org/10.2478/intox-2019-0007

Palma-Lara, I., M. Martínez-Castillo, J.C. Quintana-Pérez, M.G. Arellano-Mendoza, F. Tamay-Cach, O.L. Valenzuela-Limón, E.A. García-Montalvo & A. Hernández-Zavala (2020). Arsenic exposure: a public health problem leading to several cancers. *Regulatory Toxicology and Pharmacology* 110: 104539. https://doi.org/10.1016/j.yrtph.2019.104539

R Core Team (2023). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.r-project.org/

Resgalla, Jr. C., L.I. Weber & M.B. Conceição (2008). *O mexilhão Perna perna (L.): Biologia, ecologia e aplicações*. Interciência, Rio de Janeiro, 324 pp.

Santos, G.B.M. & G. Boehs (2023). Chemical elements in sediments and in bivalve mollusks **from estuarine regions in the south of Bahia State, northeast Brazil.** *Brazilian Journal of Biology* 83: e249641. https://doi.org/10.1590/1519-6984.249641

Silva, C.A., C.A.B. Garcia, H.L.P. Santana, G.C. Pontes, J.C. Wasserman, & S.S.L. Costa (2021). Metal and metalloid concentrations in marine fish marketed in Salvador, BA, northeastern Brazil, and associated human health risks. *Regional Studies in Marine Science* 43: 101716. https://doi.org/10.1016/j.rsma.2021.101716

Silva, E.P., R.C. Souza, T.A. Lima, F.C. Fernandes, K.D. Macario, B.M. Netto, E.Q. Alves, C. Carvalho, O. Aguilera & M.R. Duarte (2018). Zooarchaeological evidence that the brown mussel (*Perna perna*) is a bioinvader of coastal Brazil. *Holocene* 28(11): 1771–1780. https://doi.org/10.1177/0959683618788670

Soares-Gomes, A., B.A.P. da Gama, J.A. Baptista Neto, D.G. Freire, R.C. Cordeiro, W. Machado, M.C. Bernardes, R. Coutinho, F.L. Thompson & R.C. Pereira (2016). An environmental overview of Guanabara Bay, Rio de Janeiro. *Regional Studies in Marine Science* 8(2): 319–330. https://doi.org/10.1016/j.rsma.2016.01.009

Suami, R.B., D.M.M. Al Salah, C.D. Kabala, J.P. Otamonga, C.K. Mulaji, P.T. Mpiana & J.W. Poté (2019). Assessment of metal concentrations in oysters and shrimp from Atlantic Coast of the Democratic Republic of the Congo. *Heliyon* 5(12): e03049. https://doi.org/10.1016/j.heliyon.2019.e03049

Venables, W.N. & B.D. Ripley (2002). *Modern Applied Statistics with S.* Springer, New York, 497pp.

Wang, S.-L., X.-R. Xu, Y.-X. Sun, J.-L. Liu & H.-B. Li (2013). Heavy metal pollution in coastal areas of South China: A review. *Marine Pollution Bulletin* 76(1–2): 7–15. https://doi.org/10.1016/j.marpolbul.2013.08.025

WHO—World Health Organization (2019). Food safety fact sheet. https://www.who.int/news-room/fact-sheets/detail/foodsafety. Electronic version accessed 21 May 2023.

Willems, T., A. De Backer, T. Kerkhove, N.N. Dakriet, M. De Troch, M. Vincx & K. Hostens (2016). Trophic ecology of Atlantic sea-bob shrimp *Xiphopenaeus kroyeri*: intertidal benthic microalgae support the subtidal food web off Suriname. *Estuarine Coast and Shelf Science* 182(A): 146-157. https://doi.org/10.1016/j.ecss.2016.09.015

Zappes, C.A., P.C. Oliveira & A.P.M. Di Beneditto (2016). Percepção de pescadores do norte fluminense sobre a viabilidade da pesca artesanal com a implantação de megaempreendimento portuário. *Boletim do Instituto de Pesca* 42: 73-88.

Zhang, C., Z.-G. Yu, G.-M. Zeng, M. Jiang, Z.-Z. Yang, F. Cui, M.-V. Zhu, L.-G. Shen & L. Hu (2014). Effects of sediment geochemical properties on heavy metal bioavailability. *Environment International* 73: 270-281. https://doi.org/10.1016/j.envint.2014.08.010

Author details: Di Beneditto, A.P.M.: PhD in Biosciences and Biotechnology; Professor at Universidade Estadual do Norte Fluminense Darcy Ribeiro; and specialist in conservation of marina fauna. Pestana, I.A.: PhD in Ecology and Natural Resources; Researcher at Universidade Estadual do Norte Fluminense Darcy Ribeiro; Professor at Universidade Federal Fluminense; and specialist in biogeochemistry and statistic modelling. Lima, D.F.: PhD in Sciences; Reseacher at Universidade Estadual do Norte Fluminense Darcy Ribeiro; and specialist in condensed matter. Franco, R.W.A.: PhD in Sciences - Applied Physics; Professor at Universidade Estadual do Norte Fluminense Darcy Ribeiro; and specialist in condensed matter.

Author contributions: APMDiB—project administration, funding acquisition, conceptualization and investigation, shrimps sampling, writing - original draft, writing - review & editing. IAP—conceptualization and investigation, formal analysis, writing - review & editing. DFL—mussels sampling, writing - review & editing.RWAF—project administration, funding acquisition, mussels sampling, writing - review & editing.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 December 2023 | 15(12): 24402–24408

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

https://doi.org/10.11609/jott.8647.15.12.24402-24408

#8647 | Received 24 July 2023 | Final received 05 October 2023 | Finally accepted 20 November 2023

OPEN ACCESS

COMMUNICATION

Three new additions to the flora of Himachal Pradesh, India from Khokhan Wildlife Sanctuary, Kullu District

Ashutosh Sharma [1], S. Noorunnisa Begum [2], G.S. Goraya [3], Gopal S. Rawat [4] & Vaneet Jishtu [5]

[1,2] Foundation for Revitalisation of Local Health Traditions, The University of Trans-Disciplinary Health Sciences and Technology (FRLHT-TDU), # 74/2, Jarakabande Kaval, Attur, Bengaluru, Karnataka 560064, India.
[3] Former Pr. Chief Conservator of Forests (HoFF), Himachal Pradesh Forest Department, Teachers' Colony, Hira Mahal, Nabha, Patiala District, Punjab 147201, India.
[4] Wildlife Institute of India, Post Box #18, Chandrabani, Dehradun, Uttarakhand 248001, India.
[5] Himalayan Forest Research Institute (HFRI), Conifer Campus, Panthaghati, district Shimla, Himachal Pradesh 171013, India.
[1] ashutosh05sn@gmail.com (corresponding author), [2] noorunnisa.begum@tdu.edu.in,
[3] gurinder9@hotmail.com, [4] gsrawat59@gmail.com, [5] vjishtuv@gmail.com

Abstract: *Chamabainia cuspidata* Wight (Urticaceae), *Debregeasia orientalis* C.J.Chen (Urticaceae), and *Hydrocotyle himalaica* P.K.Mukh. (Araliaceae) are being reported here as new additions to the flora of Himachal Pradesh, India. All three species were collected from Khokhan Wildlife Sanctuary in Kullu district. Of these, *H. himalaica* also forms an addition to the flora of western Himalayan region. Detailed description, distribution, information on habitat and colour photographs of all three species are provided for easy identification in the field.

Keywords: Araliaceae, *Debregeasia orientalis*, floristics, taxonomy, Urticaceae, Western Himalaya.

Editor: Asok Ghosh, The University of Burdwan, West Bengal, India. **Date of publication:** 26 December 2023 (online & print)

Citation: Sharma, A., S.N. Begum, G.S. Goraya, G.S. Rawat & V. Jishtu (2023). Three new additions to the flora of Himachal Pradesh, India from Khokhan Wildlife Sanctuary, Kullu District. *Journal of Threatened Taxa* 15(12): 24402–24408. https://doi.org/10.11609/jott.8647.15.12.24402-24408

Funding: None.

Competing interests: The authors declare no competing interests.

Author details: Ashutosh Sharma is a plant taxonomist currently pursuing his doctoral studies at The University of Trans-Disciplinary Health Sciences and Technology (TDU) Bangalore, he is working on the flora of Himachal Pradesh from 2018 with special interest in family Balsaminaceae and Orchidaceae. Dr. S. Noorunnisa Begum is associate professor at TDU and curator of FRLH National Herbarium of Medicinal Plants and Repository of Raw Drugs, her research over the last 20 years has focused on establishment of FRLH Herbarium and Raw Drug Repository of Medicinal Plants used in Indian System of Medicine and traded in the country. Dr. G.S. Goraya has served as former Principal Chief Conservator of Forests and HoFF, Himachal Pradesh Forest Department, he is currently independently working on the flora of Himachal Pradesh. Gopal S. Rawat currently works as Senior Research Affiliate at the Wildlife Institute of India (WII) Dehradun, formerly he had served at WII as Faculty, Dean and Director. Dr. Vaneet Jishtu is Scientist- E at ICFRE - Himalayan Forest Research Institute, Shimla, he is an experienced field botanist specialising in high altitude Himalayan flora and he has pioneered in setting up an arboretum and botanical garden at HFRI, Shimla.

Author contributions: Ashutosh Sharma designed the research as a part of his master's thesis work and S. Noorunnisa Begum supervised the work; Ashutosh Sharma & G.S. Goraya carried out field surveys and collected the material; Ashutosh Sharma, Gopal S. Rawat, Vaneet Jishtu S. Noorunnisa Begum & G.S. Goraya drafted the manuscript; Ashutosh Sharma revised the manuscript. All authors read and approved the final manuscript.

Acknowledgements: The first author (AS) is thankful to Smt. Archana Sharma (ex. PCCF Wildlife, Himachal Pradesh Forest Department) for providing with the necessary permission to survey in Khokhan WLS; to Smt. Meera Sharma (Director, GHNP, Kullu) and Sh. Nishant Mandhotra (DFO, GHNP) for their encouragement and support. AS also acknowledge help from forest guard Mr. Dharamveer and Mr. Sunil Thakur in smoothly conducting the extensive field surveys. Authors also thank the anonymous reviewers for their insightful comments, suggestions and refining the manuscript.

INTRODUCTION

The state of Himachal Pradesh, India forms the central part of western Himalaya, which is one of the important floristic regions in the Indian sub-continent and is also a part of Himalayan biodiversity hotspot (CEPF 2023). This region has had a long history of botanical explorations and its flora is relatively well documented. The flora of Himachal Pradesh has been studied by a number of workers (Collett 1921; Nair 1977; Chowdhery & Wadhwa 1984; Aswal & Mehrotra 1994; Dhaliwal & Sharma 1999; Singh & Rawat 2000; Kaur & Sharma 2004; Singh & Sharma 2006; Subramani et al. 2014; Singh 2018; Singh et al. 2019; Sinha et al. 2019). Despite detailed surveys and systematic enumeration of flora in different sub-regions, several localities still remain under-explored and fresh collections are lacking for several taxonomically challenging groups. We selected Khokhan Wildlife Sanctuary (WS) (Image 1), a little-known protected area in Kullu District of Himachal Pradesh in order to make a floristic inventory and to identify the species of high conservation significance. Results of detailed surveys conducted during this work are presented in Sharma (2023). The sanctuary has a geographical area of about 14.94 km^2, and is situated within the geo-coordinates north (31.8805N, 77.0805E), east (31.8602N, 77.1150E), south (31.8288N, 77.0822E), and west (31.8486N, 77.0552E) and is characterized by temperate climate and a wide altitudinal range (1,500–2,790 m) harbouring 510 species of plants (Sharma 2023).

In this communication, we report the occurrence of three interesting species of angiosperms collected by the first author from Khokhan WS which form new additions to the flora of Himachal Pradesh. These species are *Chamabainia cuspidata* Wight (Urticaceae), *Debregeasia orientalis* C.J.Chen (Urticaceae) and *Hydrocotyle himalaica* P.K.Mukh. (Araliaceae). Perusal of the literature on the flora of western Himalaya, from the state and 'Checklist of Flowering Plants of India' (Karthikeyan et al. 2009; Mao & Dash 2020; Pusalkar et al. 2022) reveal that so far, they have not been reported from the state. While *C. cuspidata* and *D. orientalis* are previously known from eastern part of Uttarakhand, *Hydrocotyle himalaica* is being reported for the first time from the western Himalayan region. Since all the three species are rather inconspicuous and little known, we have provided systematic treatment for these three species along with author citations, morphological description, phenology, updated global distribution, information on habitat and colour photographs for easy identification in the field. Additionally, the voucher specimens are deposited at FRLH, Bengaluru & BSS, Solan herbarium for the future references (Herbaria code follow Thiers 2023).

Systematic Treatment

Chamabainia cuspidata Wight, Icon. Pl. Ind. Orient. 6: 11. t. 1981 (1853); Hook.f., Fl. Brit. India 5: 580 (1888); Murti & Pusalkar, Fl. Pl. India Annot. Checkl. 1: 516 (2020); Murti & Pusalkar, Fl. Ind. 24: 28 (2022). *Boehmeria squamigera* Wedd., Ann. Sci. Nat., Bot., sér. 4, 1: 203 (1854). *Chamabainia squamigera* (Wedd.) Wedd, in A.DC., Prodr. 16(1): 218 (1869). (Image 2, G–J)

Lectotype: India, Tamil Nadu, Neelgherry [Nilgiris], Oct. 1852, R. Wight s.n. (K000741409!).

Synonyms

Boehmeria squamigera Wedd. in Ann. Sci. Nat., Bot., sér. 4, 1: 203 (1854)

Chamabainia cuspidata var. *denticulosa* W.T.Wang & C.J.Chen in Acta Bot. Yunnan. 3: 16 (1981)

Holotype—China, Yunnan: Fengqing, Wumulung, 2,400 m, under the bamboo forest, 09.vii.1938, T.T. Yu 16626 (PE).

Chamabainia cuspidata var. *morii* (Hayata) W.T. Wang in Acta Bot. Yunnan. 3: 15 (1981)

Chamabainia morii Hayata in J. Coll. Sci. Imp. Univ. Tokyo 30(1): 282 (1911)

Type—Taiwan, 01.vii.1908, Takiya Kawakami and Ushinosuke Mori7101 (TAIF8259) (TAIF!)

Chamabainia squamigera (Wedd.) Wall. ex Wedd. in A.P.de Candolle, Prodr. 16(1): 218 (1869)

Perennial creeping herbs, 10–60 cm long, monoecious or dioecious; stem and branches slender, ascending or procumbent, creeping and rooting at lower nodes, purplish, reddish-brown, sometimes greenish, strigose or hairy with mixed pilose hairs. Leaves opposite, usually equal or sub-equal in pairs (at nodes), sometimes unequal, narrow or broad ovate to rhombic-ovate, sub-rotund, elliptic or elliptic-ovate, 1.5–6 x 1–4 cm, base rounded or cuneate, oblique, margin bluntly or acutely serrate, apex acute to acuminate, 3-veined from base, surfaces glabrous, sparsely pubescent or lower surface pilose or strigose, often densely so along veins. Petioles 4–15 mm long, strigose; stipules four at each node, orbicular to obliquely ovate or triangular to oblong-lanceolate, mucronate, to 1 cm long, brown when dry, persistent, enclosing flower buds. Flowers sessile, subsessile or pedicellate, 0.5–1.5 cm across, in axillary fascicled glomerules; male glomerules in distal axils; female dense, proximal or sometimes

Image 1. Khokhan Wildlife Sanctuary map with approximate locations of species marked as A—*Chamabainia cuspidata* | B—*Debregeasia orientalis* | C—*Hydrocotyle himalaica*. Map made using Google Earth Pro.

mixed in the middle part of the stem. Male flowers subsessile; perianth lobes 3–4, equal or subequal, connate below, gibbous, mucronate, 1.5–3.5 mm long, puberulous or hairy above; stamens 3 or 4, exserted, pistillode rudimentary, clavate. Female flowers sessile, compactly aggregated into fascicles of 2–4, embraced by broad ovate, membranous bract; perianth tubular, subcompressed, contracted above, minutely 2–4

Image 2. A–E—*Debregeasia orientalis* C.J.Chen: A–B—flowering twig | C—buds | D—leaf (dorsal) | E—leaves (ventral) | F—inflorescence | G–J—*Chamabainia cuspidata* Wight: G–H—plant habit | I—infructescence & bracts | J—male inflorescence. © Ashutosh Sharma.

toothed, hirsute, enlarged and thin.

Flowering: July–September; **Fruiting:** August–October.

Habitat: *Chamabainia cuspidata* is found in small patches in shady moist forests, especially along stream courses and moist boulders between 1,900–2,400 m in Khokhan WS in association with *Hydrocotyle himalaica* P.K.Mukh., *Impatiens* spp., *Onychium lucidum* (D. Don) Spreng., *Parochetus communis* Buch.-Ham. ex D.Don, *Rubus macilentus* Cambess, *Sarcococca saligna* (D. Don) Müll.Arg., *Selaginella* sp. and *Girardinia diversifolia* (Link) Friis.

Distribution: India (Arunachal Pradesh, Himachal Pradesh (present work), Meghalaya, Sikkim, Tamil Nadu, Uttarakhand, West Bengal, Assam), Bhutan, China, Indonesia, Myanmar, Nepal, Sri Lanka, Taiwan, and Vietnam.

Specimens examined: 125441 (FRLH), 23.viii.2022, India, Himachal Pradesh, Kullu district, Khokhan WS, stream courses near Munjhag, 2,300 m, coll. Ashutosh Sharma; 5443 (BSS), 23.viii.2022, India, Himachal Pradesh, Kullu district, Khokhan WS, stream courses near Munjhag, 2,300 m, coll. Ashutosh Sharma; s.n. (K000741409) (K), x.1852, India, Neelgherry, coll. Wight; 4592(K000741410) (K), 1821, Nepal, coll. N. Wallich; 7101 (TAIF8259)(TAIF), 01.vii.1908, Taiwan, coll. Takiya Kawakami and Ushinosuke Mori.

Note: Recently the species was also observed at McLeod Ganj (near Bhagsu Nag waterfall), Dharamshala, Kangra district, Himachal Pradesh by the first author (AS).

Debregeasia orientalis C.J. Chen Novon 1: 56 (1991); Murti & Pusalkar in Mao & S.S. Dash, Fl. Pl. India Annot. Checkl. 1: 517 (2020); Murti & Pusalkar, Fl. Ind. 24: 32 (2022). (Image 2, A–F).

Holotype: China, southeastern Sichuan: Nanchuan Co., Sanquan, Longguxi, 550 m, alongstreams, 27.iii.1957, G.F. Li 60238 (PE); isotype (SZ).

Shrubs 1–3 m high, generally dioecious, rarely monoecious; branchlets slender, reddish, sparsely pubescent with usually fine appressed hairs or subglabrous. Leaf blade adaxially dark green, oblong to linear-lanceolate, rarely linear, 5–18(–24) × 1–2.5(4) cm, papery or thinly so, 3-veined at base, lateral ones straight, reaching to middle, secondary veins 3–5 on each side from middle of leaf, anastomosing along margins, abaxial surface thinly greenish-grey, sparsely appressed pubescent on distinct veins, adaxial surface sparsely appressed strigose, often rugose, base rounded or broadly cuneate, margins finely serrulate or denticulate, apex acuminate; petioles 0.5–2.5 cm long, pubescent; stipules oblong-lanceolate, 5–10 mm long, 2-cleft. Inflorescence on previous years' branches, usually appearing before foliage, axillary, solitary or 1–2 times dichotomously branched, 0.5–1.5 cm long, with up to 1.5 cm long peduncle, appressed pubescent; flowers in dense, globose clusters/glomerules, 3–5 mm across; bracts membranous, obovate or triangular, 0.2–1 mm long. Male flowers: short pedicellate; perianth lobes (3–)4, triangular-ovate, acute, sparsely puberulent; stamens (3–)4; rudimentary ovary sessile, obovoid. Female flowers: sessile, obovoid, 0.7–2 mm across; perianth tube membranous, glabrous, 4-denticulate. Fruit orange, of fleshy perianths, enclosing ovoid, subcompressed, 0.5–1 mm long achene.

Flowering: March–May; **Fruiting:** June–August.

Habitat: *Debregeasia orientalis* is found in shady moist forests especially along ravines between 1,700–2,000 m in Khokhan WS. Common associates of this species are *Bergenia ciliata* (Haw.) Sternb., *Debregeasia saeneb* (Forssk.) Hepper & J.R.I.Wood, *Drepanostachyum falcatum* (Nees) Keng.f., *Machilus duthiei* King ex Hook.f., *Neolitsea pallens* (D.Don) Momiy. & H.Hara, *Polystichum squarrosum* (D.Don) Fée, *Rubus macilentus* Cambess. and *Urtica* sp.

Distribution: India (Himachal Pradesh (present work), Uttarakhand, northeastern India), Bhutan, China, Japan, Nepal, and Taiwan.

Specimens examined: 125701 (FRLH), 06.iv.2023, India, Himachal Pradesh, Kullu district, Khokhan WS, Khanogi Nallah, 2,000 m, coll. Ashutosh Sharma & G.S. Goraya; 5450 (BSS), 06.iv.2023, India, Himachal Pradesh, Kullu district, Khokhan WS, Khanogi Nallah, 2,000 m, coll. Ashutosh Sharma & G.S. Goraya; 45257 (BM014617834) (BM), 22.vii.2023, China, Yunnan Province, Jiangchuan, 1,950–2,150 m, coll. David Edward Boufford, Jian-Ling Guo, Lin Su, Xin Yu.

Hydrocotyle himalaica P.K. Mukh., Indian Forester 95: 470 (1969); P.K.Mukh., R.Manik. & Murug. in Mao & S.S.Dash, Fl. Pl. India Annot. Checkl. 1: 623 (2020). *Hydrocotyle podantha* Molk. in Karthik., Sanjappa & Moorthy, Fl. Pl. India 1: 111 (2009). *Hydrocotyle javanica* Thunb. var. *podantha* C.B.Clarke in J.D.Hooker Fl. Brit. India 2: 668. (1879) (Image 3).

Holotype: India, Khursiong, 1,445 m, 24.ix.1884, C.B.Clarke 35825 A (CAL0000015439) (CAL!).

Decumbent, creeping herbs; stem 10–45 cm long, ferruginous tomentose with dark purple-brown hairs. Leaves simple, alternate, petiolate, stipulate; petiole 2.5–15 cm long, tomentose; lamina orbicular or reniform, 2–8 cm in diameter, obtuse, repand crenate, shallowly

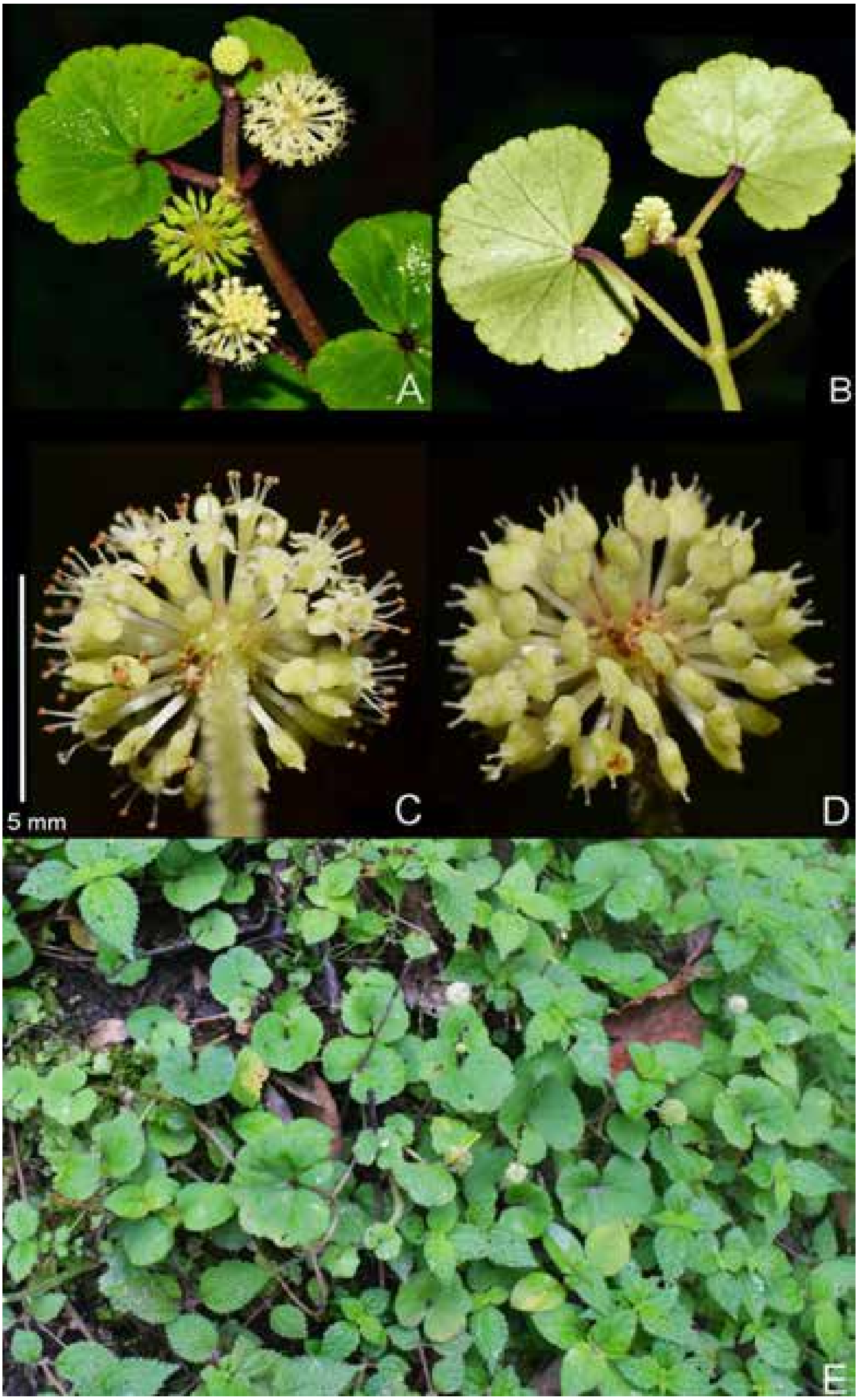

Image 3. *Hydrocotyle himalaica* P.K.Mukh: A—flowering twig & leaves (ventral view) | B—leaves (dorsal view) | C—inflorescence | D—infructescence | E—plant habit (growing with *Chamabainia cuspidata* and others). © Ashutosh Sharma.

5–7 lobed, lobes rounded, sinus wide, chartaceous, both surfaces sparsely hirsute; main nerves 9, raised on ventral surface, rough and bristly; stipules opposite, 2–3 mm long, ovate, membranaceous. Inflorescence solitary, simple, umbellate, densely capitate in flower, about 40 flowered, 1.4 cm in diameter; peduncle leaf opposed, 3–7 cm long, ferruginous. Flowers 1.5–1.7 mm long, bisexual; pedicels 0.5–0.7 cm long, puberulous. Calyx 5-lobed, minute, ±1 mm long, hairy outside. Corolla polypetalous, petals 5, white to pale yellowish, 1-1.3 mm long, triangular, membranaceous, apex slightly incurved, base broad. Stamens 5, ±1.7 mm long, exceeding the petals, anthers yellow, dorsifixed, bilobed. Ovary 2-celled, style 1 mm long, bifid; stigma obtuse. Fruit brown to purplish-red, sub-orbicular, 1 × 1.5–2 mm, broader than long, primary ridge indistinct.

Flowering: July–September; **Fruiting:** August–September.

Habitat: *Hydrocotyle himalaica* is found growing in moist evergreen forests especially in shaded damp areas between 1,800–2,100 m in Khokhan WS. Common associates of this species include *Bistorta amplexicaulis* (D.Don) Greene, *Chamabainia cuspidata* Wight, *Hydrocotyle javanica* Thunb., *Lysimachia debilis* Wall., *Oplismenus burmanni* (Retz.) P. Beauv., *Potentilla indica* (Andrews) Th.Wolf, *Sanicula elata* Buch.-Ham. ex D.Don, *Selaginella* sp. and *Viola canescens* Wall.

Distribution: India (Arunachal Pradesh, Assam, Himachal Pradesh (present work), Meghalaya, Sikkim, Darjeeling), Bhutan, China, Myanmar, and Nepal.

Specimens examined: 125442 (FRLH), 30.vii.2022, India, Himachal Pradesh, Kullu district, Khokhan WS, Kandi, 1,900 m, coll. Ashutosh Sharma; 5440 (BSS), 30.vii.2022, India, Himachal Pradesh, Kullu district, Khokhan WS, Kandi, 1,900 m, coll. Ashutosh Sharma; 35825 A (CAL0000015439) (CAL), India, Khursiong, 1,445 m, 24.ix.1884, C.B.Clarke; s.n. (MW0743359) (MW), 25.ix.2009, Nepal, Mustang Prov., Larjung village, 2,400 m, coll. A. Sukhorukov & A. Konstantinova.

Note: Recently, the species was also observed at McLeod Ganj (near Bhagsu Nag waterfall), Dharamshala, Kangra district, Himachal Pradesh by the first author (AS).

REFERENCES

Aswal, B.S. & B.N. Mehrotra (1994). *Flora of Lahaul-Spiti.* Bishen Singh Mahendra Pal Singh, Dehradun, 761 pp.

CEPF (2023). Biodiversity Hotspot maps. Conservation International Foundation. Published on the internet; https://www.cepf.net/our-work/biodiversity-hotspots/himalaya. Accessed 25 August 2023.

Chowdhery, H.J. & B.M. Wadhwa (1984). *Flora of Himachal Pradesh, Analysis Vols. 1–3*. Botanical Survey of India, Calcutta, 860 pp.

Collett, H. (1921). *Flora Simlensis: A Handbook of the Flowering Plants of Simla and the Neighbourhood*. Thacker Spink and Co., Calcutta, 652 pp.

Dhaliwal, D.S. & M. Sharma (1999). *Flora of Kullu District, Himachal Pradesh*. Bishen Singh Mahendra Pal Singh, Dehra Dun, India, 744 pp.

Karthikeyan, S., M. Sanjappa & S. Moorthy (2009). *Flowering Plants of India: Dicotyledons Volume 1 (Acanthaceae - Avicenniaceae)*. Botanical Survey of India, Kolkata, 111 pp.

Kaur, H. & M. Sharma (2004). *Flora of Sirmaur (Himachal Pradesh)*. Bishen Singh Mahendra Pal Singh, Dehra Dun, 770 pp.

Mao, A.A. & S.S. Dash (2020). *Flowering Plants of India: An Annotated Checklist (Dicotyledons). Volume 1–2*. Botanical Survey of India, Kolkata, 970 pp, 705 pp.

Nair, N.C. (1977). *Flora of Bashahr Himalayas*. International Biosciences Publishers, Hissar, Madras, India, 360 pp.

Pusalkar, P.K., A.A. Mao & P. Ingle (2022). *Flora of India. Volume 24. Urticaceae – Ceratophyllaceae.* Botanical Survey of India, Kolkata, 688 pp.

Sharma, A. (2023). *Plants of Khokhan Wildlife Sanctuary, Kullu district, Himachal Pradesh*. M.Sc. Thesis, The University of Trans-Disciplinary Health Sciences and Technology, xi + 168 pp.

Singh, H. & M. Sharma (2006). *Flora of Chamba District, Himachal Pradesh*. Bishen Singh Mahendra Pal Singh, Dehradun, 881 pp.

Singh, P.B. (2018). *Flora of Mandi District Himachal Pradesh: North West Himalaya*. Bishen Singh Mahendra Pal Singh, Dehradun, India, 723 pp.

Singh, P., S.S. Dash & B.K. Sinha (2019). *Plants of Indian Himalaya Region. An Annotated Checklist & Pictorial Guide Part I*. Botanical Survey of India, Kolkata, 448 pp.

Singh, S.K. & G.S. Rawat (2000). *Flora of Great Himalayan National Park, Himachal Pradesh*. Bishen Singh Mahendra Pal Singh, Dehradun, India, 304 pp.

Sinha, B.K., S.S. Dash & P. Singh (2019). *Plants of Indian Himalaya Region. An Annotated Checklist & Pictorial Guide Part II*. Botanical Survey of India, Kolkata, 863 pp.

Subramani, S.P., K.S. Kapoor & G.S. Goraya (2014). Additions to the floral wealth of Sirmaur District, Himachal Pradesh from Churdhar Wildlife Sanctuary. *Journal of Threatened Taxa* 6(11): 6427–6452. https://doi.org/10.11609/JoTT.o2845.6427-52

Thiers, B. (2023). *Index Herbariorum: A Global Directory of Public Herbaria and Associated Staff.* New York Botanical Garden's Virtual Herbarium. Available from: http://sweetgum.nybg.org/science/ih/. Accessed 05 July 2023.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 December 2023 | 15(12): 24409–24419
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.8696.15.12.24409-24419
#8696 | Received 18 August 2023 | Final received 21 November 2023 | Finally accepted 11 December 2023

COMMUNICATION

Comparative morphological and ethnobotanical assessment of certain taxa of genus *Glochidion* (Phyllanthaceae) from Assam, India

Priyanka Brahma [1] & **Sanjib Baruah** [2]

[1,2] Department of Botany, Bodoland University, Kokrajhar, Assam 783370, India.
[1] priyabrahma659@gmail.com (corresponding author), [2] sanjibbaruah9@gmail.com

Abstract: The genus *Glochidion*, a member of the family Phyllanthaceae, primarily comprises shrub or tree species. It stands out from other genera due to distinctive reproductive features, including prolonged styles in flowers and fruits, apiculate anthers, and lobed and unlobed capsules. This study aimed to compare the morphological characteristics of nine taxa in Assam to facilitate identification and assess ethnobotanical knowledge. Ethnobotanical information was gathered by interviewing the local community, and a taxonomic key was provided for accurate identification. Morphological data underwent principal component analysis (PCA) and cluster analysis using PAST for validation. The comparison revealed distinct characteristics in both vegetative and reproductive traits among *Glochidion* members. Reproductive features, such as inflorescence, style, ovary, and capsules, were key factors for differentiation and identification. PCA and cluster analysis demonstrated correlation and variation among the taxa, contributing significantly to their demarcation. Ethnobotanical studies indicated the genus's potential medicinal properties, supported by both primary and secondary information.

Keywords: Angiosperms, cluster analysis, ethnobotany, PCA, Phyllanthoideae, taxonomy, UPGMA.

Editor: Kannan C.S. Warrier, ICFRE - Institute of Forest Genetics and Tree Breeding, Coimbatore, India. **Date of publication:** 26 December 2023 (online & print)

Citation: Brahma, P. & S. Baruah (2023). Comparative morphological and ethnobotanical assessment of certain taxa of genus *Glochidion* (Phyllanthaceae) from Assam, India. *Journal of Threatened Taxa* 15(12): 24409–24419. https://doi.org/10.11609/jott.8696.15.12.24409-24419

Funding: None.

Competing interests: The authors declare no competing interests.

Author details: Dr. S. Baruah is working as an assistant professor at the Department of Botany, Bodoland University, Kokrajhar, Assam. SB has 15 years of research and teaching experience on the plant taxonomy and conservation of threatened plants in north-east India. Priyanka Brahma is a bona fide Ph.D. research scholar in the Department of Botany at Bodoland University. PB is pursuing her PhD on the taxonomy and phytochemistry of *Glochidion* in Assam.

Author contributions: PB has collected, done photography, identified, carried out the morphological analysis of the specimen, performed the PCA and cluster analysis and drafted the manuscript. SB contributed to the present study's design, supervised the work and revised the manuscript. The final manuscript was examined and approved by both the authors.

Acknowledgements: The authors are grateful to the Assam State Biodiversity Board (ASBB) and PCCF (Chief Wildlife Warden), Panjabari, Assam for granting permission to collect the specimen in protected areas of Assam. The authors are thankful to the authorities of BSI, Shillong, Meghalaya for providing the accession number of the deposited specimen. We also acknowledge the local villagers and traditional healers for sharing their knowledge on the collected specimens. The first author is thankful to the University Grants Commission for the National Fellowship and Scholarship for Higher Education of ST Students (NFST) scheme (Award No. 202021-NFST-ASS-01128) and the Government of India, Ministry of Tribal Affairs, Scholarship Division for financial assistance with her Ph.D.

INTRODUCTION

Northeastern India, including Assam, has a wide variety of vegetation due to its topographic and climatic diversity. It is one of the most diverse regions in the world (Dutta & Dutta 2005; Mao & Roy 2016; Bhattacharyya et al. 2020). The people of Assam have employed a number of plants to treat a wide range of ailments since ancient times (Kanjilal et al*.* 1940; Bhattacharya et al*.* 1991). There are many medicinal plants in the area that are well-known to ethnic communities, and Assam is regarded as one of the ecological hot spots in the world (Myers et al*.* 2000; Asati & Yadav 2004; Saikia et al*.* 2006).

The species of *Glochidion* J.R.Forst. & G.Forst. have been used by local people in different places in the world and have immense value in the field of medicine (Lai et al. 2004; Xiao et al. 2008; Bajpai et al*.* 2016; Chakrabarty & Balakrishnan 2018). Some important biological and pharmacological activities, including the anticancer, antioxidant, and antimicrobial activities of a few members of *Glochidion* have been reported by many workers (Azam et al. 2012; Rathod & Rajurkar 2017). The people of India mainly rely on medicinal plants and are well-known for ethnobotanical knowledge (Maikhuri & Gangwar 1993; Prakash et al. 2008). Therefore, it was felt worth exploring the genus *Glochidion* in Assam for its current taxonomy and to assess its ethnomedicinal uses.

The genus *Glochidion* J.R.Forst. & G.Forst. is a member of the family Phyllanthaceae which is native to northern Australia, Polynesia, southern Asia, and tropical Asia (Chakrabarty & Balakrishnan 2018). The members of the genus are either shrubs or trees, monoecious, pubescent, or glabrous with drooping branches. They are mostly found in evergreen, moist deciduous, tropical, primary and secondary forests, sal forests, hilly areas, and some swampy areas. There are over 320 species worldwide; about 22 species, and eight varieties in India (Balakrishnan & Chakrabarty 2007; Balakrishnan et al. 2012; Chakrabarty & Balakrishnan 2018; Brahma & Baruah 2023). Kanjilal et al. (1940) designated 16 species from erstwhile Assam in 'Flora of Assam'. At present 12 species and four varieties of the genus are found in Assam (Chakrabarty & Balakrishnan 2018). Traditionally, *Glochidion* was placed in Euphorbiaceae (Bentham & Hooker 1862–1883; Hutchinson 1973). Later, Hoffmann et al. (2006) discovered that the genus *Glochidion* sensu lato includes *Breynia* J.R.Frost & G.Forst., *Flueggea* Willd. and *Margaritaria* L.f., which are all allied to *Phyllanthus* as members of the tribe Phyllantheae and, therefore, belong to the segregate family Phyllanthaceae, and this was later ascertained by Chase et al. (2016) on the molecular basis. The absence of latex and the bi-ovulate ovary distinguish the family Phyllanthaceae from Euphorbiaceae (Chakrabarty & Balakrishnan 2018).

Earlier in some floras, *G. ellipticum* used to be referred to as *G. assamicum*, a synonym of *G. ellipticum*; *G. velutinum*, i.e., synonym of *G. heyneanum*; *G. hirsutum* or *G. tomentosum*, i.e., synonym of *G. zeylanicum* var. *tomentosum;* and *G. arborescens*, i.e., synonym of *G. zeylanicum* var. *arborescens* (Hooker 1890; Kanjilal et al. 1940). According to recent literature and taxonomy data, the taxa *G. ellipticum*, *G. heyneanum*, *G. zeylanicum* var. *tomentosum*, *G. zeylanicum* var. *arborescens* are the accepted names (Chakrabarty & Balakrishnan 2018; WFO 2023).

The present study aimed to resolve the taxonomic identity of certain members of the genus *Glochidion* based on their morphology. The principal component analysis (PCA) and cluster analysis were carried out to authenticate the morphological evaluation of the taxa studied. All the relevant ethnobotanical information about the *Glochidion* taxa collected from Assam was documented based on primary sources that could yield potential information in the field of medical research.

MATERIALS AND METHODS

Sample collection, Identification, and Ethnobotanical assessment

Field surveys were conducted in the diverse forest areas in Assam from December 2019 to January 2023. Before conducting the field survey, approval was taken from Assam State Biodiversity Board (ASBB) and PCCF Wildlife Warden, Panjabari, Assam. *Glochidion* specimens were collected randomly from various locations in Assam, India (Table 1). During the field, collected specimens were taken in an airtight poly bag for further morphological examination and photographs of the specimens were taken using a Realme XT 64 MP mobile camera phone. Garmin GPS etrex 10 was used to record and identify precise latitudes and longitudes of the area of the specimen. In the lab, both vegetative and reproductive characteristics of freshly collected specimens were examined carefully under a Biocraft 20X simple microscope and a Leica EZ4W stereo microscope.

After a critical analysis of the character, identification was made with the help of some authentic literature (Hooker 1890; Kanjilal et al. 1940; Borthakur et al. 2018; Chakrabarty & Balakrishnan 2018), online taxonomic databases (e-Floras 2008; The Plant List 2013; GBIF

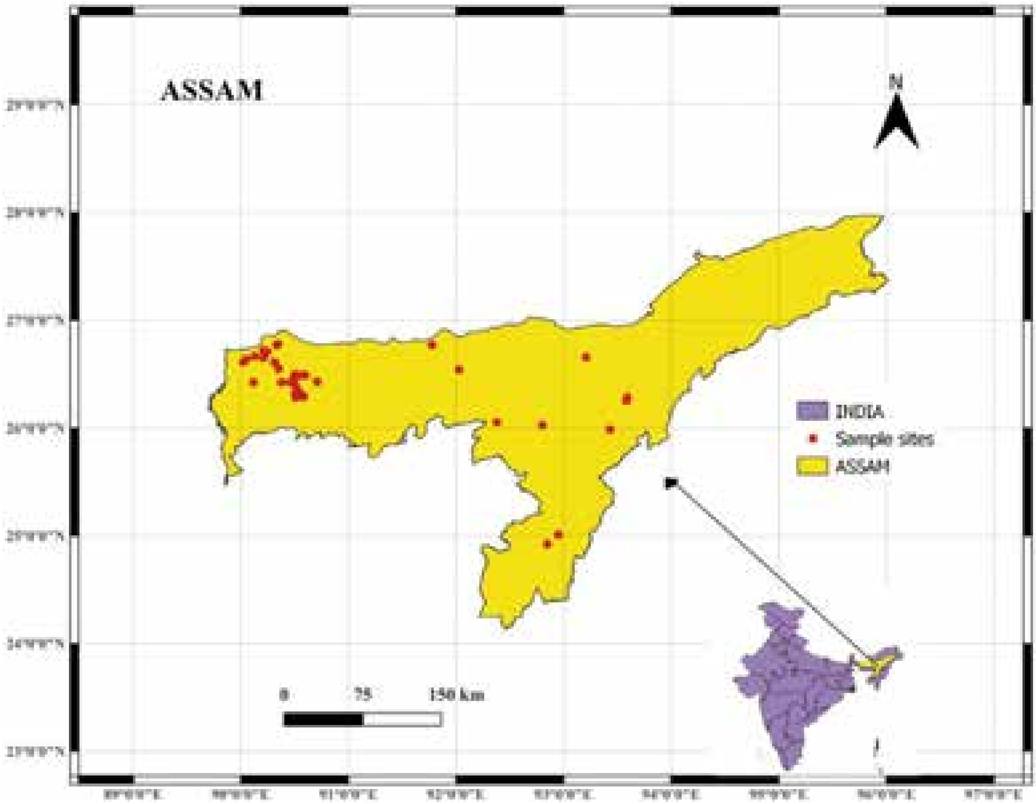

Figure 1. Distribution map of collected taxa from different places in Assam.

2021; POWO 2023) and also with the help of India herbaria (ASSAM, ARUN, and CAL) and digital herbaria (A, MO, NY) (acronyms following Thiers 2018). After reviewing pertinent literature, the threat status of the collected plant taxa was also determined (IUCN 2022). During identification, accepted scientific names and the synonyms of the collected taxa were also checked and confirmed through online databases such as IPNI, POWO, and The WFO Plant List (IPNI 2023; POWO 2023; WFO 2023). The dominant characters that played a key role in the identification of the specimen were their reproductive characters. The list of the collected specimens with their locality, accession number, GPS coordinates, and distribution map were procured (Table 1; Figure 1). The distribution map was created with QGIS 3.26.3 version software.

Ethnobotanical information of all collected taxa was made by the scrutiny of literature as well as communication with some local people and traditional healers in the study area. In addition to documenting the traditional uses and parts utilized for the specimen, we recorded their vernacular names, mode of preparation, application, and route of administration, as outlined in Table 5.

Herbarium preparation and deposition

Herbarium preparations adhered to the established techniques outlined by Jain & Rao (1977), while poisoning procedures followed the methods specified by Clark (1986). Authenticated and verified herbarium specimens for each collected taxon were deposited at the Botanical Survey of India (BSI) in Shillong, Meghalaya.

PCA and Cluster analysis

Fifteen morphological characters (Table 3) were analyzed based on using principal component analysis (PCA) and cluster analysis (Hammer et al. 2001). Multivariate PCA and hierarchical cluster analysis were assessed using the software PAST 4.06b version.

RESULTS

***Glochidion*: Morphological diagnosis**

Monoecious and rarely dioecious; primarily of shrubs or trees; pubescent or glabrous; droopingly branched. Leaves simple, alternate, usually asymmetrical at the base, entire, petiolate, stipulate. The inflorescence is usually axillary, supra-axillary, or pedunculate, with few to many flowers. Staminate flowers are mostly long

Table 1. List of recorded taxa in the studied area with their locality, accession number, and GPS coordinates.

Taxa	Locality	Accession No.	GPS coordinates
Glochidion ellipticum Wight	Kokrajhar District, Assam	98605	26.4947^{0}N, 90.4319^{0}E
G. heyneanum (Wight & Arn.) Wight	Kokrajhar District, Assam	98606	26.6236^{0}N, 90.4061^{0}E
G. lanceolarium (Roxb.) Voigt	Chakrashila Wildlife sanctuary, Kokrajhar District, Assam	98608	26.4236^{0}N, 90.4963^{0}E
G. multiloculare (Rottler ex Willd.) Voigt	Kokrajhar District, Assam	98604	26.7338^{0}N, 90.4308^{0}E
G. multiloculare var. *pubescens* Chakrab. & M.Gangop.	Orang National Park, Udalguri District, Assam	98610	26.7858^{0}N, 92.3305^{0}E
G. sphaerogynum (Mull.Arg.) Kurz	Chakrashila Wildlife Sanctuary, Kokrajhar District, Assam	98609	26.2902^{0}N, 90.3747^{0}E
G. zeylanicum var. *arborescens* (Blume) Chakrab. & M.Gangop.	Ultapani Forest Range, Kokrajhar District, Assam	98603	26.8002^{0}N, 90.3466^{0}E
G. zeylanicum var. *tomentosum* Trimen.	Ultapani Forest Range, Kokrajhar District, Assam	98607	26.7722^{0}N, 90.4158^{0}E
G. zeylanicum (Gaertn.) A.Juss	Nokpakghat, Karbi Anglong District, Assam	98611	26.3838^{0}N, 93.2061^{0}E

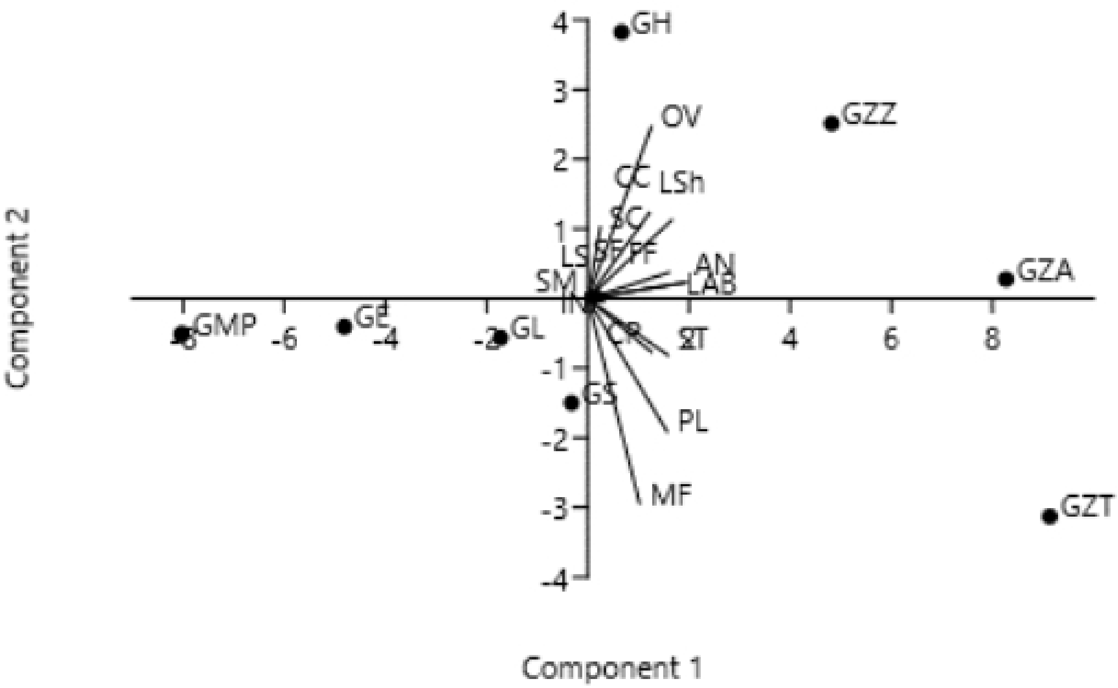

Figure 2. Multivariate Principal Component Analysis (PCA) of different members of *Glochidion* based on morphological characteristics.

pedicellate, with sepals 3–6, free, but no petals or disc. Anthers are present, 3–12, connective, pistillode absent. Pistillate flowers shortly pedicellate or sessile; sepals 3–6, free to connate; petals or disc absent; staminodes absent. Ovary 3–14 locular, biovulate locules; styles usually connate into a column, conical, or globose. Capsular pedicellate or sessile with a style column at the apex, depressed, subglobose, unlobed, and deeply or conspicuously lobed; pubescent or glabrous, green, white, or creamy to reddish. Seeds are usually 3–14, compressed, hemispherical with an arillate coat.

Review on the ethnobotanical knowledge of members of *Glochidion* in India

Some ethnobotanical uses of members of the genus *Glochidion* were mentioned by earlier workers. These are given below-

The paste of *Glochidion tomentosum* Dalz. is used externally in wounds by the tribes of Eastern Ghat, India (Reddy et al. 2006). The Chiru tribe of Manipur, India, consumed young leaves of *G. multiloculare* (Rottler ex. Willd.) Voigt and cooked them as an enjoyable curry and used them against stomach disorders (Rajkumari et

Table 2. Comparative morphological characters of certain species of genus *Glochidion* collected from different localities of Assam.

Characters	*G. ellipticum*	*G. heyneanum*	*G. lanceolarium*	*G. multiloculare* var. *multiloculare*	*G. multiloculare* var. *pubescens*	*G. sphaerogynum*	*G. zeylanicum* var. *arborescens*	*G. zeylanicum* var. *tomentosum*	*G. zeylanicum* var. *zeylanicum*
Leaf shape	Elliptic to lanceolate, oblong to obovate	Ovate to elliptic, obovate	Lanceolate to oblanceolate, elliptic	Oblong to lanceolate, elliptic to oblanceolate	Oblong to lanceolate, elliptic to oblanceolate	Oblong to elliptic, falcate	Ovate to elliptic	Ovate to elliptic, cordate	Ovate to elliptic, cordate
Leaf apex & and base	Apiculate, caudate, acuminate at apex, obtuse at base	Acute, apiculate at apex, obtuse or rounded at base	Apiculate, acuminate, or acute at apex, obtuse or rounded at base	Acute, apiculate, or retuse at apex, obtuse or rounded at base	Acute, apiculate, or retuse at apex, obtuse or rounded at base	Acuminate at apex, attenuate at base	Acute, acuminate at apex, obtuse or rounded at base	Obcordate, acute at apex, obtuse, truncate, asymmetric at base	Acute, apiculate at apex, cordate, asymmetric, truncate at base
Leaf surface	Glabrous on both surfaces	Pubescent on both surfaces and densely pubescent beneath	Glabrous on both surfaces	Glabrous on both surfaces at mature and pubescent at young	Pubescent on both surfaces and densely pubescent beneath	Glabrous on both surfaces	Densely pubescent on both surfaces	Densely pubescent on both surfaces	Glabrous on both surfaces
Petiole length	0.4–1 cm long	0.1–0.5 cm long	0.6–1 cm long	0.1–0.5 cm long	0.1–0.5 cm long	0.9–1 cm long	0.3–0.5 cm long	0.5–0.7 cm long	0.1–0.8 cm long
Inflorescence	Axillary	Axillary	Axillary	Axillary	Axillary	Axillary	Supra-axillary, pedunculate, rarely axillary	Supra-axillary, pedunculate, rarely axillary	Supra-axillary, pedunculate, rarely axillary
Male flower	Pedicellate, 0.5–1.7 cm long	Pedicellate, 0.5–1 cm long	Pedicillate, 0.9–2 cm long	Pedicellate, 0.5–1 cm long	Pedicellate, 0.5–1 cm long	Pedicellate, 0.5–1.8 cm long	Pedicellate, 0.5–0.7 cm long	Pedicellate, 0.7–1.8 cm long	Pedicellate, 0.5–1 cm long
Sepal	6	6	6	6	6	6	6	6	6
Anther	4–5	3–4	4–6	5–12	5–12	3–5	5–7	5–8	3–8
Female flower	Pedicellate, 0.1–0.5 cm long	Pedicellate, 0.1–0.6 cm long	Sessile, 0.06–0.09 cm long	Pedicellate, 0.3–0.5 cm long	Pedicellate, 0.3–0.5 cm long	Pedicellate, 0.3–0.5 cm long	Pedicellate, 0.4–0.6 cm long	Pedicellate, 0.4–1 cm long	Pedicellate, 0.1–0.9 cm long
Sepal	6	6	6	6–12	6–12	6	6	6	6
Style	Columnar, conical	Columnar	Columnar	Conical, subglobose	Conical, subglobose	Discoid	Columnar, persistent	Columnar, subconical	Free
Ovary	Subglobose, 3–6 locular	Depressed, subglobose, 4–5 locular	Depressed, subglobose, 5–8 locular	Depressed, 5-12 locular	Depressed, 5-12 locular	Depressed, 4–12 locular	Subglobose, 4–6 locular	Depressed, Subglobose, 5–8 locular	Depressed, Subglobose, 4–8 locular
Capsule	Pubescent, pedicellate, shallowly lobed	Pubescent, pedicellate, conspicuously lobed	Sparsely pubescent, sessile, shallowly lobed to deeply lobed	Pubescent, pedicellate, conspicuously lobed	Pubescent, pedicellate, conspicuously lobed	Glabrous, pedicellate, ambiguously lobed	Densely pubescent, pedicellate, obviously unlobed	Densely pubescent, pedicellate, ambiguously lobed	Glabrous, pedicellate, ambiguously lobed
Capsule color	Light green to creamy, whitish	Green to yellow-green	Light green, creamy to reddish	Green	Green	Green	Light green, yellow green to reddish	Light green, yellow green to reddish	Light green, yellow green to reddish
Seed color	Yellow green to red	Yellow green to orange	Yellow green to red	Green to red	Green to red	Green to orange	Yellow green to red	Yellow green to red	Yellow green to red

Table 3. Character state of morphological characteristics of different members of *Glochidion* used in cluster analysis.

Taxa	LSh	LAB	LS	PL	INF	MF	SM	AN	FF	SF	ST	OV	CP	CC	SC
E	1	1	2	1	0	1	0	1	1	1	1	1	1	1	1
H	4	4	1	0	0	0	0	4	3	1	2	4	2	3	3
L	2	2	2	2	0	2	0	2	2	1	2	2	2	2	1
M	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MP	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
S	3	3	2	3	0	3	0	3	0	1	3	3	3	0	2
ZA	6	6	1	5	1	4	0	6	5	1	5	6	4	4	1
ZT	5	7	1	6	1	5	0	7	6	1	6	2	5	4	1
ZZ	5	5	2	4	1	0	0	5	4	1	4	5	3	4	1

E—*G. ellipticum* | H—*G. heyneanum* | L—*G. lanceolarium* | M—*G. multiloculare* var. *multiloculare* | MP—*G. multiloculare* var. *pubescens* | S—*G. sphaerogynum* | ZA—*G. zeylanicum* var. *arborescens* | ZT—*G. zeylanicum* var. *tomentosum* | ZZ—*G. zeylanicum* var. *zeylanicum* | LSh—Leaf shape | LAB—Leaf apex & base | LS—Leaf surface | PL—Petiole length | INF— Inflorescence | MF—Male flower | SM—Sepal of male flower | AN—Anther | FF—Female flower | SF—Sepal of female flower | ST—Style | OV—Ovary | CP—Capsule | CC—Capsule color | SC—Seed color

Character states: Leaf Shape: Oblong to lanceolate, elliptic to oblanceolate = 0; Elliptic to lanceolate, oblong to obovate = 1; Lanceolate to oblanceolate, elliptic = 2; Oblong to elliptic, falcate = 3; Ovate to elliptic, obovate = 4; Ovate to elliptic, cordate = 5; Ovate to elliptic = 6; **Leaf apex & base:** Acute, apiculate or retuse at apex, obtuse or rounded at base = 0; Apiculate, caudate, acuminate at apex, obtuse at base = 1; Apiculate, acuminate or acute at apex, obtuse or rounded at base = 2; Acuminate at apex, attenuate at base = 3; Acute, apiculate at apex, obtuse or rounded at base = 4; Acute, apiculate at apex, cordate, asymmetric, truncate at base = 5; Acute, acuminate at apex, obtuse or rounded at base = 6; Obcordate, acute at apex, obtuse, truncate, asymmetric at base = 7; **Leaf surface:** Glabrous on both surfaces at mature and pubescent at young = 0; Pubescent on both surfaces and densely pubescent beneath = 1; Glabrous on both surfaces = 2; **Petiole length:** 0.1–0.5 cm long = 0; 0.4–1 cm long = 1; 0.6–1 cm long = 2; 0.9–1 cm long = 3; 0.1–0.8 cm long = 4; 0.3–0.5 cm long = 5; 0.5–0.7 cm long = 6; **Inflorescence:** Axillary = 0; Supra-axillary, pedunculate, rarely axillary = 1; **Male flower:** Pedicellate, 0.5–1 cm long = 0; Pedicellate, 0.5–1.7 cm long = 1; Pedicillate, 0.9–2 cm long = 2; Pedicellate, 0.5–1.8 cm long = 3; Pedicellate, 0.5–0.7 cm long = 4; Pedicellate, 0.7–1.8 cm long = 5; **Sepal of male flower:** 6 = 0; **Anther:** 5–12 = 0; 4–5 = 1; 4–6 = 2; 3–5 = 3; 3–4 = 4; 3–8 = 5; 5–7 = 6; 5–8 = 7; **Female flower:** Pedicellate, 0.3–0.5 cm long = 0; Pedicellate, 0.1–0.5 cm long = 1; Sessile, 0.06–0.09 cm long = 2; Pedicellate, 0.1–0.6 cm long = 3; Pedicellate, 0.1–0.9 cm long = 4; Pedicellate, 0.4–0.6 cm long = 5; Pedicellate, 0.4–1 cm long = 6; **Sepal of female flower:** 6–12 = 0; 6 = 1; **Style:** Conical, subglobose = 0; Columnar, conical =1; Columnar = 2; Discoid = 3; Free = 4; Columnar, persistent = 5; Columnar, subconical = 6; **Ovary:** Depressed, 5–12 locular = 0; Subglobose, 3–6 locular = 1; Depressed, subglobose, 5–8 locular = 2; Depressed, 4–12 locular = 3; Depressed, subglobose, 4–5 locular = 4; Depressed, Subglobose, 4–8 locular = 5; Subglobose, 4–6 locular = 6; **Capsule:** Pubescent, pedicellate, conspicuously lobed = 0; Pubescent, pedicellate, shallowly lobed = 1; Sparsely pubescent, sessile, shallowly lobed to deeply lobed = 2; Glabrous, pedicellate, ambiguously lobed =3; Densely pubescent, pedicellate, obviously unlobed =4; Densely pubescent, pedicellate, ambiguously lobed; **Capsule color:** Green = 0; Light green to creamy, whitish = 1; Light green, creamy to reddish = 2; Green to yellow green = 3; Light green, yellow green to reddish = 4; **Seed color:** Green to red = 0; Yellow green to red = 1; Green to orange = 2; Yellow green to orange = 3

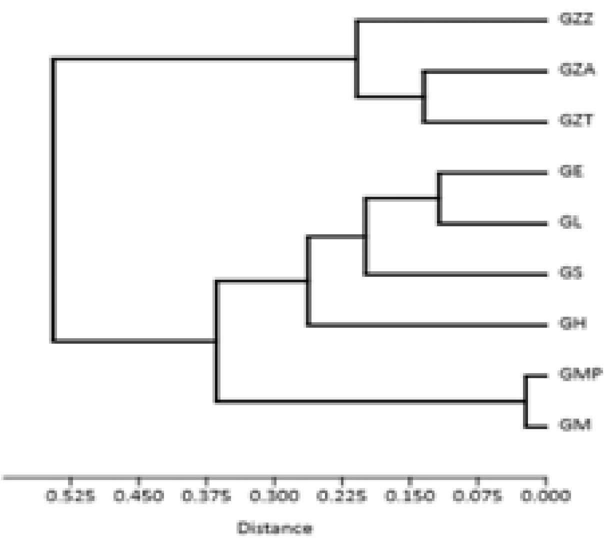

Figure 3. Paired group (UPGMA) dendrogram using hierarchical cluster analysis of different members of genus *Glochidion* based on their morphological characteristics.

Table 4. Principal component analysis (PCA) based on morphological characteristics of different members of *Glochidion*.

PC	Eigenvalue	% variance
1	41.3263	83.254
2	4.25921	8.5804
3	2.02297	4.0754

al. 2013). The bark of *G. multiloculare* is used for skin diseases and wounds (Bajpai et al. 2016). Roots of *G. multiloculare* are used in snake bites (Brahma et al. 2002). The fruit and stem of *G. heyneanum* (Wight & Arn.) Wight is used in diabetes, fever, and bone fracture (Kumar et al. 2019). Roots of *G. heyneanum* are used in snake bites (Bajpai et al. 2016). Barks and leaves of *G. zeylanicum* (Gaertn.) A.Juss. are used in snake bites and stomach ulcers, and tender shoots are applied to itches (Das et al. 2013; Chakrabarty & Balakrishnan 2018; Kumar et al. 2019). Branches and leaves of *G. sphaerogynum* (Mull. Arg.) Kurz. are used in influenza and eczema (Lalrinkimi & Lallianthanga 2019). Fruits of *G. daltonii* (Mull.Arg.) Kurz. is used in cough and dysentery, and the bark of *G. ellipticum* Wight is used in inflammation (Bajpai et al.

Table 5. Enumeration of ethnobotanical knowledge of *Glochidion* in Assam.

Botanical name	Vernacular names	Parts used	Mode of preparation	Application	Route of administration
Glochidion multiloculare (Rottler ex Willd.) Voigt	Thakha Biphang or thakha mala (Bodo), Gorumora, Dolpoduli (Assamese)	Leaves, barks, Roots	- A small number of leaves are ground into a paste. - A small amount of bark is taken and ground into a paste. - 3–4 roots are taken to make a paste.	- Fracture and body swelling - Skin diseases and wounds - Snake bite	- External - External - External
G. ellipticum Wight	Thakha Biphang or thakha mala (Bodo), Panimadhuri (Assamese), Latimaowa (Nepali)	Bark, stem branches, and roots	- A small amount of bark is removed and ground into a paste, which is then administered to the diseased area. - A paste is made by crushing the stem and applying it to the swelling area. - Roots are ground into a paste.	- Body swelling, Skin problem - Body swelling - Snake bite	- External - External - External
G. sphaerogynum (Mull.Arg.) Kurz.	Thakha Biphang or thakha mala (Bodo), Panimadhuri (Assamese), Boljakru (Garo)	Young branches and leaves	Young branches and leaves are ground into a paste and blended with a small amount of water.	- Skin diseases - Branches are used as firewood also.	- External

2016). The paste made from the seeds of *G. ellipticum* is used as an antiallergic (Babu 1995). The bark of *G. lanceolarium* (Roxb.) Voigt is used in stomach diseases and is used as an anti-itch drug, oil made from seeds is also used as a source of light (Chanda et al. 2007; Bajpai et al. 2016; Chakrabarty & Balakrishnan 2018). The seeds of *G. calocarpum* Kuna are applied externally for skin diseases, and leaves are used orally to cure fever (Elanchezhian et al. 2007). According to Lalfakzuala et al. (2007), fruits of *G. arborescens* are used as wild edible fruits that are consumed by the local people of Mizoram. The fruits of *G. khasicum* (Mull.Arg.) Hook.f. are also edible and consumed by the tribal people of the Khasi hills in Meghalaya (Chakrabarty & Balakrishnan 2018).

DISCUSSION

The comparative morphological characteristics of certain species of the genus *Glochidion* showed many similarities and distinctive characteristics, which can be helpful for the identification and classification of the taxa (Table 2). Some of the major distinctive characteristics were leaf morphology, petiole length, and reproductive structures, i.e., inflorescences, male and female flowers, anthers, style, ovary, and capsule. The presence or absence of hairs on stems, leaves, inflorescence, and capsules also significantly differentiates the taxa. *G. multiloculare* var. *pubescens* an endemic variety of Assam showed nearly identical habit, vegetative and reproductive characteristics, with the exception of a glabrous plant body in *G. multiloculare* var. *multiloculare* (Chakrabarty & Balakrishnan 2018). The other major distinctive characteristics of both the taxa are that solitary or individual flowers and fruits occur in each axil in *G. multiloculare* var. *pubescens* while multiple flowers and fruits in each axil of the plant body have been observed in *G. multiloculare* var. *multiloculare*. The variety *G. zeylanicum* var. *tomentosum* presented almost the same character as *G. zeylanicum* var. *zeylanicum*, with the major difference being its hairy or tomentose character. *G. heyneanum* showed puberulous habits on the stems and leaves. In some taxa, leaves were asymmetric or symmetric at the base.

The majority of taxa exhibited axillary inflorescence while *G. zeylanicum* var. *zeylanicum, G. zeylanicum* var. *tomentosum* and *G. zeylanicum* var. *arborescens* showed supra-axillary or pedunculate and rarely axillary inflorescence. Male flowers of the taxa revealed remarkably similar traits, but the number of anthers separated them. Female flowers presented different characteristics from male flowers. The peduncles of all the female flowers were shorter than the male flowers. The number of locules in the ovary varied by taxon, and style characters also played a key role. The shape, size, color, locules, and hairy habit of the capsule were distinguished among taxa, which showed taxonomic significance. Some taxa like *G. zeylanicum* var. *zeylanicum* and their varieties, were easily identified with their unlobed and ambiguously lobed capsule. *G. multiloculare* and *G. sphaerogynum* exhibited deeply or conspicuously lobed capsules while *G. ellipticum* presented a superficially lobed capsule. The capsule of *G. lanceolarium* was sessile, i.e., the fruit without the stalk or it lacked a pedicel, which distinguished it from other taxa. When dried, most of the leaves of the members were curled at the margin. While *Glochidion* and *Epicephala* moths were mutualists (Kato et al.

2003), most *Glochidion* leaves and drooping branches were found in insect-damaging conditions. As a result, some easily detectable characters for taxa identification could exist.

Based on morphological data, both PCA and cluster analysis were analyzed (Table 3–4 & Figure 2–3). The first PCA variance was 83.254% with an eigenvalue of 41.3263 followed by the second PCA variance of 8.5804% with an eigenvalue of 4.25921. The line connected to PC1 and PC2 makes up 91.8344% of the total variance and is a good sign of the variability of the initial data. PC1 represented the variation of the taxa based on the characters such as leaf shape (LSh), leaf apex and base (LAB), anther (AN), female flower (FF), sepal of the female flower (SF), ovary (OV), capsule color (CC), seed color (SC) and PC2 represented the characters such as leaf surface (LS), petiole length (PL), inflorescence (INF), male flower (MF), sepal of male flower (SM), style (ST), capsule (CP). In PC1, five taxa were observed i.e., *G. ellipticum* (GE), *G. lanceolarium* (GL), *G. multiloculare* var. *pubescens* (GMP), *G. sphaerogynum* (GS), and *G. zeylanicum* var. *tomentosum* (GZT). PC2 denoted a total of four taxa, viz., *G. heyneanum* (GH), *G. multiloculare* var. *multiloculare* (GM), *G. zeylanicum* var. *arborescens* (GZA), and *G. zeylanicum* var. *zeylanicum* (GZZ). From cluster analysis the tree revealed that *G. multiloculare* var. *multiloculare* (GM) and *G. multiloculare* var. *pubescens* (GMP) as cluster 1, *G. heyneanum* (GH) as cluster 2, *G. sphaerogynum* (GS) as cluster 3, *G. ellipticum* (GE) and *G. lanceolarium* (GL) as cluster 4, *G. zeylanicum* var. *arborescens* (GZA), and *G. zeylanicum* var. *tomentosum* (GZT) as cluster 5, *G. zeylanicum* var. *zeylanicum* (GZZ) as cluster 6. Taxa present in the same cluster specified more correlation than the taxa present in the different clusters.

The ethnobotanical study revealed that some members of the genus *Glochidion* were traditionally used to cure different diseases (Table 5) in Assam. Among the uses, the most frequent are skin diseases, fractures, body swelling, and snake bites.

CONCLUSION

The study revealed that there are similarities and differences among the members of the genus *Glochidion* which are more reliable for grouping and classifying the taxa. Documentation of ethnobotanical evidence signifies the importance of the genus. Both primary and secondary sources of the ethnobotanical knowledge showed the members have medicinally important properties and almost all parts, i.e., leaves, bark, and roots, have been used by the local people for the treatment of various diseases in India including Assam. This study summarized that both taxonomical study and conservation of ethnobotanical knowledge are of great significance, with the ability to stimulate subsequent biological investigation. Moreover, PCA and cluster analysis also validated the data on comparative morphological traits that showed correlation and variation among the analyzed species.

Key to the species and varieties based on vegetative and reproductive characters

1. Inflorescence axillary 2
1. Inflorescence axillary to supra-axillary 6

2. Capsules shortly pedicellate 3
2. Capsules sessile .... *G. lanceolarium*

3. Leaves curl upwards with a margin when dry .... *G. sphaerogynum*
3. Leaves do not curl upwards with a margin when dry 4

4. Plant part glabrous except the reproductive organs .... *G. multiloculare* var. *multiloculare*
4. Plant parts all pubescent .... *G. multiloculare* var. *pubescens*

5. Capsules 3–6 locular; green to white creamy .... *G. ellipticum*
5. Capsules 4–5 locular; yellowish-green .... *G. heyneanum*

6. Fruits obscurely lobed 7
6. Capsules unlobed .... *G. zeylanicum* var. *arborescens*

7. Plants entirely glabrous .... *G. zeylanicum* var. *zeylanicum*
7. Plant parts all pubescent .... *G. zeylanicum* var. *tomentosum*

Image 1. Morphological characters: A—*Glochidion multiloculare* var. *multiloculare* | B—*G. ellipticum* | C—*G. heyneanum* | D—*G. lanceolarium* | E—*G. sphaerogynum* | F—*G. multiloculare* var. *pubescens* | G—*G. zeylanicum* var. *zeylanicum* | H—*G. zeylanicum* var. *arborescens* | I—*G. zeylanicum* var. *tomentosum*. © Priyanka Brahma.

REFERENCES

Asati, B.S. & D.S. Yadav (2004). Diversity of horticultural crops in north eastern region. *ENVIS Bulletin: Himalayan Ecology* 12: 1–11.

Azam, A.T.M.Z., A.H. Abdullah, G.U. Mohammad, M.M. Mohammad & M.H. Choudhury (2012). Antimicrobial, Antioxidant and Cytotoxic Activities of *Glochidion multiloculare* (Roxb. Ex Willd.) Mull. Arg. (Euphorbiaceae). *Dhaka University Journal of Pharmaceutical Sciences* 11(2): 117–120. http://doi.org/10.3329/dujps.v11i2.14560

Babu, P.S.P. (1995). Euphorbiaceae of Andhra Pradesh, India. Ph.D. Thesis. Department of Botany, Sri Krishnadevaraya University, Andhra Pradesh, India.

Bajpai, O., A. Kumar, A.K. Srivastava, A.K. Kuhwaha, J. Pandey & L.B. Chaudhary (2015). Tree species of Himalayan Terai region of Uttar Pradesh, India: a checklist. *Checklist* 11(4): 1–15. https://doi.org/10.15560/11.4.1718

Balakrishnan, N.P. & T. Chakrabarty (2007). *The Family Euphorbiaceae in India: A synopsis of its Profile, Taxonomy and Bibliography*. M/s Bishen Singh Mahendra Pal Singh, Dehradun, India, 342 pp.

Balakrishnan, N.P., T. Chakrabarty, M. Sanjappa, P. Lakshminarsimhan & P. Singh (eds.) (2012). *Flora of India.* Vol. 23. Botanical Survey of India, New Delhi, India, 414 pp.

Bentham, G. & J.D. Hooker (1862–1883). *Genera Plantarum*. Vol. 3. L. Reeve & Co., 6 Henrietta Street, Covent Garden, London, England, 279 pp.

Bhattacharya, P., R. Muzumder & G. Sarmah (1991). Rare medicinal plants of Assam. *Ancient Science of Life* 10(4): 234–8.

Bhattacharyya, R., K.K. Medhi, S.K. Borthakur & S. Borkataki (2020). An ethnobotanical study of medicinal plants used against jaundice by tea tribes of Morigaon District, Assam (India). *Journal of Natural Remedies* 20(1): 16–28. https://doi.org/10.18311/jnr/2020/23879

Borthakur, S.K., A. Bawri, D. Baro & A. Boro (2018). *Flora of BTAD (Bodoland Territorial Area Districts, Assam)*. Vol. 3. EBH publishers, India, 74 pp.

Brahma, B.K., B. Patere & H. Basumatary (2002). *Boroni Muli Biphang Laiphang*. Bodo Publication Board, Bodo Sahitya Sabha, Kokrajhar, Guwahati, Assam, 93 pp.

Brahma, P. & S. Baruah (2023). Extended distribution of an endemic variety *Glochidion zeylanicum* var. *paucicarpum* Chakrab. & N.P.Balakr. (Phyllanthaceae) from Assam, India. *Vegetos*. https://doi.org/10.1007/s42535-023-00650-0

Chakrabarty, T. & N.P. Balakrishnan (2018). *Indo-Burmese Phyllanthaceae*: *A Taxonomic Revision*. M/s Bishen Singh Mahendra Pal Singh, Dehradun, India, 194 pp.

Chanda, R., J. Mohanty, N.R. Bhuyan, P.K. Kar & L.K. Nath (2007). Medicinal plants used against gastrointestinal tract disorders by the traditional healers of Sikkim Himalayas. *Indian Journal of Traditional Knowledge* 6(4): 606–610.

Chase, M.W., M.J.M. Christenhusz, M.F. Fay, J.W. Byng, W.S. Judd, D.E. Soltis, D.J. Mabberley, A.N. Sennikov, P.S. Soltis & P.F. Stevens (2016). An update of the angiosperm phylogeny group classifications for the orders and families of flowering plants: APG IV. *Botanical Journal of the Linnaean Society* 181(1): 1–20. https://doi.org/10.1111/boj.12385

Clark, S.H. (1986). Preservation of Herbarium Specimens: An Archive Conservator's Approach. *Taxon* 35(4): 675–682.

Das, A.K., N. Stalin, C. Muthuperumal & P.S. Swamy (2013). Wild plants used by Muthuvan and Kattunaikkan tribal communities of Palakkayam settlement in Nilambur of Malappuram district, Kerala. *Medicinal Plants - International Journal of Phytomedicines and Related Industries* 5(2): 82–89. http://doi.org/10.5958/j.0975-6892.5.2.013

Dutta, B.K. & P.K. Dutta (2005). Potential of ethnobotanical studies in North East India: An overview. *Indian Journal of Traditional Knowledge* 4(1): 7–14.

eFloras (2008). Missouri Botanical Garden, St. Louis, MO & Harvard University Herbaria, Cambridge, MA. http://www.efloras.org. Electronic version accessed 18 May 2021.

Elanchezhian, R., R.S. Kumar, S. Beena & M.A. Suryanarayana (2007). Ethnobotany of Shompens - a primitive tribe of Great Nicobar Island. *Indian Journal of Traditional Knowledge* 6(2): 342–345.

GBIF (2021). GBIF- Global Biodiversity Information Facility. https://www.gbif.org Electronic version accessed 24 May 2021.

Hammer, O., D. Harper & P. Ryan (2001). PAST: Paleontological Statistics Software Package for Education and Data Analysis. *Palaeontologia Electronica* 4: 1–9.

Hoffmann, P., H. Kathriarachchi & K.J. Wurdack (2006). A phylogenetic classification of Phyllanthaceae (Malpighiales; Euphorbiaceae sensu lato). *Kew Bulletin* 61: 37–53. http://www.jstor.org/stable/20443245

Hooker, J.D. (1890). *The Flora of British India.* Vol. 5. L. Reeve & Co., Henrietta street, Covent Garden, London, 456 pp.

Hutchinson, J. (1973). *The Families of Flowering Plants*. 3rd Edition. The Clarendon Press, Oxford, 519 pp.

IPNI (2023). International Plant Name Index. Published on the Internet http://www.ipni.org. The Royal Botanic Gardens, Kew, Harvard University Herbaria & Libraries and Australian National Herbarium. Electronic version accessed 25 July 2023.

IUCN (2022). The IUCN Red List of Threatened Species. Version 2021-3. https://www.iucnredlist.org Electronic version accessed 8 May 2022.

Jain, S.K. & R.R. Rao (1977). A Handbook of Field & Herbarium Methods. Today & Tomorrow Printers & Publishers, New Delhi, India, 22 pp.

Kanjilal, U.N., P.C. Kanjilal, R.N. Dey & A. Das (1940). *Flora of Assam*. Vol. 4. Prabasi Press, Upper Circular Road, Calcutta, 179 pp.

Kato, M., A. Takimura & A. Kawakita (2003). An obligate pollination mutualism and reciprocal diversification in the tree genus *Glochidion* (Euphorbiaceae). *Proceedings of the National Academy of Sciences*, USA 100(9): 5264–5267. https://doi.org/10.1073/pnas.0837153100

Kumar, J.U.S., M.J.K. Chaitanya, A.J. Semotiuk & V. Krishna (2019). Indigenous knowledge on medicinal plants used by ethnic communities of South India. *Ethnobotany Research and Applications* 18: 1–112. https://ethnobotanyjournal.org/index.php/era/article/view/1291

Lai, X.Z., Y.B. Yang & X.L. Shan (2004). The investigation of Euphorbiaceous medicinal plants in Southern China. *Economic Botany* 58: S307–S320. https://doi.org/10.1663/0013-0001(2004)58[S307:TIOEMP]2.0.CO;2

Lalfakzuala, R., H. Lalramnghinglova & H. Kayang (2007). Ethnobotanical usage of plants in western Mizoram. *Indian Journal of Traditional Knowledge* 6(3): 486–493.

Lalrinkimi & R.K. Lallianthanga (2019). Documentation of tree species within Mizoram Science Centre, Berawtlang, Aizawl, India with notes on their ethnomedicinal values. *Science Vision* 19(3): 63–78. https://doi.org/10.33493/scivis.19.03.01

Maikhuri, R.K. & A.K. Gangwar (1993). Ethnobiological notes on the Khasi and Garo tribes of Meghalaya, Northeast India. *Economic Botany* 47: 345–357. https://doi.org/10.1007/BF02907348

Mao, A.A. & D.K. Roy (2004). Ethnobotanical studies in northeast India: a review,) pp. 99–112. In: Jain, A.K. (ed.). Indian Ethnobotany: Emerging Trends. Scientific Publisher, India.

Myers, N., R.A. Mittermeier, C.G. Mittermeier, G.A.B. da Fonseca & J. Kent (2000). Biodiversity hotspots for conservation priorities. *Nature* 403(6772): 853–858. https://doi.org/10.1038/35002501

POWO (2023). Plants of the Word Online. Facilitated by the Royal Botanical Gardens, Kew. http://www.plantsoftheworldonline.org/ Electronic version accessed 1 August 2023.

Prakash, J.W., R.D.A. Raja, N.A. Anderson, C. Williams, G.S. Regini, K. Bensar, R. Rajeev, S. Kiruba, S. Jeeva & S.M. Das (2008). Ethnomedicinal plants used by Kani tribes of Agasthiyarmalai Biosphere Reserve, southern Western Ghats. *Indian Journal of Traditional Knowledge* 7(3): 410–413.

Rajkumari, R., P.K. Singh, A.K. Das & B.K. Dutta (2013). Ethnobotanical investigation of wild edible and medicinal plants used by the Chiru Tribe of Manipur, India. *Pleione*7(1): 167–174.

Rathod, V. & N.S. Rajurkar (2017). Phytochemical screening and antioxidant activity of *Glochidion ellipticum*. *Journal of Applicable

Chemistry 6(2): 219–226.

Reddy, S.R., K.N. Reddy, C. Pattanaik, V.S. Raju & J. Autonagar (2006). Ethnobotanical observations on some endemic plants of Eastern Ghats, India. *Ethnobotanical Leaflets 10:* 82–91.

Saikia, A.P., V.K. Ryakala, P. Sharma, P. Goswami & U. Bora (2006). Ethnobotany of medicinal plants used by Assamese people for various skin ailments and cosmetics. *Journal of Ethnopharmacology* 106(2): 149–157. https://doi.org/10.1016/j.jep.2005.11.033

The Plant List (2013). Version 1.1. http://www.theplantlist.org/. Accessed on 20 April 2021.

The World's Herbaria (2018). A Summary Report Based on Data from Index Herbariorum Issue 3.0, published January 10, 2019, Barbara M. Thiers Editor, Index Herbariorum.

WFO (2023). World Flora Online. http://www.worldfloraonline.org. Accessed on 22 June 2023.

Xiao, H.T., H.P. He, J. Peng, Y.H. Wang, X.W. Yang, X.J. Hu, X.Y. Hao & X.J. Hao (2008). Two new norbisabolane sesquiterpinoid glycosides from *Glochidion coccineum*. *Journal of Asian Natural Product Research* 10(1-2): 1–5. https://doi.org/10.1080/10286020701189393

Threatened Taxa

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 December 2023 | 15(12): 24420–24426

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

https://doi.org/10.11609/jott.8698.15.12.24420-24426

#8698 | Received 18 August 2023 | Final received 11 October 2023 | Finally accepted 22 November 2023

OPEN ACCESS

COMMUNICATION

Notes on *Discospermum sphaerocarpum* Dalzell ex Hook.f., a rare species of Rubiaceae (Ixoroideae: Coffeeae) from southern India

C. Pramod [1], V.V. Drisya [2], A.K. Pradeep [3] & K.T. Chandramohanan [4]

[1,3] Department of Botany, University of Calicut, Calicut University P.O., Kerala 673635, India.
[2,4] Department of Botany, Government Brennen College, Dharmadam P.O., Thalassery, Kerala 670106, India.
[1] cpramod4@gmail.com (corresponding author), [2] drisyachandran96@gmail.com, [3] akpradeep1@uoc.ac.in, [4] chandrubrennen@gmail.com

Abstract: *Discospermum sphaerocarpum* is a rare species in the tribe Coffeeae of the family Rubiaceae and its occurrence on the Madayippara lateritic plateau of the Kannur district of Kerala, southern India is discussed. This plant is endemic to southern India and Sri Lanka. In Kerala, this species was previously recorded from the low-altitude evergreen forests of Thiruvananthapuram district. The present study gives a detailed description, distribution and figures & images illustrating the diagnostic characters of *D. sphaerocarpum* for easy identification and conservation.

Keywords: Conservation, endemism, laterite ecosystems, Madayippara, sacred groves.

Editor: Shiny Mariam Rehel, Keystone Foundation, Kotagiri, India. **Date of publication:** 26 December 2023 (online & print)

Citation: Pramod, C., V.V. Drisya, A.K. Pradeep & K.T. Chandramohanan (2023). Notes on *Discospermum sphaerocarpum* Dalzell ex Hook.f., a rare species of Rubiaceae (Ixoroideae: Coffeeae) from southern India. *Journal of Threatened Taxa* 15(12): 24420–24426. https://doi.org/10.11609/jott.8698.15.12.24420-24426

Funding: This study was not funded by external sources.

Competing interests: The authors declare no competing interests.

Author details: C. Pramod—specialized in angiosperm taxonomy and floristics, has started his career at Government Victoria College, Palakkad as an assistant professor in 2007, and presently working at the Department of Botany, University of Calicut. A.K. Pradeep—an expert in the family Malvaceae and angiosperm floristics, has about 35 years of research experience in angiosperm taxonomy; started career at Government Mahatma Gandhi College, Androth and joined University of Calicut in 1995. V.V. Drisya is a PhD research scholar at the Department of Botany, Government Brennen College, Thalassery under Kannur University. K.T. Chandramohanan—started his professional career in 2005 at Government Brennen College, Thalassery and presently is the principal, Krishna Menon Memorial Government Women's College, Kannur.

Author contributions: Design of the study, field surveys and communications—CP; Assistance and support in the field surveys—VVD, AKP & KTC; Laboratory studies—CP & VVD; Preparation of the first draft of the manuscript—CP, VVD & AKP; Critical comments for the preparation of the final manuscript—CP, VVD, AKP & KTC; All authors read and approved the final manuscript.

Acknowledgements: The authors are grateful to Dr. S.E. Dawson and Dr. A.P. Davis, Herbarium Royal Botanic Gardens, Kew, for their help in identification; and to the head of the Department, University of Calicut, Kerala, and the Principal, Government Brennen College, Kerala, for the facilities provided for the study.

INTRODUCTION

The genus *Discospermum* Dalzell ex Hook.f. comprises 13 species, mainly shrubs or trees, growing primarily in wet tropical biomes with native ranges from India to the Philippines (POWO 2023). In India, *Discospermum* is represented by three species, *D. sphaerocarpum* Dalzell ex Hook.f., *D. apiocarpum* Dalzell ex Hook.f., and *D. abnorme* (Korth.) S.J. Ali & Robbr. The former two species were reported in southern India and the latter one from Assam. *D. sphaerocarpum* is a medium-sized tree which grows in dry and wet tropical biomes and it is native to southern India and Sri Lanka (POWO 2023).

The genus was originally described by Dalzell in 1850 from Sri Lanka. Later, Hooker (1880) reduced the genus *Discospermum* to a section of *Diplospora*. This synonymy was widely accepted until Ali & Robbrecht (1991) revived *Discospermum*. To resolve the issue of the generic position of asian species classified as *Tricalysia* or *Diplospora*, Ali & Robbrecht (1991) reviewed traits of asian *Diplospora*/*Tricalysia* species, and proved that the Asian species cannot be accommodated within the African genus *Tricalysia*; and *Discospermum*, which was included in the synonymy of *Diplospora* for over a century, was reinstated at generic rank. They found that the two genera differ in placentation, fruit size and fruit wall texture, the number of seeds per locule, seed shape, and exotestal cell anatomy. Using molecular techniques, Arriola et al. (2018) have shown that *Diplospora* and *Discospermum* represent separate lineages in the tribe Coffeeae. Molecular investigations by Tosh et al. (2009) further supported the decision to keep *Diplospora* and *Discospermum* as two distinct genera.

Another much-debated topic was the taxonomic placement of this genus. Initially, *Discospermum* was placed in the tribe Gardenieae. Robbrecht & Puff (1986) emended the circumscription of Gardenieae to include *Tricalysia* and *Diplospora*. Subsequently, Ali & Robbrecht (1991) attributed generic status to *Discospermum,* and included it in the *Gardenieae* subtribe *Diplosporinae*. They stated that *Discospermum* "links the Diplosporinae with the Gardeniinae and supports the rank (subtribe) given to these". Results of the phylogenetic study by Andreasen & Bremer (2000) do not support such a relationship and they concluded that at least some genera of Diplosporinae belong to Coffeeae. In a recent study, Davis et al. (2007) expanded the circumscription of Coffeeae and confirmed the placement of *Discospermum* in this tribe based on plastid sequence data and morphological data set.

Previous reports of the species *Discospermum sphaerocarpum* in India were from the wet and dry evergreen forests from the coast to high altitudes (50–1,000 m) of the Western Ghats regions of Kerala, Tamil Nadu, Karnataka, Goa, and Maharashtra (Singh et al. 2015). Gamble (1921) reported the species from Courtallum of Tinnevelly (Tirunelveli) district of Tamil Nadu; later distribution record extended to Cuddalore and Villupuram districts and Coromandel coast (Narayanasami & Natesan 2020). In Kerala, *D. sphaerocarpum* was earlier reported from the low-elevation evergreen forests of Thiruvananthapuram district (Sasidharan 2004). This species now has been recorded from a totally different habitat close to seashore, the sacred groves of a Lateritic hill of Madayippara at an altitude of less than 50 m in the Kannur district (Pramod & Pradeep 2020, 2021).

During a botanical exploration of the Madayippara lateritic plateau of southern India in 2008, the authors encountered a rare Rubiaceae member in vegetative condition in two patches of vegetation associated with sacred groves. The identity of the species remained a mystery as no flowering was seen in the two populations until early January 2014, when the plant produced a few flower buds which did not open. However, after a gap of five months, following the first summer shower in May, the flowers opened. After critical studies of the specimens, they were referred to Dr. S.E. Dawson, Rubiaceae systematics, Herbarium Royal Botanic Gardens, Kew, and confirmed the identity as *Discospermum sphaerocarpum,* and commented "it is very interesting that it comes from such a different habitat" (Sally Dawson pers. comm. 13.vi.2014). The aforementioned pattern of flowering was repeated in the year 2023 as well. The present paper aims to provide a detailed taxonomy, distribution and conservation status, illustration and photographic images of *D. sphaerocarpum*, for future reference and conservation.

MATERIALS AND METHODS

The present account of the species *Discospermum sphaerocarpum* is based on two populations; one growing in a sacred grove associated with Madayikkavu Thiruvarkkattu Bhagavathi temple and another one in an undisturbed patch of vegetation in a private land near Sree Chalilkkavu Bhagavathi temple (Image 1A,B). The current location is in the northernmost of Kerala, in Madayippara lateritic plateau in the Kannur district, which has a completely different habitat not far separated from the sea coast. Madayippara is one of

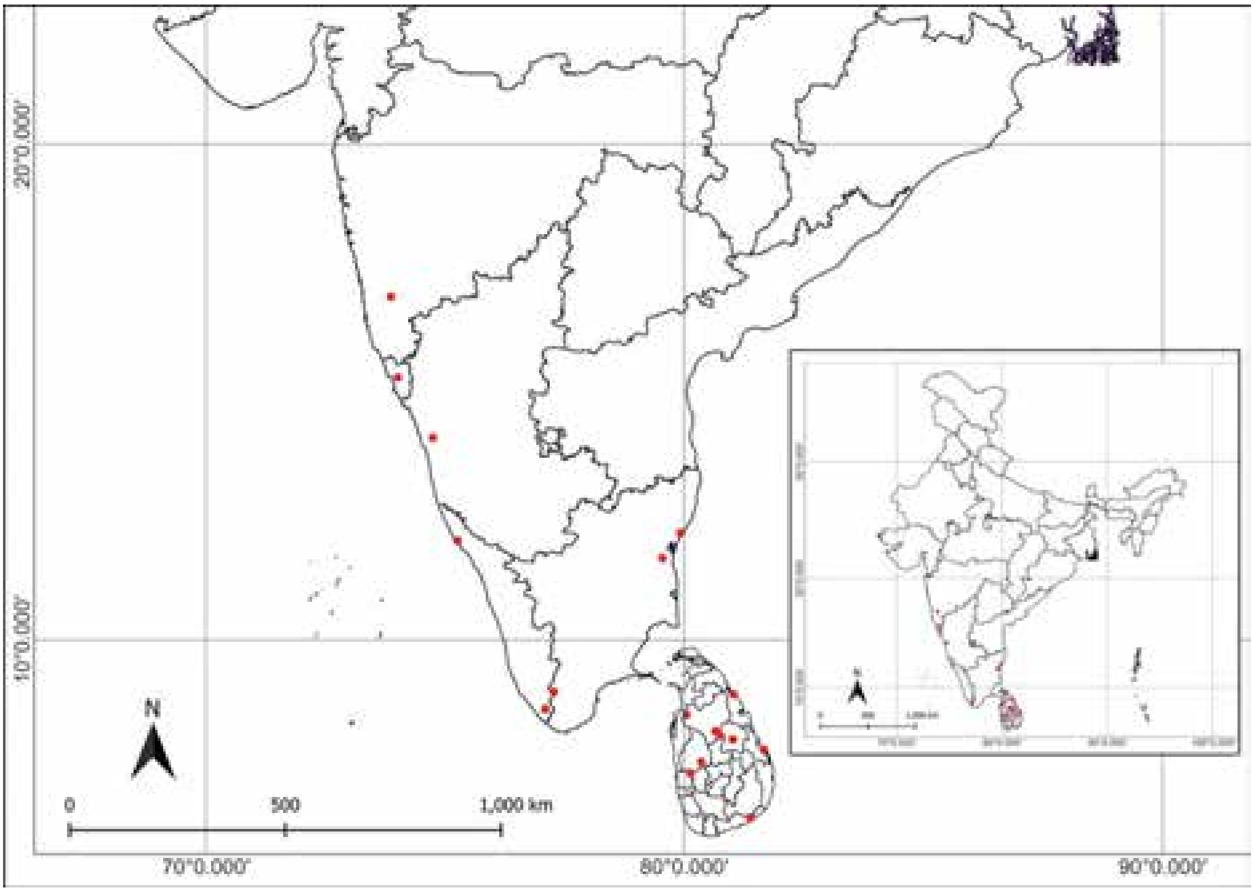

Figure 1. Distribution of *Discospermum sphaerocarpum* Dalzell ex Hook.f.

the most remarkable midland lateritic plateaus in Kerala (Pramod & Pradeep 2020) located in Madayi Panchayath, near Payangadi town, Kannur district, between 12.017–12.050 ^{0}N and 75.233–75.267 ^{0}E, at an altitude of about 50 m and extending an area of 3.65 km^2 on the top (Pramod & Pradeep 2021).

Madayikkavu sacred grove covers an area of about 0.4 ha (Image 1A) with a number of rare and endemic species. A population of *Discospermum spaerocarpum* of seven trees with heights ranging from 5 m–15 m, and 37 saplings was recorded in this location, covering an area of about 0.0014 km^2 between 12.033358–12.033374 ^{0}N and 75.25018–75.250185 ^{0}E. The second population is about 200 m away from Madayikkavu sacred grove, in an undisturbed patch of vegetation in a private-owned land close to Chalilkavu Bhagavathi temple (Image 1B). The population consists of 11 trees ranging in height from 4–20 m, and 15 saplings, covering an area of about 0.0011 km^2, between 12.033386–12.03339 ^{0}N and 75.250229–75.250238 ^{0}E.

Plant materials were collected from the two populations available at Madayippara lateritic plateau for laboratory studies and preparation of voucher specimens. The specimens collected for laboratory studies were worked out using LEICA M80, ZEISS Stemi DV4 and LABOMED CSM2 microscopes. Photographs of the plant specimens and habitats were taken using Nikon Coolpix L110 and Olympus C-7070 cameras. The voucher specimens were prepared following wet method (Fosberg & Sachet 1965) and are deposited at the Calicut University Herbarium (CALI). The distribution status was determined from 'Plants of the World Online' (POWO), pertinent floras and literature; and the distribution map was created using QGIS ver. 3.28.2 (QGIS 2022).

RESULTS AND DISCUSSION

Taxonomic Treatment

Discospermum sphaerocarpum Dalzell ex Hook.f. in Thwaites, Enum. Pl. Zeyl. 158. 1859; Dassan., A Revised Handbook to the Fl. Ceylon 12: 187. 1998; Pramod & Pradeep, A Hillock of Biod. Fl. Madayippara 442. 2020. *Diplospora sphaerocarpa* (Dalzell ex Hook.f.) Hook.f., Fl.

Brit. India 3: 123. 1880; Theodore Cooke, Fl. Bombay 2: 32. 1958. *Tricalysia sphaerocarpa* (Dalzell ex Hook.f.) Gamble, Fl. Madras 620. 1921; R.S. Rao, Fl. Goa, Diu, Daman, Dadra & Nagarhaveli 2: 216. 1986; A.N. Henry et al., Fl. Tamil Nadu, India, 1987; Sasidh., Biod. Doc. Kerala 6. Fl. Pl. 237. 2004.

Lectotype: India, Maharashtra, Bombay, Dalzell, s.n., K000031320 (K, image!).

Discospermum dalzellii Thwaites, Enum. Pl. Zey. 15: 158. 1859. *Diplospora dalzellii* (Thwaites) Hook.f., Fl. Brit. India 3: 123. 1880. *Tricalysia Dalzellii* (Thwaites) Alston in Trimen, Hand-Book. Fl. Ceylon (Suppl. 6.) 151. 1931.

Lectotype: Sri Lanka, *Thwaites G.H.K.,* C.P. 561 (K000031319, K, image!). (Image 1; Figure 2).

Medium-sized trees, up to 20 m tall; bark greyish-brown, smooth; branches terete, compressed towards the apices, glabrous. Leaves simple, opposite, elliptic, 8–15 x 3–6 cm, margins entire, base acute, apex acute-acuminate, glabrous on both sides except domatia, sub-coriaceous, shining above; lateral veins 8–12 pairs, mostly with pubescent domatia in the vein axils beneath; stipules interpetiolar, triangular, aristate, glabrous; petiole 1–1.5 cm long, glabrous. Inflorescence axillary, mostly in the axils of fallen leaves, very short branched fascicled cymes, peduncle short; bracts a pair, ovate, c. 1 mm long, puberulous outside; bracteole 1, oblong, c. 2 mm long, glabrous. Flowers subsessile, c. 5 mm long; calyx cupular, c. 1.5 mm long, lobes 4, subequal, ovate, ciliate, obtuse or shortly retuse at apex, green; tube short; corolla yellowish green, glabrous outside; tube c. 2 mm long, hairy inside; lobes 4, elliptic-oblong, c. 2 mm long, apically notched; stamens 4, filaments short, attached at corolla throat, anthers 1.5–2 mm long; ovary subglobose, ovules many; style c. 2 mm long, glabrous, forked at the apex. Berry subglobose to obovoid, 1–1.5 cm long; calyx persistent forming a crown at the apex of fruit; seeds 8–12, immersed in the well-developed placenta, flat, compressed, reniform, 4–6 × 3–4 mm.

Vernacular names: English: Wild coffee, Tamil: Irrukulimaram, Kannada: Kaadu kafi bija. Sri Lanka: Vella.

Phenology: Since 2008, flowering in this species was observed only twice, in the year 2014 and 2023. The buds appeared in early January, and remained dormant till the middle of May (until heavy summer shower), and the fruits were seen till July.

Distribution and Ecology: The species is endemic to the Western Ghats and Sri Lanka. However, its recent reports from Philippines (Biag & Alejandro 2021) and Bangladesh (Uddin et al. 2023) are doubtful, as its description or voucher specimens were not available for confirmation. In southern India, the species was recorded from the low altitude to high range (50–1,000 m) evergreen forests of the southern Western Ghats (Figure 1) (Gamble 1921; Singh et al. 2015). In Sri Lanka, populations were reported from the dry zone at low altitudes in secondary and rocky areas (Dassanayake 1998). The trees of the population of *Discospermum sphaerocarpum* present in the Madayikkavu sacred grove were seen growing associated with other species such as *Aglaia elaeagnoidea* (A.Juss.) Benth., *Vitex altissima* L.f., *Canthium coromandelicum* (Burm.f.) Alston, *Falconeria insignis* Royle, *Hugonia mystax* L., *Tinospora sinensis* (Lour.) Merr., *Cissus latifolia* Lam., *Tabernaemontana alternifolia* L., *Schleichera oleosa* (Lour.) Oken, *Benkara malabarica* (Lam.) Tirveng., *Getonia floribunda* Roxb., *Glycosmis mauritiana* (Lam.) Tanaka, *Sapindus trifoliatus* L., *Diospyros candolleana* Wight, *Memecylon randerianum* S.M.Almeida & M.R.Almeida, *Strychnos nux-vomica* L., *Dalbergia horrida* (Dennst.) Mabb. var. *horrida*, *Alstonia scholaris* (L.) R.Br., *Croton caudatus* Geiseler, *Grewia nervosa* (Lour.) Panigrahi and *Bridelia stipularis* (L.) Blume.

Similarly, the trees of the population of the species seen in the vegetation patch near Chalilkavu Bhagavathi temple are growing associated with other species such as *Tectona grandis* L.f., *Diospyros candolleana* Wight, *Strychnos nux-vomica* L., *Glycosmis pentaphylla* (Retz.) DC., *Glycosmis mauritiana* (Lam.) Tanaka, *Mallotus philippensis* (Lam.) Müll.-Arg., *Tabernaemontana alternifolia* L., *Bombax ceiba* L., *Caryota urens* L., *Spondias pinnata* (L.f.) Kurz, *Holoptelea integrifolia* (Roxb.) Planch., *Ixora malabarica* (Dennst.) Mabb., *Zingiber zerumbet* (L.) Roscoe ex Sm., *Gomphia serrata* (Gaertn.) Kanis, *Ixora brachiata* Roxb., *Mangifera indica* L., *Grewia nervosa* (Lour.) Panigrahi, *Mitragyna parvifolia* (Roxb.) Korth., *Macaranga peltata* (Roxb.) Müll.-Arg., *Chrysophyllum cainito* L., *Alstonia scholaris* (L.) R.Br. and *Chassalia curviflora* var. *ophioxyloides* (Wall.) Deb & B.Krishna.

Specimens examined: India, Kerala, Kannur district, Madayippara, Madayikkavu, 16.i.2011, C. Pramod 133024; 17.i.2014, C. Pramod 138241; 28.iv.2014, C. Pramod 138276; near Chalilkkavu, 28.iv.2014, C. Pramod 138277; 14.v.2014, C. Pramod 138287; 04.vi.2014, C. Pramod 138293 (CALI [CALI129230, CALI129231, CALI129232, CALI129233, CALI129234, CALI129235, CALI129236, CALI129237, CALI129238, CALI129239, CALI129240, CALI129241, CALI129242, CALI129243, CALI129244, CALI129245]).

Economic importance: The berries are known as wild coffee; the drink made from the roasted and powdered seeds has a coffee flavour. In addition to

Image 1. ***Discospermum sphaerocarpum*** **Dalzell ex Hook.f.: A–B—habitats of populations | C—leafy twig | D—domatia on the abaxial surface of leaf | E—stipule | F—bole | G—twig with flower buds | H—flower buds on a node | I—developing buds | J—flowers | K—mature fruits.**
© A,B,C,F-K—Pramod C.; D-E—Drisya V.V.

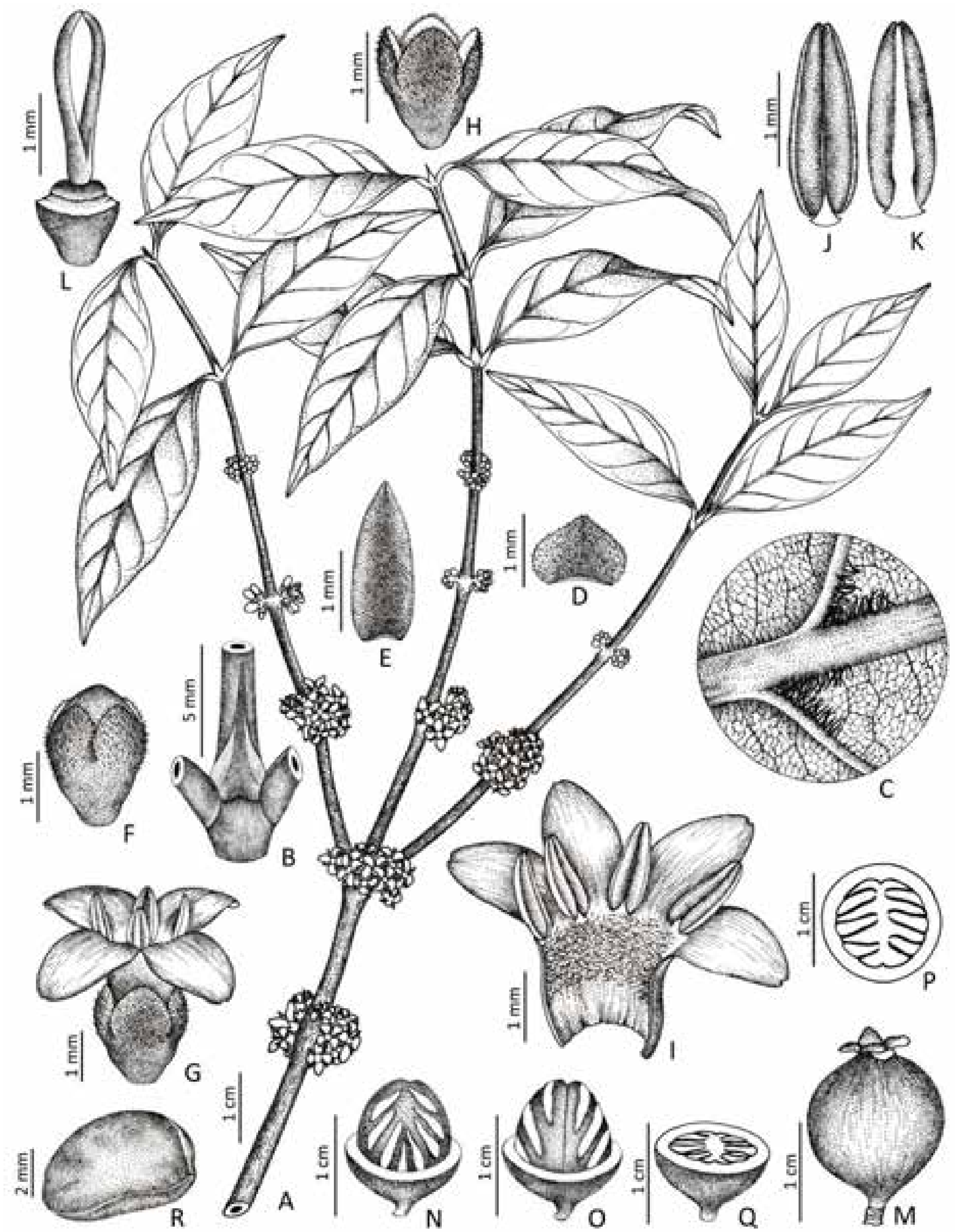

Figure 2. ***Discospermum sphaerocarpum*** **Dalzell ex Hook.f.: A—habit | B—a node showing stipule | C—domatia on the abaxial surface of leaf | D—bract | E—bracteole | F—flower bud | G—flower | H—calyx | I—corolla split opened with attached stamens | J—anther (ventral view) | K—anther (dorsal view) | L—pistil | M—fruit | N–O—fruit with pericarp removed showing seed arrangement | P–Q—lateral section of the fruit | R—seed. Drawn by Drisya V.V., A–L from C. Pramod 138287 | M–Q from C. Pramod 138293.**

this, many alkaloids, astringent, aromatic bodies, fat, sugars and mineral matter are found in seeds (Nadkarni 1976). Being a reservoir of phytochemical components, this plant is used as a potential drug for the treatment of a variety of human illnesses such as depression and diabetes, and also effective as a good antioxidant. Wood is used for making comb.

Conservation: An assessment of tropical dry evergreen forests of Tamil Nadu, recorded that *Discospermum sphaerocarpum* occupies an area of about 10 km^2, has around 500 mature individuals, and is declining at a rate of more than 50% due to the widespread usage of the wood for making comb. No regular flowering and seed set was observed in this species in the current location. There is a serious risk of losing the population in the second location mentioned, the habitat is on a private-owned land, and will be cleared off for construction purposes (Image 1B). *Discospermum* appears to be at a lower level of evolution than *Diplospora* and *Tricalysia* due to its large, dry fruits, frequent well-developed placental extension around the seeds, and radial exotestal cell-thickenings (Ali & Robbrecht 1991). These factors necessitate urgent measures for the conservation of the species and their habitats. In vitro propagation will be useful for the conservation and sustainable utilization of this species.

REFERENCES

Ali, S.J. & E. Robbrecht (1991). Remarks on the tropical Asian and Australian taxa included in *Diplospora* or *Tricalysia* (Rubiaceae—Ixoroideae—Gardenieae). *Blumea* 35(2): 279–305.

Andreasen, K. & B. Bremer (2000). Combined phylogenetic analysis in the Rubiaceae-Ixoroideae: morphology, nuclear and chloroplast DNA data. *American Journal of Botany* 87(11): 1731–1748. https://doi.org/10.2307/2656750

Arriola, A.H., A.P. Davis, N.M. Davies, U. Meve, S. Liede-Schumann & G.J.D. Alejandro (2018). Using multiple plastid DNA regions to construct the first phylogenetic tree for Asian genera of Coffeeae (Ixoroideae, Rubiaceae). *Botanical Journal of the Linnean Society* 188(2): 132–143. https://doi.org/10.1093/botlinnean/boy059

Biag, R.D. & G.J.D. Alejandro (2021). Rubiaceae flora of northern Sierra Madre Natural Park, Isabela, Luzon, Philippines: Species richness, distribution, and conservation status. *Philippine Journal of Science* 150(3): 907–921.

Dalzell, N.A. (1850). *Discospermum* genus novum. Hook. Journ. Bot. Kew Gard. Misc. 2: 257- 258.

Dassanayake, M.D. (1998). *A Revised Handbook to the Flora of Ceylon*. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi.

Davis, A.P., M. Chester, O. Maurin & M.F. Fay (2007). Searching for the relatives of *Coffea* (Rubiaceae, Ixoroideae): the circumscription and phylogeny of Coffeeae based on plastid sequence data and morphology. *American Journal of Botany* 94(3): 313–329. https://doi.org/10.3732/ajb.94.3.313

Fosberg, F.R. & M.H. Sachet (1965). *Manual of Tropical Herbaria* (Regnum Vegetabile 39). International Bureau for Plant Taxonomy and Nomenclature, Utrecht, Netherlands, 132 pp.

Gamble, J.S. & C.E.C. Fischer (1921). *The Flora of the Presidency of Madras,* Volume 2. Adlard & Son Ltd., London.

Hooker, J.D. (1880). Rubiaceae. *Flora of British India* 3: 17–210.

Nadkarni, K.M. (1976). *Indian Materia Medica*. Popular Prakashan Private ltd., Bombay, 454 pp.

Narayanasami, D. & B. Natesan (2020). Endemic vascular plants from the Coromandel Coast of Tamil Nadu, southern India, pp. 89–107 In: Kumar, S. (Ed.). *Endangered Plants*. IntechOpen, 180 pp. https://doi.org/10.5772/intechopen.94333

POWO (2023). *Plants of the World Online*. Facilitated by the Royal Botanical Gardens, Kew. *Discospermum* Dalzell. https://powo.science.kew.org/results?q=discospermum. Accessed on 30 June 2023.

Pramod, C. & A.K. Pradeep (2020). *A Hillock of Biodiversity - Ecology and Flora of Madayippara, A South Indian lateritic Plateau*. Indian Association for Angiosperm Taxonomy, Calicut.

Pramod, C. & A.K. Pradeep (2021). Observations on the flowering plant diversity of Madayippara, a southern Indian lateritic plateau from Kerala, India. *Journal of Threatened Taxa* 13(2): 17780–17806. https://doi.org/10.11609/jott.3883.13.2.17780-17806

QGIS (Quantum GIS Development Team) (2022). Quantum GIS geographic information system. Version 3.28.2. Downloaded on 4 January 2023.

Robbrecht, E. & C. Puff (1986). A survey of the Gardenieae and related tribes (Rubiaceae). *Botanische Jahrbucher fur Systematik, Pflanzengeschichte und Pflanzengeographie* 108: 63–137.

Sasidharan, N. (2004). *Biodiversity documentation for Kerala. Part 6. Flowering Plants*. Kerala Forest Research Institute, Peechi, Thrissur, 237 pp.

Singh, P., K. Karthigeyan, P. Lakshminarasimhan & S.S. Dash (2015). *Endemic vascular plants of India*. Botanical Survey of India, Kolkata, 239 pp.

Tosh, J., A.P. Davis, S. Dessein, P. De Block, S. Huysmans, M.F. Fay, E. Smets & E. Robbrecht (2009). Phylogeny of *Tricalysia* (Rubiaceae) and its relationships with allied genera based on plastid DNA data: Resurrection of the genus *Empogona*. *Annals of the Missouri Botanical Garden* 96(1): 194–213. https://doi.org/10.3417/2006202

Uddin, M.S., A. Mazumder & S.B. Uddin (2023). Addition of one hundred and forty-seven new vascular taxa to the flora of Bangladesh. *Species* 24: 1–8. https://doi.org/10.54905/disssi/v24i73/e13s1013

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 December 2023 | 15(12): 24427–24436
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.8176.15.12.24427-24436
#8176 | Received 06 September 2022 | Final received 22 September 2023 | Finally accepted 11 November 2023

COMMUNICATION

Legumes (Fabaceae) from Satmala hills, Maharashtra, India

Swapnil D. Wagh [1] & **Manoj T. Patil** [2]

[1,2] SNJB's KKHA Arts, SMGL Commerce and SPHJ Science College, Chandwad, District Nasik, Maharashtra 423101, India.
[1] swapnildwagh@gmail.com (corresponding author), [2] manojtpatil@gmail.com

Abstract: A floristic survey was carried out in Satmala hill range of Nasik district. The study area is dry throughout the year except monsoon period. During this survey, the authors recorded 74 taxa of the family Fabaceae or Leguminosae, belonging to three subfamilies and 38 genera. The majority of the legumes are herbs & shrubs, while few are climbers & trees. Updated nomenclature, habit, habitat, life forms, GPS coordinates, phenology, voucher specimens & images of legumes found in the study area are provided.

Keywords: Checklist, endemics, ethno medicine & economics, northern Western Ghats.

Marathi: नाशिक जिल्यामध्ये पसरलेल्या सातमाळा डोंगर रांगामध्ये गेली चार वर्ष (२०१८ ते २०२१) फुलांच्या वनस्पतींचे सर्वेक्षण करण्यात आले. पावसाळा सोडला तर या डोंगर रांगामध्ये वर्षभर कोरडे व उष्ण हवामान असते. तरीदेखील चांगल्या प्रमाणात या ठिकाणी शेंगा असणाऱ्या फुल झाडांच्या प्रजाती आपले अस्तित्व सिद्ध करतात. या सर्वेक्षणा दरम्यान अभ्यासकांनी फॅब्यासी (शेंगा असणाऱ्या वनपस्ती) या कुळातील वनस्पतींच्या काही विशिष्ट्य अश्या नोंदी केल्या आहेत ज्यामध्ये ऐकून चौऱ्यात्तर वनस्पतींचे तीन उपकुळात व आडोतीस संवर्गामध्ये वर्गीकरण करण्यात आलेले आहे. यामध्ये जास्तीत जास्त वनस्पती ह्या झुडूपाच्या आकाराच्या किंवा त्यापेक्षाही लहान असून काही वनस्पती ह्या वेलवर्गीय व मोठाले वृक्ष आहेत. या शोध निबंधामध्ये वनस्पतींचे अद्ययावत वैज्ञानिक नावे, संरचना, सुष्म निवास, जीवन स्वरूप, अक्षांश व रेखांश, फुलं व शेंगा लागण्याचा कालावधी, गोळा केलेल्या वनस्पतींचे नमुने, वनस्पतींचे फोटो इत्यादी गोष्टी समाविष्ट करण्यात आलेल्या आहेत.

Editor: V. Sampath Kumar, Botanical Survey of India, Coimbatore, India. **Date of publication:** 26 December 2023 (online & print)

Citation: Wagh, S.D. & M.T. Patil (2023). Legumes (Fabaceae) from Satmala hills, Maharashtra, India. *Journal of Threatened Taxa* 15(12): 24427–24436. https://doi.org/10.11609/jott.8176.15.12.24427-24436

Funding: Department of Science & Technology under the FIST program (Project number SR/FIST-415/2018).

Competing interests: The authors declare no competing interests.

Author details: Swapnil D. Wagh is an assistant professor in the PG Department of Botany, SNJB's KKHA Arts, SMGL Commerce & SPHJ Science College Chandwad. He was qualified CSIR NET JRF, ICAR NET, SET, GATE Exams & recently awarded doctor of philosophy in the subject of botany (floristic) from Savitribai Phule Pune University, Pune. His area of interest is angiosperm taxonomy & ecology. Manoj T. Patil is an assistant professor in the PG Department of Botany, SNJB's KKHA Arts, SMGL Commerce & SPHJ Science College Chandwad. His area of interest is ethno botany & genetics.

Author contributions: SDW was carried out regular field tours, exploration, collection, photography, herbarium preparation, identification & data compilation. He wrote the draft of manuscript. MTP help for the collection.

Acknowledgements: Authors are grateful to the honourable Management, Principal of SNJB's KKHA Arts, SMGL Commerce & SPHJ Science College Chandwad, Dist. Nasik. 423101 for the facilities provided for this research work. Authors are also thankful to the department of Science & Technology under the FIST program. (Project number SR/FIST-415/2018). We also thanks to Authorities of Forest department, Maharashtra for permit us to work on Satmala hill ranges. First author is thankful to Dr. Jagdish V. Dalavi for his cooperation during compilation of data.

INTRODUCTION

The family Fabaceae or Leguminosae is one of the socio-economically important families in Angiosperms. It is commonly known as legume, pea, or bean family. This family members possess all types of habits such as herbs, trees, shrubs, and climbers. It is easily recognised by their pods (legume). Fabaceae Lindl. is the third largest family of angiosperms in terms of number of taxa. It is represented by 770 genera & 19,500 taxa worldwide (FAO 2016; LPWG 2017). In India, the family Fabaceae is represented by 174 genera, 1110 species & 256 intraspecific taxa (Sanjappa 2020). Legumes are very important source of proteins in developing countries. In tropical and temperate region wild beans used in the manufacture of resins, tannins, oils, varnishes, paints, dyes, and medicines (LPWG 2017). Other than socio-economic importance legumes are equally beneficial for ecosystems and recycling via nitrogen uptake, enhance soil porosity, recycling of nutrients, decreasing soil pH, reduction of soil compaction and in rotation with cereals they offer a source of slow-fixation of nitrogen to sustainable cropping (USDA 1998; Popelka et al. 2004). In brief, it is economically important family for development of the region therefore present study focuses on preparation of checklist of legumes from Satmala hill range for future advancement.

MATERIAL & METHODS

Study Area

Satmala is well known hill range in Nasik district, Maharashtra, India. Due to low rainfall & hot climatic condition, the hill range harbour seasonal vegetation. The co-ordinates of hill range is 20.3902 ^{0}N & 73.9086 ^{0}E. This hill range consist many high peaks with elevation of more than 1,200 m. Some of them are Dhodap (1,451 m), Achala (1,238 m), Ahivant (1,226 m), Saptashrungigad (1,240 m), Markandya (1,331 m), Indrai (1,475 m), Sadetin Rodaga (1,350 m), Chandreshwari (1,300 m), and Rajdher (1,325 m). Major habitats on this hill range are slopes, exposed rock surfaces, grasslands, ephemeral flush vegetation, soil covered areas & seasonal ponds. Average rainfall recorded during last decades ranges 900–1,200 mm and temperature is 28–45 ^{0}C. The climate of these plateaus is dry throughout the year except during the south-west monsoon season.

Data collection

Preliminary checklist of taxa belonging to the family Fabaceae from Nashik district was prepared from all the available floras & checklists (Cherian & Pataskar 1969; Lakshminarasimhan & Sharma 1991; Singh & Karthikeyan 2001; Yadav & Dhanke 2010; Pawar & Pokle 2011; Auti et al. 2021). Studies on herbarium specimens was carried out by visiting some important herbaria such as BSI, CAL, DD, and SUK, which is followed by extensive & intensive field visits from June 2020 to January 2022. All important microhabitats were covered by conducting more than 45 field tours and data. on habit, life form, endemism, ethno botany, microhabitat, distribution, and flowering phenology was recorded. Three herbarium specimens were prepared for every collected taxa following standard herbarium methodology (Jain & Rao 1976). Identification of specimens was carried out using local & regional floras as well as all available taxonomic literature (Hooker 1876; Lakshminarasimhan & Sharma 1991; Naik 1998; Singh & Karthikeyan 2001; Yadav & Dhanke 2010). Some doubtful specimens identified by direct comparison with identified specimens deposited in BSI and CAL. Also digital images such as Kew herbarium catalogue (accessed from June 2020 to January 2022), JSTOR Global plants (accessed from June 2019 to February 2022) were consulted online. The names of species checked using POWO (Plants of the world online accessed from July 2020 to March 2022). All species were classified according to latest phylogenetic classification of leguminosae (LPWG 2017) and listed in Table 1. Study area map and pie diagram is provided for sub-family wise distribution of species. Colour photo plates of a few important taxa are given for easy identification (Images 1–3).

RESULTS

Checklist

A total of 69 species, four varieties, and one subspecies of family Fabaceae have been reported from Satmala hill range of Nashik district. All the species classified into three subfamilies of Fabaceae, viz., Cercidoideae, Caesalpinioideae, and Faboideae/ Papilionoideae. Among these subfamilies, Faboideae or Papilionoideae is the largest subfamily with 59 taxa under 27 genera followed by subfamily Caesalpinioideae with 13 species and nine genera, subfamily cercidoideae with two species and two genera (Figure 2). *Crotalaria* L. is the largest genus with eight taxa, followed by *Alysicarpus* Desv. with seven taxa, *Indigofera* L. & *Vigna*

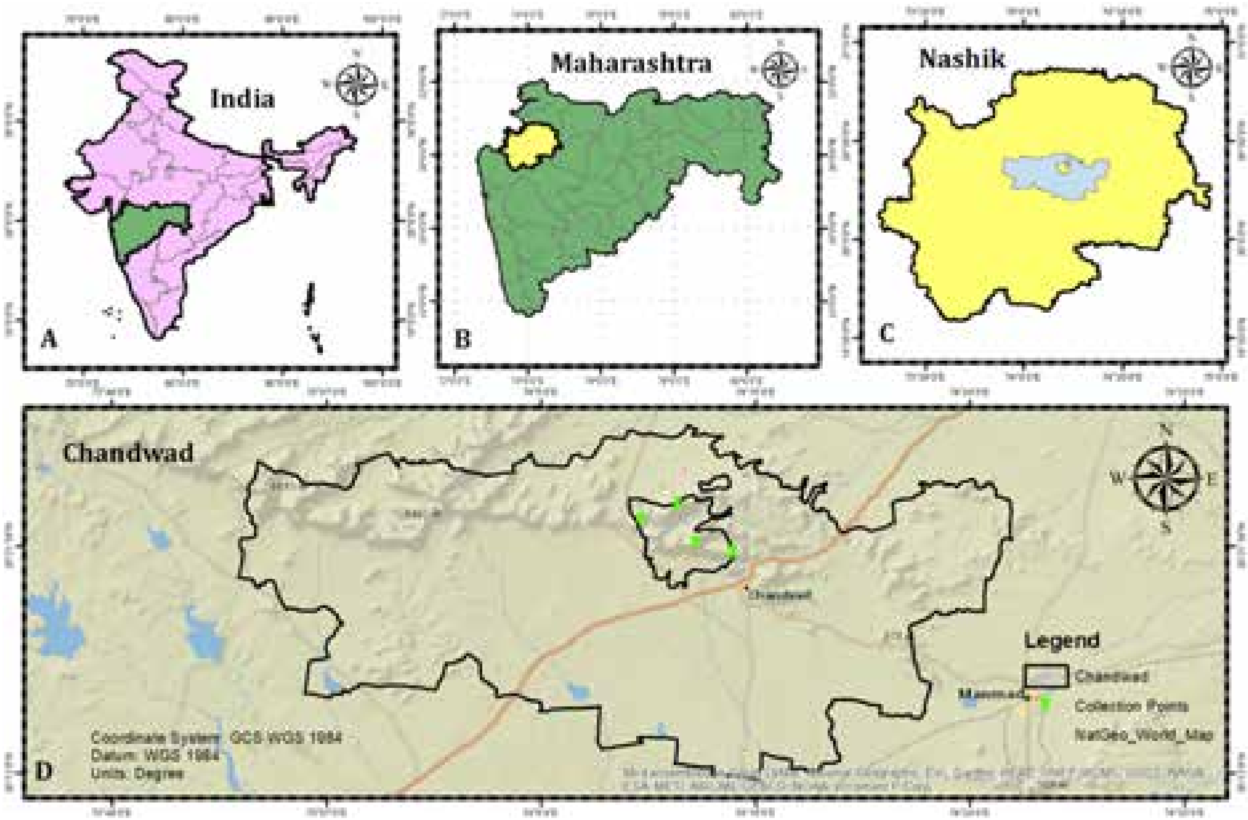

Figure 1. Study area: A—Position of Maharashtra in India | B—Position of Nashik in Maharashtra | C—Position of Chandwad in Nashik | D—Position of collection localities in Nashik district.

Savi with five taxa each. Fabaceae of Satmala hill range consists of 26 herbs, 21 shrubs, 14 trees, and 12 climbers. During field visits it is observed that Satmala hill range is dominated by species of Fabaceae family after family Poaceae.

Endemism

Few taxa are endemic to Peninsular India, viz., *Alysicarpus bupleurifolius* var. *hybridus* Burm.f. ex DC. found to be growing near edges of seasonal streams. *Alysicarpus pubescens* Law and *Cajanus sericeus* (Benth. ex Baker) Maesen were collected from soil rich areas on uppermost plateau. *Clitoria annua* J. Graham found to be growing inside bushes. It is observed that population of *Vigna khandalensis* (Santapau) Sundararagh. & Wadhwa is very small and restricted to uppermost plateau but *Vigna indica* T.M.Dixit, K.V.Bhat & S.R.Yadav is a dominant species found inside grasslands. *Indigofera glandulosa* var. *sykesii* Griff. ex Baker found to be growing on edges/ cliffs of plateaus.

Ethno Medicine & Economics

Few wild legumes from study area used by local people/community to cure ailments. The decoction made from the leaf powder of *Dichrostachys cinerea* (L.) Wight & Arn. used to cure common fever. Ringworms were cured by powdered seeds of *Senna sophera* (L.) Roxb. A juice made by leaves of *Guilandina bonduc* L. is taken to cure piles. Gum of *Butea monosperma* (Lam.) Kuntze used by tribal people in nearby villages to cure diarrhoea. Few plants are economically important, young pods of *Vigna indica* T.M.Dixit K.V.Bhat & S.R.Yadav are eaten as raw by local community & visitors directly. The leaves of *Senna tora* (L.) Roxb. used as a wild vegetable. The fruits of *Tamarindus indica* L. & *Pithecellobium dulce* (Roxb.) Benth. are edible. Also fruits of *Mucuna pruriens* (L.) DC. are used by tribal community as a wild vegetable. The whole plant of *Crotalaria medicaginea* Lam. is used as cattle feed. The seeds of *Crotalaria mysorensis* Roth used as manure. Dry pods of *Vachellia nilotica* (L.) P.H.J.Hurter are used to prepare tooth powder. *Aeschynomene virginica* (L.) Britton, Sterns & Poggenb., used as a fodder for milk cattle's. Timber of *Butea monosperma* (Lam.) Kuntze, *Tamarindus indica* L., *Cassia fistula* L., *Dalbergia sissoo* Roxb. ex DC, *Dichrostachys cinerea* (L.) Wight & Arn., *Pithecellobium dulce* (Roxb.) Benth., *Piliostigma*

Table 1. Checklist of Legumes from Satmala Hill Range as per latest classification of LPWG (2017).

	Botanical name	Vernacular name	Habit, habitat, life form	GPS coordinates		Phenology	Exsiccata
				Latitude	Longitude		
Subfamily: **CERCIDOIDEAE** (02 Genera & 02 Species)							
01	*Piliostigma malabaricum* (Roxb.) Benth.	Kanchan	Tree, Soil Rich Area, P	20.336 N	74.260 E	Nov–Feb	SDW-1160
02	*Tamarindus indica* L.	Chinch	Tree, Hill Slopes, P	20.353 N	74.233 E	Feb–Jun	SDW-1212
Subfamily: **CAESALPINIOIDEAE** (09 Genera & 13 Species)							
03	*Biancaea decapetala* (Roth) O.Deg	Chilar	Shrub, Edges of Seasonal Streams, P	20.336 N	74.259 E	Oct–Nov	SDW-1005
04	*Cassia fistula* L.	Bahawa	Tree, Hill Slopes, P	20.236 N	74.257 E	Jul–Sep	SDW-369
05	*Chamaecrista abscus* (L.) H.S.Irwin & Barneby	Chimar	Herb, Soil Covered Area, T	20.359 N	74.260 E	Aug–Sep	SDW-173
06	*Chamaecrista mimosoides* (L.) Greene	Chinchani	Herb, Rock Crevices, T	20.386 N	74.195 E	Oct–Nov	SDW-922
07	*Guilandina bonduc* L.	Sagargota	Shrub, Edges of Seasonal Streams, P	20.336 N	74.257 E	Oct–Nov	SDW-1350
08	*Pithecellobium dulce* (Roxb.) Benth.	Vilayati chinch	Tree, Hill Slopes, P	20.360 N	74.207 E	Dec–Feb	SDW-1218
09	*Prosopis cineraria* (L.) Druce	Shami	Tree, Gravelly Hill Slopes, P	20.353 N	74.232 E	Mar–Apr	SDW-1214
10	*Senna auriculata* (L.) Roxb.	Tarvad	Shrub, Hill Slopes, P	20.335 N	74.257 E	Jan–Mar	SDW-1351
11	*Senna oxyphylla* (Kunth) H.S.Irwin & Barneby	Jangali takala	Shrub, Soil Rich Area, P	20.354 N	74.229 E	Sep–Oct	SDW-672
12	*Senna sophera* (L.) Roxb.	Jangali takala	Sub-Shrub, Hill Slopes, P	20.387 N	74.193 E	Aug–Sep	SDW-1353
13	*Senna tora* (L.) Roxb.	Takala	Herb, Hill Slopes, P	20.334 N	74.258 E	Jul–Dec	SDW-20
14	*Senegalia catechu* (L.f) P.J.H.Hurter & Mabb.	Khair	Tree, Hill Slopes, P	20.386 N	74.192 E	Feb–Sep	SDW-1167
15	*Vachellia nilotica* (L.) P.H.J.Hurter & Mabb.	Babhul	Tree, Hill Slopes, P	20.360 N	74.208 E	Mar–Dec	SDW-1356
Subfamily: **FABOIDEAE** (27 Genera & 59 Species)							
16	*Abrus precatorius* L.	Gunj	Climber, Inside Bushes, P	20.351 N	74.227 E	Sep–Dec	SDW-281
17	*Aeschynomene aspera* L.	Nalabi	Sub-Shrub, Edges of Seasonal Streams, T	20.361 N	74.208 E	Aug–Sep	SDW-149
18	*Alysicarpus bupleurifolius* (L.) DC	Shevara	Herb, Inside Grasses, T	20.356 N	74.225 E	Aug–Jan	SDW-610
19	*Alysicarpus bupleurifolius* var. *hybridus* Burm.f.ex DC.	Shevara	Herb, Edges of Seasonal Streams, T	20.356 N	74.225 E	Sep–Nov	SDW-165
20	*Alysicarpus heyneanus* Wight & Arn.	Shevara	Herb, Soil Rich Area, T	20.388 N	74.189 E	Sep–Nov	SDW-349
21	*Alysicarpus monilifer* (L.) DC.	Shevara	Herb, Soil Covered Area, T	20.356 N	74.220 E	Aug–Sep	SDW-607
22	*Alysicarpus pubescens* Law	Durangi Shevara	Herb, Soil Rich Area, T	20.388 N	74.189 E	Sep–Oct	SDW-195
23	*Alysicarpus tetragonolobus* Edgew	Lal Shevara	Herb, Hill Slopes, T	20.334 N	74.259 E	Jul–Aug	SDW-153
24	*Alysicarpus vaginalis* (L.) DC	Shevara	Herb, Exposed Rock Surfaces, T	20.355 N	74.219 E	Aug–Sep	SDW-121
25	*Butea monosperma* (Lam.) Kuntze	Palas	Tree, Cliffs, Hill Slopes, P	20.335 N	74.260 E	Feb–Jun	SDW-1357
26	*Cajanus sericeus* (Benth. ex Baker) Maesen	Reshami Tur	Shrub, Soil Rich Area, T	20.389 N	74.190 E	Oct–Feb	SDW-918
27	*Cajanus scarabaeoides* (L.) Thouars	Ran Tur	Climber, Inside Bushes, T	20.337 N	74.260 E	Oct–Nov	SDW-372
28	*Clitoria annua* J. Graham	Gokarn	Sub-Shrub, Soil Rich Area, P	20.338 N	74.258 E	Aug–Sep	SDW-1093
29	*Clitoria ternatea* L.	Nila Gokarn	Climber, Inside Bushes, C	20.356 N	74.219 E	Oct–Dec	SDW-1174
30	*Crotalaria bifaria* L.f	Nili godhadi	Herb, Inside Bushes, T	20.390 N	74.193 E	Oct–Nov	SDW-290
31	*Crotalaria gajureliana* Gholave, Madhav & Gosavi	Khulkhula	Herb, Soil Rich Area, T	20.386 N	74.195 E	Oct–Nov	SDW-919
32	*Crotalaria hebecarpa* (DC) Rudd	Piwali godhadi	Herb, Soil Rich Area, T	20.361 N	74.209 E	Jun–Oct	SDW-768

	Botanical name	Vernacular name	Habit, habitat, life form	GPS coordinates		Phenology	Exsiccata
				Latitude	Longitude		
33	*Crotalaria juncea* L	Tagada	Shrub, Soil Rich Area, T	20.339 N	74.258 E	Sep–Oct	SDW-764
34	*Crotalaria medicaginea* Lam.	Rangas	Shrub, Soil Rich Area, T	20.389 N	74.194 E	Sep–Dec	SDW-943
35	*Crotalaria mysorensis* Roth	Khulkhula	Sub-Shrub, Soil Rich Area, T	20.363 N	74.209 E	Sep–Oct	SDW-1072
36	*Crotalaria orixensis* Willd.	Andabel	Herb, Soil Rich Area, T	20.356 N	74.218 E	Oct–Nov	SDW-359
37	*Crotalaria triquetra* Dalzell	Ghati	Herb, Soil Rich Area, T	20.388 N	74.194 E	Sep–Oct	SDW-693
38	*Dalbergia sissoo* Roxb. ex DC.	Shisav	Tree, Hill Slopes, P	20.339 N	74.258 E	Sep–Feb	SDW-1358
39	*Desmodium dichotomum* (Willd.) DC.	Asud, Lupti	Herb, Gravelly Hill Slopes, T	20.338 N	74.258 E	Sep–Oct	SDW-701
40	*Desmodium gangeticum* (L.) DC.	Salwan	Herb, Gravelly Hill Slopes, T	20.352 N	74.220 E	Sep–Oct	SDW-841
41	*Dichrostachys cinerea* (L.) Wight & Arn.	Durangi Babhul	Tree, Hill Slopes, T	20.362 N	74.210 E	Dec–Jan	SDW-1168
42	*Dolichos trilobus* L.	Ran Pawata	Climber, Inside Bushes, C	20.338 N	74.257 E	Oct–Nov	SDW-688
43	*Erythrina stricta* Roxb.	Pangara	Tree, Hill Slopes, P	20.356 N	74.213 E	Jan–Mar	SDW-1301
44	*Gliricidia sepium* (Jacq.) Kunth	Undirmari	Tree, Hill Slopes, P	20.338 N	74.258 E	Jan–Feb	SDW-1227
45	*Indigofera cassioides* Rottler ex DC.	Baroli	Shrub, Inside Bushes, P	20.339 N	74.252 E	Jul–Oct	SDW-339
46	*Indigofera cordifolia* B. Heyne ex Roth	Godhadi	Herb, Rock Crevices, T	20.221 N	74.196 E	Sep–Oct	SDW-698
47	*Indigofera glandulosa* J.C.Wendl.	Barbaada	Herb, Soil Covered Area, T	20.338 N	74.254 E	Aug–Oct	SDW-227
48	*Indigofera glandulosa* var. *sykesii* Baker	Borupdi	Herb, Soil Covered Area, T	20.387 N	74.196 E	Aug–Oct	SDW-700
49	*Indigofera linifolia* (L.f) Retz.	Pandarphali	Herb, Rock Crevices, T	20.363 N	74.194 E	Aug–Sep	SDW-377
50	*Indigofera trifoliata* var. *duthiei* (J.Drumm. ex Naik) Sanjappa	Borupdi	Herb, Hill Slopes, T	20.355 N	74.212 E	Oct–Nov	SDW-600
51	*Macrotyloma uniflorum* (Lam.) Verdc.	Ran Kulid	Twining Herb, Gravelly Hill Slopes, C	20.337 N	74.254 E	Sep–Oct	SDW-231
52	*Mucuna pruriens* (L.) DC.	Kachkuyari	Climber, Edges of Seasonal Streams, P	20.356 N	74.211 E	Sep–Dec	SDW-1359
53	*Mundulea sericea* (Willd) A.Chev.	Supli	Shrub, Hill Slopes, P	20.386 N	74.196 E	May–Jun	SDW-02
54	*Paracalyx scariosus* (Roxb.) Ali	Kachquiri	Climber, Inside Bushes, P	20.357 N	74.210 E	Jan–Feb	SDW-1134
55	*Pongamia pinnata* (L.) Pierre	Karanj	Tree, Hill Slopes, P	20.341 N	74.258 E	Mar–May	SDW-1314
56	*Rhynchosia minima* (L.) DC	Dhakta Ranghevada	Climber, Soil Rich Area, T	20.343 N	74.209 E	Aug–Oct	SDW-145
57	*Rhynchosia rothii* Benth. ex Aitch.	Motha Ranghevada	Climber, Inside Bushes, T	20.339 N	74.257 E	Sep–Dec	SDW-308
58	*Sesbania bispinosa* (Jacq.) W.Wight	Ran Sevari, Hadga	Tree, Edges of Seasonal Streams, P	20.362 N	74.211 E	Nov–Dec	SDW-566
59	*Smithia bigemina* Dalzell	Lahan Kavala	Herb, Moist Places, T	20.356 N	74.211 E	Sep–Oct	SDW-206
60	*Smithia sensitiva* Aiton	Motha Kavala	Herb, Edges of Seasonal Streams, T	20.336 N	74.259 E	Oct–Dec	SDW-275
61	*Stylosanthes fruticosa* (Retz.) Alston		Herb, Rock Crevices, T	20.340 N	74.263 E	Sep–Oct	SDW-269
62	*Tephrosia purpurea* (L.) Pers.	Unhali	Sub-Shrub, Hill Slopes, P	20.353 N	74.233 E	Jul–Aug	SDW-13
63	*Tephrosia senticosa* Pers.	Unhali	Sub-Shrub, Gravelly Hill Slopes, P	20.385 N	74.195 E	Jul–Aug	SDW-881
64	*Tephrosia villosa* (L.) Pers.	Unhali	Sub-Shrub, Hill Slopes, P	20.352 N	74.222 E	Jul–Aug	SDW-12
65	*Teramnus mollis* Benth.	Ran udid	Climber, Inside Bushes, C	20.391 N	74.222 E	Oct–Nov	SDW-391
66	*Teramnus repens* subsp. *gracilis* (Chiov.) Verdc.	Ran udid	Climber, Inside Bushes, C	20.361 N	74.210 E	Nov–Dec	SDW-1105
67	*Vigna indica* T.M. Dixit, K.V. Bhat & S.R.Yadav	Ran mug	Climber, Soil Covered Area, C	20.384 N	74.196 E	Aug–Sep	SDW-118
68	*Vigna khandalensis* (Santapau) Sundararagh. & Wadhwa	Bud mung	Shrub, Exposed Rock Surfaces, T	20.335 N	74.256 E	Sep–Oct	SDW-836

	Botanical name	Vernacular name	Habit, habitat, life form	GPS coordinates		Phenology	Exsiccata
				Latitude	Longitude		
69	*Vigna mungo* (L.) Hepper	Udid	Creeping Herb, Soil Covered Area, T	20.360 N	74.210 E	Sep–Oct	SDW-184
70	*Vigna radiata* (L.) Wilczeck.	Mukani	Creeping Herb, Soil Rich Area, T	20.385 N	74.197 E	Oct–Dec	SDW-328
71	*Vigna radiata* var. *sublobata* (Roxb.) Verdc.	Mug	Creeping Herb, Moist Soil Covered Area, T	20.384 N	74.198 E	Oct–Nov	SDW-1112
72	*Vigna vexillata* (L.) A. Rich	Halunda	Climber, Inside Bushes, C	20.335 N	74.264 E	Sep–Oct	SDW-590
73	*Zornia diphylla* (L.) Pers.	Jimgari	Herb, Rock crevices, T	20.336 N	74.255 E	Aug–Sep	SDW-302
74	*Zornia gibbosa* Span.	Landgu	Herb, Hill Slopes, T	20.349 N	74.228 E	Aug–Sep	SDW-126

SP—Sadetin Rodaga Plateau | CP—Chandreshwari Plateau | KP—Koldher Plateau | RP—Rajdher Plateau | IP—Indrai Plateau | DP—Dhodap Plateau | P—Phanerophyte | T—Therophyte | C—Chamaephytes.

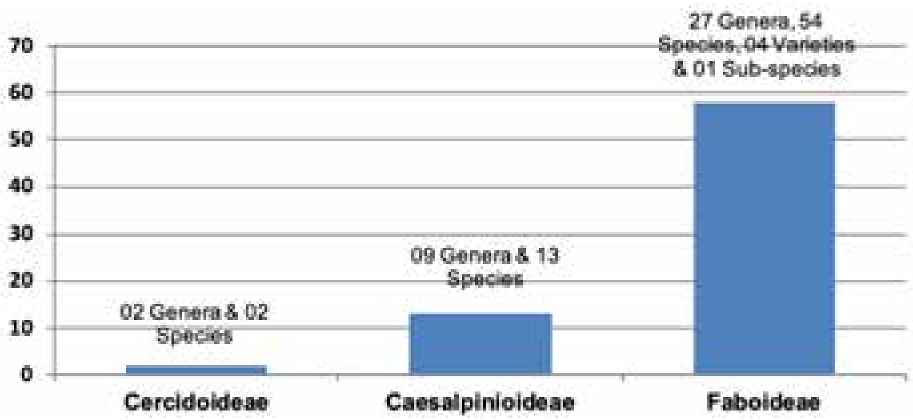

Figure 2. Subfamily wise distribution of species as per LPWG 2017.

malabaricum (Roxb.) Benth, *Prosopis cineraria* (L.) Druce, *Pongamia pinnata* (L.) Pierre, *Senegalia catechu* (L.f) P.J.H.Hurter & *Vachellia nilotica* (L.) P.H.J.Hurter are often used for construction purposes. The seeds of few plants such as *Dalbergia sissoo* Roxb. ex DC., *Cassia fistula* L., *Erythrina stricta* Roxb., and *Butea monosperma* (Lam.) Kuntze collected by local people to grow saplings in their garden.

CONCLUSION

The family Fabaceae Lindl. is the second largest family after Poaceae due to its high adaptability on various microhabitats. Many species of Fabaceae are good source of ethno medicine, timber, and wild edible. Some herbaceous members belonging to the genus, *Chamaecrista* Moench, *Alysicarpus* Desv, *Crotalaria* L., *Desmodium* Desv, *Indigofera* L., *Senna* Mill., are dominant inside grasslands while some such as *Piliostigma* Hochst, *Tamarindus* Tourn. ex. L., *Cassia* L., *Prosopis* L., *Vachellia* Wight & Arn., *Butea* Roxb. ex Willd., *Dichrostachys* (A.Dc.) Wight & Arn., *Dalbergia* L.f, *Senegalia* Raf., *Guilandina* L., *Vachellia* Wight & Arn, *Pongamia* Adans. are dominant in dry deciduous forest cover the hill slopes. Few endemic species such as *Vigna khandalensis* (Santapau) Sundararagh. & Wadhwa, *Alysicarpus pubescens* Law, *Crotalaria juncea* L., and *Cajanus sericeus* (Benth. ex Baker) Maesen restricted to uppermost plateau only. Few legumes, *Sesbania bispinosa* (Jacq.) W.Wight & *Smithia sensitiva* Aiton are restricted to edges of seasonal streams only. According to the IUCN Red List of Threatened Species, 27 species were 'Least Concern' and one species is 'Near Threatened'. It is observed that major threats to these species are over grazing & human interference. So there is urgent need to conserve these special habitats for sustainable utilization of legumes from study area.

REFERENCES

Auti, S.G., S.S. Kambale, K.V.C. Gosavi & A.N. Chandore (2020). Floristic diversity of Anjaneri hills, Maharashtra, India. *Journal of Threaten Taxa* 12(10): 16295–16313. https://doi.org/10.11609/

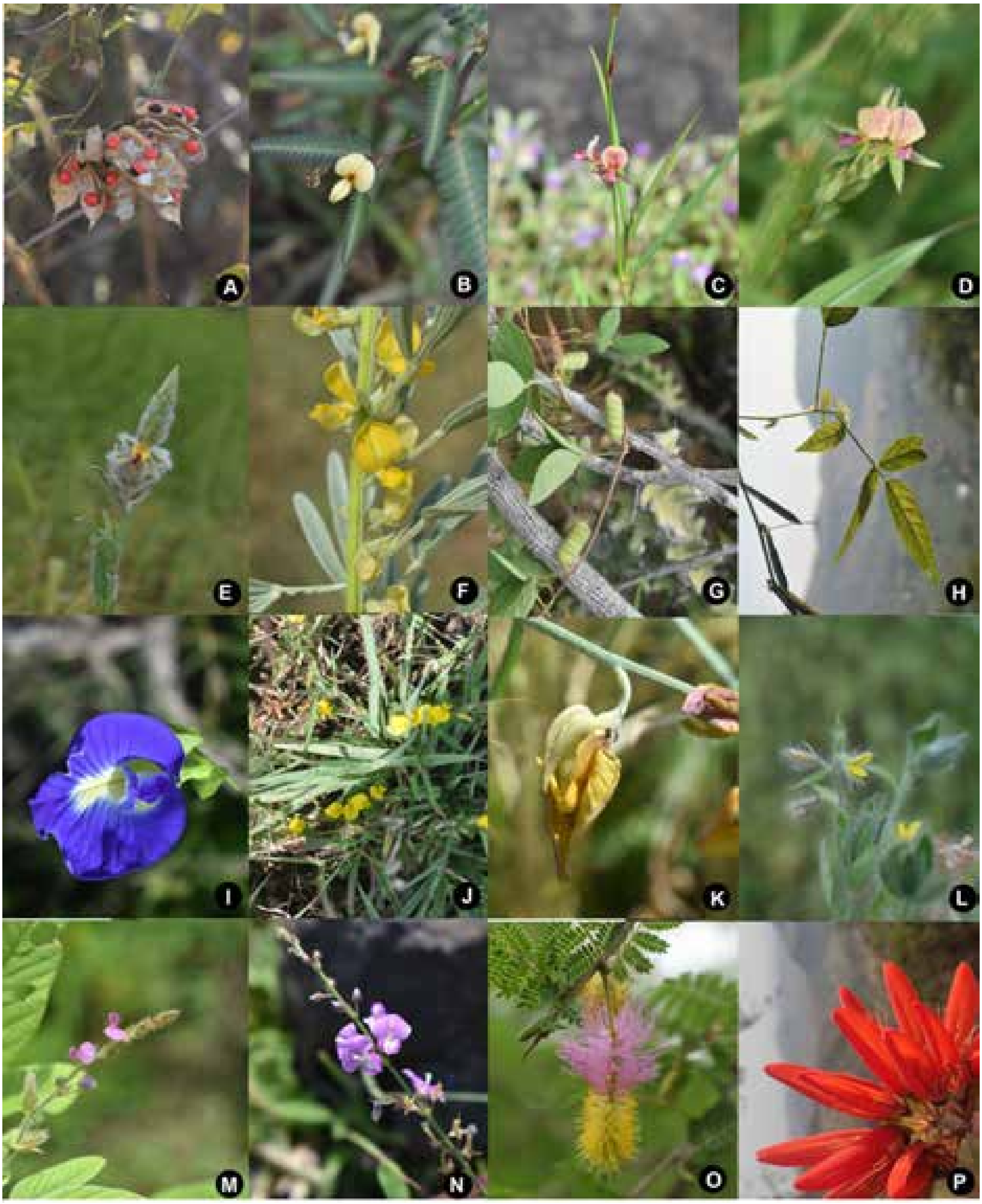

Image 1. A —*Abrus precatorius* L.| B— *Aeschynomene aspera* L. | C—*Alysicarpus bupleurifolius* (L.) DC. | D—*Alysicarpus heyneanus* Wight & Arn. | E—*Alysicarpus pubescens* Law | F—*Cajanus sericeus* (Benth. ex Baker) Maesen | G— *Cajanus scarabaeoides* (L.) Thouars | H— *Clitoria annua* J. Graham | I—*Clitoria ternatea* L. | J—*Crotalaria hebecarpa* (DC) Rudd. | K—*Crotalaria juncea* L. | L— *Crotalaria mysorensis* Roth | M–*Desmodium dichotomum* (Willd.) DC. | N— *Desmodium gangeticum* (L.) DC |O— *Dichrostachys cinerea* (L.) Wight & Arn. | P— *Erythrina stricta* Roxb. © Swapnil D. Wagh.

Image 2. A—*Gliricidia sepium* (Jacq.) Kunth | B—*Indigofera cassioides* Rottler ex DC. | C– *Indigofera cordifolia* B. Heyne ex Roth | D—*Indigofera linifolia* (L.f) Retz. | E—Alysicarpus vaginalis (L.) DC | F—*Crotalaria medicaginea* Lam. | G—*Dolichos trilobus* L. | H— *Indigofera trifoliata* var. *duthiei* (J.Drumm. ex Naik) Sanjappa | I—*Macrotyloma uniflorum* (Lam.) Verdc. | J—*Mundulea sericea* (Willd) A. Chev. | K—*Mucuna pruriens* (L.) DC. | L—*Paracalyx scariosus* (Roxb.) Ali | M—*Pongamia pinnata* (L.) Pierre | N—*Rhynchosia minima* (L.) DC | O—*Rhynchosia rothii* Benth. ex Aitch. | P—*Sesbania bispinosa* (Jacq.) W. Wight. © Swapnil D. Wagh.

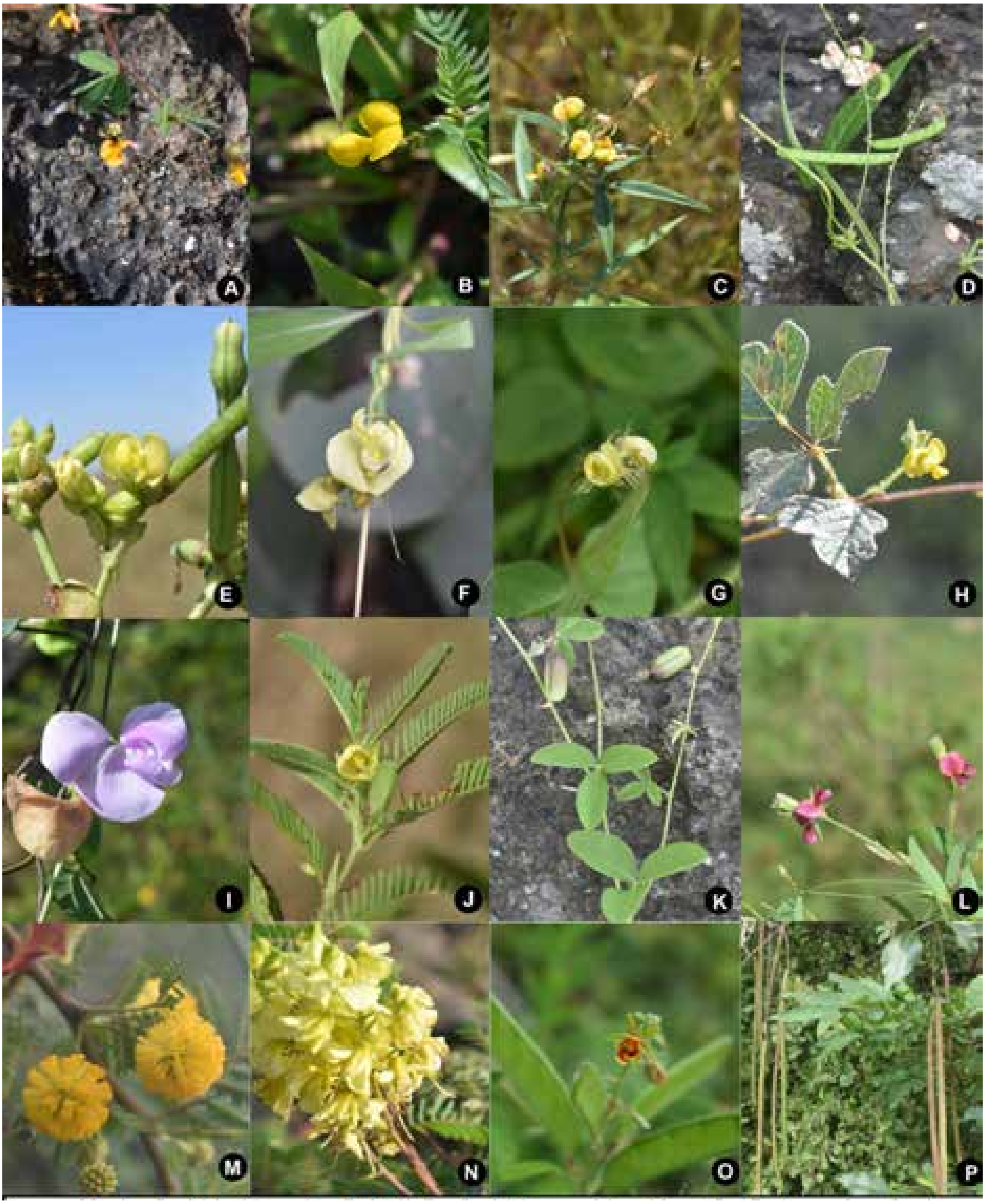

Image 3. A—*Smithia bigemina* Dalzell | B—*Smithia sensitiva* Aiton | C—*Stylosanthes fruticosa* (Retz.) Alston | D—*Teramnus mollis* Benth. | E—*Vigna khandalensis* (Santapau) Sundararagh. & Wadhwa | F—*Vigna radiata* (L.) Wilczeck. | G—*Vigna mungo* (L.) Hepper | H—Vigna indica T.M. Dixit, K.V. Bhat & S.R.Yadav | I—*Vigna vexillata* (L.) A. Rich | J—*Chamaecrista mimosoides* (L.) Greene | K—*Crotalaria orixensis* Willd. | L—*Alysicarpus monilifer* (L.) DC. | M—*Vachellia nilotica* (L.) P.H.J.Hurter & Mabb. | N—*Biancaea decapetala* (Roth) O.Deg | O—*Chamaecrista abscus* (L.) H.S.Irwin & Barneby | P –*Cassia fistula* L. © Swapnil D. Wagh.

jott.3959.12.10.16295-16313

Cherian, P.J. & R.D. Pataskar (1969). Contribution to the flora of Saptashrungi and adjoining hills, Maharashtra. *Nelumbo*, The Bulletin of Botanical Survey of India 11(1–2): 23–34

Cooke, T. (1958). *The Flora of the Presidency of Bombay* (Reprint Editon). *Vol. 1.* Taylor and Francis, London, 645 pp.

FAO (2016). https://www.fao.org/faostat/en/#home. Accessed on 24 August 2022.

Hooker, J.D. (Ed.) (1876). *The Flora of British India* 2(4): 56–240. L. Reeve & Co., Henrietta Street, London, 792 pp.

Jain, S.K. & R.R. Rao (1976). *A Hand Book of Field and Herbarium Methods*. Today and Tomorrow's Printers and Publishers, New Delhi, 157 pp.

LPWG (2017). A new subfamily classificaton of the Leguminosae based on a taxonomically comprehensive phylogeny. *Taxon* 66(1): 44–77. https://doi.org/10.12705/661.3

Lakshminarasimhan, P. & B.D. Sharma (1991). *Flora of Nasik District*. Botanical Survey of India, Calcutta, 644 pp.

Naik, V.N. (1998). *Flora of Marathwada*. *Vol. 1*. Amrut Prakashan, Aurangabad, 602 pp.

Pawar, B.R. & D.S. Pokle (2011). Flora of hills of Nashik district. PhD Thesis. Department of Botany, Dr. Babasaheb Ambedkar Marathwada University, Aurangabad, 191 pp

Popelka, J.C., N. Terryn & T.H.V. Higgins (2004). Gene technology for grain legumes: can it contribute to the food challenge in developing countries? *Plant Science* 167: 195–206.

Sanjappa, M. (2020). Fabaceae (Leguminosae), pp. 300–446. In: Mao, A.A. & S.S. Dash (eds.). *Flowering Plants of India an Annotated Checklist Dicotyledons.* Botanical Survey of India, Kolkata, 705 pp.

Singh, N.P. & S. Karthikeyan (2001). *Flora of Maharashtra State*. *Vol. 1*. Botanical Survey of India, Calcutta, 916 pp.

USDA (1998). Legumes and Soil Quality. *Soil Quality–agronomy Technical Note* 6: 1–3.

Yadav, S. & P.B. Dhanke (2010). *A Checklist of Plants of Nashik District.* Orient Press Ltd, Mumbai, 143 pp.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 December 2023 | 15(12): 24437–24442

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

https://doi.org/10.11609/jott.8242.15.12.24437-24442

#8242 | Received 29 October 2022 | Final received 07 November 2023 | Finally accepted 28 November 2023

COMMUNICATION

Report of new myristica swamp ecosystems from the Western Ghats at Pathanapuram, Kerala, India

Niji Joseph [1], R. Sreejai [2] & M. Ajayakumar [3]

[1,2] DST-FIST Zoology Research Centre, St. Stephen's College, Pathanapuram, Pathanapuram, Kerala 689695, India.
[3] Ambanar Forest Station, Pathanapuram, Kerala 689696, India.
[1] nijijoseph43@gmail.com (corresponding author), [2] sreejaiksbb@gmail.com, [3] ajayakumarmadhavan2012@gmail.com

Abstract: We present a new distributional report of myristica swamp ecosystems in the Western Ghats at Pathanapuram, Kerala, India based on several distinct field surveys from April 2022 to June 2022. From Kerala, myristica swamp has previously been reported mainly from Shendurney Wildlife Sanctuary, Kulathupuzha Reserve Forests, and adjoining regions of the Anchal forest ranges in southern Western Ghats. The present study described and illustrated the occurrence of myristica swamp from the Pathanapuram forest range in Kerala for the first time. The observed myristica swamps from the Pathanapuram forest range are seen inside the Ambanar model forest station and Punnala forest station limits. A total of 18 myristica swamp patches from Ambanar and seven myristica swamps from Punnala were reported and captured. A pilot survey from these sites suggests they are abundant with various faunal and floral wealth. Therefore, recognition and conservation of these ecosystems are essential and vital and suggest further surveys and conservation efforts.

Keywords: Conservation, ecological diversity, endemic species, field survey, habitat restoration, indigenous flora new distribution records, Pathanapuram forest range, tropical freshwater swamps, wetland forest ecosystem.

2022 ഏപ്രിൽ മുതൽ 2022 ജൂൺ വരെയുള്ള നിരവധി വ്യത്യസ്തമായ ഫീൽഡ് സർവേകളെ അടിസ്ഥാനമാക്കി, പശ്ചിമഘട്ടത്തിലെ പത്തനാപുരത്ത്, ഇന്ത്യയിലെ മിരിസ്റ്റിക്ക ചതുപ്പ് ആവാസവ്യവസ്ഥയുടെ ഒരു പുതിയ വിതരണ റിപ്പോർട്ട് ഞങ്ങൾ അവതരിപ്പിക്കുന്നു. തെക്കൻ പശ്ചിമഘട്ടത്തിലെ കേരളത്തിൽ നിന്ന്, പ്രധാനമായും കുളത്തൂപ്പുഴ റിസർവ് ഫോറസ്റ്റ്, ശെന്തുരുണി വന്യജീവി സങ്കേതം,അഞ്ചൽ വനമേഖല തുടങ്ങിയ പ്രദേശങ്ങളിൽ നിന്നുമാണ് മിരിസ്റ്റിക്ക ചതുപ്പ് മുമ്പ് റിപ്പോർട്ട് ചെയ്യപ്പെട്ടിട്ടുള്ളത്. കേരളത്തിലെ പത്തനാപുരം ഫോറസ്റ്റ് റേഞ്ചിൽ നിന്ന് മിരിസ്റ്റിക്ക ചതുപ്പുനിലത്തിനെ കുറിച്ച് വിവരിക്കുകയും വിശദീകരിക്കുകയും ചെയ്യുന്ന ആദ്യ പഠനം ആണ് ഇത്. പത്തനാപുരം ഫോറസ്റ്റ് റേഞ്ചിൽ നിന്ന് നിരീക്ഷിക്കപ്പെടുന്ന മിരിസ്റ്റിക്ക ചതുപ്പുകൾ അമ്പനാർ മോഡൽ ഫോറസ്റ്റ് സ്റ്റേഷൻ പരിധിയിലും പുന്നല ഫോറസ്റ്റ് സ്റ്റേഷൻ പരിധിയിലും കാണപ്പെടുന്നു. അമ്പനാറിൽ നിന്ന് 18 മിരിസ്റ്റിക്ക ചതുപ്പുകളും പുന്നലയിൽ നിന്ന് ഏഴ് മിരിസ്റ്റിക്ക ചതുപ്പുകളും റിപ്പോർട്ട് ചെയ്തു. ഇവിടെ നിന്നുള്ള പൈലറ്റ് സർവേ സൂചിപ്പിക്കുന്നത് ഇവിടെയുള്ള മിരിസ്റ്റിക ചതുപ്പുകൾ വിവിധ ജന്തുജാലങ്ങളും പുഷ്പ സമ്പത്തും കൊണ്ട് സമൃദ്ധമാണെന്നാണ്. അതിനാൽ, ഈ ആവാസവ്യവസ്ഥകളുടെ അംഗീകാരവും സംരക്ഷണവും അത്യന്താപേക്ഷിതവും സുപ്രധാനവുമാണ്. കൂടാതെ കൂടുതൽ സർവേകളും സംരക്ഷണ ശ്രമങ്ങളും നിർദ്ദേശിക്കുന്നു.

Editor: Mandar Nilkanth Datar, MACS-Agharkar Research Institute, Pune, India. **Date of publication:** 26 December 2023 (online & print)

Citation: Joseph, N., R. Sreejai & M. Ajayakumar (2023). Report of new myristica swamp ecosystems from the Western Ghats at Pathanapuram, Kerala, India. *Journal of Threatened Taxa* 15(12): 24437–24442. https://doi.org/10.11609/jott.8242.15.12.24437-24442

Funding: Self-funded.

Competing interests: The authors declare no competing interests.

Author details: Niji Joseph, a PhD scholar, has a fundamental interest in benthic macroinvertebrates and forest ecosystems. Sreejai R holds the position of a professor at St. Stephen's College, Pathanapuram, while M. Ajayakumar serves as the Deputy Forest Range Officer at Ambanar Forest Station, Pathanapuram.

Author contributions: NJ conceived the concept of the work, conducted the fieldwork, and wrote the manuscript. Revisions and editing of the work were done by SR. MA assisted in preparing the map for the article.

Acknowledgements: We would like to express our sincere gratitude to Mr. Ajayakumar (Deputy Range Forest Officer, Ambanar Forest Station), Vishnu V (Reserve Forest Watcher, Punnala), Hari V Nair and Jomy Jose for their invaluable assistance during our field visit to the site. Additionally, we extend our thanks to Mr. Biju Kumar (Deputy Range Forest Officer, Shendurney) for generously sharing his wealth of knowledge with us. We are also indebted to Dr. Shibu Varghese from the Department of Botany, St. Stephen's College, Pathanapuram, for his expertise in identifying several plant species at the site. Furthermore, we are truly thankful for the unwavering support and guidance provided by all the officers from Ambanar and Punnala forest stations. Our successful journey would not have been possible without their assistance. I extend my heartfelt gratitude to St. Stephen's College, Pathanapuram, for their generous provision of essential facilities and Encouragement, pivotal to the successful completion of this research publication.

Myristica swamps are the wetland forest ecosystems that are inundated fully or partially for the greater part of the year. These tropical freshwater swamps are characterized by the dominance of Myristicaceae family members like *Myristica fatua* var. *magnifica* (Bedd.) Sinclair and *Gymnacranthera farquhariana* (Wall. ex-Hook. fil. & Thomson) Warb. (Varghese & Menon 1999; Bhat & Kaveriappa 2009; Jose et al. 2014a; Sujitha et al. 2019). Myristica swamps are confined to valleys with flat bottoms and slow-moving streams in the altitude range of 100–200 m. Myristica swamps shelter several rare and threatened floral–faunal species (Vasudeva et al. 2001; Ganesan 2002; Ranganathan et al. 2022). Over six decades ago, myristica swamps were initially described by Krishnamoorthy (1960) from the Travancore region in Kerala State of southern Western Ghats. Champion & Seth (1968) named these tropical swamps as 'Myristica Swamp Forest' and categorized them under the sub group 4C. Rodgers & Panwar (1988) emphasized the importance of conservation of the vegetation. According to the data so far, in Kerala these swamps were mainly spanned in the valleys of Shendurney Wildlife Sanctuary, in Kulathupuzha Reserve Forests, and adjoining regions of the Anchal forest ranges in the southern Western Ghats (Krishnamoorthy 1960; Varghese & Kumar 1997; Varghese & Menon 1999; Nair et al. 2007; Roby 2011; Jose et al. 2014b). In addition to Kerala, myristica swamps have also been reported from Goa, Karnataka, and Maharashtra (Santhakumaran et al. 1995; Chandran et al. 1999; Sreedharan & Indulkar 2018). However, the once-pristine myristica swamps in the Western Ghats are presently encountering disruption and fragmentation due to increasing growing demands for land and water (Champion & Seth 1968; Chandran et al. 1999; Chandran & Mesta 2001; Ranganathan et al. 2022). Increasing forest surveys in recent times have led to the documentation of a few myristica swamps across Western Ghats (Sreedharan & Indulkar 2018). This paper reports the identification of a new myristica swamp ecosystems from Pathanapuram forest range in the southern part of the Western Ghats.

We have been sampling myristica swamp forests in southern Kerala for a proposed study on *Myristicaceae* members. On 20 April 2022, we found some canopy of *Myristicaceae* members in Pathanapuram forest range (9.08534^{0}N, 76.8551^{0}E) of Punalur division in Kollam District, Kerala, India (Figure 1). The observed *Myristica* swamps from Pathanapuram Forest Range fall within Ambanar Model Forest Station and Punnala Forest Station limits. During our first visit, we noticed the swampy habitat, as well as the occurrence of 'knee roots' and 'stilt roots' both of which are characteristics of myristica swamps. We have conducted 11 field surveys during the period from April 2022–June 2022. For the systematic study of vegetation, we chose 25 sample plots from both Ambanar and Punnala. Quadrats of 20 × 20 m were laid along the linear course of the swamps from Ambanar and Punnala respectively for the enumeration of trees having minimum grith ≥30 cm. Girth of all trees and shrubs was calculated using a measuring tape. For swamps smaller than 400 m^2 no quadrats were placed; instead, the species were simply listed. Both trees and underground vegetation were taken into consideration. Two sub-quadrats of 5 × 5 m were laid for the shrub layer within each tree quadrat (plants above one meter height). Within each of the 5 × 5 m quadrats, two smaller quadrats of 1 × 1 m were laid for the herb layer (plants less than one meter height). The plant species were identified by an expert and also by comparing pictures from published sources including the internet (Gamble & Fischer 1936; Varghese & Menon 1999; Sasidharan 2006; Nair et al. 2007). Geographic coordinates were recorded at each sampling point using Garmin® eTrex® 20x GPS. Image 1 shows some individual photographs of myristica swamps from both Ambanar and Punnala Forest Station.

The Ambanar Forest Station covers an area of 89.22587 km^2. The area of research is 0.86 ha of the total forest area. The topographic conditions of Ambanar vary from 75–1,050 m asl. In general, red loamy soil which is rich in minerals is found. Apart from this, alluvial soil is also found in river banks and valleys. The degree of soil pH is 4.48–6.10. The climate of this forest area has an air temperature of 29^0–31^0 C. Ambanar receives annual rainfall of 2,400 mm. Humidity is highest in the months of June, July, and August and lowest in February. The noted measures of general relative humidity at 0830 h IST and 1730 h IST from February to March are about 52% and 98%, respectively.

The Punnala Forest Station covers an area of 49.85 km^2 Compared to the surrounding level, this region has an elevation of about 10–400 m. In terms of climate, it experiences both moderately hot as well as humid conditions. The hottest period is from February–May and the coldest in December and January. The maximum and minimum reported temperatures are 37^{0}C and 20^{0}C, respectively. The area receives an average annual rainfall of 2,400 mm. The plants growing on the hills at higher altitudes are prone to severe damage made by the dry easterly winds. Humidity is highest in the months of June, July, and August and lowest in February. General relative humidity at 0830 h IST and 1730 h IST during February to March are about 52% to 98%, respectively.

All 18 patches of myristica swamps and the

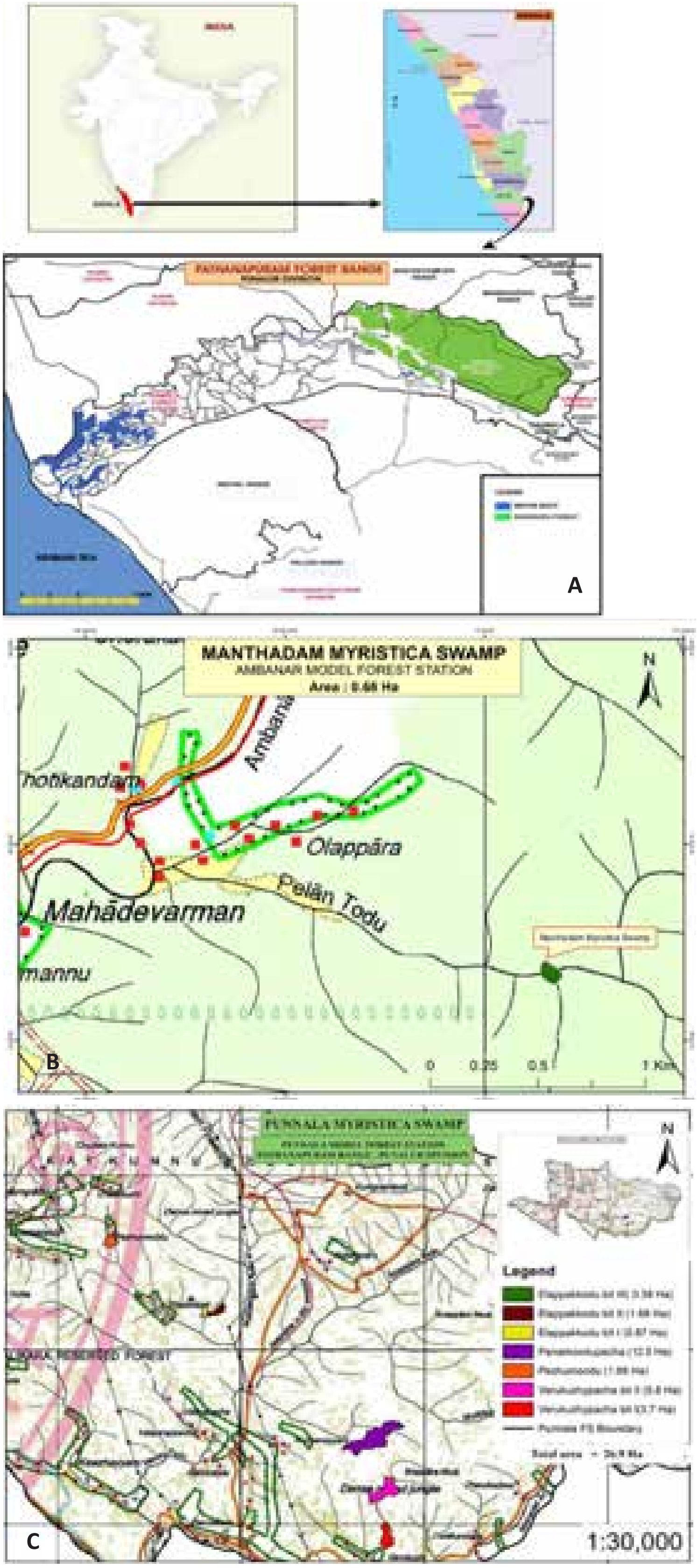

Figure 1. A—map of Pathanapuram Forest Range Kerala, India showing the study sites, Ambanar and Punnala. Legend: Colours: Green—Reserve forests | Blue—Water body) | B—location of the Myristica swamps at Ambanar model forest station | C—locations of the Myristica swamps at Punnala forest station. Map courtesy: Pathanapuram Forest Department.

geographical coordinates of the sampling points in the Ambanar area are presented in Table 1. Geographically, all these 18 patches are located in Manthadam region of the Ambanar. The region Manthadam comprises a small stream that maintains the distinctive swampy ecosystem. Olappara and Minnaminni are the places near Manthadam in which saplings of Myristicaceae family members are found.

In the Punnala Forest Station range, there are seven Myristica swamps present with a total area of 26.9 ha. They are Elappakkodu Bit 1, Elappakkodu Bit 2, Elappakkodu Bit 3, Pezhummodu, Verukuzhypacha Bit 1, Verukuzhypacha Bit 2, and Pannamood pacha. Most of the swamps in Punnala are inundated throughout the year due to the presence of three rivulets – Elappakkodu Thodu, Pezhumoodu Thodu, and Mukkalampadu Thodu. These three rivulets flow into the Kallada river. Table 2 shows the geo-coordinates of locations and the total area occupied by the myristica swamp in the Punnala region. There were large numbers of Myristica trees in Elappakodu swamps. Along with these seven sites, saplings of Myristica trees grow at Choorapacha, Thulasithara, and Therdhakkara in Punnala Forest Station. The neighbouring forest of these swamps is semi-evergreen in nature. The Kerala Forest Development Corporation (KFDC) Limited, Punalur Division is situated nearest to the Elappakodu swamp. Elappakodu and Pezhumood pacha are the reserved forests in Punnala. However, some regions of Elappakodu swamp are disturbed due to locally originated anthropogenic activities like fishing and crabbing. In Punnala Station limits, reserve forest is much smaller and therefore more vulnerable to local disturbances. Hence the swamps in Punnala need special attention from a management perspective.

Table 1. List of myristica swamps under Ambanar model forest area, Pathanapuram range.

	Name of the swamp	Geocoordinates of the swamps		Area (Ha)
		Latitude (⁰N)	Longitude (⁰E)	
1	Manthadam Bit 1	90.05375	76.99838	0.8
2	Manthadam Bit 2	90.05477	76.99887	
3	Manthadam Bit 3	90.05361	76.99866	
4	Manthadam Bit 4	90.05344	76.99830	
5	Manthadam Bit 5	90.05333	76.99913	
6	Manthadam Bit 6	90.05327	76.99897	
7	Manthadam Bit 7	90.05336	76.99883	
8	Manthadam Bit 8	90.05322	76.99855	
9	Manthadam Bit 9	90.05316	76.9985	
10	Manthadam Bit 10	90.05336	76.99811	
11	Manthadam Bit 11	90.05347	76.99772	
12	Manthadam Bit 12	90.05344	76.99755	
13	Manthadam Bit 13	90.05369	76.99730	
14	Manthadam Bit 14	90.05375	76.99727	
15	Manthadam Bit 15	90.05383	76.99736	
16	Manthadam Bit 16	90.05383	76.99738	
17	Manthadam Bit 17	90.05372	76.99736	
18	Manthadam Bit 18	90.05363	76.99805	

Table 2. List of myristica swamps under Punnala forest area, Pathanapuram range.

	Name of swamp	Geo coordinates of the swamps		Area (ha)
		Latitude (⁰N)	Longitude (⁰E)	
1	Elappakkodu Bit 1	09. 08762	076. 95453	0.87
2	Elappakkodu Bit 2	09. 08762	076. 95470	1.66
3	Elappakkodu Bit 3	09. 08922	076. 95295	0.38
4	Pezhumoodu	09. 09545	076. 94337	1.99
5	Verukuzhypacha Bit 1	09. 05970	076. 97498	3.7
6	Verukuzhypacha Bit 2	09. 06812	076. 97509	5.8
7	Panamoodupacha	09. 07138	076. 69757	12.5

When examining the vegetation listed in Table 3, *Gymnacranthera farquhariana*, *Myristica fatua* var. *magnifica*, and *Knema attenuata* (Hook.f. & Thoms.) Warb. consistently appear in both the Ambanar and Punnala regions. These species seem to thrive in diverse environmental conditions represented in both the areas. However, *Myristica dactyloides* (Gaertn.) displays a distinct pattern, being present in Ambanar but remarkably absent in Punnala. Our observations suggest disparities in species distribution within Ambanar and Punnala highlight the intricate interplay of ecological forces, suggesting a dynamic and diverse nature shaped by a combination of microclimatic variations, historical influences, and human activities. A comparison of the distribution of non-Myristicaceae trees between Ambanar and Punnala shows notable differences in species presence. Based on our preliminary findings, we recognize the need for further investigation to better understand the disparities in species distribution among these sites.

Myristica swamps are rich with numerous invertebrates and vertebrates, both terrestrial and

Image 1. Myristica swamps: A—In Manthadam with the occurrence of pneumatophores | B—rivulet that flows through Elappakodu swamp | C—In Elappakodu Bit 1 | D—water inundation of Myristica swamp with the presence pneumatophores. © Niji Joseph.

aquatic (Jose et al. 2014b; Sinu & Sharma 2013; Sujitha et al. 2019; Ranganathan et al. 2022). A pilot survey from these sites suggests they are abundant with various faunal and floral wealth. Studies documenting the biodiversity of flora and fauna, climatic factors, hydrology, and soil, and so forth of these ranges are not well studied and documented. For this reason, a clear picture of these factors is not available yet. As per the pilot study, we noticed plenty of juveniles of ecologically significant species present in these swamp forests. This indicates that numerous species use the *Myristica* swamps as breeding grounds (Abraham et al. 2018; Ranganathan et al. 2022). Mapping and documenting the specifics of these swamp forests is both important and potent for further research. Preventing the incursion of non-swampy plant species into the swamp helps to maintain the swampy habitat. Raising the status of these swamps will restrict the anthropogenic and natural disturbances. In order to ensure a long-term monitoring, incorporating the interests of local communities in the conservation and management activities are also desirable. With this new reporting, the revised Indian distribution of myristica swamps should include Ambanar and Punnala of Pathanapuram forest range.

REFERENCES

Abraham, R.K., J.K. Mathew, D.V. Raju, R. Rao & A. Zachariah (2018). Reproduction and metamorphosis in the Myristica Swamp Tree Frog, *Mercurana myristicapalustris* (Anura: Rhacophoridae). *PeerJ 6*: e5934. https://doi.org/10.7717/peerj.5934

Bhat, P.R. & K.M. Kaveriappa (2009). Ecological studies on *Myristica* swamp forests of Uttara Kannada, Karnataka, India. *Tropical Ecology* 50(2): 329–337.

Champion, S.H. & S.K. Seth (1968). A revised survey of the forest types of India, Government of India Press, New Delhi, 404 pp.

Chandran, M.D.S. & D.K. Mesta (2001). On the conservation of the *Myristica* swamps of the Western Ghats, pp. 1–19. In: Umashaanker, R., K.N. Ganeshaiah & K.S. Bawa (eds.). *Forest Genetic Resources: Status, Threats, and Conservation Strategies*. Oxford & IBH, New Delhi.

Table 3. List of vegetation at Ambanar and Punnala Forest Station.

Species	Ambanar	Punnala
Myristicaceae trees		
**Gymnacranthera farquhariana* (Wall. ex-Hook. fil. & Thomson) Warb.	P	P
**Myristica fatua var. magnifica* (Bedd.) Sinclair	P	P
**Knema attenuata* (Hook.f.&Thoms.) Warb	P	P
Myristica dactyloides Gaertn	P	A
Non Myristicaceae trees		
**Vateria indica* L.	P	A
*Prioria pinnata (*Roxb. ex-DC.*)* Breteler	P	A
Neolamarckia cadamba (Roxb.) Bosser	P	P
**Semecarpus auriculata* Bedd.	P	A
Polyalthia fragrans (Dalzell) Hook. f. & Thomson	P	A
Hydnocarpus pentandra (Buch -Ham.) Oken	P	A
Homonoia riparia Lour.	P	A
Schleichera oleosa (Lour.) Oken	P	P
Lagerstroemia speciosa (L.) Pers.	P	A
**Cinnamomum malabatrum* (Burm. f.) Presl	P	A
**Hopea glabra* Wight & Arn.	P	A
Hopea malabarica Bedd.	P	A
Tetrameles nudiflora R. Br.	P	A
**Holigarna arnottiana* Hook.f.	P	P
Diospyros buxifolia (Blume) Hiern	P	A
Non Myristicaceae trees		
Syzygium gardneri Thw.	P	A
Baccaurea courtallensis (Wight) Müll.Arg.	P	A
Persea macrantha (Nees) Kosterm.	A	P
**Actinodaphne bourdillonii* Gamble	A	P
Xylia xylocarpa (Roxb.) Taub.	A	P
**Hydnocarpus laurifolia* (Dennst.) Sleum.	A	P
Delonix regia (Hook.) Raf.	A	P
Mitragyna parvifolia (Roxb.) Korth.	A	P
Terminalia bellirica (Gaertn.) Roxb.	A	P
Macaranga peltata (Roxb.) Müll.Arg.	A	P
Grewia tiliaefolia Vahl	A	P
Other vegetation		
Calamus rotang L.	P	A
Pandanus spp.	P	A
Ferns	P	A
Lagenandra ovata (L.) Thwaites	P	A
Cheilocastus speciosus (J. Koenig) C.D. Specht	P	P
Phrynium capitatum Willd	A	P
Carissa carandas L.	A	P
Colocasia esculenta (L.) Schott	A	P

***Endemic to Western Ghat**

Chandran, M.D.S., D.K. Mesta & M.B. Naik (1999). *Myristica* swamps of Uttara Kannada district. *My Forest* 35(3): 217–222.

Gamble, J.S & C.E.C. Fischer (1936). *Flora of the Presidency of Madras.* Vol. 1-3. West, Newman and Adlard, London, 477–480 pp.

Ganesan, R. (2002). Evergreen forest swamps and their plant species diversity in Kalakad-Mundanthurai tiger reserve, South Western Ghats, India. *Indian forester* 128(12): 1351–1359.

Jose, J., T.J. Roby, K.K. Ramachandran & P.V. Nair (2014b). Species abundance distributions of selected communities in the Myristica swamp forests of southern Kerala. *Current Science* 107(3): 447–453.

Moorthy, K.K. (1960). myristica swamps in the evergreen forests of Travancore. *Indian Forester* 86(5): 314–315.

Nair, P.V., K.K. Ramachandran, K. Swarupanandan & T.P. Thomas (2007). Mapping biodiversity of the myristica swamps in southern Kerala. Kerala Forest Research Institute, Peechi, Kerala, 255 pp.

Ranganathan, P., G. Ravikanth & N.A. Aravind (2022). A review of research and conservation of myristica swamps, a threatened freshwater swamp of the Western Ghats, India. *Wetlands Ecology and Management* 30(1): 171–189. https://doi.org/10.1007/s11273-021-09825-5

Roby, T.J. (2011). Floristic structure and diversity of *Myristica* Swamps at Kulathupuzha in a GIS perspective. Ph.D. thesis, FRIU, Dehradun, 148 + xxxi pp.

Rodgers, W.A. & H.S. Panwar (1988). *Planning Wildlife Protected Area Network in India*. Wildlife Institute of India .

Santhakumaran, L.N., A. Singh & V.T. Thomas (1995). Description of a sacred grove in Goa (India), with notes on the unusual aerial roots produced by its vegetation. *Wood* (Oct–Dec): 24–28.

Sasidharan, N. (2006a). *Flowering plants of Kerala. A Checklist*. Kerala Forest Research Institute. CD, (6).

Sasidharan, N. (2006b). TreeID. Tree identification key for Kerala". a search engine for taxonomical purposes developed at Kerala Forest Research Institute, Peechi.**Senthilkumar, N., S. Prakash, C.R. Kannan, A.A. Prasath & N. Krishnakumar (2014).** Revisiting forest types of India (Champion and Seth, 1968): A case study on *Myristica* swamp forest in Kerala. *International Journal* of *Advanced Research* 2(2): 492– 501.

Sinu, P.A. & M.V. Sharma (2013). Insect functional guilds in the flowering canopy of *Myristica fatua* in a lowland swamp, central Western Ghats, India. *Tropical Conservation Science* 6(5): 653–662. https://doi.org/10.1177/194008291300600505

Sreedharan, G. & M. Indulkar (2018). New distributional record of the northernmost *Myristica* swamp from the Western Ghats of Maharashtra. *Current Science* 115(8): 434–1436.

Sujitha, P. C., G. Prasad & K. Sadasivan (2019). Butterflies of the *Myristica* swamp forests of Shendurney Wildlife Sanctuary in the southern Western Ghats, Kerala, India. *Journal of Threatened Taxa 11*(3): 13320–13333. https://doi.org/10.11609/jott.4399.11.3.13320-13333

Varghese A.V. & B.M. Kumar (1997). Ecological observations in the fresh water swamp forests of Southern Kerala, India. *Journal of Tropical Forest Science* 9(3): 299–314.

Varghese, A.O. & A.R. Menon (1999). Floristic composition, dynamics, and diversity of *Myristica* swamp forests of Southern Western Ghats, Kerala. *Indian Forester* 125: 775–783.

Vasudeva, R., H.B. Raghu, U.S.R. Dasappa & K.N. Ganeshaiah (2001). Population structure, reproductive biology, and conservation of Semecarpus kathalekanensis: a critically endangered fresh water swamp tree species of the Western Ghats. Forest genetic resources: status, threats, and conservation strategies. 211–223.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 December 2023 | 15(12): 24443–24446
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.8624.15.12.24443-24446
#8624 | Received 03 July 2023 | Final received 24 October 2023 | Finally accepted 28 November 2023
OPEN ACCESS
SHORT COMMUNICATION

First confirmed record of Arabian Gazelle *Gazella arabica* Lichtenstein, 1827 (Mammalia: Artiodactyla: Bovidae) on Masirah Island, off the coast of eastern Oman in the Arabian Sea

Taimur Al Said [1], Haitham Al Rawahi [2], Maha Al Ansari [3], Al Mutasim Al Hinai [4], Ahmed Al Amri [5], Ahmed Al Wahaibi [6], Ghasi Al Farsi [7], Saud Al Wihibi [8] & Salman Al Farsi [9]

[1–9] Environment Authority, P.O Box 323, Muscat, P.C. 100, Sultanate of Oman.
[1] taimur_a_alsaid@hotmail.com (corresponding author), [2] haitham.alr88@gmail.com, [3] maha.s.alansari@hotmail.com, [4] almutasim90@gmail.com, [5] ahmedamri87@gmail.com, [6] ahmed.alwahaibi150@gmail.com, [7] ghasi.alfarsi@hotmail.com, [8] saudalwahibi60@gmail.com, [9] alfarsisalman908@gmail.com

Abstract: In Oman, the Arabian Gazelle *Gazella arabica* is known to be distributed in the Hajar mountains of the north, desert plains in central of Oman, and Jabal Samhan foothills & Nejd area in the south. We report the first confirmed record of the Arabian Gazelle on Masirah island, 15 km off the mainland of eastern Oman. This finding was part of a national survey of biodiversity in Oman in which 29 camera traps were set to survey the majority of the island which covers about 400 km^2. Only two camera traps detected Arabian Gazelle, in an area covering only 22 km^2. The survey on the island suggests that the population is small and isolated. Future research studies are required both in the field of ecology and genetics.

Keywords: Camera trapping, conservation, Mountain Gazelle, Sultanate of Oman, ungulate.

The Arabian Gazelle *Gazella arabica* is one of the five ungulate species that occur in Oman along with the Arabian Oryx *Oryx leucoryx*, Arabian Tahr *Arabitragus jayakari*, Nubian Ibex *Capra nubiana*, and Arabian Sand Gazelle *Gazella marica* (Mallon & Kingswood 2001; Al Hikmani et al. 2015). Arabian Gazelle was previously known as Mountain Gazelle *Gazella gazella* before the species was split into two genetically distinct lineages (Lerp et al. 2013). The adult males and females have an average body weight of 22.5 kg and 18.3 kg, respectively, whilst the adult male has larger and thicker neck and horns compared to the adult female (Horwitz et al. 1990). The species is distributed across the Arabian Peninsula in arid and semi-arid environments (Harrison & Bates 1964). In Oman, they usually occur in habitats where the *Vachellia tortilis* (= *Acacia tortilis*; 'simr' in Arabic) trees appear, which they use as shade and feed on their leaves and seed-pods. Arabian Gazelles are usually found in both plains and rugged mountains but are likely to avoid rocky areas (Al Jahdhami et al. 2017). The species may once have been found in far north of Oman in Musandam governorate, but today they are likely to be locally extinct (Al Hikmani et al. 2015). Northern populations of Arabian Gazelles in Al Batinah governorate have also disappeared but smaller populations still exist in the foothills of the Hajar mountains (Al Hikmani et al. 2015). The Arabian Oryx

Editor: David Mallon, Manchester Metropolitan University, Manchester, UK. **Date of publication:** 26 December 2023 (online & print)

Citation: Al Said, T., H. Al Rawahi, M. Al Ansari, A.M. Al Hinai, A. Al Amri, A. Al Wahaibi, G. Al Farsi, S. Al Wihibi & S. Al Farsi (2023). First confirmed record of Arabian Gazelle *Gazella arabica* Lichtenstein, 1827 (Mammalia: Artiodactyla: Bovidae) on Masirah Island, off the coast of eastern Oman in the Arabian Sea. *Journal of Threatened Taxa* 15(12): 24443–24446. https://doi.org/10.11609/jott.8624.15.12.24443-24446

Funding: The National Survey of Biodiversity is fully funded by the Environment Authority of Oman.

Competing interests: The authors declare no competing interests.

Acknowledgements: The National Survey of Biodiversity is one of the objectives of the 2040 vision of Oman. This survey was made possible by the permission of the Chairman of the Environment Authority, H.E Dr Abdullah bin Ali Al Amri and under the direction of Mr. Zahran Al Abdulasalam, the Office for Conservation of the Environment, Environment Authority. Special thanks to the Environment Center of Wilayat Masirah under the direction of Mr. Majid Al Arami and the staff for their help. Furthermore, thanks to the department of Environment Control including the rangers: Mr. Yousuf Al Ghidani, Mr. Samer Al Naabi, and Mr. Mazin Al Ghusaini, for further assistance. Finally, yet importantly the Administration and Finance Departments for their help in logistics and administration work.

Sanctuary in Al Wusta governorate previously held the largest population of Arabian Gazelles in Arabia with an estimate of 10,000 gazelles, but currently holds a small population (Mallon & Kingswood 2001; Al Hikmani et al. 2015; Al Jahdhami et al. 2017; Alsaid et al. 2019). In the south of Oman in Dhofar governorate, the Arabian Gazelle once occurred all over the arid areas such as the northern foothills known as (the 'Nejd'), the gravel plains south of the Empty Quarter, and the southern coastal plain and plateau of the arid Jabal Samhan massif. It has never been reported in the monsoon habitats on Jabal Al Qamar and Jabal Al Qara. Today, only a small population exists in the Nejd and the southern coastal plains between Mirbat and Sadah (Al Hikmani et al. 2015). A more recent joint survey was conducted by the Office for Conservation of the Environment and the Ministry of Environment in 2019 on the gazelle population in Dhofar in the area running from Thumrait to Demeet. The survey area was approximately 1,547 km^2 and consisted of flat rolling plains, and wadis. Distance sampling and analyses were used to collect and process line transect data. The population estimate for the area was calculated as 127 gazelles (). Ras As Shagar Nature Reserve and As Saleel Natural Park have the healthiest and largest wild populations of Arabian gazelle (Al Hikmani et al. 2015; Al Jahdhami et al. 2017; Ross et al. 2019). Threats such as habitat loss, habitat fragmentation, road kills and mainly poaching have caused population declines over the past few years. However, Oman remains the stronghold for Arabian Gazelle since the highest wild population resides in the country, due to conservation efforts (Mallon & Kingswood 2001; Strauss et al. 2009; Al Hikmani et al. 2015; Al Jahdhami et al. 2017).

Interestingly, reviews of the status and distribution of mammals in the Arabian Peninsula do not mention the presence of Arabian Gazelles on Masirah Island (Harrison & Bates 1964; Harrison 1968). Furthermore, the International Union for Conservation of Nature (IUCN) Red List also does not include Masirah island within the Arabian Gazelle distribution range. However, the BirdLife International Data Zone contains information on a bird survey conducted on Masirah Island in 1980

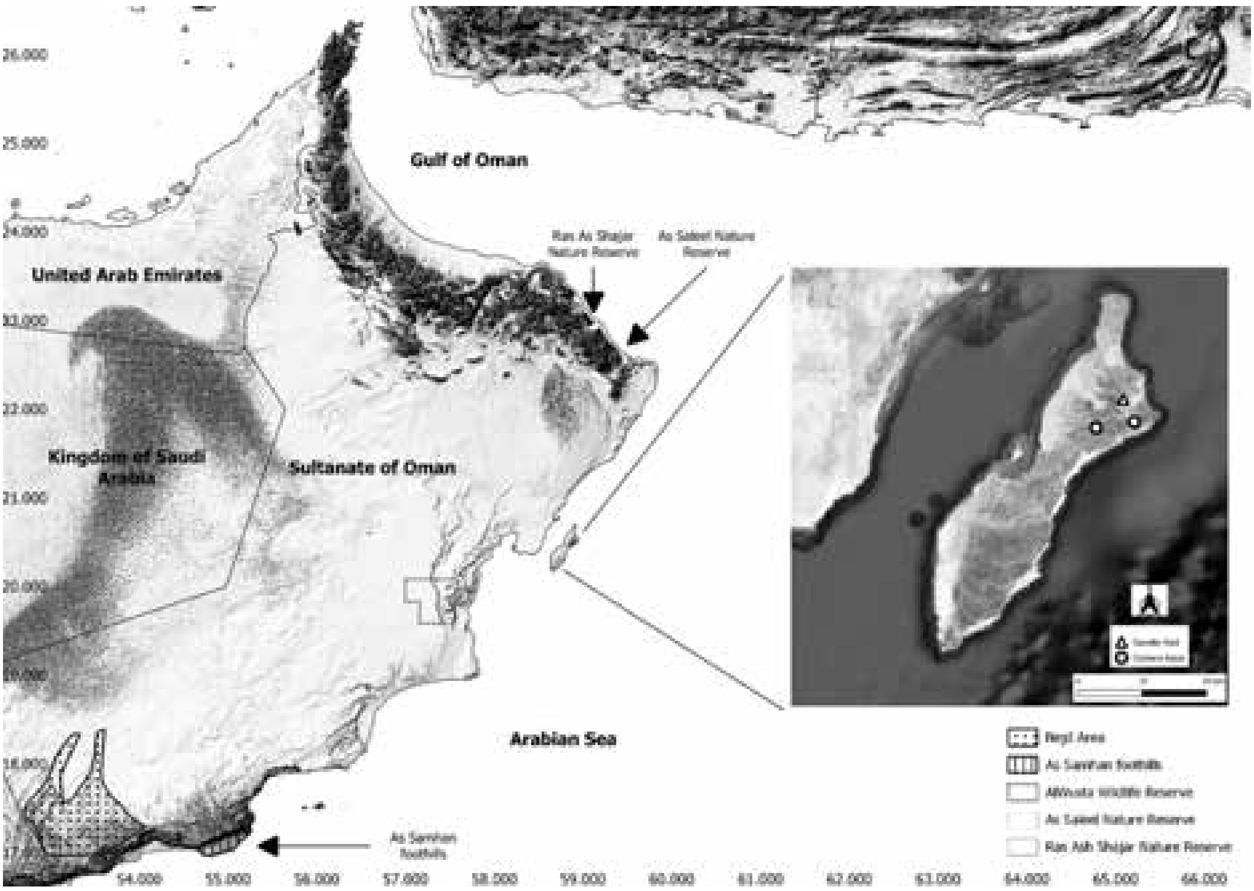

Image 1. The study area, Masirah Island, Oman, and the locations of the cameras that captured the Arabian Gazelle and location of the gazelle foot (right). Confirmed Arabian Gazelle distribution in Oman (left).

Image 2. Camera trap photographs of male Arabian Gazelle in Masirah Island, Oman: a— camera NM24 | b—camera NM25.

which reported a list of key bird species and non-bird species on the Island. They listed Cape Hare *Lepus capensis jefferyi* as being endemic to Masirah island and Mountain Gazelle *Gazella gazella* as present (BirdLife International 2023), although to date there has been no confirmed evidence (e.g., specimen, photograph).

The study area is Masirah Island (Figure 1) which lies in Ash Sharquiyah governorate and is Oman's largest island. It lies 15 km off the mainland in the Arabian Sea. The total area of the island is 649 km^2 and has a human population of 12,000 who are mostly concentrated in the north of the island where the Royal Air Force of Oman has a base (Abdul-Wahab et al. 2020). The island consists of a combination of mountains, cliffs and plains where the highest peak— Jabal Ash Shabbah lies north-east of the island at an altitude of ~210 m (Jansen 2023). The average annual rainfall is approximately 70 mm (Kwarteng et al. 2009).

A total of 29 camera traps (Spypoint & Bushnell) were placed by wildlife biologists and rangers of the Environment Authority on 4–18 December 2022. They were installed on rocks or boulders facing animal pathways and resting areas at a height of 0.25–0.75 m above the ground to survey large and medium mammals. The cameras used normal infrared sensors to trigger a three-photograph burst with a 5 s delay between captures. The camera trap sampling area was approximately 400 km^2 (Figure 1).

Here we describe the first confirmed photographic sighting of Arabian Gazelle on Masirah using camera traps. The gazelles were photographed on the north-eastern cliffs of the island. Both camera traps (NM24) and (NM25) photographed a male Arabian Gazelle on 7 January and 22 February 2023 respectively (Image 2). Moreover, on 6 December 2022 during the camera trap survey conducted by the Environment Authority, remains of an Arabian Gazelle foot were found close to where the camera traps photographed both gazelles (Image 3). There were also recent sightings by locals in the area. Regardless of a fairly large camera trapping survey, only two individuals were captured by camera traps in an area covering only 22 km^2. This indicates that the population may be both small and isolated. It

Image 3. Photograph taken by the survey team on which appears to be an Arabian gazelle foot in the northeastern cliffs of Masirah Island.

is difficult to know the reason for the populations' small size, however this population on Masirah island could be genetically different from the rest of the Arabian Gazelle population. Currently, an ongoing camera trap survey is being conducted on the island and this will provide a better understanding of their current distribution and population size. Further research on their genetics is required and therefore a plan is currently being designed to collect fecal pellets, tissue, and bone from the remains of dead Arabian Gazelle for genetic analysis to determine any genetic differences with the remaining Arabian Gazelle population in Oman. Another future research for the Arabian Gazelle in Masirah island would be to have a long-term camera trap study in place to understand their population status and distribution. Setting global positioning system (GPS) collars on Arabian Gazelle would allow us to gain an understanding of their home range estimation, movement patterns, and resource selection.

References

Abdul-Wahab, S.A., Y. Charabi, A.M. Al-Mahruqi & I. Osman (2020). Design and evaluation of a hybrid energy system for Masirah Island in Oman. *International Journal of Sustainable Engineering* 13(4): 288–297. https://doi.org/10.1080/19397038.2020.1790057

Al Hikmani, H., S. Zabanoot, T. Al Shahari, N. Zabanoot, K. Al Hikmani & A. Spalton (2015). Status of the Arabian Gazelle, *Gazella arabica* (Mammalia: Bovidae), in Dhofar, Oman. *Zoology in the Middle East* 61(4): 295–299.

Al Jahdhami, M.H., S. Al Bulushi, H. Al Rawahi, W. Al Fazari, A. Al Amri, A. Al Owaisi, S. Rubaiey, Z. Al Abdulasalam, M. Al Ghafri, S. Yadav & S. Al Rahbi (2017). The status of Arabian Gazelles *Gazella arabica* (Mammalia: Cetartiodactyla: Bovidae) in Al Wusta Wildlife Reserve and Ras Ash Shajar Nature Reserve, Oman. *Journal of Threatened Taxa* 9(7): 10369–10373. https://doi.org/10.11609/jott.3398.9.7.10369-10373

Alsaid, T., A. Aluwaisi, S. Albalushi, Z. Alabdulsalam, S. Alharsusi & S. Ross (2019). New record of Blanford's Fox *Vulpes cana* (Mammalia: Carnivora: Canidae) in central Oman: a connection between the northern and southern populations. *Journal of Threatened Taxa 11*(9): 14244–14246. https://doi.org/10.11609/jott.4908.11.9.14244-14246

BirdLife International (2023). Important Bird Area factsheet: Masirah island. http://datazone.birdlife.org/site/factsheet/8231. Downloaded on 03 July 2023.

Harrison, D.L. (1968). The large mammals in Arabia. *Oryx* 9(5): 357–363. https://doi.org/10.1017/S0030605300006992

Harrison, D.L. & P.J.J Bates (1964). *The Mammals of Arabia*. *Vol 2.* Benn, London, 354 pp.

Mallon, D.P. & S.C Kingswood (eds.) (2001). *Antelopes: Global Survey and Regional Action Plans. North Africa, the Middle East, and Asia, Part 4.* IUCN, Gland, Switzerland and Cambridge, 260 pp.

Jansen, M. (2023). Exposed ocean crust on Masirah Island, SE Oman: Crustal accretion and melt evolution at an ancient slow-spreading mid-ocean ridge. PhD Thesis. Cardiff University, 223 pp.

Horwitz, L.K., C. Cope & E. Tchernov (1990). Sexing the bones of mountain-gazelle (*Gazella gazella*) from prehistoric sites in the southern Levant. *Paléorient* 16(2): 1–12.

Kwarteng, A.Y., A.S Dorvlo & G.T Vijaya-Kumar (2009). Analysis of a 27-year rainfall data (1977–2003) in the Sultanate of Oman. *International Journal of Climatology* 29(4): 605–617. https://doi.org/10.1002/joc.1727

Lerp, H., T. Wronski, T.M Butynski & M. Plath (2013). Speciation of Arabian Gazelles, pp. 59–82. In: M. Pawel (Ed.). *Speciation: Natural Processes, Genetics and Biodiversity.* Hauppauge, New York, 274 pp.

Strauss, M., Y.A Kharousi & A. Spalton (2009). Status of the mountain gazelle population in the Arabian Oryx Sanctuary of Oman. *Wildlife Middle East News* 3(4): 5.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 December 2023 | 15(12): 24447–24450
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.8417.15.12.24447-24450
#8417 | Received 21 February 2023 | Final received 25 November 2023 | Finally accepted 02 December 2023
OPEN ACCESS
SHORT COMMUNICATION

First report of the longhorn beetle, *Rosalia* (*Eurybatus*) *formosa* (Saunders, 1839) (Insecta: Coleoptera: Cerambycidae) from Mizoram, India

Amit Rana [1] & **Lobeno Mozhui** [2]

[1] Zoological Survey of India, North Eastern Regional Centre, Shillong, Meghalaya 793003, India.
[2] Department of Zoology, Nagaland University, Lumami, Nagaland 798627, India.
[1] rana.amit13@rediffmail.com, [2] lobenommozhui@gmail.com (corresponding author)

Abstract: The present paper records *Rosalia* (*Eurybatus*) *formosa* (Saunders, 1839), a cerambycid or longhorn beetle for the first time from the state of Mizoram in northeastern India. The documentation was done on the basis of two specimens that were collected from the District of Champhai, Mizoram. In this communication, photographs, as well as notes on the morphological features of the species are presented.

Keywords: Cerambycinae, Champai district, Compsocerini, Murlen National Park, new record, northeastern India.

Cerambycidae Latreille, 1802, commonly known as longicorns or long-horned beetles are one of the largest groups of beetles with approximately 40,000 known species in 4,000 genera and eight subfamilies (Wang 2017). A total of 1,536 longhorn beetles classified under 72 tribes, 440 genera and eight subfamilies are reported from India, of which, 592 species are from the northeastern region, which accounts to 38.1% of the total cerambycid species in India (Kariyanna et al. 2017). The subfamilies which represent the cerambycids from the regions are Spondylidinae, Lepturinae, Prioninae, Cerambycinae, and Lamiinae. Within the northeastern states, 95 species under 64 genera and three subfamilies are reported from Assam (Mitra et al. 2017), 92 species under three subfamilies from Meghalaya (Hegde et al. 2022), 61 species under five subfamilies from Manipur (Kariyanna et al. 2017), 49 species under three subfamilies from Arunachal Pradesh (Kumawat et al. 2015), 36 species under three subfamilies from Nagaland (Mozhui et al. 2020), and 28 species under three subfamilies from Tripura (Agarwala & Bhattacharjee 2012). As per literature, not much work has been conducted in Mizoram.

The genus *Rosalia* Audinet-Serville, 1883 is divided into three subgenera: *Rosalia*, *Eurybatus* Thomson, 1860, and *Eurybatodes* Semenov, 1911. The subgenus *Eurybatus* differs from the subgenus *Rosalia* in several characters: (a) both males and females do not have tuft of hairs but spines on the antennae, (b) males do not possess a tooth at the outer angles of the mandibles, and (c) the body is covered with vermilion pubescence along with black bands and spots in *Eurybatus* and pale blue or bluish-grey pubescence with black bands and spots in *Rosalia*.

The beetle *R.* (*Eurybatus*) *formosa* is a species belonging to the tribe Compsocerini (Cerambycinae) and is known to occur in northeastern states of India

Editor: Anonymity requested. **Date of publication:** 26 December 2023 (online & print)

Citation: Rana, A. & L. Mozhui (2023). First report of the longhorn beetle, *Rosalia* (*Eurybatus*) *formosa* (Saunders, 1839) (Insecta: Coleoptera: Cerambycidae) from Mizoram, India. *Journal of Threatened Taxa* 15(12): 24447–24450. https://doi.org/10.11609/jott.8417.15.12.24447-24450

Funding: None.

Competing interests: The authors declare no competing interests.

Acknowledgements: The author is grateful to Dr. U. Saikia and his entire team, North Eastern Regional Centre, Zoological Survey of India, Shillong for their sincere effort in order to collect the specimens and in the proper preservation of the same. Dr. Limasanen is also acknowledged for preparing the map.

such as Meghalaya, Assam, Arunachal Pradesh, and Sikkim (Mukhopadhyay & Haldar 2003). However, there is no record of *R.* (*Eurybatus*) *formosa* from the state of Mizoram. During one of the tours to Champhai district, Mizoram, the specimens of *R.* (*Eurybatus*) *formosa* were collected and examined.

Materials and Methods

Study area

Mizoram is situated between at 23.36°N & 92.8°E and is located in northeastern India, bounded by Myanmar to the east and south, Bangladesh to the west, state of Tripura to the north-west, Assam to the north, and Manipur to the north-east. The state of Mizoram has a great diversity in phyto-physiognomies which are distributed according to an altitudinal gradient from tropical evergreen to montane and temperate areas. High rainfall and moist climate provide a high base for rich biodiversity consequently the total land under vegetation is 90.68% (Sati et al. 2014). With a tree cover area of about 75%, Mizoram ranks third in India with the highest total forest cover with immense timber plant species such as *Schima wallichi*, *Tectona grandis*, *Castanopsis* sp., and *Macaranga* sp. (SFR 2019). These timber plant species attract a large number of insects belonging to Cerambycidae.

Sample collection

The specimens were collected during faunistic surveys conducted at Murlen National Park, Mizoram in 2018 (Figure 1). Prior permission was taken from the Murlen National Park office for conducting the survey and collection of specimens. Two females were collected from dense vegetation. Both specimens are deposited at the National Zoological Collections of Zoological Survey of India, North Eastern Regional Centre, Shillong, Meghalaya. The specimens were dried and examined under a Labomed CZM4 stereo zoom microscope, and photographed with Canon PowerShot G3 X digital camera.

Results

Materials examined

Two females collected from a woody forest at Murlen, Champhai district, Mizoram, 01.xi.2018 & 03.xi.2018, geocoordinate readings, 23.39°N & 93.17°E; 23.31°N & 93.16°E, coll. Dr. U. Saikia and group, ZSI, NERC, Shillong, Registration No.: I/COL/NERC/221; I/COL/NERC/222. The species was identified using keys/characters in Gahan (1906).

Diagnostic characters

Female: Head black; pronotum red, bearing from three to four distinct black marks or spots; the entire

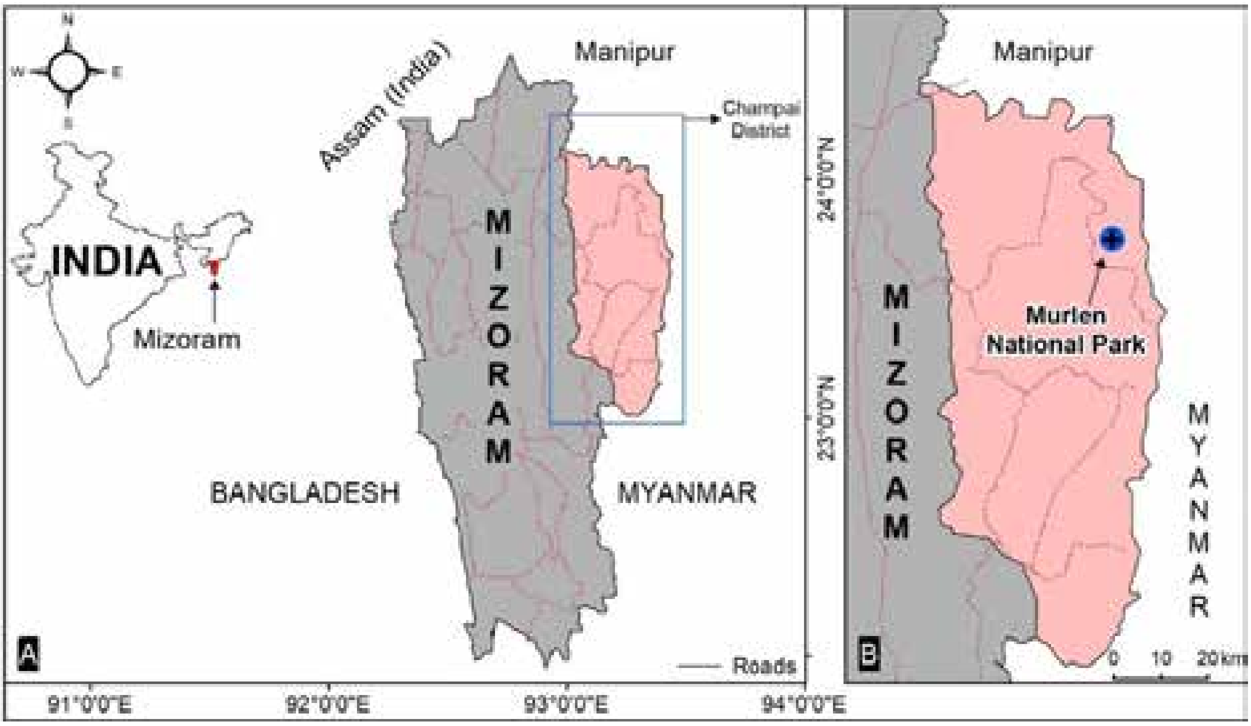

Figure 1. Location map of Murlen National Park in Champhai District, Mizoram.

region of the mesosternum along with the coxal borders of prosternum and metasternum black; elytra red, having a broad black band at the base and also behind the middle, with two black oblique spots, one placed on the dorsal and the other one laterally between the bands; body beneath red, with last ventral segment black (Image 1, 2). Femora is sub clavately thickened beyond the middle or sub-fusiform, scantily punctulate and slightly nitid. Intercoxal process of the prosternum and mesosternum is narrow.

Disc of the pronotum is prominent with four black spots, two are median while the remaining two are lateral. The antero-median spot on the prothorax is small and disappears in some as it is apparent in one of the studied specimens in this communication. Prothorax is globose and protuberant at the sides, a character which is distinct in the case of females and this is very much clearly visible and prominent in the two specimens studied; each of the lateral black spots is placed on a small conical tubercle making it distinct in females. All measurements are in 'mm'.

Specimen 1/ Specimen 2; total length: 25.25/28.45; antennae length: 26.40/30.77; prothorax length: 4.86/4.84; prothorax width: 5.45/5.82; humeral angle width: 6.52/8.15.

Image 1. ***Rosalia formosa*** **(Saunders, 1839), dorsal view. © Amit Rana.**

Image 2. ***Rosalia formosa*** **(Saunders, 1839), ventral view. © Amit Rana.**

Discussion

Based on earlier works by Gahan (1906), a total of six species have been recorded under the genus, *Rosalia* Audinet-Serville, 1833. *Rosalia formosa* (Saunders, 1839) has been recorded from the Himalaya: Sikkim: Darjeeling; Barrackpore; Assam (as per Gahan 1906) but not from Mizoram- hence this is a new record for the state. The other five species known to occur in northeastern India are: *Rosalia decempunctata* (Westwood, 1848), *Rosalia gravida* Lameere, 1887, *Rosalia lateritia* (Hope, 1831), *Rosalia hariola* Thomson, 1860, and *Rosalia lameerei* Brongniart, 1891 (Takakuwa 1994; Sreedevi et al. 2017). Elsewhere, *R. formosa* has been reported from, China, Myanmar, Nepal, Laos, and Thailand (Mitra et al. 2017). Another subspecies *Rosalia formosa pallens* Gressitt, 1945, which has its distribution in China and Vietnam, has been redescribed by Takakuwa (1994). The subspecies is very similar to the nominotypical subspecies from India at first sight; however, the basal black band of elytra, in the case of *R. formosa pallens*, partly touches the external margins which in the case of *R. formosa* extends completely; while, the postmedian black band of elytra is more or less oblique at anterior margin when compared to *R. formosa* where it is nearly straight. Given the rich biodiversity of the region, and the diverse species of cerambycid beetles, more faunistic surveys and systematic studies can lead to discoveries of new species or addition to known species.

References

Agarwala, B.K. & P.P. Bhattacharjee (2012). Long-horned Beetles (Coleoptera: Cerambycidae) and Tortoise Beetles (Chrysomelidae: Cassidinae) of Tripura, northeastern India with some new additions. *Journal of Threatened Taxa* 4(13): 3223–3227. https://doi.org/10.11609/JoTT.o2951.3223-7

Gahan, C.J. (1906). *The Fauna of British India, Ceylon &Burma*, *Vol. I*. Taylor and Francis, London, 329 pp.

Hegde, V.D., S. Yadav, P. Burathoki & B. Saikia (2022). New state records of longhorn beetles (Insecta: Coleoptera: Cerambycidae) from Meghalaya, India. *Journal of Threatened Taxa* 14(8): 21720–21726. https://doi.org/10.11609/jott.7058.14.8.21720-21726

Kariyanna, B., M. Mohan, R. Gupta & F. Vitali (2017). The checklist of longhorn beetles (Coleoptera: Cerambycidae) from India. *Zootaxa* 4345(1): 001−317.

Kumawat, M.M., K.M. Singh & V.V. Ramamurthy (2015). A checklist of the Long-horned Beetles (Coleoptera: Cerambycidae) of Arunachal Pradesh, northeastern India with several new reports. *Journal of Threatened Taxa* 7(12): 7879−7901. https://doi.org/10.11609/JoTT.o4007.7879-901

Mitra, B., U. Chakraborti, K. Mallick, S. Bhaumik & P. Das (2017). An updated list of cerambycid beetles (Coleoptera: Cerambycidae) of Assam, India. *Records of the Zoological Survey of India* 117(1): 78−90.

Mozhui, L., A. Rana, K. Neikha & L.N. Kakati (2020). A checklist of long horn beetles (Coleoptera: Cerambycidae) of Lumami, Zunheboto District, Nagaland with 23 new records. *Halteres* 11: 118–128.

Mukhopadhyay, P. & S.K. Halder (2003). Insecta: Coleoptera: Cerambycidae. Fauna of Sikkim. State Fauna Series, Zoological Survey of India 9(3): 181−199.

Sati, V.P., P. Rinawma, N.B. Singh & C.U.B. Rao (2014). Diversity, use pattern and management of forest resources in the Eastern Himalaya: a case study of Mizoram, India. *Journal of Forests* 1(1): 1−10.

SFR (2019). *Forest Survey of India, Vol. II*. Indian State of Forest Report. Ministry of Environment Forest and Climate Change, Government of India, Allied Printers, Dehradun, 382 pp.

Sreedevi, K., H.V. Ghate, M. Sharma & S. Kulanthaivel (2017). First record of the longhorn beetle, *Rosalia lameerei* Brongniart (Cerambycidae: Cerambycinae: Compsocerini) from India, with additional descriptions of male. *Entomon* 42(1): 37−40.

Takakuwa, M. (1994). The genus *Rosalia* (Coleoptera, Cerambycidae) from North Vietnam with description of a new species. *Bulletin of the Kanagawa Prefectural Museum Natural Science* 23: 1−6.

Wang, Q. (ed.) (2017). *Cerambycidae of the World: Biology and Pest Management*. CRC Press, Taylor and Francis Group, Boca Raton, FL, 628 pp.

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,
43/2 Varadarajulu Nagar, 5th Street West, Ganapathy, Coimbatore,
Tamil Nadu 641006, India
ravi@threatenedtaxa.org

OPEN ACCESS

www.threatenedtaxa.org

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

December 2023 | Vol. 15 | No. 12 | Pages: 24291–24450
Date of Publication: 26 December 2023 (Online & Print)
DOI: 10.11609/jott.2023.15.12.24291-24450

Articles

Communications

Short Communications

Publisher & Host

WILD zooreach
Zoo Outreach Organisation
Threatened Taxa