Building evidence for conservation globally

Journal of Threatened Taxa

Open Access

10.11609/jott.2023.15.9.23827-23930
www.threatenedtaxa.org

26 September 2023 (Online & Print)
15(9): 23827-23930
ISSN 0974-7907 (Online)
ISSN 0974-7893 (Print)

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

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

Host
Zoo Outreach Organization
www.zooreach.org

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: Stripe-necked Mongoose *Urva vi   icolla* in poster colours, adapted from photograph by Ashni Dhawale, by Pooja Ramdas Patil.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 September 2023 | 15(9): 23827–23835

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

https://doi.org/10.11609/jott.8491.15.9.23827-23835

#8491 | Received 26 April 2023 | Final received 07 September 2023 | Finally accepted 11 September 2023

OPEN ACCESS

ARTICLE

Phylogenetic insights on the delineation of Mysore and Malabar subspecies of the Grey Slender Loris *Loris lydekkerianus* in southern India

Vinay Teja [1], Shivakumara Manu [2], Honnavalli N. Kumara [3] & Govindhaswamy Umapathy [4]

[1,2,4] CSIR-Centre for Cellular and Molecular Biology, Uppal Road, Habsiguda, Hyderabad, Telangana 500007, India.
[3] Salim Ali Centre for Ornithology and Natural History, Anaikatty (POST), Coimbatore, Tamil Nadu 641108, India.
[1] vinay@ccmb.res.in, [2] smanu@ccmb.res.in, [3] honnavallik@gmail.com, [4] guma@ccmb.res.in (corresponding author)
[1,2] contributed equally.

Abstract: Slender lorises are a threatened genus of small and nocturnal strepsirrhine primates confined to India and Sri Lanka. The Grey Slender Loris *Loris lydekkerianus* is divided into several subspecies based on morphological variation and geographical distribution but not supported by molecular data. We investigated the phylogenetic divergence of two subspecies of the Grey Slender Loris in southern India: the Mysore Slender Loris *Loris lydekkerianus* ssp. *lydekkerianus* and the Malabar Slender Loris *Loris lydekkerianus* ssp. *malabaricus*. We generated whole genome shotgun sequence data and assembled the whole mitochondrial genomes of representative individuals from their distribution in southern India and compared them with publicly available mitogenomes of other lorises. We found that the Mysore and Malabar Slender Lorises vary by 2.09% in the COX1 and CYTB gene regions. Further, phylogenetic analysis of 13 protein-coding and two ribosomal RNA genes in the mitochondrial genome showed that the Mysore and Malabar Slender Lorises form distinct monophyletic clades that diverged about 1.049 million years ago, shortly after the divergence of Red Slender Loris *Loris tardigradus*. Considering this relatively high sequence variation and evolutionary divergence together with their already established morphological differences and geographically distinct habitats, we propose to recognize the Mysore and Malabar Slender Lorises as two distinct species *Loris lydekkerianus* and *Loris malabaricus*.

Keywords: Grey Slender Loris, Malabar Slender Loris, molecular dating, Mysore Slender Loris, phylogenetics.

Editor: K.A.I. Nekaris, Oxford Brookes University, Oxford, United Kingdom.

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

Citation: Teja, V., S. Manu, H.N. Kumara & G. Umapathy (2023). Phylogenetic insights on the delineation of Mysore and Malabar subspecies of the Grey Slender Loris *Loris lydekkerianus* in southern India. *Journal of Threatened Taxa* 15(9): 23827–23835. https://doi.org/10.11609/jott.8491.15.9.23827-23835

Funding: Council of Scientific and Industrial Research (CSIR) and Department of Biotechnology (DBT), Govt. of India.

Competing interests: The authors declare no competing interests.

Author details: Vinay Teja is a PhD student at CSIR-CCMB. He is interested in Bioinformatics and Molecular evolution of traits in primates.
Shivakumara Manu is a PhD student at CSIR-CCMB. He holds a Master's degree in Bioinformatics and Applied Biotechnology and is interested in solving biological problems through genomics and computational approaches.
Dr. Honnavalli N. Kumara is a wildlife biologist working as a Principal Scientist at SACON. His interest lies in understanding population dynamics, behavioural ecology, and conservation of primates, other mammals and birds.
Dr. Govindhaswamy Umapathy is a conservation biologist working as a Senior Principal Scientist and Group Leader at the LaCONES, CSIR-CCMB. His research interests include understanding species extinction in human dominated landscapes, genome sequencing and developing biotechnological tools for biodiversity conservation.

Author contributions: G.U. and H.N.K conceived the idea for this study and collected the samples. V.T. and S.M. analyzed the data and drafted the manuscript. All authors contributed to the revision of the manuscript and agreed to the final version of the manuscript.

For **Tamil abstract** see end of this article.

Acknowledgements: V.T. was supported by a CSIR PhD fellowship, S.M. was supported by a DBT-BINC PhD fellowship, and G.U. was supported by CSIR, Govt. of India. We thank Dr. Mihir Trivedi for providing useful suggestions for the phylogenetic analysis.

INTRODUCTION

Slender lorises (genus *Loris*) are one of the two genera of extremely specialized nocturnal primates that inhabit India (Nekaris 2014). They belong to the family Lorisidae, which also includes Slow lorises, Pottos, and Angwantibos. Slender lorises are confined to India and Sri Lanka, where they inhabit dry to moist and lowland to montane forests (Singh et al. 2021). Slender lorises are characterized by their small size, long limbs, vestigial tail, large eyes, and slow locomotion. They are adapted for arboreal life, using their opposable thumbs and toes to grasp branches and their binocular vision to judge distances, visual acuity, precise hand-eye coordination and social communication. They feed mainly on insects but also consume fruits, flowers, gums, and other plant materials (Nekaris & Rasmussen 2003; Radhakrishna & Kumara 2010). They have a variety of vocalizations that may help them avoid predators and communicate with conspecifics (Radhakrishna & Singh 2002). Slender lorises are divided into two species: the Grey Slender Loris *Loris lydekkerianu*s found in southern India and Sri Lanka and the Red Slender Loris *Loris tardigradus* found only in Sri Lanka (Groves 2001). Both species show high phenotypic variation in fur color, body size, and cranial morphology, leading to the recognition of several subspecies, most of which are refuted by molecular studies (Nijman et al. 2020). The Mysore Slender Loris *Loris lydekkerianus* ssp. *lydekkerianus* (Image 1) and the Malabar Slender Loris *Loris lydekkerianus* ssp*. malabaricus* (Image 2), which live in the dry and wet forests of the Eastern and Western Ghats, respectively, are the two subspecies that have been recognized thus far in southern India (Kumara et al. 2013). There are several regions in their distribution where slender lorises face serious threats to their existence such as habitat loss due to deforestation and urbanization, electrocution on live wires, road accidents, pet trade, and illegal poaching for traditional medicine and black magic (Dittus et al. 2022; Gnanaolivu et al. 2022). The IUCN Red List of Threatened Species classifies the Mysore Slender Loris (Kumara et al. 2022a) and Malabar Slender Loris (Kumara et al. 2022b) as 'Near Threatened' and they are listed under Schedule I of the Indian Wild Life (Protection) Act, 1972. Recently, Tamil Nadu became the first Indian state to notify a sanctuary for slender lorises spanning 118.06 km^2, which is crucial for protecting their habitat and ensuring the survival of this unique primate species (Government of Tamil Nadu 2022).

The Mysore and Malabar subspecies of the Grey Slender Loris were delineated based on their morphological differences and geographic distribution (Groves 2001; Kumara et al. 2013). The Mysore Slender Loris is relatively larger (ca. 260 g) than Malabar Slender Loris (ca. 180 g) (Kumara et al. 2006). The Mysore Slender Loris has a grayish-brown coat and a prominent white stripe on its forehead, whereas the Malabar Slender Loris has a reddish-brown coat and a less distinct forehead stripe (Groves 2001; Kumara et al. 2006). The relative distribution of the two subspecies as well as their comparative densities and the extent of overlap between their distributions have been very well established (Kumara et al. 2013). The Mysore Slender Loris is found in the Eastern Ghats and eastern foothills of the southern Western Ghats, while the Malabar Slender Loris is confined to the western slope of the entire Western Ghats (Kumara et al. 2013). The Mysore Slender Loris prefers dry deciduous forests with moderate canopy cover and high tree density, while the Malabar Slender Loris prefers moist evergreen forests with high canopy cover and low tree density (Kumara et al. 2013). Their distributions overlap along the southern ridges of the Western Ghats, where hybridization may occur. While the diet of Mysore Slender Loris mostly consists of insects, plant material, and gum, the feeding behavior of the Malabar Slender Loris is not well studied (Radhakrishna & Kumara 2010). The reproductive biology and social system of the Mysore subspecies is influenced by factors such as seasonality, food availability, predation risk, and population density. It also has a seasonal breeding cycle that coincides with periods of high food availability (Radhakrishna & Singh 2004). No such information on the reproductive biology of the Malabar subspecies is available. Behavioral studies on lorises have always been more challenging than on relatively large, diurnal, and group-living primates such as macaques and langurs because they are nocturnal, small in size, and mostly semi-gregarious. Given the distinct habitat preferences and morphology of these two subspecies, understanding their evolutionary history and genetic differences is vital to address their conservation status and management issues.

Therefore, the main objective of this study is to investigate the phylogenetic relationship and genetic divergence between the Mysore and Malabar Slender Lorises in southern India. To achieve this, we sequenced and assembled the whole mitochondrial sequences from three representative samples. We aligned these sequences with the publicly available sequences of other lorises and constructed phylogenetic trees. We estimated the sequence divergence and divergence time between the two subspecies using phylogenetic analysis.

Image 1. Mysore Slender Loris *Loris lydekkerianus* ssp. *lydekkerianus.*

Image 2. Malabar Slender Loris *Loris lydekkerianus* ssp. *malabaricus.*

Our results support the morphological and geographical delineation of the Malabar and Mysore Slender Lorises and advocates for recognizing them as two distinct species. This study will contribute to the understanding of the biogeography and speciation processes of these threatened lorises and provide crucial insights for their conservation and management.

MATERIALS AND METHODS

Sample Collection, DNA extraction, and Sequencing

We followed the sample collection guidelines of the animal ethics committees of the CSIR-Centre for Cellular and Molecular Biology and Salim Ali Centre for Ornithology and Natural History. Necessary permissions for sample collection were obtained from the Central Zoo Authority of India, Ministry of Environment, Forests & Climate Change, Government of India, vide Ref. No. 9-2/2005-CZA(M) Vol III. Rescued lorises of known wild origin within the IUCN designated ranges (Figure 1) that were captive in Mysore and Hyderabad zoos were the sources of our samples. Blood samples were collected in EDTA vacutainers by qualified zoo veterinarians from three representative individuals of *Loris lydekkerianus* ssp. *lydekkerianus* (N = 2) and *Loris lydekkerianus* ssp. *malabaricus* (N = 1). We used the Qiagen DNeasy Blood and Tissue Kit to isolate the genomic DNA from the blood samples. We measured the quality and quantity of genomic DNA using Nanodrop and Qubit 4. We constructed whole genome libraries using the Truseq PCR-free library preparation kit according to Illumina's protocols. Briefly, 1 ug of genomic DNA was sheared to approximately 350 bp using the Covaris ultrasonicator. The fragmented DNA was then end-repaired and blunt-end ligated with sequencing adapters containing unique dual indices from IDT. The library was then size-selected using SPRI beads and verified on the Agilent fragment analyzer. The cleaned-up libraries were finally quantified in qPCR using the standards and Illumina adapter-specific primers from the Roche library quantification kit. Libraries having good concentration were pooled along with other samples and sequenced on the Illumina Novaseq 6000 platform for 300 cycles in paired-end mode.

Mitochondrial genome assembly

We demultiplexed the base call files to separate the three samples with the dual-indexed barcodes using the BCL2FASTQ tool from Illumina. Raw reads were quality-filtered with a phred quality score threshold of 15 using FASTP v0.20 (Chen et al. 2018). We subsampled 10 million quality filtered reads to de novo assemble the circular mitochondrial genomes of all three samples using GetOrganelle v1.7.1 (Jin et al. 2020). We then annotated all the mitogenomes using MITOS2 (Bernt et al. 2013) with the Refseq 89 Metazoa reference mitochondrial database and the vertebrate mitochondrial genetic code. All the coding and non-coding genes were extracted from the mitochondrial genomes using the annotations.

Sequence and Phylogenetic analyses

We aligned the full-length COX1 and CYTB genes of lorises using Clustal Omega with the "distmat" flag and calculated the pairwise distances between the sequences (Sievers & Higgins 2021). To build the phylogeny, along

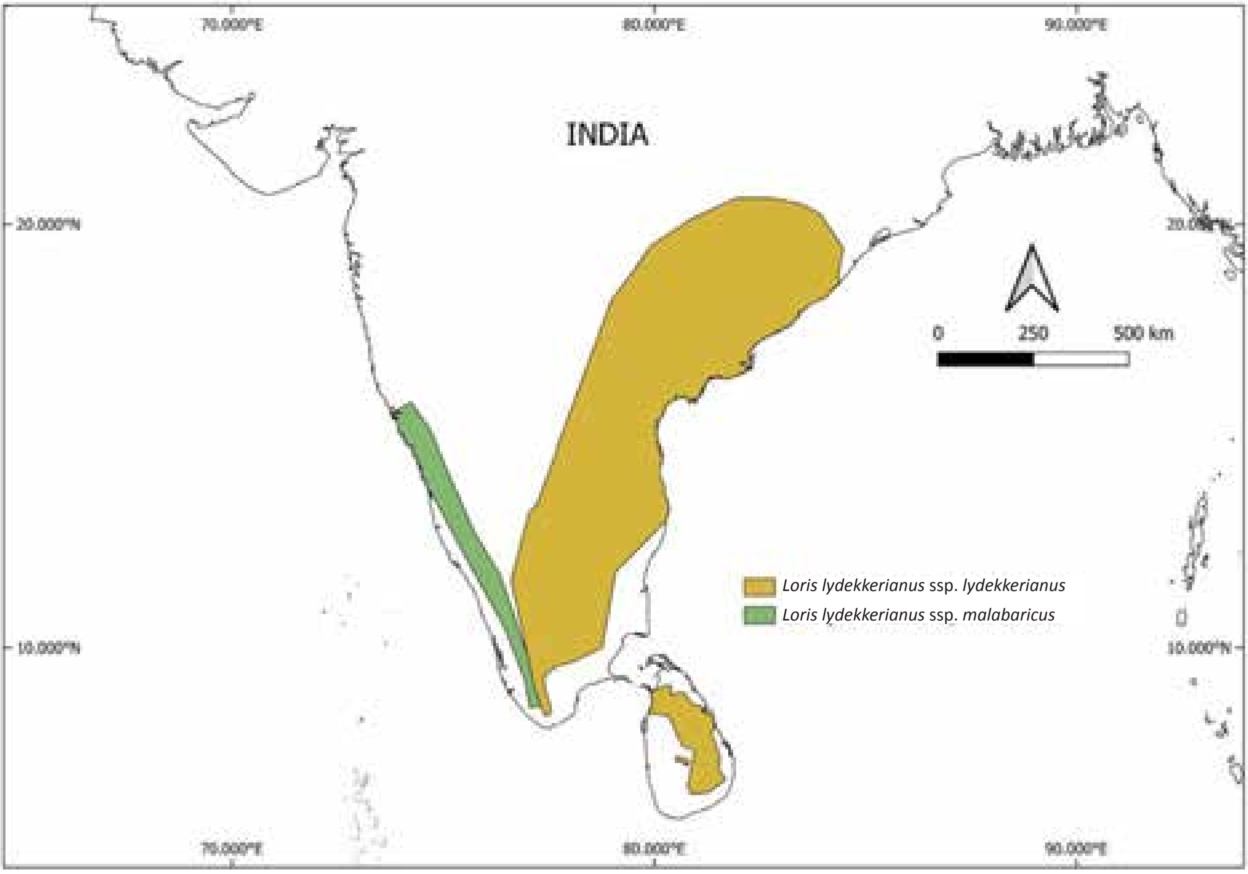

Figure 1. IUCN Red List distribution range of the Grey Slender Loris subspecies in southern India and Sri Lanka.

with our samples we used the NCBI RefSeq mitochondrial sequences from strepsirrhines namely, *Loris lydekkerianus*, *Loris tardigradus*, *Nycticebus coucang*, *Nycticebus bengalensis*, *Galago senegalensis*, and *Lemur catta*. We aligned the 13 protein-coding genes and two non-coding ribosomal RNA genes individually from the assembled mitochondrial genomes and reference sequences using the MUSCLE algorithm in MEGA7 (Kumar et al. 2016) and checked for the presence of any sequencing errors or frameshifts for codon position. We then concatenated all the gene alignments using MEGA7 (Kumar et al. 2016) and identified the optimum nucleotide substitution model for each partition based on the corrected Akaike information criterion (AICc) values using PartitionFinder2 (Lanfear et al. 2017) (Supplementary file 1). We built the maximum likelihood (ML) tree based using IQ-TREE (Minh et al. 2020) with 1000 times bootstrapping. The ML tree was visualized in Evolview v3 (Subramanian et al. 2019).

We utilized BEAST2.5 (Bouckaert et al. 2014) to create a divergence time tree using the same concatenated alignment of 13 coding and two non-coding genes from the complete mitochondrial genomes. We used the same partitioning scheme and substitution models identified by PartitionFinder2. We then chose two fossil calibration points:

1) We calibrated the crown node of Galagos with 38 mya based on the age of the fossil *Saharagalago misrensis* (PaleoDB collection 67706) (Seiffert et al. 2003). We applied a normal distribution at 40 Mya (SD = 0.04; 95% range: 36–43)

2) We calibrated the crown node of Slow Lorises with 13.82 mya based on the age of the fossil *Nycticebus linglom* (PaleoDB collection 48126) (Harrison 2010). We applied a normal distribution at 14 Mya (SD = 0.05; 95% range: 9–17)

For all the partitions, we created a relaxed lognormal clock and employed a birth-death process using prior distributions. To get to the final tree, we ran for 40 million generation runs, sampling every 2,000th generation using TreeAnnotator (Helfrich et al. 2018) with a 10% burn-in. We verified that all the ESS values were over 200 in Tracer 1.7 (Rambaut et al. 2018) and visualized the tree in FigTree v1.4.4 (Rambaut 2014).

RESULTS

Phylogenetic analyses support the morphological and geographical delineation of Mysore & Malabar Slender Lorises

To investigate the genetic differences between the two subspecies of slender loris in southern India, we first assembled three new circular mitochondrial genomes with an average length of 16,771 bp from two samples of the Mysore Slender Loris *Loris lydekkerianus* ssp. *lydekkerianus* and one sample of Malabar Slender Loris *Loris lydekkerianus* ssp. *malabaricus*. We annotated the mitochondrial genomes along with published reference sequences and obtained the full-length sequences of 13 protein-coding genes and two ribosomal RNA genes. To check the variation in the nucleotide sequence within the *Loris* genus, we estimated the pairwise sequence similarity in the COX1 and CYTB regions spanning 2,682 bp between all six Loris samples (Table 1). We observed the highest average sequence variation of 2.82% (S.D. 0.16) between the four sequences of the Grey Slender Loris *Loris lydekkerianus* and the two sequences of the Red Slender Loris *Loris tardigradus* as they belong to two different species within the *Loris* genus. While there was no sequence variation found within the two sequences of Red Slender Loris, there was considerable variation within the four sequences of Grey Slender Loris contributed by the difference between the two subspecies. We found about 2.09% (S.D 0.0) variation in the COX1 and CYTB sequences of the Mysore and Malabar Slender Lorises.

We then used phylogenetic analyses to understand the evolutionary relationships between the two subspecies. Along with our three samples, we included reference mitochondrial sequences from two species of slender lorises (*L. lydekkerianus*, *L. tardigradus*) and two species of slow lorises (*Nycticebus bengalensis*, *N. coucang*) along with galago and lemur as outgroups (Figure 2). The phylogenetic tree recapitulates the broad evolutionary relationships of slender lorises with slow lorises and the outgroups. It reveals an interesting pattern within the clade of slender lorises where the Mysore Slender Loris *L.l.* ssp. *lydekkerianus* clusters with the reference sequence of Grey Slender Loris to form a monophyletic clade and the Malabar Slender Loris *L.l.* ssp. *malabaricus* forms a separate monophyletic clade with very strong statistical support. We noted that the Malabar Slender Loris appears more closely related to the Red Slender Loris *L. tardigradus*, albeit with a very small branch length (Figure 2). To estimate the divergence time between the two subspecies and other lorises, we constructed a fossil-calibrated Bayesian tree (Figure 3). Our results suggest that the split between the Grey Slender Loris *L. lydekkerianus* and Red Slender Loris *L. tardigradus* occurred approximately 1.087 million years ago (mya). This was immediately followed by diversification of the Mysore Slender Loris *L.l.* ssp. *lydekkerianu*s and Malabar Slender Loris *L.l.* ssp. *malabaricus* at around 1.049 mya (Posterior probability = 1) (Figure 3).

DISCUSSION

Our results from the phylogenetic analyses based on the mitochondrial sequences show that the Mysore and Malabar Slender Lorises have significant genetic variation (2.09%) in the COX1 and CYTB genes and form distinct monophyletic clades in the phylogenetic tree that diverged a long time ago (1.049 mya), shortly after the divergence of Red Slender Loris from the Grey Slender Loris (1.087 mya). The observed sequence variation and divergence time between the Mysore and the Malabar Slender Lorises are surprisingly high, which is not very common between primate subspecies. Since they have been evolving independently for a

Table 1. Sequence distance matrix of the *Loris* genus based on full-length cytochrome b and cytochrome oxidase 1 genes.

Sample	*Loris tardigradus-1*	*Loris tardigradus-2*	*Loris lydekkerianus malabaricus*	*Loris lydekkerianus lydekkerianus-1*	*Loris lydekkerianus lydekkerianus-2*	*Loris lydekkerianus-Ref*
Loris tardigradus-1	-	0	2.58	2.82	2.95	2.9
Loris tardigradus-2	0	-	2.58	2.82	2.97	2.9
Loris lydekkerianus malabaricus	2.58	2.58	-	2.09	2.09	2.09
Loris lydekkerianus lydekkerianus-1	2.82	2.82	2.09	-	0.16	0.08
Loris lydekkerianus lydekkerianus-2	2.97	2.97	2.09	0.16	-	0.16
Loris lydekkerianus-Ref	2.9	2.9	2.09	0.08	0.16	-

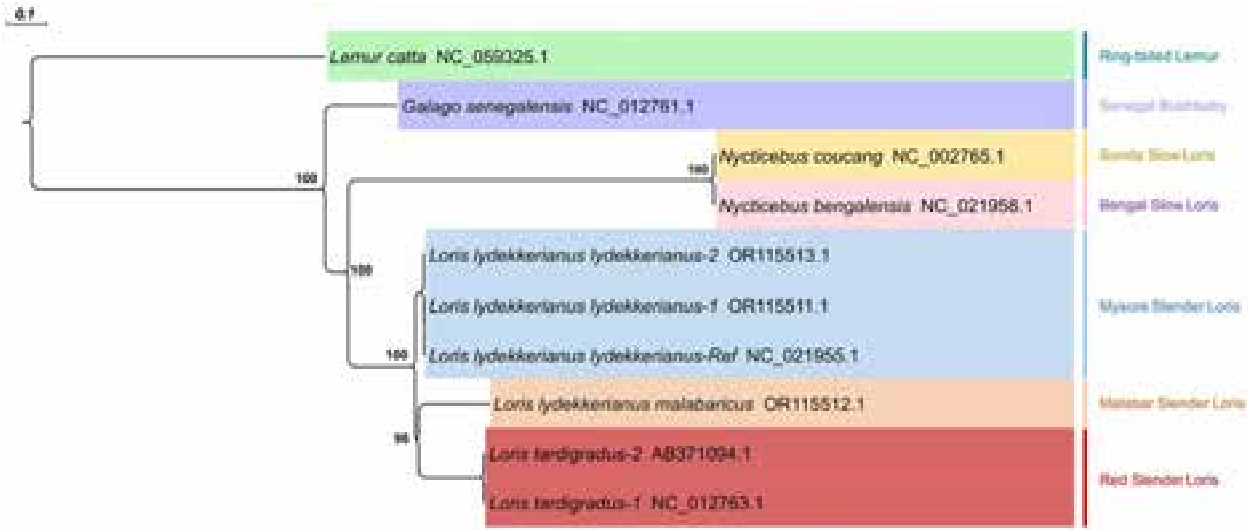

Figure 2. Maximum likelihood tree based on 13 protein-coding and two ribosomal RNA genes from whole mitochondrial genomes. The bootstrap values are denoted at the nodes.

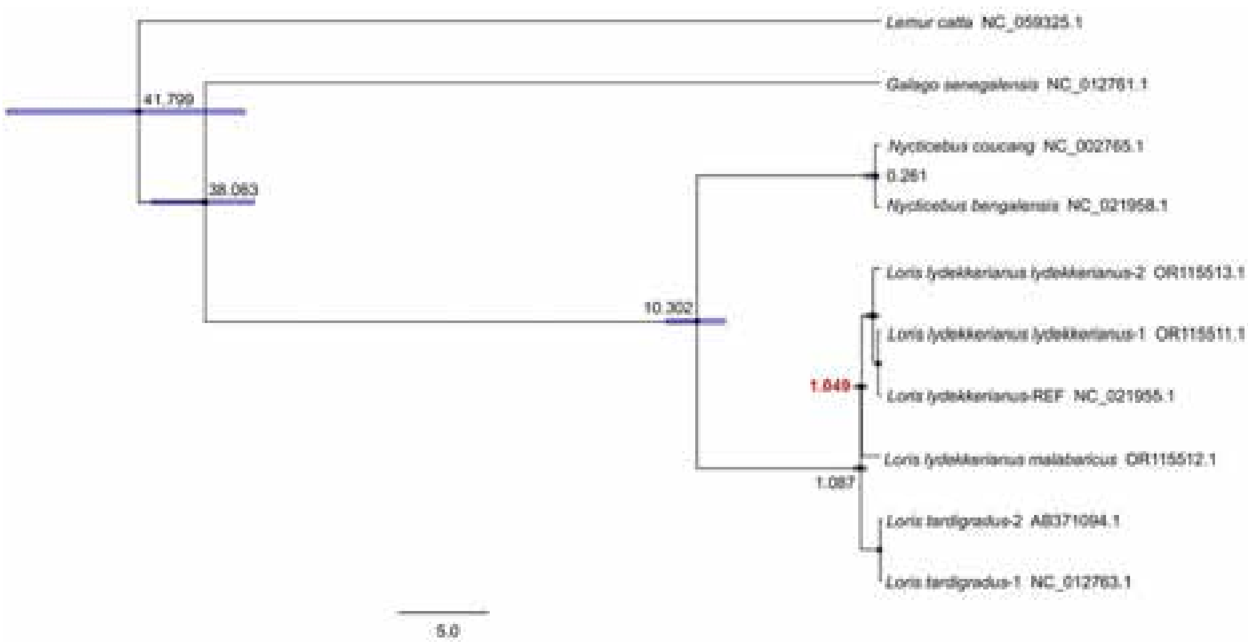

Figure 3. Fossil-calibrated Bayesian inference tree based on 13 protein-coding and two ribosomal RNA genes from whole mitochondrial genomes showing the divergence time estimates at the nodes in Mya. Bars indicate 95% CI.

long period comparable to the divergence time of their closest species (*Loris tardigradus*), the Mysore and Malabar Slender Lorises deserve independent recognition. Moreover, they occupy a geographically different landscape and unique habitat, where the Malabar Slender Loris occupies the wet zone of the Western Ghats, while the Mysore Slender Loris occupies the dry habitat of the eastern slope of the Western Ghats, dry forests of the Deccan plateau and Eastern Ghats (Kumara et al. 2006, 2009; 2013). They are also morphologically distinct, where the Malabar Slender Loris appears reddish in color and almost half the body size of the greyish colored Mysore Slender Loris (Kumara et al. 2006). Considering these significant differences in the morphological, geographical, and genetic factors, we propose to recognize the Mysore Slender Loris *Loris lydekkerianus* ssp. *lydekkerianus* and Malabar Slender Loris *Loris lydekkerianus* ssp. *malabaricus* as two distinct species, *Loris lydekkerianus* and *Loris malabaricus*, respectively.

The divergence time estimates are supported by a number of molecular markers in the whole mitochondrial genome and is consistent with previous studies on the evolutionary history of this genus (Finstermeier et al. 2013). Several environmental, climatic, and geographical factors might have influenced the divergence of the Mysore and Malabar Slender Lorises about one million years ago. The mid-Pleistocene transition (1.25–0.7 Mya) was a time of dramatic climatic change and glaciation that influenced the environments and biogeography of Earth (Herbert 2023). The glaciation and interglaciation cycles affected the sea level, precipitation, temperature, vegetation, and habitat availability. The environmental conditions in India specifically during the Pleistocene were diverse and dynamic, ranging from deserts, tropical forests to grasslands (Morley & Morley 2022). The variability of monsoon coupled with expansion and contraction of forests due to glacial-interglacial cycles could have influenced availability of resources, fragmentation of habitats, and changes in forest cover promoting genetic differentiation and divergence of the Mysore and Malabar Slender Lorises.

Understanding the genetic structure and variation of species is crucial for the scientific management of threatened species and their eventual recovery. The findings of this study have important implications for the conservation and management of the slender lorises in India. With a clearer understanding of the genetic differences between the Mysore and Malabar Slender Lorises, it will be possible to more accurately identify and classify individual animals, which will in turn facilitate the development of an effective conservation breeding program. Such a program can be particularly beneficial for species like the slender loris that are threatened by habitat loss and fragmentation, and whose populations have been declining in recent years (Kumara et al. 2006, 2016).

The main drawback of this study is the limited sample size which we duly acknowledge. It is to be noted that the construction of whole mitochondrial genomes from WGS data for accurate molecular dating often requires good-quality DNA from animals of known geographic origin which is very difficult to obtain, especially for the Malabar Slender Loris. More samples from the Malabar Slender Loris could better resolve the phylogenetic tree and nuclear markers could also be used to confirm our findings and validate the species delimitation. Furthermore, sampling the individuals from the range edges and the overlapping ranges in the southern ridge of Western Ghats would provide more statistical power to establish the monophyly and identify any hybridization. It would also be prudent to include samples of the Mysore subspecies from Sri Lanka in future studies to fully comprehend the diversity and understand the evolutionary history of the slender lorises throughout its geographical range. Comprehensive genome sequencing of all the subspecies of slender loris would also help to understand the genomic basis of morphological differences and their adaptations to respective niches.

In conclusion, this study provides the first molecular evidence for the genetic divergence and distinctiveness of the Mysore and Malabar Slender Lorises. The sequence analysis, phylogenetic analyses, and molecular dating suggest that the Mysore and Malabar Slender Lorises are genetically distinct and have been evolving independently for a significant period. The high level of genetic divergence between them highlights the importance of preserving their genetic diversity and underscores the need for more efforts to conserve them in the wild. By considering the significant differences in the morphological, geographical, and genetic factors, we recommend to elevate *L.l.* ssp. *lydekkerianus* and *L.l.* ssp. *malabaricus* to the species level. We propose to recognize them as two distinct species *Loris lydekkerianus* and *Loris malabaricus* as each of them represents a unique evolutionary lineage and deserves separate recognition and protection. We advocate for further studies to validate the species delimitation with larger sample sizes and recommend for separate conservation measures and management actions to preserve their unique genetic diversity in the wild and captivity.

Data Availability Statement

The three whole mitochondrial genome sequences generated in this study have been submitted to the NCBI database under the accessions OR115511, OR115512, and OR115513.

REFERENCES

Bernt, M., A. Donath, F. Jühling, F. Externbrink, C. Florentz, G. Fritzsch, J. Pütz, M. Middendorf & P.F. Stadler (2013). MITOS: improved de novo metazoan mitochondrial genome annotation. *Molecular Phylogenetics and Evolution* 69(2): 313–319. https://doi.org/10.1016/j.ympev.2012.08.023

Bouckaert, R., J. Heled, D. Kühnert, T. Vaughan, C.-H. Wu, D. Xie, M.A. Suchard, A. Rambaut & A.J. Drummond (2014). BEAST 2: a software platform for Bayesian evolutionary analysis. *PLoS Computational Biology* 10(4): e1003537. https://doi.org/10.1371/journal.pcbi.1003537

Chen, S., Y. Zhou, Y. Chen & J. Gu (2018). fastp: an ultra-fast all-in-one FASTQ preprocessor. *Bioinformatics* 34(17): i884–i890. https://doi.org/10.1093/bioinformatics/bty560

Dittus, W., M. Singh, S.N. Gamage, H.N. Kumara, A. Kumar & K.A.I. Nekaris (2022). *Loris lydekkerianus* (amended version of 2020 assessment). The IUCN Red List of Threatened Species 2022: e.T44722A217741551. Downloaded on 28 March 2023. https://doi.org/10.2305/IUCN.UK.2022-1.RLTS.T44722A217741551.en

Finstermeier, K., D. Zinner, M. Brameier, M. Meyer, E. Kreuz, M. Hofreiter & C. Roos (2013). A mitogenomic phylogeny of living primates. *PLoS ONE* 8(7): e69504. https://doi.org/10.1371/journal.pone.0069504

Gnanaolivu, S.D., M. Campera, K.A.I. Nekaris, V. Nijman, R. Satish, S. Babu & M. Singh (2022). Medicine, black magic and supernatural beings: Cultural rituals as a significant threat to slender lorises in India. *People and Nature* 4(4): 1007–1019. https://doi.org/10.1002/pan3.10336

Government of Tamil Nadu (2022). Notification of Kadavur Slender Loris Sanctuary in Karur and Dindigul districts of the Wild Life (Protection) Act, 1972. [G.O. Ms. No. 175, Environment, Climate Change and Forests (FR.5), 12th October 2022] No. II(2)/ECCF/809(a)/2022.

Groves, C.P. (2001). *Primate taxonomy*. Smithsonian Institution Press, Washington (DC), 350 pp.

Harrison, T. (2010). Later tertiary Lorisiformes, pp. 875–912. In: Werdelin, L. & W.J. Sanders (eds.). *Cenozoic Mammals of Africa*. University of California Press, California, 1008 pp.

Helfrich, P., E. Rieb, G. Abrami, A. Lücking & A. Mehler (2018). TreeAnnotator: Versatile Visual Annotation of Hierarchical Text Relations. In: *Proceedings of the Eleventh International Conference on Language Resources and Evaluation (LREC 2018)*. European Language Resources Association (ELRA), Miyazaki, Japan.

Herbert, T.D. (2023). The mid-Pleistocene climate transition. *Annual Review of Earth and Planetary Sciences* 51(1): 389–418. https://doi.org/10.1146/annurev-earth-032320-104209

Jin, J.J., W.B. Yu, J.B. Yang, Y. Song, C.W. DePamphilis, T.S. Yi & D.Z. Li (2020). GetOrganelle: a fast and versatile toolkit for accurate de novo assembly of organelle genomes. *Genome Biology* 21: 1–31. https://doi.org/10.1186/s13059-020-02154-5

Kumar, S., G. Stecher & K. Tamura (2016). MEGA7: molecular evolutionary genetics analysis version 7.0 for bigger datasets. *Molecular Biology and Evolution* 33(7): 1870–1874. https://doi.org/10.1093/molbev/msw054

Kumara, H.N., K.A.I. Nekaris & M. Singh (2022a). *Loris lydekkerianus* ssp. *lydekkerianus*. The IUCN Red List of Threatened Species 2022: e.T44719A217742793. Downloaded on 28 March 2023. https://doi.org/10.2305/IUCN.UK.2022-1.RLTS.T44719A217742793.en

Kumara, H.N., K.A.I. Nekaris & M. Singh (2022b). *Loris lydekkerianus* ssp. *malabaricus* (amended version of 2020 assessment). The IUCN Red List of Threatened Species 2022: e.T44720A217744540. Downloaded on 28 March 2023. https://doi.org/10.2305/IUCN.UK.2022-1.RLTS.T44720A217744540.en

Kumara, H.N., M. Singh & S. Kumar (2006). Distribution, habitat correlates, and conservation of Loris lydekkerianus in Karnataka, India. *International Journal of Primatology* 27: 941–969. https://doi.org/10.1007/s10764-006-9054-z

Kumara, H.N., M. Irfan-Ullah & S. Kumar (2009). Mapping potential distribution of slender loris subspecies in peninsular India. *Endangered Species Research* 7: 29–38. https://doi.org/10.3354/esr00185

Kumara, H.N., R. Sasi, S. Chandran & S. Radhakrishna (2016). Distribution of the Grey Slender Loris (*Loris lyddekerianus* Cabrera, 1908) in Tamil Nadu, southern India. *Folia Primatologica* 87(5): 291–302. https://doi.org/10.1159/000452405

Kumara, H.N., M. Singh, M. Irfan-Ullah & S. Kumar (2013). Status, Distribution, and Conservation of Slender Lorises in India pp. 343–352. In: Masters, J., M. Gamba & F. Génin (eds.). *Leaping Ahead: Advances in Prosimian Biology*. Springer, New York, 410 pp.

Lanfear, R., P.B. Frandsen, A.M. Wright, T. Senfeld & B. Calcott (2017). PartitionFinder 2: new methods for selecting partitioned models of evolution for molecular and morphological phylogenetic analyses. *Molecular Biology and Evolution* 34(3): 772–773. https://doi.org/10.1093/molbev/msw260

Minh, B.Q., H.A. Schmidt, O. Chernomor, D. Schrempf, M.D. Woodhams, A. von Haeseler & R. Lanfear (2020). IQ-TREE 2: New Models and Efficient Methods for Phylogenetic Inference in the Genomic Era. *Molecular Biology and Evolution* 37(5): 1530–1534. https://doi.org/10.1093/molbev/msaa015

Morley, R.J. & H.P. Morley (2022). The prelude to the Holocene: tropical Asia during the Pleistocene, pp. 1–32. In: Kumaran, N. & P. Damodara (eds.). *Holocene Climate Change and Environment*. Elsevier, 661 pp.

Nekaris, K.A.I. (2014). Extreme primates: ecology and evolution of Asian lorises. *Evolutionary Anthropology: Issues, News, and Reviews* 23(5): 177–187. https://doi.org/10.1002/evan.21425

Nekaris, K.A.I. & D.T. Rasmussen (2003). Diet and feeding behavior of Mysore Slender Lorises. *International Journal of Primatology* 24(1): 33–46. https://doi.org/10.1023/A:1021442411455

Nijman, V., T. Robbins, A.J. Maddock & A. Ang (2020). Molecular phylogeny, taxonomy and conservation of slender Lorises. *Primate Conservation* 34: 143–151.

Radhakrishna, S. & H.N. Kumara (2010). Behavioural variation in the Mysore slender loris *Loris lydekkerianus lydekkerianus*. *Current Science* 99(9): 1226–1232.

Radhakrishna, S. & M. Singh (2002). Social behaviour of the slender loris (*Loris tardigradus lydekkerianus*). *Folia Primatologica* 73(4): 181–196. https://doi.org/10.1159/000065426

Radhakrishna, S. & M. Singh (2004). Reproductive biology of the slender loris (*Loris lydekkerianus lydekkerianus*). *Folia Primatologica* 75(1): 1–13. https://doi.org/10.1159/000073424

Rambaut, A. (2014). FigTree, a graphical viewer of phylogenetic trees. https://github.com/rambaut/figtree Accessed on 15 March 2023.

Rambaut, A., A.J. Drummond, D. Xie, G. Baele & M.A. Suchard (2018). Posterior summarization in Bayesian phylogenetics Using Tracer 1.7. *Systematic Biology* 67(5): 901–904. https://doi.org/10.1093/sysbio/syy032

Seiffert, E.R., E.L. Simons & Y. Attia (2003). Fossil evidence for an ancient divergence of lorises and galagos. *Nature* 422(6930): 421–424. https://doi.org/10.1038/nature01489

Sievers, F. & D.G. Higgins (2021). The Clustal Omega Multiple Alignment Package, pp. 3–16. In: Katoh, K. (ed.). *Multiple Sequence Alignment: Methods and Protocols*. Springer US, New York, 287 pp.

Singh, M., M. Singh, H.N. Kumara, S. Kumar, S.D. Gnanaoliu & R. Sasi (2021). A review of research on the distribution, ecology, behaviour, and conservation of the Slender Loris *Loris lydekkerianus* (Mammalia: Primates: Lorisidae) in India. *Journal of Threatened Taxa* 13(11): 19540–19552. https://doi.org/10.11609/jott.7562.13.11.19540-19552

Subramanian, B., S. Gao, M.J. Lercher, S. Hu & W.H. Chen (2019). Evolview v3: a webserver for visualization, annotation, and management of phylogenetic trees. *Nucleic Acids Research* 47(W1): W270–W275. https://doi.org/10.1093/nar/gkz357

Supplementary file 1. Partitioning scheme and nucleotide substitution model selection output from PartitionFinder2.

Best partitioning scheme

Scheme lnL : -64454.10696411133
Scheme AICc : 129409.318896
Number of params : 246
Number of sites : 13594
Number of subsets : 33

Subset	Best Model	# sites	Partition names
1	GTR+I+X	622	NAD1_pos1, NAD4l_pos3, ATP6_pos1
2	TRN+I+X	533	NAD1_pos2, ATP6_pos2
3	HKY+X	223	ATP6_pos3
4	HKY+X	132	ATP8_pos1, ATP8_pos2
5	GTR+X	317	ATP8_pos3, COX3_pos3
6	HKY+G+X	368	COB_pos1
7	GTR+I+X	368	COB_pos2
8	TRN+I+X	368	COB_pos3
9	GTR+G+X	496	COX1_pos1
10	HKY+G+X	496	COX1_pos2
11	HKY+G+X	496	COX1_pos3
12	K80	222	COX2_pos1
13	TRN+X	222	COX2_pos2
14	TRN+I+X	424	NAD3_pos1, NAD4l_pos2, COX2_pos3
15	JC	251	COX3_pos1
16	HKY+X	251	COX3_pos2
17	HKY+X	310	NAD1_pos3
18	GTR+I+X	340	NAD2_pos1
19	HKY+I+X	340	NAD2_pos2
20	HKY+I+X	339	NAD2_pos3
21	TRN+I+X	111	NAD3_pos2
22	GTR+I+X	201	NAD4l_pos1, NAD3_pos3
23	HKY+X	457	NAD4_pos1
24	HKY+X	456	NAD4_pos2
25	HKY+I+X	456	NAD4_pos3
26	HKY+I+X	596	NAD5_pos1
27	GTR+I+X	596	NAD5_pos2
28	HKY+I+X	596	NAD5_pos3
29	GTR+G+X	181	NAD6_pos1
30	HKY+I+X	180	NAD6_pos2
31	GTR+G+X	180	NAD6_pos3
32	GTR+G+X	1454	rrns
33	GTR+I+X	1012	rrnl

Tamil: மெலிந்த தேவாங்குகள், இந்தியா மற்றும் இலங்கையில் மட்டும் வாழும் இரவில் நடமாடுகிற சிறிய வகை ஈரமூக்கு கொண்ட முதனிகளில் ஒன்றான பேரினமாகும். இந்தப் பேரினம் தற்பொழுது அழிவுநிலைக்கு அச்சுறுத்தப்பட்டுள்ளது.. சாம்பல் நிற மெலிந்த தேவாங்கு (*Loris lydekkerianus*), உருவவியல் மாறுபாடு மற்றும் புவியியல் பரவல் ஆகியவற்றின் அடிப்படையில் பல துணை இனங்களாகப் பிரிக்கப்பட்டுள்ள போதும், இந்தப் பிரிவினை மூலக்கூறு சான்றுகளால் ஆதரிக்கப்படவில்லை. தென்னிந்தியாவில் வாழும் இந்த சாம்பல் நிற மெலிந்த தேவாங்குகளின் இரண்டு துணை இனங்கள்: அதாவது மைசூர் மெலிந்த தேவாங்கு (Loris lydekkerianus ssp. lydekkerianus) மற்றும் மலபார் மெலிந்த தேவாங்கு (*Loris lydekkerianus* ssp. *malabaricus*), பரிணாம வரலாற்றில் எப்பொழுது பிரிந்தன என்று ஆராய்ந்தோம். தென்னிந்தியாவில் வாழும் அவற்றின் புவியியல் தொகைகளில் இருந்து மாதிரிகள் எடுத்து, அவ்விலங்குகளின் முழு இழைமணி மரபணு தகவல்களை shotgun sequence எனப்படும் தகவல்களில் இருந்து ஒருங்கிணைத்து, பொது தரவுத்தளங்களில் கிடைக்கும் பிற தேவாங்குகளின் மரபணு தகவல்களுடன் ஒப்பிட்டோம். இதில் இருந்து மைசூர் மற்றும் மலபார் மெலிந்த தேவாங்குகளை ஒப்பிடுகையில், அவற்றின் இடையே COX1 மற்றும் CYTB மரபணு பகுதிகள் 2.09 சதவிகிதம் வேறுபடுவதை நாங்கள் கண்டறிந்தோம். மேலும், இழைமணி மரபணுவில் காணப்படும் 13 புரதங்கள் மற்றும் 2 ரைபோசோமல் RNAக்களைக் குறியிடக்கூடிய மரபணு தகவல்களை பகுப்பாய்வு செய்கையில், மைசூர் மற்றும் மலபார் மெலிந்த தேவாங்குகள், பரிணாம வரலாற்றில் சுமார் 10. 49 இலட்சம் ஆண்டுகளுக்கு முன்பு பிரிந்தன என விளங்கியது. இது சிவப்பு மெலிந்த தேவாங்கு (Loris tardigradus) பிரிந்த சற்று காலத்திற்குப் பின் நிகழ்ந்த நிகழ்வாகும். மரபணு தகவல்களில் உள்ள மாற்றங்கள் மற்றும் பரிணாம வேறுபாடுகளை கருத்தில் கொண்டு , அவற்றுடன் ஏற்கனவே நிறுவப்பட்ட உருவ வேறுபாடுகள் மற்றும் புவியியல் ரீதியாக தனித்துவமான வாழ்விடங்களை சேர்க்கையில், மைசூர் மற்றும் மலபார் மெலிந்த தேவாங்குகளை *Loris lydekkerianus* மற்றும் *Loris malabaricus* என இரண்டு தனித்துவமான இனங்களாக அங்கீகரிக்க நாங்கள் முன்மொழிகிறோம்.

Threatened Taxa

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 September 2023 | 15(9): 23836–23842

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

https://doi.org/10.11609/jott.8179.15.9.23836-23842

#8179 | Received 07 September 2022 | Final received 04 August 2023 | Finally accepted 20 August 2023

OPEN ACCESS

COMMUNICATION

New localities and sexual dichromatism in Blue-green eyed Spotted Cuscus *Spilocuscus wilsoni* Helgen et Flannery, 2004 (Mammalia: Marsupialia: Phalangeridae) from Biak Island, Indonesia

Aksamina Maria Yohanita [1], Kanthi Arum Widayati [2], Tri Atmowidi [3], Hiroo Imai [4] & Bambang Suryobroto [5]

[1-3,5] Department of Biology, IPB University, Kampus IPB Dramaga, Bogor, Indonesia.
[4] Molecular Biology Section, Center for the Evolutionary Origins of Human Behavior (eHUB), Kyoto University, Inuyama, Aichi 484-8506, Japan.
[1] a.yohanita@unipa.ac.id, [2] kanthiarum@gmail.com (corresponding author), [3] atmowidi@apps.ipb.ac.id, [4] imai.hiroo.5m@kyoto-u.ac.jp, [5] suryobroto@apps.ipb.ac.id

Abstract: Spotted cuscuses are medium-sized tree-dwelling mammals native to tropical forests of Australo-Papua that primarily feed on fruits and leaves. They belong to the phalangerid genus *Spilocuscus* (Gray, 1862). The difference in pelage color between male and female *Spilocuscus wilsoni* has not yet been well described morphologically. In the present study, we describe the coat color of four *S. wilsoni* individuals: a male adult, a sub-adult male, a sub-adult female, and a juvenile female. Dorsal, lateral, and ventral body section images were captured on camera, and body weight & length, tail & ear length were measured. The adult male *S. wilsoni* had brown spot and blotch patterns on the dorsal and lateral regions, and the ventral region was plain beige. The sub-adult male had distinct spot patterns without blotches on the dorsal and lateral regions, while the ventral region was plain with a cream base color. The sub-adult female had a mottled pattern that blended with the base color, making a silvery appearance. The female juvenile was spotless throughout, with a foundation hue ranging from creamy to somewhat yellow.

Keywords: Biak Island Spotted Cuscus, coat color, medium-sized tree-dwelling mammal, morphologically describe.

Editor: Spartaco Gippoliti, Socio Onorario Società Italiana per la Storia della Fauna "Giuseppe Altobello", Italy. **Date of publication:** 26 September 2023 (online & print)

Citation: Yohanita, A.M., K.A. Widayati, T. Atmowidi, H. Imai & B. Suryobroto (2023). New localities and sexual dichromatism in Blue-green eyed Spotted Cuscus *Spilocuscus wilsoni* Helgen et Flannery, 2004 (Mammalia: Marsupialia: Phalangeridae) from Biak Island, Indonesia. *Journal of Threatened Taxa* 15(9): 23836–23842. https://doi.org/10.11609/jott.8179.15.9.23836-23842

Funding: This study was funded by Penelitian Disertasi Doktor contract number 1967/IT3.L1/PN/2021 from the Ministry of Research, Technology, and Higher Education to KAW. JSPS Kakenhi 21KK0130 (Fund for the Promotion of Joint International Research (Fostering Joint International Research (B)) and Future Development Funding Program of Kyoto University Research Coordination Alliance to KAW.

Competing interests: The authors declare no competing interests.

Author details: Aksamina Maria Yohanita has studied small mammals in Papua for approximately 15 years since joining as a lecturer at the University of Papua, Manokwari. Currently, she is registered as a student in the animal biosciences doctoral program at Bogor Agricultural University. Dr. Kanthi Arum Widayati is working as a lecturer in the Department of Biology, Bogor Agricultural University. She is specialized in primatology and focuses on experimental biology and human biology. Dr. Tri Atmowidi is the head of the Animal Bioscience study program, Bogor Agricultural University (IPB University). He is specialized in Entomology and focuses on the Insect pollinator biology. Prof. Hiroo Imai is a professor in molecular and cellular biology at the Molecular Biology Section, Center for the Evolutionary Origins of Human Behavior (eHUB), Kyoto University. Bambang Suryobroto is working as a senior lecturer in the Department Biology, Bogor Agricultural University. He is specialized in the life history and focuses on symmetry/asymmetry. He is also supervising PhD scholar in the field of anthropology, mammalogy, and developmental biology.

Author contributions: AMY: field work, conceptualization, and manuscript writing; KAW: conceptualization, manuscript writing, and review; TAW, HI, and BS: review.

Acknowledgements: The authors would like to thank the field guide and assistants for the cuscus survey. We also thank the Head of the Biak Bird and Orchid Park for the permission to access the cuscus in captivity.

INTRODUCTION

Spotted cuscuses are medium-sized tree-dwelling marsupials that primarily feed on fruits and leaves and are native to tropical forests of Australo-Papua. They belong to the phalangerid genus *Spilocuscus* (Gray, 1862). Previously, Biak Island's Spotted Cuscus was considered belonging to the group *S. maculatus* (Flannery 1995b), but later it was separated as a new species *Spilocuscus wilsoni* Helgen et Flannery, 2004. Among all the species of Spilocuscus, this is the only one that possesses blue-green eyes. *S. wilsoni* is one of the smaller species from genus *Spilocuscus* that coexist with *S. maculatus* on Biak Island.

S. wilsoni is found exclusively on the oceanic islands of Biak-Supiori, located in the northern region of New Guinea. Biak-Supiori Island has an area of 2,497 km^2, located off the coast of Sahul, which has no connection with mainland New Guinea. The endemicity and restricted range of *S. wilsoni* make it 'Critically Endangered' on the IUCN Red List (Aplin & Helgen 2016). The description of *S. wilsoni* was based on two samples; a juvenile male (holotype) and an adult male (paratype) from the Rijksmuseum van Natuurlijke Historie, Leiden, Netherlands (RMNH) (now Naturalis) (Helgen & Flannery 2004). Furthermore, an immature individual of unspecified sex, residing as a domesticated animal within a family setting on Biak, was captured in photograph by Flannery 1992, and constitutes an additional paratype (Helgen & Flannery 2004).

The description of *S. wilsoni* is based on craniodental characters and coat color diagnosis of an adult male (paratype) on dry skin. The adult paratype has a pure white coat dorsally and ventrally, shared only with *S.m. maculatus* of northern New Guinea (Helgen & Flannery 2004). The immature holotype is known to be male, however, there is no information about coat color and body size (Helgen & Flannery 2004).

The pelage color description is essential in the identification of species and individuals. Although the identification of species involved adult individuals, immature individuals also need to be known because the pelage colors of mammals are not necessarily fixed throughout their lifetimes (Caro & Mallarino 2020). Baby marsupials, including cuscus, have pink skin and very little hair, and most weigh less than 0.01% of the mother's weight at birth (Hughes & Hall 1988). The difference in pelage color between male and female *S. wilsoni* has not yet been well described morphologically. We found that sub-adult *S. wilsoni* show sexual dicromatism (mottled in females versus spotted and pale color in males), a limited phenomenon among mammals (Caro 2009) but not unusual among cuscuses (Flannery 1995a,b; Caro 2013).

In this study, we describe the coat color pattern of an adult male, sub-adult male, sub-adult female, and juvenile female of *S. wilsoni*. We also measured the body and marked the location where *S. wilsoni* was found for this distribution data.

MATERIAL AND METHODS

This study was conducted from July 2021 to October 2021. Four individuals of *S. wilsoni* from Biak represented the age categories of adult male, sub-adult male, sub-adult female, and juvenile female, one individual, respectively. Information on the origin of the cuscus habitat was obtained directly from a local resident for 1, 2, and 3 and from a keeper in the Biak Bird and Orchid Park for 4 (Figure 1). The subjects were recorded using Canon EOS 750D digital camera with Canon lens EF-S 18–55 mm/F3.5–5.6 (Canon, Tokyo, Japan) in the RAW format. Photographs of the dorsal, lateral, and ventral areas are made in the same frame with a color checker passport. *S. wilsoni* body measurements include weight (W), head-body length (HBL), tail length (TL), and ear length (EL). All length measurements are in centimeters and weight measurements are in grams. This study has received approval from the IPB Animal Ethics Commission (Number 207-2021 IPB).

RESULTS

Adult male

The adult male appears to have a creamy base color and brown spotted and blotched morphs. The spotted and blotched morphs dominate the dorsum and flank, spreading from the head, back, limbs, and half of the tail. The blotch of the head is very dark, and the ears are covered with hair. The muzzle is hairless and darker in color compared to the chin area. The pelage on the foot is darker than the arms. Some ends of the hair strands look blackish and silvery in the dorsum and flank areas, while the ventral area does not. The ventral coat is creamy from the chin and belly to the limbs. This individual has blue-green eyes. The body measurements are as follows: W = 2,480 g; HBL = 46.5 cm; TL = 44 cm; and EL = 2.5 cm. This individual was found in the secondary forest around Warsa village, northern Biak (Image 1).

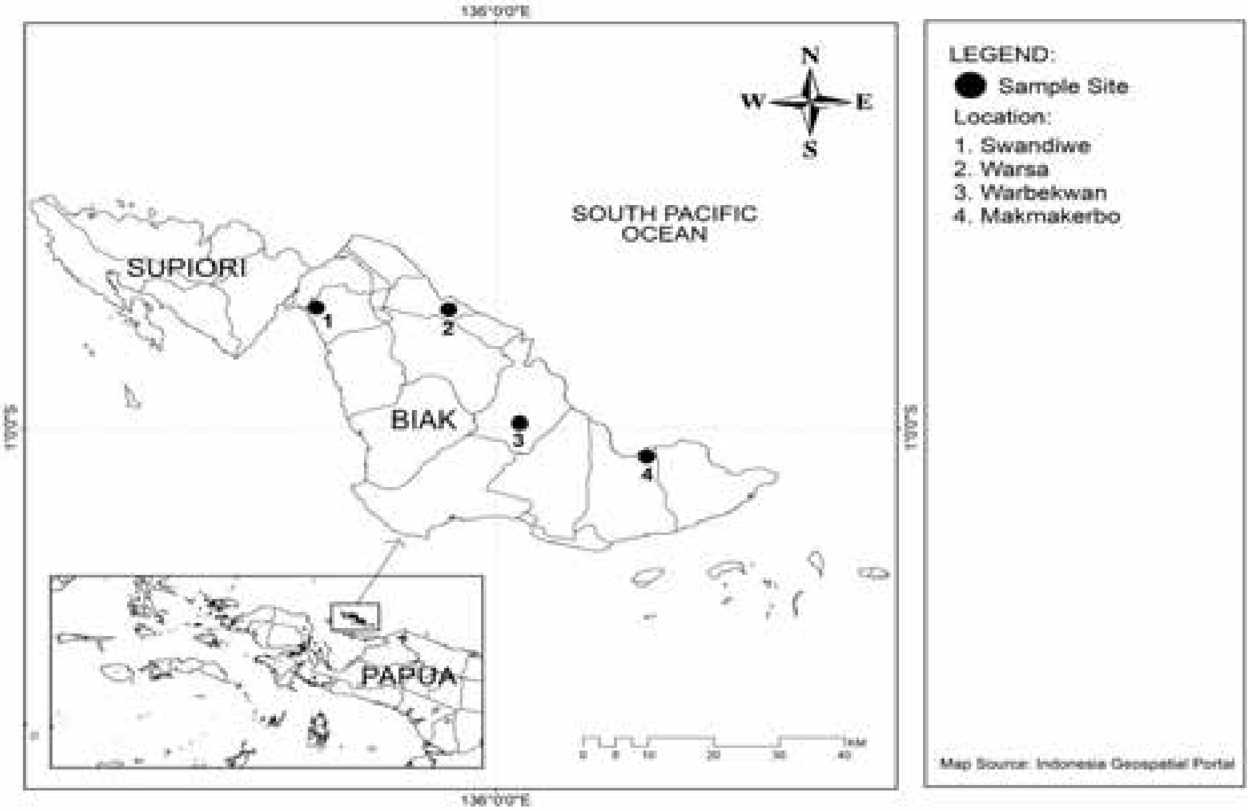

Figure 1. Original habitat of *Spilocuscus wilsoni*.

Image 1. Adult male of *Spilocuscus wilsoni*. © Yohanita AM, 2021.

Sub-adult male

The sub-adult male appears to have a more dominant creamy base color, and the spotted morph is brown. Spotted morphs spread from the head, back, limbs, and half of the tail but is less than that of adults. The blotch area of the head is brown, the area from the cheeks to the chin is creamy, and the ears are covered with hair. The pelage on the foot is dark. The ventral coat is creamy and a little orange in the chest area. This individual has blue-green eyes. The body measurements are as follows: W = 1,300 g; HBL = 36 cm; TL = 35 cm; and EL = 2 cm. This individual was found in the secondary forest around Makmakerbo Village, eastern Biak (Image 2).

Sub-adult female

The whole body of this sub-adult female is a mixture of creamy, light brown, and dark brown colors. The hair of the head area is a mixture of light brown on the face and dark brown on the head. The ears are covered with brown hair. The hair on the dorsum and flank areas has a mottled pattern of creamy and dark brown, while the tail area is light brown. The ends of the hair strands on the dorsum and flank areas appear silvery-buff hairs. The pelage on the foot is darker than the arms. The creamy-colored ventral area looks like a coat from head to legs. The belly part has an unopened sac. This individual has blue-green eyes. The body measurements are as follows: W = 1,100 g; HBL = 33 cm; TL = 30.7 cm; and EL = 1.5 cm. This individual was found in the secondary forest around Swandiwe Village, western Biak (Image 3).

Juvenile female

The whole body of this juvenile female looks creamy and unspotted (dorsum, flank, and belly visible). The hair on the head is thinner than that on the body. The muzzle is hairless and pink, and the ears are covered with light yellow hair. The dorsum and flank parts, including the legs, are creamy and look a little yellow in the upper back. Some ends of the hair strand on the dorsum and flank areas appear blackish and silvery. The belly part has an unopened sac. This individual has yellow-green

Image 2. Sub-adult male of *Spilocuscus wilsoni.* © Yohanita AM, 2021.

Image 3. Sub-adult female of *Spilocuscus wilsoni.* © Yohanita AM, 2021.

Image 4. Juvenile female of *Spilocuscus wilsoni.* © Yohanita AM, 2021.

Table 1. Differences in pelage coloration and iris color in *Spilocuscus wilsoni* compare to other *Spilocuscus*.

Species	Pelage color		Iris color
	Male	Female	
S. wilsoni	Adult males unspotted are yellowish white (Helgen 2007). Sub-adult has a more dominant creamy base color, and the spotted morph is brown. The adult male has a creamy base color and, more brown blotch that are dominant in the dorsum and flank (present study).	Sub-adult female is red-spotted (ZMB 91706) (Helgen 2007). The juvenile is creamy and unspotted in the entire body (dorsum, flank, and belly visible). Sub-adults have a mottled pattern that looks like a mixture of creamy, light brown, and dark brown colors (present study).	Blue-green (Helgen & Flannery 2004). Yellow-green (juvenile) and blue-green (sub-adult and adult).
S. papuensis	The complete lower surface and base color of the dorsum are creamy in apperance, while the spots covering the back, head, and limbs are dark brown or blackish. Frequently, the upper surface of the body is washed with a yellowish hue and commonly exhibits lighter patches of yellow and brownish speckles, while the tail is typically characterized by gold or red-brown spotting. The markings are more prominent and blotchy in males (Helgen 2007).	The female has the same basic coloration and spot pattern all over the body as the male. However, the spots are smaller and more discrete (Helgen 2007).	Carmine-red (Jentink 1885); as either brown or hazel (Flannery 1994, 1995b; Gray, 1862).
S. maculatus from northern and western New Guinea	Mature males typically have a yellowish-white or orange hue, often featuring substantial orange and white spots or blotches on their mid-back (Helgen 2007).	Mature females exhibit colors ranging from yellowish-white to orange, and some may have yellowish-white coats with orange markings (Helgen 2007).	Brown to hazel (Flannery, 1994, 1995a, 1995b; Gray, 1862).
S. rufoniger	The dorsum of the animal has a creamy base-color with a superimposed pattern of intensely blackish (ranging from jet-black to maroon) spots or blotches on the mid-back and hind legs. The face, head, nape, shoulders, hands, feet, and sometimes the body of the limbs are covered in a vibrant red-orange or golden fur. The tail can be either golden or whitish, and the underside of the throat and chin is typically white fur that often extends as a crescent shape to the cheeks and ears, creating a striking contrast with the intense color of the head (Helgen 2007).	The female displays a coloration identical to that of the male, with the exception of the absence of black spots on the back. Instead, they have a black saddle marking that extends over the mid-back and hind limbs (Helgen 2007).	Brown to hazel (Flannery 1994, 1995a, 1995b; Gray 1862).

eyes. The body measurements are as follows: W = 825 g; HBL = 30 cm; TL = 28.5 cm; and EL = 1.5 cm. This individual cuscus was found in the secondary forest around Warbekwan Village, northern Biak (Image 4).

DISCUSSION

Our observation of the coat colors of four individual *S. wilsoni* showed differences in pelage color patterns between males and females. The female had a mottled pattern throughout the dorsal and lateral to ventral edges and appeared to be wearing a coat. The male had a spotted and blotched pattern on the dorsal and lateral areas, while the ventral area was unspotted. We conclude that the sub-adult *S. wilsoni* shows sexual dichromatism (mottled in females versus spotted and pale color in males). Some cuscuses have spots or dorsal stripes; the spotted cuscuses *S. maculatus* and *S. rufoniger* show sexual dichromatism as females lack spots (Flannery 1995a; Helgen & Flannery 2004; Caro 2013), except for *S. papuensis* in which both males and females had spots (Table 1). The spotted cuscus has a unique color, especially in females, and it is recorded that four species inhabit the mainland and islands of Papua. The female *S. maculatus* in the northern islands is plain yellowish-white, while in mainland Papua it is yellowish-white with orange markings from mid-back to the abdomen. Furthermore, the *S. rufoniger* female displays black saddle markings that cover both the mid-back and hind limbs (Helgen 2007).

The sub-adult and adult males in this study showed a brown spotted pattern. Nevertheless, the spots on the sub-adult individual are smaller and more discrete, so the beige base is more dominant. In adults, a blotch on the head extends to the upper back to the forelimbs, and a blotch on the lower back area to the tail and hind limbs; therefore, the brown blotch is more dominant. *S. wilsoni* juvenile female has a plain cream coloration all over the body, and it seems that pale, plain colors are common among juveniles of Spilocuscus. The colors of mammal pelage may not remain constant over their entire lifespan (Caro & Mallarino 2020). Certain pigs and peccaries experience age-related transformation; for example, they are born with spotted and striped coats that eventually become consistent as their young become mobile (Caro et al. 2018).

The immature *S. wilsoni* photographed by Flannery in 1992 was of unknown sex and was used as additional paratype information (Helgen & Flannery 2004). We saw similar color patterns between the photo and *S. wilsoni* in this study (Image 3), and we conclude that its morphology belongs to the sub-adult female individual. We also found differences in the iris color of juvenile (yellow-green) and sub-adult or adult individuals (blue-green), but this needs further investigation.

REFERENCES

Aplin, K. & K. Helgen (2016). *Spilocuscus wilsoni*. The IUCN Red List of Threatened Species 2016. e.T136443A21950078. Downloaded on 04 September 2016. https://doi.org/10.2305/IUCN.UK.2016-2.RLTS.T136443A21950078.en

Caro, T. (2009). Contrasting coloration in terrestrial Mammals. *Philosophical transactions of The Royal society B* 364: 537–548. https://doi.org/10.1098/rstb.2008.0221

Caro, T. (2013). The colours of extant mammals. *Seminar in cell and developmental Biology* 24(6–7): 542–552. https://doi.org/10.1016/j.semcdb.2013.03.016

Caro, T. & R. Mallarino (2020). Coloration in Mammals. *Trends in Ecology and evolution* 35(4): 357–366. https://doi.org/10.1016/j.tree.2019.12.008

Caro, T., C. Newell & T. Stankowich (2018). Ecocorrelates of pelage coloration in pigs and peccaries. *Journal of Mammalogy* 99(5): 1093–1100. https://doi.org/10.1093/jmammal/gyy107

Flannery, T.F. (1994). *Possums of the World*: *a Monograph of the Phalangeroidea*. GEO Productions, Sydney, 240 pp.

Flannery, T.F. (1995a). *Mammals of New Guinea*. Revised Edition. Cornell University Press, New York, 568 pp.

Flannery, T.F. (1995b). *Mammals of the South-West Pacific and Moluccan Islands*. Cornell University Press, New York, 464 pp.

Gray, J.E. (1862). Additional observations on the genus *Cuscus*. Proceedings of the Zoological Society of London 1861: 314–321.

Helgen, K. & T. Flannery (2004). Notes on the Phalangerid marsupial genus *Spilocuscus*, with description of a new species from Papua. *Journal of Mammalogy* 85(5): 825–833. https://doi.org/10.1644/BER-110

Helgen, K.M. (2007). A reassessment of taxonomic diversity and geographic patterning in the Melanesian Mammal fauna. PhD Thesis. The school of Earth and Environmental Sciences, University of Adelaide, 446 pp.

Hughes, R.L. & L.S. Hall (1988). Structural Adaptations of the Newborn Marsupial, pp. 8–27. In: Tyndale-Biscoe, C.H & P.A. Janssen (eds.). *The Developing Marsupial*. Springer-Verlag Berlin Heidelberg, German, 245 pp.

Jentink, F.A. (1885). A monograph of the genus *Cuscus*. Notes from the Leyden Museum 7: 87–119.

Indonesian Abstract: Kuskus bertotol adalah penghuni pohon berukuran sedang berasal dari hutan tropis Australia-Papua yang memakan buah dan daun. Kuskus bertotol termasuk ke dalam famili Phalageridae dan genus Spilocuscus (Gray, 1862). Perbedaan warna rambut antara *S. wilsoni* jantan dan betina belum terdeskripsikan secara morfologi. Pada penelitian ini, kami mendeskripsikan warna rambut dan mengukur bagian tubuh eksternal dari empat individu *S. wilsoni*: jantan dewasa, jantan dewasa muda, betina dewasa muda, dan betina remaja. Pengambilan foto bagian tubuh area dorsal, lateral, dan ventral dilakukan menggunakan kamera. Pengukuran tubuh meliputi bobot, panjang tubuh, panjang telinga, dan panjang ekor. *S. wilsoni* jantan memiliki pola totol dan bercak berwarna coklat di area dorsal dan lateral, sementara area ventral berwarna krem tanpa totol. Individu jantan dewasa muda memiliki pola totol di area dorsal dan lateral, sementara area ventral berwarna krem tanpa totol. Selanjutnya, individu betina dewasa muda memiliki pola perpaduan bintik warna coklat dan krem yang tampak seperti lurik dengan ujung keperakan. Individu betina remaja, satu-satunya yang tidak memiliki totol maupun bercak dan keseluruhan tubuh berwarna krem sampai kuning muda.

Threatened Taxa

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 September 2023 | 15(9): 23843–23856

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

https://doi.org/10.11609/jott.8149.15.9.23843-23856

#8149 | Received 12 August 2022 | Final received 03 August 2023 | Finally accepted 24 August 2023

OPEN ACCESS

COMMUNICATION

Nest construction and repairing habits of Baya Weaver *Ploceus philippinus* (Aves: Passeriformes: Ploceidae) in the agricultural landscape of Villupuram District, Tamil Nadu, India

M. Pandian

No. F1901, AIS Housing Complex, Natesan Nagar West, Virugambakkam, Chennai, Tamil Nadu 600092, India.
pandian.m14@gmail.com

Abstract: The intricate nesting habits of Baya Weaver *Ploceus philippinus* were studied on two Palmyrah Palm *Borassus flabellifer* trees in Chendur village, Villupuram district, Tamil Nadu between 20 March and 30 November 2020. Observations concentrated on sources of fibers, developmental stages of nests, re-construction & repairing of nests, deposition of clay in the nest walls, and various threats. A total of 98 nests of various developmental stages (wad stage—4, helmet stage—31, egg-chamber closed stage—5, and complete nests—58) were studied on these two nest colonies. The birds used leaf fibers of Indian date Palm *Phoenix sylvestris* and Sugarcane *Saccharum officinarum* as nest materials, and took 6–48 days for construction of a complete nest. 95% of helmet stage nests (n = 126) contained clay deposits. Analysis of plastered clay revealed it was alkaline with pH 9, and dry weight ranged from 5.1–5.8 g. Males re-constructed new nests from the remnant stalks attached to tips of palm fronds, and also made repairs on damaged nests. Anthropogenic factors, wind, rain, and avian predators, such as House Crow *Corvus splendens*, Long-billed Crow *Corvus macrorhynchos*, Rufous Treepie *Dendocitta vagabunda*, and Shikra *Accipeter badius* posed threats to Baya Weavers. A total of 42 nests, 11 broken eggs, and 14 dead chicks were found fallen under the two nest supporting trees. The detailed systematic survey covering entire district, rapid urbanization, and the anthropogenic pressures will help in drafting an action plan to conserve local populations of Baya Weaver.

Keywords: Clay deposit, nest fall, nest materials, nest re-construction, nest repair, threats.

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

Citation: Pandian, M. (2023). Nest construction and repairing habits of Baya Weaver Ploceus philippinus (Aves: Passeriformes: Ploceidae) in the agricultural landscape of Villupuram District, Tamil Nadu, India. *Journal of Threatened Taxa* 15(9): 23843–23856. https://doi.org/10.11609/jott.8149.15.9.23843-23856

Funding: None.

Competing interests: The author declares no competing interests.

Author details: M. Pandian has completed M.Sc., Ph.D., in botany and BLIS from University of Madras and Bachelor of Education (B.Ed.) from Annamalai University, Chidambaram and now serves in Tamil Nadu Police Department. His area of interest is ecology and nesting biology of birds and published a few papers on House Sparrows, Baya Weavers, Streaked Weaver and Black-breasted Weaver, Grey Francolins, Indian Flying Fox, munias and Ring-necked Parakeets.

Acknowledgements: I thank D. Balaji (Mailam), A. Giridharan, S. Kamarajan, and P. Poornima (Narasingapuram) for data collection and analysis.

INTRODUCTION

Baya Weaver *Ploceus philippinus* (Linnaeus, 1766) is a social, polygamous, colonial nester. It occurs in the Indian subcontinent (Ali et al. 1956), Java, Malacca and Sumatra (Blyth 1845; Wood 1926), China, Indonesia, Laos, Myanmar, Singapore, Thailand, and Vietnam (BirdLife International 2016). The IUCN Red List of Threatened Species classifies *Ploceus philippinus* under 'Least Concern' (Birdlife International 2016). In India, the breeding season of Baya Weaver is from May–November (Ali & Ripley 1987; Rasmussen & Anderton 2005). While weavers select a variety of trees for nesting, they most prefer tall, unbranched trunks, and long-swaying foliage of palm trees to keep away predators and provide convenient leaf strips for building nests (Davis 1974). Males usually build partial helmet stage nests and complete them only after females select them and mate (Ali et al. 1956). Nesting birds prefer *Cocos nucifera* (Arecaceae) along the west coast of the Indian peninsula, *B. flabellifer* (Arecaceae) along the east coast, and *Vachellia nilotica* (Fabaceae) in the arid northwestern region (Sharma 1989). The breeding biology of this species was studied by Ali & Ambedkar (1956), Ambedkar (1964), and Mathew (1977). Several researchers have reported construction of abnormal nests (Ali & Ambedkar 1956; Ambedkar 1964; Crook 1964; Sharma 1989; Pandian 2018). Asokan et al. (2008) studied the timeline of nest construction. No other detailed studies have been carried out on the time taken for construction of various stages of nests, nest repairing, nest reconstruction, and physico-chemical analysis of clay deposited in the helmet stage nests of this species in Tamil Nadu. To fill this gap the present study was carried out.

The following questions were kept in mind: (1) How do weavers select substrata on the trees for nest construction? (2) What are the sources of nesting material? (3) What are the developmental stages of nests like wad, helmet, egg-chamber closed and complete nests, re-construction of nests and repairing of damaged nests? (4) How much time is taken to build various stages of nests? (5) What is the physico-chemical nature of clay deposits? And, (6) what are probable threats to weaver populations?

MATERIALS AND METHODS

Study Area

The present study was carried out in Chendur Village, Tindivanam Taluk, Villupuram District of northeastern Tamil Nadu. The district spreads over 3,715 km^2, with a human population of c. 2,090,000 (Figure 1). Agriculture is the primary occupation of the people. The major crops of the area are Paddy *Oryza sativa*, Jowar *Sorghum bicolor*, Pearl Millet *Pennisetum glaucum*, Finger Millet *Eleusine coracana*, Sugarcane *Saccharum officinarum*, Groundnut *Arachis hypogaea,* and Green Gram *Vigna radiata*. Three nest-supporting plant species, such as Palmyrah Palm, Indian Date Palm, and Coconut occur abundantly in the agricultural lands. Among them, only two individuals of *B. flabellifer* were chosen for study, considering the past history of Baya Weavers selecting these two trees for nest construction, proximity to road, and location of trees suitable for study by fixing camera. The maximum and minimum temperatures in the district are 36°C and 20°C, respectively. The average annual rainfall is 1,060 mm (Viluppuram 2021).

Methods

With help from field assistants/informants (4), I identified two *B. flabellifer* nesting trees in Chendur village having a history of Baya Weavers constructing nests since 2016. These two nesting trees were surveyed with the help of field assistants on two shifts, i.e., one person each from 0600 h to 1200 h and 1200 h to 1800 h on a daily basis between 20 March and 30 November 2020. All the nests found in these two trees were treated as nest colony-I and colony-II. The height of the trees, gbh, and distances from nesting trees with source of fibers, distance of source of wet clay, and cultivation of grains crop were measured using a 100 m measuring tape. The locations of nesting trees were determined using GPS. Using 10 x 42 field binoculars (Nikon-Monarch-7), the nests, males plucking nest fibers, developmental stages of nests, clay deposits on inner wall of helmet stage nests, and the total number of birds visiting nesting trees were observed. Clay deposits from helmet stage nests were collected separately from each side of inner walls of fallen nests and analyzed. The physico-chemical analyses of collected clay samples including temperature, salinity, dissolved oxygen, oxidation reduction potential, specific conductivity, electrical conductivity, total dissolved solids, and other metals & minerals were carried out by using YSI multiparameter (Model: 600XL-B-O, 650MDS, YSI Incorporated, Yellow Springs, Ohio 45387, USA) and Perkin Elmer Atomic Absorption Spectrophotometer

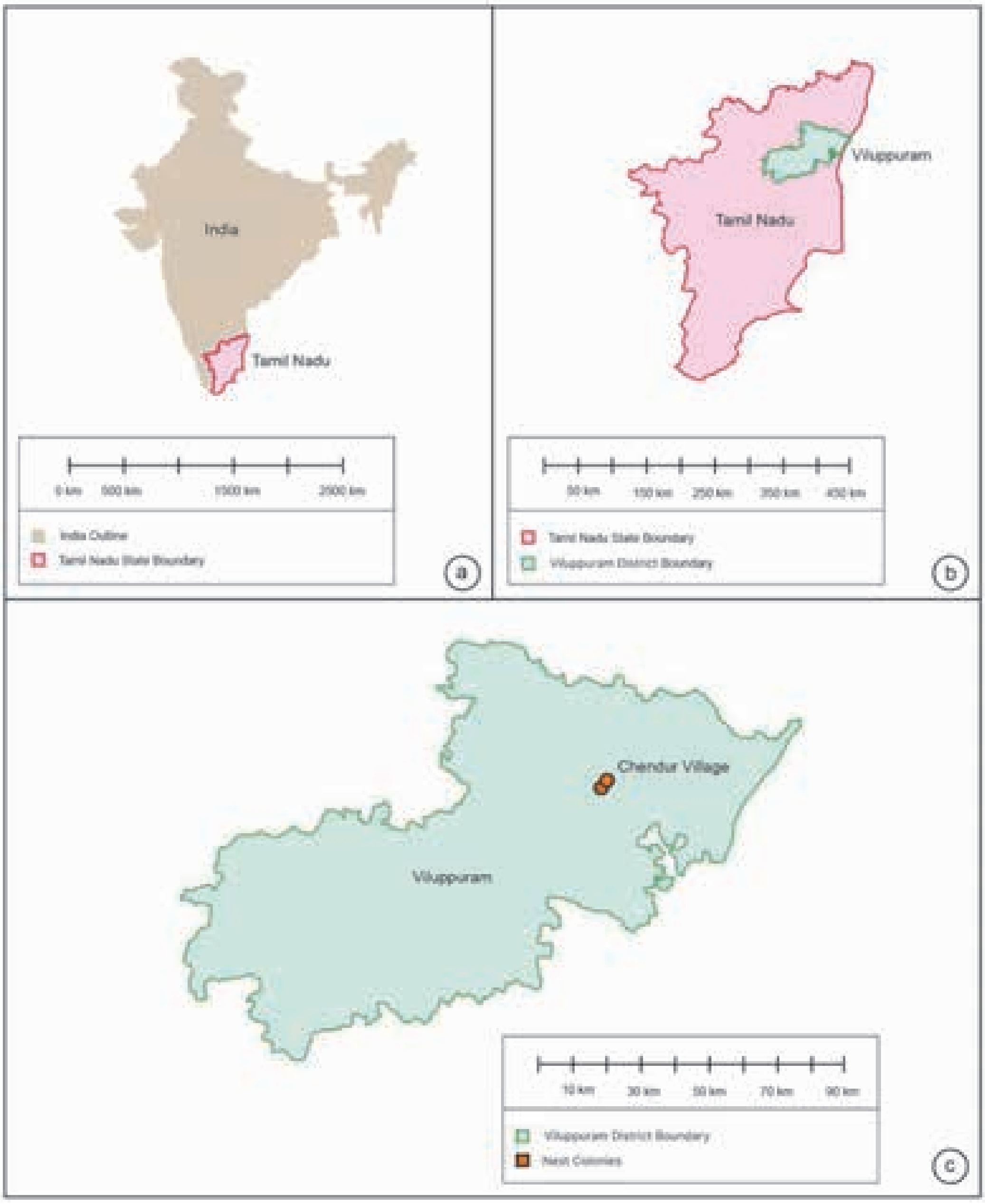

Figure 1. Study area map: a—India map showing Tamil Nadu | b—Tamil Nadu map showing Villupuram district | c—Villupuram district map showing locations of two nest colonies in Chendur village.

Analyst 400. The recorded results were tabulated (SPSS software). Re-constructions of nests, repairing of damaged nests, fall of nests, eggs & chicks, and impact of avian predators were recorded and photographed. Photographs were taken using Nikon P1000 digital camera. Collected data were tabulated, analyzed as total number of fronds used by the birds, average number of nests per frond and shown as tables.

RESULTS

It was observed that no old or torn nests from previous years were found on these two male *B. fabellifer* trees when the study was commenced on 20 March 2020 (Image 1). Baya Weavers constructed a total of 98 nests (Wad stage—4, helmet stage—31, egg-chamber closed stage—5, and complete nests—58) on two male *B. fabellifer* trees. Birds failed to continue constructions on four wad stage nests, and 31 helmet stage nests and five egg-chamber closed stage nests. The remaining 58 nests were complete nests with entrance tubes. The study revealed that the birds built an average of 1.17 nests per palm frond. Nest colony-I contained 62.24% nests (n = 61) and the remaining 37.76% nests (n = 37) were found in nest colony-II (Table 1).

Commencement of nest construction

All the males had commenced nest constructions on 02 April 2020. From 20 March to 01 April, no Baya Weaver was observed on these two nesting trees. On 02 April between 0600 h and 0830 h, 16 males with partial plumage first visited on these two palm trees probably searching for suitable substrata for construction of nests.

Selection of Palm fronds

Males visited distal ends of palm fronds randomly, except the lowermost dried and the uppermost partially opened young fronds. After selection of the distal ends of fronds, they bit the margins by using their beaks and made the margins serrate/rough and also made punctures on the leaf blades probably to make the knots strong. Out of 248 leaf tips studied, the margins of 232 leaf tips was serrate, and 16 leaf tips had serrate as well as punctures. This process of making frond margins serrate continued for five days, i.e., from 02–06 April and the males were observed on nesting trees between 0600 h and 0830 h. During these periods, no activities of nest construction were noted. After 0830 h, they left the nesting trees for foraging in the crop fields and perching on nearby tress/shrubs. They did not return to the nesting trees till the next morning.

Sources of fibers

Males plucked fibers from Indian date palm *P. sylvestris* trees (n = 6) and Sugarcane crops *S. officinarum* situated within c.120 m distance from the nest-supporting trees. Males moved to west to puck fibers from *P. sylvestris* and to all directions to get fibers from *S. officinarum* crops. The study revealed that the males had visited *P. sylvestris* trees daily from 0600 h to 1730 h, perched on rachis/leaflets, made incisions on the margins of leaflets near the bases and speedily tears off fine fibers toward the distal ends. The birds tore off fibers in this manner and carried to the nesting trees. Observations on 100 trips from the sources of fibers (*P. sylvestris* and *S. officinarum*) to nest-supporting trees revealed that the birds carried 2–5 fibers per trip. They selected young fronds for peeling fibers and avoided the old fronds on the bottom of the tree crown. Study on 10 fronds from four *P. sylvestris* trees where birds tore off fibers revealed that the mean size of fronds was 106 cm (Standard Error of 4.73) and the birds had selected leaflets from the distal half of rachis, i.e., from middle to distal part of the rachis and never selected hardened leaflets found on the lower half of rachis, i.e., towards leaf bases. Similarly, males tore off fibers from young and green leaf blades of sugarcane crop and no incident of selection of fibers from dried and partly dried leaves were observed (Image 2).

Behaviour of stealing fibers

Thirty-two incidents of males stealing fibers from adjacent nests when the resident birds of the nests were away were observed. Such incidents of stealing fibers from nests of other birds within the colony were observed throughout the breeding season.

Stages of nest constructions

Four developmental stages of nest constructions such as wad stage, helmet stage, egg-chamber closed stage, and complete nest stage were taken into account and studied in detail (Image 5).

Wad stage

The males plait knots round the margins of leaf blades by using legs and beak called wad stage (Image 5a,b). The study on 98 wad stage nests revealed that the time taken for construction of wad stage varied and the males took minimum two hours to maximum of nine days for construction of wads. In an exceptional case, a male plaited knot continuously for nine days and the wad stage became an amorphous ball like structure. The males usually plaited knot on one leaf tip, but in many cases they used up to six leaf tips for plaiting a knot/wad stage (Image 3). The males built 22.45% wad stage nests (n = 22) in 1–2 days, 54.09% wad stage nests (n = 53) in 3–4 days, 19.38% wad stage nests (n = 19) in 5–6 days, and 4.08% wad stage nests (n = 4) in 7–9 days.

Helmet stage

The males took 1–15 days to construct helmet stage nests. Out of 98 wad stage, 94 were developed into helmet stage nests (birds abandoned 4 wad stage nests). When the females reached the nesting colony, the males perched on helmet stage nests and made loud noises by flapping their wings (Image 4 d). The males built 84% helmet stage nests (n = 79) in 1–5 days (including 27 nests were built within one day from dawn to dusk), 13.8% helmet stage nests (n = 13) in 6–10 days, and 2.1% helmet stage nests (n = 2) in 11–15 days.

Table 1. Details of nest colonies of Baya Weaver on Borassus flabellifer trees in Chendur village, Villupuram district.

Nesting trees with GPS	Height (m)	GBH (cm)	Total no. of fronds found in the crown	No. of fronds without nests	No. of fronds used by birds for construction of nests	Total no. of nests (including all developmental stages) counted	Average no. of nests per frond
Borassus flabellifer (colony-I) (12.123446 N 79.591657 E)	7.5	78	54	30	24	61	0.88
Borassus flabellifer (colony-II) (12.113396 N 79.580264 E)	9.5	82	61	25	18	37	1.64
Total			115	55	42	98	1.17 (average)

Image 1. Nest colonies on *Borassus flabellifer* trees in Chendur village: a—Nesting colony-I | b—Nesting colony –II. © M. Pandian.

Image 2. Baya Weaver: a—Male | b—Female | c & d—Male makes Borassus flabellifer frond margins rough around midrib | e & f—Male bird plucking fibers from leaflets of Phoenix sylvestris. © M. Pandian.

Table 2. Details of number of days taken by the birds to construct complete nests.

Number of complete nests	Percentage (%)	Number of days taken
02	3.4	1–5
18	31	06–10
20	34.4	11–15
08	13.8	16–20
03	5.1	21–25
7	12	Above 26

Image 3. Nests attached on tip of palm frond: a—Nest attached with two leaf tips | b—Nest attached with four leaf tips. © M. Pandian.

Egg-chamber closed stage

Out of 94 helmet stage nests, 31 helmet stage nests were abandoned by the males and did not develop further probably due to non-selection of helmets by females or abandoning by resident males themselves. The remaining 63 helmet stage nests were developed further into egg-chamber closed stage nests. After construction of helmet stage nests, males wait for arrival of females for selection of their helmet stage nests followed by pairing. Hence, further development of nests depends on the chances of selection of helmet stage nests by females and time taken for such selection followed by pairings. My studies revealed that the number of days taken for development of helmet stage nests including the time taken for arrival of females, selection of helmets, and followed by pairing were found varied from one day to 29 days. Out of 63 helmet stage nests, 35 helmet stage nests were developed into egg-chamber closed stage nests in 1–5 days, followed by 20 nests in 6–10 days, four nests in 11–15 days, three nests in 16–20 days and one nest took 29 days (Image 4e).

Complete nests

The birds abandoned five egg-chamber closed stage nests without any further development. Birds took 1–28 days to complete the construction of entrance tube. Out of 58 complete nests studied, in 69% nests (n=40), the entrance tubes were constructed in 1–5 days, while in 12 nests, it took 6–10 days, 11–15 days for four nests, and 21–28 days for two nests (Image 4f; Table 2). During the entire study period, neither courtships nor mating were observed on the helmet stage nests or source of fibers or on nest-supporting trees.

Deposition of clay in the nests

After completion of construction of helmet stage nests and before arrival of females to select such nests, the males plastered two sides of the inner walls of helmet stage nests with wet clay. Observation on 132 helmet stage nests (94 first time built helmet stage nests and 38 re-built helmet stage nests) revealed that 95 % of nests (n = 126) contained clay deposits. Only a very small percentage (4.65%; n = 6) did not have clay. My studies revealed that the males did not take readily available wet clay from the paddy fields, situated c.300 m from the two nesting trees. Males waited for the frequent spell of rainfall during south west monsoon. Immediately after rainfall, the next day morning between 0600 h and 0730 h the males swarmed to the wet fallow land and mud road situated c.40 m distance from the nesting trees and scooped wet clay through their beaks in many trips and carried it to helmet stage nests. Continuous observations revealed that the males did not take clay directly from wet soil surfaces from all the sites. They selected sites where wet clay was exposed in tire tracks left by vehicles on mud roads and fallow land. The practice of males scooping clay after rainfall was observed from April–October 2020 in the morning between 0600 h and 0730 h. It was not possible to ascertain whether the birds added clay on the inner walls after closing of egg-chamber and construction of entrance tube. Dissection of two fallen nests (helmet stage—1 and egg-chamber closed—1) revealed that the

Table 3. Details of properties of clay deposited in the nests.

Parameters	Soil sample collected from the site where Baya Weaver took soil	Egg-chamber closed stage (Left wall)	Egg-chamber closed stage (Right wall)	Helmet stage (Left wall)	Helmet stage (Right wall)
Weight (g)	25	5.1	5.2	5.4	5.8
Temperature (°C)	25.91	26.01	25.93	26.02	25.92
Specific Conductance (Ms/Cm)	0.048	0.048	0.035	0.051	0.024
Conductivity (Ms/Cm)	0.049	0.049	0.036	0.051	0.025
Resistivity (Ω Cm)	22193.3	19805.2	27440.7	19490.3	40131.3
Total Dissolved Solids (TDS %)	0.031	0.033	0.023	0.032	0.016
Salinity (Sal)	0.02	0.02	0.02	0.02	0.01
Dissolved Oxygen (DO %)	32.4	37.2	23.7	30.7	19.4
Dissolved Oxygen milligrams per litre (DO Mg/L)	2.72	2.94	1.94	2.42	1.89
Dissolved Oxygen charge (DO Ch)	15.5	16.5	13.5	15.5	12.4
Potential of Hydrogen (pH)	9.36	9.30	9.30	9.23	9.30
Potential of Hydrogen in Milli Volt (pHml/)	-179.3	-175.0	-175.9	-172.4	-176.4
Oxidation Reduction Potential (ORP)	-110.4	-103.5	-103.4	-99.7	-102.1

Table 4. Details of month-wise nest fall from two nesting trees.

Month	No. of nests felled down
May 2020	11
June 2020	13
July 2020	17
August 2020	1
Total	42

Table 5. Details of impact of avian predators on Baya Weaver colonies in Chendur village.

	Name of the predator	No. of sightings noted	No. of nests damaged	No. of Baya Weaver killed
1	*Corvus splendens*	72	3	0
2	*Corvus macrorhynchos*	27	0	0
3	*Dendrocitta vagabunda*	4	4	0
4	*Accipiter badius*	7	0	1
Total		110	7	1

males smudged two patches of clay on each side of the nest. The surface of dried plaster of clay had many beak marks as scars (Image 5f). It was observed in one egg-chamber closed stage nest that even after plastering of clay, another layer of fresh fibres was found on the patches of clay. It indicates that even after smudging clay, males further added fibres above the layer of clay (Image 6e). No female was seen scooping clay and carrying to nests (Image 5).

Physico-chemical analysis of clay deposits taken from one helmet and one egg-chamber closed stage nests revealed it was alkaline (pH 9). The dry weights of the clay ranged 5.1–5.8 g. The other parameters also showed no major variations. The physical and chemical properties of clay collected from both walls of two nests matched with the soil sample collected from the nearby ground where male birds scooped clay (Table 3).

Falling of nests

Of 98 nests constructed during the study period, 43% (n = 42) of various developmental stages (helmet stage—22, egg-chamber closed stage—03, and complete nests—17) fell from the nest-supporting trees due to biotic and abiotic factors. 31 nests fell after rainfall, and the remaining 11 fell when no rainfall occurred (Table 4).

Re-construction of nests

The males started to rebuild 38 nests from the remnants of wad fibers found attached to the tips of palm fronds. Twenty-three nests were developed into helmet stage nests but did not progress further. The remaining 15 nests were successfully developed into complete nests. When studying the number of days taken to re-built a complete nest revealed that the birds took 6–37 days to re-built complete nests. The study reveals that the birds had constructed 13 complete nests in 6–25 days and for another two nests took 26 days and

Image 4. Various stages of nest development: a —Male individual brought fiber to tie a knot | b—Male bird perching on wad stage nest | c—Ring stage nest | d—Helmet stage nest | e—Egg-chamber closed stage nest | f—Complete nest with entrance tube. © M. Pandian.

37 days, respectively.

One re-built helmet stage nest was again felled down on 21 May and a male had started to construct another helmet stage nest at the same tip of frond on 24 May and completed the construction of helmet stage nest on 25 May. Later the helmet stage nest did not develop further. On 30 June, another re-built helmet stage nest was felled down and a male had again constructed helmet stage nest from the same tip of palm frond within two days i.e., on 01 and 02 July. Later in nine days, i.e., on 11 July and it was developed into a complete nest (Image 6).

Repairing of damaged nests

Incidents of partial damages to seven nests (egg-chamber closed stage—4, and complete nests—3) by House Crow and Rufous Treepie were recorded in the study area. In all these nests the birds brought fresh plant fibers and plait on the edges of damaged walls. Then the birds had continued further construction activities and repaired all the nests. The repaired nests resembled two different colours, i.e., the older part resembled pale colour and the repaired portion resembled green colour due to the addition of fresh green fibers (Image 7).

Image 5. Plastering of wet clay on the inner walls of helmet stage nests: a & b—Males engaged in collection of clay from wet ground | c—Plastering of clay on the inner wall of helmet stage nest | d—Clay deposit found in dissected nest | e—Layer of fibres found above clay deposit | f—Beak marks on clay deposit. © M. Pandian.

Threats

Opportunistic sightings of predatory birds such as House Crow *C. splendens*, Long-billed Crow *C. macrorhynchos*, Rufous Treepie *D. vagabunda,* and Shikra *A. badius* were observed on these two nesting trees. On 24 July at 1240 h, one Shikra had chased the individuals of Baya Weaver from nesting colony-I and when seeing the predator, all the individuals of Baya Weaver fled from the nest colony. One male Baya became a prey to Shikra and later took the victim to a nearby shrub and ate it completely, except feathers (Image 8 j). On 11 June, one Rufous Treepie visited nesting colonies and made punctures on the egg-chambers. The predator had inserted its head into the egg-chamber but we were unable to ascertain whether it prey upon the eggs/chicks from the nests. Individuals of House Crow and Large-billed Crow were found perching on nesting trees and chased the individuals of Baya Weaver but preying adult birds/chicks were not observed during the study period. On 28 May, a House Crow plucked fibers from three nests (complete nests-3) and caused partial damages to the nests (Table 5).

On 30 September, one land holder had uprooted and removed *P. sylvestris* trees (n = 14) found on bunds of fallow lands situated 60 m from nesting trees while clearing the land for cultivation. The males had plucked fibers from these trees for construction of nests. A total of 42 fallen nests, 11 broken eggs, and 14 dead chicks

Image 6. Re-construction of nest: a—Stalk of the fallen nest | b—Plaiting green fresh fibers on pale old stalk | c—Remnant stalk of old nest | d—Male plaiting green fresh fibers around old stalk | e—Re-construction of new helmet from old stalk | f—Re-constructed complete nest. © M. Pandian.

were observed under the nesting trees. In one instance, farmer burnt bushes around nesting tree which caused temporary driven of birds from nesting tree (Image 9).

Roosting

During the entire breeding period from April–November, no Baya Weaver was found night roosting on the nest-supporting trees. Between 1745 h and 1810 h all the birds used to fly away from the nest colonies and roost on the shrubs found 1–1.5 km from nest colonies and return to their nest colonies the next morning. Continuous observations revealed that some females entered their nests during the evening hours did not come out and stayed in the nests itself. These females might have incubated their eggs or nestlings.

DISCUSSION

Commencement of nest construction

The study revealed that starts of the breeding season of Baya Weaver vary from area to area in India. For example, date of commencement of nest construction was 22 May 1930 in Kolaba district of Maharashtra (Ali 1931), early June in Parbati Hill, Poona city (Ali et al. 1956), mid-June in Chorao Island, Goa (Borges et al. 2002), and mid-April in Rajampet Taluk of Cuddapah district, Andhra Pradesh (Mathew 1972). In the present

Image 7. Nest damage and repair: a—Male perching on damaged nest | b—View of damaged nest | c—Repairing of damaged nest | d—Further growth of nest. © M. Pandian.

study, breeding commences in the first week of April which corroborate the observation of Mathew (1972). It indicates that the breeding of Baya Weaver is related to South-West monsoon in Tamil Nadu.

Selection of Palm fronds

Baya Weavers construct nests from the distal ends of midribs of the coconut palm in South Goa (Borkar & Komarpant 2003). The birds wrap considerable amounts of fibers around a chosen frond and makes a strong base for further development of the nest (Wood 1926). Also in the present study nests were found attached at the distal ends of the midribs of *B. flabellifer* fronds. This indicates that the males selected the distal ends of palm fronds for construction of nests. No nest was found in the middle or basal parts of fronds in the two nest colonies.

Source of fibers

Except in northern India, the birds used leaf fibers of *C. nucifera* and *P. sylvestris* for nest construction in other parts of the country (Dewar 1909). Baya Weaver used pliant grass and fibers from palm fronds in the Northern Province of Sri Lanka (Wood 1926), and leaves of *Phoenix* sp., coarse grass and paddy in Kolaba district, Maharashtra (Ali 1931) as nest materials.

The present findings of Baya Weaver using fibers from *P. sylvestris* for construction of nests matches with the observations of Dewar (1909), Wood (1926), and Ali (1931). Apart from that the birds also used sugarcane leaves as nest material in the study area.

Time taken for construction of nest

Asokan et al. (2008) stated that the birds took 18 days to construct one complete nest in Nagapattinam and Tiruvarur districts of Tamil Nadu. Achegawe et al. (2016) had also found similar results in Nanded region of Maharashtra. The present study revealed that the time taken for construction of a complete nest was not uniform for all the nests. The birds took 6–48 days for construction of complete nests. The study also revealed that the males had capable of constructing helmet stage nest in one day, i.e., from dawn to dusk. Hence, the present findings of number of days taken to construct complete nest in Villupuram district found differ with the observations of Asokan et al. (2008)

Plastering of inner nest walls with wet clay

The habits of smudging of clay in the nests are observed only in Asian weavers (*P. manyar, P. benghalensis,* and *P. philippinus*) and not found in African

Image 8. Various threats to Baya Weavers: a & b—Nests dangling from the stalk | c & d Fallen nests | d—Broken egg near fallen nest | e–g—Dead chicks under the nesting tree | i—Bushes burnt under nesting tree | j—Shikra eating a male Baya Weaver individual. © M. Pandian.

weavers and the quantity of mud varies from region to region in India (Crook 1963; Davis 1973). Plastering of inner walls of nest with wet clay is done when the nest construction reaches the helmet stage prior to pairing with females (Dewar 1909; Ali 1931; Ambedkar 1964; Borkar & Komarpant 2003).

Davis (1973) stated that about 18.33% nests did not show presence of mud blobs on the inner walls of nests in South Goa. He added that females were never found bringing mud. In the present study also, 4.54 % of helmet stage nests did not have clay deposits, and no female was observed carrying clay. This matches with the findings of Davis (1973). Ali (1931) had observed 0.5–1 oz of mud in the nest. Davis (1973) also found that the average dry weight of mud deposit per nest was 66.2 g. But in the present study, the dry weight of clay ranged from 5.1–5.8 g. Average weight of mud blobs on left side was greater in comparison with right side (Borkar & Komarpant 2003). The present study on two nests revealed that there was no major variation in the weight of clay deposited on the right and left side of the inner walls. In the present study, the clay collected from nests and in the original sites where birds took clay was found alkaline (pH 9). The exact causes of plastering of mud in the nest walls require further studies.

Fallen nests

The practice of male cutting down the nest of rival cock was common when the owner had gone to fetch building materials (Ali et al. 1956). Pandian (2021) had observed that male Baya Weaver cut down a complete nest occupied by White-rumped Munia *Lonchura striata* in Villupuram district. In the present study, 42.85% nests (n = 42) of various developmental stages were found fallen under the nest-supporting trees. Apart from rain and wind, these might have also occurred due to rival males as stated by Ali et al. (1956). Falling of such a great number of nests (42.85%) from two nest colonies in a single breeding season is of great concern and it needs further study.

Re-construction of nests

The study indicates that the birds are capable of constructing complete nests from the same stalks from where the earlier nests were detached. It was not possible to differentiate whether the same male commences construction of nest from the torn stalk or different male uses the stalk for further construction of nest. However the birds have the intelligent to re-construct their nests from the stalk of detached nests.

Repairing of damaged nests

Baya Weavers have the capacity to repair their damaged nests with fresh green strips of fibers, i.e., various types of artificial nest mutilations (Ali & Ambedkar 1957; Collias & Collias 1959, 1962). In the present study also the birds had repaired heavily damaged nests by using fresh fibers and hence it matches with the findings of Ali & Ambedkar (1957) and Collias & Collias (1959, 1962).

Threats

Ali (1931) had stated that agitated behaviour of Baya Weaver was observed when Crow Pheasants *Centropus sinensis* appeared in close proximity of the nesting tree. He also observed a Shikra making an unsuccessful stoop on nest colony. In the present study also, Baya Weaver had exhibited agitated behaviours when House Crows visited nesting trees and all birds fled away from tree crown when they saw Shikra and a Rufous Treepie near the nesting trees.

Ali et al. (1956) had observed that many completed nests were blown down due to recurring spells of bad weather during June–August in Bombay area and was major natural mortality factor of nest colonies. He also noted accidental drowning of chicks from nests. Similarly in the present study also, 31 nests were found fallen down immediately after rainfall. Out of 14 dead chicks, five were found under the nesting trees after rain and wind. Hence, the present observations match with the findings of Ali et al. (1956).

CONCLUSION

This is a systematic study on the nesting habits on Baya Weaver on two Palmyrah Palm trees in a confined geographical area of one village in Villupuram district. Increasing urbanization by conversion of cultivated lands into residential areas, expansion of roads, abandoning cultivations along with indiscriminate felling of principal nest-supporting palm plants, such as Palmyrah Palm *B. flabellifer*, Coconut *C. nucifera*, and Indian Date Palm *P. sylvestris* that are vital for Baya Weaver is a conservation issue in this landscape. Increasing practices of monoculture of *Casuarina*, Sugarcane, and flower crops, declining areas of cultivation of cereals and millets also causes shortage of grains to birds. Fall of viable nests due to various anthropogenic factors, winds, rain and avian predators cause severe stress on the breeding of Baya Weaver. Therefore, it is essential to conduct sustained surveys and monitor the nesting sites during the subsequent breeding seasons and efforts should be taken to create suitable nesting habitats by not destroying the nesting trees. Based on the above the following could be options for securing the bird's habitat from the area.

(a) Establish a special management plan for the area, considering the anthropogenic and natural stresses that the habitat is currently subjected to.

(b) Local community, particularly land holders, and agricultural workers should be sensitized to understand the need to preserve the precious nesting sites.

(c) The detailed systematic survey covering the entire Villupuram district will help in drafting an action plan to conserve the populations of Baya Weaver.

(d) The impact of abiotic factors such as rain and wind on the nest fall need further studies.

(e) The exact causes of males depositing wet clay on the inner walls of nests during helmet stage, fall of large number of nests, and mortality to chicks require further studies.

REFERENCES

Ali, S. (1931). The nesting habits of the Baya (*Ploceus philippinus*). *Journal of the Bombay Natural History Society* 34(4): 947–964.

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

Ali, S. & C.V. Ambedkar (1956). Further notes on the Baya, *Ploceus philippinus* (Linn.). *Journal of the Bombay Natural History Society* 54(3): 491–502.

Ali, S., & S.D. Ripley (1987). *Compact handbook of the birds of India and Pakistan together with those of Bangladesh, Nepal, Bhutan and Sri Lanka*. 2nd ed. Delhi: Oxford University Press. pp. i–xlii, 1 l., 1–737, 52 ll.

Ambedkar, V.C. (1964). *Some Indian weaver birds: a contribution to their breeding biology, Bombay*. University of Bombay, Bombay, pp 75.

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.

BirdLife International (2016). *Ploceus philippinus*: The IUCN Red List of Threatened Species 2016: e.T22719005A94606190. https://doi.org/10.2305/IUCN.UK.2016-3.RLTS.T22719005A94606190.en. Accessed on 22 September 2023.

Blyth (1845). Notices and descriptions of various new or little known species of birds. *Journal of the Asiatic Society of Bengal*. Vol. XIV, Part-II Calcutta, 553 pp.

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.

Borkar, M.R. & N. Komarpant (2003). Observations on the nesting ecology of Baya Weaver bird (*Ploceus philippinus* Linn.) in South Goa, with notes on aberrant nest designs. *Ecology, Environment and Conservation* 9(2): 217–227.

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

Collias, N.E. & E.C. Collias (1962). An Experimental Study of the Mechanisms of nest building in a weaverbird. *The Auk* 79: 568–595.

Crook, J.H. (1963). A Comparative Analysis of Nest Structure in the Weaver Birds (Ploceinae). *Ibis* 105: 238–262.

Crook, J.H. (1964). Field experiments on the nest construction and repair behavior of Certain Weaver birds. *Proceedings of the Zoological Society of London* 142: 217–255.

Davis, T.A. (1973). Mud and dung plastering in Baya nests. *Journal of the Bombay Natural History Society* 70(1): 57–71.

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

Dewar, D. (1909). The nesting habits of the Baya. *Journal of the Bombay Natural History Society* 19(3): 627–634.

Mathew, D.N. (1972). Ecology of the Baya Weaver in Rajampet, Cuddapah district, A.P. *Journal of the Bombay Natural History Society* 69: 188–191.

Mathew, G. (1977). A Sporadic Bird Pest, *Ploceus philippinus* (Linnaeus) attacking paddy plants at Mannuthy, Kerala. *Research Journal of Kerala* 15(1): 96.

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

Rasmussen, P.C. & J.C. Anderton (2005). *The Birds of South Asia: The Ripley Guide*, 2 Volumes, Smithsonian Institute, Washington, D. C. & Lynx Edicions, Barcelona. pp. 1–378; 1–683.

Sharma, S.K. (1989). Host plants used by Baya Weaver Bird *Ploceus philippinus* (L.) for nesting in Udaipur district, Rajasthan. *Journal of the Bombay Natural History Society* 86: 453–454.

Wood, C.A. (1926). The nest of the Baya Weaver bird. *The Auk* 43(3): 295–302.

Viluppuram (2021). www.tn.gov.in/district_details/1582. Government of Tamil Nadu. Website: www.tn.gov.in/district_details/1582. Accessed on 07 March 2021.

Threatened Taxa

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 September 2023 | 15(9): 23857–23869
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.8419.15.9.23857-23869
#8419 | Received 22 February 2023 | Final received 01 June 2023 | Finally accepted 14 August 2023

OPEN ACCESS

COMMUNICATION

A checklist of the avifauna of Samanatham tank, Madurai, Tamil Nadu, India

H. Byju [1], N. Raveendran [2], S. Ravichandran [3] & Reshmi Vijayan [4]

[1,3] Centre of Advanced Study in Marine Biology, Annamalai University, Parangipettai, Tamil Nadu 608502, India.
[2] Iragukal Amritha Nature Trust, 61, Ramachandra Thadaga Street, Thirumangalam, Madurai, Tamil Nadu 625706, India.
[4] Department of Zoology, BJM Government College, Chavara, Kollam, Kerala 691583, India.
[1] byjuhi@gmail.com (corresponding author), [2] Iant.ravee@gmail.com, [3] sravicas@gmail.com, [4] reshmidileeb@gmail.com

Abstract: This avifaunal checklist from the Samanatham tank of Madurai District of Tamil Nadu is the first baseline data for this wetland. The study was done from August 2015 to March 2019 and from August 2020 to January 2022. A total of 150 species of birds comprising 17 orders and 52 families were documented. Order wise, Passeriformes 35% (n = 53), Pelecaniformes 15% (n = 22), and Charadriiformes 14% (n = 21) dominated the wetland bird community. The relative diversity (RDi) of families with the most species were Anatidae, Scolopacidae, and Accipitridae with 7.33%. Among the 150 species, 37 (25%) were winter visitors; and one passage migrant Rosy Starling *Pastor roseus*. The relative abundance indicated that 56% (84 species) were common, 28.6 % (43 species) were uncommon, and 15.4 % (23 species) were rare. The study recorded eight globally Red Listed 'Near Threatened' species—Oriental Darter *Anhinga melanogaster*, Painted Stork *Mycteria leucocephala*, Black-headed Ibis *Threskiornis melanocephalus,* Spot-billed Pelican *Pelecanus philippensis,* Black-tailed Godwit *Limosa limosa*, Bar-tailed Godwit *Limosa lapponica,* River Tern *Sterna aurantia*, & Osprey *Pandion haliaetu*—and two 'Vulnerable' species—Indian Spotted Eagle *Clanga hastata* & Great Spotted Eagle *Clanga clanga*.

Keywords: Baseline, bird sanctuaries, shorebirds, waterbirds, wetland, winter visitors.

Editor: P.A. Azeez, Coimbatore, Tamil Nadu, India.

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

Citation: Byju, H., N. Raveendran, S. Ravichandran & R. Vijayan (2023). A checklist of the avifauna of Samanatham tank, Madurai, Tamil Nadu, India. *Journal of Threatened Taxa* 15(9): 23857–23869. https://doi.org/10.11609/jott.8419.15.9.23857-23869

Funding: None.

Competing interests: The authors declare no competing interests.

Author contributions: BH—conceptualization, writing and editing; RN—data compilation, writing; SR—writing and editing; RV—writing.

Acknowledgements: We thank all the school and college student volunteers of various institutions in Madurai who monitored and collected the information all these years. We are also grateful for Trisa Bhattacharjee for helping with the map.

INTRODUCTION

Bird diversity is high among vertebrates due to their wide distribution. They are biodiversity indicators (Canterbury et al. 2000; Piersma & Lindström 2004) and documentation of their diversity, distribution, and taxonomy in India has been widely done (Ali & Ripley 1987; Kazmierczak 2006; Grimmett et al. 2011; Deomurari et al. 2023). India's share is 12.5% of the global avifaunal richness (Grimmett et al. 2011; Praveen & Jayapal 2023). As there are continuous landscape changes due to economic development in new areas (Jha et al. 2000; Purvis & Hector 2000), regional-level monitoring of birds is essential (Gadgil 1996). Avifaunal studies help to understand the long-term changes in the landscape and the vegetative structures (Rika & Santosa 2007; Rashiba et al. 2022) which aids in conservation planning (Paul & Cooper 2005). Baseline data from any site is essential for any long-term conservation efforts (Peterson et al. 2000; Llanos et al. 2011).

Avifaunal wetland studies in Tamil Nadu had been done in many wetlands like Pallikaranai (Raj et al. 2010), Karaivetti (Gokula 2010), Vaduvoor (Gokula & Raj 2011), and Karangad (Byju et al. 2023). In Madurai the avifaunal studies are scanty and literature search revealed few older studies (Nichols 1944a,b, 1945). Recent studies done on diversity and distribution were restricted to urban landscapes (Sathasivam 2015; Rajagopal et al. 2022) or thorn forest landscapes (Roopha et al. 2022). Wetlands worldwide are on the decline and India is no exception due to human interventions (Pringent et al. 2012; Sievers et al. 2018). The wetland diversity of Madurai is less documented, except for a few scanty works mentioned from the urban areas, no detailed long-term studies have been made on the diversity of birds in the wetland areas of Madurai. In this background, the current study highlights the status, composition, feeding guilds, and diversity of birds of Samanatham tank, one of the important wetlands of Madurai, Tamil Nadu.

MATERIALS AND METHODS

Study Area

Samanatham tank 9.866674°N, 78.14719°E is located in Thiruparankundram block in the Madurai District of Tamil Nadu, India. The tank and its surrounding areas have various types of vegetation, including shrubs, trees, and aquatic plants. The main habitat types observed in the tank include: 1. Open water habitat (WL = Wetland), 2. Agricultural land (AL), 3. Trees (Tr) bordering the wetland, 4. Grassland (GL) on the wetland area, and 5. Scrub habitat (OS = Open scrub type). Some of the common trees found in the area include Neem *Azadirachta indica*, Mango *Mangifera indica*, Banyan *Ficus benghalensis*, *Acacia nilotica*, and Tamarind *Tamarindus indica*. The tank and its surrounding areas also have invasive species like *Prosopis juliflora*. The surrounding area also supports a variety of flowering plants, including Jasmine, Hibiscus, Lotus, and many others. In addition, the tank is home to a variety of aquatic plants, such as water lilies, Water Hyacinth, and Cattails. The area supports a variety of animals including reptiles like snakes & turtles, amphibians like frogs & toads, and fishes like catfish, tilapia, & carp. Overall, the flora and fauna in and around Samanatham tank are an important aspect of the ecosystem of the region and contribute to its rich biodiversity.

Madurai, located in the southern part of India, has a tropical climate with hot and humid summers and mild winters. The temperature ranges from 20^0 C to around 38^0C. The average annual rainfall is 800 mm. The highest amounts of rainfall are during October and November.

Bird survey method

In the Samanatham tank, bird monitoring was continued for seven years (2015–2022) to maintain the baseline data. The period of observation was carried out every month from August 2015 to March 2019 and from August 2020 to January 2022. The birds were observed during the peak hours of their activity from 0600–1000 h and 1600–1800 h. Later, bird surveys were conducted using block count and direct visual count methods (Howes & Bakewell 1989; Bibby et al. 2000). In this method, six scanning points were identified (Figure 1) and birds in the blocks were observed using field binoculars (10 x 52 Olympus; Celestron outland 10 x 42) and recorded with a camera (Nikon D750, Canon 100–400 mm f/5.6 lens). We began counting five minutes after the arrival at each scanning points for the waterbirds to acclimate to the human presence. The identification of birds was done using the following field guides (Ali 2002; Grimmett et al. 2011). The common name, scientific name, IUCN Red List status, and migratory status are followed using (Praveen & Jayapal 2023). The feeding guild data for each species were collected from the existing literature (Ali & Ripley 1987; Byju et al. 2023). The data recorded were later analyzed for relative abundance based on the frequency of sightings, as per MacKinnon & Phillips (1993): common (C) sighted from seven to nine times; un-common (UC) sighted from three to six times; rare (R) sighted once or twice. The relative diversity (RDi) of

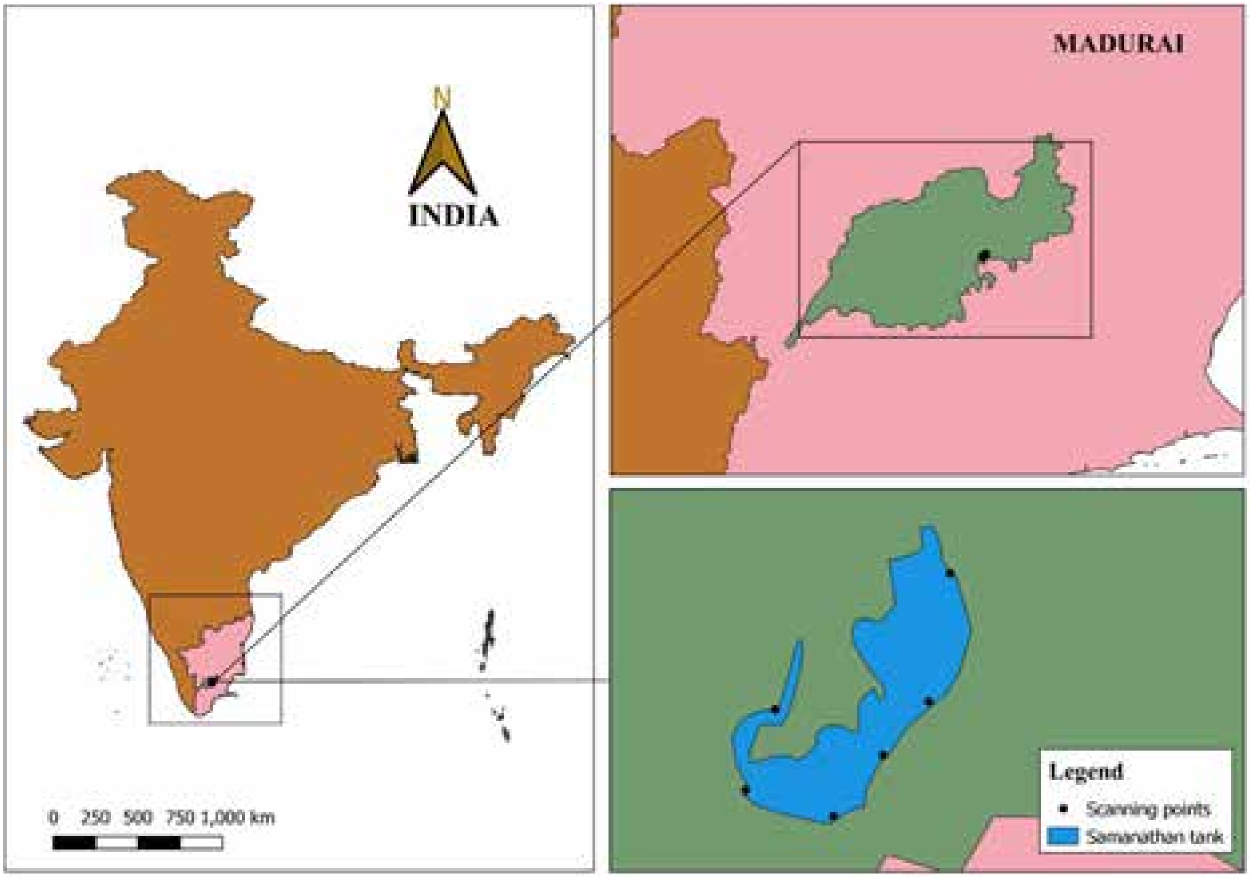

Figure 1. Map of the Samanatham tank, Madurai.

families was calculated using the following the formula by La Torre-Cuadros et al. (2007).

$$\text{RDi} = \frac{\text{Number of bird species in a family}}{\text{Total number of species}}$$

RESULTS AND DISCUSSION

A total of 150 species of birds belonging to 52 families under 17 orders were recorded from the Samanatham tank (Table 1; Images 1–18). The order Passeriformes dominated the study area with a maximum number of species, i.e., 53 species (35%), and with the lowest Strigiformes, Bucerotiformes, Falconiformes, Psittaciformes, sharing one species (0.66%) each (Figure 2). Similarly, family-wise Scolopacidae, Anatidae, and Accipitridae with relative abundance (RDi) of 7.33 % (11 species each), followed by Ardeidae (nine species) comprised the maximum number of birds species (Table 2).

As per the IUCN Red List (IUCN 2021), the wetland supports, eight globally 'Near Threatened' (NT) species -Oriental Darter *Anhinga melanogaster*, Painted Stork *Mycteria leucocephala*, Black-headed Ibis *Threskiornis melanocephalus,* Spot-billed Pelican *Pelecanus philippensis,* Black-tailed Godwit *Limosa limosa*, Bar-tailed Godwit *Limosa lapponica,* River Tern *Sterna aurantia*, & Osprey *Pandion haliaetus*; two 'Vulnerable' (Vu) species – Indian Spotted Eagle *Clanga hastata* & Great Spotted Eagle *Clanga clanga*; and the remaining 140 species are under 'Least Concern' (LC).

An analysis of the feeding guilds of these birds revealed that 38% (57 species) were insectivorous, 33% (49 species) were carnivorous, 14% (21 species) were omnivorous, 7% (11 species) were granivorous, 5% (eight species each) were frugivorous, and 3% (four species) were nectarivorous (Figure 3). Further analysis of relative abundance based on the frequency of observation indicated that 56 % (84 species) were C (common), 28.6 % (43 species) were UC (uncommon), and 15.4 % (23 species) were Ra (rare). The analysis of data on residential status revealed that out of 150 species, 37 (25%) were winter visitors (WV) and one

Table 1. Checklist of bird species in Samanatham tank, Madurai, Tamil Nadu, India.

	Order/Family/Common name	Scientific name	IUCN Red List status	Habitat	Resident status	Relative abundance	Feeding habits
	Anseriformes: Anatidae						
1	Knob-billed Duck	*Sarkidiornis melanotos*	LC	WL/AL	R/NB	UC	O
2	Common Teal	*Anas crecca*	LC	WL	WV	UC	O
3	Bar-headed Goose	*Anser indicus*	LC	WL	WV	UC	O
4	Eurasian Wigeon	*Mareca penelope*	LC	WL	WV	UC	O
5	Fulvous Whistling Duck	*Dendrocygna bicolor*	LC	WL	LM	C	O
6	Garganey	*Spatula querquedula*	LC	WL	WV	UC	O
7	Northern Shoveler	*Spatula clypeata*	LC	WL	WV	UC	O
8	Indian Spot-billed Duck	*Anas poecilorhyncha*	LC	WL	R	C	O
9	Lesser Whistling Duck	*Dendrocygna javanica*	LC	WL	R/NB	C	O
10	Northern Pintail	*Anas acuta*	LC	WL	WV	Ra	O
11	Ruddy Shelduck	*Tadorna ferruginea*	LC	WL	WV	Ra	O
	Phoenicopteriformes: Phoenicopteridae						
12	Greater Flamingo	*Phoenicopterus roseus*	LC	WL	LM	Ra	I
	Podicipedidae						
13	Little Grebe	*Tachybaptus ruficollis*	LC	WL	R	C	C
	Columbiformes: Columbidae						
14	Rock Pigeon	*Columba livia*	LC	AL/OS/GL	R	C	G
15	Spotted Dove	*Spilopelia chinensis*	LC	AL/OS/GL	R	C	G
16	Eurasian collared Dove	*Streptopelia decaocto*	LC	AL/OS/GL	R	C	G
17	Laughing Dove	*Spilopelia senegalensis*	LC	AL/OS/GL	R	C	G
	Caprimulgiformes: Apodidae						
18	Asian Palm Swift	*Cypsiurus balasiensis*	LC	Tr	R	C	I
19	Alpine Swift	*Apus melba*	LC	Tr	R	UC	I
	Cuculiformes: Cuculidae						
20	Asian Koel	*Eudynamys scolopaceus*	LC	OS	R	C	O
21	Common Hawk-Cuckoo	*Hierococcyx varius*	LC	OS	R	Ra	O
22	Greater Coucal	*Centropus sinensis*	LC	OS	R	C	C
23	Blue faced Malkoha	*Phaenicophaeus viridirostris*	LC	OS	R	C	I
24	Pied Crested Cuckoo	*Clamator jacobinus*	LC	OS	R/NB	C	I
	Gruiformes: Rallidae						
25	Baillon's Crake	*Zapornia pusilla*	LC	WL	R	UC	C
26	Eurasian Coot	*Fulica atra*	LC	WL	R	C	C
27	Eurasian Moorhen	*Gallinula chloropus*	LC	WL	R	C	C
28	Gray-headed Swamphen	*Porphyrio poliocephalus*	LC	WL	R	C	C
29	White-breasted Waterhen	*Amaurornis phoenicurus*	LC	IWB	R	C	C
	Galliformes: Phasianidae						
30	Grey Francolin	*Ortygornis pondicerianus*	LC	GL/OS	R	C	G
31	Indian Peafowl	*Pavo cristatus*	LC	AL/OS	R	C	O
	Pelecaniformes: Ciconiidae						
32	Asian Openbill Stork	*Anastomus oscitans*	LC	WL	R	C	C
33	Painted Stork	*Mycteria leucocephala*	NT	WL	R	C	C
34	Asian Wooly-necked Stork	*Ciconia episcopus*	LC	WL	WV	Ra	C
	Pelecanidae						
35	Spot-billed Pelican	*Pelecanus philippensis*	NT	WL	R	C	C

	Order/Family/Common name	Scientific name	IUCN Red List status	Habitat	Resident status	Relative abundance	Feeding habits
	Ardeidae						
36	Black-crowned Night Heron	*Nycticorax nycticorax*	LC	WL	R	C	C
37	Cattle Egret	*Bubulcus ibis*	LC	WL	R	C	C
38	Purple Heron	*Ardea purpurea*	LC	WL	R	C	C
39	Grey Heron	*Ardea cinerea*	LC	WL	R	C	C
40	Indian Pond-Heron	*Ardeola grayii*	LC	WL	R	C	C
41	Intermediate Egret	*Ardea intermedia*	LC	WL	R	C	C
42	Great Egret	*Ardea alba*	LC	WL	R	C	C
43	Little Egret	*Egretta garzetta*	LC	WL	R	C	C
44	Striated Heron	*Butorides striata*	LC	WL	R	C	C
	Threskiornithidae						
45	Black-headed Ibis	*Threskiornis melanocephalus*	NT	WL	R	C	C
46	Eurasian Spoonbill	*Platalea leucorodia*	LC	WL	R	C	C
47	Glossy Ibis	*Plegadis falcinellus*	LC	WL	R	C	C
48	Red-naped Ibis	*Pseudibis papillosa*	LC	WL/AL	R	UC	C
	Phalacrocoracidae						
49	Great Cormorant	*Phalacrocorax carbo*	LC	WL	R	UC	C
50	Indian Cormorant	*Phalacrocorax fuscicollis*	LC	WL	R	C	C
51	Little Cormorant	*Microcarbo niger*	LC	WL	R	C	C
	Anhingidae						
52	Oriental Darter	*Anhinga melanogaster*	NT	WL	R	UC	C
	Charadriiformes: Recurvirostridae						
53	Black Winged Stilt	*Himantopus himantopus*	LC	WL	R	C	I
	Charadriidae						
54	Kentish Plover	*Charadrius alexandrinus*	LC	WL	LM	UC	I
55	Little Ringed Plover	*Charadrius dubius*	LC	WL	WV	UC	I
56	Red-wattled Lapwing	*Vanellus indicus*	LC	WL	R	C	O
57	Yellow-wattled Lapwing	*Vanellus malabaricus*	LC	WL/AL	R	Ra	O
	Jacanidae						
58	Pheasant-tailed Jacana	*Hydrophasianus chirurgus*	LC	WL	R	C	I
	Scolopacidae						
59	Black-tailed Godwit	*Limosa limosa*	NT	WL	WV	UC	I
60	Bar-tailed Godwit	*Limosa lapponica*	NT	WL	WV	UC	I
61	Ruff	*Calidris pugnax*	LC	WL	WV	UC	O
62	Temminck's Stint	*Calidris temminckii*	LC	WL	WV	UC	I
63	Little Stint	*Calidris minuta*	LC	WL	WV	UC	I
64	Common Sandpiper	*Actitis hypoleucos*	LC	WL	WV	UC	I
65	Green Sandpiper	*Tringa ochropus*	LC	WL	WV	UC	I
66	Marsh Sandpiper	*Tringa stagnatilis*	LC	WL	WV	UC	I
67	Wood Sandpiper	*Tringa glareola*	LC	WL	WV	UC	I
68	Pin-tailed Snipe	*Gallinago stenura*	LC	WL	WV	UC	I
69	Common Greenshank	*Tringa nebularia*	LC	WL	WV	UC	I
70	Small Pratincole	*Glareola lactea*	LC	WL	WV	UC	I
	Laridae						
71	Gull-billed Tern	*Gelochelidon nilotica*	LC	WL	WV	Ra	C
72	Whiskered Tern	*Chlidonias hybrida*	LC	WL	WV	Ra	C

	Order/Family/Common name	Scientific name	IUCN Red List status	Habitat	Resident status	Relative abundance	Feeding habits
73	River Tern	*Sterna aurantia*	NT	WL	WV	Ra	C
	Accipitriformes: Pandionidae						
74	Osprey	*Pandion haliaetus*	NT	WL/Tr	WV	Ra	C
	Accipitridae						
75	Booted Eagle	*Hieraaetus pennatus*	LC	Tr	WV	UC	C
76	Black Kite	*Milvus migrans*	LC	Tr	R	C	C
77	Black-winged Kite	*Elanus caeruleus*	LC	Tr	R	C	C
78	Greater Spotted Eagle	*Clanga clanga*	VU	Tr	WV	UC	C
79	Indian Spotted Eagle	*Clanga hastata*	VU	Tr	WV	UC	C
80	Shikra	*Accipiter badius*	LC	Tr	R	C	C
81	Short-toed Snake Eagle	*Circaetus gallicus*	LC	Tr	LM	Ra	C
82	Eurasian Marsh- Harrier	*Circus aeruginosus*	LC	Tr	WV	Ra	C
83	White-eyed Buzzard	*Butastur teesa*	LC	GL	R	Ra	C
84	Oriental Honey-Buzzard	*Pernis ptilorhynchus*	LC	Tr	LM	UC	C
85	Common Buzzard	*Buteo buteo*	LC	Tr	WV	Ra	C
	Strigiformes: Strigidae						
86	Spotted Owlet	*Athene brama*	LC	OS	R	C	C
	Bucerotiformes: Upupidae						
87	Common Hoopoe	*Upupa epops*	LC	OS/GL	R	C	I
	Piciformes: Picidae						
88	Black-rumped Flameback	*Dinopium benghalense*	LC	Tr	R	C	I
	Megalaimidae						
89	Coppersmith Barbet	*Psilopogon haemacephalus*	LC	Tr	R	C	F
	Coraciiformes:Meropidae						
90	Blue-tailed Bee-eater	*Merops philippinus*	LC	OS	R	C	I
91	Green Bee-eater	*Merops orientalis*	LC	OS	R	UC	I
	Coraciidae						
92	Indian Roller	*Coracias benghalensis*	LC	OS/GL	R	C	I
	Alcedinidae						
93	Pied Kingfisher	*Ceryle rudis*	LC	WL/OS	R	C	C
94	Common Kingfisher	*Alcedo atthis*	LC	WL/OS	R	C	C
95	White-throated Kingfisher	*Halcyon smyrnensis*	LC	WL/OS	R	C	C
	Falconiformes: Falconidae						
96	Red-necked Falcon	*Falco chicquera*	LC	OS/GL	WV	Ra	C
	Psittaciformes: Psittacidae						
97	Rose-ringed Parakeet	*Psittacula krameri*	LC	Tr	R	C	F
	Passeriformes: Oriolidae						
98	Indian Golden Oriole	*Oriolus kundoo*	LC	Tr	R	C	O
	Pittadae						
99	Indian Pitta	*Pitta brachyura*	LC	OS/GL	WV	Ra	I
	Artamidae						
100	Ashy Woodswallow	*Artamus fuscus*	LC	OS	R	C	I
	Dicruridae						
101	Black Drongo	*Dicrurus macrocercus*	LC	OS	R	C	I
102	Ashy Drongo	*Dicrurus leucophaeus*	LC	OS	R	UC	I

	Order/Family/Common name	Scientific name	IUCN Red List status	Habitat	Resident status	Relative abundance	Feeding habits
	Laniidae						
103	Brown Shrike	*Lanius cristatus*	LC	OS	WV	UC	I
104	Long-tailed Shrike	*Lanius schach*	LC	OS	R	C	C
	Vangidae						
105	Common Woodshrike	*Tephrodornis pondicerianus*	LC	OS	R	Ra	I
	Corvidae						
106	House Crow	*Corvus splendens*	LC	OS/Tr	R	C	O
107	Rufous Treepie	*Dendrocitta vagabunda*	LC	OS	R	C	O
108	Large-billed Crow	*Corvus macrorhynchos*	LC	OS/Tr	R	C	O
	Monarchidae						
109	Indian Paradise-Flycatcher	*Terpsiphone paradisi*	LC	OS/GL	R/NB	UC	I
	Nectariniidae						
110	Loten's Sunbird	*Cinnyris lotenius*	LC	OS	R	UC	N
111	Purple-rumped Sunbird	*Leptocoma zeylonica*	LC	OS	R	C	N
112	Purple Sunbird	*Cinnyris asiaticus*	LC	OS	R	C	N
	Ploceidae						
113	Baya Weaver	*Ploceus philippinus*	LC	OS	R	C	G
114	Streaked Weaver	*Ploceus manyar*	LC	OS	R	C	G
	Estrildidae						
115	Tricolored Munia	*Lonchura malacca*	LC	OS	R	C	G
116	Indian Silverbill	*Euodice malabarica*	LC	OS	R	C	G
117	Scaly-breasted Munia	*Lonchura punctulata*	LC	OS	R	C	G
	Passeridae						
118	House Sparrow	*Passer domesticus*	LC	AL/GL	R	C	G
	Motacillidae						
119	Citrine Wagtail	*Motacilla citreola*	LC	GL	WV	UC	I
120	Paddyfield Pipit	*Anthus rufulus*	LC	GL/AL	R	C	I
121	Grey Wagtail	*Motacilla cinerea*	LC	GL	R/NB	UC	I
122	White-browed Wagtail	*Motacilla maderaspatensis*	LC	WL	R	C	I
123	Western Yellow Wagtail	*Motacilla flava*	LC	OS	WV	Ra	I
	Alaudidae						
124	Ashy-crowned Sparrow-Lark	*Eremopterix griseus*	LC	AL/OS/GL	R	C	I
125	Jerdon's Bushlark	*Mirafra affinis*	LC	AL/OS/GL	R	C	I
126	Oriental Skylark	*Alauda gulgula*	LC	AL/OS/GL	R	C	I
	Cisticolidae						
127	Common Tailorbird	*Orthotomus sutorius*	LC	AL/OS/GL	R	C	I
128	Plain Prinia	*Prinia inornata*	LC	AL/OS/GL	R	C	I
129	Zitting Cisticola	*Cisticola juncidis*	LC	AL/OS/GL	R	C	I
130	Ashy Prinia	*Prinia socialis*	LC	AL/OS/GL	R	C	I
131	Jungle Prinia	*Prinia sylvatica*	LC	OS	R	C	I
	Leiothrichidae						
132	Yellow-billed Babbler	*Argya affinis*	LC	OS	R	C	I
	Acrocephalidae						
133	Blyth's Reed Warbler	*Acrocephalus dumetorum*	LC	OS	R/NB	UC	I
134	Booted Warbler	*Iduna caligata*	LC	OS	R/NB	Ra	I
135	Clamorous Reed-Warbler	*Acrocephalus stentoreus*	LC	OS	R	C	I

	Order/Family/Common name	Scientific name	IUCN Red List status	Habitat	Resident status	Relative abundance	Feeding habits
136	Thick-billed Warbler	*Arundinax aedon*	LC	OS	R/NB	Ra	I
137	Sykes's Warbler	*Iduna rama*	LC	OS	R/NB	Ra	I
	Hirundinidae						
138	Barn Swallow	*Hirundo rustica*	LC	AL/WL	WV	Ra	I
139	Red-rumped Swallow	*Cecropis daurica*	LC	AL/WL	R	UC	I
140	Dusky crag Martin	*Ptyonoprogne concolor*	LC	WL/AL	R	UC	I
	Pycnonotidae						
141	Red-vented Bulbul	*Pycnonotus cafer*	LC	OS	R	C	F
142	White-browed Bulbul	*Pycnonotus luteolus*	LC	OS	R	Ra	F
	Sturnidae						
143	Brahminy Starling	*Sturnia pagodarum*	LC	OS	R	UC	F
144	Common Myna	*Acridotheres tristis*	LC	OS	R	C	F
145	Chestnut-tailed Starling	*Sturnia malabarica*	LC	OS	WV	UC	F
146	Rosy Starling	*Pastor roseus*	LC	OS	PM	UC	F
	Muscicapidae						
147	Indian Robin	*Copsychus fulicatus*	LC	OS/AL	R	C	I
148	Oriental Magpie-Robin	*Copsychus saularis*	LC	OS/AL	R	C	I
149	Pied Bushchat	*Saxicola caprata*	LC	OS	R	C	I
	Dicaeidae						
150	Pale-billed Flowerpecker	*Dicaeum erthrorhynchos*	LC	OS	R	UC	N

IUCN Red list status: LC—Least Concern | NT—Near Threatened | Vu—Vulnerable.
Resident status: WV—Winter Visitor | LM—Local Migrant | R—Resident | R/NB—Resident/Non-Breeding.
Relative abundance: C—Common | UC—Uncommon | Ra—Rare.
Habitats: W—Wetland | AL—Agricultural Land | Tr—Tree | GL—Grass Land | OS—Open Scrub.
Feeding status: I—Insectivore | G—Granivore | C—Carnivore | O—Omnivore | N—Nectarivore | F—Frugivore.

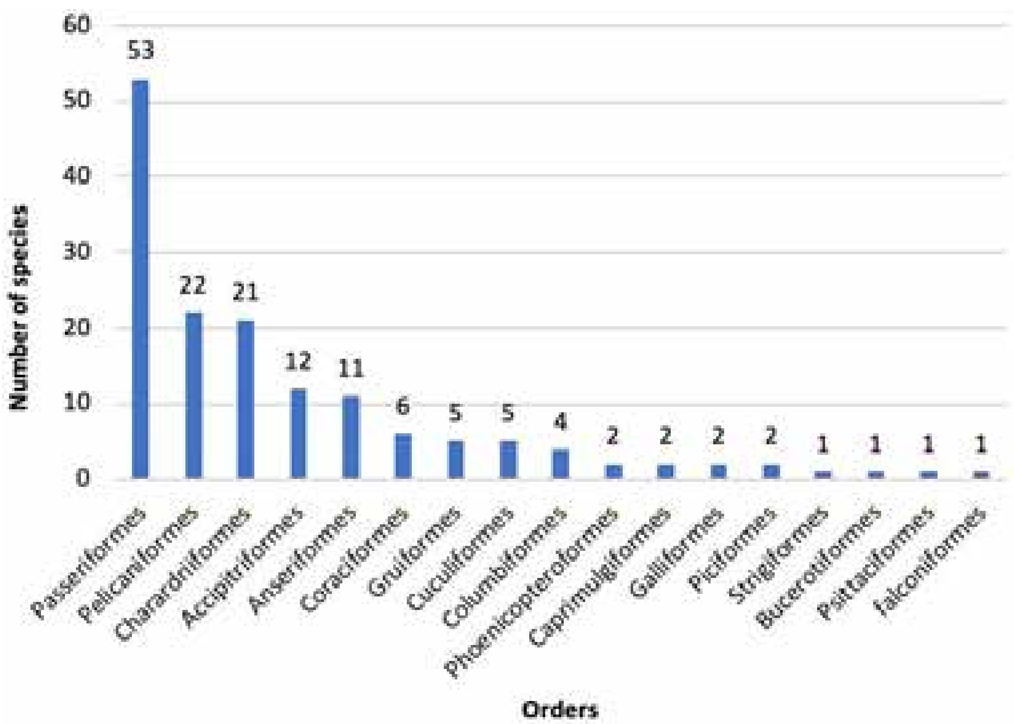

Table 1. Checklist of bird species in Samanatham tank, Madurai, Tamil Nadu, India.

Table 2. Relative diversity (RDi) of various avian families at Samanatham tank, Madurai.

	Family	No of species	RDi %
1	Anatidae	11	7.33
2	Phoenicopteridae	1	0.66
3	Podicipedidae	1	0.66
4	Columbidae	4	2.66
5	Apodidae	2	1.33
6	Cuculidae	5	3.33
7	Rallidae	5	3.33
8	Phasianidae	2	1.33
9	Ciconiidae	3	2.00
10	Pelecanidae	1	0.66
11	Ardeidae	9	6.00
12	Threskiornithidae	4	2.66
13	Phalacrocoracidae	3	2.00
14	Anhingidae	1	0.66
15	Recurvirostridae	1	0.66
16	Charadriidae	4	2.66
17	Jacanidae	1	0.66
18	Scolopacidae	11	7.33
19	Laridae	3	2.00
20	Pandionidae	1	0.66
21	Accipitridae	11	7.33
22	Strigidae	1	0.66
23	Upupidae	1	0.66
24	Picidae	1	0.66
25	Megalaimidae	1	0.66
26	Meropidae	1	0.66
27	Coraciidae	1	0.66

	Family	No of species	RDi %
28	Alcedinidae	3	2.00
29	Falconidae	1	0.66
30	Psittacidae	1	0.66
31	Oriolidae	1	0.66
32	Pittidae	1	0.66
33	Artamidae	1	0.66
34	Dicruridae	1	0.66
35	Laniidae	2	1.33
36	Vangidae	1	0.66
37	Corvidae	3	2.00
38	Monarchidae	1	0.66
39	Nectariniidae	3	2.00
40	Ploceidae	2	1.33
41	Estrildidae	3	2.00
42	Passeridae	1	0.66
43	Motacillidae	5	3.33
44	Alaudidae	3	2.00
45	Cisticolidae	5	3.33
46	Leiotrichidae	1	0.66
47	Acrocephalidae	5	3.33
48	Hirundinidae	3	2.00
49	Pycnonotidae	3	1.65
50	Sturnidae	4	2.66
51	Muscicapidae	3	1.65
52	Dicaeidae	1	0.66
	Total	150	

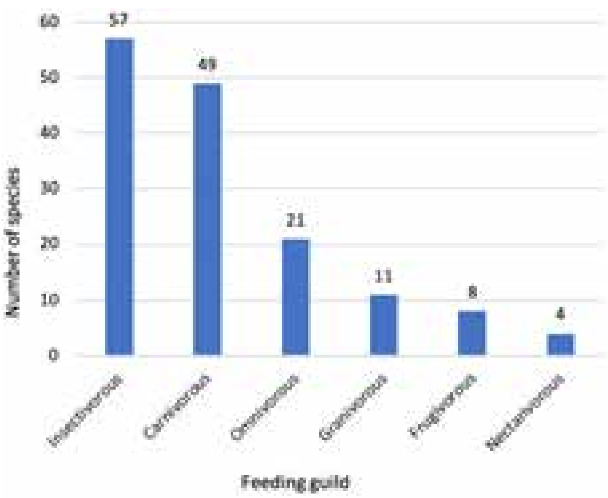

Figure 3. Feeding guilds of birds at Samanatham tank, Madurai.

passage migrant (PM) Rosy Starling *Pastor roseus*.

The wetland being used by the long-distance migrant shorebirds including the Bar-tailed Godwit and the Black-tailed Godwit, the two Near Threatened species in reasonable numbers makes this an important wintering area for those species. Similar works were reported recently from the Changaram wetlands of Kerala highlighting the need of conserving hitherto undocumented new areas of shorebird wintering sites (Anand et al. 2023). The consistent occurrence of the Near Threatened River Tern represents another ecologically significant species within this geographic region. It is also interesting to note that another two Near Threatened species namely Spot-billed Pelican and Oriental Darter were breeding in the Samanatham tank. Tamil Nadu is home to 535 bird species (Praveen et al.

Image 1–8. 1—Black-crowned Night Heron *Nycticorax nycticorax* | 2—Black-tailed Godwit *Limosa limosa* | 3—Black headed Ibis *Threskiornis melanocephalus* & Glossy Ibis *Plegadis falcinellus* | 4—Eurasian Spoonbill *Platalea leucorodia* | 5— Greater Flamingos *Phoenicopterus roseus*, Northern Shoveler *Spatula clypeata*, & Garganey *Spatula querquedula* | 6—Bar-headed Goose *Anser indicus* & Black-winged Stint *Himantopus Himantopus* | 7—Flocks of duck species with Greater Flamingos | 8—Spot-billed Pelican *Pelecanus philippensis* nesting. © N. Raveendran.








Image 9–16. 9—Painted Stork *Mycteria leucocephala* | 10—Osprey *Pandion haliaetus* | 11—Oriental Darter *Anhinga melanogaster* | 12—Grey Heron *Ardea cinerea* | 13— *Prosopis juliflora* serves as nesting trees for cormorants and egrets | 14—*Prosopis juliflora* trees used as roosting spot for egrets | 15—Brown Shrike *Lanius cristatus* | 16—Greater Spotted Eagle *Clanga clanga*. © N. Raveendran.

17

18

Image 17–18. 17—Indian Spotted Eagle *Clanga hastata* | 18—Samanatham tank view. © N. Raveendran.

2018) and we recorded 150 (28%) species during the current study at this single water tank in Madurai.

Our study provides important baseline information and the presence of many important waterbird species; this will help in the long-term monitoring of birds in the tank besides acting as an essential document in planning conservation efforts for the wetland. This tank is an artificial waterbody that supports a variety of plant and animal life. Samanatham tank plays a role in water management and flood control for the surrounding area. Hence, this tank should be recognized as a valuable ecosystem that should be elevated to protection status and conserved for future generations.

REFERENCES

Anand, J., H. Byju, A. Nefa, S. Abhijith, O.R. Reshi & K.M. Aarif (2023). Conservation significance of Changaram wetlands - a key wintering site for migratory shorebirds and other waterbirds in the western coast of Kerala, India. *Journal of Threatened Taxa* 15(1): 22410–22418. https://doi.org/10.11609/jott.8089.15.1.22410-22418

Ali, S. (2002). *The Book of Indian Birds*. Oxford University Press, New Delhi, 326 pp.

Ali, S. & S.D. Ripley (1987). *Compact handbook of the Birds of India and Pakistan together with those of Bangladesh, Nepal, Bhutan, and Sri Lanka.* Oxford University Press, Delhi, India, 737 pp.

Bibby, C.J., N.D. Burgess, D.A. Hill & S. Mustoe (2000). *Bird Census Techniques*. Academia Press, Belgium, 302 pp.

Byju, H., N. Raveendran, S. Ravichandran & R. Kishore (2023). An annotated checklist of the avifauna of Karangadu mangrove forest, Ramanathapuram, Tamil Nadu, with notes on the site's importance for waterbird conservation. *Journal of Threatened Taxa* 15(3): 22813–22822. https://doi.org/10.11609/jott.8356.15.3.22813-22822

Canterbury, G.E., T.E. Martin, D.R. Petit. L.J. Petit & D.F. Bradford (2000). Bird communities and habitat as ecological indicators of forest condition in regional monitoring. *Conservation Biology* 14(2): 544–558. https://doi.org/10.1046/j.1523-1739.2000.98235.x

Deomurari, A., A. Sharma, D. Ghose & R. Singh (2023). Projected shifts in bird distribution in India under climate change. *Diversity* 15(3): 404. https://doi.org/10.3390/d15030404

Gadgil, M. (1996). Documenting diversity: An experiment. *Current Science* 70: 36–44.

Gokula, V. (2010). Avifauna of Karaivetti Bird Sanctuary, Tamil Nadu, India. *Zoo's Print Journal* 28(6): 23–29.

Gokula V. & P.A. Raj (2011). Birds of Vaduvoor Bird Sanctuary, Tamil Nadu, India: an annotated checklist. *Zoo's Print* 26(6): 20–24.

Grimmett, R., C. Inskipp & T. Inskipp (2011). *Birds of the India, Pakistan, Nepal, Bangladesh, Bhutan, Sri Lanka, and the Maldives*. Princeton University Press, New Jersey, 528 pp.

Howes, J.G. & D. Bakewell (1989). Shore Bird Studies Manual. Asian Wetland Bureau Publication No. 55, Kuala Lumpur, 362 pp.

Jha, C.S., C.B.S. Dutt & K.S. Bawa (2000). Deforestation and land use changes in Western Ghats, India. *Current Science* 79: 231–238.

Kazmierczak, K. (2006). *A Field Guide to the Birds of India*. Pica Press, United Kingdom, 352 pp.

La Torre-Cuadros, M.Á., S. Herrando-Pérez & K.R. Young (2007). Diversity and structural patterns for tropical montane and premontane forests of central Peru, with an assessment of the use of higher-taxon surrogacy. *Biodiversity Conservation* 16: 2965–2988. https://doi.org/10.1007/s10531-007-9155-9

Llanos, F.A., M. Failla, G.J. García, P.M. Giovine, M. Carbajal, P.M. González, D.P. Barreto, P. Quillfeldt & J.F. Masello (2011). Birds from the endangered Monte, the Steppes, and Coastal biomes of the province of Río Negro, northern Patagonia, Argentina. *Checklist* 7(6): 782–797.

MacKinnon, J. & K. Phillips (1993). *A field guide to the birds of Borneo, Sumatra, Java and Bali.* Oxford University Press, 391 pp.

Nichols, E.G. (1944a). Occurrence of birds in Madura District [Part I]. *Journal of the Bombay Natural History Society* 44(3): 387–407.

Nichols, E.G. (1944b). Occurrence of birds in Madura District. Part II. *Journal of the Bombay Natural History Society* 44(4): 574–584.

Nichols, E.G. (1945). Occurrence of birds in Madura District. Part III. *Journal of the Bombay Natural History Society* 45(2): 122–132.

Paul, E. & R.J. Cooper (2005). New opportunities for bird conservation research. In: Ralph, C., R. John & D. Terrel (eds.). Bird Conservation Implementation and Integration in the Americas: *Proceedings of the Third International Partners in Flight Conference,* Asilomar, California (Vol. 2). US Department of Agriculture, Forest Service, Pacific Southwest Research Station 191: 1008–1017.

Peterson, A.T., L.G. Ball & K.W. Brady (2000). Distribution of the birds of the Philippines: biogeography and conservation priorities. *Bird Conservation International* 10(2): 149–167.

Piersma, T. & Å. Lindström (2004). Migrating shorebirds as integrative sentinels of global environmental change. *Ibis* 146(1): 61–69. https://doi.org/10.1111/j.1474-919X.2004.00329.x

Praveen, J. & R. Jayapal (2023). Taxonomic updates to the checklists of birds of India and the South Asian region. *Indian BIRDS* 18(5):

131–134

Praveen, J., & R. Jayapal & A. Pittie (2021). Updates to the checklists of birds of India, and the South Asian region—2021. *Indian BIRDS* 17 (1): 1–3.

Prigent, C., F. Papa, F. Aires, C. Jimenez, W.B. Rossow & E. Matthews (2012). Changes in land surface water dynamics since the 1990s and relation to population pressure. *Geophysical Research Letters* 39(8): 1–5. https://doi.org/10.1029/2012GL051276

Purvis, A. & A. Hector (2000). Getting the measure of biodiversity. *Nature* 405(6783): 212–219. https://doi.org/10.1038/35012221

Raj, P.P.N., J. Ranjini, R. Dhanya, J. Subramaniyan, P.A. Azeez & S. Bhupathy (2010). Consolidated checklist of birds in the Pallikaranai Wetlands, Chennai, India. *Journal of Threatened Taxa* 2(8): 1114–1118. https://doi.org/10.11609/JoTT.o2220.1114-8

Rajagopal, T., K. Sonaimuthu, S. Subbiah, P. Ponmanickam & M. Sekar (2022). A survey on avifauna diversity in some selected localities in and around Madurai city. *Ecology Environment & Conservation* 28 (December Suppl. Issue): 207–216. https://doi.org/10.53550/EEC.2022.v28i08s.032

Rashiba, A.P., K. Jishnu, H. Byju, C.T. Shifa, J. Anand, K. Vichithra, Y. Xu, A. Nefla, S.B. Muzaffar, K.M. Aarif & K.A. Rubeena (2022). The paradox of shorebird diversity and abundance in the west coast and east coast of India: a comparative analysis. Diversity 14: 885. https://doi.org/10.3390/ d14100885

Rika S.D. & Y. Santosa (2007). Diversity of bird species at some habitat type in Ciremai Mountain National Park. *Conservation Media* 12(3): 1–3.

Roopha, D.P., A.J. Thatheyus, T. Sonia & R. Kishore (2022). Avifaunal diversity in the tropical thorn forest of Kiluvamalai, Madurai district, Tamil Nadu, India. *Asian Journal of Conservation Biology* 11(2): 274–280. https://doi.org/10.53562/ajcb.71111

Sathasivam, K. (2015). The birds of Madurai city. *Indian BIRDS* 10(2): 29–34

Sievers, M., R. Hale, M.K. Parris & S.E. Swearer (2018). Impacts of human-induced environmental change in wetland on aquatic animals. *Biological Reviews* 93(1): 529–554. https://doi.org/10.1111/brv.12358

Threatened Taxa

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 September 2023 | 15(9): 23870–23878
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.8507.15.9.23870-23878
#8507 | Received 05 May 2023 | Final received 10 August 2023 | Finally accepted 05 September 2023
OPEN ACCESS
COMMUNICATION

Composition of avian communities in Ranjit Sagar Conservation Reserve, Punjab, India

Onkar Singh Brraich [1], **Sunil Kumar Saini** [2] & **Jagdeep Singh** [3]

[1–3] Department of Zoology and Environmental Sciences, Punjabi University, Patiala, Punjab 147002, India.
[1] singhonkar@yahoo.com, [2] sunilkumar1315@gmail.com, [3] Jagdeepsingh1656@gmail.com (corresponding author)

Abstract: The Ranjit Sagar wetland, a critical aquatic ecosystem supporting diverse flora and fauna, has been the subject of investigation from January 2013 to January 2015. The study revealed the presence of 167 avian species across 19 orders and 52 families. Notably, areas with minimal disturbance within the wetland serve as key niches for a substantial avian population, encompassing 47.31% migrant and 52.69% resident species. Significantly, 10 Near Threatened species, alongside the Vulnerable Common Pochard *Aythya ferina* and the Endangered Egyptian Vulture *Neophron percnopterus*, underscore the wetland's conservation value. Dominated by order Passeriformes (55 species), followed by Charadriiformes (29 species), and Anseriformes (20 species), the avian community exhibits varied feeding guilds, with insectivores (37.13%), omnivores (18.56%), aquatic animal feeders (16.16%), carnivores (14.97%), frugivores (5.39%), granivores (4.79%), and herbivores (3%) comprising its composition. This study elucidates the intricate avian ecosystem's dynamics in Ranjit Sagar wetland, emphasizing its conservation significance and ecological structure, thereby contributing valuable insights for preservation and future research.

Keywords: Aquatic ecosystems, avifauna, conservation, habitats, IUCN Red List, mining, niche, vegetation, water birds, wetlands.

Punjabi: ਪੰਜਾਬ ਦੇ ਰੁੱਖਾਂ ਅਤੇ ਜੀਵਾਂ ਦੇ ਨਿਰੀਖਣ ਲਈ ਰਣਜੀਤ ਸਾਗਰ ਝੀਲ ਨੂੰ ਚੁਣਿਆ ਗਿਆ ਜਿਸ ਦੌਰਾਨ ਜਨਵਰੀ 2013 ਤੋਂ ਜਨਵਰੀ 2015 ਤੱਕ ਦੇ ਅਧਿਅਨ ਵਿੱਚ ਪਾਇਆ ਗਿਆ ਕਿ ਇਸ ਥਾਂ ਉੱਤੇ 167 ਪੰਛੀ ਹਨ ਜੋ ਕਿ 19 ਆਰਡਰ, 52 ਫੇਮਿਲੀਆਂ ਨਾਲ ਸਬੰਧ ਰੱਖਦੇ ਹਨ। ਇਸ ਥਾਂ ਤੇ ਮਨੁੱਖੀ ਦਖਲਅੰਦਾਜੀ ਨਾ-ਮਾਤਰ ਹੋਣ ਕਰਕੇ ਇਹ ਇਲਾਕਾ ਪੰਛੀਆਂ ਲਈ ਪਸੰਦੀਦਾ ਥਾਂ ਹੈ ਜਿਸ ਕਰਕੇ ਇੱਥੇ 47.31 ਫੀਸਦੀ ਪ੍ਰਵਾਸੀ ਪੰਛੀ ਆਉਂਦੇ ਹਨ ਅਤੇ 52.69 ਫੀਸਦੀ ਪੰਛੀ ਇੱਥੋਂ ਦੇ ਹੀ ਵਸਨੀਕ ਹਨ। ਇੱਥੇ 10 ਦੇ ਆਸਪ।ਸ ਪ੍ਰਜਾਤੀਆਂ ਲੁਪਤ ਹੋਣ ਦੀ ਕਗਾਰ ਤੇ ਹਨ ਜਿਨ੍ਹਾਂ ਵਿੱਚੋਂ ਕਮਜੋਰ/vulnerable ਪ੍ਰਜਾਤੀ ਕਾਮਨ ਪੋਚਾਰਡ (ਅਥਿਇਆ ਫੇਰਿਨਾ) ਸ਼ਾਮਿਲ ਹੈ ਅਤੇ ਖਤਰੇ ਦੀ ਕਗਾਰ/ Endangered ਤੇ ਖੜੀ ਚਿੱਟੀ ਗਿੱਦ (ਨਿਓਫਿਰੋਨ ਪਰਕਨੋਪਟੇਰਸ) ਸ਼ਾਮਿਲ ਹੈ। ਇਸ ਝੀਲ ਵਿੱਚ ਆਰਡਰ ਪੇਜਰੀਫਾਰਮਿਸ (55 ਪ੍ਰਜਾਤੀਆਂ) ਦੇ ਪੰਛੀਆਂ ਦੀ ਬਹੁਤਾਤ ਹੈ ਅਤੇ ਇਸ ਤੋਂ ਬਾਅਦ ਕਰਾਡਰੀਫਾਰਮਿਸ (29 ਪ੍ਰਜਾਤੀਆਂ) ਅਤੇ 20 ਪ੍ਰਜਾਤੀਆਂ ਅਨਜੇਰੀਫਾਰਮਿਸ ਆਰਡਰ ਦੀਆਂ ਹਨ। ਇਹ ਪੰਛੀ ਵੱਖ ਵੱਖ ਤਰ੍ਹਾਂ ਦੇ ਭੋਜਨ ਉੱਤੇ ਨਿਰਭਰ ਕਰਦੇ ਹਨ ਜਿਵੇਂ ਕਿ 37.13% ਕੀੜੇ-ਖਾਣ ਵਾਲੇ, 18.56% ਸਰਵਹਾਰੇ, 16.16% ਪਾਣੀ ਵਾਲੇ ਜੀਵ ਖਾਂਦੇ ਹਨ, 14.97% ਮਾਸਾਹਾਰੀ, 5.39% ਫਲ-ਖਾਣੇ, 4.79% ਦਾਣੇ ਖਾਣ ਵਾਲੇ ਅਤੇ 3% ਸ਼ਾਕਾਹਾਰੀ ਹਨ। ਇਸ ਅਧਿਅਨ ਤੋਂ ਰਣਜੀਤ ਸਾਗਰ ਝੀਲ ਦੇ ਗਤੀਸ਼ੀਲ/ਜੀਵੰਤ ਸੁਭਾਅ ਦਾ ਪਤਾ ਲਗਦਾ ਹੈ ਜਿਸ ਕਰਕੇ ਇਸ ਝੀਲ ਦੇ ਸਾਂਭ-ਸੰਭਾਲ ਦਾ ਅਪਣਾ ਇੱਕ ਮਹੱਤਵ ਹੈ।

Editor: Anil Kumar, Zoological Survey of India, Dehradun, India.

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

Citation: Brraich, O.S., S.K. Saini & J. Singh (2023). Composition of avian communities in Ranjit Sagar Conservation Reserve, Punjab, India. *Journal of Threatened Taxa* 15(9): 23870–23878. https://doi.org/10.11609/jott.8507.15.9.23870-23878

Funding: Ministry of Environment, Forest and Climate Change of India.

Competing interests: The authors declare no competing interests.

Author details: Dr. Onkar Singh Brraich—assistant professor, Department of Zoology and Environmental Sciences Punjabi University, Patiala. He has a keen interest in fish taxonomy, birds, and biodiversity currently working on the environmental issues of Punjab. Dr. Sunil Kumar Saini—assistant professor, Zoology PDM University Bahadurgarh, Kherka Musalman, Haryana. Specialized in fish taxonomy, birds and water quality analysis. Jagdeep Singh—currently pursuing a PhD in ornithology and wetland ecology in the Department of Zoology and Environmental Sciences Punjabi University, Patiala, is keenly interested in studying birds from the Indian subcontinent. Alongside research, he is also a passionate scientific writer and believes that science communication is a great way to promote research.

Author contributions: OSB—PhD supervisor, edited MS., SKS— Field survey and M.S writing, JS—Final manuscript preparation, editing and communication with journal.

Acknowledgements: Authors are thankful to Yodha Singh, assistant professor, Botany Govt. Mohindra College, Patiala and Mr. Amandeep Singh helping in preparation of maps.

INTRODUCTION

Wetlands serve as a crucial transitional zone bridging terrestrial and aquatic ecosystems, characterized by a shallow water table or the presence of shallow water covering the land's surface. They play a pivotal role in providing habitat for diverse biota and offer a range of ecological services (Coppes et al. 2018; Kakati et al. 2021; Wu et al. 2021). India, in particular, boasts an impressive avian diversity, with 1,353 documented bird species, of which approximately 310 are known to be dependent on wetlands (Kumar et al. 2005; Praveen & Jayapal 2023). Wetlands hold special significance for birds, serving as essential sites for roosting, foraging, drinking, resting, shelter, and social interactions (Singh & Banyal 2013; Kumar & Sharma 2019; Yao et al. 2020; Casazza et al. 2021; Joshi et al. 2021; Teng et al. 2021).

Birds are reliable indicators of water quality and wetland health (Yao et al. 2020; Anand et al. 2023). In wetland ecosystems, birds can be broadly classified into two categories: wetland specialists, which exclusively nest, feed, and roost in wetlands and are entirely reliant on aquatic habitats, and generalists, which frequent wetlands but also inhabit other environments. The development of an avifaunal baseline checklist specific to this habitat plays a pivotal role in shaping site and species-specific conservation strategies, applicable to both protected and unprotected areas, as supported by previous research (Bibby 1998; Anand et al. 2023; Byju et al. 2023a,b). Birds offer a valuable avenue for assessing biodiversity, often indicative of a healthy ecology through their diverse populations. Enumeration of avian diversity also contributes to our understanding of the status of endangered or threatened species. Furthermore, it holds educational value, fostering greater regional species and ecosystem appreciation, while encouraging community participation in conservation initiatives. Multiple researchers have conducted extensive studies on bird diversity in Punjab's wetlands, yielding noteworthy findings (Ali et al. 1981; Robson 1996; Kazmierczak et al. 1998; Robson 1999; Sawant & Sudhagar 2013; Prasad 2008a,b; Singh & Brraich 2021). This comprehensive study serves to elucidate the importance of wetlands and their relevance in shaping effective conservation strategies.

MATERIALS AND METHODS

Study area

The Ranjit Sagar wetland came into existence in 2004 with the construction of a barrage on the river Ravi of the Indus River system a freshwater wetland (32.442° N and 75.725° E, at the altitudes of 540 m) located near Pathankot City, Punjab (Figure 1). This wetland falls into three states, i.e., Punjab, Himachal Pradesh, and Jammu & Kashmir, and is spread over an area of 87.60 km^2 with a catchment area spread over 6,086 km^2. In and around this wetland, several habitats, including marshy parts, shallow areas, riparian vegetation, deep areas, islands, large trees (for the roosting of birds), fallow fields near the banks (for the breeding purposes) have developed over the time, generally preferred by migratory birds. It also provides food for different birds in the form of fishes, amphibians, reptiles, insects, zooplankton, phytoplankton, and weeds.

Methods

Field surveys were conducted from January 2013 to January 2015, utilizing visual counting methods following Gaston's (1975) methodology for bird observation. To ensure comprehensive coverage of the wetland area, about 12 vantage points were established. Data collection was conducted year-round, with observations made on five days each month, both in the morning (0700–1000 h) and evening (1600–1830 h). Species identification was based on references from bird identification guides, including works by Ali & Ripley (1983), Grimmett & Inskipp (2010), and Grimmett et al. (2012). Bird species were categorized into three groups: annual, winter, and summer birds, following Mavi & Tiwana's (1993) classification system. The checklist was meticulously compiled using standardized common and scientific names, adhering to guidelines by Clements et al. (2022) and Praveen & Jayapal (2023).

RESULTS AND DISCUSSION

In the present study, which focused on avian diversity at Ranjit Sagar Wetland, a total of 167 species were observed. The majority, accounting for 157 species, fall within the IUCN's Least Concern category, while the remaining 10 species are classified as threatened. Notable among these are the Vulnerable Common Pochard *Aythya ferina* and the Endangered Egyptian Vulture *Neophron percnopterus*. Additionally, species such as the Himalayan Vulture *Gyps himalayensis*,

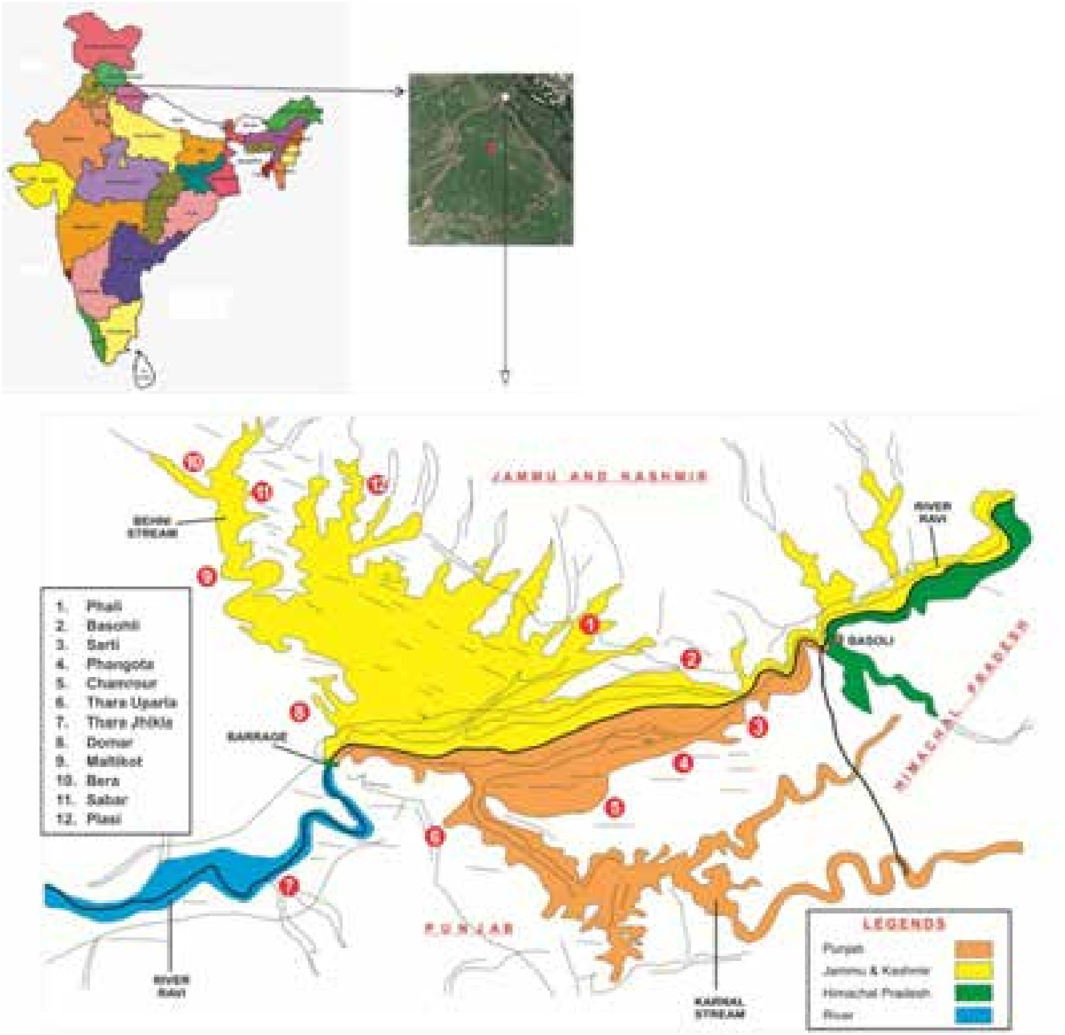

Figure 1. Ranjit Sagar Wetland on the map.

Ferruginous Duck *Aythya nyroca*, Black-tailed Godwit *Limosa limosa*, River Lapwing *Vanellus duvaucelii*, Eurasian Curlew *Numenius arquata*, Painted Stork *Mycteria leucocephala*, Black-headed Ibis *Threskiornis melanocephalus*, Alexandrine Parakeet *Psittacula eupatria*, and Oriental Darter *Anhinga melanogaster* are categorized as Near Threatened. Vulnerable River Tern *Sterna aurantia*, Common Pochard *Aythya ferina*, and the Endangered Egyptian Vulture *Neophron percnopterus* complete the list of threatened species.

Concerning dietary preferences, the observed species display diverse feeding habits. The majority, comprising 37.13% (62 species), are insectivorous, followed by 18.56% (31 species) categorized as omnivorous, 16.16% (27 species) primarily feeding on aquatic animals, and 14.97% (25 species) displaying carnivorous tendencies. Additionally, 5.39% of species are frugivorous (9 species), while 4.79% are granivorous (8 species). Herbivorous birds constitute only 3% (5 species) of the observed population, as detailed in Table 1.

The Ranjit Sagar Wetland, characterized by its extensive open spaces in comparison to other wetlands in the region, provides an ideal habitat for waterfowls and aquatic birds. Furthermore, the presence of 44 fish species within this wetland area may attract piscivorous birds classified as Aquatic animal feeders. Adjacent agricultural lands offer ample opportunities to attract herbivorous migratory birds, including the Bar-headed Goose *Anser indicus* and Greylag Goose *Anser anser*. Nevertheless, the study underscores the negative impact of anthropogenic activities such as mining, poaching, and sewage discharge on wetland health. To mitigate these concerns and enhance the future attraction of migratory birds, it is recommended to implement conservation efforts that include conservation efforts, including habitat restoration, bans on sand mining and

Table 1. A checklist of the avian species of Ranjit Sagar wetland, Punjab.

	Taxon	Family	Season	Feeding habit	Residential status	IUCN Status
Order: Anseriformes						
1	Bar-headed Goose *Anser indicus* (Latham, 1790)	Anatidae	W	H	Migrant	Least Concern
2	Knob-billed Duck *Sarkidiornis melanotos* (Pennant, 1769)	Anatidae	A	O	Resident	Least Concern
3	Common Pochard *Aythya ferina* (Linnaeus, 1758)	Anatidae	W	O	Migrant	Vulnerable
4	Cotton Pygmy Goose *Nettapus coromandelianus* (Gmelin, J.F., 1789)	Anatidae	W	O	Migrant	Least Concern
5	Common Teal *Anas crecca* (Linnaeus, 1758)	Anatidae	W	O	Migrant	Least Concern
6	Eurasian Wigeon *Mareca penelope* (Linnaeus, 1758)	Anatidae	W	H	Migrant	Least Concern
7	Gadwall *Mareca strepera* (Linnaeus, 1758)	Anatidae	W	H	Migrant	Least Concern
8	Garganey *Spatula querquedula* (Linnaeus, 1758)	Anatidae	W	O	Migrant	Least Concern
9	Greylag Goose *Anser anser* (Linnaeus, 1758)	Anatidae	W	H	Migrant	Least Concern
10	Indian Spot-billed Duck *Anas poecilorhyncha* (Forster, 1781)	Anatidae	A	H	Resident	Least Concern
11	Lesser Whistling Duck *Dendrocygna javanica* (Horsfeld, 1821)	Anatidae	S	O	Migrant	Least Concern
12	Northern Shoveler *Spatula clypeata* (Linnaeus, 1758)	Anatidae	W	O	Migrant	Least Concern
13	Northern Pintail *Anas acuta* (Linnaeus, 1758)	Anatidae	W	O	Migrant	Least Concern
14	Red-crested Pochard *Netta rufina* (Pallas, 1773)	Anatidae	W	O	Migrant	Least Concern
15	Ruddy Shelduck *Tadorna ferruginea* (Pallas, 1764)	Anatidae	W	O	Migrant	Least Concern
16	Common Shelduck *Tadorna tadorna* (Linnaeus, 1758)	Anatidae	W	O	Migrant	Least Concern
17	Ferruginous Duck *Aythya nyroca* (Guldenstadt, 1770)	Anatidae	W	O	Migrant	Near Threatened
18	Tufted Duck *Aythya fuligula* (Linnaeus, 1758)	Anatidae	W	O	Migrant	Least Concern
Order: Galliformes						
19	Grey Francolin *Ortygornis pondicerianus* (Gmelin, 1789)	Phasinidae	A	O	Resident	Least Concern
20	Indian Peafowl *Pavo cristatus* (Linnaeus, 1758)	Phasinidae	A	O	Resident	Least Concern
Order: Phoenicopteriformes						
21	Greater Flamingo *Phoenicopterus roseus* (Pallas, 1811)	Phoenicopteridae	W	AqA	Migrant	Least Concern
	Order: Podicipediformes					
22	Little Grebe *Tachybaptus ruficollis* (Pallas, 1764)	Podicipedidae	A	AqA	Resident	Least Concern
23	Great Crested Grebe *Podiceps cristatus* (Linnaeus, 1758)	Podicipedidae	W	AqA	Migrant	Least Concern
24	Black-necked Grebe *Podiceps nigricollis* (Brehm, 1831)	Podicipedidae	W	AqA	Migrant	Least Concern
Order: Columbiformes						
25	Rock Pigeon *Columba livia* (Gmelin, 1789)	Columbidae	A	G	Resident	Least Concern
26	Eurasian Collared Dove *Streptopelia decaocto* (Frivaldszky, 1838)	Columbidae	A	G	Resident	Least Concern
27	Laughing Dove *Spilopelia senegalensis* (Linnaeus, 1766)	Columbidae	A	G	Resident	Least Concern
28	Red Collared Dove *Streptopelia tranquebarica* (Hermann, 1804)	Columbidae	A	G	Resident	Least Concern
29	Spotted Dove *Spilopelia chinensis* (Scopoli, 1786)	Columbidae	A	G	Resident	Least Concern
30	Yellow-footed Green Pigeon *Treron phoenicopterus* (Latham, 1790)	Columbidae	A	F	Resident	Least Concern
Order: Cuculiformes						
31	Asian Koel *Eudynamys scolopaceus* (Linnaeus, 1758)	Cuculidae	S	I	Migrant	Least Concern
32	Greater Coucal *Centropus sinensis* (Stephens, 1815)	Cuculidae	A	C	Resident	Least Concern
33	Pied Cuckoo *Clamator jacobinus*(Boddaert, 1783)	Cuculidae	A	I	Resident	Least Concern
Order: Caprimulgiformes						
34	Alpine Swift *Tachymarptis melba* (Linnaeus, 1758)	Apodidae	A	I	Resident	Least Concern

	Taxon	Family	Season	Feeding habit	Residential status	IUCN Status
Order: Gruiformes						
35	Eurasian Coot *Fulica atra* (Linnaeus, 1758)	Rallidae	W	O	Migrant	Least Concern
36	Common Moorhen *Gallinula chloropus* (Linnaeus, 1758)	Rallidae	A	O	Resident	Least Concern
37	Grey-headed Swamphen *Porphyrio poliocephalus* (Latham, 1801)	Rallidae	A	O	Resident	Least Concern
38	White-Breasted Waterhen *Amaurornis phoenicurus* (Pennant, 1769)	Rallidae	A	O	Resident	Least Concern
39	Common Crane *Grus grus* (Linnaeus, 1758)	Gruidae	W	O	Migrant	Least Concern
40	Demoiselle Crane *Grus virgo* (Linnaeus, 1758)	Gruidae	W	O	Migrant	Least Concern
Order: Charadriiformes						
41	Black-winged Stilt *Himantopus himantopus* (Linnaeus, 1758)	Recurvirostridae	A	I	Resident	Least Concern
42	Pied Avocet *Recurvirostra avosetta* Linnaeus, 1758	Recurvirostridae	W	C	Migrant	Least Concern
43	Little Ringed Plover *Charadrius dubius* Scopoli, 1786	Charadriidae	W	I	Migrant	Least Concern
44	Kentish Plover *Charadrius alexandrinus* Linnaeus, 1758	Charadriidae	W	I	Migrant	Least Concern
45	Red-wattled Lapwing *Vanellus indicus* (Boddaert, 1783)	Charadriidae	A	I	Resident	Least Concern
46	River Lapwing *Vanellus duvaucelii* (Lesson, 1826)	Charadriidae	W	AqA	Migrant	Near Threatened
47	White-tailed Lapwing *Vanellus leucurus* (Lichtenstein, MHC, 1823)	Charadriidae	W	I	Migrant	Least Concern
48	Yellow-wattled Lapwing *Vanellus malabaricus* (Boddaert, 1783)	Charadriidae	W	I	Migrant	Least Concern
49	Greater Painted-snipe *Rostratula benghalensis* (Linnaeus, 1758)	Rostratulidae	W	O	Migrant	Least Concern
50	Pheasant-tailed Jacana *Hydrophasianus chirurgus* (Scopoli, 1786)	Jacanidae	S	I	Migrant	Least Concern
51	Black-tailed Godwit *Limosa limosa* (Linnaeus, 1758)	Scolopacidae	W	O	Migrant	Near Threatened
52	Common Redshank *Tringa totanus*(Linnaeus, 1758)	Scolopacidae	W	I	Migrant	Least Concern
53	Common Sandpiper *Actitis hypoleucos* Linnaeus, 1758	Scolopacidae	W	I	Migrant	Least Concern
54	Common Snipe *Gallinago gallinago* (Linnaeus, 1758)	Scolopacidae	W	I	Migrant	Least Concern
55	Dunlin *Calidris alpina* (Linnaeus, 1758)	Scolopacidae	W	AqA	Migrant	Least Concern
56	Green Sandpiper *Tringa ochropus* (Linnaeus, 1758)	Scolopacidae	W	I	Migrant	Least Concern
57	Common Greenshank *Tringa nebularia* (Gunnerus, 1767)	Scolopacidae	W	AqA	Migrant	Least Concern
58	Marsh Sandpiper *Tringa stagnatilis* (Bechstein, 1803)	Scolopacidae	W	AqA	Migrant	Least Concern
59	Ruff *Calidris pugnax* (Linnaeus, 1758)	Scolopacidae	W	AqA	Migrant	Least Concern
60	Spotted Redshank *Tringa erythropus* (Pallas, 1764)	Scolopacidae	W	I	Migrant	Least Concern
61	Wood Sandpiper *Tringa glareola* Linnaeus, 1758	Scolopacidae	W	I	Migrant	Least Concern
62	Eurasian Curlew *Numenius arquata* (Linnaeus, 1758)	Scolopacidae	W	AqA	Migrant	Near threatened
63	Black-headed Gull *Chroicocephalus ridibundus* (Linnaeus, 1766)	Laridae	W	AqA	Migrant	Least Concern
64	Brown-headed Gull *Chroicocephalus brunnicephalus* (Jerdon, 1840)	Laridae	W	AqA	Migrant	Least Concern
65	Pallas's Gull *Ichthyaetus ichthyaetus* (Pallas, 1773)	Laridae	W	C	Migrant	Least Concern
66	Lesser Black-backed Gull *Larus fuscus* (Linnaeus, 1758)	Laridae	W	C	Migrant	Least Concern
67	River Tern *Sterna aurantia* (Gray, 1831)	Laridae	A	AqA	Resident	Near Threatened
68	Little Tern *Sternula albifrons* (Pallas, 1764)	Laridae	W	AqA	Migrant	Least Concern
69	Whiskered Tern *Chlidonias hybrida* (Pallas, 1811)	Laridae	W	AqA	Migrant	Least Concern
Order: Suliformes						
70	Oriental Darter *Anhinga melanogaster* (Pennant, 1769)	Anhingidae	A	AqA	Resident	Near Threatened
71	Great Cormorant *Phalacrocorax carbo* (Linnaeus, 1758)	Phalacrocoracidae	A	AqA	Resident	Least Concern
72	Little Cormorant *Microcarbo niger* (Vieillot, 1817)	Phalacrocoracidae	A	AqA	Resident	Least Concern

	Taxon	Family	Season	Feeding habit	Residential status	IUCN Status
73	Indian Cormorant *Phalacrocorax fuscicollis* Stephens, 1826	Phalacrocoracidae	W	AqA	Migrant	Least Concern
Order: Pelecaniformes						
74	Cattle Egret *Bubulcus ibis* (Linnaeus, 1758)	Ardeidae	A	I	Resident	Least Concern
75	Grey Heron *Ardea cinerea* (Linnaeus, 1758)	Ardeidae	A	C	Resident	Least Concern
76	Indian Pond Heron *Ardeola grayii* (Sykes, 1832)	Ardeidae	A	C	Resident	Least Concern
77	Intermediate Egret *Ardea intermedia* (Wagler, 1829)	Ardeidae	A	C	Resident	Least Concern
78	Great Egret *Ardea alba* (Linnaeus, 1758)	Ardeidae	A	AqA	Resident	Least Concern
79	Little Egret *Egretta garzetta* (Linnaeus, 1766)	Ardeidae	A	AqA	Resident	Least Concern
80	Black-crowned Night Heron *Nycticorax nycticorax* (Linnaeus, 1758)	Ardeidae	A	AqA	Resident	Least Concern
81	Purple Heron *Ardea purpurea* (Linnaeus, 1766)	Ardeidae	A	AqA	Resident	Least Concern
82	Yellow Bittern *Ixobrychus sinensis* (Gmelin, 1789)	Ardeidae	S	AqA	Migrant	Least Concern
83	Striated Heron *Butorides striata* (Linnaeus, 1758)	Ardeidae	A	AqA	Resident	Least Concern
84	Red-naped Ibis *Pseudibis papillosa* (Temminck, 1824)	Threskiornithidae	A	C	Resident	Least Concern
85	Black-headed Ibis *Threskiornis melanocephalus* (Latham, 1790)	Threskiornithidae	A	C	Resident	Near Threatened
86	Glossy Ibis *Plegadis falcinellus* (Linnaeus, 1766)	Threskiornithidae	W	C	Migrant	Least Concern
87	Eurasian Spoonbill *Platalea leucorodia* Linnaeus, 1758	Threskiornithidae	W	C	Migrant	Least Concern
Order: Accipitriformes						
88	Osprey *Pandion haliaetus* (Linnaeus, 1758)	Pandionidae	A	C	Migrant	Least Concern
89	Black Kite *Milvus migrans* (Boddaert, 1783)	Accipitridae	A	C	Resident	Least Concern
90	Black-winged Kite *Elanus caeruleus* (Desfontaines, 1789)	Accipitridae	A	C	Resident	Least Concern
91	Brahminy Kite *Haliastur indus* (Boddaert, 1783)	Accipitridae	W	C	Migrant	Least Concern
92	Shikra *Accipiter badius* (Gmelin, 1788)	Accipitridae	A	C	Resident	Least Concern
93	Common Buzzard *Buteo buteo* (Linnaeus, 1758)	Accipitridae	W	C	Migrant	Least Concern
94	White-eyed buzzard *Butastur teesa* (Franklin, 1831)	Accipitridae	A	C	Resident	Least Concern
95	Himalayan Vulture *Gyps himalayensis* (Hume, 1869)	Accipitridae	W	C	Migrant	Near Threatened
96	Egyptian Vulture *Neophron percnopterus* (Linnaeus, 1758)	Accipitridae	A	C	Resident	Endangered
97	Montagu's Harrier *Circus pygargus* (Linnaeus, 1758)	Accipitridae	W	C	Migrant	Least Concern
Order:Strigiformes						
98	Spotted Owlet *Athene brama* (Temminck, 1821)	Strigidae	A	C	Resident	Least Concern
Order: Bucerotiformes						
99	Eurasian Hoopoe *Upupa epops* (Linnaeus, 1758)	Upupidae	A	I	Resident	Least Concern
100	Indian Grey Hornbill *Ocyceros birostris* (Scopoli, 1786)	Bucerotidae	A	F	Resident	Least Concern
Order: Coraciiformes						
101	Common Kingfisher *Alcedo atthis* (Linnaeus, 1758)	Alcedinidae	A	AqA	Resident	Least Concern
102	White-throated Kingfisher *Halcyon smyrnensis* (Linnaeus, 1758)	Alcedinidae	A	C	Resident	Least Concern
103	Pied Kingfisher *Ceryle rudis* (Linnaeus, 1758)	Alcedinidae	A	AqA	Resident	Least Concern
104	Green Bee-eater *Merops orientalis* (Latham, 1801)	Meropidae	A	I	Resident	Least Concern
105	Blue-tailed Bee-eater *Merops philippinus* (Linnaeus, 1766)	Meropidae	S	I	Migrant	Least Concern
106	Indian Roller *Coracias benghalensis* (Linnaeus, 1758)	Coraciidae	A	C	Resident	Least Concern
Order: Piciformes						
107	Brown-headed Barbet *Psilopogon zeylanicus* (Gmelin, 1788)	Megalaimidae	A	F	Resident	Least Concern
108	Coppersmith Barbet *Psilopogon haemacephalus* (Muller, 1776)	Megalaimidae	A	F	Resident	Least Concern
109	Black-rumped Flameback *Dinopium benghalense* (Linnaeus, 1758)	Picidae	A	I	Resident	Least Concern

	Taxon	Family	Season	Feeding habit	Residential status	IUCN Status
Order: Psittaciformes						
110	Alexandrine Parakeet *Psittacula eupatria* (Linnaeus, 1766)	Psittaculidae	A	F	Resident	Near Threatened
111	Rose-ringed Parakeet *Psittacula krameri* (Scopoli, 1769)	Psittaculidae	A	F	Resident	Least Concern
112	Plum-headed Parakeet *Psittacula cyanocephala* (Linnaeus, 1766)	Psittaculidae	A	F	Resident	Least Concern
Order: Passeriformes						
113	Indian Golden Oriole *Oriolus kundoo* Sykes, 1832	Oriolidae	S	O	Migrant	Least Concern
114	Black Drongo *Dicrurus macrocercus* (Vieillot, 1817)	Dicruridae	A	I	Resident	Least Concern
115	Hair-crested Drongo *Dicrurus hottentottus* (Linnaeus, 1766)	Dicruridae	W	I	Migrant	Least Concern
116	Indian paradise Flycatcher *Terpsiphone paradisi* (Linnaeus, 1758)	Monarchidae	S	I	Migrant	Least Concern
117	Long-tailed Shrike *Lanius schach* (Linnaeus, 1758)	Laniidae	A	I	Resident	Least Concern
118	Bay-backed Shrike *Lanius vittatus* (Valenciennes, 1826)	Laniidae	A	I	Resident	Least Concern
119	Brown Shrike *Lanius cristatus* (Linnaeus, 1758)	Laniidae	W	I	Migrant	Least Concern
120	Common Raven *Corvus corax* (Linnaeus, 1758)	Corvidae	A	C	Resident	Least Concern
121	Rufous Treepie *Dendrocitta vagabunda* (Latham, 1790)	Corvidae	A	O	Resident	Least Concern
122	Grey-headed Canary Flycatcher *Culicicapa ceylonensis* (Swainson, 1820)	Stenostiridae	W	I	Migrant	Least Concern
123	Crested Lark *Galerida cristata* (Linnaeus, 1758)	Alaudidae	A	I	Resident	Least Concern
124	Yellow-bellied Prinia *Prinia flaviventris* (Delessert, 1840)	Cisticolidae	W	I	Migrant	Least Concern
125	Common Tailorbird *Orthotomus sutorius* (Pennant, 1769)	Cisticolidae	A	I	Resident	Least Concern
126	Rufous–fronted Prinia *Prinia buchanani* (Blyth, 1844)	Cisticolidae	A	I	Resident	Least Concern
127	Ashy Prinia *Prinia socialis* (Sykes, 1832)	Cisticolidae	A	I	Resident	Least Concern
128	Plain Prinia *Prinia inornata* (Sykes, 1832)	Cisticolidae	A	I	Resident	Least Concern
129	Zitting Cisticola *Cisticola juncidis* (Rafinesque, 1810)	Cisticolidae	A	I	Resident	Least Concern
130	Blyth's Reed Warbler *Acrocephalus dumetorum* (Blyth, 1849)	Acrocephalidae	W	I	Migrant	Least Concern
131	Barn Swallow *Hirundo rustica* (Linnaeus, 1758)	Hirundinidae	S	I	Migrant	Least Concern
132	Plain Martin *Riparia paludicola* (Vieillot, 1817)	Hirundinidae	S	I	Migrant	Least Concern
133	Red–Rumped Swallow *Cecropis daurica* (Laxmann, 1769)	Hirundinidae	S	I	Migrant	Least Concern
134	Wire-tailed Swallow *Hirundo smithii* (Leach, 1818)	Hirundinidae	S	I	Migrant	Least Concern
135	Streak-throated Swallow *Petrochelidon fluvicola* (Blyth, 1855)	Hirundinidae	A	I	Resident	Least Concern
136	Red–vented Bulbul *Pycnonotus cafer* (Linnaeus, 1766)	Pycnonotidae	A	F	Resident	Least Concern
137	Himalayan Bulbul *Pycnonotus leucogenys* (Gray, 1835)	Pycnonotidae	A	F	Resident	Least Concern
138	Common Chiffchaff *Phylloscopus collybita* (Vieillot, 1817)	Phylloscopidae	W	I	Migrant	Least Concern
139	Siberian Chiffchaff *Phylloscopus tristis* (Blyth, 1843)	Phylloscopidae	A	I	Resident	Least Concern
140	Indian White-eye *Zosterops palpebrosus* (Temminck, 1824)	Zosteropidae	W	O	Migrant	Least Concern
141	Common Babbler *Argya caudate* (Dumont, 1823)	Leiothrichidae	A	I	Resident	Least Concern
142	Jungle Babbler *Argya striata* (Dumont, 1823)	Leiothrichidae	A	I	Resident	Least Concern
143	Large Grey Babbler *Argya malcolmi* (Sykes, 1832)	Leiothrichidae	A	I	Resident	Least Concern
144	Asian Pied Starling *Gracupica contra* (Linnaeus, 1758)	Sturnidae	A	O	Resident	Least Concern
145	Bank Myna *Acridotheres ginginianus* (Latham, 1790)	Sturnidae	A	O	Resident	Least Concern
146	Brahminy Starling *Sturnia pagodarum* (Gmelin, 1789)	Sturnidae	A	I	Resident	Least Concern
147	Common Myna *Acridotheres tristis* (Linnaeus, 1766)	Sturnidae	A	O	Resident	Least Concern
148	Common Starling *Sturnus vulgaris* (Linnaeus, 1758)	Sturnidae	A	O	Resident	Least Concern
149	Black Redstart *Phoenicurus ochruros* (Gmelin, 1774)	Muscicapidae	W	I	Migrant	Least Concern
150	Bluethroat *Luscinia svecica* (Linnaeus, 1758)	Muscicapidae	W	I	Migrant	Least Concern
151	Brown Rock Chat *Oenanthe fusca* (Blyth, 1851)	Muscicapidae	A	I	Resident	Least Concern

	Taxon	Family	Season	Feeding habit	Residential status	IUCN Status
152	Indian Robin *Copsychus fulicatus* (Linnaeus, 1766)	Muscicapidae	A	I	Resident	Least Concern
153	Oriental Magpie Robin *Copsychus saularis* (Linnaeus, 1758)	Muscicapidae	A	I	Resident	Least Concern
154	Pied Bushchat *Saxicola caprata* (Linnaeus, 1766)	Muscicapidae	A	I	Resident	Least Concern
155	Siberian Stonechat *Saxicola maurus* (Pallas, 1773)	Muscicapidae	W	I	Migrant	Least Concern
156	White-tailed Stonechat *Saxicola leucurus* (Blyth, 1847)	Muscicapidae	A	I	Resident	Least Concern
157	Purple Sunbird *Cinnyris asiaticus* (Latham, 1790)	Nectariniidae	A	I	Resident	Least Concern
158	Baya Weaver *Ploceus philippinus* (Linnaeus, 1766)	Ploceidae	A	O	Resident	Least Concern
159	Streaked Weaver *Ploceus manyar* (Horsfield, 1821)	Ploceidae	A	I	Resident	Least Concern
160	Indian Silverbill *Euodice malabarica* (Linnaeus, 1758)	Estrildidae	A	G	Resident	Least Concern
161	Scaly-breasted Munia *Lonchura punctulata* (Linnaeus, 1758)	Estrildidae	A	G	Resident	Least Concern
162	House Sparrow *Passer domesticus* (Linnaeus, 1758)	Passeridae	A	G	Resident	Least Concern
163	Citrine Wagtail *Motacilla citreola* (Pallas, 1776)	Motacillidae	W	I	Migrant	Least Concern
164	Grey Wagtail *Motacilla cinerea* (Tunstall, 1771)	Motacillidae	W	I	Migrant	Least Concern
165	Paddyfield Pipit *Anthus rufulus* (Vieillot, 1818)	Motacillidae	A	I	Resident	Least Concern
166	Western Yellow Wagtail *Motacilla flava* (Linnaeus, 1758)	Motacillidae	W	I	Migrant	Least Concern
167	White Wagtail *Motacilla alba* (Linnaeus, 1758)	Motacillidae	W	I	Migrant	Least Concern

A—Throughout year | S—Summer | W—Winter | O—Omnivorous | AqA— Aquatic animal Feeder | C—Carnivorous | F—Frugivorous | G—Granivorous | I—Insectivorous | H—Herbivorous.

poaching activities, as well as the regulation of land reclamation and fishing practices, as detailed in the work by Brraich & Saini (2019). The intricate relationship between wetlands and avian populations is influenced by various physical and biological attributes of wetland environments. Birds rely on wetlands for their daily and seasonal needs, including food and other life-sustaining activities. Therefore, effective conservation and management measures are essential to attract migratory birds to wetland areas. A comprehensive examination of wetland ecosystems and migratory bird populations is necessary to better understand their interaction. Public awareness regarding the vital role of wetlands in supporting migratory birds is crucial, and support for restoration and maintenance initiatives aimed at safeguarding these vital habitats is highly encouraged.

REFERENCES

Ali, S. & S.D. Ripley (1983). *Compact of Handbook of the Birds of India and Pakistan.* Bombay Natural History Society and Oxford University Press, Bombay, 841 pp.

Ali, S., S.A. Hussain, P.K. Gupta & S. Subramanya (1981). *Harike Lake avifauna project*. Bombay Natural History Society, Mumbai, 104 pp.

Anand, J., H. Byju, A. Nefla, S. Abhijith, O.R. Reshi & K.M. Aarif (2023). Conservation significance of Changaram wetlands - a key wintering site for migratory shorebirds and other waterbirds in the western coast of Kerala, India. *Journal of Threatened Taxa* 15(1): 22410–22418. https://doi.org/10.11609/jott.8089.15.1.22410-22418

Basavarajappa, S. (2006). Avifauna of agro-ecosystems of Maidan area of Karnataka. *Zoo Print Journal* 21(4): 2117–2119. http://doi.org/10.11609/JoTT.ZPJ.1277.2217-9

Bellrose, F.C. & N.M. Trudeau (1988). Wetlands and Their Relationship to Migrating and Winter Populations of Waterfowl, 183–194 pp. In: *The Ecology and Management of Wetlands*. Springer, New York,. https://doi.org/10.1007/978-1-4684-8378-9_15

Bibby, C. (1998). Why count birds? In: Bibby,C., M. Jones & S. Marsden (eds.). *Expedition Field Techniques: Bird Surveys.* Expedition Advisory Centre, Royal Geographical Society. Kensington, London, 139 pp.

Brraich, O.S. & J. Singh (2021a). Status of Horned Grebe Podiceps auritus in India. *Indian BIRDS* 17(4): 121–122.

Brraich, O.S. & J. Singh (2021b). Avian fauna of village pond of Mote Majra, Punjab, India. Bird-o-soar #71, In: *Zoo's Print* 36(2): 33–40.

Brraich, O.S. & S.K. Saini (2019). Ichthyofaunal diversity of Ranjit Sagar Wetland situated in the northwestern Himalayas. *European Journal of Environmental Sciences* 9(2): 106113. https://doi.org/10.14712/23361964.2019.14

Byju, H., N. Raveendran & S. Ravichandran (2023a). Distribution of avifauna on twenty-one islands of the Gulf of Mannar Biosphere Reserve, India. *Journal of Threatened Taxa* 15(2): 22574–22585. https://doi.org/10.11609/jott.8112.15.2.22574-22585

Byju, H., N. Raveendran, S. Ravichandran & R. Kishore (2023b). An annotated checklist of the avifauna of Karangadu mangroveforest, Ramanatha-puram, Tamil Nadu, with notes on the site's importance for waterbird conservation. *Journal of Threatened Taxa* 15(3): 22813–22822. https://doi.org/10.11609/jott.8356.15.3.22813-22822

Casazza, M.L., F. McDuie, S. Jones, A.A. Lorenz, C.T. Overton, J. Yee & K.M. Thorne (2021). Waterfowl use of wetland habitats informs wetland restoration designs for multi-species benefits. *Journal of Applied Ecology* 58(9): 1–10. https://doi.org/10.1111/1365-2664.13845

Chhetry, D.T. (2006). Diversity of wetland birds around the Koshi Barrage area. *Our Nature* 4: 91–95. https://doi.org/10.3126/on.v4i1.507

**Clements, J.F., T.S. Schulenberg, M.J. Iliff, T.A. Fredericks, J.A.

Gerbracht, D. Lepage, S.M. Billerman, B.L. Sullivan & C.L. Wood (2022).** The eBird/Clements checklist of Birds of the World: v2022. Downloaded in December 2022 from https://www.birds.cornell.edu/clementschecklist/download/

Coppes, J., U. Nopp-Mayr, V. Gruenschachner-Berger, I. Storch, R. Suchant & V. Braunisch (2018). Habitat suitability modulates the response of wildlife to human recreation. *Biological Conservation* 227: 56-64. https://doi.org/10.1016/j.biocon.2018.08.018

Downard, R., M. Frank, J. Perkins, K. Kettenring & M. Larese-Casanova (2017). *Wetland Plants of Great Salt Lake, A Guide to Identification, Communities, & Bird Habitat* Utah State University Extension, Logan, Utah. Download in December 2022. https://digitalcommons.usu.edu/extension_curall/1761/

Dutta, N.N., D. Baruah & S. Borah (2011). Avifaunal diversity in an IBA site of north east India and their conservation. *Annals of Biological Research* 2(5): 374–384.

Gaston, A.J. (1975). Methods for estimating bird population. *Journal of the Bombay Natural History Society* 72(2): 272–281. https://biostor.org/reference/148629.

Grimmett, R. & C. Inskipp (2010). *Birds of Northern India.* Om Books International, Noida, India, 240 pp.

Grimmett, R., C. Inskipp & T. Inskipp (2012). *Birds of the Indian Subcontinent.* Oxford University Press, Delhi, India, 400 pp.

Joshi, K., D. Kumar, A.K. Arya & A. Bachheti (2021). An assessment of water bird species and associated water bird composition in the Haiderpur Wetland of Hastinapur Wildlife Sanctuary, Uttar Pradesh, India. *Asian Journal of Conservation Biology* 10(1): 141–145. https://doi.org/10.53562/ajcb.DCKB1009

Kakati, R., A. Bhuyan & D. Borah (2021). Status of biodiversity in wetlands of Biswanath District of Assam, India. *Biodiversitas Journal of Biological Diversity* 22(1): 235–256. https://doi.org/10.13057/biodiv/d220156

Kazmierczak, K., P. Undeland, D. Allen & R. Singh (1998). Birdwatching areas: Harike Bird Sanctuary, Punjab State, India. *Oriental Bird Club Bulletin* 27: 42–46.

Kumar, A., P.C. Sati & J.R.B. Alfred (2005). *Handbook on Indian Wetland Birds and their Conservation.* Zoological Survey of India, Kolkata, India, 468 pp.

Kumar, P. & A. Sharma (2019). Wetland birds assemblages in man-made sacred ponds of Kurukshetra, India. *Proceedings of the Zoological Society* 72(1) 1–6. https://doi.org/10.1007/s12595-018-0259-x

Lee, P.Y. & J.T. Rotenberry (2005). Relationships between bird species and tree species assemblages in forested habitats of eastern North America. *Journal of Biogeography* 32: 1139–1150. https://doi.org/10.1111/j.1365-2699.2005.01254.x

Mavi, H.S. & D.S. Tiwana (1993). *Geography of Punjab.* National Book Trust, India, 217 pp.

Mehta, H.S., M.L. Thakur, R. Paliwal & P.C. Tak (2002). Avian diversity of Ropar Wetland, Punjab, India. *Annals of Forestry* 10(2): 307–326.

Prasad, A. (2008a). Long-tailed Duck *Clangula hyemalis* at Harike Lake, Punjab, India. *Indian BIRDS* 4(1): 16–17.

Prasad, A. (2008b). Horned Grebe *Podiceps auritus* at Harike Lake, Punjab, India. *Indian BIRDS* 4(1): 25–26.

Praveen, J. & R. Jayapal (2023). Taxonomic updates to the checklists of birds of India and the South Asian region—2023. *Indian BIRDS* 18(5): 131–134.

Pulliam, H.R. & B.J. Danielson (1991). Sources, sinks, and habitat selection: A landscape perspective on population dynamics. *The American Nature,* 137: S50–S66. http://www.jstor.org/stable/2462288

Robson, C. (1996). India. *Oriental Bird Club Bulletin* 23: 49–53.

Robson, C. (1999). India. *Oriental Bird Club Bulletin* 29: 51–52.

Sawant, S. & M. Sudhagar (2013). Notes on the newly discovered population of Sind Jerdon's Babbler *Chrysomma Latirostris indicum* in Harike Wildlife Sanctuary, Punjab, India. *Journal of Bombay Natural History Society* 110(3): 187–192.

Singh, J. & O.S. Brraich (2022). Seasonal composition of avian communities in different habitats of Harike Wetland, a Ramsar site in Punjab, India. *Journal of Threatened Taxa* 14(2): 20550–20565. https://doi.org/10.11609/jott.7581.14.2.20550-20565

Singh, J. & O.S. Brraich (2021). Photographic record of Horned Grebe from Harike Bird Sanctuary, Punjab, India. Bird-o-soar #88, In: *Zoo's Print* 36(5): 51–52.

Singh, J., S. Hooda, A. Phogat & V. Malik (2021). Avian Diversity and Habitat Use of Sultanpur National Park, Haryana, India. *Asian Journal of Conservation Biology* 10(1): 124–133. https://doi.org/10.53562/ajcb.RKPR3560

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

Smith, R.L. (1992). *Elements of Ecology.* Harper Collins Publishers Ltd, London, 704 pp.

Teng, J., S. Xia, Y. Liu, X. Yu, H. Duan, H. Xiao & C. Zhao (2021). Assessing habitat suitability for wintering geese by using Normalized Difference Water Index (NDWI) in a large floodplain wetland, China. *Ecological Indicators* 122: 107260. https://doi.org/10.1016/j.ecolind.2020.107260

Thakur, M.L. & R. Paliwal (2012). Avian diversity of Chandigarh (UT). *Journal of Advances in Biological Research* 2(1): 103–114.

Wu, H., J. Dai, S. Sun, C. Du, Y. Long, H. Chen, G. Yu, S. Ye & J. Chen (2021). Responses of habitat suitability for migratory birds to increased water level during middle of dry season in the two largest freshwater lake wetlands of China. *Ecological Indicators* 121: 107065. https://doi.org/10.1016/j.ecolind.2020.107065

Yao, S., X. Li, C. Liu, J. Zhang, Y. Li, T. Gan & W. Kuang (2020). New assessment indicator of habitat suitability for migratory bird in wetland based on hydrodynamic model and vegetation growth threshold. *Ecological Indicators* 117: 106556. https://doi.org/10.1016/j.ecolind.2020.106556

Threatened Taxa

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 September 2023 | 15(9): 23879–23888

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

https://doi.org/10.11609/jott.8522.15.9.23879-23888

#8522 | Received 12 May 2023 | Final received 15 June 2023 | Finally accepted 06 August 2023

COMMUNICATION

Faunistic overview of the freshwater zooplankton from the urban riverine habitats of Pune, India

Avinash Isaac Vanjare [1], Yugandhar Satish Shinde [2] & Sameer Mukund Padhye [3]

[1] Freshwater Invertebrates Biology Laboratory, Department of Zoology, Ahmednagar College, Ahmednagar, Maharashtra 414001, India.
[2] Department of Zoology, PES's Modern College of Arts, Science and Commerce (Autonomous) Shivajinagar, Pune, Maharashtra 411005, India.
[3] Biologia Life Science LLP, Savedi, Ahmednagar, Maharashtra 414003, India.
[1] avinashisaac7@gmail.com (corresponding author), [2] yugandharshinde@gmail.com, [3] sameer.m.padhye@gmail.com

Abstract: Urbanization modifies the physical, chemical, and biological nature of all ecosystems including rivers. Such changes negatively impact all aquatic biodiversity including the freshwater zooplankton. Given the fast pace of urbanization in all the major cities across India, the aim is to provide a faunistic overview of Rotifera, Cladocera, and Ostracoda from two polluted rivers flowing through Pune, one of the rapidly growing cities in the state of Maharashtra, India. A one-year survey of three localities on the rivers Mula & Mutha and data from published literature on another locality revealed the presence of 73 species which includes 47 rotifers, 15 cladocerans, and 11 ostracods. A higher species number of rotifers was seen at lesser polluted localities while cladocerans and ostracods occurred even in the most urbanized sampling locality. Many of the species found were commonly observed species from the region. Epizoic associations of cladocerans and rotifers and red coloration in the former group were observed during a low dissolved oxygen phase in both rivers. Such observations underscore the potential bioindicator value of these small animals to the impacts of urbanization.

Keywords: Biodiversity, Cladocera, Epizoic, Mula-Mutha river, Ostracoda, pollution, Rotifera, urbanization.

Editor: Anonymity requested. **Date of publication:** 26 September 2023 (online & print)

Citation: Vanjare, A.I., Y.S. Shinde & S.M. Padhye (2023). Faunistic overview of the freshwater zooplankton from the urban riverine habitats of Pune, India. *Journal of Threatened Taxa* 15(9): 23879–23888. https://doi.org/10.11609/jott.8522.15.9.23879-23888

Funding: None.

Competing interests: The authors declare no competing interests.

Author details: Dr. Avinash Vanjare is working as an associate professor in Zoology. His area of work includes freshwater invertebrates like rotifers, large branchiopods and odonates. Dr. Yugandhar Shinde is working as an assistant professor in Zoology. His expertise includes freshwater micro-crustaceans and molluscans. Dr. Sameer Padhye is working as a principal scientist at Biologia Life Science LLP. He has published 53 research articles in journals of repute and has reported many new species to science. His expertise includes biodiversity and ecology of Branchiopods and data analysis.

Author contributions: All the authors contributed equally to the idea, methodology, field work and analysis. AIV and SMP contributed to writing of the manuscript and its subsequent revisions

Acknowledgements: AIV would like to thank the principal of Ahmednagar College and the head of the Department of Zoology at Ahmednagar College for their support. SMP would like to thank the director of Biologia Life Science LLP, Ahmednagar for her support. YSS would like to thank the principal of Modern College, Shivajinagar, Pune and the head of the Department of Zoology, Modern College, Shivajinagar, Pune. Authors would also like to acknowledge the support of Jeevitnadi – Living River Foundation, Pune and Adhiwas Foundation, Pune for their support. The authors are grateful to the Maharashtra Biodiversity Board for giving permission for collection (MSBB/DESK5/Appl/NOC/CR-292/233/2016-17).

INTRODUCTION

Urbanization refers to the mass migration of human populations from rural to urban settings (Kuddus et al. 2020). More than half the world's population (~4.3 billion) lives in urban areas which may increase to six billion by the year 2041 (Ritchie & Roser 2018; UNDESA 2018). Thus, urban areas, especially in developing countries like India, are expanding at an exponential rate assisted by the ever-increasing population (Henderson 2002; Cohen 2006; Onda et al. 2019; Kuddus et al. 2020). Such rapid urbanization can have adverse effects on different ecosystems by way of native species loss and/or an increase in the number of non-native species (McMichael 2000; McKinney 2002, 2006).

Rivers are an important component of many urban centres providing water, power, and means of transport besides harbouring high biodiversity (McMichael 2000; Everard & Moggridge 2012; Tran Khac et al. 2018). Many studies have shown that anthropogenic activities like modification of the river channel/bank and untreated waste disposal impact riverine biodiversity in multiple ways which include cultural eutrophication and biotic homogenization to name a few (Blair 2001; Ouyang et al. 2002; Dudgeon et al. 2006; Schindler 2012; Braghin et al. 2018; Du et al. 2023).

Freshwater zooplankton is a well-represented group of invertebrates in rivers and forms an important component of aquatic food chains (Dumont & Negrea 2002; Liu et al. 2020). Zooplankton communities respond to physical and chemical changes in the riverine habitats by displaying variations in their growth, community composition, density, diversity, and distribution (Bērziņš & Pejler 1987, 1989; Duggan et al. 2001; Nogrady et al. 1993; Hulyal & Kaliwal 2008; Jeppesen et al. 2011; Adamczuk et al. 2015; Du et al. 2023).

Literature exists on the different limnological aspects of lotic and lentic habitats in India, though, several of them, especially in the case of zooplankton, have issues like species misidentifications (Sharma & Sharma 2021). Data from reliable studies point to species losses occurring in response to changes in environmental variables like nutrients (phosphorus and nitrogen), dissolved oxygen, turbidity and water flow (Padmavati & Goswami 1996; Arora & Mehra 2003; Rajaram & Das 2008; Padhye & Dahanukar 2015).

Pune is a rapidly growing city in India where its population has grown exponentially within the last 70 years from 3.75 lakhs (1941) to 5 million (2011) and is expected to be >9 million by 2035 (see Butsch et al. 2017; UNDESA 2018). Mula & Mutha, the two rivers that provide water to this urban centre are highly polluted within the city limits due to various anthropogenic activities (Wagh & Ghate 2008; Padhye 2020). Existing faunal literature on these rivers suggests decreasing species numbers across animal groups like odonates, molluscs, fish and birds due to this urbanization effects (Gole 1983; Kharat et al. 2001, 2003; Wagh & Ghate 2008; Kulkarni & Subramanian 2013; Kulkarni et al. 2021). Studies on zooplankton from a single locality on the Mula River have also shown a similar trend (Vanjare et al. 2010; Padhye 2020).

The present study aims to provide a faunistic overview of Rotifera, Cladocera, and Ostracoda of Mula & Mutha rivers passing through the urban part of Pune, Maharashtra. Additionally, peculiar observations and habits of some of the species found in the study are also commented upon.

MATERIALS AND METHODS

Site

Mula & Mutha are tributaries of the Bhima River (Pune, Maharashtra) and are heavily polluted within the city limits, receiving large amounts of untreated waste. Both rivers originate in the Western Ghats, meet in Pune and then join the Bhima River outside the city limits. Floating vegetation (*Pistia* sp., *Eichhornia* sp., and *Lemna* sp.) is observed here frequently and in high densities, after post-monsoon in the urban regions while submerged (*Hydrilla* sp.) and emergent vegetation (*Typha* sp.) is also seen at many places.

Two sampling sites were selected along the Mula River (Ram-Mula confluence & Aundh Bridge) and Mutha River (Vitthalwadi & Garware College) within Pune City for the study (Figure 1). Urbanization around Ram-Mula confluence and Vitthalwadi is comparatively lower than Aundh Bridge and Garware College sites (authors pers. obs. 19 November 2017).

Field and laboratory work

Qualitative sampling was carried out at Ram-Mula confluence, Vitthalwadi, and Garware College between post monsoon and winter season in 2017–18. Sample aliquots were taken (~3–4) from a stretch of ~100 m at each site and concentrated in a single container (100 ml). Effort was made to collect the sample once in each season. A plankton net of 53-micron and hand net of 100-micron mesh size was used for the collection. The sediment was gently disturbed, and water was filtered subsequently with the hand net for better

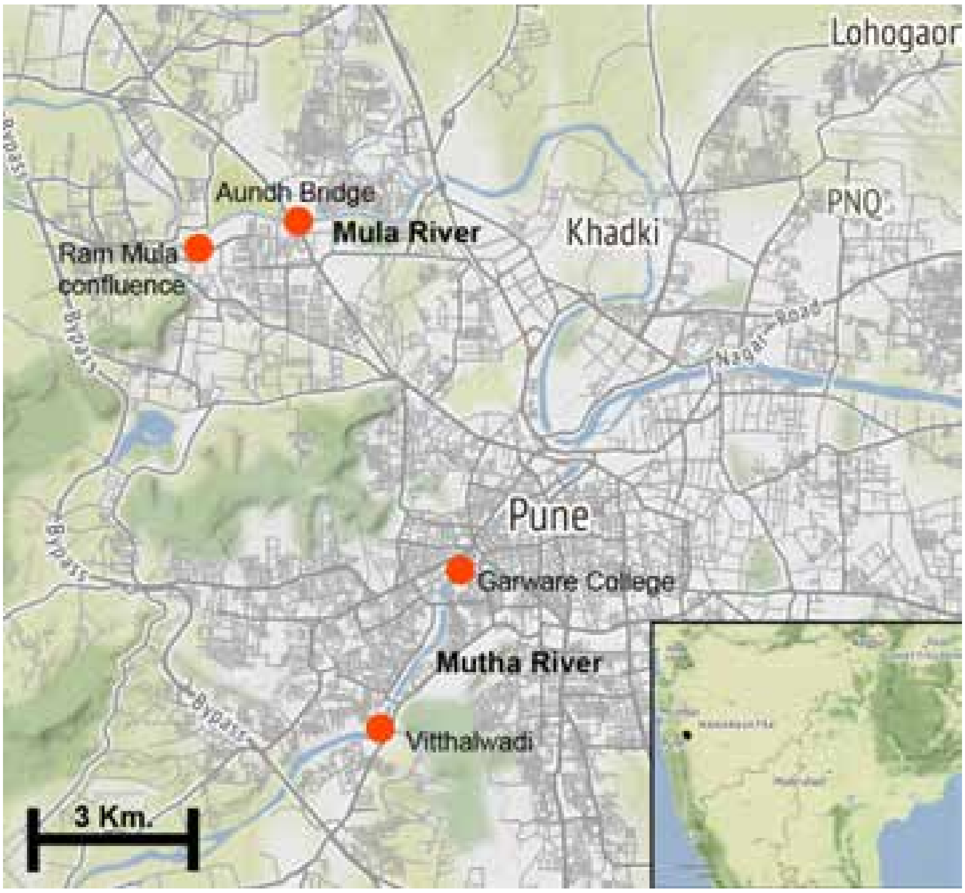

Figure 1. The collection localities along the Mula & Mutha rivers, Pune.

representation of meiobenthic species. The samples were preserved in 4% formalin. Dissolved Oxygen was taken using a DO probe (Hanna) and salinity, pH, water temperature were taken at each sampling station using a multiparameter probe (Eutech). Identifications were done under light microscope (Olympus CH20i) and stereo microscope (Magnus MS 24). Identification was done using standard literature available for the respective groups (Supplementary list 1). Zooplankton data for the Aundh Bridge site was taken from Vanjare et al. (2010) and Padhye & Dahanukar (2015) since the site was inaccessible during the sampling period. Urbanization extent was assessed qualitatively by visual inspection.

RESULTS AND DISCUSSION

Environmental data recorded during the study are shown in supplementary Table 1. The pH ranged from 7.12–8.6, dissolved oxygen from 0.25–11.8 mg/L, water temperature from 18.6–32°C and salinity from 105–386 ppm. No environmental data was collected for the Garware College site.

Seventy-three species of three different zooplankton groups were documented, of which rotifers being the most species rich with 47 species, followed by cladocerans—15 and ostracods—11, respectively (supplementary Table 2). Rotifers were reported from only three localities while cladocerans and ostracod species were observed at all the four sampling stations (Figure 2). Sampling stations having lesser urbanization had more species of rotifers (Ram Mula = 31 & Vitthalwadi = 34) with no species seen at the locality in the city centre (Garware College, Figure 1). Maximum species of cladocerans and ostracods were found at the Aundh Bridge (cladocerans = 11; ostracods = 7) though, representatives of these groups were also found at the Garware College site.

Among the 47 rotifer species, 41 were from the order Ploima, five from the order Flosculariaceae (subclass Monogononta) and one from the family Philodinidae within the subclass Bdelloidea. The Brachionidae family was the most species-rich with 13 species followed by Lecanidae with nine species while eight rotifer families were represented by a single species only. Rotifer genera *Brachionus* and *Lecane* (n = 9 each) were found in high numbers which is typical of these genera in tropical waters (Arora & Mehra 2002). Notable findings include rotifers with a restricted geographic distribution like *Brachionus durgae* (Ram Mula & Vitthalwadi), *Epiphanes brachionus spinosa* (all sites) and *Lecane stenroosi* (Vitthalwadi) were also seen in the study. Three predatory rotifers from the family Asplanchnidae, viz. *Asplanchnopus multiceps, Asplanchna brightwellii and Asplanchna priodonta* were also observed at three of the four sites (Image 2). Most of the recorded rotifer species are common and cosmopolitan in distribution.

Chydorids were the most species rich cladoceran group with five species followed by Daphniidae with three. Both the moinid species were observed in high densities at the site located on river Mutha in the most urbanized region of Pune city (Garware College). Some of the species such as *Simocephalus mixtus*, *Macrothrix spinosa*, and *Ilyocryptus spinifer* are known to occur seasonally at one of the sites on Mula River (Aundh Bridge). Most of these species are commonly known from the region with *Leydigia* (*Neoleydigia*) *ciliata* and *I. spinifer* being the most commonly occurring species in Pune (Padhye et al. 2023) (Image 2).

Only one species from the ostracod genus, *Ilyocypris* sp., was seen at all the four sampling points while the oriental endemics like *Stenocypris derupta* Vávra, *Plesiocypridopsis* cf. *dispar* (Hartmann, 1964) and *Chrissia formosa* (Klie, 1938) were seen at the Ram-Mula confluence only. *Heterocypris incongruens* (Ramdohr, 1808) reported from Garware college is a cosmopolitan species known to tolerate high levels of pollution (Karakaş-Sarı & Külköylüoğlu 2008). *Plesiocypridopsis* cf *dispar* and *Stenocypris* sp. were seen near a natural spring pouring into the Mutha River at the Vitthalwadi site (Image 1).

Seventy-three species of rotifers, cladocerans, and ostarcods from just four locations in Pune City is a good number as compared to riverine fauna documented from some other urban zones of India. Arora & Mehra (2003) documented 89 rotifers from river Yamuna in Delhi, Hulyal & Kaliwal (2007) found 10 rotifers and six cladocerans in Almatti Reservoir of Bijapur, while Kamboj & Kamboj (2020) observed 10 rotifers and eight cladocerans in the Ganga River, Uttarakhand, and Rao (2001) reported 17 rotifers and six cladocerans from the river Ganga between Rishikesh and Kanpur, Uttar Pradesh. Reliable faunistic studies providing species numbers of ostracods from such habitats are not available. The variation observed in the species numbers between these studies could be explained by many possible differences in the geomorphological and geochemical features of the rivers, the local environmental conditions and biotic conditions such as predation pressure. Still, the trend in species numbers concerning the specific taxonomical groups was consistent with other studies, i.e., rotifers having the most number of species as

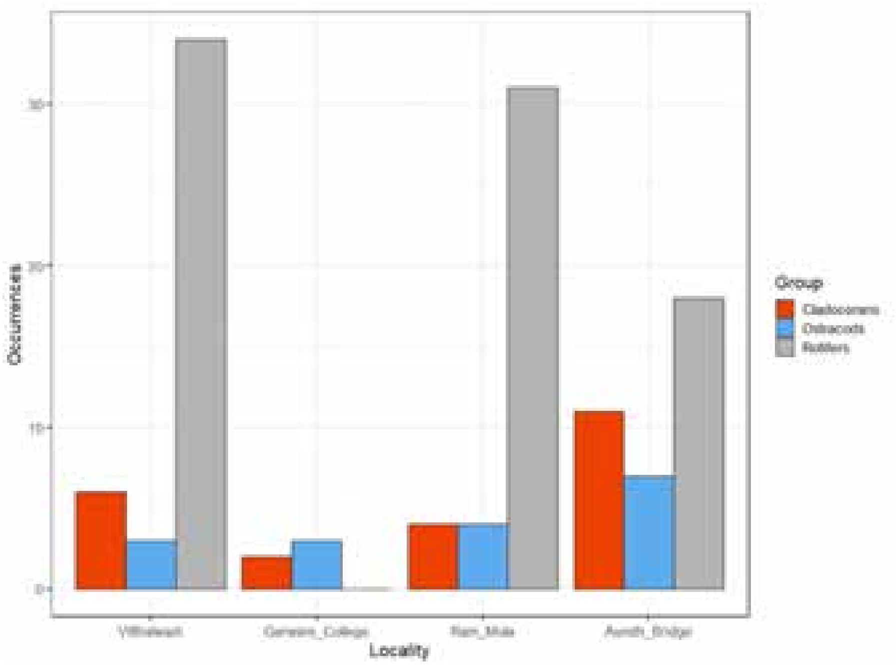

Figure 2. Number of species occurring at each of the study sites.

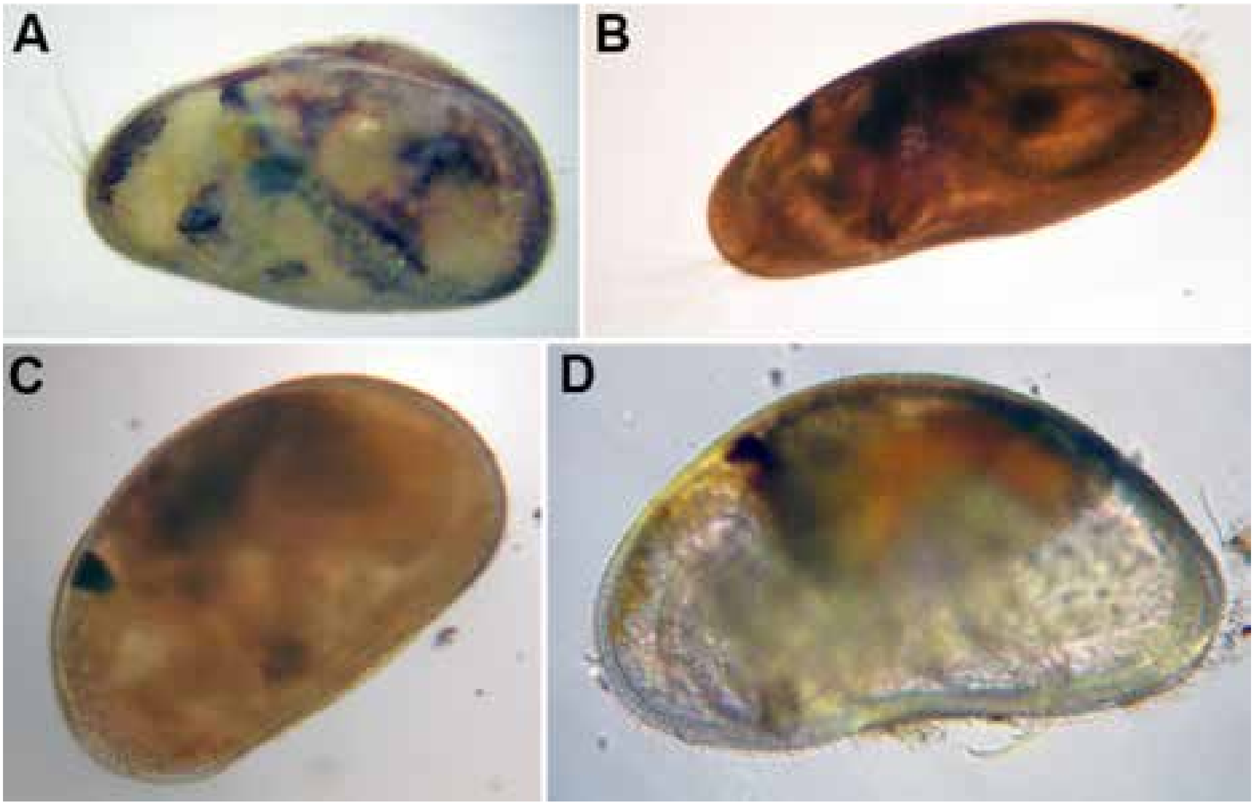

Image 1. Ostracods: A—*Cyprinotus cingalensis* Brady, 1886 | B—*Chrissia formosa* (Klie, 1938) | C—*Physocypria* sp. | D—*Plesiocypridopsis* cf. *dispar* (Hartmann, 1964). A–B images taken at 40x and C–D at 100x final magnification. © Yugandhar Shinde.

compared to cladocerans and ostracods (Sharma & Naik 1996; Arora & Mehra 2003; Sharma 2011). Similarly, the species number distribution between the order/families of each group was also in agreement with the studies available in India and other regions (Ploima being the most species-rich order in rotifers, Chydoridae being the most species-rich cladoceran family)

Occurrence of common species such as, *Moina micrura*, *Brachionus* spp., *Polyarthra* sp., and *Heterocypris incongruens* at such sites imply the ability of these organisms to tolerate a wide range of environmental conditions (Nogrady et al. 1993; Külköylüoğlu et al. 2018). Cultural eutrophication which can happen due to rapid urbanization (Dudgeon et al. 2006; Schindler 2006; Lodi et al. 2011) is known to affect zooplankton richness and increase the dominance of such common species in many cases (Nogrady et al. 1993; Dodson et al. 2000; Yuan & Pollard 2018; Kambhoj & Kambhoj 2020). Certain zooplankton species are known to evolve rapidly to cope with such environmental change to persist in unfavourable conditions like *Daphnia magna* adapting to an increased water temperature (Brans et al. 2017). The presence of such generalist species can lead to biotic homogenization, i.e., reduction in β diversity across space (Wang et al. 2021), which is a worldwide phenomenon noticed in disturbed ecosystems (Blair 2001; McKinney 2002, 2006, 2008; Liu et al. 2020). Kulkarni et al. (2021) showed that the species richness of aquatic gastropods decreased along an urbanization gradient including the rivers studied here with only invasive species reported in the most urbanized locality. This locality was very close to the Garware College site for which we recorded the lowest species numbers (Supplementary Table 1; Figure2).

The presence or absence of certain species/ groups like zooplankton can be applied to indicate environmental disturbances (Duggan et al. 2001; Hulyal & Kaliwal 2008; Du et al. 2023). Certain species from the genus *Brachionus* are indicators of eutrophic conditions of water (Mäemets 1983) and we found seven species in our collections especially *B. angularis*, *B. rubens*, *B. calyciflorus*). An epizoic association of the rotifer *Brachionus rubens* and cladoceran *Moina macrocopa* was observed at the Aundh Bridge site with over 40 individuals of *B. rubens* attached to a single individual of *M. macrocopa*. This association was seen during the peak summer months (April/May) when the DO level was very low (Vanjare et al. 2010) and not observed at any

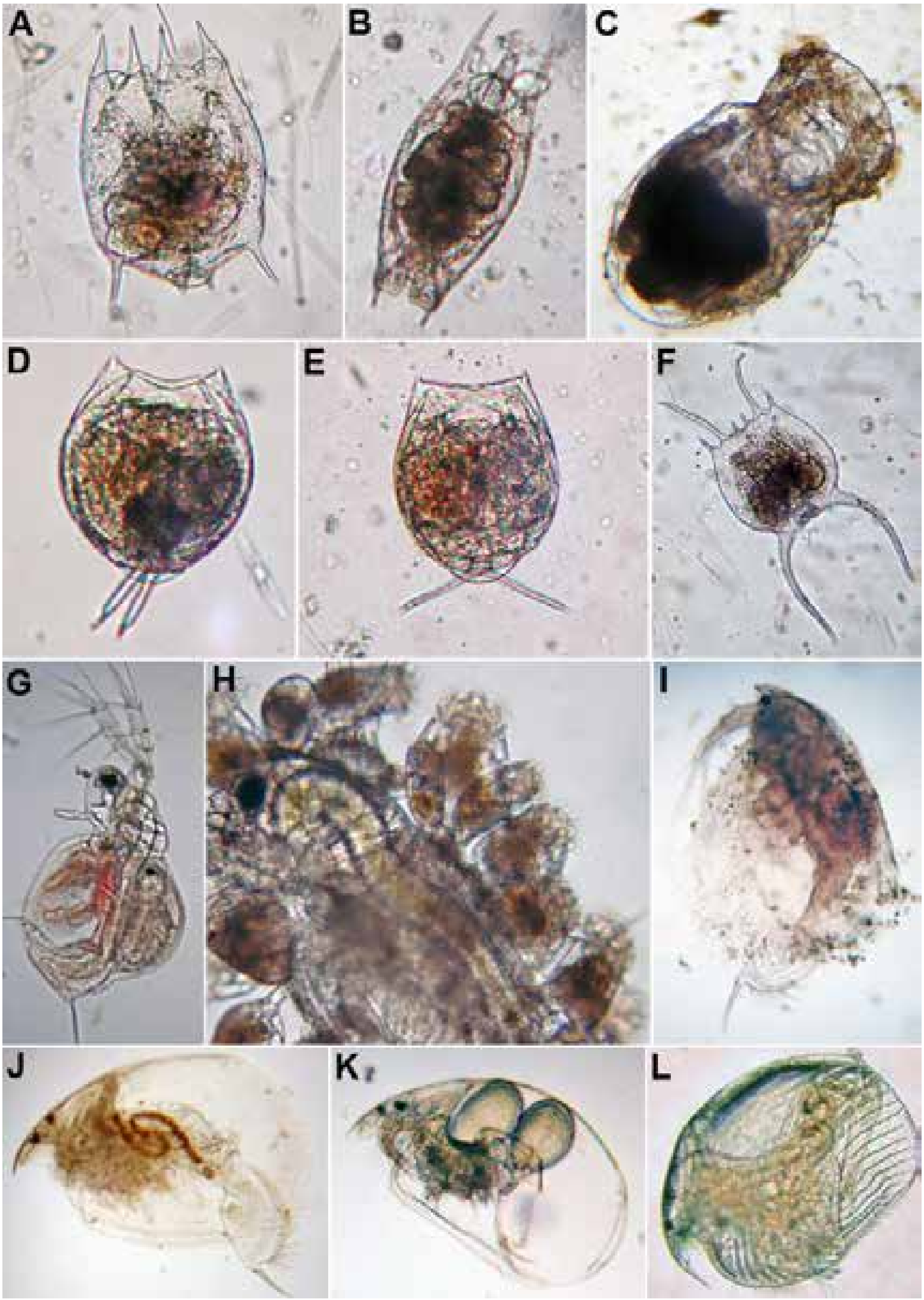

Image 2. Representative rotifers and cladocerans: A—*Brachionus calyciflorus* Pallas, 1766 | B—*Mytilina ventralis* (Ehrenberg, 1830) | C—*Asplanchnopus multiceps* (Schrank, 1793) | D—*Lecane luna* (Müller, 1776) | E—*Lecane curvicornis* (Murray, 1913) | F—*Brachionus falcatus* Zacharias, 1898 | G—*Moina micrura* Kurz, 1874 | H—Epizoic interaction of *Brachionus rubens* with *Moina macrocopa* (Straus, 1820) | I—*Ilyocryptus spinifer* Herrick, 1882 | J—*Leydigia ciliata* Gauthier, 1939 | F—*Ovalona cambouei* (Guerney et Richard, 1893) | L. *Kurzia longirostris* (Daday, 1898). H—image taken at 400x final magnification | A–G & I–L—images taken at 100x final magnification. © (A–F)—Avinash Vanjare, (G–L)—Sameer Padhye.

other studied site. Dark red-coloured cladoceran species (*Moina micrura*, *M. macrocopa*, and *K. longirostris*) were spotted at the Aundh bridge site during the summer months when the DO was the lowest (Vanjare et al. 2010). We also observed a faint red coloration in the *Moina* species collected at the other localities in the winter samples. This colour change occurs due to haemoglobin production as a response to low dissolved oxygen in the water (Fox 1949).

Our study was based only on four sites on rivers Mula Mutha with no data available for upstream patches of both the rivers where the urbanization is relatively lower than the main city. Exhaustive sampling including more upstream localities would certainly increase the species number. Studying the environmental change indicator potential of these zooplankton groups along with long-term monitoring of their community dynamics will surely help us understand and devise ways of monitoring the impacts of urbanization. Conducting such studies is crucial in light of biodiversity loss happening as a consequence of increasing urbanization (Kharat et al. 2001, 2003).

REFERENCES

Adamczuk, M., T. Mieczan, M. Tarkowska-Kukuryk & A. Demetraki-Paleolog (2015). Rotatoria–Cladocera–Copepoda relations in the long-term monitoring of water quality in lakes with trophic variation (E. Poland). *Environmental Earth Sciences* 73: 8189–8196.

Arora, J. & N.K. Mehra (2003). Seasonal dynamics of rotifers in relation to physical and chemical conditions of the river Yamuna (Delhi), India. *Hydrobiologia* 491: 101–109.

Arora, J. & N.K. Mehra (2003). Species diversity of planktonic and epiphytic rotifers in the backwaters of the Delhi segment of the Yamuna River, with remarks on new records from India. *Zoological Studies* 42(2): 239–247.

Bērziņš, B. & B. Pejler (1987). Rotifer occurrence in relation to pH. *Hydrobiologia 147*(1): 107–116.

Bērziņš, B. & B. Pejler (1989a). Rotifer occurrence in relation to oxygen content. *Hydrobiologia* 183(2): 165–172.

Bērzinš, B. & B. Pejler (1989b). Rotifer occurrence in relation to temperature. *Hydrobiologia* 175: 223–231.

Blair, R.B. (2001). Birds and butterflies along urban gradients in two ecoregions of the U.S. pp. 33–56. In: Lockwood, J.L. & M.L. McKinney (eds.). *Biotic Homogenization*. Norwell (MA): Kluwer

Braghin, L., B.D.C. Almeida, T.F. Canella, B. Garcia & C.C. Bonecker (2018). Effects of dams decrease zooplankton functional -diversity in river-associated lakes. *Freshwater Biology* 63: 721–730

Butsch, C., S. Kumar, P.D. Wagner, M. Kroll, L.N. Kantakumar, E. Bharucha, K. Schneider & F. Kraas (2017). Growing 'smart'? Urbanization processes in the Pune urban agglomeration. *Sustainability* 9(12): 2335. https://doi.org/10.3390/su9122335

Cohen, B. (2006). Urbanization in developing countries: current trends, future projections, and key challenges for sustainability. *Technology in Society* 28(1–2): 63–80.

Dodson, S.I., S.E. Arnott & K.L. Cottingham (2000). The relationship in lake communities between primary productivity and species richness. *Ecology* 81(10): 2662–2679.

Du, C., F. Zhao, G. Shang, L. Wang, E. Jeppesen, L. Zhang, W. Zhang, & X. Fang (2023). Ammonia Influences the Zooplankton Assemblage and Beta Diversity Patterns in Complicated Urban River Ecosystems. *Water* 15(8): 1449.

Dudgeon, D., A.H. Arthington, M.O. Gessner, Z.I. Kawabata, D.J. Knowler, C. Lévêque, R.J. Naiman, A-H Prieur-Richard, D. Soto, M.L.J. Stiassny & C.A. Sullivan (2006). Freshwater biodiversity: importance, threats, status and conservation challenges. *Biological reviews* 81(2): 163–182. https://doi.org/10.1017/S1464793105006950

Duggan, I.C., J.D. Green & R.J. Shiel (2001). Distribution of rotifers in North Island, New Zealand, and their potential use as bioindicators of lake trophic state. *Hydrobiologia* 446/447: 155–164.

Dumont, H.J. & S.V. Negrea (2002). *Branchiopoda. Guides to the Identification of Microinvertebrates of the Continental Waters of the World*. Backhuys, Netherlands.

Everard, M. & H.L. Moggridge (2012). Rediscovering the value of urban rivers. *Urban Ecosystems* 15: 293–314.

Fox, H. (1949). Hæmoglobin in Crustacea. *Nature* 164: 59.

George, S. & K. Martens (2002). On a new species of *Potamocypris* (Crustacea, Ostracoda) from Chalakkudy River (Kerala, India), with a checklist of the *Potamocypris* species of the world. *Zootaxa* 66: 115.

George, S. & K. Martens (2004). On the taxonomic position of the Indiacypridinae (Crustacea, Ostracoda), with the description of a new species of *Indiacypris*. *Journal of Natural History* 38: 537–548.

Gole, P. (1983). Birds of a polluted river. *Journal of Ecological Society* 32–33: 140–149

Henderson, V. (2002). Urbanization in developing countries. *The World Bank Research Observer* 17(1): 89–112.

Hulyal, S.B. & B.B. Kaliwal (2008). Water quality assessment of Almatti Reservoir of Bijapur (Karnataka State, India) with special reference to zooplankton. *Environmental Monitoring and Assessment* 139: 299–306.

Jeppesen, E., P. Noges, T.A. Davidson, J. Haberman, T. Nõges, K. Blank, T.L. Lauridsen, M. Søndergaard, C. Sayer, R. Laugaste, L.S. Johansson, R. Bjerring & S.L. Amsinck (2011). Zooplankton as indicators in lakes: a scientific-based plea for including zooplankton in the ecological quality assessment of lakes according to the European Water Framework Directive (WFD). *Hydrobiologia* 676: 279–297

Kamboj, V. & N. Kamboj (2020). Spatial and temporal variation of zooplankton assemblage in the mining-impacted stretch of Ganga River, Uttarakhand, India. *Environmental Science and Pollution Research* 27: 27135–27146.

Kar, S., P. Das, U. Das, M Bimola, D. Kar & G. Aditya (2018). Correspondence of zooplankton assemblage and water quality in wetlands of Cachar, Assam, India: Implications for environmental management. *Limnological Review* 18(1): 9.

Karakaş-Sarı, P. & O. Külköylüoğlu (2008). Comparative ecology of Ostracoda (Crustacea) in two rheocrene springs (Bolu, Turkey). *Ecological Research* 23: 821–830.

Kharat, S.S., N. Dahanukar & R. Raut (2001). Decline of freshwater fish of Pune urban area. *Journal of Ecological Society* 13(14): 46–51.

Kharat, S.S., N. Dahanukar, R. Raut & M. Mahabaleshwarkar (2003). Long-term changes in freshwater fish species composition in North Western Ghats, Pune District. *Current Science* 84(6): 816–820.

Koparde, P. & N. Raote (2016). Areas of avian richness across an urban-rural setting: A case study of selected water-bodies from Pune, Maharashtra, India. *Indian Birds* 12(2&3): 50–55

Kulkarni, A.S. & K.A. Subramanian (2013). Habitat and seasonal distribution of Odonata (Insecta) of Mula and Mutha river basins, Maharashtra, India. *Journal of Threatened Taxa* 5(7): 4084–4095. https://doi.org/10.11609/JoTT.o3253.4084-95

Kulkarni, M.R., A. Bagade & S.M. Padhye (2021). Freshwater gastropod richness patterns along an urbanization gradient in tropical India. *Journal of Urban Ecology* 7(1): juab035. https://doi.org/10.1093/jue/juab035

Külköylüoğlu, O., M. Yavuzatmaca, D. Akdemir, E. Çelen & N. Dalkıran (2018). Ecological classification of the freshwater Ostracoda (Crustacea) based on physicochemical properties of waters and habitat preferences. *Annales de Limnologie-International Journal of Limnology* 54: 26. https://doi.org/10.1051/limn/2018017

Liu, P., S. Xu, J. Lin, H. Li, Q. Lin & B.P. Han (2020). Urbanization increases biotic homogenization of zooplankton communities in tropical reservoirs. *Ecological Indicators* 110: 105899. https://doi.org/10.1016/j.ecolind.2019.105899

Lodi, S., L.C. Vieira, G. Velho, L.F.M. Bonecker, C.C.P. de Carvalho & L.M. Bini (2011). Zooplankton community metrics as indicators of eutrophication in urban lakes. *Natureza & Conservação* 9(1): 87–92.

McKinney, M.L. (2002). Urbanization, Biodiversity, and Conservation. The impacts of urbanization on native species are poorly studied, but educating a highly urbanized human population about these impacts can greatly improve species conservation in all ecosystems. *Bioscience* 52(10): 883–890.

McKinney, M.L. (2006). 'Urbanization as a Major Cause of Biotic Homogenization. *Biological Conservation* 127: 247–60.

McKinney, M.L. (2008). Effects of urbanization on species richness: a review of plants and animals. *Urban Ecosystems* 11: 161–176.

McMichael, A.J. (2000). The urban environment and health in a world of increasing globalization: issues for developing countries. *The Bulletin of the World Health Organization* 78(9): 1117–26.

Nogrady, T., R.L. Wallace & T.W. Snell (1993). *Rotifera, Vol. 1. Biology, ecology and systematics.* In: Nogrady, T. & H.J. Dumont (eds.). *Guides to the Identification of the Microinvertebrates of the Continental Waters of the World*. SPB Academic Publishing BV, The Hague, 142 pp.

Ouyang, Y., J. Higman, J. Thompson, T. O'Toole & D. Campbell (2002). Characterization and spatial distribution of heavy metals in sediment from Cedar and Ortega rivers Basin. *Journal of Contaminant Hydrology* 54(1–2): 19–35.

Padhye, S.M. & N. Dahanukar (2015). Determinants of 'water fleas' (Crustacea: Branchiopoda: Cladocera) diversity across seasonal and environmental gradients of a polluted river. *Current Science* 109: 1777–1780.

Padhye, S.M. (2020). Seasonal variation in functional composition and diversity of cladoceran zooplankton of a lotic eutrophic habitat from India. *Annales de Limnologie-International Journal of Limnology* 56: 11.

Padhye, S.M., A.I. Vanjare & K. van Damme (2023). Cladoceran community composition and diversity patterns from different lentic freshwater bodies in peninsular India. *Fundamental and Applied Limnology* 196(2): 121–135. https://doi.org/10.1127/fal/2023/1491

Padmavati, G. & S.C. Goswami (1996). Zooplankton ecology in the Mandovi-Zuari estuarine system of Goa, west coast of India. *Indian Journal of Geo-Marine Sciences* 25(3): 268–273.

Rajaram T. & A. Das (2008). Water pollution by industrial effluents in India: discharge scenarios and case for participatory ecosystem specific local regulation. *Futures* 40: 56–69.

Rao, R.J. (2001). Biological resources of the Ganga River, India. *Hydrobiologia* 458: 159–168.

Ritchie, H. & H. Roser (2018). "Urbanization". Published online at OurWorldInData.org. Retrieved from: 'https://ourworldindata.org/urbanization' Online Resource. Accessed on 1 March 2023

Schindler, D.W. (2006). Recent advances in the understanding and management of eutrophication. *Limnology and Oceanography* 51(1part2): 356–363.

Schindler, D.W. (2012). The dilemma of controlling cultural eutrophication of lakes. *Proceedings of the Royal Society B: Biological Sciences* 279: 4322–4333.

Sharma, B.K. & L.P. Naik (1996). Results on planktonic Rotifers in the Narmada River (Madhya Pradesh), pp. 189–198 In: Schiemer, F. & K.T. Boland (eds.). *Perspectives in Tropical Limnology*. SPB Academic Publishing bv. Amsterdam, The Netherlands.

Sharma, B.K. (2011). Zooplankton communities of Deepor Beel (a Ramsar site), Assam (N. E. India): ecology, richness, and abundance. *Tropical Ecology* 52(3): 293–302.

Sharma, B.K. & S. Sharma (2021). Biodiversity of Indian Rotifers (Rotifera) with remarks on biogeography and richness in diverse ecosystems. *Opuscula Zoologica (Budapest)* 52(1): 69–97. https://doi.org/10.18348/opzool.2021.1.69

Tran Khac, V., Y. Hong, D. Plec, B.J. Lemaire, P. Dubois, M. Saad & B. Vinçon-Leite (2018). An Automatic Monitoring System for High-Frequency Measuring and Real-Time Management of Cyanobacterial Blooms in Urban Water Bodies. *Processes* 6(2): 11. https://doi.org/10.3390/pr6020011

UNDESA (2018). World Urbanization Prospects: The 2018 Revision, Online Edition. United Nations, Department of Economic and Social Affairs, Population Division**.** https://population.un.org/wup/Download/Files/WUP2018-F22 Cities_Over_300K_Annual.xls. Accessed on 28 April 2023.

Vanjare, A.I., S.M. Padhye & K. Pai (2010). Zooplankton from a polluted river, Mula (India), with record of *Brachionus rubens* (Ehrenberg, 1838) epizoic on *Moina macrocopa* (Straus, 1820). *Opuscula Zoologica* 41: 89–92.

Wagh, G. K. & H.V. Ghate (2003). Freshwater fish fauna of the rivers Mula and Mutha, Pune, Maharashtra. *Zoos' Print Journal* 18(1): 977–981. https://doi.org/10.11609/JoTT.ZPJ.18.1.977-89

Yuan, L.L. & A.I. Pollard (2018). Changes in the relationship between zooplankton and phytoplankton biomasses across a eutrophication gradient. *Limnology and Oceanography* 63(6): 2493–2507. https://doi.org/10.1002/lno.10955

Supplementary Table 1. Environmental parameters at the site.

Site/ Parameter	Temperature (°C)	pH	Salinity (ppm)	DO (mg/L)	Remarks
Aundh Bridge	23.8–32.0	7.3–8.2	227–386	1.2–7.3	See Vanjare et al. 2010
Aundh Bridge	24–31.2	7.12–8.05	105–386	0.81–4.15	See Padhye & Dahanukar 2015
Ram-Mula	18.6–24.0	7.2–7.8	227–382	0.44–8.80	Current study
Vitthalwadi	22.0–30.1	7.2–8.6	129–356	0.25–11.8	Current study

Supplementary Table 2. List of species observed at the sites.

Phylum Rotifera	
Asplanchnidae	*Asplanchna brightwellii* Gosse, 1850
	Asplanchna priodonta Gosse, 1850
	Asplanchnopus multiceps Schrank, 1793
Brachionidae	*Brachionus angularis* (Gosse, 1851)
	Brachionus bidentata (Anderson, 1889)
	Brachionus calyciflorus (Pallas, 1766)
	Brachionus caudatus (Barrois & Daday, 1894)
	Brachionus diversicornis Daday, 1883
	Brachionus durgae (Dhanapathi, 1974)
	*Brachionus falcatus (*Zacharias, 1898)
	Brachionus quadridentatus (Hermann, 1783)
	Brachionus rubens (Ehrenberg, 1838)
	Keratella cochlearis (Gosse, 1851)
	Keratella tropica (Apstein, 1907)
	Plationus patulus (Müller, 1786)
	Platyias quadricornis (Ehrenberg, 1832)
Epiphanidae	*Epiphanes brachionus spinosa* (Rousselet, 1901)
	Beauchampiella eudactylota (Gosse, 1886)
	Euchlanis dilatata (Ehrenberg, 1832)
Euchlanidae	*Tripleuchlanis plicata* (Levander, 1894)
Lecanidae	*Lecane bulla* (Gosse, 1851)
	Lecane closterocerca (Schmarda, 1859)
	Lecane hamata (Stokes, 1896)
	Lecane leontina (Turner, 1892)
	Lecane luna (Müller, 1776)
	Lecane lunaris (Ehrenberg, 1832)
	Lecane papuana (Murray, 1913)
	Lecane curvicornis (Murray, 1913)
	Lecane stenroosi (Meissner, 1908)
Lepadellidae	*Colurella obtusa* (Gosse, 1886)
	Lepadella (*Heterolepadella*) *ehrenbergii* (Perty, 1850)
	Lepadella (*Lepadella*) *ovalis* (Müller, 1786)
	Squatinella lamellaris (Müller, 1786)
Mytilinidae	*Mytilina bisulcata* (Lucks, 1912)
	Mytilina ventralis (Ehrenberg, 1830)
Notommatidae	*Cephalodella* sp.
	Monommata sp.
	Taphrocampa annulosa (Gosse, 1851)

Phylum Rotifera	
Scaridiidae	*Scaridium longicaudum* (Müller, 1786)
Synchaetidae	*Polyarthra vulgaris* (Carlin, 1943)
Trichocercidae	*Trichocerca cylindrica* (Imhof, 1891)
Hexarthridae	*Hexarthra mira* (Hudson, 1871)
Filiniidae	*Filinia longiseta* (Ehrenberg, 1834)
Testudinellidae	*Testudinella patina* (Hermann, 1783)
Flosculariidae	*Sinantherina semibullata* (Thorpe, 1893)
	Lacinularia elliptica Shephard, 1897
Philodinidae	*Rotaria neptunia* (Ehrenberg, 1830)
CLADOCERA	
Sididae	*Latonopsis australis* Sars, 1888 s.lat.
	Diaphanosoma sarsi (Richard, 1895)
Daphniidae	*Daphnia* (*Ctenodaphnia*) *lumholtzi* (Sars, 1885)
	Ceriodaphnia cornuta (Sars, 1885)
	Simocephalus (*Simocephalus*) *mixtus* (Sars, 1903)
Moinidae	*Moina macrocopa* (Straus, 1820)
	Moina micrura (Kurz, 1874)
Macrothricidae	*Macrothrix spinosa* (King, 1853)
	Macrothrix triserialis (Brady, 1886)
Ilyocryptidae	*Ilyocryptus spinifer* (Herrick, 1882)
Chydoridae	*Flavalona cheni* (Sinev, 2001)
	Ovalona cambouei (Guerney et Richard, 1893)
	Kurzia longirostris (Daday, 1898)
	Leydigia (*Neoleydigia*) *ciliata* (Gauthier, 1939)
	Chydorus eurynotus (Sars, 1901)
OSTRACODA	
Cyprididae	*Chrissia formosa* (Klie, 1938)
	Stenocypris hislopi (Ferguson, 1969)
	Stenocypris derupta (Vávra, 1906)
	Cypris granulata (Daday, 1898)
	Plesiocypridopsis cf *dispar* (Hartmann, 1964)
	Heterocypris incongruens (Ramdohr, 1808)
	Hemicypris pyxidata (Moniez, 1892)
	Hemicypris ovata Sars, 1903
	Cyprinotus cingalensis Brady, 1886
Candonidae	*Physocypria* sp.
Ilyocyprididae	*Ilyocypris* sp.

Supplementary List 1. List of references used for identification, classification and nomenclature used for identifying Rotifera, Claodocera, and Ostracoda.

Benzie, J.A.H. (2005). The genus *Daphnia* (including *Daphniopsis*) (Anomopoda: Daphniidae). In: Dumont, H.J. (ed.). Guides to the identification of the microinvertebrates of the continental waters of the world. SPB Academic Publishing, 383 pp.

Berner, D.B. (1985). Morphological differentiation among species in the *Ceriodaphnia cornuta* complex (Crustacea, Cladocera). *Verhandlungen der Internationalen Vereinigung fuer Theoretische und Angewandte Limnologie* 22: 3099–3103.

Dumont, H.J. & J. Pensaert (1983). A revision of the Scapholeberinae (Crustacea: Cladocera). *Hydrobiologia* 100: 3–45. https://doi.org/10.1007/BF00027420

Dumont, H.J. & M. Silva–Briano (2000). *Karualona* n. gen. (Anomopoda: Chydoridae), with a description of two new species, and a key to all known species. *Hydrobiologia* 435: 61–82.

Dumont, H.J., M. Silva–Briano & K.K.S. Babu (2002). A re-evaluation of the Macrothrix rosea–triserialis group, with the description of two new species (Crustacea Anomopoda: Macrothricidae). *Hydrobiologia* 467: 1–44.

Goulden, C.E. (1968). The **systematics** and evolution of the Moinidae. *Transactions of the American Philosophical Society Held at Philadelphia* 58: 1–101. https://doi.org/10.2307/1006102

Hudec, I. (1991). A comparison of populations from the *Daphnia similis* group (Cladocera: Daphniidae). *Hydrobiologia* 225: 9–22.

Hudec, I. (2000). Subgeneric differentiation within Kurzia (Crustacea: Anomopoda: Chydoridae) and a new species from Central America. *Hydrobiologia* 421: 165–178.

Karanovic, **I. (2011**). On the recent Cyclocypridinae (Podocopida, Candonidae) with description of two new genera and one new species. *Zootaxa* 61: 1–61.

Korovchinsky, N.M. (1992). *Sididae & Holopediidae (Crustacea: Daphniiformes). Guides to the identification of the microinvertebrates of the continental waters of the world 3*. SPB Academic Publishing, The Hague, 82 pp.

Koste, W. (1978). Rotatoria*. Die Rädertiere Mittel-europas, begründet von Max Voigt. Überordnung Monogononta*. Gebrüder Borntraeger, Berlin, Stuttgart. I. 673 pp., II. Tafelband, 234 pp.

Koste, W. & R.J. Shiel (1987). Rotifera from Australian inland waters. II. Epiphanidae and Brachionidae (Rotifera, Monogononta). *Invertebrate taxonomy* 7: 949–1021.

Koste, W. & R.J. Shiel (1990). Rotifera from Australian inland waters. V. Lecanidae (Rotifera, Monogononta). *Transactions of the Royal Society of South Australia* 114: 1–36.

Kotov, A.A. (2000). Re-description and assignment of the chydorid *Indialona ganapati* Petkovski, 1966 (Branchiopoda: Anomopoda: Aloninae) to Indialonini, new tribus. *Hydrobiologia* 439: 161–178.

Kotov, A.A. (2009). A revision of Leydigia Kurz, 1875 (Anomopoda, Cladocera, Branchiopoda), and subgeneric differentiation within the genus. *Zootaxa* 2082: 1–68.

Kotov, A.A. & P. Štifter (2006). Ilyocryptidae of the world. Guides to the identification of the microinvertebrates of the continental waters of the world. Dumont, H.J., SPB Academic Publishing: 1–172.

Kotov, A.A., S. Ishida & D.J. Taylor (2009). Revision of the genus Bosmina Baird, 1845 (Cladocera: Bosminidae), based on evidence from male morphological characters and molecular phylogenies. *Zoological Journal of the Linnean Society* 156: 1–51.

Kuddus, M. A., E. Tynan & E. McBryde (2020). Urbanization: a problem for the rich and the poor? *Public Health Reviews* 41: 1–4.

Michael, R.G. & B.K. Sharma (1988). *Fauna of India and adjacent countries. Indian Cladocera (Crustacea: Branchiopoda: Cladocera).* Zoological Survey of India, Calcutta, 262 pp.

Onda, K., P. Sinha, A.E. Gaughan, F.R. Stevens & N. Kaza (2019). Missing millions: undercounting urbanization in India. *Population and Environment* 41: 126–150.

Rajapaksa, R. & C.H. Fernando (1986). A review of the systematics and distribution of *Chydorus ventricosus* Daday, 1898, with the first description of the male and redescription of the species. *Canadian Journal of Zoology* 64: 818–832. https://doi.org/10.1139/z86-123

Rajapaksa, R. & C.H. Fernando (1987). Redescription and assignment of *Alona globulosa* Daday, 1898 to a new genus *Notoalona* and a description of *Notoalona freyi* sp. nov. *Hydrobiologia* 144: 131–153. https://doi.org/10.1007/BF00014527

Segers, H. (1995) Rotifera 2: Lecanidae. In: Dumont, H.J. & Nogrady, T. (Eds.) *Guides to identification of the Microinvertebrates of* the *Continental waters of the world*, *6*. SPB Academic Publishing bv. Amsterdam, the Netherlands, 226 pp.

Segers, H. (2002). The nomenclature of the Rotifera: annotated checklist of valid familyand genus-group names. *Journal of Natural History* 36(6): 631–640.

Segers, H. (2007). Annotated checklist of the rotifers (Phylum Rotifera), with notes on nomenclature, taxonomy and distribution. *Zootaxa* 1564 (1): 1–104.

Sinev, A.Y. (1999). *Alona costata* Sars, 1862 versus related palaeotropical species: the first example of close relations between species with a different number of main head pores among Chydoridae (Crustacea: Anomopoda). *Arhropoda Selecta* 8(3): 131–148.

Sinev, A.Y. (2001). Separation of *Alona cambouei* Guerne & Richard, 1893 from *Alona pulchella* King, 1853 (Branchiopoda: Anomopoda: Chydoridae). *Arthropoda Selecta* 10(1): 5–18.

Sinev, A.Y., K. Van Damme & A.A. Kotov (2005). Redescription of tropical–temperate cladocerans *Alona diaphana* King, 1853 and *Alona davidi* Richard, 1895 and their translocation to *Leberis* Smirnov, 1989 (Branchiopoda: Anomopoda: Chydoridae). *Arthropoda Selecta* 14(3): 183–205.

Sinev, A.Y. (2011). Re-description of the rheophilous Cladocera *Camptocercus vietnamensis* Than, 1980 (Cladocera: Anomopoda: Chydoridae). *Zootaxa* 2934: 53–60.

Sinev, A.Y., P.G. Garibian & Y. Gu (2016). A new species of *Pseudochydorus* Fryer, 1968 (Cladocera: Anomopoda: Chydoridae) from South-East Asia. *Zootaxa* 4079: 129–139.

Sharma, B.K. & S. Sharma (2014). The diversity of Indian Brachionidae (Rotifera: Eurotatoria: Monogononta) and their distribution. *Opuscula Zoologica (Budapest)* 45(2): 165–180.

Sharma, B.K. & S. Sharma (2021). Biodiversity of Indian Rotifers (Rotifera) with remarks on biogeography and richness in diverse ecosystems. *Opuscula Zoologica (Budapest)* 52(1): 69–97.

Smirnov, N.N. (1971). Chydoridae fauny mira. Fauna USSR. Rakoobraznie, 1. Leningrad [English translation: Chydoridae of the World]. *Israel Program for Scientific Translations*, Jerusalem.

Smirnov, N.N. (1992). The Macrothricidae of the world. In: Dumont, H.J. (ed.). *Guides to the Identification of the Microinvertebrates of the Continental Waters of the World*. SPB Academic Publications, 143 pp.

Smirnov, N.N. (1996). Cladocera: The Chydorinae and Sayciinae (Chydoridae) of the World*.* In: Dumont, H.J. (ed.). *Guides to the Identification of the Microinvertebrates of the Continental Waters of the World*. SPB Academic Publications, 197 pp.

van Damme, K. & H.J. Dumont (2008). The 'true' genus *Alona* Baird, 1843 (Crustacea: Cladocera: Anomopoda): characters of the A. quadrangularis group and description of a new species from Democratic Republic Congo. *Zootaxa* 1945: 1–25.

van Damme, K., A.Y Sinev & H.J. Dumont (2011). Separation of *Anthalona* gen.n. from *Alona* Baird, 1843 (Branchiopoda: Cladocera: Anomopoda): morphology and evolution of scraping tenothermic alonines. *Zootaxa* 2875: 1–64.

Victor, R. & C.H. Fernando (1979). Freshwater ostracods (Ostracoda: Crustacea) of India. *Records of Zoological Survey of India* 74: 147–242.

Victor, R. & C.H. Fernando (1981a). Freshwater Ostracoda of the genera *Chrissia* Hartmann, 1957 and *Stenocypris* Sars, 1839 from Malaysia, Indonesia and the Philippines. *Mitteilungen aus dem Hamburgischen Zoologischen Museum und Institut* 78: 151–168.

Victor, R. & C.H. Fernando (1981b). Freshwater ostracods (Crustacea: Ostracoda) of the subfamily Cyprinotinae Bronstein, 1947 from Malaysia, Indonesia and the Philippines. *Hydrobiologia* 83: 11–27.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 September 2023 | 15(9): 23889–23897

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

https://doi.org/10.11609/jott.8153.15.9.23889-23897

#8153 | Received 18 August 2022 | Final received 19 June 2023 | Finally accepted 05 July 2023

COMMUNICATION

Utilization of a new restoration technique for the rehabilitation of a degraded mangrove ecosystem: a case study from Koggala Lagoon, Sri Lanka

Mahanama Gamage Greshan Dhanushka [1], Maduwe Guruge Manoj Prasanna [2], Kariyawasam Marthinna Gamage Gehan Jayasuriya [3] & Indupa Hasindi Vitanage [4]

[1] Wildlife and Ocean Resources Conservation Society, 121/3, Seethawaka Estate, Urugamuwa, Matara, Sri Lanka.
[2] Ministry of Environment, 414 1C, Robert Gunawardana Mw., Baththaramulla, Sri Lanka.
[3] Department of Botany, University of Peradeniya, Peradeniya, Sri Lanka.
[4] Young Zoologists' Association of Sri Lanka, National Zoological Gardens, Anagarika Dharmapala Mawatha, Dehiwala, Sri Lanka.
[1] mggdhanushka1981@yahoo.com, [2] mprasanna74@yahoo.com, [3] gejaya@gmail.com, [4] hvitanage@gmail.com (corresponding author)

Abstract: Mangrove ecosystems, amongst the most productive and biologically complex on Earth, are being degraded worldwide, and their widespread decline during the past decades has affected vital ecosystem services. Mangroves at Koggala lagoon on the southern coast of Sri Lanka have been degraded at an alarming rate due to agricultural practices, coastal zone development, and tourism activities. Most of the banks are heavily eroded due to boat and sea plane activities, and the mangrove ecosystem has been significantly damaged. Implementation of a scientific rehabilitation project was needed to restore this degraded mangrove ecosystem, and research was carried out to enrich the mangrove community by re-establishing mangroves on the eroded banks using corrosion-resistant plastic barrels. The sustainability of replanted mangroves was monitored under phase one and the re-establishment of ecological functions in the mangrove community was monitored under phase two. The accumulated biomass carbon during the period of two and half years was calculated by an allometric equation suggested for calculating biomass carbon of mangroves using the girth and height of individuals. The highest rate of girth increment was observed by the 24th month from establishment, whilst the growth rate declined between the 18th and the 30th months. During the study period, the average above-ground and below-ground biomass per barrel showed a linear increment. Our case study showed that the new method used for restoration is successful in establishing mangroves in sites with high erosion. This restoration technique was successful in coping with the situation in Koggala lagoon where previous restoration attempts were failures. Thus, we recommend this restoration method for sites facing the threat of severe erosion.

Keywords: Allometric equations, carbon stocks, ecological function, eroded banks, growth rate, mangrove establishment, restoration technique.

Editor: Anonymity requested.

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

Citation: Dhanushka, M.G.G., M.G.M. Prasanna, K.M.G.G. Jayasuriya & I.H. Vitanage (2023). Utilization of a new restoration technique for the rehabilitation of a degraded mangrove ecosystem: a case study from Koggala Lagoon, Sri Lanka. *Journal of Threatened Taxa* 15(9): 23889–23897. https://doi.org/10.11609/jott.8153.15.9.23889-23897

Funding: Commercial Bank, MAS Intimates and INSEE Cement Corporation.

Competing interests: The authors declare no competing interests.

Author details: MAHANAMA GAMAGE GRESHAN DHANUSHKA serves as Chairman of Wildlife and oceans Resources Conservation Society. Actively contributes to the conservation and restoration of mangrove and coral reefs. Direct contribution to turtle conservation and awareness programmes is provided as well. MADUWE GURUGE MANOJ PRASANNA obtained his PhD from University of Peradeniya and currently working as project coordinator at Biodiversity Secretariat. Contributed several research programmes and published more than 10 research papers on mangrove ecology and it functions under the Biodiversity Secretariat. His major research area is mangrove ecology. KARIYAWASAM MARTHINNA GAMAGE GEHAN JAYASURIYA obtained his PhD from University of Kentucky and currently working as a professor in Botany in the Department of Botany, University of Peradeniya. Contributed to more than 35 SCI-indexed publications. His major research area is the seed biology of wild species assisting towards their conservation. INDUPA HASINDI VITANAGE obtained Diplomas in Palaeobiodiversity and Zooarchaeology from Postgraduate Institute of Archaeology, University of Kelaniya. Actively contributes to biodiversity conservation, related research and awareness programmes as a member of Young Zoologists' Association of Sri Lanka (YZA). Contributed to two publications.

Author contributions: M.G.G Dhanushka contributed to the study conception and design. Experimental arrangements and data collection were conducted by M.G.G Dhanushka. Data analysis was performed by K.M.G.G. Jayasuriya. The first draft of the manuscript was written by M.G.M. Prasanna, I.H. Vitanage and K.M.G.G. Jayasuriya and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Acknowledgements: The authors sincerely thank the principal sponsor, Commercial Bank and other sponsors, MAS Intimate, DER Touristik Foundation, and INSEE Cement Corporation for their faithful contribution towards the project. Furthermore, Trustees of the Commercial Bank CSR Trust, Coordinator - CSR Trust and the whole staff of CSR Unit, Alle Indrasobana Nayaka Thero of Thalathuduwa Aranya Senasana, L. J. Mendis Wickramasinghe, W.D. Dayawathi, Thilak Leelasena and Indika Sampath Ruwankumara are acknowledged for their valuable support.

INTRODUCTION

Mangroves are among the world's most productive and biologically complex ecosystems, acting as bridges between land and sea. Thriving in intertidal areas along tropical and subtropical coastlines, mangroves consist of salt-tolerant woody plant species and are commonly found in lagoons, bays, and estuaries (Prasanna & Ranawana 2014), including several locations in Sri Lanka (Ministry of Environment 2012). Mangroves provide a multitude of essential goods and services crucial for human well-being and survival. They play a crucial role in maintaining the ecological integrity of coastal zones and provide many ecosystem services categorized as provisioning, regulatory, supportive as well as cultural services (Donato et al. 2011; Feller et al. 2017). Carbon sequestration is one of the most significant services provided by mangroves, as they possess a remarkable capacity to capture and retain high amounts of carbon in the soil owing to high productivity compared to other terrestrial ecosystems (Alongi 2014). Consequently, mangroves contribute significantly to the reduction of greenhouse gases and aid climate change mitigation efforts. Despite their importance, mangrove ecosystems have suffered global degradation (Duke et al. 2017; Feller et al. 2017), resulting in the decline of their ecosystem services over the past decades. According to Mukherjee et al. (2014), approximately 60% of major global ecosystem services have been degraded either totally or partially.

Mangrove Ecosystems of Sri Lanka

Sri Lanka, a tropical island with numerous estuaries and lagoons, possesses a diverse range of mangrove ecosystems along its coastline (Edirisinghe et al. 2012). These mangrove ecosystems consist of two types of plant communities: true mangroves and mangrove associates. True mangroves are woody plants that exclusively occur in mangrove forests, displaying specific adaptations to the environment and physiological mechanisms to tolerate high salinity levels (Tomlinson 2016). In contrast, mangrove associates are primarily herbaceous plants found in terrestrial or aquatic habitats, but they can also be present within the mangrove ecosystem (Tomlinson 1986). Most Sri Lankan mangrove areas (92.6%) are confined to the dry and intermediate zones. Similar to the global situation, Sri Lankan mangroves were also degraded especially during the last four decades due to various anthropogenic activities (Wickramasinghe et al. 2022).

Nevertheless, mangrove research and rehabilitation efforts have progressed steadily over the last several decades as the importance of mangrove ecosystems has been better understood and documented. Furthermore, the mangrove ecosystems are considered a predominantly important ecosystem for coastal communities due to their provision of ecosystem services, such as supplying timber and fuel wood, supporting fisheries, sediment trapping, coastal defence and carbon storage (Donato et al. 2011; Feller et al. 2017). Amongst all the ecosystems across the tropics, mangrove ecosystems are considered one of the most threatened (Duke et al. 2017) mainly due to impacts from anthropogenic activities including conversion to agriculture and aquaculture as well as urbanisation and pollution (Feller et al. 2017). Under these circumstances, huge efforts are being put into mangrove rehabilitation and restoration in degraded areas. Though, such large-scale efforts are generally unsuccessful due to various reasons such as poor species selection, inappropriate location selection and poor knowledge of mangrove ecology as well as physiology (Kodikara et al. 2017). However, when elements of species biology and hydrological requirements are incorporated into the design and implementation of rehabilitation projects with an appropriate knowledge base, some efforts are becoming more successful (Feller et al. 2017).

Status of Koggala Lagoon mangrove ecosystem

The Koggala lagoon is situated in the Southern province of Sri Lanka, specifically between 5°58'–6°20' N & 80°17'–80°22' E. It encompasses an area of 727 ha and consists of 14 islets (IUCN and Central Environmental Authority, 2006; Gunaratne et al. 2010). Several tributaries, including the Koggala Oya, provide freshwater input to the lagoon. The hydrology and water quality of the lagoon, including salinity and pH, are influenced by heavy rainfall and the characteristics of the lagoon mouth due to its location in the wet zone of the country. Previous studies have reported the presence of 10 true mangrove species in the lagoon. However, the classification of *Acrosticum aurium* and *Dolchandrone spathacia* as true mangroves by IUCN and Central Environmental Authority (2006) is disputed by the experts' team of the National Red List (2012), who considers them as mangrove associates. Therefore, the number of true mangrove species identified in the lagoon is recognized as eight. Mangroves are found in a narrow strip surrounding the lagoon's islands and along the stream banks. Unfortunately, due to activities such as boating and sea plane landing, and take-off, many of the banks have undergone degradation and significant erosion, leading to substantial damage to the mangrove ecosystems in the area.

The structure of the lagoon mouth has changed since 1990 due to the removal of the natural sand barrier (Gunarathne 2011). Consequently, sand started to deposit on the river mouth and the bridge over Pol Oya in Galle-Matara main road, blocking the water flow. A rubble mound groyne system (old groyne) was built in 1997 to prevent the issue. Due to this artificial construction, erosion of the lagoon bank became threatened as the Galle-Matara main road and bridge became vulnerable to sea erosion. Another groyne (new groyne) (Image 1) was established in 2005 to control the said situation (Gunarathne 2011). The outlet (Image 2) has been diverted westward creating an approximately 30–40 m wide open passage to the sea consequently (Gunawickrama & Chandana 2006).

The construction of an artificially built groyne in the Koggala lagoon initially resulted in a reduction of sand deposition. However, it also led to seawater intrusion into the lagoon (Gunawickrama & Chandana 2006). Over time, sand deposition resumed at the river mouth, causing water blockage and a subsequent decrease in water salinity and a rise in water level. The increased water level further contributed to bank erosion within the lagoon. These degraded banks, characterized by high erosion and stream flow, present challenges for natural regeneration and make it impossible to rehabilitate the mangrove community. Additionally, the degradation and heavy erosion of the banks caused by boating and seaplane activities further exacerbate the problem.

Despite previous attempts at planting mangrove seedlings in the Koggala lagoon, the general approach has failed multiple times in recent years. Natural regeneration has not been observed in the degraded banks of the lagoon, necessitating a new restoration approach and the implementation of a continuous monitoring mechanism to ensure the success of mangrove restoration. Therefore, the primary objective of the study was to enhance the mangrove community in the Koggala lagoon using a technique suitable for the prevailing conditions in the lagoon.

METHODS

Establishment of the restoration trail

A controlled plot using general restoration processes could not be established due to the unsuitable ground conditions and heavy erosion of the lagoon banks. A new restoration approach was designed to support restored plants to withstand the bank erosion. In this approach mangrove saplings were planted in plastic barrels.

Empty and well-cleaned chemical plastic barrels (~38 cm diameter and ~79 cm height) were gathered from factories located in the area. The top and bottom of all the barrels were removed. Thirty seven of these barrels were placed in holes excavated in eroded banks of three islands: Thalathuduwa, Kuruluduwa (Image 3) and Ganduwa. Barrels were placed with 60–90 cm spacing between each other, covering ~600 m stretch of the banks. The barrels were filled with soil excavated from the same restoration site. Two true mangrove species occurring in the area, *Rhizophora mucronata* and *R. apiculta* were selected as restoring species for this pilot study. These two species were selected as they contain large numbers of prop and stilt roots which assist in the proper establishment of the plant in the planted site. The availability of diaspores at the time of nursery establishment was also considered. Four *R. mucronata* saplings (~20–35 cm height) and one *R. apiculta* sapling (~20–35 cm height) were planted in each barrel. Saplings were raised in a nearby nursery using the diaspores collected from trees in the existing vegetation of the Koggala lagoon.

Maintenance and monitoring

Planted seedlings were observed weekly during the first six months, and later monthly. Dead saplings were not replaced as it would affect the final analysis. There was no need to replenish the soil, as the soil in the barrels was not eroded during the period (Image 4). The diameter at breast height (dbh) and height of each sapling in each barrel were recorded on the first day of planting and then after every six months for two and half years. Monthly measurements were not taken as the changes in girth and height were not significant within a month.

Data analysis

Height and dbh increments were separately plotted against time. A logistic four-parameter sigmoidal curve was fitted to determine the pattern of growth (Tsoularis 2001). The growth rate based on height and dbh was calculated separately for six months period from the initial planting date to August 2020. Accumulated biomass carbon during the period of two and half years was calculated using the dbh and height of the individuals with an allometric equation suggested for calculating biomass carbon of mangroves.

Above ground biomass (AGB) for *Rhizophora mucronata*,

Image 1. Satellite image of lagoon outlet with the existing groyne structures in 2010 (Source: Google Earth Pro 2022).

Image 2. The present situation of Koggala Lagoon mouth (Source: Google Earth Pro 2022).

Image 3. First mangrove planting in Kurulu Duwa island in July 2018.

Image 4. The soil in the barrels was not eroded even after a year from planting, another mangrove hedge was planted in barrels parallel to the previous mangrove hedge.

$\log_e(AGB) = 6.247+2.64 \log_e(dbh)$ (Amarasinghe & Balasubramaniam 1992b)

and for *Rhizophora apiculata*,

$AGB = 0.251 \rho\, dbh^{2.46}$ (Komiyama et al. 2005)

Bellow ground biomass (BGB) for both species,

$BGB = 0.199 \rho^{0.899} dbh^{2.46}$ (Komiyama et al. 2005)

RESULTS

Survival of plants during the two-and-half years of the monitoring period

After the first six months of establishment, all the *R. mucronata* and *R. apiculata* saplings survived in the study site. Within the next six months period, more *R. apiculata* saplings died compared to *R. mucronata* saplings. After 18 months of establishment, 85 % of the R. *mucronata* and 67 % of R. *apiculata* saplings survived (Figure 1). Thereafter, none of the remaining saplings died during the observation period of 30 months.

Growth of established saplings

The height of both *R. mucronata* and *R. apiculta* increased gradually with time, following a sigmoidal curve as expected (Figure 2). However, the height increment of *R. apiculata* was slightly higher than that of *R. mucronata.* The dbh of the saplings of both species increased with time in a similar pattern (Figure 3). dbh increment of *R. apiculata* was also higher than that of *R. mucronata*.

The height increment rate of *R. apiculata* was higher than that of *R. mucronata* throughout the observational period (Figure 4A). However, during the first 12 months period, the dbh increment rate of *R. mucronata* was higher than that of *R. apiculta*, whereas, during the rest of the period, the dbh increment rate of *R. apiculata* was slightly higher than *R. mucronata* (Figure 4B). The rate of height increment of the two species increased with time until the 18th month from the establishment and started to decline thereafter. Thus, the highest rate of height increment was observed by the 18th month of the establishment. The highest rate of dbh increment was observed by the 24th month from establishment whilst the increment rate declined between the 18th–30th month from establishment.

Biomass Carbon accumulation by the established stand

The average above-ground and below-ground biomass per barrel showed a linear increment during the study period (Figure 5). At the end of the study period, the average above-ground biomass per barrel was 70.7 ± 11.7 kg. This biomass included 29.7 ± 4.9 kg of carbon and it is equivalent to 108.2 ± 17.9 kg of CO_2. Bellow ground biomass content at the time of final observation was 35.0 ± 5.8 kg per barrel. This included 14.7 ± 2.4 kg of carbon and equivalent to 53.5 ± 8.3 kg of CO_2. By the end of the study period, plants have accumulated 105.8 ± 17.5 kg of biomass per barrel which contained 44.4 ± 7.3 kg of carbon per barrel and which is equivalent to 161.7 ± 26.8 kg of CO_2. Thus, these plants have sequestrated 217.15 tonnes of carbon per hectare, which is equivalent to 788.1 tonnes of CO_2 per hectare.

According to the calculations up to the final sampling date, the study site has accumulated 2,619.5 kg, 1294.5 kg and 3,914.9 kg of above-ground, below-ground and total biomass respectively. Furthermore, the total biomass accumulated up to the final monitoring date included 1,643.9 kg of carbon which is equivalent to 5,983.9 kg of CO_2.

However, up to the end of the monitoring period, no natural recolonization was observed in the restored area.

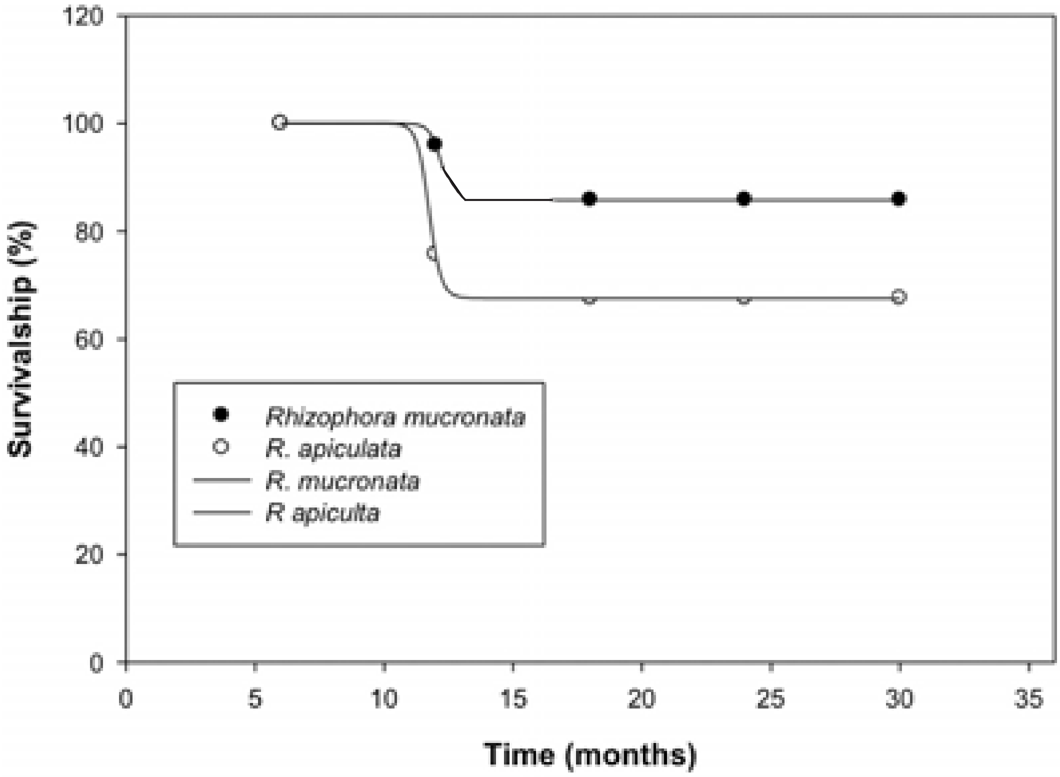

Figure 1. Survival percentage of *Rhizophora mucronata* and *R. apiculata* saplings during the 30th months of the observation period. Four-parameter logistic curves were fitted to observe the pattern of survival.

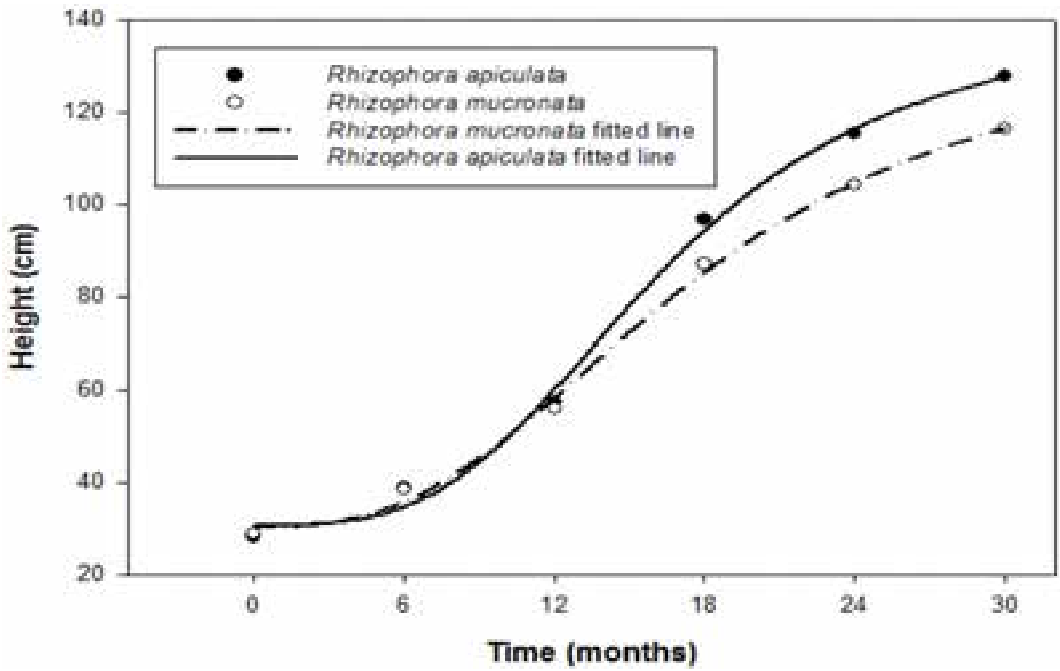

Figure 2. Height increment of *Rhizophora mucronata* and *R. apiculata* saplings against time, during the monitoring period. Four-parameter logistic sigmoidal curves were fitted to determine the pattern of height increment.

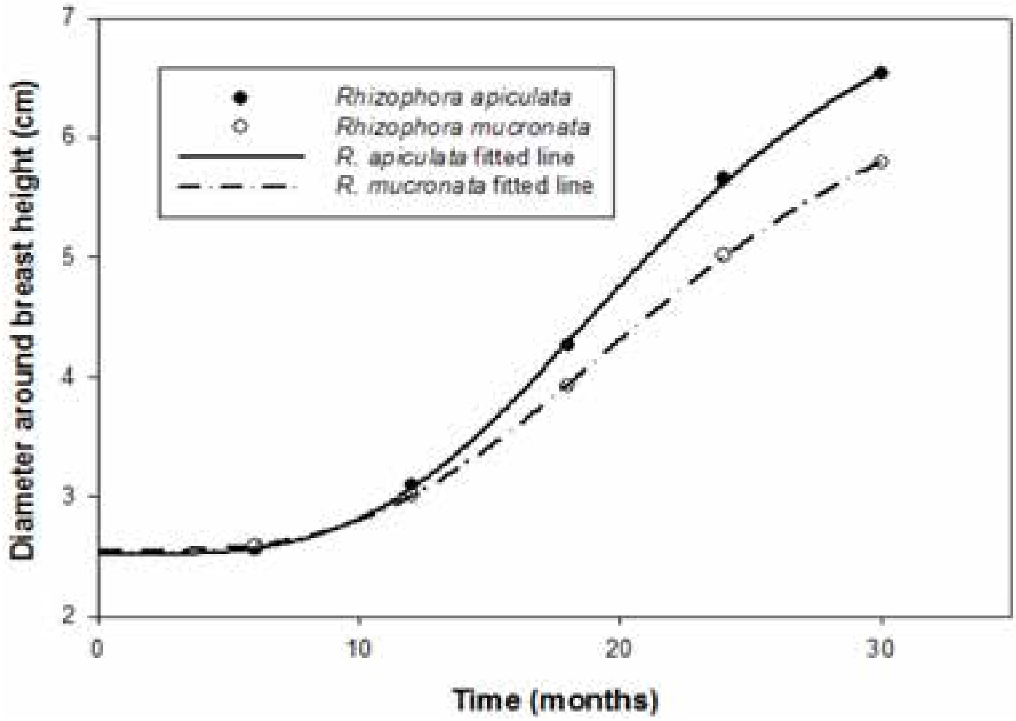

Figure 3. Diameter at breast height increment of *Rhizophora mucronata* and *R. apiculata* saplings during the monitoring period. Four parameter logistic sigmoidal curves were fitted to determine the pattern of height increment.

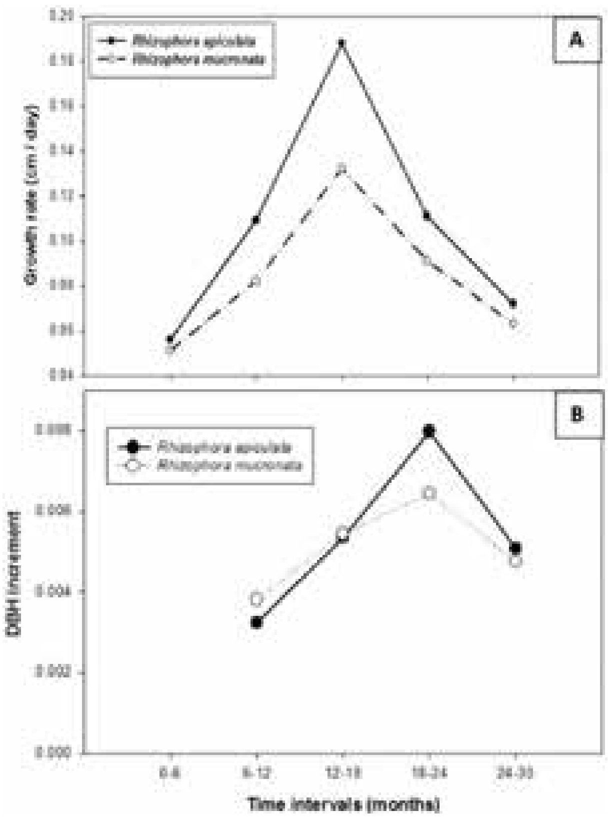

Figure 4. A—Height increment rate | B—girth increment rate of *Rhizophora mucronata* and *R. apiculata* were established in barrels in the Koggala lagoon.

DISCUSSION

The results of this study indicate the success of the restoration technique employed, as evidenced by the high survival rates of the restored species after a substantial period since the establishment (2½ years). The observed survival rates of 85% for *R. mucronata* saplings and 65% for *R. apiculta* suggest the effectiveness of the restoration approach.

Comparison with previous trials conducted without a controlled plot revealed a significant improvement in sapling survival. In contrast to previous attempts, where none of the saplings survived for more than a year, the current restoration technique demonstrated higher success rates. These findings align with research conducted by Kodikara et al. (2017) on mangrove restoration projects in Sri Lanka, where most restored sites exhibited less than 50% survival, and only a small number surpassed this threshold. Thus, the higher sapling survival rates observed at the Koggala mangrove restoration site indicate a comparative success compared to other restoration efforts.

Sapling growth analysis showed that saplings of both species used have normal sigmoidal growth patterns and they were reaching the maturity level. Especially, the reduction in growth rate during the 24^{th}–30^{th} month of

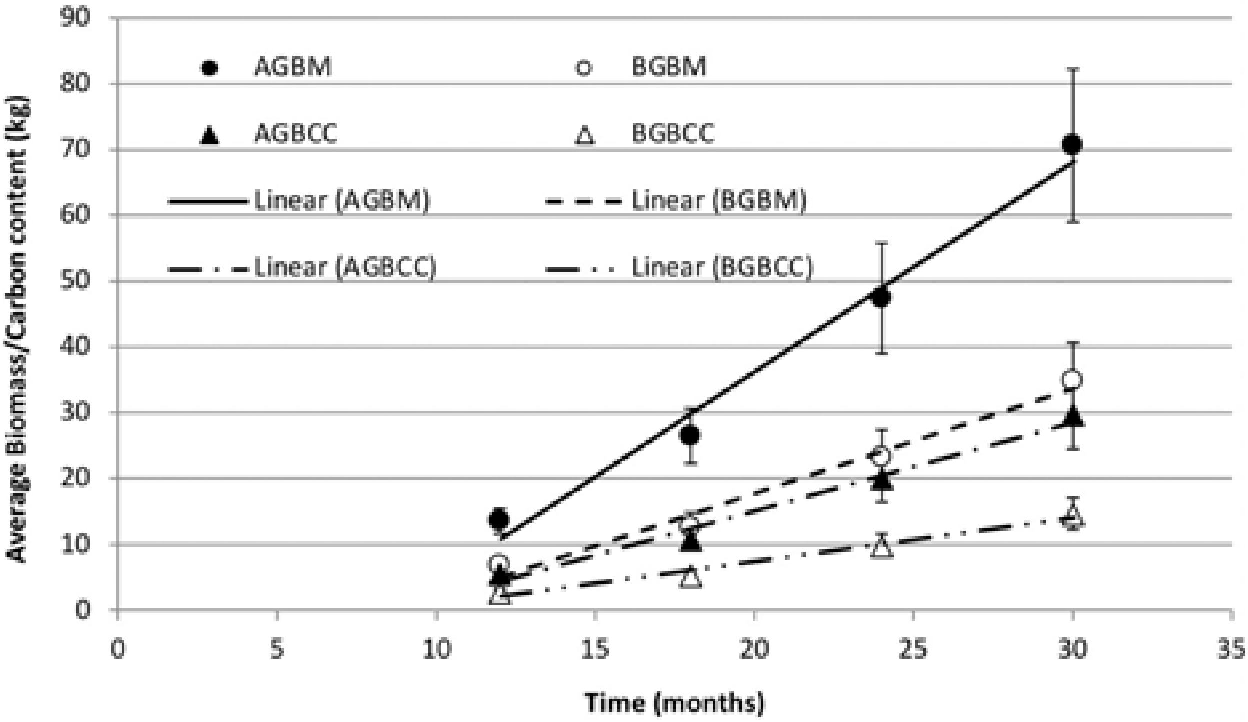

Figure 5. Average biomass and carbon accumulation of the established plant with time. Error bars are ± SE.

Image 5. Mangrove plants after forty-five months from planting.

establishment shows that these saplings were gradually reaching the matured stage. Thus, it seems that the plants have well established within the restored sites.

The restoration of the mangrove site demonstrated a significant potential for carbon sequestration, with an observed carbon sequestration rate of 217.15 tonnes per ha (equivalent to 788.1 tonnes of CO_2 per ha), highlighting its contribution to reducing atmospheric CO_2 levels. However, it cannot be compared with the total carbon content reported in other mangroves. However, the above-ground biomass carbon content of the restored site (128.8 t per ha) was higher than the average above-ground carbon content for global mangroves (78 t of carbon per ha; Estrada & Soares 2017), Mahanadi Mangrove, India (Sahu et al. 2016), and Negambo estuary (80.5 t of carbon per ha; Perera et al. 2018). This value is slightly lower than that was reported for Batticaloa lagoon (131 t of carbon per ha; Perera et al. 2018) in Sri Lanka. These unusually high values may have been caused due to lower planting spacing of the restoration site than the usual spacing of a natural mangrove community. Further, the used spacing in the current study is less than the recommended spacing between mangrove seedlings planting for restoration (80–120 cm recommended [Intenational Coral Reef Initiative and Pole-Relais, Zones Humides Tropicales, 2020] vs. 60–90 in the current study). Thus, thinning of the mangrove vegetation of the restored site may be required to allow the saplings to grow in their usual manner.

Our analysis showed a higher growth rate in *R. apiculata* compared to *R. mucronata* when considering the dbh and height. This could be due to the genetic potential of the two species as the same type of observation has been reported by Nit et al. (2011). However, further studies are needed to conclude the growth rates of the two species.

Our case study showed that the new method of mangrove restoration is successful in establishing mangroves in sites facing high erosion (Image 5). Especially, it seems that the new method is successful in coping with the situation in the Koggala lagoon as previous normal restoration trials conducted on this site failed. Thus, we recommend this restoration method for sites facing the threat of severe erosion.

REFERENCES

Alongi, D.M. (2014). Carbon sequestration in mangrove forests. *Carbon Management* 3(3): 313–322.

Donato, D.C., J.B. Kauffman, D. Murdiyarso, S. Kurnianto, M. Stidham & M. Kanninen (2011). Mangroves among the most carbon-rich forests in the tropics. *Journal of Nature Geoscience* 4: 293–297.

Duke, N.C., J.M. Kovacs, A. Griffith, L. Preece, D.J. Hill, P. Oosterzee, J. Mackenzie, H.S. Morning & D. Burrows (2017). Large-scale dieback of mangroves in Australia's Gulf of Carpentaria: a severe ecosystem response, coincidental with an unusually extreme weather event. *Journal of Marine and Freshwater Research* 68(10): 1816–1829. https://doi.org/10.1071/MF16322

Edirisinghe, E.A.P.N., K.P. Ariyadasa & R.P.D.S. Chandani (2012). Forest Cover Assessment of Sri Lanka. *The Sri Lankan Forester* 34: 1–12.

Estrada, G.C.D. & M.L.G. Soares (2017). Global patterns of aboveground carbon stock and sequestration in mangroves. *Annals of the Brazilian Academy of Sciences* 89(2): 973–989. https://doi.org/10.1590/0001-3765201720160357

Feller, I.C., D.A. Friess, K.W. Krauss & R.R. Lewis III (2017). The state of the world's mangroves in the 21st century under climate change. *Journal of Hydrobiologia* 803: 1–12. https://doi.org/10.1007/s10750-017-3331-z

Gunaratne, G.L., L. Tanaka, G.P. Amarasekara, T. Priyadarshana & J. Manatunge (2011). Impact of rubble mound groyne structural interventions in restoration of Koggala lagoon, Sri Lanka; numerical modelling approach. *Journal of Coast Conservation* 15: 113–121. https://doi.org/10.1007/s11852-010-0125-0

Gunawickrama, K.B.S. & E.P.S. Chandana (2006). Some Hydrographic aspects of Koggala Lagoon with preliminary results on distribution of the marine bivalve *Saccostrea forskalli*: pre-tsunami status. *Ruhuna Journal of Science* 1: 16–23.

Kodikara, K.A.S., N. Mukherjee, L.P. Jayatissa, F. Dahdouh-Guebas & N. Koedam (2017). Have mangrove restoration projects worked? An in-depth study in Sri Lanka. *Restoration Ecology* 25: 705–716. https://doi.org/10.1111/rec.12492

Ministry of Environment (2012). *The National Red List 2012 of Sri Lanka; Conservation Status of the Fauna & Flora.* Ministry of Environment, Colombo, Sri Lanka, viii + 476 pp.

Mukherjee, N., W.J. Sutherland, L. Dicks, J. Huge, N. Koedam & F. Dahdouh-Guebas (2014). Ecosystem Service Valuations of Mangrove Ecosystems to Inform Decision Making and Future Valuation Exercises. *PLoS ONE* 9(9): e107706. https://doi.org/10.1371/journal.pone.0111386

Nit, L.B.E. & P.P. Abit (2011). Growth and survival of mangrove seedlings under different levels of salinity and drought stress. *Annals of Tropical Research* 33(2): 107–129.

Perera, K.A.R.S., K.H.W.L. De Silva & M.D. Amarasinghe (2018). Potential Impact of Predicted Sea-Level Rise on Carbon Sink Function of Mangrove Ecosystems with Special Reference to Negombo Estuary, Sri Lanka. *Journal of Global and Planetary Change* 161: 162–177.

Prasanna, M.G.M. & K.B. Ranawana (2014). *Guide to Mangroves of Sri Lanka.* Biodiversity Secretariat, Ministry of Environment and Renewable Energy, Battaramulla, Sri Lanka, 70 pp.

Prasanna, M.G.M., K.B. Ranawana, K.M.G.G. Jayasuriya, P. Abeykoon & M. Ranasinhe (2017). Mangrove Species Distribution, Diversity and Present Status in the North and East Coast of Sri Lanka. *Journal of Wild Lanka* 5(3): 90–98.

Sahu, S.C., M. Kumar & N.H. Ravidranath (2016). Carbon Stocks in Natural and Planted Mangrove forests of Mahanadi Mangrove Wetland, East Coast of India. *Current Science* 110(12): 2253–2260. https://doi.org/10.18520/cs/v110/i12/2334-2341

Tomlinson, P.B. (1986). *The Botany of Mangroves.* Cambridge University Press, Cambridge, 225 pp.

Tomlinson, P.B. (2016). *The Botany of Mangroves* 2. Cambridge University Press, Cambridge, 436 pp.

Tsoularis, A. (2001). Analysis of logistic growth models. *Research Letters in the Information and Mathematical Sciences* 2: 23–46.

Wickramasinghe, S., M. Wijesinghe & C. Sarathchandra (2022). Sri Lankan Mangroves: Biodiversity, Livelihoods, and Conservation, pp. 297–329. In: Das, S.C., Pullaiah & E.C. Ashton, (eds.). *Mangroves: Biodiversity, Livelihoods and Conservation.* Springer, Singapore, 461 pp.

Sinhala abstract:

ලෝකයේ පරිසර පද්ධතීන් අතර ජීවවිද්‍යාත්මකව සංකීර්ණතම සහ ජෛව නිෂ්පාදිතාවය අධිකතම පරිසර පද්ධතියක් වන කඩොලාන පරිසර පද්ධතිය, ලොවපුරා දිනෙන් දින විනශය කරා ඇදීයයි. පසුගිය දශක ගණනාවක් පුරා සිදුවූ කඩොලාන විනශය නිසා, කඩොලාන මගින් ලබාදුන් බොහොමයක් පාරිසරික සේවාවන් මිනිසට අහිමිවෙමින් පවතී. ශ්‍රී ලංකාවේ දකුණු මුහුදු තීරයේ කොග්ගල කළපුව ආශ්‍රිත කඩොලාන පරිසරයද, සංචාරක ව්‍යාපාරයට සම්බන්ධ කටයුතු, කෘෂිකාර්මික කටයුතු සහ නාගරික සංවර්ධන කටයුතු නිසා එසේ සීග්‍රලෙස විනාශවන කඩොලාන පරිසර පද්ධතියකි. මෙම කළපුවේ ඉවුර, කළපු ජලතලය මත මුහුදු ගුවන්යානා ගොඩබෑම නිසා අධික ලෙස ඛාදනයට ලක්වී ඇති අතර, කඩොලාන පරිසරයද අධිකව විනාශයට ලක්වී ඇත. මෙම කඩොලාන පරිසර පද්ධතිය නැවත පුනරුත්තාපනය කිරීම සඳහා, විද්‍යානුකූල ව්‍යාපෘතියක අවශ්‍යතාවය පැනනැගී ඇතිහෙයින්, ඒ සඳහා පෙරහුරුවක් ලෙසද, මෙම පද්ධතියෙහි කඩොලාන ප්‍රතිස්තාපනය කිරීම අරමුණු කොටගෙනද, පර්යේෂණයක් ආරම්භ කරනලදි. ඛාදනය වූ ඉවුරෙහි සමන්‍ය ආකරයට කඩොලාන ප්‍රතිස්තාපනය කල නොහැකි හෙයින්, කඩොලාන පැල ඉවුරෙහි ස්ථාපිත කිරීම සඳහා විඛාදනයට ලක් නොවන ප්ලස්ටික් බැරල් යොදා ගන්නාලදි. ප්‍රතිස්තාපනයෙන් අනතුරුව, පළමු පියවර යටතේ, පරිසර පද්ධතියේ කඩොලාන ශාක ස්ථිරව ස්ථාපනයවීම අධීක්ෂණය කරනුලැබූ අතර, දෙවන පියවර යටතේ ස්තාපිත පරිසර පද්ධතිය මගින් ලබාදෙන පාරිසරික සේවාවන්ගේ ප්‍රතිස්තාපනයවීම අධීක්ෂණය කරනු ඇත. කඩොලාන ප්‍රතිස්තාපනය වීමෙන් අවුරුදු 2.5 කට පසුව කඩොලාන ජෛව ස්කන්ධයතුල තිරකර ඇති කාබන් ප්‍රමණය, කඩොලාන ශාක විශේෂවල ජෛව ස්කන්ධ කාබන් ප්‍රමාණය ගණනය කිරීම සඳහා ඉදිරිපත් කර ඇති සමීකරණ යොදාගෙන ගණනය කරන ලදි. කඩොලාන ශාක ප්‍රතිස්තාපනයෙන් මාස 24කට පසුව කඩොලාන ශාක කඳේ වට ප්‍රමාණය වැඩිවීමේ වැඩිම වේගය වාර්තාවිය. එමෙන්ම, ශාකවල වර්ධන වේගය, මාස 18 සිට 30 දක්වා ක්‍රමිකව අඩුවිය. පර්යේෂණ කාලය තුළදී, මධ්‍යන අපි-භෞමික සහ අධෝ-භෞමික ජෛව ස්කන්ධ කාබන් ප්‍රමාණය රේඛීයව වැඩිවිය. සිදුකරන ලද මෙම පර්යේෂණයේ ප්‍රතිඵල වලට අනුව ඛාදනය වූ කළපු ඉවුරුවල කඩොලාන ප්‍රතිස්තාපනය කිරීම සඳහා භාවිතා කරන ලද ක්‍රමය ඉතා සුදුසු බවට නිගමනය කලහැක. විශේෂයෙන්, ඛදනය වූ කොග්ගල කළපුවෙ ඉවුරුවල කඩොලාන ප්‍රතිස්තාපනය කිරීම සඳහා, විඛාදනය නොවන ප්ලස්ටික් බැරල්වල කඩොලාන සිටුවීම ඉතාම යෝග්‍ය වූ හෙයින්, මෙවැනි ඛාදනය වූ ඉවුරු සහිත වෙනත් කළපුවල කඩොලාන ප්‍රතිස්තාපනය කිරීම සඳහා මෙම ක්‍රමය නිර්දේෂ කල හැකිය.

Threatened Taxa

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 September 2023 | 15(9): 23898–23910

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

https://doi.org/10.11609/jott.8585.15.9.23898-23910

#8585 | Received 12 June 2023 | Final received 24 July 2023 | Finally accepted 04 September 2023

COMMUNICATION

OPEN ACCESS

Diversity of powdery mildew fungi from protected areas of Jizzak region, Uzbekistan - a checklist

I.M. Mustafaev [1], I.Z. Ortiqov [2], K.K. Nuraliev [3] & D.S. Khujaqulova [4]

[1,2,4] Institute of Botany of Academy of Sciences of the Republic of Uzbekistan, Tashkent 100053, Uzbekistan.
[3] Tashkent State Agrarian University, Tashkent 100140, Uzbekistan.
[1] elyor-mustafaev@inbox.ru (corresponding author), [2] ortiqovi@inbox.ru, [3] h.nuraliev@mail.ru, [4] durdonaxojaqulova@gmail.com

Abstract: The first-ever compilation of a checklist for powdery mildew fungi within the protected areas of Uzbekistan's Jizzakh region, specifically Nuratau Nature Reserve, Zaamin National Nature Park, and Zaamin Nature Reserve is presented through this study. Field research spanning from 2009 to 2022 facilitated this comprehensive endeavor. A comprehensive identification process revealed a total of nine groups, consisting of 57 distinct types, 69 variations, and four different strains of powdery mildew. Two species, namely *Erysiphe platani* and *E. syringae*, were newly identified within the mycobiota of the country. Additionally, the plant index of Uzbekistan documented 11 powdery mildew species and ten variations on 18 previously unrecorded host plant species. Most species of powdery mildew fungi belong to the genera *Erysiphe* and *Leveillula*. The annotated checklist includes data on the host plant, location, date and collection number of every species.

Keywords: Disease, Erysiphaceae, host plants, Nuratau Nature Reserve, Zaamin Nature Reserve, Zaamin National Nature Park.

Uzbek: Ushbu maqolada O'zbekistonning Jizzax viloyatida joylashgan Nurota qo'riqxonasi, Zomin milliy bog'i va Zomin davlat qo'riqxonasi hududlarida tarqalgan un-shudring zamburug'larining dastlabki ro'yxati keltirilgan. Natijalar 2009 yildan 2022 yilgacha bo'lgan tadqiqot natijalari asosida shakllantirilgan. Dala tadqiqotlari davomida olib kelingan mikologik gerbariy namunalarini identifikatsiya qilish jarayonida un-shudring zamburug'larining 57 tur, 69 forma va 4 variatsiyasi qayd etildi. Shundan, *Erysiphe platani* va *E. syringae* O'zbekiston mikobiotasi uchun yangi ekanligi aniqlangan. Bundan tashqari, 11 tur un-shudring zamburug'lari xo'jayin o'simliklarning 18 turida ilk bor qayd etilgan. Tadqiqot hududlarida un-shudring zamburug'lari orasida *Erysiphe* va *Leveillula* turkumi vakillari yetakchilik qiladi. Ushbu maqolada xar bir zamburug' turning xo'jayin o'simligi, qayd etilgan yilllari keltirilgan.

Editor: Anonymity requested. **Date of publication:** 26 September 2023 (online & print)

Citation: Mustafaev, I.M., I.Z. Ortiqov, K.K. Nuraliev & D.S. Khujaqulova (2023). Diversity of powdery mildew fungi from protected areas of Jizzak region, Uzbekistan - a checklist. *Journal of Threatened Taxa* 15(9): 23898–23910. https://doi.org/10.11609/jott.8585.15.9.23898-23910

Funding: Agency for Innovative development under the ministry of higher education, science and innovation of the Republic of Uzbekistan.

Competing interests: The authors declare no competing interests.

Author details: Ilyor Muraddullayevich Mustafayev, Institute of Botany of Academy of Sciences of the Republic of Uzbekistan. Head of the laboratory of Mycology and Algology. Specialization—fungal diversity, fungal taxonomy, fungal ecology, plant disease management. Islom Ziyodulla ugli Ortiqov, PhD student, Institute of Botany of Academy of Sciences of the Republic of Uzbekistan. Specialization—mycology, fungal diversity, plant disease management. Khamra Khaydaraliyevich Nuraliev, Tashkent State Agrarian University. Professor of the Department of Plant Protection. Specialization—mycology, plant disease management. Durdona Sadriddin qizi Khujaqulova, PhD student, Institute of Botany of Academy of Sciences of the Republic of Uzbekistan. Specialization—mycology.

Author contributions: I.M.M. - reviewing and editing; I.Z.O. - writing, reviewing and editing; K.K.N. - data collection; D.S.K. - reviewing and data collection. All authors have read and agreed to the published version of the manuscript.

Acknowledgements: This work was partly supported by the Ministry of Innovative Development of the Republic of Uzbekistan (the project "A-FA-2021-144") and state program "Pathogenic fungi of economically important plants exporting fruits, vegetables and melons: diversity, monitoring, and creation of an electronic database". Valuable suggestions of anonymous reviewers for improving the manuscript are appreciated.

INTRODUCTION

Powdery mildews belong to the *Erysiphaceae*. The main geographical regions of the distribution are in the temperate zone of the northern hemisphere. They are obligate biotrophs responsible for diseases in many plants. They are cosmopolitan, widespread on various hosts including vegetables, trees, herbs, shrubs, grasses, ornamental plants and weeds (Braun 1987). In many cases, powdery mildew fungi are more common in cultivated plant hosts (Pawar & Patil 2011). The fungi infect almost every group of plants, i.e., from grasses to higher angiosperms (Braun & Cook 2012). Powdery mildews are easily visible on infected plant leaves, stems, and fruits. The first symptoms appear as white powdery spots on leaves, branches and sometimes on fruits. Over time, disease severity increases under favorable conditions. Disease symptoms usually appear with the onset of summer and begin to disappear during the scorching heat and rainy season (Pap et al. 2013).

A considerable number of powdery mildew samples were collected and examined during exploring of the fungal diversity of Uzbekistan; contributions have been published in 1926–2023 (Zaprometov 1926; 1928; Golovin 1949; Rotkevich 1960; Gaponenko 1965; Gaponenko et al. 1983; Solieva 1989; Kamilov 1991; Nuraliev 1998; Gafforov 2004; Mustafaev 2018; Mustafaev et al. 2019; Abdurazakov et al. 2021).

Recently, invasive species of powdery mildew, originating from other regions of the world, have spread extensively in Uzbekistan (e.g., *Erysiphe australiana* on *Lagerstroema indica*); they are mostly found on introduced trees and shrubs that are widely used for landscaping (Nabieva et al. 2021).

The current study aims to compile a checklist of powdery mildew of vascular plants of the Nuratau Nature Reserve, Zaamin Nature Reserve, and Zaamin National Nature Park in the Jizzakh region. The present checklist serves as one of the sources to make the complete modern list of powdery mildew of the Rebuplic of Uzbekistan.

Study Area

The present compilation brings together as much information, related to powdery mildew reported from protected areas of Jizzakh region (Nuratau Nature Reserve 40°30’34.8’’ 66°44’18.4’’, Zaamin Nature, Reserve 39°34’41.4’’ 68°24’21.5’’, Zaamin National Nature Park 39°39’56.4’’ 68°24’18.3’’) (Fig. 1), as possible.

METHODS

About 1,000 powdery mildew fungi were collected in 2009–2022 years in different habitats of protected natural areas. Samples were collected from the affected parts of the plants and either used fresh or stored dry as herbarium material until analysis, as described by Heluta (1989). These are designated in the checklist by the following abbreviations: NNR –Nuratau Nature Reserve, ZNR – Zaamin Nature Reserve, ZNNP – Zaamin National Nature Park. Specimens: Chasmothecia, conidiophores, and conidia were observed and measured in oil immersion, using a Moticam 5N-300M microscope at a magnification up to ×400 and identified using the relevant literature (Zaprometov 1926; 1928; Golovin 1941; Gaponenko 1965; Panfilova & Gaponenko 1983; Gaponenko et al. 1983; Heluta et al. 2004; Braun 2012; Raximova et al. 2014). (1968–1993) and ‘Flora of Uzbekistan’ (1941–1962). All collected specimens are stored in the Fungarium of the Institute of Botany in Tashkent. Voucher specimens for each species of powdery mildew fungi are cited in the checklist below. The name of the collector is designated by abbreviation: IM – Ilyor Mustafaev, IOZ – Islom Ortiqov, XD – Xo`jaqulova Durdona. The taxonomy and nomenclature of powdery mildew fungi in the checklist follow international databases Index Fungorum (2023) and Mycobank (2023). The nomenclature of host plants is given according to powo.science.kew.org/results (2023). All collected specimens are stored in the Tashkent Mycological Herbarium (TASM) of the Institute of Botany.

RESULTS

In the protected areas of the Jizzakh region, including NNR, ZNR, and ZNNP, an extensive survey uncovered a diverse range of powdery mildew fungi. These findings encompass nine genera and 57 species, with 69 forms and four varieties, all identified through morphological characteristics. These fungi were documented on 137 host plant species, further grouped into 107 genera and 34 families (Table 1). *Erysiphe* emerged as the most species-rich genus, boasting 19 species, 26 forms, and four variations, closely followed by *Leveillula* with 16 species and 27 forms. *Podosphaera* accounted for nine species and three forms, while *Phyllactinia* exhibited four species and four forms. Additionally, *Golovinomyces* and *Sphaerotheca* each comprised four and three species, respectively, while *Uncinula*, *Neoerysiphe*, and *Blumeria* were each confined to one host plant species.

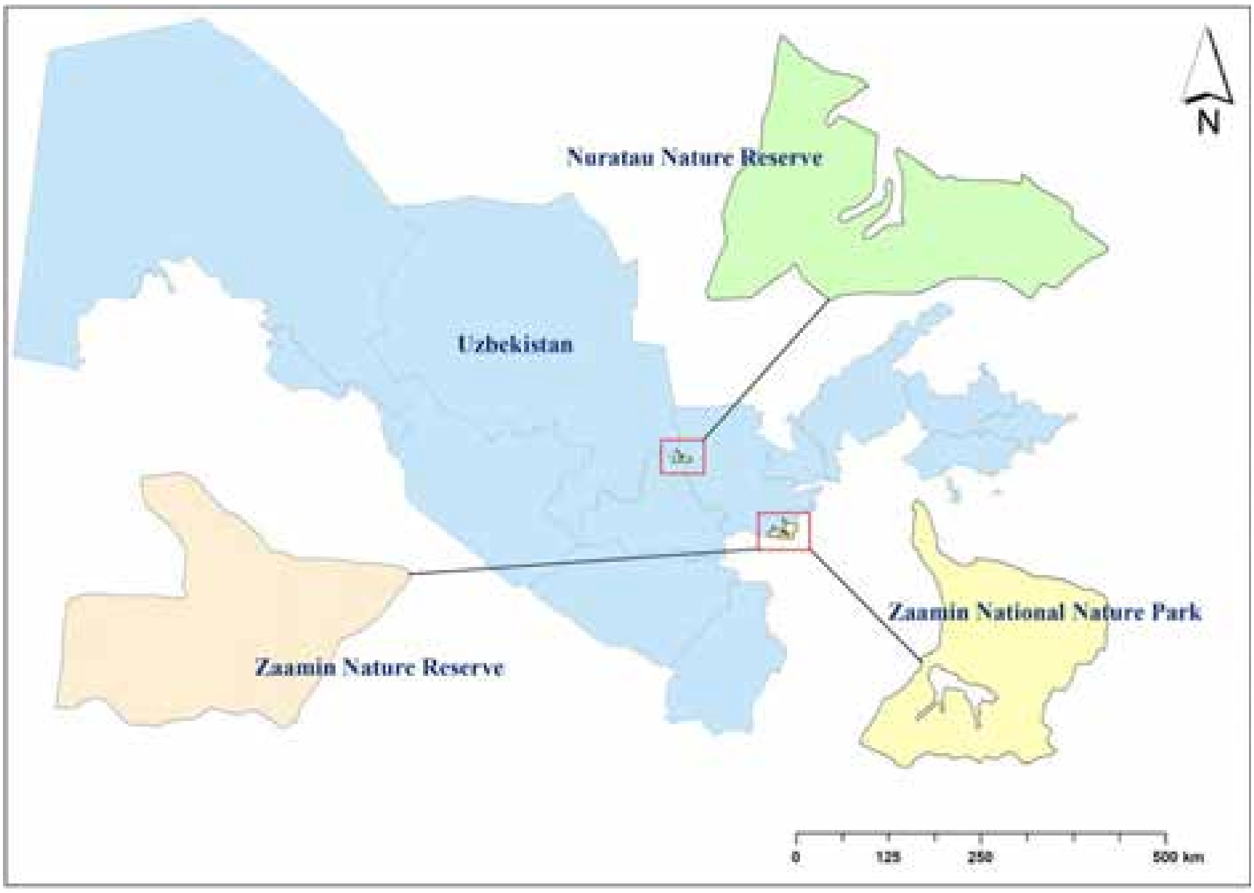

Figure 1. The map illustrates the location of the protected areas in the Jizzakh region.

Erysiphe species demonstrated the broadest host range, infecting 57 host plant species (41.6 % of the total), followed by *Leveillula* with 35 host plant species (25.4 %), and *Podosphaera* with 19 host plant species (13.8 %). *Sphaerotheca* was found on 11 host plant species (8.0 %), while the remaining genera—*Blumeria*, *Phyllactinia*, *Golovinomyces*, *Neoerysiphe*, and *Uncinula*—showed isolation to fewer host species. This comprehensive investigation highlights the wide distribution of powdery mildew fungi in the protected areas of the Jizzakh region, underscoring the need for further research to uncover their ecological roles and potential impacts.

Two species *Erysiphe platani* – on *Platanus orientalis* and *E. syringae* – on *Ligustrum* sp. were found for the first time for the mycobiota of Uzbekistan. Eleven species, 10 variaties of powdery mildew were recorded on 18 new host plant species index of Uzbekistan: *Blumeria graminis* – *Poa trivialis*, *Erysiphe cichoracearum* f. *lactucae* – *Lactuca orientalis*, *E. cichoracearum* f. *tanaceti*- *Lepidolopha komarowii*, *E. cruciferarum* – *Descurainia sophia*, *E. heraclei* – *Ferula penninervis*, *Ferula angreni* and *Physocaulis nodosus*, *Leveillula boraginacearum* f. *lappulae* – *Pseudoheterocaryum szovitsianum*, *L. compositarum* f. *artemisiae* – *Artemisia oliveriana*, *L. compositarum* f. *helichrysi* – *Helichrysum nuratavicum*, *L. labiatarum* f. *dracocephali* – *Dracocephalum nuratavicum*, *L. labiatarum* f. *scutellariae* – *Scutellaria ramosissima*, *L. labiatarum* f. *phlomidis* – *Phlomis nubilans*, *L. umbelliferarum* f. *heraclei* – *Semenovia pimpinelloides*, *Podosphaera fugax* – *Geranium rotundifolium*, *Sphaerotheca fuliginea* f. *lophanthi* – *Lophanthus schtschurowskianus*, *Sph. fuliginea* f. *sedi* – *Pseudosedum lievenii*, *Sphaerotheca* sp. – *Geum kokanicum*.

Among them, *Helichrysum nuratavicum*, *Phlomis nubilans* are endemic species for Nuratau ridge and *Phlomis nubilans*, *Helichrysum nuratavicum* and *Platanus orientalis* are listed in the Red Data Book of Uzbekistan (2019).

Thirty-two hosts of family Asteraceae were infected with powdery mildew followed by Rosaceae (19), Lamiaceae (14), Poaceae (13), Brassicaceae (12), Apiaceae (10), Fabaceae Boraginaceae (8 each), Dipsacaceae, Polygonaceae (5 each), Scrophulariaceae, Geraniaceae

Table 1. In this section, the scientific name of host plants along with the powdery mildew fungi occurring on them are provided.

Host plant (scientific name)	Powdery mildew fungi (scientific name)
Achillea sp.	*Leveillula taurica* f. *achilleae*
Aegilops crassa	*Blumeria graminis*
Aegilops cylindrica	*Blumeria graminis*
Aegilops triuncialis	*Blumeria graminis*
Alcea nudiflora	*Erysiphe cichoracearum* f. *althaeae*
Alhagi maurorum	*Leveillula alhagi*
Alhagi sp.	*Leveillula alhagi*
Alyssum alyssoides	*Erysiphe cruciferarum*
Alyssum minutum	*Erysiphe cruciferarum*
Alyssum dasycarpum	*Erysiphe cruciferarum*
Alyssum desertorum	*Erysiphe cruciferarum*
Arctium umbrosum	*Erysiphe cichoracearum* f. *cousiniae*
Arctium lappa	*Golovinomyces depressus*
Artemisia oliveriana	*Leveillula compositarum* f. *artemisiae*
Artemisia vulgaris	*Golovinomyces cichoracearum*
Asperugo procumbens	*Erysiphe horridula*
Astragalus sp.	*Leveillula leguminosarum* f. *astragali*
Atraphaxis pyrifolia	*Erysiphe atraphaxis*
Avena fatua	*Blumeria graminis*
Bidens tripartita	*Sphaerotheca fuliginea* f. *bidentis*
Capparis spinosa	*Leveillula capparidacearum* f. *capparidis*
Carthamus lanatus ssp. turkestanicus	*Leveillula compositarum* f. *carthami*
Centaurea besseriana	*Leveillula compositarum* f. *centaureae*
Cichorium intybus	*Golovinomyces cichoracearum* *Sphaerotheca fuliginea*
Chaerophyllum nodosum	*Erysiphe heraclei*
Convolvulus arvensis	*Erysiphe convolvuli* var. *convolvuli*
Cousinia microcarpa	*Erysiphe cichoracearum* f. *cousiniae*
Cousinia sp.	*Erysiphe cichoracearum* f. *cousiniae*
Cousinia coronata	*Leveillula compositarum* f. *cousiniae*
Crambe cordifolia ssp. kotschyana	*Erysiphe communis* f. *crambes*
Crataegus songarica	*Phyllactinia guttata*
Crataegus turkestanica	*Podosphaera oxyacanthae* f. *crataegi* *Phyllactinia guttata*
Crepis pulchra	*Sphaerotheca fuliginea* f. *crepidis*
Crepis sp.	*Erysiphe cichoracearum* f. *crepidis*
Cydonia oblonga	*Podosphaera oxyacanthae* f. *cydoniae*
Datisca cannabina	*Leveillula datiscacearum* f. *datiscae*
Daucus carota	*Leveillula umbelliferarum* f. *dauci*
Delphinium semibarbatum	*Leveillula ranunculacearum* f. *delphinii*
Descurainia sophia	*Erysiphe cruciferarum*
Dipsacus azureus	*Sphaerotheca fuliginea* f. *dipsaci*
Dodartia orientalis	*Leveillula scrophulariacearum* f. *dodartiae*
Dracocephalum nuratavicum	*Leveillula labiatarum* f. *dracocephali*
Erysimum sp.	*Erysiphe cruciferarum* f.*erysimi*
Euphorbia sp.	*Podosphaera euphorbiae*
Eremogone griffithii	*Leveillula caryophyllacearum* f. *arenariae*
Ferula angreni	*Erysiphe heraclei*
Ferula penninervis	*Erysiphe heraclei*
Fraxinus sogdiana	*Phyllactinia fraxini*
Galium aparine	*Neoerysiphe galii*
Galium pamiroalaicum	*Neoerysiphe galii*
Geranium linearilobum	*Podosphaera fugax*
Geranium pusillum	*Podosphaera fugax*
Geum kokanicum	*Sphaerotheca* sp.
Hedysarum sp.	*Erysiphe communis* f. *hedysari*
Helichrysum nuratavicum	*Leveillula compositarum* f. *helichrysi*
Heracleum lehmannianum	*Leveillula umbelliferarum* f. *heraclei*
Hieracium sp.	*Erysiphe cichoracearum* f. *euhieracium*
Hippophae rhamnoides	*Phyllactinia suffulta* f. *hippophaes*
Hordeum spontaneum	*Blumeria graminis*
Hordeum bulbosum	*Blumeria graminis*
Hypericum perforatum	*Erysiphe hyperici*
Hypericum scabrum	*Leveillula guttiferarum*
Juglans regia	*Erysiphe juglandis*
Lactuca orientalis	*Erysiphe cichoracearum* f. *lactucae*
Lepidium draba	*Leveillula cruciferarum* f. *lepidii*
Lepidolopha komarowii	*Erysiphe cichoracearum* f. *tanaceti*
Ligustrum sp.	*Erysiphe syringae*
Lindelofia anchusoides ssp. macrostyla	*Erysiphe horridula* f. *lindelofiae*
Lomelosia micrantha	*Leveillula datiscacearum* f. *scabiosae*
Lomelosia songarica	*Sphaerotheca fuliginea* f. *scabiosae*
Malus domestica	*Podosphaera leucotricha*
Marrubium anisodon	*Erysiphe labiatarum* f. *marrubii*
Medicago sativa	*Erysiphe communis* f.sp. *medicaginis–sativae* *Leveillula leguminosarum* f. *medicaginis*
Melilotus officinalis	*Erysiphe trifoliorum*
Morus alba	*Phyllactinia suffulta* f. *moricola*
Nepeta schtschurowskiana	*Sphaerotheca fuliginea* f. *lophanthi*
Ornithogalum gulnariense	*Podosphaera fugax*
Onobrychis chorassanica	*Leveillula leguminosarum* f. *onobrychidis*
Origanum vulgare	*Erysiphe labiatarum* f. *origami*

Host plant (scientific name)	Powdery mildew fungi (scientific name)
Peganum harmala	*Leveillula taurica* f. *pegani*
Pentanema britannica	*Erysiphe cichoracearum* f. *inulae*
Phlomis nubilans	*Erysiphe labiatarum* f. *phlomidi* *Leveillula labiatarum* f. *phlomidis*
Phlomis thapsoides	*Leveillula labiatarum* f. *phlomidis*
Phlomoides labiosa	*Erysiphe labiatarum* f. *eremostachydis*
Pistacia vera	*Phyllactinia suffulta* f. *pistaciae*
Plantago lanceolate	*Leveillula plantaginis*, *Podosphaera plantaginis*
Plantago major	*Erysiphe cichoracearum* var. *plantaginis*
Platanus orientalis	*Erysiphe platani*
Poa trivialis	*Poa trivialis*
Poa versicolor	*Blumeria graminis*
Poa bulbosa	*Blumeria graminis*
Polygonum aviculare	*Erysiphe polygoni* f. *polygoni*
Populus afghanica	*Phyllactinia populi*
Potentilla pedata	*Sphaerotheca macularis*
Potentilla reptans	*Erysiphe thuemenii*
Prangos pabularia	*Leveillula umbelliferarum* f. *prangotis*
Pseudosedum lievenii	*Sphaerotheca fuliginea* f. *sedi*
Psychrogeton cabulicum	*Podosphaera fusca*
Prunus persica	*Podosphaera pannosa*
Prunus cerasus	*Podosphaera tridactyla* f. *cerasi*
Prunus erythrocarpa	*Phyllactinia suffulta* f. *pruni* *Podosphaera tridactyla* f. *cerasi*
Prunus bucharica	*Podosphaera pannosa*, *Phyllactinia suffulta* f. *pruni*
Pseudopodospermum inconspicuum	*Leveillula compositarum* f. *scorzonerae*
Pseudoheterocaryum szovitsianum	*Leveillula boraginacearum* f. *lappulae*
Ranunculus sericeus	*Erysiphe aquilegiae* var. *ranunculi*
Rochelia cardiosepala	*Erysiphe horridula* f. *rocheliae*

Host plant (scientific name)	Powdery mildew fungi (scientific name)
Rochelia sp	*Erysiphe horridula* f. *rocheliae*
Rosa canina	*Podosphaera pannosa*
Rosa persica	*Podosphaera pannosa*
Rosa beggeriana var. *beggeriana*	*Podosphaera pannosa*
Rosa ecae	*Podosphaera pannosa*
Rumex acetosa	*Erysiphe polygoni* var. *rumicis*
Rumex chalepensis	*Erysiphe polygoni* var. *rumicis*
Salvia austriaca	*Golovinomyces salvia*
Salvia scrophulariifolia	*Leveillula compositarum* f. *perovskia*
Scandix pecten–veneris	*Erysiphe heraclei*
Scutellaria ramosissima	*Leveillula labiatarum* f. *scutellariae*
Semenovia pimpinellioides	*Leveillula umbelliferarum* f. *heraclei*
Solenanthus circinnatus	*Erysiphe horridula* f. *solenanthi* *Leveillula umbelliferarum* f. *seseli*
Solenanthus turkestanicus	*Erysiphe horridula* f. *solenanthi*
Sonchus asper	*Erysiphe cichoracearum* f. *sonchi*
Tanacetopsis mucronata	*Erysiphe cichoracearum* f. *tanaceti*
Taraxacum officinale	*Erysiphe cichoracearum* f. *taraxaci*
Taraxacum maracandicum	*Podosphaera erigerontis–canadensis*
Trifolium pretense	*Erysiphe trifolii*
Thinopyrum intermedium ssp. *intermedium*	*Blumeria graminis*
Ulmus laevis	*Uncinula ulmi*
Urtica dioica	*Erysiphe urticae*
Verbascum songaricum	*Leveillula verbasci*
Verbena officinalis	*Erysiphe cichoracearum* f. *verbenae*
Veronika argute–serrata	*Erysiphe cichoracearum* f. *veronicae*
Vitis vinifera	*Erysiphe necator*
Vickifunkia thomsonii	*Sphaerotheca fuliginea* f. *senecionis*
Ziziphora tenuior	*Erysiphe labiatarum* f. *ziziphorae*

(4 each), Euphorbiaceae, Oleaceae, Plantaginaceae, Ranunculaceae, Rubiaceae, Hypericaceae, Malvaceae (2 each), Capparaceae, Caryophyllaceae, Crassulaceae, Datiscaceae, Elaeagnaceae, Juglandaceae, Anacardiaceae, Moraceae, Peganaceae, Platanaceae, Salicaceae, Ulmaceae, Urticaceae, Verbenaceae, Vitaceae (1 each).

The highest number of powdery mildew species was reported in the following host genera: *Plantago*, *Prunus* (3 species each, 5.26% of the total species number), *Cichorium*, *Arctium*, *Artemisia*, *Cousinia*, *Crataegus*, *Crepis*, *Lomelosia*, *Medicago*, *Phlomis*, *Potentilla*, *Salvia*, *Solenanthus* and *Taraxacum* (2 species each, 3.50%), while other plant genera host one powdery mildew species per genus.

The recorded powdery mildew species were found on 31 medicinal species such as *Alcea nudiflora*, *Alhagi maurorum*, *Capparis spinosa*, *Cichorium intybus*, *Crataegus songarica*, *C. turkestanica*, *Crambe cordifolia* ssp. *kotschyana*, *Hippophae rhamnoides*, *Hypericum perforatum*, *Juglans regia*, *Malus domestica*, *Medicago sativa*, *Morus alba*, *Nepeta schtschurowskiana*, *Pistacia vera*, *Plantago lanceolate*, *P. major*, *Prunus erythrocarpa*, *P. bucharica*, *Helichrysum nuratavicum*, *Rosa canina*, *R. persica*, *R. beggeriana* var. *beggeriana*, *R. ecae*, *Rumex acetosa*, *R. chalepensis*, *Taraxacum* *officinale*, *T. maracandicum*, *Urtica dioica*, *Vitis vinifera*, *Ziziphora tenuior* etc.

This work represents itself as a checklist of powdery mildew fungi in the Jizzakh region of protected areas. The fungal species listed below have been arranged in alphabetical order.

Blumeria graminis (DC.) Speer

(= Erysiphe communis f. graminis (DC.) Fr., Alphitomorpha communis var. graminearum Wallr., Erysiphe graminis DC., Tigria graminis (DC.) Trevis.)
Host: Poaceae
Poa trivialis (2015) NNR (Xayatsay V.) - First record on Poa trivialis in Uzbekistan.
Poa versicolor (2015) NNR (Tikchasay V.)
Poa bulbosa (2010), NNR (Beshbarmoq V.) (2019–2022) ZNNP (Usmanlisay, Qorongisay V.)
Thinopyrum intermedium subsp. intermedium (=Agropyron trichophorum) (2022) ZNNP (Ettikechuvsay V.)
Aegilops crassa (2010) NNR (Xayatsay V.)
Aegilops cylindrica (2012), NNR (Qarisay V.)
Aegilops triuncialis (2022) ZNNP (Usmanlisay V.)
Hordeum bulbosum (1983) ZNR (Kulsay V.), (2009–20120) NNR (Xayatsay V.), (2019) ZNNP (Usmanlisay V.), (2021) ZNNP (Boytepa V.)
Hordeum spontaneum (2021) ZNNP (Qo'riq V.)
Avena fatua (2022) ZNNP (Usmanlisay V.)

Erysiphe aquilegiae var. **ranunculi** (Grev.) R.Y. Zheng & G.Q. Chen.

Host: Ranunculaceae
Ranunculus sericeus (2016) NNR (Xayatsay V.).

E. atraphaxis (Golovin) U. Braun & S. Takam.

Host: Polygonaceae
Atraphaxis pyrifolia (2019) ZNNP (O'riklisay V.).

E. communis f. ***crambes*** Jacz.

Host:Brassicaceae
Crambe cordifolia ssp. *kotschyana* (Boiss.) Jafri. (2014) NNR (Gurdara V.), (2021) ZNNP (Qorong'isay V.).

E. communis f. ***dianthi*** Jacz.

Host: Caryophyllaceae
Dianthus helenae (2017) NNR (Beshbarmaq V.).

E. communis f. ***hedysari*** Jacz.

Host: Fabaceae
Hedysarum sp.- (2010) NNR (Beshbarmaq V.).

E. communis f. sp. ***medicaginis-sativae*** Hammarl.

Host: Fabaceae
Medicago sativa (2019) ZNNP (O'riklisay V.).

E. cichoracearum f. ***althaeae*** Jacz.

Host: Malvaceae
Alcea nudiflora (2010) NNR (Xayatsay V.), (2019) ZNNP (O'riklisay V.).

E. cichoracearum f. ***lactucae*** Jacz.

Host: Asteraceae
Lactuca orientalis (2010) NNR (Xayatsay V.), (2012) NNR (Majrumsay V.) - Note: First record on *Lactuca orientalis* in Uzbekistan.

E. cichoracearum f. ***tanaceti*** Jacz.

Host: Asteraceae
Lepidolopha komarowii (2015) NNR (Xayatboshi V.) - Note: First record on *Lepidolopha komarowii* in Uzbekistan.

E. cichoracearum f. ***veronicae*** Jacz.

Host: Scrophulariaceae
Veronica argute-serrata (2010) NNR (Beshbarmoq V.).

E. cichoracearum f. ***verbenae*** Jacz.

Host: Verbenaceae
Verbena officinalis (2010) NNR (Xayatboshi V.), (2017) NNR (Xayatsay V.).

E. cichoracearum f. ***crepidis*** Jacz.

Host: Asteraceae
Crepis sp. (2019) ZNNP (Ettikechuvsay V.).

E. cichoracearum f. ***euhieracium*** S. Blumer.

Host: Asteraceae
Hieracium sp. (2019) ZNNP (Sherbulaq V.).

E. cichoracearum f. ***tanaceti*** Jacz.

Host: Asteraceae
Tanacetopsis mucronata (2019) ZNR (Qizilmazar V.).

E. cichoracearum f. ***taraxaci*** Jacz .

Host: Asteraceae
Taraxacum officinale – (2021) ZNNP (Boytepa V.).

E. cichoracearum f. ***sonchi*** Jacz .

Host: Asteraceae
Sonchus asper (2021) ZNNP (Sherbulaq, Irg'aylisay V.).

E. cichoracearum f. ***cousiniae*** (Jacz). Golov.
Host: Asteraceae
Cousinia sp. (2021) ZNNP (Boytepa V.).
Cousinia microcarpa (2022) ZNNP (O'riklisay).

E. cichoracearum var. ***plantaginis*** (Link).
Host: Plantaginaceae
Plantago major (2021) ZNNP (Qorong'isay V.).

E.cichoracearum f. ***inulae*** Jacz .
Host: Asteraceae
Pentanema britannica (2022) ZNNP (Irg'aylisay V.)

E. cruciferarum Opiz ex L. Junell.
(= *Erysiphe communis* (Wallr.) Link., *Erysiphe communis* (Wallr.) Schltdl., *Erysiphe cruciferarum var. longispora* G.J.M. Gorter., *Erysiphe pisi* var. *cruciferarum* (Opiz ex L. Junell) Ialongo., *Erysiphe radulescui* Docea.)
Host: Brassicaceae
Alyssum dasycarpum (2010–2012) NNR (Tikchasay, Qarisay V.).
Alyssum alyssoides (2010) NNR (Xayatsay V.).
Alyssum desertorum (2020) ZNNP (Sufa V.), (2022) ZNNP (Qorong'isay V.).
Alyssum minutum (2020) ZNNP (Usmanlisay V.)
Descurainia sophia (2022) ZNNP (Usmanlisay V.) - Note: First record on *Descurainia sophia* in Uzbekistan.

E. cruciferarum f. ***erysimi*** (Jacz).
Host: Brassicaceae
Erysimum sp. (2022) ZNNP (Usmanlisay V.).

E. convolvuli var. ***convolvuli***
Host: Convolvulaceae
Convolvulus arvensis (2010) NNR (Xayatsay V.), (2021) ZNNP (Usmanlisay V.).

E. horridula f. ***asperuginis*** S. Blumer.
Host: Boraginaceae
Asperugo procumbens (2010) NNR (Xayatsay V.), (2019) ZNNP (O'riklisay V.).

E. horridula f. ***lindelofiae*** Golovin.
Host: Boraginaceae
Lindelofia anchusoides ssp. *macrostyla* (2010) NNR (Beshbarmoq Mt.), (2018) ZNNP (O'riklisay).

E. horridula f. ***rocheliae*** Golovin.
Host: Boraginaceae
Rochelia sp. (2009) NNR (Tikchasay V.) *Rochelia cardiosepala* (2012) NNR (Qarisay, Gurdara V.).

E. horridula f. ***solenanthi*** Jacz.
Host: Boraginaceae
Solenanthus circinnatus (2010) NNR (Parandoz V.).
Solenanthus turkestanicus (2011) NNR (Majrumsay V.).

E. heraclei DC.
(= *Erysiphe heraclei* var. *himalayensis* Y.S. Paul & V.K. Thakur.)
Host: Apiaceae
Ferula penninervis (2017) NNR (Xayatsay, Beshbarmaq V.) - Note: First record on *Ferula penninervis* in Uzbekistan.
Ferula angreni (2017) NNR (Xayatsay V.)- First record on *Ferula angreni* in Uzbekistan.
Chaerophyllum nodosum (2014) NNR (Gurdara V.).
Scandix pecten veneris (2012) NNR (Xayatsay V.), (2019) ZNNP (Boytepa V.), (2022) ZNNP (Qorong'isay V.).

E. thuemenii U. Braun (= *E. communis* f. *potentillae* Jacz).
Host: Rosaceae
Potentilla reptans (2019) ZNNP (Usmanlisay V.).
E. trifolii Grev. (= *Erysiphe martii* Lév., *Microsphaera martii* (Lév.) YS Paul & VK Thakur., *Microsphaera trifolii* (Grev.) U. Braun).
Host: Fabaceae
Trifolium pretense (2021) ZNNP (Usmanlisay V.).

E. trifoliorum (Wallr.) U. Braun.
Host: Fabaceae
Melilotus officinalis (2019) ZNNP (O'riklisay V.).

E. hyperici (Wallr.) S. Blumer.
Host: Hypericaceae
Hypericum perforatum (2012) NNR (Qarisay V.).

E.juglandis (Golovin) U. Braun & S. Takam.
(= *Microsphaera juglandis* Golovin.).
Host: Juglandaceae
Juglans regia (2019) ZNNP (Usmanlisay V.).

E. labiatarum f. ***origani*** (H.A. Dietr.) Jacz.
Host: Lamiaceae
Origanum vulgare (2014) NNR (Parandoz V.).

E. labiatarum f. ***phlomidis*** Jacz.
Host: Lamiaceae

Phlomis nubilans (2014), NNR (Majrumsay V.).

E. labiatarum f. ***leonuri*** Jacz.
Host: Lamiaceae
Leonurus turkestanicus (2017), NNR (Xayatboshi V.).

E. labiatarum f. ***ziziphorae*** Pospelov.
Host: Lamiaceae
Ziziphora tenuior (2019) ZNNP (Yettikechuvsay V.).

E. labiatarum f. ***eremostachydis*** Golovin.
Host: Lamiaceae
Phlomoides labiosa (1983) ZNR (Guralashsay V.).

E. labiatarum f. ***marrubii*** Jacz.
Host: Lamiaceae
Marrubium anisodon (2021) ZNNP (Qorong'isay V.).

E. necator Schwein.
(= *Erysiphe necator* var. *ampelopsidis* (Peck) U. Braun & S. Takam., *Oidium tuckeri* Berk., *Uncinula americana* Howe., *Uncinula ampelopsidis* Peck., *Uncinula necator* (Schwein.) Burrill., *Uncinula necator* var. *ampelopsidis* (Peck) U. Braun.).
Host: Vitaceae
Vitis vinifera (2016) NNR (Qarisay V.), (2022) ZNNP (Qorong'isay V.).

E. platani (Howe) U. Braun (= *Microsphaera platani* Howe.)
Host: Platanaceae
Platanus orientalis (2022) ZNNP (Usmanliysay V.) - Note: First report in Uzbekistan.

E. polygoni f. ***polygoni*** DC.
Host: Polygonaceae
Polygonum aviculare (2010) NNR (Qarisay V.), (2019) ZNNP (O'riklisay V.), (2022) ZNNP (Usmanliysay V.).

E. polygoni var. ***rumicis*** Y.S. Paul & V.K. Thakur.
Host: Polygonaceae
Rumex chalepensis (2017) NNR (Xayatsay V.).
Rumex acetosa (2021) ZNNP (Usmanliysay V.).

E. syringae Schwein. (= *Microsphaera syringae* (Schwein.) H. Magn.).
Host: Oleaceae
Ligustrum sp. (2022) ZNNP (Qorong'isay V.) - Note: First report in Uzbekistan.

E. urticae (Wallr.) S. Blumer
Host: Urticaceae
Urtica dioica (2014) NNR (Xayatsay V.).

Golovinomyces cichoracearum (DC.) VP Heluta.
(= *Erysiphe communis* var. *cichoracearum* (DC.) Link., *Erysiphe cichoracearum* var. *luvungae* M.S. Patil & Maham., *Erysiphe cichoracearum* var. *saussureae* Y.S. Paul & V.K. Thakur., *Erysiphe cichoracearum* var. *transvaalensis* G.J.M. Gorter & Eicker., *Golovinomyces cichoracearum* var. *latisporus* (U. Braun) U. Braun., *Golovinomyces cichoracearum* var. *transvaalensis* (G.J.M. Gorter & Eicker) U. Braun., *Oidium asteris-punicei* Peck., *Oidium tabaci* Thüm.).
Host: Asteraceae
Artemisia vulgaris (2019) ZNR (Qashqasuv V.).

G. salviae (Jacz.) M. Scholler, U. Braun & Anke Schmidt.
(= *Erysiphe biocellata var. salviae* (Jacz.) VP Heluta., *Erysiphe labiatarum* f. *salviae* Jacz., *Erysiphe salviae* (Jacz.) S. Blumer., *Leveillula labiatarum* f. *salviae* (Jacz.) Golovin.).
Host: Lamiaceae
Salvia austriaca (2017) NNR (Xayatsay V.).

G. depressus (Wallr.) VP Heluta.
(=*Erysiphe cichoracearum* f. *bardanae* (Wallr.) Jacz., *Erysiphe communis* f. *depressa* (Wallr.) Fr., *Erysiphe depressa* (Wallr.) Link., *Erysiphe depressa var. artemiciae* Link., *Erysiphe depressa* var. *bardanae* Wallr.).
Host: Asteraceae
Arctium lappa (2009) NNR (Xayatsay V.).

Golovinomyces cichoracearum (DC.) VP Heluta.
(= *Erysiphe communis* var. *cichoracearum* (DC.) Link., Erysiphe cichoracearum DC., *Erysiphe cichoracearum* f. *cichorii* S. Blumer., *Erysiphe cichoracearum* var. *latispora* U. Braun., *Erysiphe cichoracearum* var. *luvungae* M.S. Patil va Maham., *Erysiphe cichoracearum* var. *saussureae* Y.S. Pol va VK Thakur., *Erysiphe cichoracearum* var. *transvaalensis* G.JM Gorter & Eicker., *Golovinomyces cichoracearum* var. *latisporus* (U. Braun) U. Braun., *Golovinomyces cichoracearum* var. *transvaalensis* (GJM Gorter & Eicker) U. Braun., *Oidium asteris-punicei* Peck., *Oidium tabaci* Thüm.).
Host: Asteraceae
Cichorium intybus (2017) NNR (Xayatsay V.).

Leveillula alhagi **(**Sorokīn) U. Braun.
(= *Erysiphe alhagi* Sorokīn., *Leveillula leguminosarum* f. *alhagi* (Sorokīn) Golovin.).
Host: Fabaceae
Alhagi sp. (2009) NNR (Xayatsay V.), (2017) NNR (Majrumsay V.).
Alhagi maurorum (2021) ZNNP (Boytepa V.).

L. boraginacearum f. ***lappulae*** (Jacz). Golov.
Host: Boraginaceae
Pseudoheterocaryum szovitsianum (2022) ZNNP (O'riklisay V.) - Note: First record on *Pseudoheterocaryum szovitsianum* in Uzbekistan.

L.capparidacearum **f.** ***capparidis*** (Jacz.) Golovin.
Host: Capparaceae
Capparis spinosa (2019–2021) ZNNP (O'riklisay, Usmanlisay V).

L. caryophyllacearum f. ***arenariae*** Golovin.
Host: Caryophyllaceae
Arenaria griffithii (2015–2016) NNR (Xaytbashi V.).

L. compositarum f. ***scorzonerae*** (Kuprev.) Golovin.
Host: Asteraceae
Pseudopodospermum inconspicuum (2022) ZNNP (Ettikechuvsay V.).

L. compositarum f. ***artemisiae*** (Jacz.) Golovin.
Host: Asteraceae
Artemisia oliveriana (2017) NNR (Majrumsay V.) - Note: First record on *Artemisia oliveriana* in Uzbekistan.

L. compositarum f. ***helichrysi*** (Jacz.) Golovin.
Host: Asteraceae
Helichrysum nuratavicum (2015) NNR (Fargun V.) - Note: First record on *Helichrysum nuratavicum* in Uzbekistan.

L. compositarum f. ***centaureae*** (Jacz.) Golovin.
Host: Asteraceae
Centaurea besseriana (2010-2014) NNR (Xayatbashi - Majrumsay V.).

L. compositarum f. ***carthami*** (Jacz.) Golovin.
Host: Asteraceae
Carthamus lanatus ssp. turkestanicus (2015) NNR (Xayatsay V.).

L. compositarum f. ***cousiniae*** (Jacz.) Golovin.
Host: Asteraceae
Arctium umbrosum (2016) NNR (Tikchasay V.).
Cousinia coronata (2019) ZNNP (Yettikechuvsay V.).

L. compositarum f. ***perovskiae*** Kurbana.
Host: Lamiaceae
Salvia scrophulariifolia (2017) NNR (Beshbarmaq V.).

L. cruciferarum f. ***lepidii*** (Jacz.) Golovin.
Host: Brassicaceae
Lepidium draba (2014) NNR (Xayatsay V.).

L. datiscacearum f. ***datiscae*** (Jacz.) Golovin.
Host: Datiscaceae
Datisca cannabina (2014) NNR (Majrumsay V.), (2016) NNR (Tikchasay V.).

L. dipsacacearum f. ***scabiosae*** (Jacz.) Golovin.
Host: Dipsacaceae
Lomelosia micrantha (2022) ZNNP (Usmanlisay V.).

L. guttiferarum Golovin.
Host: Hypericaceae
Hypericum scabrum (2016) NNR (Tikchasay V.).

L. labiatarum f. ***dracocephali*** Golovin.
Host: Lamiaceae
Dracocephalum nuratavicum (2015) NNR (Andibaraut V.) - Note: First record on *Dracocephalum nuratavicum* in Uzbekistan.

L. labiatarum f. ***scutellariae*** (Jacz.) Golovin.
Host: Lamiaceae
Scutellaria ramosissima (2015) NNR (Xayatbashi-Xayatsay V.) - Note: First record on *Scutellaria ramosissima* in Uzbekistan.
Scutellaria sp.- (2016) NNR (Tikchasay V.).

L. labiatarum f. ***phlomidis*** (Jacz.) Golovin.
Host: Lamiaceae
Phlomis thapsoides (2010) NNR (Xayatsay V.).
Phlomis nubilans (2015) NNR (Fargun V.) - Note: First record on *Phlomis nubilans* in Uzbekistan.

L. leguminosarum f. ***astragali*** (Jacz.) Golovin.
Host: Fabaceae
Astragalus sp. (20221) ZNNP (Sherbuloq V.).

L. leguminosarum f. ***onobrychidis*** Golovin.
Host: Fabaceae

Onobrychis chorassanica (2015) NNR (Fargun V.).

L. leguminosarum f. ***medicaginis*** (Jacz.) Golovin.
Host: Fabaceae
Medicago sativa (2017) NNR (Xayatsay V.).

L. plantaginis Golovin.
Host: Plantaginaceae
Plantago lanceolata (2010) NNR (Xayatsay V.).

L. scrophulariacearum f. ***dodartiae*** (Jacz.) Golovin.
Host: Scrophulariaceae
Dodartia orientalis (2010) NNR (Xayatbashi V.).

L. taurica f. ***pegani*** Jacz.
Host: Peganaceae
Peganum harmala (2010) NNR (Tikchasay V.).

L. taurica f. ***achilleae*** Jacz.
Host: Asteraceae
Achillea sp. (2019) ZNNP (O'riklisay V.).

L. umbelliferarum f. ***dauci*** Golovin.
Host: Apiaceae
Daucus carota (2010) NNR Xayatsay V.).

L. umbelliferarum f. ***seseli*** Golovin.
Host: Boraginaceae
Solenanthus circinnatus (2015) NNR (Xayatbashi V.).

L. umbelliferarum f. ***prangotis*** Golovin.
Host: Apiaceae
Prangos pabularia (2017) NNR (Xayatsay V.).

L. umbelliferarum f. ***heraclei*** Golovin.
Host: Apiaceae
Heracleum lehmannianum (2018) ZNNP (O'riklisay V.).
Semenovia pimpinelloides (2022) ZNNP (Qorong'isay V.) - Note: First record on *Semenovia pimpinelloides* in Uzbekistan.

L. ranunculacearum f. ***delphinii*** Golovin.
Host: Ranunculaceae
Delphinium semibarbatum (2019) ZNNP (Yettikechuvsay V.).

L. verbasci (Jacz.) Golovin. (= *Leveillula taurica* f. *verbasci* Jacz.).
Host: Scrophulariaceae
Verbascum songaricum (2015) NNR (Tikchasay V.), (2016) NNR (Xayatbashi V.).

Neoerysiphe galii (S. Blumer) U. Braun.
(= *Erysiphe galii* S. Blumer).
Host: Rubiaceae
Galium aparine - (1983) ZNR (Kulsay V.), (2022) ZNNP (O'riklisay V.).
Galium pamiroalaicum (2016) NNR (Parandoz V.).

Phyllactinia suffulta f. ***pistaciae*** Jacz.
Host: Anacardiaceae
Pistacia vera (2015) NNR (Xayatsay V.), (2021) ZNNP (Boytepa V.).

P. populi (Jacz.) Y.N. Yu.
(= *Phyllactinia suffulta* f. *populi* Jacz.).
Host: Salicaceae
Populus afghanica (2014) NNR (Majrumsay V.), (2019–2021) ZNNP (Qorong'isay-O'riklisay V.).

P. suffulta f. ***pruni*** Golov.
Host: Rosaceae
Prunus bucharica (2019–2021) ZNNP (O'riklisay – Usmanliysay V.).
Prunus erythrocarpa (2018) ZNNP (O'riklisay V.).

P. suffulta f. ***hippophaes*** Jacz.
Host: Elaeagnaceae
Hippophae rhamnoides (2022) ZNNP (Umanlisay V.).

P. suffulta f. ***moricola*** Jacz.
Host: Moraceae
Morus alba (2009–2010–2016) NNR (Xayatsay, Tikchasay V.), (2021) ZNNP (Qorong'isay V.).

P. guttata (Wallr.) Lév.
(= *Phyllactinia berberidis* Palla., *Phyllactinia betulae* (DC.) Fuss., *Phyllactinia corylea* (Pers.) P. Karst., *Phyllactinia suffulta* (Rebent.) Sacc.).
Host: Rosaceae
Crataegus turkestanica (2017) NNR (Xayatsay V.).
Crataegus songarica (2022) ZNNP (Yettikechuvsay V.).

P. fraxini (DC.) Fuss.
(= *Erysiphe communis f. lamprocarpa* (Wallr.) Fr., *Erysiphe fraxini* DC., *Erysiphe lamprocarpa* (Wallr.) Link.).
Host: Oleaceae
Fraxinus sogdiana (2017) NNR (Qarisay V.).

Podosphaera euphorbiae (Castagne) U. Braun & S. Takam.
(= *Sphaerotheca euphorbiae* (Castagne) E.S. Salmon., *Sphaerotheca tomentosa* G.H. Otth.).
Host: Euphorbiaceae
Euphorbia sp. (2016) NNR (Tikchasay V.).

P. fugax (Penz. & Sacc.) U. Braun & S. Takam.
(=*Erysiphe communis var. geranii* Klotzsch., *Sphaerotheca fugax* Penz. & Sacc.).
Host: Geraniaceae
Geranium linearilobum (2013) NNR (Gurdara V.).
Geranium pusillum (2010) NNR (Tikchasay V.).
Geranium rotundifolium (2012) NNR (Gurdara V.) - Note: First record on *Geranium rotundifolium* in Uzbekistan.

P. fusca (Fr.) U.Braun va Shishkoff.
(= *Podosphaera phaseoli* (Z.Y. Zhao) U. Braun & S. Takam., *Podosphaera xanthii* (Castagne) U.Braun & Shishkoff., *Sphaerotheca astragali* var. *phaseoli* Z.Y.Zhao., *S. calendulae* (Malbr. & Roum.) Malbr., *S. cucurbitae* (Jacz.) Z.Y.Zhao., *S. fuliginea* f. *calendulae* (Malbr. & Roum.) Jacz., *S. fuliginea* f. *cucurbitae* Jacz., *S. fusca* (Fr.) S. Blumer., *S. fuscata* (Berk. & M.A.Curtis) Serbinow., *S. indica* Patw., *S. melampyri* L. Junell., *S. microcarpa* Hazsl., *S. phaseoli* (Z.Y.Zhao) U.Braun., *S. verbenae* Săvul. & Negru., *S. xanthii* (Castagne) L. Junell.).
Host: Asteraceae
Psychrogeton cabulicum (2016) NNR (Tikchasay V.).

P. tridactyla f. ***cerasi*** Jacz.
Host: Rosaceae
Prunus cerasus (2017) NNR (Xayatsay V.).
Prunus erythrocarpa (2018) ZNNP (O‘riklisay V.).

P. leucotricha (Ellis & Everh.) E.S.Salmon.
(= *Sphaerotheca leucotricha* Ellis & Everh.).
Host: Rosaceae
Malus domestica (2009) NNR (Majrumsay V.), (2021) ZNNP (Ettikechuvsay V.).

P. erigerontis-canadensis (Lév.) U.Braun & T.Z.Liu. (= *Erysiphe erigerontis-canadensis* Lév., *Sphaerotheca erigerontis-canadensis* (Lév.) L. Junell.).
Host: Asteraceae
Taraxacum maracandicum (1983) ZNR (Guralashsay V.).

P. euphorbiae (Castagne) U. Braun & S. Takam.
(= *Sphaerotheca euphorbiae* (Castagne) E.S. Salmon., *S. tomentosa* G.H. Otth.).
Host: Euphorbiaceae
Euphorbia sp. (2016) NNR (Xayatsay V.).

P. oxyacanthae f. ***cydoniae*** Jacz.
Host: Rosaceae
Cydonia oblonga (1956) ZNR (Guralashsay V.).

P. oxyacanthae f. ***crataegi*** Maurizio.
Host: Rosaceae
Crataegus turkestanica (2021) ZNNP (Yetikechuvsay V.).

P. plantaginis (Castagne) U.Braun & S.Takam.
(= *Erysiphe plantaginis* Castagne., *Sphaerotheca plantaginis* (Castagne) L.Junell.)
Host: Plantaginaceae
Plantago lanceolata (2016) NNR (Tikchasay V.).

P. pannosa (Wallr.) de Bary.
(= *Erysiphe pannosa* (Wallr.) Link., *Leucothallia pannosa* (Wallr.) Trevis., *Oidium forsythiae* Bunkina., *O. leucoconium* Desm., *O. leuconium* Desm., *Sphaerotheca macularis* f. *rosae* Jacz., *S. pannosa* (Wallr.) Lév., *S. pannosa* var. *persicae* Woron., *S. pannosa* var. *rosae* Woron., *S. persicae* (Woron.) Erikss., *S. rosae* (Jacz.) Z.Y.Zhao.).
Host: Rosaceae
Rosa canina (2010-2012) NNR (Xayatsay - Gurdarasay V.).
Rosa beggeriana var. *tilanchi* (2011) NNR (Majrumsay V.), (2021) ZNNP (Sufa-Usmanlisay V.).
Rosa persica (2011–2017) NNR (Xayatsay V.).
Rosa ecae (2021–2022) ZNNP (Yetikechuvsay - O‘riklisay V.).
Prunus bucharica (2012) NNR (Tikchasay V.).
Prunus persica (2009) NNR (Xayatsay V.).

Sphaerotheca fuliginea f. ***scabiosae*** Jacz.
Host: Dipsacaceae
Lomelosia songarica (1983) ZNR (Guralashsay V.), (2010) NNR (Beshbarmaq V.).

S. fuliginea f. ***crepidis*** Jacz.
Host: Asteraceae
Crepis pulchra (2019) ZNNP (O‘riklisay V.).

S. fuliginea f. ***senecionis*** Jacz.
Host: Asteraceae
Vickifunkia thomsonii (2022) ZNNP (Irgaylisay V.).

S. fuliginea f. ***bidentis*** Jacz.

Host: Asteraceae

Bidens tripartite (2018) ZNNP (O'riklisay V.).

S. fuliginea f. ***dipsaci*** Jacz.

Host: Dipsacaceae

Dipsacus azureus (2010) NNR (Beshbarmaq V.), (2021) ZNNP (Usmanlisay V.).

S. fuliginea f. ***lophanthi*** Jacz.

Host: Lamiaceae

Nepeta schtschurowskiana (2015–2016–2017) NNR (Xayatbashi, Tikchasay, Beshbarmaq V.) - Note: First record on *Lophanthus schtschurowskianus* in Uzbekistan.

S. fuliginea f. ***sedi*** Kalymb.

Host: Crassulaceae - *Pseudosedum lievenii* (2012) NNR (Gurdara V.) - Note: First record on *Pseudosedum lievenii* in Uzbekistan.

S. macularis f. ***potentillae*** Jacz.

Host: Rosaceae

Potentilla pedata (2016) NNR (Tikchasay V.).

***Sphaerotheca* sp.**

Host: Rosaceae

Geum kokanicum (2015) NNR (Xayatboshi V.) - Note: First record on *Geum kokanicum* in Uzbekistan.

Uncinula ulmi M.N.Kusnezowa.

Host: Ulmaceae

Ulmus laevis (2017) NNR (Qarisay V.).

DISCUSSION

It is known that the diversity of the powdery mildew fungi is closely related to the diversity of the plant flora. Uzbekistan's plant flora consists of more than 4,500 species and 88 species (334 forms) of powdery mildew fungi were registered on 778 host plant species (Gaponenko et al. 1983). The plant flora from protected areas of the Jizzakh region includes 1986 species of 645 genera and 115 families (Tojibaev et al. 2015) and found 57 species, 69 forms and 4 variaties of powdery mildew on 137 host plant species from 34 families.

The distribution of powdery mildew species in host plants is given based on the regions of Jizzakh region in which they are distributed. The largest number of powdery mildew and host plants were found in the Nuratau Nature Reserve (8 genera, 40 species, 41 forms, 3 forms, of the total species number 70.17%), followed by the Zaamin National Nature Park (7 genera, 35 species, 32 forms, 3 varieties, of the total species number 61.40%), Zaamin Nature Reserve (8 genera, 20 species, 36 forms, 2 varieties, of the total species number 35.08 %).

It is noted that studies on powdery mildew fungi of many regions of Uzbekistan including the Anger river basin, and Fergana valley carried out by some mycologists (Panfilova & Gaponenko 1963; Gaponenko et al. 1983; Abdurazakov et al. 2021). The diversity of powdery mildew fungi in protected areas of the Jizzakh region has been compared with their research results (Table 2).

This diversity of powdery mildew fungi of protected areas of the Jizzakh region is represented by 9 genera and 57 species, 69 forms and 4 variaties species and has approximately 30.80% of the currently known mildew fungi biota of Uzbekistan. On the territory of protected areas of the Jizzakh region, the powdery mildew diseases occur frequently and severely damage plants belonging to *Aegilops*, *Alhagi*, *Artemisia*, *Alyssum*, *Capparis*, *Cousinia*, *Convolvulus*, *Ferula*, *Morus, Populus*, *Rosa*, *Rumex*, and *Trifolium*.

The present checklist is the third work about powdery mildew microfungi of Uzbekistan and serves as one of the sources for a complete list of powdery mildew microfungi of the Rebuplic of Uzbekistan.

Table 2. Comparison of the powdery mildew diversity of protected areas of the Jizzakh region with other regions of Uzbekistan.

Study areas	Plant flora species	Powdery mildew	Powdery mildew host plant species (Percentage towards overall flora)
Uzbekistan (Gaponenko et al. 1983)	4500	88 species, 334 forms	778 (17.28 %)
Angren river basin (Panfilova & Gaponenko 1963)	1500	25 species, 100 forms and 4 varieties	164 (10.93%)
Fergana Valley (Abdurazakov et al. 2021)	2625	67 species	153 (5.82%)
Jizzakh region (this research)	1986	57 species, 69 forms and 4 varieties	137 (6,89 %)

REFERENCES

Abdurazakov, A.A., T.S. Bulgakov, T.N. Kholmuradova & Y.S. Gafforov (2021). Powdery mildew fungi (*Erysiphaceae*) of the Fergana Valley (within Uzbekistan): a first annotated checklist. *Новости систематики низших растений — Novosti sistematiki nizshikh rastenii* 55(1): 55–78. https://doi.org/10.31111/nsnr/2021.55.1.55

Alibekov, L.A. (2013). Geographical foundations of the Zaamin National Park and geoecological problems. Toolkit. Tashkent. 38 pp. (In Uzbek).

Braun, U. (1987). A monograph of the Erysiphales (powdery mildews). *Beihefte zur Nova Hedwigia*, Germany, 89, 1–700 pp.

Braun, U. & R.T. Cook (2012). Taxonomic manual of the Erysiphales (powdery mildews). CBS Biodiversity series. Vol. 11. CBS-KNAW Fungal Biodiversity Centre, Utrecht, Netherlands, 707 p.

Gafforov, Y.S. (2004). Micromycetes on vascular plants of Namangan province: PhD thesis, Tashkent, 21 pp. (In Uzbek.).

Gaponenko, N.I. (1965). Obzor gribov Bukharskoi oblasti [Overview of fungi in Bukhara Region]. AN UzSSR. Tashkent, 61-62 pp. (In Russ.).

Gaponenko, N.I., F.G. Akhmedova, S.S. Ramazanova, M.Sh. Sagdulayeva & Kh.M. Kirgizbayeva (1983). Flora gribov Uzbekistana. T. I. Muchnistorosyanye griby [Fungal Flora of Uzbekistan. Vol. I. Powdery mildew fungi]. Fan. Tashkent, 361 p. (In Russ.).

Golovin, P.N. (1949). Mikoflora Sredney Azii. T. 1. Muchnistorosyanyye griby Sredney Azii [Mycoflora of Central Asia. T. 1. Powdery fungi of Central Asia]. Tashkent, 145 p. (In Russ.).

Heluta V.P., S.P. Wasser & S.O. Voityuk (2004). *Sphaerotheca parietariae* (*Erysiphales, Ascomycota*), a new powdery mildew fungus in Europe. *Flora Mediterranea*. 14. 285-289.

Heluta, V.P. (1989). Flora gribov Ukrainy. Muchnistorosyanye griby [The fungal flora of Ukraine. Powdery mildews]. Naukova Dumka, Kiev, 255 p. (in Russ.).

Kamilov, Sh.G. (1991). Micromycetes on vascular plants of the Botanical Garden of the Academy of Sciences of Uzbekistan. F.N.Rusanova: PhD thesis, Tashkent, 22 p. (In Russ.).

Mustafaev, I.M., N.Y. Beshko & M.M. Iminova (2019). Checklist of ascomycetous microfungi of the Nuratau Nature Reserve (Uzbekistan). *Новости систематики низших растений — Novosti sistematiki nizshikh rastenii* 53(2). 315–332. https://doi.org/10.31111/nsnr/2019.53.2.315

Mustafaev, I.M. (2018). Micromycetes on vascular plants of Nuratau nature Reserve: PhD thesis, Tashkent, 20 p. (In Uzbek.).

Nabieva, D.B., I.M. Mustafaev & M.M. Iminova (2021). First report of *Erysiphe australiana* from Uzbekistan. *New disease reports* 44: e12032. https://doi.org/10.1002/ndr2.12032

Nuraliev, H.H. (1999). Micromycetes on vascular plants of Kashkadarya province: PhD thesis, Tashkent, 22 p. (In Uzbek.).

Panfilova, T.S. & N.I. Gaponenko (1963). *Mikoflora basseina r. Angren* [Mycoflora of Angren River basin]. AN UzSSR, Tashkent, 208 p. (In Russ.).

Pap, P., B. Ranković & S. Maširević (2013). Effect of temperature, relative humidity and light on conidial germination of oak powdery mildew (*Microsphaera alphitoides* Griff. et Maubl.) under controlled conditions. *Archives of Biological Sciences,* Belgrade, 65 (3), 1069-1077. https://doi.org/10.2298/ABS1303069P

Pawar, V.P. & V.A. Patil (2011). Occurrence of powdery mildew on some wild plants from Khandesh region of Maharashtra state. *Recent Research in Science and Technology* 3(5): 94–95.

Rahimova, E.V., G.A. Nam & B.D. Ermekova (2014). Short determinant of powder mildew fungi of Kazakhstan and borger area. Novosibirsk, 129 p. (In Russ.)

Rotkevich, T.K. (1960). Materials for the microflora of the former mountain-juniper reserve Guralash (northern spurs of the Turkestan ridge). Materials of the 1st coordination meeting of mycologists of the republics of Central Asia and Kazakhstan. Frunze, 142-143 pp. (in Russ.).

Solieva, Y.S. (1989). Micromycetes on vascular plants of Surkhandarya province: PhD thesis. Tashkent, 23 p. (In Russ.).

Tojibaev, K.Sh., N.Y. Beshko, V.A. Popov, C.G. Jang & K.S. Chang (2017). *Botanical Geography of Uzbekistan*. Pocheon, Republic of Korea, 250 p.

Tojibaev, K.S., N.Y. Beshko, A.R. Batoshov & D.E. Azimova (2015). Cadastre of flora of Jizzakh region of Uzbekistan (vascular plants). Chinor ENK, Tashkent, 3-238 pp.

Zaprometov, N.G. (1926). Materialy po mikoflore Srednei Azii. T. 1 [Materials on the mycoflora of Central Asia. Vol. 1]. AN UzSSR, Tashkent, 1–36 pp. (In Russ.).

Zaprometov, N.G. (1928). Materialy po mikoflore Srednei Azii. T. 2 [Materials on the mycoflora of Central Asia. Vol. 2]. AN UzSSR, Tashkent, 1–70 pp. (In Russ.).

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 September 2023 | 15(9): 23911–23913

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

https://doi.org/10.11609/jott.8232.15.9.23911-23913

#8232 | Received 18 October 2022 | Final received 02 September 2023 | Finally accepted 08 September 2023

NOTE

A case report on chronic renal disease in a captive wild Leopard *Panthera pardus* (Mammalia: Carnivora)

Abhishek Verma [1], Rakesh Kumar [2], Smriti Jamwal [3], Ankita [4], Rajendra Damu Patil [5] & Rajesh Kumar Asrani [6]

[1–6] Department of Veterinary Pathology, Dr. G.C Negi College of Veterinary and Animal Sciences, CSK Himachal Pradesh Agricultural University, Palampur, Himachal Pradesh 176062, India.
[1] vermabhishek98@gmail.com, [2] rkvetpath@gmail.com (corresponding author), [3] smritijamwal98@gmail.com, [4] ankitajaikaria@gmail.com, [5] rdpatil02@gmail.com, [6] asranirk@gmail.com

Leopards are found all throughout Africa and Asia, but due to isolated and declining populations, they have disappeared from a significant portion of their original range (Stein et al. 2020). The IUCN Red List of Threatened Species (2020) has categorised leopards as 'Vulnerable'. An ideal age distribution for a species population would include a large proportion of young animals and a progressively declining proportion of adults with increasing age. For a number of our captive felid species, the age distribution pattern is now biased toward older individuals. In older captive felids, chronic renal illness is a major cause of death and morbidity (Wack 2008). Age is one of the major contributing factors for glomerular and interstitial alterations in kidneys (Junginger et al. 2015). The kidneys in geriatric canines are often found to exhibit contracted, pale, and indented appearance (Kumar et al. 2020). Captive Leopards are now outliving their free ranging counterparts due to advancing husbandry and veterinary care (Longley 2011).

In the present investigation, on the same day of detection of collapse a Leopard carcass was sent for necropsy examination to the Department of Veterinary Pathology, DGCN COVAS, CSKHPKV, Palampur. A detailed postmortem examination was conducted (Image 1) and representative tissue samples of approximately 0.5 cm thickness were collected in 10% neutral buffered formalin (NBF) for histopathological examination. The fixed tissue sections were dehydrated in ascending grades of alcohol, cleared in benzene, and impregnated in molten paraffin. The tissue sections containing paraffin blocks were sectioned with microtometo 2–3 micron thickness and were stained with Haematoxylin and Eosin (H&E) stain and Masson's trichrome stain as per the standard protocol (Luna 1968) and were microphotographed (Olympus BX40).

The necropsy examination of the animal showed enlargement of both kidneys, which showed irregular or rough surface along with completely adhered and tense capsule which was hard to peel (Image 2). The lungs were voluminous with oedematous fluid accumulation (Image 3). The small intestine showed the presence of blood mixed with catarrhal exudate (Image 4). The histological examination of the renal tissue exhibited severely congested vasculature with multiple areas of tubular necrosis along with hyaline and cellular degenerations. The glomerular tufts were occupied

Editor: Rajeshkumar G. Jani, Anand Agricultural University, Anand, India. **Date of publication:** 26 September 2023 (online & print)

Citation: Verma, A., R. Kumar, S. Jamwal, Ankita, R.D. Patil & R.K. Asrani (2023). A case report on chronic renal disease in a captive wild Leopard *Panthera pardus* (Mammalia: Carnivora). *Journal of Threatened Taxa* 15(9): 23911–23913. https://doi.org/10.11609/jott.8232.15.9.23911-23913

Funding: The study was not supported by any funding agency.

Competing interests: The authors declare no competing interests.

Acknowledgements: Authors sincerely acknowledge CSKHVKV, Palampur administration for carrying out the present investigation.

Image 1. Leopard presented for necropsy examination. © Rakesh Kumar.

Image 2. Rough surface of kidney with tightly adhered renal capsule. © Rakesh Kumar.

Image 3. Tracheal lumen with mucus mixed oedematous contents. © Rakesh Kumar.

Image 4. Intestinal lumen showing mucus mixed hemorrhagic contents. © Rakesh Kumar.

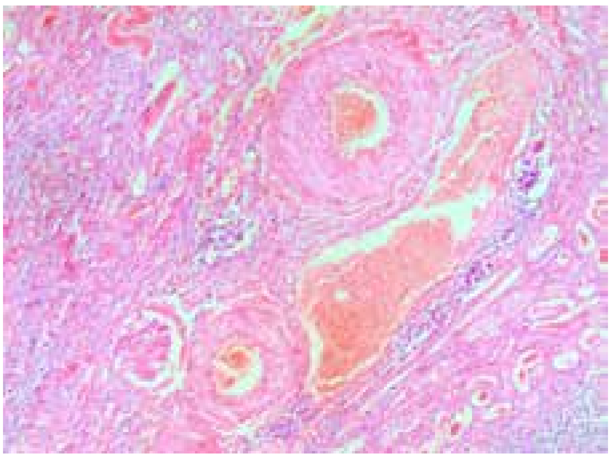

Image 5. Renal tissue showing congested blood vessels and eosinophilic material in tubular lumen along with peri-vascular infiltration of lymphocytes. H&E x 100. © R.K Asrani.

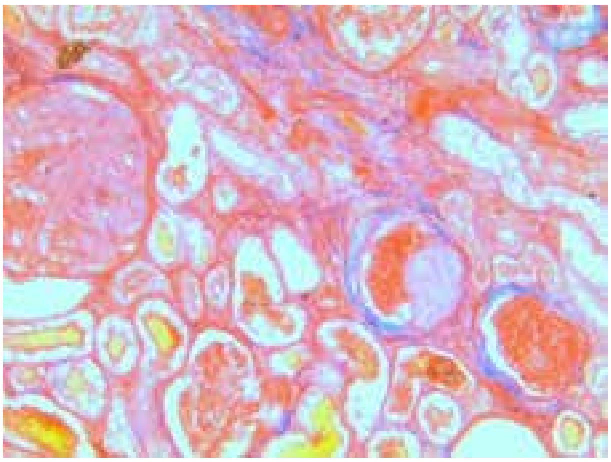

Image 6. Peri-glomerular fibrosis, glomerulosclerosis and glomerular atrophy in kidney section. MSTx200. © R.K Asrani.

by collagenous fibrous tissue deposition with resulted atrophy and infiltrating inflammatory cells especially lymphocytes (Image 5). The fibrous tissue in kidneys observed on histopathological examination was further confirmed by Masson's trichrome staining which showed widespread peri-glomerular, inter-tubular fibrosis along with glomerulosclerosis (Image 6) and similar results are supported by a book compiled by Maxie & Newman (2007). Among geriatric dogs and felines**,** age-related systemic hypertension can contribute to the progression of CKD (Bidani et al. 2012). It has been speculated that environmental stressors like dehydration, psychological stress etc. coupled with aging produce pronounced detrimental impacts on renal perfusion. Furthermore, evidence suggests that inflammatory bowel disease or gastroenteritis in felines and human beings would be expected to cause mild to moderate renal injury due to inflammatory changes or drug therapy (Mitchell et al. 2018)

Based on gross and microscopic changes in kidneys, the leopard in the present investigation is speculated to have died of chronic lymphocytic tubulo-interstitial nephritis with associated lesions in intestine and lungs. The life expectancy of captive felids is longer compared to their free ranging counterparts owing to advances in management and treatment aspects. Animals in captivity are thus more prone to develop age-related degenerative diseases.

References

Bidani, A.K., K.A. Griffin & M. Epstein (2012). Hypertension and chronic kidney disease progression: why the suboptimal outcomes? *The American Journal of Medicine* 125(11): 1057–1062. https://doi.org/10.1016/j.amjmed.2012.04.008

Junginger, J., F. Hansmann, V. Herder, A. Lehmbecker, M. Peters, M. Beyerbach, P. Wohlsein & W. Baumgärtner (2015). Pathology in captive wild felids at German zoological gardens. *PLoS One* 10(6): e0130573. https://doi.org/10.1371/journal.pone.0130573

Kumar, R., A. Kumar, R. Masand, A. Bisht, A. Singla & R.K. Asrani (2020). Clinico-pathological characterization of chronic renal diseases in geriatric dogs. *Indian Journal of Veterinary Pathology* 44(2): 123–128.

Longley, L. (2011). A review of ageing studies in captive felids. *International Zoo Yearbook* 45(1): 91–98.

Luna, G. (1968). *Manual of Histological Staining Method of the Armed Forces Institute of Pathology, 3rd Edition*. New York, McGraw-Hill Book Company, xii + 258 pp.

Maxie, M.G. & S.J. Newman (2007). Urinary system, pp. 425–522. In: Maxie, G. (ed.). *Jubb, Kennedy, and Palmer's Pathology of Domestic Animals. 5th Edition, Vol. 2*. Elsevier, Philadelphia, PA, 782 pp.

Mitchell, E.P., L. Prozesky & J. Lawrence (2018). A new perspective on the pathogenesis of chronic renal disease in captive cheetahs (*Acinonyx jubatus*). *PLoS One* 13(3): e194114. https://doi.org/10.1371/journal.pone.0194114

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 2020: e.T15954A163991139. https://doi.org/10.2305/IUCN.UK.2020-1.RLTS.T15954A163991139.en

Wack, R.F. (2008). Treatment of chronic renal failure in nondomestic felids, pp. 462–465. In: Fowler, M.E. & R.E. Miller (eds.). *Zoo and Wild Animal Medicine*. WB Saunders, 495 pp.

Threatened Taxa

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 September 2023 | 15(9): 23914–23916

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

https://doi.org/10.11609/jott.8358.15.9.23914-23916

#8358 | Received 07 January 2023 | Final received 20 June 2023 | Finally accepted 31 August 2023

OPEN ACCESS

NOTE

The first photographic evidence of Ruddy Mongoose *Herpestes smithii* Gray, 1837 (Mammalia: Carnivora: Herpestidae) in Katerniaghat Wildlife Sanctuary, Uttar Pradesh, India

Javed Anver [1], **Vipul Maurya** [2] & **Sanjay Kumar Pathak** [3]

[1,2] Wildlife Institute of India, Post Box #18, Chandrabani, Dehradun, Uttarakhand 248001, India.
[3] Dudhwa Tiger Reserve, Kachari Road, Lakhimpur, Uttar Pradesh 262701, India.
[1] rajanwar17@gmail.com (corresponding author), [2] vipulforestry@gmail.com, [3] spathakifs@gmail.com

The herpestid family of mongooses is highly adaptable and can be found in diverse environments, ranging from tropical forests to deserts. These mongooses have a diverse diet that includes insects, crabs, small mammals, birds, and reptiles, with a particular fondness for snakes, and they also consume bird eggs. Some mongoose also consume vegetable matter in the form of tubers, fruits, and berries (Feldliamer et al. 1999). The enormous variety of food they consume is produced in a wide range of environments, making it difficult to measure, even though they must respond to site productivity in some way. Hence, the apparent food abundance is not a good indicator of the distribution or abundance of the majority of species. Environmental and landscape parameters play a significant role in shaping the distribution of mongoose in India, as highlighted in the study by Kalle et al. (2012). The Indian Grey Mongoose *Herpestes edwardsii* is commonly sighted in disturbed areas, dry secondary forests, and thorn woods, as reported by Gupta (2011). However, it's worth noting that despite their natural habitat preferences, these mongooses are still under high demand in the wildlife trade. Trappers readily capture them to sell them as pets, as documented by Hanfee & Ahmed (1999) and Kalle (2011).

The black-tipped tail of the Ruddy Mongoose, which is slightly larger than the Indian grey mongoose, is a defining characteristic (Mudappa 2013). The IUCN's Red List of Threatened Species, categorised it as 'Least Concern' (Mudappa & Choudhury 2016). It is found in peninsular India and Sri Lanka, in the Western and Eastern Ghats, up to the open thorn forest of Rajasthan, and north to Bihar (Phillips 1984; Dookia 2013; Mudappa 2013). In more recent times, the species was documented in Nepal as reported by Subba et al. (2014).

Located on the Indo-Nepal border in the Bahraich District of Uttar Pradesh, the Katerniaghat Wildlife Sanctuary covers an area of 400.69 km^2 and is positioned between $28^0$56'72"N, $81^0$20'97"E. It lies in the Tarai-Bhabhar biogeographic subdivision of the upper Gangetic Plain and supports a variety of habitats (Kalam 2005). In the Katerniaghat Wildlife Sanctuary, the major rivers Karnali and Girwa from Nepal converge and give rise to the Ghaghara River, as documented by Bajpai et al. (2012).

Three distinct Ruddy Mongoose sightings were

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

Citation: Anver, J., V. Maurya & S.K. Pathak (2023). The first photographic evidence of Ruddy Mongoose *Herpestes smithii* Gray, 1837 (Mammalia: Carnivora: Herpestidae) in Katerniaghat Wildlife Sanctuary, Uttar Pradesh, India. *Journal of Threatened Taxa* 15(9): 23914–23916. https://doi.org/10.11609/jott.8358.15.9.23914-23916

Funding: None.

Competing interests: The authors declare no competing interests.

Acknowledgements: The authors are thankful to the Uttar Pradesh Forest Department and front line forest staff of Katerniaghat Wildlife Sanctuary. Also, we would like to acknowledge the local community and their knowledge about the wildlife around Katerniaghat Wildlife Sanctuary.

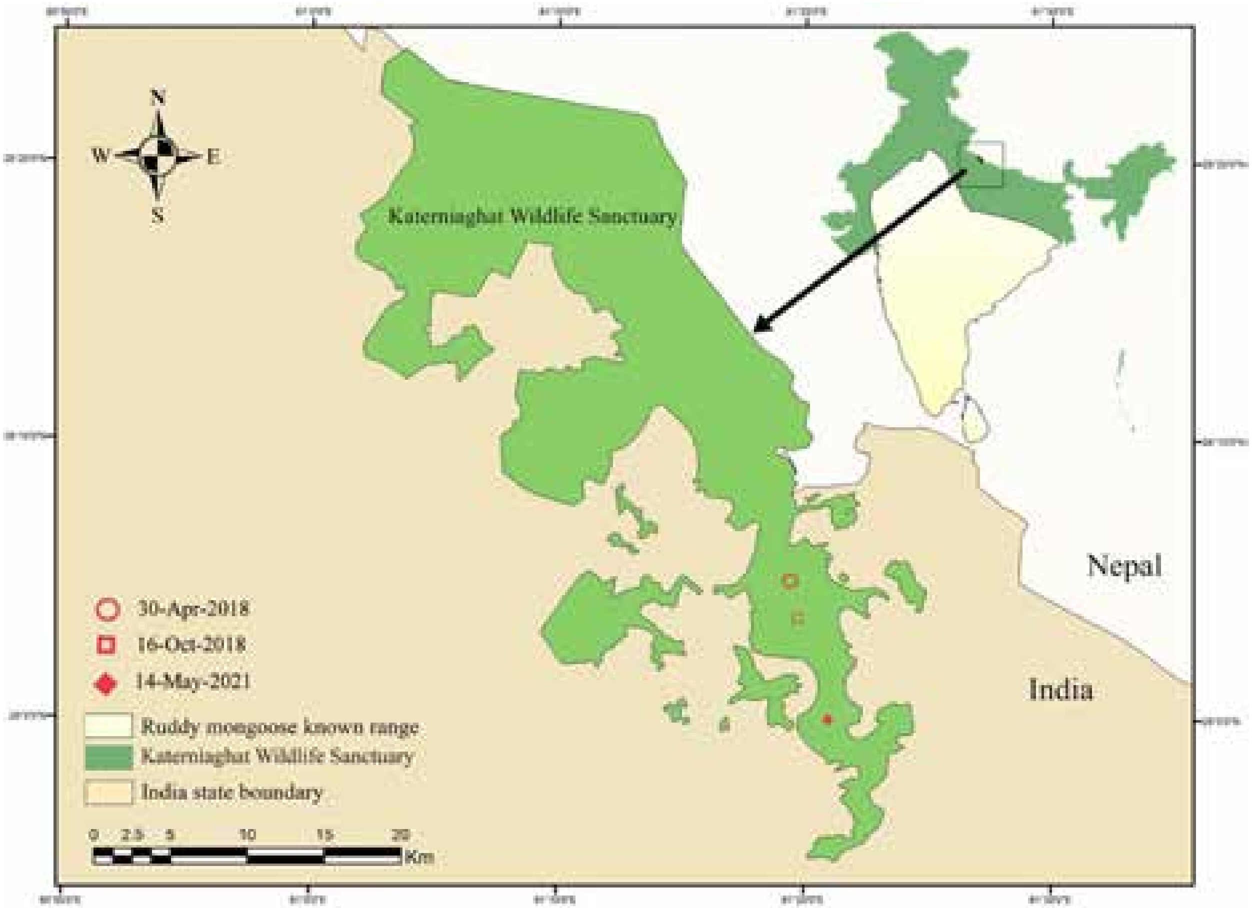

Figure 1. Distribution map of Ruddy Mongoose with recorded locations in the study area (Katerniaghat Wildlife Sanctuary) with sightings date highlighted.

Table 1. Distribution records of Ruddy Mongoose.

	Date	Time	Latitude	Longitude	Altitude	Record	Individuals
1	14.v.2021	1444	28.01482	81.32987	134 m	Direct sighting	2
2	30.iv.2018	1255	27.99394	81.33528	138 m	Direct sighting	2
3	16.x.2018	1410	28.02814	81.32841	134 m	Direct sighting	1

made in the Katerniaghat Wildlife Sanctuary. The photo that was taken during the direct observation was used to assist identify the species. All three observations were made directly. The species was sighted and photographed while crossing the forest road in the Motipur range of Katerniaghat WS. The Indian Grey Mongoose and Small Indian Mongoose, the other two species living in the study area, can be distinguished from the Ruddy Mongoose by their black-tipped tail. With its diverse vegetation, the Katerniaghat Wildlife Sanctuary is with tropical moist deciduous forest (Bajpai et al. 2012). *Ficus benghalensis, Ficus racemosa, Shorea robusta, Tectona grandis, Syzygium cumini*, and the shrub species *Lantana camara, Glycosmis pentapjhylla*, and *Clerodendrum viscosu* make up the majority of the vegetation at all three observation sites.

Previously known distribution range of the Ruddy Mongoose is in peninsular India, and the states of Rajasthan and Bihar, and Sri Lanka (Muddappa 2013). The Ruddy Mongoose is less tolerant toward humans and is considered to dwell in habitats with less human disturbance (Hussain 1999). It was previously recorded in Asola Wildlife Sanctuary in Delhi, but there were no previous records of Ruddy Mongoose from Katerniaghat

Image 1. Adult Ruddy Mongoose *Herpestes smithii* with a visible black-tail tip.

Image 2. Ruddy Mongoose *Herpestes smithii*.

Wildlife Sanctuary; however, it was recently recorded from Banke National Park in Nepal (Subba et al. 2014). Thus, our record of Ruddy Mongoose in Katerniaghat Wildlife Sanctuary marks the distribution in gap regions of its known distribution range.

Image 3. Ruddy Mongoose in its recorded habitat in the Motipur range of Katerniaghat Wildlife Sanctuary.

References

Bajpai, O., A. Kumar, A.K. Mishra, M. Sahu, J. Pandey, S.K. Behera & L.B. Chaudhary (2012). Congregation of tree species of Katerniaghat Wildlife Sanctuary, Uttar Pradesh, India. *Journal of Biodiversity and Environmental Sciences* 2(12): 24

Dookia, S. (2013). Recent sightings of Ruddy Mongoose (*Herpestes smithii*) in Eserna hill range, Jalore Rajasthan, India: northwest extension of its known range. *Small Carnivore Conservation* 49: 25.

Feldliamer, G.A., L.C. Drickamer, S.H. Vessey & J.F. Merritt (1999). Mammalogy, Adaptation, Diversity and Ecology. *Journal of Mammalogy* 80(2): 699–701.

Gupta, S. (2011). Ecology of medium and small sized carnivores in Sariska Tiger Reserve, Rajasthan, India. Doctoral Dissertation, Saurashtra University.

Hanfee, F. & A. Ahmed (1999). Some observations on India's illegal trade in mustelids, viverrids and herpestids. *ENVIS Bulletin* 2(2): 113–115.

Hussain, S.A. (1999). Mustelids, viverrids and herpestids of India: species profile and conservation status. *ENVIS Bulletin* 2(2): 1–38.

Kalam, A. (2005). Birds of Katerniaghat Wildlife Sanctuary, Bahraich district, Uttar Pradesh. *Indian Birds* 1(4): 74–76.

Kalle, R. (2011). Wildlife, a treasure or a delicacy. *Nature Watch, Hornbill* 107(2): 32–33.

Kalle, R., T. Ramesh, K. Sankar & Q. Qureshi (2012). Diet of mongoose in Mudumalai Tiger Reserve, southern India, *Journal of Scientific Transactions in Environment and Technovation* 6: 44–51.

Mudappa, D. (2013). Herpestids, viverrids and mustelids, pp. 471–498. Johnsingh, A.J.T. & N. Manjrekar (eds.). *Mammals of South Asia* 1. Universities Press, Hyderabad, 766 pp.

Mudappa, D. & A. Choudhury (2016). *Herpestes smithii*. The IUCN Red List of Threatened Species 2016: e.T41617A45208195. Accessed on 09 September 2023. https://doi.org/10.2305/IUCN.UK.2016-1.RLTS.T41617A45208195.en

Phillips, W.W.A. (1984). The Sloth Bear, pp. 290–296. In. Wildlife and Nature Protection Society of Sri Lanka (eds.). *Manual of Mammals of Sri Lanka. Colombo, Sri Lanka*. Sri Lanka, 389 pp.

Subba, S.A., S. Malla, M. Dhakal, B.B. Thapa, L.B. Bhandari, K. Ojha, P. Bajracharya & G.S. Gurung (2014). Ruddy Mongoose (*Herpestes smithii*): a new species for Nepal. *Small Carnivore Conservation* 51: 88–89.

Threatened Taxa

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 September 2023 | 15(9): 23917–23919

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

https://doi.org/10.11609/jott.8643.15.9.23917-23919

#8643 | Received 22 July 2023 | Final received 17 August 2023 | Finally accepted 22 August 2023

NOTE

New locality record of the Asiatic Long-tailed Climbing Mouse *Vandeleuria oleracea* (Bennett, 1832) (Mammalia: Rodentia: Muridae) from Kohora River Basin, Assam, India

Sourav Gupta [1], Ramie H. Begum [2], Jayanta Kumar Roy [3], M. Firoz Ahmed [4] & Shyamkant S. Talmale [5]

[1,3,4] Aaranyak, 13, Tayab Ali Byelane, Bishnu Rabha Path, Guwahati, Assam 781028, India.
[1,2] Department of Life Science and Bioinformatics, Assam University, Diphu Campus, Karbi Anglong, Assam 782460, India.
[5] Zoological Survey of India, Western Regional Centre, Vidyanagar, Sector 29, Ravet Road, PCNT Post, Pune, Maharashtra 411044, India.
[1] souravassamwild@gmail.com, [2] ani.ara73@gmail.com (corresponding author), [3] roy.jayantakumar47@gmail.com,
[4] mfa.aaranyak@gmail.com, [5] s_talmale@yahoo.co.in

Vandeleuria oleracea (Bennett, 1832) is a 'Least Concern' species belonging to the genus *Vandeleuria* found in southern and southeastern Asia (Aplin & Molur 2017). Although Agrawal & Chakraborty (1980), Agrawal (2000), and Srinivasulu & Pradhan (2003) mention that *Vandeleuria oleracea* has two subspecies, namely, *V. o. oleracea* from southern India and *V. o. dumeticola* from northern India, the present taxonomic changes indicate that *V. oleracea* may be a species complex with subspecies recognized by earlier workers synonymized under *V. oleracea*, pending further studies (Musser & Carleton 1993, 2005; Srinivasulu & Srinivasulu 2012; Wilson et al. 2017).

On 5 June 2023, during our regular field survey, we encountered a small dead individual of a mouse at Rongtara Village of Kohora River Basin, (26.53–26.60 ^{0}N & 93.33–93.43 ^{0}E; covering an area of 31.50 km^2) Karbi Anglong District, Assam (Figure 1). Morphological measurements were taken (Head and body length: 60.66 mm; tail length: 100.31 mm; hindfoot: 14.12 mm, and ear length: 11.35 mm). The mouse was identified as *Vandeleuria oleracea* by its rusty brown dorsum and white ventral coloration with the head and body length less than 100 mm, unicoloured tail, which was much longer, about one and a half times the head and body length; hallux and fifth toe clawless; fifth toe appeared to be opposable (Agrawal 2000) (Image 1).

The mouse was seen dead in the Jhum plantation near a bamboo clump. Later that day, we conducted informal interviews among the local community in Rongtara Village and showed community members photographs of the species (Image 1). According to the local community, the species is rarely seen in the forest (Image 2). The species was known to them and they call

Editor: Anonymity requested. **Date of publication:** 26 September 2023 (online & print)

Citation: Gupta, S., R.H. Begum, J.K. Roy, M.F. Ahmed & S.S. Talmale (2023). New locality record of the Asiatic Long-tailed Climbing Mouse *Vandeleuria oleracea* (Bennett, 1832) (Mammalia: Rodentia: Muridae) from Kohora River Basin, Assam, India. *Journal of Threatened Taxa* 15(9):23917–23919. https://doi.org/10.11609/jott.8643.15.9.23917-23919

Funding: Aaranyak, IUCN-KfW, and USFWS.

Competing interests: The authors declare no competing interests.

Acknowledgements: We are grateful to Rong Asar Amei, of Rongtara for permission and support. We sincerely thank our field assistant Mr. Bimol Rongpi and Mr. Rajib Hanse for his help in the field. The author, SG, gratefully acknowledges receiving a research stipend and field expenses support from Aaranyak through funding provided by IUCN-KfW and USFWS.

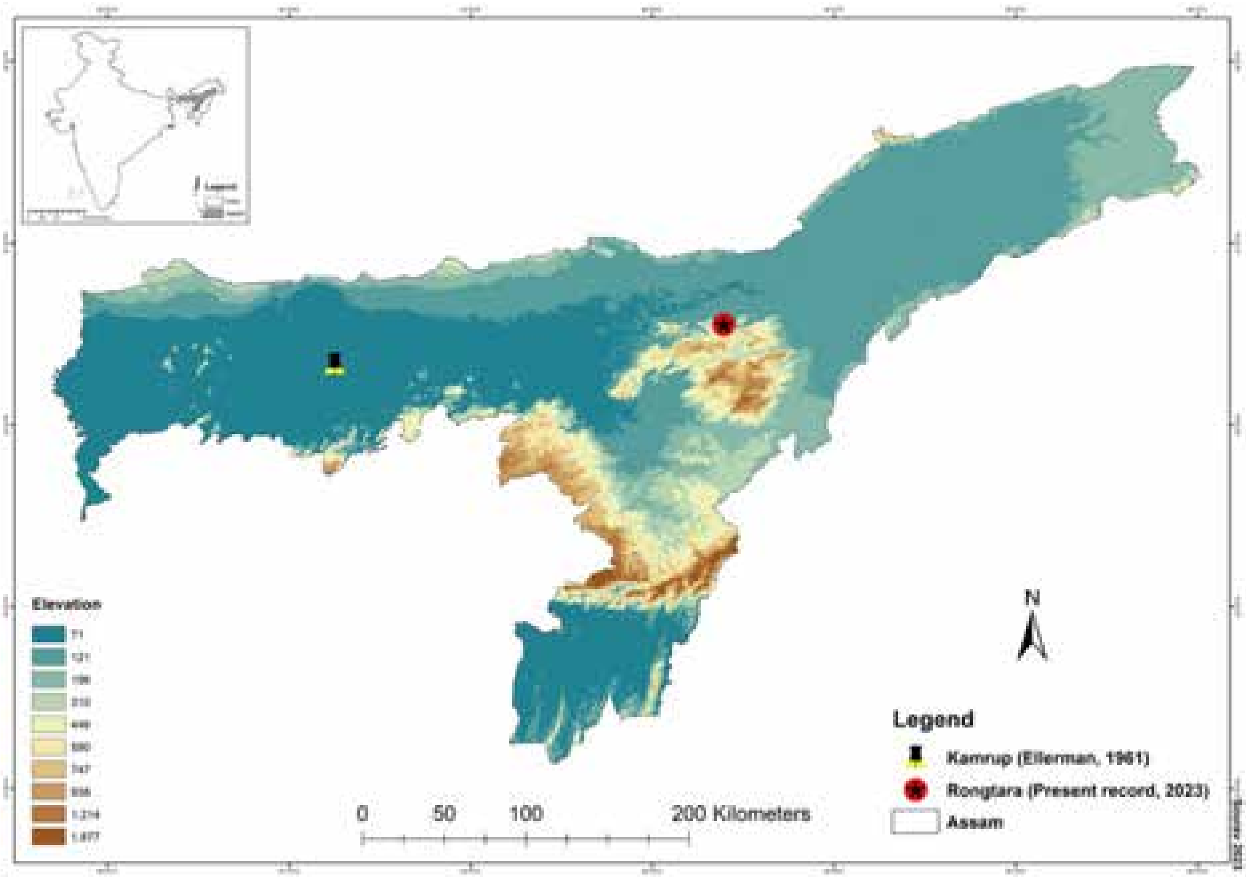

Figure 1. Distribution map of *Vandeleuria oleracea* in Assam with the past record at Kamrup in 1961 and the present record at Rongtara in 2023.

Image 1. Dead *Vandeleuria oleracea* at Rongtara.

it 'Jukikso' in Karbi dialect.

The only known record of *Vandeleuria oleracea* from Assam was from Angarkhata, North Kamrup (Ellerman & Morrison-Scott 1951; Ellerman 1961; Molur et al. 2005; Chatterjee et al. 2020; Talukdar et al. 2021). The new site record from Rongtara Village is approximately 215 km from the earlier report by Ellerman (1961) (Figure 1). The species inhabits agricultural regions (Jhum) in close

Image 2. Habitat of *Vandeleuria oleracea* at Rongtara.

proximity to secondary bamboo forests. This species is arboreal and exhibits nocturnal behavior, primarily consuming fruits, buds, and flowers.

The present study reported the new locality record from Karbi Anglong that confirms its distribution in Assam and Northeast India with an addition of a second confirmed locality in Assam.

Further studies on the ecology and the habitat of the species are needed to understand the species' habitat requirements. Studies involving an integrative taxonomic approach including phylogenetic studies will help resolve this species complex.

References

Agrawal, V.C. (2000). Taxonomic studies on Indian Muridae and Hystricidae (Mammalia: Rodentia). *Records of the Zoological Survey of India, Occasional Paper* No. 180, viii+186 pp.

Agrawal, V.C. & S. Chakraborty (1980). Intraspecific geographical variations in the Indian Long-tailed Tree Mouse, *Vandeleuria oleracea* (Bennett). *Bulletin of the Zoological Survey of India* 3(1&2): 77–85.

Aplin, K. & S. Molur (2017). *Vandeleuria oleracea*. The IUCN Red List of Threatened Species 2017: e.T22845A22430846. Accessed on 22 August 2023. https://doi.org/10.2305/IUCN.UK.2017-2.RLTS.T22845A22430846.en

Chatterjee, P., D. Dam, B. Tripathy & K. Chandra (2020). Status, distribution, and research gaps of rodents (Mammalia: Rodentia) in north-eastern states of India. *Travaux du Muséum National d'Histoire Naturelle "Grigore Antipa"* 63(2): 261–277. https://doi.org/10.3897/travaux.63.e48607

Ellerman, J.R. (1961). Rodentia. Vol. 3., pp. 483–884. In: Roonwal, M.L. (ed.). *The Fauna of India including Pakistan, Burma and Ceylon. Mammalia*, *2nd Edition*. Manager of Publications, Delhi. Part 2, 884 pp.

Ellerman, J.R. & T.C.S. Morrison-Scott (1951). *Checklist of Palaearctic and Indian Mammals 1758–1946*. British Museum (Natural History), London, 810 pp.

Molur, S., C. Srinivasulu, B. Srinivasulu, S. Walker, P.O. Nameer & L. Ravikumar (2005). *Status of South Asian Non-volant Small Mammals: Conservation Assessment and Management Plan (CAMP) Workshop Report.* Zoo Outreach Organization/CBSG-South Asia, Coimbatore, India, 618 pp.

Musser, G.G. & M.D. Carleton (1993). Family Muridae, pp. 501–755. In: Wilson, D.E. & D.M. Reeder (eds.). *Mammal Species of the World: A Taxonomic and Geographic Reference*, *2nd Edition*. Smithsonian Institution Press, Washington D.C., xviii + 1206 pp.

Musser, G.G. & M.D. Carleton (2005). Superfamily Muroidea, Order Rodentia, pp. 894–1531. In: Wilson, D.E. & D.M. Reeder (eds.). *Mammal Species of The World: A Taxonomic and Geographic Reference, 3rd Edition*, *Johns Hopkins University Press,* Baltimore, 2141 pp.

Srinivasulu, C. & M. S. Pradhan (2003). Checklist of Murids (Mammalia: Rodentia: Muridae) of South Asia. *Zoos' Print Journal* 18(12): 1286–1310. http://doi.org/10.11609/JoTT.ZPJ.18.12.1286-310

Srinivasulu, C. & B. Srinivasulu (2012). *South Asian Mammals. Their Diversity, Distribution, and Status*. Springer, New York, 468 pp.

Talukdar, N.R., P. Choudhury, R.A. Barbhuiya, F. Ahmad, D. Daolagupu & J.B. Baishya (2021). Mammals of northeastern India: an updated checklist. *Journal of Threatened Taxa* 13(4): 18059–18098. https://doi.org/10.11609/jott.6010.13.4.18059-18098

Wilson, D.E., T.E. Lacher & R.A. Mittermeier (2017). *Handbook of The Mammals of the World. Vol. 7. Rodents II*. Lynx Edicions, Barcelona, 1008 pp.

Threatened Taxa

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 September 2023 | 15(9): 23920–23924
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.8496.15.9.23920-23924
#8496 | Received 29 April 2023 | Final received 25 July 2023 | Finally accepted 02 September 2023
NOTE

New distribution record of fish *Clupisoma garua* (Hamilton, 1822) (Siluriformes: Ailiidae) from the Sarpang District in southern central part of Bhutan

Sangay Dorji [1] & Jigme Tenzin [2]

[1] Southern Wildlife Rescue and Rehabilitation Centre, Divisional Forest Office, Sarpang, Department of Forests & Park Services, Ministry of Energy & Natural Resources, 31002, Bhutan.
[2] Research and Information Unit, Divisional Forest Office, Sarpang, Department of Forests & Park Services, Ministry of Energy & Natural Resources, 31002, Bhutan.
[1] sangaydorji73@gmail.com, [2] jigmetenzin16@gmail.com (corresponding author)

Clupisoma garua (Hamilton, 1822) falls under catfish group, which is widely known by different names as Neria (Assam in India), Ghaura (Bangladesh), Baikha/Jalkapoor (Nepal) (Wang et al. 2016). It belongs to the Ailiidae family under Siluriformes order and it is widely distributed across the Indian rivers and reservoirs. Globally, Ailiidae familiey is native to Africa and Asia which comprises of 66 species that belongs to 14 genera. However, nearly half of the species (32 species) are known from Asian countries that comprises of five genera including *Clupisoma*, *Ailia*, *Horabagrus*, *Laides*, and *Pseudeutropius* (Wang et al. 2016). Among them, the *Clupisoma* genus has five species of which four are reported from the Indian region: *garua*, *bastari*, *naziri*, and *montana* (Hora 1937). Globally, *C. garua* is distributed around the Ganga River system in India and Nepal, Ganga-Brahmaputra River system in Bangladesh and Indus River system in Pakistan (Bhokta & Solanki 2020). In case of India, *C. garua* is widely distributed in Bihar, West Bengal, Odisha, Madhya Pradesh, and Assam (Brahmaputra and Barak drainage) (Bhokta & Solanki 2020). However, this species is threatened in some localities such as southwestern Bengal due to overfishing (Verma et al. 2014) and decline from natural water bodies (Patra et al. 2005; Mishra et al. 2009). Meanwhile, the recent record of *C. garua* from Ayechu River had set new distribution record from the Bhutan. As per the IUCN Red List, the species is categorized under ‘Least Concern’ (LC) IUCN Red List (2020). However, both CAMP (Molur & Walker 1998) and CAFF (2006) had declared it as Vulnerable (VU), due to the reduction of populations in their natural habitats; while, in Bangladesh, the species is recently kept under Critically Endangered (Hanif et al. 2015) due to restricted geographical distribution fueled by the increasing anthropogenic and natural hazards (Siddik et al. 2017).

Clupisoma garua is commercially important freshwater fish that has a potential species for aquaculture system (Saraswat et al. 2014). The studies of Bhuiyan (1964) and Memon et al. (2010) also reported that *C. garua* is mostly consumed by various group of people including the marginalized people due

Editor: J.A. Johnson, Wildlife Institute of India, Dehradun, India. **Date of publication:** 26 September 2023 (online & print)

Citation: Dorji, S., & J. Tenzin (2023). New distribution record of fish *Clupisoma garua* (Hamilton, 1822) (Siluriformes: Ailiidae) from the Sarpang District in southern central part of Bhutan. *Journal of Threatened Taxa* 15(9): 23920–23924. https://doi.org/10.11609/jott.8496.15.9.23920-23924

Funding: None.

Competing interests: The authors declare no competing interests.

Acknowledgements: The author would like to acknowledge Mr. Lobzang Dorji, Director, Department of Forests and Park Services and Mr. Phub Dhendup, Chief Forestry Officer, Divisional Forest Office, Sarpang for their support and encouragement. Likewise, we also owed our indebtness to Prof. Dhan Bahadur Gurung, College of Natural Resources (CNR), University of Bhutan (RUB) for confirming the species and Mr. Subha, Fisher man, for his support during the survey.

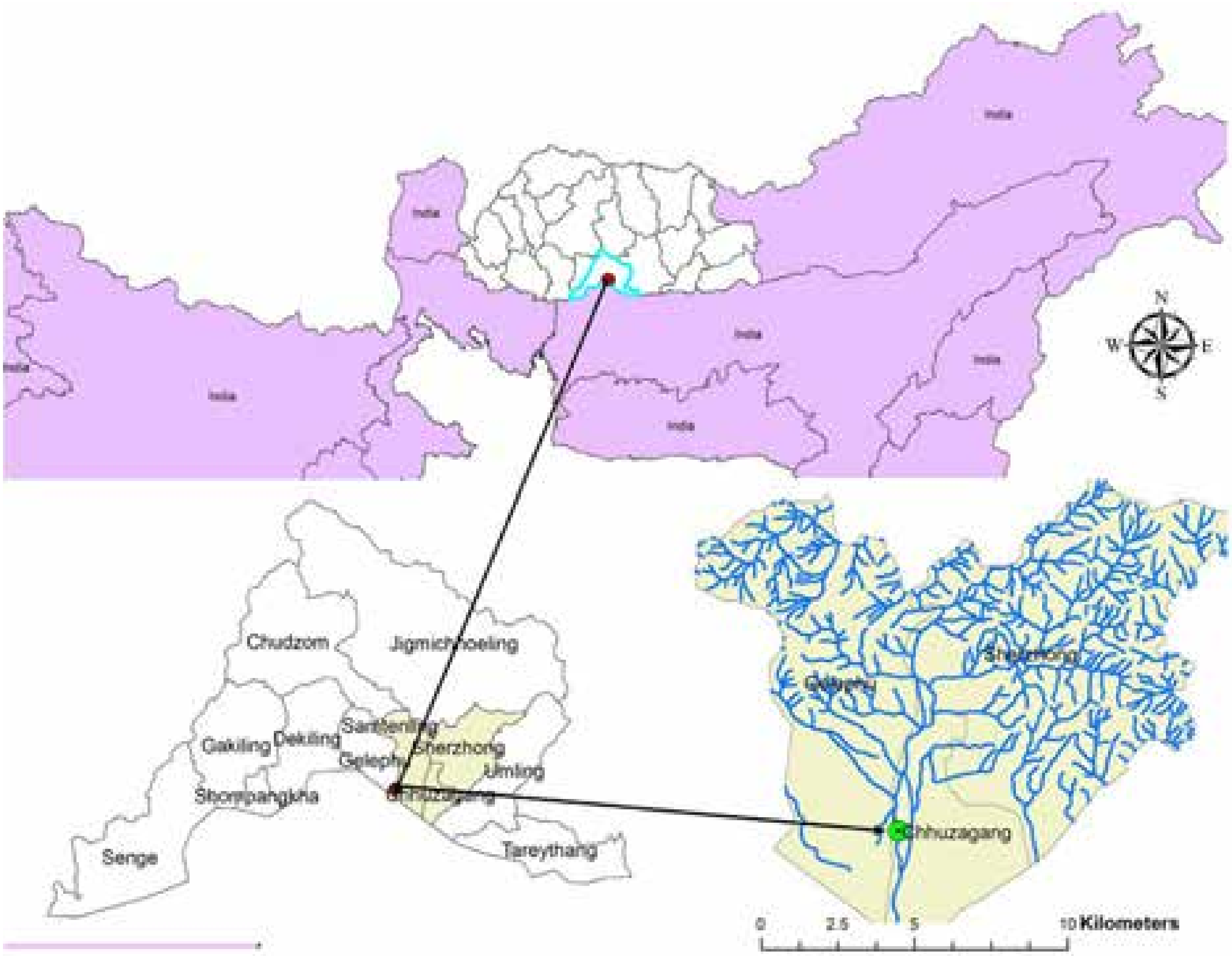

Figure 1. Bhutan map showing the location of Ayechu where *Clupisoma garua* was recorded in Sarpang District.

to high level of protein (18.40%) and fat (5.2%) content, followed by most abundant in some of the river system (Galib et al. 2009). Besides these, the species also has ornamental values that promotes livelihood of the coastal communities (Gupta et al. 2016).

Mouchhu basin in Gelephu is located between 26.923–26.847°N & 90.506-–90.504°E that falls under Sarpang District in the southern central part of Bhutan (Figure 1). Mouchu basin drains from the Black Mountain which is located at the central part of Bhutan that flows through Gelephu and exit towards India, which finally confluences with Brahmaputra River. In the case of Ayechu (26.875°N, 90.501°E), which is the diverted river of Mouchhu basin whereby *C. garua* was opportunistically recorded for the first time from this river in September 2020 using cast net. Since *C. garua* is a migratory species, it could have migrated from India during monsoon season through Mouchu basin as it hasn't been recorded during the past survey. With this new addition, Bhutan now has 126 fish species (DoFPS 2020), out of which 28 fish species are found in Sarpang District that belongs to 11 families (Tenzin 2022). Among 28 species, three species were categorized under Vulnerable, three Endangered, two Near Threatened and rest are Least Concern as per Tenzin (2022). The district falls within the convergences of three ecologically-diverse protected areas of Bhutan which are connected with each other by Biological Corridor No. 03 (Tenzin et al. 2021). Sarpang shares the southern border with the northeastern state of Assam in India which is further connected with the Royal Manas National Park (RMNP) and Indian Manas National Park (MNP) towards the east and Phibsoo Wildlife Sanctuary (PWS) in the west (Tenzin et al. 2021). Floristically, this area comprises of subtropical broad-leaved forests located at an elevation of 200 m and this area receives the average precipitation of 3,500–5,500 mm (Tenzin et al. 2022). The specimen was confirmed with professor D.B. Gurung from College of Natural Resources, Punakha District, Bhutan through morphometric measurements using digital caliper. The studies of Bhokta & Solanki (2020) was also referred for confirmation. Meanwhile, the specimen was collected and euthanized using 0.001 percent clove oil and treated in 10% formalin for fixation as per Gurung et al. (2012) and Tenzin & Dhendup (2017) and it is currently deposited in the Laboratory of the Southern Wildlife Rescue and Rehabilitation Centre (SWRRC) in Sarpang District. Fin formula is the key feature been used for identification and comparison as tabulated (Table 1).

The studies of Jayaram (1977) found that *Clupisoma garua* is a herring-shaped fish that gradually tapers toward both ends and abdominal edge between pelvic fins and vent (Image 1, 2 & 3). Talwar & Jhingran (1991) also substantiated that the adipose dorsal fin is absent in adults, while, caudal fin is deeply forked with lower lobe longer than upper with black edged dorsal, pectoral and caudal. On other hand, the eyes are large with circular adipose eyelids and their mouth is wide and terminal.

Table 1. Morphometric measurement of Fin formula of *C. garua* species and compared with morphometric studies of Bhokta & Solanki (2020).

	Variables of fin formula (cm)	Specimen of current study	Specimen Fin formula of Bhokta & Solanki (2020)
1	D	1/7	1/6
2	A	27	3/28
3	P	1/11	1/11
4	V	1/5	1/5
5	C	18	17–20
6	Maximum length (TL)	16.6 cm	60.9–100 cm
7	Colour of fin	Yellowish-orange	Yellowish-orange
8	Presence of adipose fin	No.	No.

D—Dorsal fin | A—Anal fin | P—Pectoral fin | V—Ventral/Pelvic fin | C—Caudal fin.

Image 1. Ventral view of *Clupisoma garua* species. © Sangay Dorji 2020.

Image 2. Lateral view, mouth and head view of *Clupisoma garua* species. © Sangay Dorji 2020.

Image 3. Head and mouth view of *Clupisoma garua* species. © Sangay Dorji 2020.

Nonetheless, body is coloured with silvery grey on the back which is lighter on the sides and abdomen with tinted grey color fins and black edged dorsal, pectoral and caudal fin respectively (Talwar & Jhingran 1991). The present *C. garua* specimen has a total length (TL) of 16.60 cm; however, it can grow up to maximum TL of 60.90 cm (Bhokta & Solanki 2020).

The species is mainly found in lacustrine habitat in larger rivers and reservoirs with stagnant impoundments (Bhokta & Solanki 2020). The studies of Froese & Pauly (2013) and Saraswat et al. (2014) reported that *C. garua* is potamodromous that migrates within streams & rivers and travels a long distance (>100 km) for feeding as well as for seeking suitable breeding habitat in new water bodies. Further, *C. garua* is a carnivorous fish that exploits food resources in the surface guild and also feeds along the margins of the river. Feeding intensity is higher during the September–October months (Bhokta & Solanki 2020).

As per IUCN Red List (2020), the species is categorized as 'Least Concern' (LC). However, it's categorized under Critically Endangered in Bangladesh IUCN Bangladesh (2000) and Vulnerable in India (Molur & Walker 1998; Lakra et al. 2010). In several parts of the range country, the populations are reported to be declining from the natural habitat (Bhokta & Solanki 2020). Biswa et al. (2018) also substantiated that over exploitation, habitat loss, human interference, climate change, pollution, and siltations are the main causes of the population decline, besides overfishing in range countries. However, in-depth ecology and pertinent conservation threats from Bhutan is still unknown, due to recent occurrences which may require separate ecological studies along the Mouchu River in future.

References

Bhakta, D & Sonia (2020). Review on *Clupisoma garua* (Hamilton, 1822), an inhabitant species in inland open waters of India. *Innovation Farming* 5: 25–29.

Bhokta, D. & S. Solanki (2020). Review on *Clupisoma garua* (Hamilton, 1822), an inhabitant species in inland open waters of India. *Innovative Farming* 5: 25–29.

Bhuiyan, A.L (1964). *Fishes of Dacca*. Dacca, 71 pp.

CAFF (2006). Conservation Assessment of Freshwater Fish Diversity for Central India. Proc. workshop, organized by National Bureau of Fish Genetic Resources, 25 Nov, CIAE, Bhopal, MP, India.

DoFPS (2020). Biodiversity Monitoring and Social Surveying Protocol of Bhutan, Department of Forests and Park Services, Ministry of Agriculture and Forests, Thimphu, Bhutan, 58 pp.

Froese, R. & D. Pauly (2013). FishBase. World Wide Web electronic publication. *http://www.fishbase.org.in.*

Galib, S.M., M.A. Samad., A.B.M. Mohsin., F.A. Flowra & M.T. Alam (2009). Present Status of Fishes in the Chalan Beel- the Largest Beel (Wetland) of Bangladesh. *International Journal of Animal Fisheries Science* 2: 214–218.

Gupta, S., S.K. Dubey, R.K. Trivedi, B.K. Chand & S. Banerjee (2016). Indigenous ornamental freshwater ichthyofauna of the Sundarban Biosphere Reserve, India: status and prospects. *Journal of Threatened Taxa* 8(9): 9144–9154. https://doi.org/10.11609/jott.1888.8.9.9144-9154

Gurung, D.B., Ugyen & D. Tshering (2012). Mon-paa Frog Survey Report from Mithun village (24–27 April 2012) under Dophuchen, Samtse District. Unpublished Technical Report. District Forestry Sector, Samtse, Bhutan, 30 pp.

Hanif, M.A., M.A.B., Siddik, M.R. Chaklader, A. Nahar & S. Mahmud (2015). Fish diversity in the southern coastal waters of Bangladesh: present status, threats and conservation perspectives. *Croatian Journal of Fisheries* 73: 251–271.

Hora, S.L. (1937). The game fishes of India. III. "Garuabachcha or Gaurchcha", *Clupisoma garua* (Hamilton) and two allied species. *Journal of the Bombay Natural History Society* 39: 659–678.

IUCN Bangladesh (2000). Red Book of Threatened Fishes of Bangladesh, IUCN- The World Conservation Union, 116 pp.

IUCN Red List (2020). *Clupisoma garua*. https://www.iucnredlist.org/search?query=Clupisoma%20garua&searchType=species. Accessed on 23 August 2023.

Jayaram, K.C. (1977). Aid to the identification of siluroid fishes of India, Burma, Sri Lanka, Pakistan and Bangladesh. 2. Siluridae, Schilbeidae, Pangasidae, Amblycipitidae, Akysidae. Records of the Zoological Survey of India, Miscellaneous Publication, *Occasional Paper* no. 10: 1–33.

Talwar, P.K. & A.G. Jhingran (1991). Inland fishes of India and adjacent countries (Vol. 1 & 2) (p. 1158). Oxford and IBH Publishing Co., Pvt. Ltd., New Delhi, India.

Lakra, W.S., U.K. Sarkar, R.S. Kumar, A. Pandey, V.K. Dubey & O.P. Gusain (2010). Fish diversity, habitat ecology and their conservation and management issues of a tropical River in Ganga basin, India. *The Environmentalist* 30: 306–319.

Memon, N.N., F.L. Talpur & M.I. Bhanger (2010). A comparison of proximate composition and fatty acid profile of Indus River fish species. *International Journal of Food Properties* 13: 328–337.

Mishra, S.S., S.K. Acherjee & S.K. Chakraborty (2009). Development of tools for assessing conservation categories of siluroid fishes of fresh water and brackish water wetlands of South West Bengal, India. *Environmental Biology of Fishes* 84: 395–407.

Molur, S. & S. Walker (eds.) (1998). Report of the workshop on "Conservation, Assessment and Management Plan for Freshwater fishes of India". Zoo Outreach Organization and Conservation Breeding Specialist Group India, Coimbatore, India, 156 pp.

Patra, M.K., S.K. Acharjee & S.K. Chakraborty (2005). Conservation categories of siluroid fishes in North-East Sundarbans, India. *Biodiversity and Conservation* 14: 1863–1876.

Saraswat., D, W.S. Lakra, P. Nautiyal, M. Goswami, K. Shyamakant & A. Malakar (2014). Genetic characterization of *Clupisoma garua* (Hamilton, 1822) from six Indian populations using mtDNA cytochrome b gene. *Mitochondrial DNA* 25: 70–77.

Siddik., M.A.B., M.R. Chaklader, M.A. Hanif, A. Nahar, I. Lham, A. Cole & R. Fotedar (2017). Variation in the life-history traits of a Schilbid catfish, *Clupisoma garua* (Hamilton, 1822) in the coastal waters of southern Bangladesh. *Chinese Journal of Oceanology and Limnology* 3: 1189–1196.

Tenzin, J., P. Dhendup, D. Dorji, S. Nidup & P. Thinley (2021). Annotated checklist and conservation status of mammal species in Sarpang District, Bhutan. *Indonesian Journal of Social and Environmental Issues* 2: 258–270. https://doi.org/10.47540/ijsei.v2i3.398

Tenzin, J., Y. Yangdon, K. Wangchuk, P. Rinchen & Tashi (2022). Water Sources Inventory, Annotated checklist and distribution of water sources under Gelephu, Samtenling and Dekiling Gewog in Sarpang District, Bhutan. *Indonesian Journal of Social and Environmental Issues* 3: 49–57. https://doi.org/10.47540/ijsei.v3i1.452

Tenzin, J. (2022). Biodiversity checklists of Sarpang district in Bhutan, Divisional Forest Office, Sarpang, Department of Forests & Park Services, 61 pp.

Tenzin, J. & P. Dhendup (2017). Habitat characteristics, relative abundance and conservation threats of Himalayan bull frogs (*Nanorana leibigii* Günther, 1860) in primary tributaries of Simkhar River, Bhutan. *Bhutan Journal of Natural Resources & Development* 4: 29–38. https://doi.org/10.17102/cnr.2017.07

Verma, J., A. Kashyap & M. Serajuddin (2014). Phylogeny based on truss analysis in five populations of freshwater catfish: *Clupisoma Garua*. *International Journal of Scientific Research* 3: 1414–1418.

Wang, J., B. Lu, R. Zan, J. Chai, W. Ma, W. Jin, R. Duan, J. Luo, R.W. Murphy, H. Xiao & Z. Chen (2016): Phylogenetic relationships of five Asian schilbid genera including *Clupisoma* (Siluriformes: Schilbeidae). *PLoS ONE* 11(1): e0145675. https://doi.org/10.1371/journal.pone.0145675

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 September 2023 | 15(9): 23925–23927
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.8199.15.9.23925-23927
#8199 | Received 20 September 2022 | Final received 01 August 2023 | Finally accepted 22 August 2023

NOTE

Kukumseri: a home to *Colchicum luteum* Baker (Colchicaceae), a rare and endangered medicinal herb

Rajender Kumar Sharma

Department of Botany, Deshbandhu College, University of Delhi, Delhi 110019, India.
rksharmabio@yahoo.co.in

Colchicum luteum Baker (Colchicaceae) commonly known as Hirantutiya (Hindi), Hiranyatutha (Sanskrit), Suranjantalkh (Urdu), and Kukum (locally) is an important medicinal herb, used in various traditional herbal medicine systems (Ayurveda, Siddha, Unani) (Rather et al. 2022). The species contains alkaloids including, colchicine & democolcine which have anti-mitotic properties and used for the treatment of solid tumors and leukemia (Ondra et al. 1995; Yue et al. 2010). *C. luteum* also reported to have analgesic, anti-inflammatory, antimicrobial, aphrodisiac, carminative, laxative & wound healing properties, and especially useful in gout, rheumatism and Alzheimer disease (Aisen et al. 2001; Javed et al. 2005; Rather et. al. 2022). The said effects have been well proven in various studies through animal models (Ahmad et al. 2006; Akbar 2020)

Colchicum luteum is found in the Hindu Kush-Himalayan region and has very restricted distribution, endemic to certain places only, and considered as a rare species (CAMP report 2010; Rather et al. 2022). The habitat specificity; requirement of low temperature, less relative humidity and specific soil types for growth are being the reasons for their restricted distribution among others. Besides its restricted distribution and rarity, the indiscriminate over-exploitation for medicinal use has further endangered the survival and has been categorized as an endangered plant species (CAMP report 2010). In Indian Himalayan region (IHR) *C. luteum* has only been reported from certain places of Kashmir and Himachal Pradesh (Ved et al. 2003). The literature revealed, lack of systematic studies on diversity and distribution of *C. luteum*, the available data being either subjective or ethnobotanical. Further, the absence of species in detailed reports/ works on flora of the area including, flora of Lahaul-Spiti (Aswal & Mehrotra 1994) confirm the same. Rather et al. (2022) also observed the lack of information regarding distribution and population size of *C. luteum* from Kashmir Himalaya.

Therefore, to explore the distribution and population size of *C. luteum* in Lahaul, Himachal Pradesh, India, a survey was conducted during March–April, 2021 and 2022. The species was found on open moist slopes between 2,650–3,000 m elevation (Images 1 & 2). The species appeared soon after the melting of the snow in March and were the earliest plants to flower during spring, completing the growth cycle (vegetative, flowering, and seed set) within two to three months (March–May). During this period of the year the area remains mostly snow bound, less accessible, and has poor vegetation due to unfavorable or cold weather conditions. Thus, due to above listed facts (habitat specificity, rare and endangered population status and comparatively very short life cycle during unusual period of the year) people rarely visit the places and/

Editor: Afroz Alam, Banasthali Vidyapith, Rajasthan, India. **Date of publication:** 26 September 2023 (online & print)

Citation: Sharma, R.K. (2023). Kukumseri: a home to *Colchicum luteum* Baker (Colchicaceae), a rare and endangered medicinal herb. *Journal of Threatened Taxa* 15(9): 23925–23927. https://doi.org/10.11609/jott.8199.15.9.23925-23927

Funding: None.

Competing interests: The author declares no competing interests.

Images 1 & 2. *Colchicum luteum* in its natural habitat in Lahaul, Himachal Pradesh. © Rajender Kumar Sharma.

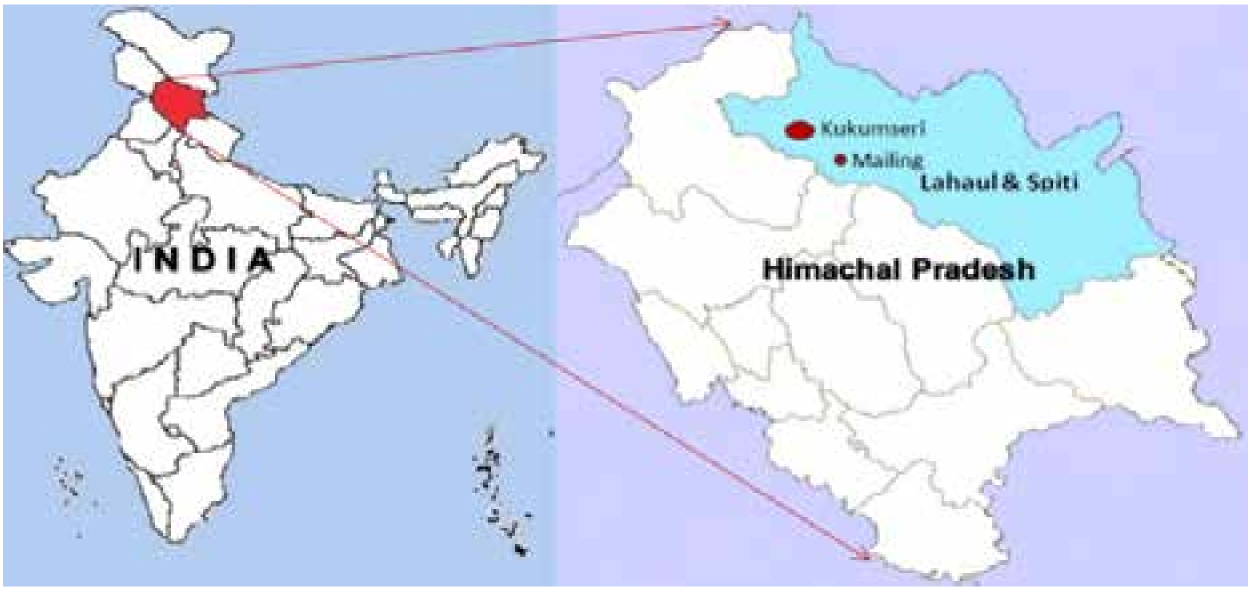

Figure 1. Locations of *Colchicum luteum* population in Lahaul, Himachal Pradesh, India.

or notice the species during the said period. Therefore, despite the importance of this elite genotype (Wagh et al. 2015), the species has been poorly investigated.

In the present study area, the species were recorded at two locations: Mailing (32.605˚N, 76.934˚E, 2,925 m elevation) and Kukumseri (32.698˚N, 76.687˚E, 2675 m elevation) (Figure 1 & Image 3). The observed species density in Mailing and Kukumseri was 6.4 ± 5.7 and 3.08 ± 4.15/m^2, respectively, determined by counting the total number of individuals of a species in all quadrants (1 × 1 m, each), and divided by total number of quadrants studied. The extent of occurrence (EOO) of species in Kukumseri region was found higher than the Mailing. In Mailing, the species were only distributed in an area of about three Km^2. The distribution of species only to a certain specific place seems due to the requirement of specific soil condition, and the latter need to be explored. Very interestingly, it was observed that one location (Kukumseri) has been named after the species (*Colchicum luteum*) where, 'Kukum' means *Colchicum luteum* and 'Seri' means field. Thus, 'Kukumseri' means,the field of *Colchicum luteum*.

Images 3. A view of habitat of *Colchicum luteum* population at Kukumseri in Lahaul, Himachal Pradesh, India.

Furthermore, the location justifies its name due to the presence of a reasonably large number of species in the area. Recently, huge destruction of natural habitat (4.2 ha) in Kukumseri, has been done for the opening of Krishi Vigyan Kendra (2.6 ha) and College campus (1.6 ha). The latter would have been avoided considering the restricted distribution, habitat specificity, rarity, endangered status and medicinal/economic importance of *C. luteum*.

The information reported here will be of immense help to locate and visit the places at appropriate period of the year for studies, aimed at propagation, cultivation, and conservation of the species. Further, such data plays crucial role while assessing the population status of the species.

References

Ahmad, B., H. Khan, S. Bashir & M. Ali (2006). Antimicrobial bioassay of *Colchicum luteum* Baker. *Journal of Enzyme Inhibition and Medicinal Chemistry* 21(6): 765–769.

Aisen, P.S., D.B. Marin, A.M. Brickman, J. Santoro & M. Fusco (2001). Pilot tolerability studies of hydroxychloroquine and colchicine in Alzheimer disease. *Alzheimer Disease and Associated Disorders* 15: 96–101.

Akbar, S. (2020). *Handbook of 200 Medicinal Plants*. Springer, Cham, 216 pp. https://doi.org/10.1007/978-3-030-16807-0_72

Aswal, B.S. & B.N. Mehrotra (1994). *Flora of Lahaul-Spiti (A cold desert in North West Himalaya)*. Bishen Singh Mahendra Pal Singh, Dehradun, India, 761 pp.

CAMP report (2010). Conservation Assessment & Management Prioritisation (CAMP) Workshop on threatened medicinal plants of Himachal Pradesh. Sponsored by National Medicinal Plants Board, Government of India. Himachal Pradesh Forest Department, Shimla, 186 pp.

Javed, M., J.A. Khan & M.M.H. Siddiqui (2005). Effect of *Colchicum luteum* Baker in the management of rheumatoid arthritis. *Indian Journal of Traditional Knowledge* 4(4): 421–423.

Ondra, P., I. Valka, J. Vicar, N. Sütlüpinar & V. Simasnek (1995). Chromatographic determination of constituents of the genus *Colchicum* (Colchicaceae). *Journal of Chromatography* 704: 351–356.

Rather, R.A., H. Bano, A. Firoz, H.M. Ali, M.A. Bhat, S.A. Padder, H. Nafees & K.R. Hakeem (2022). The assessment of morphological diversity of *Colchicum luteum* Baker, an economically important threatened medicinal plant of Kashmir Himalaya. *Sustainability* 14: 1327. https://doi.org/10.3390/su14031327

Ved, D.K., G.A. Kinhal, K. Ravikumar, V. Prabhakaran, U. Ghate, V.R. Shankar & J.H. Indresha (Eds.) (2003). *Conservation assessment and management prioritization for the medicinal plants of Jammu & Kashmir, Himachal Pradesh & Uttaranchal*. Foundation for Revitalisation of Local Health Traditions, Bangalore, India, 206 pp.

Wagh, P.J., V.W. Patil & M.C. Kale (2015). Effect of soluble chitosan application on *in-vitro* germination and growth of dormant corms of *Colchicum luteum* Baker. *International Journal of Researches in Biosciences, Agriculture and Technology* 2(3): 179–182.

Yue, Q.X., X. Liu & D.A. Guo (2010). Microtubule-binding natural products for cancer therapy. *Planta Medica* 76: 1037–1043.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 September 2023 | 15(9): 23928–23930
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.8059.15.9.23928-23930
#8059 | Received 16 June 2022 | Final received 15 August 2023 | Finally accepted 18 August 2023
NOTE

First record of the Western Himalayan Yew *Taxus contorta* (Gymnosperms: Cupressales: Taxaceae) from Lumbini Province, Nepal

Santa Bahadur Thing [1], Deepak Raj Prakash Janga Shahi [2] & Shashi Shrestha [3]

[1–3] Ministry of Forests, Environment and Soil Conservation, Lumbini Province, Nepal.
[1] Current address: Division Forest Office, Kapilvastu, Taulihawa, Nepal.
[1] sonam.lama200@gmail.com (corresponding author), [2] deepakthakuri132@gmail.com, [3] shrestha.shashi2015@gmail.com

Yews (*Taxus* spp.) are among the most threatened plant species within the Hindu Kush-Himalaya (HKH) region including Nepal (Mulliken & Crofton 2008). Due to over exploitation of the species for the production of anticancer drugs and in some areas intense local use for medicine, timber, and fodder the natural yew populations along the HKH region have been cleared up to 90% over the last few decades (Schippmann 2001; Mohapatra et al. 2009). Delayed germination (1.5–2 years) of its seeds and poor survival rate of seedlings have further accelerated the decline of yew population in the Himalaya (Rikhari et al. 1998). Despite its threatened (EN) status, little information is available regarding the size and status of its populations (Iqbal et al. 2019). Even the taxonomic identification of species remained controversial in Nepal till the year 2012 (Poudel et al. 2012). The Forest Regulation, 1995 named the taxus species found in Nepal as *Taxus baccata* in its annex till 12 October 2015, which was corrected and named as *Taxus contorta* Griff., *Taxus wallichiana* Zucc., and *Taxus mairei* (Lemée & H. Léveillé) S.Y. Hu ex T.S. Liu in its fifth amendment in the year 2015.

Currently, a total of 13 (four in North and South America, one in Europe and eight in Asia) species of *Taxus* have been identified in the world (Gao et al. 2007; Farjon 2010; Liu et al. 2011). The threatened Western Himalayan Yew *T. contorta* is one among three of the *Taxus* species (*T. contorta, T. mairei, T. wallichiana*) found in Nepal (Thomas 2011; Poudel et al. 2012, 2014; Bhatt et al. 2017). It is assumed to be distributed sparsely over Darchula District in the far western region to the northern belt of Gorkha District in the central region of Nepal (Poudel et al. 2014). It has been recorded from several districts of three of the seven provinces of Nepal (Bhatt et al. 2017). However, this is the first record from Lumbini Province, Nepal.

T. contorta is a medium-sized dioecious evergreen tree species which grows naturally within the elevation range of 2,000–3,500 m in Nepal and the recorded height of *T. contorta* in Nepal is 25–30 m (Bhatt et al. 2017). The species has diagnostic characters such as bud scales few, ovoid, persistent at the base of branchlets; leaves arranged irregularly, pectinate, usually linear, equally wide throughout length, base cuneate, mostly symmetric, apex acute, midrib papillate, midrib & leaf margin underneath not shiny, loosely arranged (6–9)

Editor: D.S. Rawat, G.B. Pant University of Agriculture & Technology, Pantnagar, India **Date of publication:** 26 September 2023 (online & print)

Citation: Thing, S.B., D.R.P.J. Shahi & S. Shrestha (2023). First record of the Western Himalayan Yew *Taxus contorta* (Gymnosperms: Cupressales: Taxaceae) from Lumbini Province, Nepal. *Journal of Threatened Taxa* 15(9): 23928–23930. https://doi.org/10.11609/jott.8059.15.9.23928-23930

Funding: Division Forest Office, Rolpa. Ministry of Forests, Environment and Soil Conservation, Lumbini Province. Annual Programme of the Fiscal Year, 2077/078.

Competing interests: The authors declare no competing interests.

Acknowledgements: We would like to thank Division Forest Office, Rolpa; divisional forest officer Mr. Dadhi Lal Kandel and forest officers Mr. Birendra Kumar Roka, Mr. Baburam Pokharel and forest guard Mr. Sahadev Chaudhary for their support to complete this piece of work. We also acknowledge Mr. Rajan Dumre for helping me to prepare the study map.

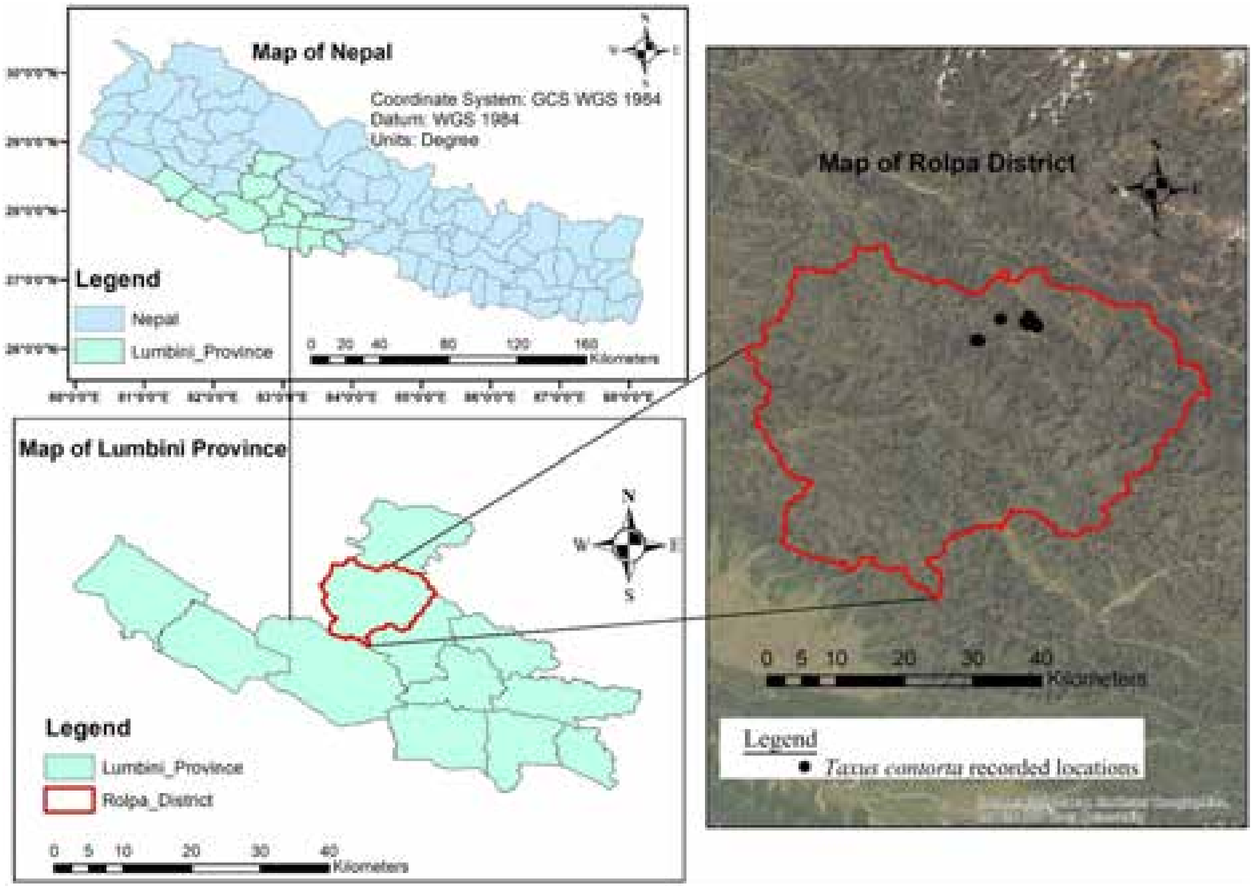

Image 1. Map showing the *Taxus contorta* recorded locations in Rolpa, Lumbini Province, Nepal.

stomatal bands, margin revolute-incurving when dried (Poudel et al. 2012).

During the transect walk survey conducted on March–April 2021 along the four distinct elevation gradient of 2,000–2,400 m, 2,400–2,800 m, 2,800–3,200 m, and 3,200–3,600 m in Thawang Rural Municipality (28.50^{0}N, 82.71^{0}E) of Rolpa District in Lumbini Province, we recorded *T. contorta* in at least 55 locations (Image 1). *Taxus contorta* is recorded mostly (90%) in the northern aspect along the wet sites, a habitat also mentioned in earlier literature (Poudel et al. 2012; Bhatt et al. 2017), with slopes more than 35 degrees, crown cover more than 70% and elevation range of 2,424–3,002 m. The species was recorded at sites away from human dominated landscapes where anthropogenic activities are either minimum or totally absent. The species was found in association with *Picea smithiana* Wall., *Tsuga dumosa* (D.Don) Eichler, *Quercus semecarpifolia* Sm., *Abies pindrow* D.Don, *Rhododendron arboreum* Sm. (Freitag 1971; Rau 1974; Sapru 1975), *Daphne bholua* D.Don, *Rhododendron barbatum* Wall., and *Himalayacalamus asper* Stapleton in the temperate forest.

In western Nepal, *T. contorta* populations are on a satisfactory level inside the protected areas (Api-Nampa Conservation Area, Khaptad National Park, Rara National Park, and Dhorpatan Hunting Reserve), however, it is sporadically distributed outside the protected areas (Bhatt et al. 2017). Furthermore, the *T. contorta* is an 'Endangered' species (Thomas 2011), and these newly located populations provide an opportunity for in-depth study of their niche and associated site specific threats that will further aid in developing community engagement conservation programmes outside the protected area. Also, the species is facing a threat due to illegal felling for timber and leaves, improper harvesting methods, loss of its natural habitat, unmanaged grazing, delayed germination and lower survival rate. Therefore, it is comprehended to conserve them in-situ and promote its revival through nursery cultivation and plantation initiatives.

Image 2–4. 2—Branching habit of healthy *Taxus contorta* sapling (X: 669769, Y: 3148319, Elevation: 2,810 m.) | 3—Tree stem of *Taxus contorta* (X: 665087, Y: 3149405, Elevation: 2,947 m.) | 4—*Taxus contorta* forest patch (X: 669637, Y: 3148356, Elevation: 2,720 m.). © Image 2—Deepak Raj Prakash Jung Shahi, 3–4—Santa Bahadur Thing.

References

Bhatt, G.D., R.C. Poudel, T.R. Pandey & R. Basnet (2017). *Yews of Nepal.* National Herbarium and Plant Laboratories (NHPL), Godawari, Lalitpur, 76 pp. http://kath.gov.np/image/data/publication/Yews%20of%20Nepal.pdf

Farjon, A. (2010). *A Handbook of the Worlds Conifers*. Leiden: Brill, New York, USA, 1150 pp.

Freitag, H. (1971). Studies in the natural vegetation of Afghanistan, Pp. 89–106. In: P.H. Davis, P.C. Harper, and I.C. Hedge, eds. Plant life of south-west Asia, Botanical Society of Edinburgh, 335 pp.

Gao, L.M., M. Möller, X.M. Zhang, M.L. Hollingsworth, J. Liu, R.R. Mill, M. Gibby & D.Z. Li (2007). High variation and strong phylogeographic pattern among cpDNA haplotypes in *Taxus wallichiana*(Taxaceae) in China and North Vietnam. *Molecular Ecology* 16**:** 4684–4698.

Iqbal, J., R. Meilan & B. Khan (2019). Assessment of Risk, Extinction, and Threats to Himalayan Yew in Pakistan. *Saudi Journal of Biological Sciences* 27(2020): 762–767. https://doi.org/10.1016/j.sjbs.2019.12.033

Liu, J.I.E., M. Möller, L.M. Gao, D.Q. Zhang & D.Z. Li (2011). DNA barcoding for the discrimination of Eurasian yews (*Taxus* L., Taxaceae) and the discovery of cryptic species. *Molecular Ecology Resources* 11: 89–100.

Mohapatra, K., R. Sehgal, R. Sharma & T. Mohapatra (2009). Genetic analysis and conservation of endangered medicinal tree species Taxus wallichiana in the Himalayan region. *New Forests* 37: 109–121.

Mulliken, T. & P. Crofton (2008). Review of the status, harvest, trade and management of seven Asian CITES-listed medicinal and aromatic plant species. BfN-Skripten, Federal Agency for Natural Conservation, Bonn, Germany.

Poudel, R.C., M. Möller, D.Z. Li, A. Shah & L.M. Gao (2014). Genetic diversity, demographical history and conservation aspects of the endangered yew tree Taxus contorta (syn. *Taxus fuana*) in Pakistan. *Tree Genetics & Genomes* 10: 653–665.

Poudel, R.C., M. Möller, J. Liu, L.M. Gao, S.R. Baral & D.Z. Li (2014). Low genetic diversity and high inbreeding of the endangered Yews in Central Himalaya: Implications for Conservation for their highly fragmented populations. *Diversity and Distributions* 20(11): 1270–1284

Poudel, R.C., M. Möller, L.M. Gao, A. Ahrends, S.R. Baral, J. Liu, P. Thomas & D.Z. Li (2012). Using morphological, molecular and climatic data to delimitate yews along the Hindu Kush-Himalaya and adjacent regions. PLoS ONE 7(10): e46873. https://doi.org/10.1371/journal.pone.0046873

Rau, M.A. (1974). Vegetation and Phytogeography of the Himalaya. In: Mani, M.S. (eds) Ecology and Biogeography in India. Monographiae Biologicae, vol 23. Springer, Dordrecht, 792 pp. https://doi.org/10.1007/978-94-010-2331-3_10

Rikhari, H.C., L.M.S. Palni, A.S. Sharma & S.K. Nandi (1998). Himalayan yew: stand structure, canopy damage, regeneration and conservation strategy. Environmental Conservation 25: 334–341. https://doi.org/10.1017/S0376892998000411

Sapru, B.L. (1975). Vegetational studies in Jhelum Valley. *Botanique* 6:151–164.

Schippmann, U. (2001). CITES medicinal plants significant trade study. Project S 109, Germany.

Thomas, P. (2011). *Taxus contorta*. The IUCN Red List of Threatened Species 2011: e.T39147A10170545. Accessed on 04 May 2022. https://doi.org/10.2305/IUCN.UK.2011-2.RLTS.T39147A10170545.en

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

www.threatenedtaxa.org

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

September 2023 | Vol. 15 | No. 9 | Pages: 23827–23930
Date of Publication: 26 September 2023 (Online & Print)
DOI: 10.11609/jott.2023.15.9.23837-23930

Article

Communications

Notes

Publisher & Host

Threatened Taxa