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Journal of Threatened Taxa

Open Access

10.11609/jott.2026.18.8.29375-29558
www.threatenedtaxa.org

26 August 2026 (Online & Print)
18(8): 29375–29558
ISSN 0974-7907 (Online)
ISSN 0974-7893 (Print)

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

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

Host
Zoo Outreach Organization
www.zooreach.org

Srivari Illam, No. 61, Karthik Nagar, 10th Street, Saravanampatti, Coimbatore, Tamil Nadu 641035, India
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continued on the back inside cover

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Journal of Threatened Taxa | www.threatenedtaxa.org | 26 August 2026 | 18(8): 29375–29389

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

https://doi.org/10.11609/jott.10551.18.8.29375-29389

#10551 | Received 24 March 2026 | Final received 26 June 2026 | Finally accepted 22 July 2026

ARTICLE

Bat assemblages at two contrasting agricultural sites in northern Algeria: a preliminary conservation assessment

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Abstract: Agricultural intensification is a key driver of biodiversity loss in Mediterranean agroecosystems, yet its effects on protected bat assemblages remain poorly documented in northern Africa. All six bat taxa recorded are legally protected in Algeria. Several of the recorded species are also covered by international conservation instruments for their European populations, while the probable North African endemic *Plecotus* cf. *gaisleri* is of particular biogeographic interest. We conducted a preliminary assessment of bat activity, diversity, and community composition at two representative agricultural sites—a low-input citrus orchard and an intensively managed vineyard—in northern Algeria. Acoustic monitoring was conducted from March to November 2023. A total of 349 acoustic contacts were recorded at the citrus orchard site and 74 at the vineyard site, corresponding to a 4.6-fold difference in observed activity. Negative binomial modelling indicated a substantially lower fitted contact rate at the vineyard than at the orchard (IRR = 0.215, 95% CI: 0.130–0.355). Monthly taxon richness and Shannon diversity were also higher at the orchard. The vineyard assemblage was strongly dominated by *Pipistrellus kuhlii*, whereas a more taxonomically diverse assemblage was detected at the orchard. NMDS suggested site-associated structuring of bat assemblages, and a paired PERMANOVA detected a significant difference between the two sampled sites (R^2 = 0.281, pseudo-F = 6.26, p = 0.004). No statistically significant difference in multivariate dispersion was detected (PERMDISP: F = 0.808, p = 0.100), although the small sample size limits the power of this diagnostic test. Although based on a single orchard–vineyard pair, these results suggest that the low-input orchard examined here may provide favourable conditions for a protected bat assemblage. Replicated multi-site studies are needed before generalizing this pattern to low-input perennial agroecosystems across North African farmland.

Keywords: Acoustic monitoring, agroecosystems, biodiversity conservation, community composition, low-input farming, Mediterranean landscapes, preliminary assessment.

Editor: Bhargavi Srinivasulu, Zoo Outreach Organisation, Hyderabad, India. **Date of publication:** 26 August 2026 (online & print)

Citation: Meghezzi, S., F.Z. Bissaad, F. Bounaceur, A. Boukhari, M. Ait-Abdesselam & L. Benfekih (2026). Bat assemblages at two contrasting agricultural sites in northern Algeria: a preliminary conservation assessment. *Journal of Threatened Taxa* 18(8): 29375–29389. https://doi.org/10.11609/jott.10551.18.8.29375-29389

Funding: No specific funding was received for this study.

Competing interests: The authors declare no competing interests.

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

Acknowledgements: The authors sincerely thank M. Taharout Djamel, the farmer, for kindly granting access to his agricultural property and allowing us to conduct this study on his farms.

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INTRODUCTION

Agricultural pests are a major constraint on crop productivity and represent a significant source of economic loss in global agroecosystems (Oerke 2006). In Algeria, pest-driven reductions in agricultural output intersect with broader economic vulnerabilities linked to hydrocarbon dependency and climate variability, increasing the need for resilient and sustainable agricultural systems (Bouchenak 2021). Climate change is expected to intensify pest pressure through shifts in phenology, distribution, and trophic interactions (Deutsch et al. 2018; Lehmann et al. 2020), further reinforcing the urgency of effective pest management strategies.

Integrated Pest Management (IPM) provides a coherent framework for reducing reliance on synthetic pesticides while maintaining crop yields and profitability (Pretty & Bharucha 2014). IPM combines biological control, habitat management, resistant cultivars, diversified cropping systems, and decision-support tools to prevent or limit pest outbreaks (Roubos et al. 2014; Gurr et al. 2017). Beyond direct pest suppression, IPM can enhance biodiversity and long-term agroecosystem resilience by promoting functional diversity and ecosystem services (Gupta et al. 2024; Marcelino et al. 2024). These approaches are particularly relevant in Mediterranean agricultural systems, where pest outbreaks and pesticide resistance generate substantial economic and environmental costs (Biondi et al. 2012).

Insectivorous bats constitute a potentially important, yet underutilized, component of biological control in agricultural landscapes. Numerous studies show that bats consume large proportions of agricultural pest taxa, often exceeding 40% of their diet in intensive crop systems (Zhu et al. 2024), and bats have been estimated to provide agricultural pest-control services worth at least USD 3.7 billion annually in North America, although such estimates remain context-dependent (Boyles et al. 2011; Maas et al. 2016). In Mediterranean contexts, bat assemblages exploit agricultural pest prey and can provide ecologically and economically relevant pest regulation services (Russo & Ancillotto 2015; Ancillotto et al. 2022). The efficiency of these ecosystem services depends on bat species composition, habitat structure, landscape complexity, and exposure to agrochemical inputs (Tuneu-Corral et al. 2023). Structurally complex agricultural habitats with permanent vegetation generally support greater insect abundance and foraging opportunities, whereas intensive management and frequent pesticide applications may reduce prey availability and limit bat activity, thereby decreasing the potential for natural pest suppression.

In northern Africa, chiropteran research has predominantly focused on natural, cavernicolous, urban, and rural habitats, documenting species distributions, roosting ecology, trophic patterns, and conservation status (Bendjeddou et al. 2014, 2017, 2020; Farfar et al. 2017; Loumassine et al. 2017a,b, 2019, 2020; Mokrani et al. 2018a,b). More recently, studies in Algeria have expanded to forest ecosystems, including Mediterranean montane habitats (Hamida et al. 2021; Ait-Abdesselam et al. 2025; Boukhari et al. 2025). Collectively, this literature highlights the taxonomic and functional diversity of Algerian bats across non-agricultural environments. However, agroecosystems remain largely unstudied, despite being characterized by high pest pressure, frequent pesticide use, and landscape simplification, and despite the well-established role of bats as biological control agents in agricultural systems elsewhere.

Bat taxa recorded in the present study are legally protected under Algerian national legislation. Several of the identified species are also covered by international conservation instruments for their European populations, although these listings should not automatically be interpreted as applying to the Algerian populations recorded here. Despite their national legal protection, bat diversity, activity, and habitat use in Maghreb agroecosystems remain poorly documented, even though agricultural landscapes occupy extensive areas of the Mediterranean lowlands. Assessing bat assemblages in agricultural landscapes can therefore provide useful baseline information for regional conservation planning and the development of biodiversity-friendly farming practices.

The present study addresses this knowledge gap by characterizing bat assemblages at two contrasting agricultural sites in the Sebaou Valley, near Draâ Ben Khedda, Tizi Ouzou Province, northern Algeria. Because only one citrus orchard and one vineyard were surveyed, the study should be interpreted as a preliminary conservation-oriented case study rather than as a spatially replicated comparison of crop types or management systems. Given the preliminary two-site design, we evaluated three site-specific predictions: (1) monthly taxon richness and Shannon diversity would be higher at the sampled citrus orchard than at the sampled vineyard; (2) the vineyard assemblage would show stronger numerical dominance by generalist taxa, particularly *Pipistrellus* spp.; and (3) assemblage composition would differ between the two sampled sites. Potential relationships with vegetation structure, management intensity, pesticide use, and prey availability were treated as hypotheses for future replicated studies rather than as mechanisms directly tested here. By integrating acoustic activity, α-diversity indices, and community composition analyses, this study provides a first preliminary assessment of bat communities in Algerian agroecosystems and highlights their potential conservation value within Mediterranean agricultural landscapes.

MATERIALS AND METHODS

Study area and sampling sites

The study was conducted in the Sebaou Valley, near Draâ Ben Khedda, Tizi Ouzou Province, northern Algeria (36.733° N, 3.950° E), at an elevation of approximately 56 m. The area lies within the sub-humid Mediterranean bioclimatic zone and is characterized by mild winters. Mean annual temperature is approximately 19.2°C, and annual precipitation exceeds 600 mm. Soils at both study sites were classified as sandy clay loam. The surrounding area is predominantly agricultural and includes several crop types (Image 1).

The first selected citrus orchard (Site A) is embedded within an extensive agricultural landscape dominated by long-established citrus orchards, interspersed with vegetable cropping systems. This orchard is managed under an extensive conventional production system, characterized by a low planting density (800–850 trees ha^{-1}), infrequent application of agricultural inputs, and the absence of weed management practices. Over the monitoring period spanning March–November 2023, no pesticide treatments were applied by the farmer (Table 1).

By contrast, the second selected vineyard is located in an area characterized by high agricultural production intensity. This table grape vineyard operates under a high-input intensive production system, featuring a high planting density (1,111–1,200 vines ha^{-1}), raised-bed cultivation, and drip irrigation combined with frequent applications of agrochemical inputs, including fertilizers, herbicides, and pesticides, with the objective of maximizing yield. Weed management was continuously implemented through the use of chemical herbicides throughout the study period (Table 1).

Vineyards in the area are also susceptible to fungal diseases, notably powdery mildew (*Uncinula necator*) and downy mildew (*Plasmopara viticola*), for which farmers applied fungicides such as Mancozeb and Cyproconazole. To control insect pests, including the African leafhopper, mites, and grape moths, insecticides such as Deltamethrin and Chlorpyrifos-methyl were used. Glyphosate was applied for weed control as a chemical herbicide.

Because only one citrus orchard and one vineyard were included, these two sites were considered representative examples of contrasting agricultural management contexts rather than independent replicates of each habitat type. Therefore, observed differences in bat activity and assemblage structure should be interpreted as site-specific patterns that provide preliminary insights for future multi-site investigations.

Sampling design

Acoustic surveys were conducted monthly from March to November 2023 at both study sites. Each monthly survey consisted of a one-hour acoustic monitoring period conducted after sunset during the period of peak bat activity. The same fixed 500-m transect was traversed four consecutive times, once during each 15-minute segment (P1–P4), at an approximately constant walking speed of 2 km h^{-1}. The Batlogger M operated throughout the monitoring period and stored triggered acoustic files of 5 s at a sampling frequency of 312.5 kHz. The four 15-minute segments within each monthly survey were treated as non-independent subsamples and pooled at the site × month level before statistical analyses. Thus, all inferential analyses were based on 18 pooled site × month observations. These observations represent repeated monthly measurements from the same two sites and should not be interpreted as independent spatial replicates of orchard and vineyard habitats (Image 2).

Acoustic surveys and environmental variables

At each site, a fixed 500-m transect was traversed four consecutive times during the one-hour session, with each traversal lasting approximately 15 min at a walking speed of about 2 km h^{-1}. Successive traversals were conducted in alternating directions along the same route. Surveys began at sunset. The two sites were surveyed on consecutive nights, with each survey beginning at sunset. Survey order was alternated among months: when Site A was surveyed on the first night and Site B on the following night during one monthly survey, Site B was surveyed first during the next monthly survey. Bat calls were recorded using a Batlogger M (Elekon AG, Lucerne, Switzerland; firmware v2.6.2). The detector operated continuously in automatic trigger mode

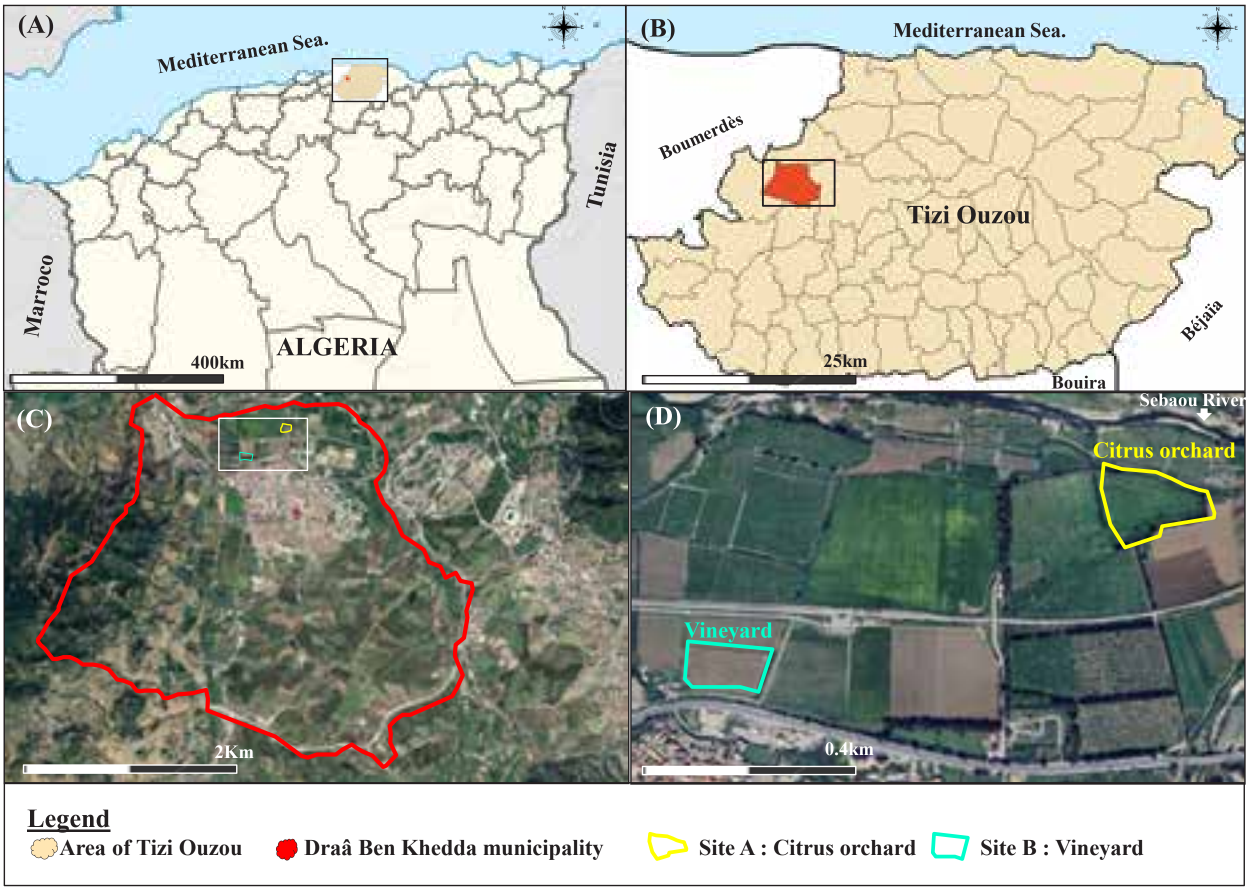

Image 1. Study area: A—Location of the study area in northern Algeria | B—Location of Tizi Ouzou Province within Algeria | C—Draâ Ben Khedda municipality showing the locations of the citrus orchard and vineyard study sites | D—Enlarged satellite image of the study sites in Draâ Ben Khedda municipality.

throughout each one-hour survey and stored triggered acoustic events as 5-s recordings. Acoustic signals were sampled at 312.5 kHz, corresponding to a Nyquist frequency of 156.25 kHz. During each one-hour survey, air temperature and relative humidity were measured every 15 minutes using an IHM6150SI pocket thermo-hygrometer (type K) (precision ±1°C; ±5% RH). Cloud cover and wind speed were also recorded to document weather conditions potentially influencing bat activity and detectability (Russo & Jones 2003). Weather variables were recorded to document survey conditions and to ensure that surveys were not conducted during rainfall or strong winds. They were not included as model covariates because of the small sample size, the limited number of observations relative to the number of potential predictors, and their seasonal collinearity with month. Consequently, seasonal climatic effects cannot be separated from other sources of month-related variation.

Call identification

Recorded calls were manually inspected using BatSound v3.10 (Pettersson Elektronik AB, Sweden). Spectrograms were examined using call structure, start and end frequencies, frequency of maximum energy, bandwidth, call duration, and pulse shape. Taxonomic assignments followed Barataud (2012) and regional reference data from northwestern Africa (Russo & Jones 2003; Disca et al. 2014; Dalhoumi et al. 2016; Ahmim et al. 2020).

A total of 1,978 call sequences were recorded during the sampling period. After manual validation, 423 high-quality sequences (21.39%) were retained for species identification and acoustic analyses. The remaining 1,555 recordings were excluded (78.61%) because of poor signal quality, ambiguous acoustic characteristics, or environmental and insect noise.

A bat contact was defined as one triggered 5-s recording containing a sequence of echolocation calls attributable to a single bat pass. Recordings containing simultaneous calls from clearly distinguishable taxa were counted separately for each taxon.

High-duty-cycle calls of *Rhinolophus hipposideros* were identified from their characteristic FM/CF/FM structure and a peak-frequency range of 115.9–121.0 kHz reported for northern Algeria (Ahmim et al. 2020). Because rhinolophid calls are highly directional and may be detected less readily during walked transects, only recordings with a clear constant-frequency component and diagnostic harmonic structure were retained.

Low-duty-cycle calls assigned to *Eptesicus isabellinus*, *Hypsugo savii*, *Pipistrellus kuhlii*, and *Pipistrellus pipistrellus* were identified from a combination of FM/QCF structure, frequency of maximum energy, pulse shape, and regional reference data. Calls falling within known frequency-overlap ranges and lacking additional diagnostic characteristics were retained only at acoustic-group level and excluded from species-level analyses.

Calls assigned to *Plecotus* showed an FM structure and a starting-frequency range consistent with regional descriptions of *P. gaisleri* (Dalhoumi et al. 2016). However, because species within *Plecotus* cannot be reliably distinguished using acoustic data alone, these records are reported provisionally as *Plecotus* cf. *gaisleri*. This designation indicates probable, but not definitive, species identity.

The six bat taxa retained for analysis were *Rhinolophus hipposideros* (Borkhausen, 1797) (Rhinolophidae), *Eptesicus isabellinus* (Temminck, 1840) (Vespertilionidae), *Hypsugo savii* (Bonaparte, 1837) (Vespertilionidae), *Pipistrellus kuhlii* (Kuhl, 1817) (Vespertilionidae), *Pipistrellus pipistrellus* (Schreber, 1774) (Vespertilionidae), and *Plecotus cf. gaisleri* (Benda et al., 2004) (Vespertilionidae).

Acoustic parameters measured in the present study are summarized in Table 2, and representative spectrograms are shown in Image 3. The global conservation status, international convention listings, and Algerian legal protection status of all recorded bat taxa are summarized in Supplementary Table S1.

Data structure and response variables

For each sampling session, the dataset contained species-specific contact counts. Overall bat activity per session was quantified as the total number of acoustic contacts across all detected species: Total contacts = $\sum_{n=1}^{6} n_i$, where n_i is the number of contacts for species *i* in that session. A sampling session was considered positive when Total contacts > 0. Monthly totals (per site) were obtained by aggregating the four periods (P1–P4) within each month.

Taxon richness, composition, and diversity indices

Taxon richness was computed per site × month as the number of detected taxa (contacts > 0). Assemblage composition was expressed as the proportion of total contacts contributed by each taxon at each site.

Community diversity was quantified monthly using standard indices. Shannon diversity was computed as $H' = -\sum_{i=1}^{S} p_i \ln(p_i)$ following Shannon (1948), with $p_i = \frac{n_i}{N}$ and $N = \sum_{i=1}^{S} n_i$. Diversity metrics were computed in R ver-sion 4.5.2 (R Core Team 2025) following standard community ecology workflows, including the *vegan* package (version 2.7-1) when applicable (Oksanen et al. 2022).

Statistical analysis

Different statistical approaches were used to address complementary ecological questions. Monthly taxon richness and Shannon diversity were compared using Wilcoxon signed-rank tests, bat activity was analysed using a negative binomial regression model, whereas differences in community composition were evaluated using NMDS and PERMANOVA. This analytical framework avoided the use of multiple statistical tests to address the same biological question.

Wilcoxon signed-rank test

To compare monthly taxon richness and Shannon diversity between the citrus orchard and the vineyard, we used the Wilcoxon signed-rank test for paired comparisons. This non-parametric test was selected because the paired data did not meet the assumptions of normality. The Wilcoxon signed-rank test was therefore applied only to taxon richness and Shannon diversity. Statistical significance was assessed at $p < 0.05$ using the function wilcox.test in R.

Non-metric multidimensional scaling (NMDS)

Community composition was analyzed using a taxon-by-sample abundance matrix based on the number of acoustic contacts recorded for each bat species at the site × month level (n = 18), with detections pooled across the four 15 min segments within each monthly session. Bray–Curtis dissimilarities were calculated from quantitative acoustic activity data to quantify differences in assemblage composition among sampling units. Non-metric multidimensional scaling (NMDS) was performed using the *vegan* package in R (Oksanen et al. 2022). The stress value was used to evaluate ordination quality, with values < 0.1 considered indicative of a good representation of the data.

Permutational analysis of variance (PERMANOVA)

Site-associated differences in bat assemblage structure were evaluated using PERMANOVA based on Bray–Curtis dissimilarities, implemented with the *adonis2* function in the *vegan* package (Oksanen et al. 2022). The analysis was conducted on the taxon-by-sample matrix containing the 18 pooled site × month observations. To preserve the paired temporal structure, permutations of the Site labels were restricted within Month. With nine monthly pairs, 511 permutations were generated in addition to the observed configuration. Because only one site represented each agricultural context, the analysis evaluates a repeated contrast between the sampled orchard and vineyard and does not provide spatial replication of crop type or management intensity. Homogeneity of multivariate dispersion was evaluated using *betadisper* (Anderson 2001) and *permutest*, with permutations following the same paired monthly structure.

Negative binomial model of bat activity

Monthly bat activity was analysed using a negative binomial generalized linear model with a log link, implemented in the glmmTMB package (family = nbinom2; Brooks et al. 2017). The response variable was the total number of acoustic contacts recorded during each pooled one-hour site × month session (n = 18). Site and Month were included as fixed effects, and the fitted model was: Total contacts ~ Site + Month. Because each agricultural context was represented by only one site, the Site coefficient is interpreted strictly as a contrast between the sampled orchard and vineyard rather than as a general effect of crop type or management intensity. Effect sizes are presented as incidence rate ratios with 95% confidence intervals obtained by exponentiating the model coefficients.

Model diagnostics

Model adequacy was assessed using simulation-based residual diagnostics implemented in DHARMa (Hartig 2016), including checks for residual uniformity, dispersion, and outliers.

Data visualization and software

All analyses were performed in R (RStudio environment). Figures were produced using ggplot2 (Wickham 2016) and exported at publication-quality resolution.

RESULTS

Bat activity

A total of 423 bat acoustic contacts were recorded across both agricultural habitats during the sampling period. Bat activity was substantially higher in the orchard (Site A), with 349 contacts, compared to the vineyard (Site B), where only 74 contacts were detected, corresponding to a 4.6-fold difference in total activity.

Bat contacts were detected in 33 of the 36 15-min segments at the orchard site (91.7%) and in 21 of the 36 segments at the vineyard site (58.3%). Segment-level detection frequencies are reported descriptively only; all inferential analyses were conducted at the pooled site × month level. Monthly activity patterns differed markedly between sites (Image 4). In the orchard, bat activity peaked in March (92 contacts) and remained relatively high in August (53 contacts) and October (47 contacts), followed by a pronounced decline in June (4 contacts) and November (18 contacts). In contrast, vineyard activity remained consistently low throughout the season, with moderate increases in October (20 contacts) and in July and September (12 contacts each), and minimal activity in June (1 contact) and November (3 contacts).

The negative binomial model indicated a significantly lower fitted contact rate at the sampled vineyard than at the sampled orchard (IRR = 0.215, 95% CI = 0.130–0.355, $p < 0.001$). The fitted contact rate at the vineyard was approximately 79% lower than that at the orchard. This estimate represents a contrast between the two sampled sites and should not be interpreted as a general effect of habitat type or management intensity. Relative to March, activity was significantly lower in June and November, whereas the remaining month-specific coefficients did not differ significantly from the March reference level (Table 3).

Taxon richness and diversity

Taxon richness was consistently higher in the orchard than in the vineyard throughout the sampling period (Image 5). A total of six bat taxa were detected in the orchard, including *R. hipposideros*, *E. isabellinus*, *H. savii*, *P. kuhlii*, *P. pipistrellus*, and *Plecotus* cf. *gaisleri*. In contrast, only three taxa were recorded in the vineyard: *E. isabellinus*, *P. kuhlii*, and *P. pipistrellus*.

Monthly taxon richness in the orchard ranged 2–6 taxa, with a maximum observed in April, whereas vineyard assemblages were frequently dominated by a single taxon and reached a maximum of three taxa only in August. Wilcoxon signed-rank tests indicated

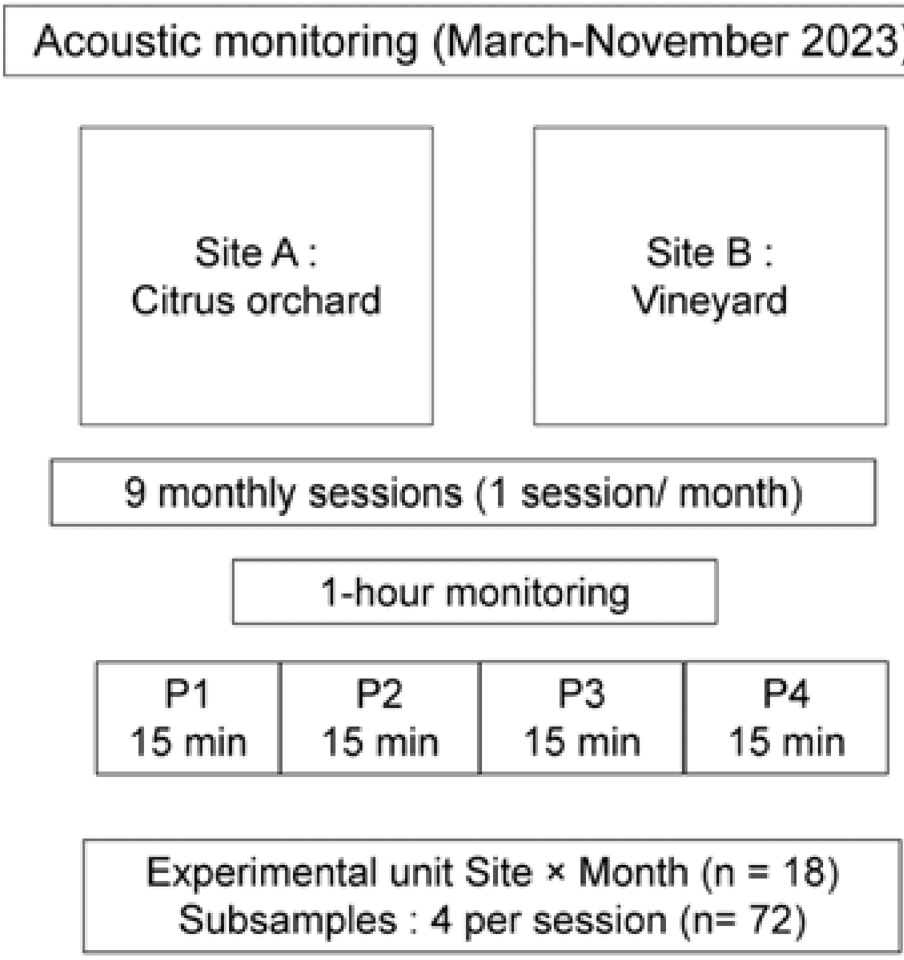

Image 2. Nested sampling design of monthly acoustic monitoring: Monthly acoustic monitoring was conducted at two sites from March to November 2023. Each site × month session (n = 18) consisted of one hour of continuous acoustic monitoring in automatic trigger mode, during which detected acoustic events were stored as 5-s recordings subdivided into four consecutive 15-minute segments (P1–P4; 72 subsampling segments in total).

Table 1. Characteristics of the selected citrus orchard and vineyard in the Sebaou Valley, near Draâ Ben Khedda, Tizi Ouzou Province, northern Algeria.

Characteristics	Site A: citrus orchard	Site B: vineyard
Geographical coordinates	36.740° N, 3.958° E	36.741° N, 3.960° E
Variety	Orange (Washington Navel)	Table grape (Red Globe)
Rootstock	*Citrus volkameriana*	41B
Management intensity	Low-input management	High-input management
Weeding method	No weeding	Chemical weeding
Phytosanitary pressure	No pesticide application during the monitoring period; historically low input use.	Regular treatments
Type of irrigation	Drip irrigation	Drip irrigation
Soil texture	Sandy clay loam	Sandy clay loam
Age (years)	5	5
Area (ha)	1.0	1.5
Plant spacing (m)	3 × 4	3 × 3

significantly higher monthly taxon richness in the orchard (V = 28, p = 0.0213), with median values of three taxa per month compared to one taxon per month in the vineyard, corresponding to a median difference of two taxon (Table 4).

Shannon diversity followed a similar pattern (Image 6). Median Shannon diversity was 0.971 in the orchard and 0 in the vineyard, and this difference was statistically significant (V = 44, p = 0.0129). Overall, these findings indicate that the citrus orchard supported significantly richer and more diverse bat assemblages than the vineyard.

Taxon composition

Taxon composition differed markedly between the two agricultural habitats (Image 7). In the orchard, bat activity was co-dominated by *P. kuhlii* (43.6% of total contacts) and *E. isabellinus* (43.3%), with additional

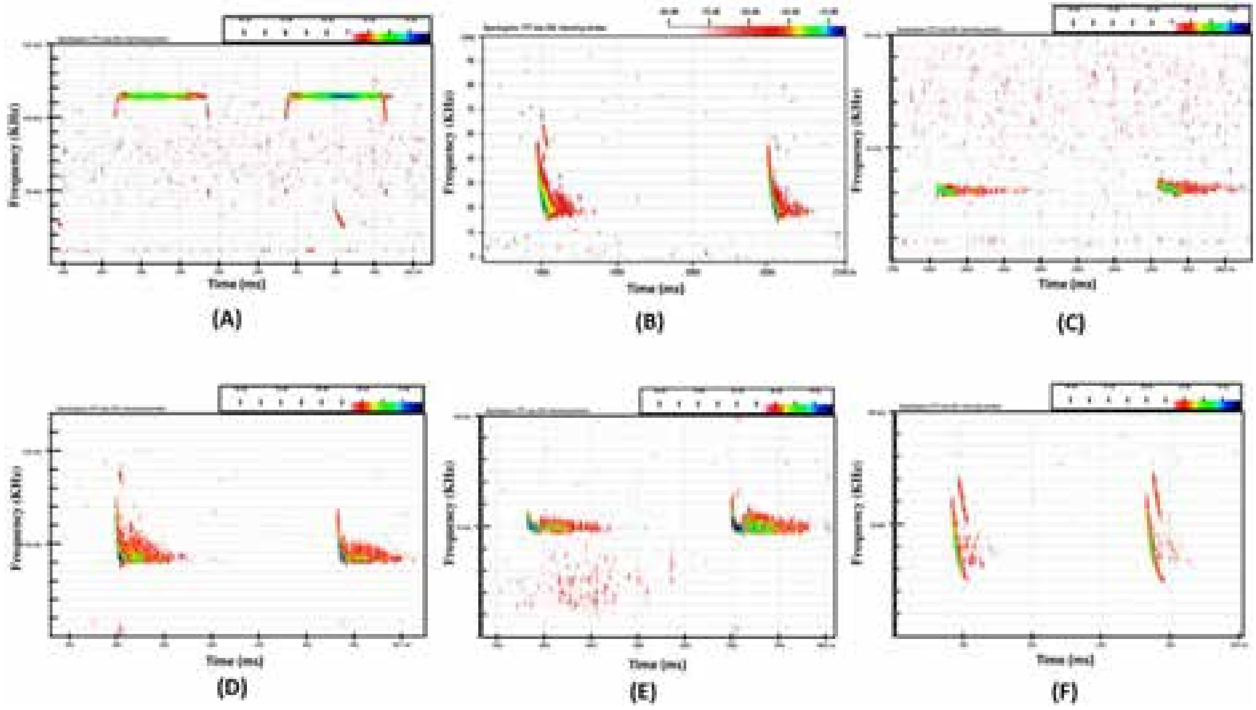

Image 3. Representative spectrograms of echolocation calls assigned to the six bat taxa recorded at the two agricultural study sites in northern Algeria: A—*Rhinolophus hipposideros* | B—*Eptesicus isabellinus* | C—*Hypsugo savii* | D—*Pipistrellus kuhlii* | E—*Pipistrellus pipistrellus* | F—*Plecotus* cf. *gaisleri*. Spectrograms were generated in BatSound v3.10. Frequency is shown in kHz and time in ms. Display ranges were adjusted to facilitate visualization of the diagnostic call structure of each taxon.

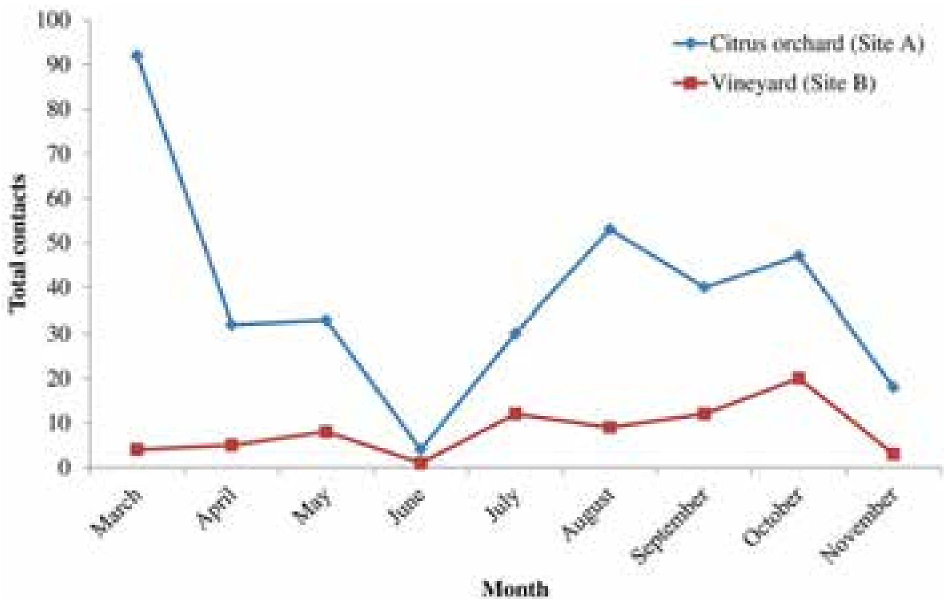

Image 4. Monthly bat activity (total contacts) in the citrus orchard (Site A) and vineyard (Site B) from March to November.

contributions from *H. savii* (5.7%), *P. pipistrellus* (4.6%), *Plecotus cf. gaisleri* (2.3%), and *R. hipposideros* (0.6%).

In contrast, the vineyard assemblage was overwhelmingly dominated by *P. kuhlii*, which accounted for 93.4% of all contacts, while *E. isabellinus* (3.9%) and *P. pipistrellus* (2.6%) were only sporadically detected. This overwhelming dominance by a single species was consistent with the lower taxon richness and Shannon

Table 2. Acoustic parameters of bat taxa recorded at the two agricultural study sites in northern Algeria. Values are presented as mean ± SD.

Taxon	N	Pulse structure	SF (kHz)	EF (kHz)	FME (kHz)	D (ms)	Identification source
Rhinolophus hipposideros	2	FM/CF/FM	100.06 ± 1.55	97.73 ± 0.89	115.8 ± 0.62	45.3 ± 2.70	Ahmim et al. (2020)
Eptesicus isabellinus	153	FM/QCF	39.58 ± 9.27	23.15 ± 1.57	27.24 ± 1.28	9.54 ± 2.01	Ahmim et al. (2020)
Hypsugo savii	20	FM/QCF	38.48 ± 4.02	31.63 ± 2.20	33.66 ± 1.17	9.01 ± 2.84	Disca et al. (2014)
Pipistrellus kuhlii	222	FM/QCF	63.94 ± 8.16	38.76 ± 1.23	41.24 ± 1.14	5.19 ± 1.50	Dalhoumi et al. (2016)
Pipistrellus pipistrellus	18	FM/QCF	62.9 ± 8.04	46.45 ± 3.1	50.02 ± 2.37	6.58 ± 2.22	Russo & Jones (2003)
Plecotus cf. *gaisleri*	8	FM	50.24 ± 5.20	26.86 ± 1.07	33.28 ± 0.94	3.11 ± 0.57	Dalhoumi et al. (2016);

N—number of sequences measured in this study | FM—frequency-modulated | CF—constant-frequency | QCF—quasi-constant-frequency | SF—start frequency | EF—end frequency | FME—frequency of maximum energy | D—duration | ms—milliseconds.

Table 3. Results of the negative binomial regression model (glmmTMB) for bat activity (total acoustic contacts per pooled one-hour site × month session). Regression coefficients (β), standard errors (SE), incidence rate ratios (IRR), 95% confidence intervals (95% CI), and p-values are presented.

Predictor	β	SE	z	p	IRR (95% CI)
Site: Vineyard vs Orchard	-1.538	0.256	-5.994	<0.001	0.215 (0.130–0.355)
Month: April vs March	-0.742	0.489	-1.517	0.129	0.476 (0.182–1.242)
Month: May vs March	-0.550	0.489	-1.125	0.261	0.577 (0.221–1.504)
Month: June vs March	-2.671	0.656	-4.071	<0.001	0.069 (0.019–0.250)
Month: July vs March	-0.392	0.492	-0.796	0.426	0.676 (0.257–1.774)
Month: August vs March	-0.219	0.475	-0.461	0.645	0.803 (0.317–2.039)
Month: September vs March	-0.254	0.484	-0.524	0.600	0.776 (0.301–2.003)
Month: October vs March	0.174	0.482	0.360	0.719	1.19 (0.462–3.061)
Month: November vs March	-1.287	0.515	-2.500	0.012	0.276 (0.101–0.757)

diversity observed in the vineyard.

Community structure: NMDS, PERMANOVA, and multivariate dispersion

The NMDS ordination suggested site-associated structuring of monthly bat assemblages (Image 8). The two-dimensional solution provided a good representation of the Bray–Curtis dissimilarity matrix (stress = 0.062). Orchard observations appeared more widely distributed in ordination space than vineyard observations.

PERMANOVA based on permutations restricted within Month detected a significant difference in assemblage structure between the two sampled sites (pseudo-F = 6.26, R^2 = 0.281, paired permutation p = 0.004). The repeated contrast between the orchard and vineyard therefore accounted for 28.1% of the variation in the monthly assemblage data. The test of multivariate dispersion did not detect a statistically significant difference between sites (PERMDISP: F = 0.808, paired permutation p = 0.100). Thus, there was no statistical evidence that the PERMANOVA result was explained solely by unequal multivariate dispersion, although the small sample size limits the power of the dispersion test. Because only one site represented each agricultural context, these findings describe a repeated difference between the two sampled sites rather than a general effect of orchard versus vineyard habitat.

Table 4. Comparison of monthly taxon richness and Shannon diversity between the citrus orchard and vineyard. Values represent median monthly observations. Differences between habitats were assessed using the paired Wilcoxon signed-rank test.

Metric	Citrus orchard (median)	Vineyard (median)	Median of paired monthly differences	Statistics (V; *p*)
Shannon diversity	0.971	0	0.656	44; 0.0129
Monthly richness	3	1	2	28; 0.0213

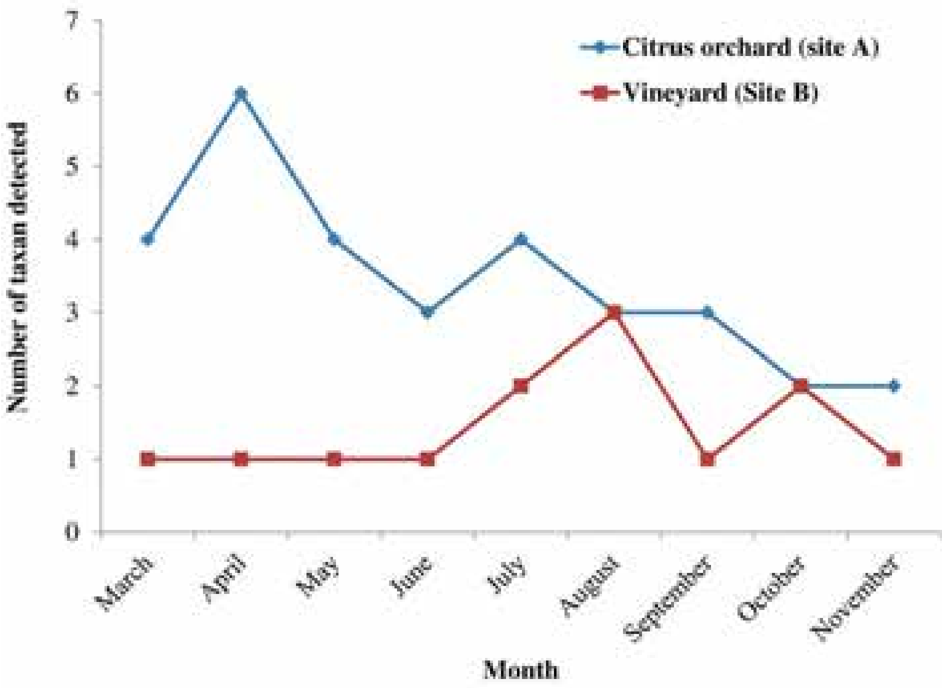

Image 5. Monthly taxon richness (number of taxa detected) in the orchard (Site A) and vineyard (Site B).

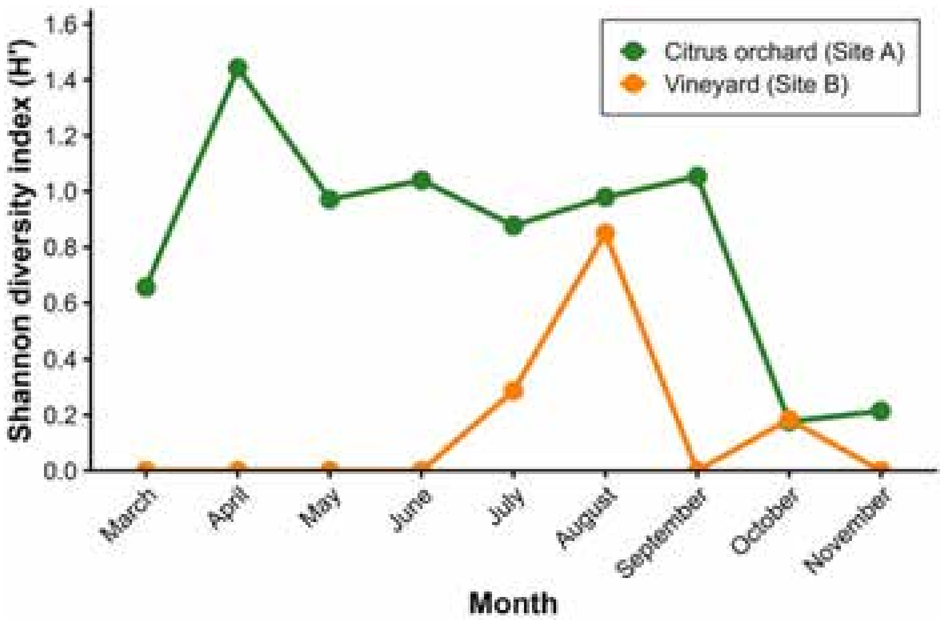

Image 6. Monthly Shannon diversity in the citrus orchard (Site A) and vineyard (Site B).

DISCUSSION

Before discussing the ecological implications of our findings, an important limitation of the present study should be acknowledged. Because the study was conducted in only one citrus orchard and one vineyard, habitat type is confounded with site identity, and the observed differences cannot be attributed solely to differences in agricultural management intensity. Consequently, our results should be interpreted as preliminary evidence highlighting contrasting bat assemblages between two representative agricultural

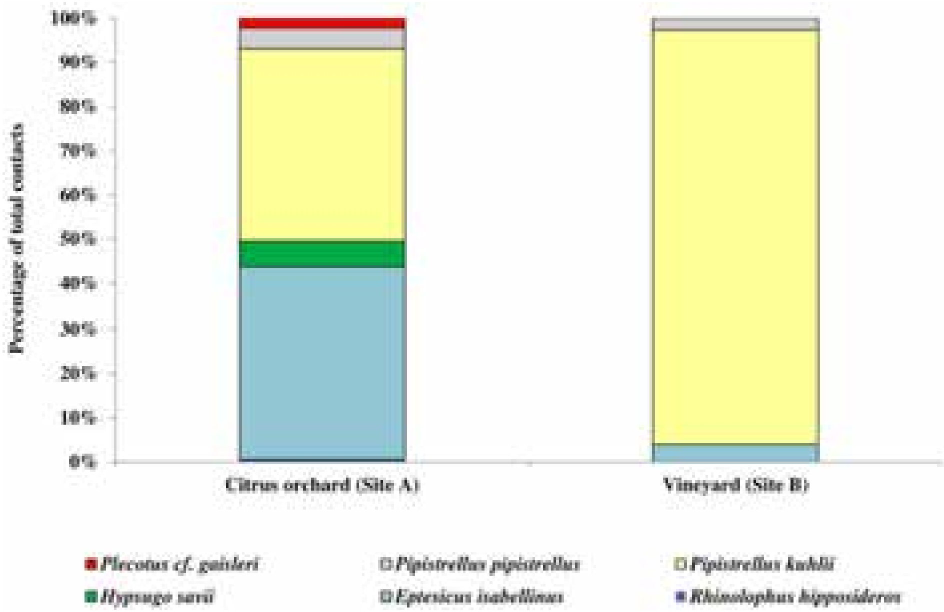

Image 7. Taxon composition (% of total contacts) in the citrus orchard (Site A) and vineyard (Site B).

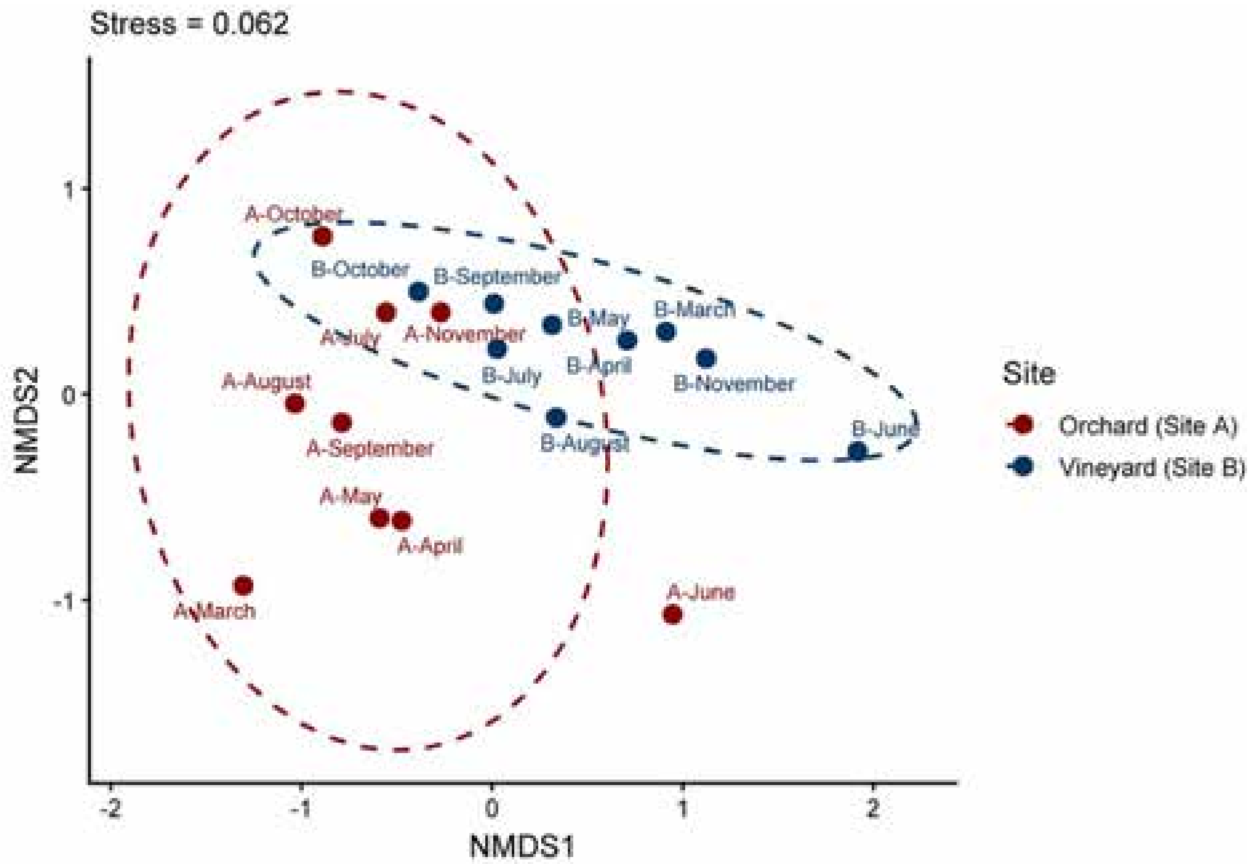

Image 8. NMDS ordination based on Bray–Curtis dissimilarities of monthly bat assemblages at the citrus orchard (Site A) and vineyard (Site B): Points represent pooled site × month observations, and distances reflect differences in assemblage structure. The two-dimensional solution had a stress value of 0.062. A paired PERMANOVA, with permutations of site labels restricted within month, detected a significant contrast between the two sampled sites (pseudo-F = 6.26, R^2 = 0.281, p = 0.004). Multivariate dispersion did not differ significantly between sites (PERMDISP: F = 0.808, p = 0.100). Ellipses are included for descriptive visualization only.

sites rather than definitive comparisons between cropping systems. These findings provide a baseline for future replicated, multi-site studies that incorporate direct measurements of insect prey availability, pesticide exposure, and other environmental variables to better disentangle the effects of agricultural management from site-specific characteristics.

Within the limits of this two-site case study, the sampled citrus orchard consistently showed higher bat activity, richness, and Shannon diversity than the sampled vineyard. These differences describe contrasting patterns between the two sites but cannot be attributed specifically to crop type, management intensity, pesticide use, or vegetation structure because these factors were not independently replicated.

Several non-exclusive mechanisms could plausibly explain the higher activity observed at the orchard site. Its perennial canopy, unmanaged ground vegetation, and lower reported input use may provide greater structural complexity and potentially more stable prey resources than the vineyard. However, insect abundance, pesticide residues, surrounding landscape composition, roost proximity, and microclimatic conditions were not quantified. These explanations should therefore be treated as hypotheses for future replicated studies (Russo & Jones 2003; Fahrig et al. 2011; Park 2015; Azam et al. 2016). Evergreen orchards, in particular, may sustain insect populations across seasons, thereby offering more reliable foraging opportunities for bats. Previous studies have shown that vegetation structure, hedgerows, and landscape heterogeneity can influence bat activity and prey availability in agricultural landscapes (Boughey et al. 2011; Maas et al. 2016; Froidevaux et al. 2019). Recent Algerian studies have also documented variation in bat activity and richness along environmental gradients and among structurally different habitats (Ait-Abdesselam et al. 2025; Boukhari et al. 2025).

In contrast, the vineyard exhibited low bat activity and strong dominance of *P. kuhlii*, a generalist species widely recognized for its tolerance to habitat simplification and anthropogenic disturbance (Barataud 2012; Jung & Threlfall 2016). Such dominance reflects a community simplification process frequently observed in intensively managed agricultural systems, where habitat homogenization and chemical inputs act as strong ecological filters (Geiger et al. 2010; Tscharntke et al. 2012). Vineyards are often associated with frequent pesticide applications, which can reduce arthropod abundance and diversity and thereby limit food resources for insectivorous bats (Wickramasinghe et al. 2004; Sánchez-Bayo & Wyckhuys 2019). Although pesticide applications were reported at the vineyard site, neither pesticide exposure nor insect abundance was quantified. The observed differences therefore cannot be attributed directly to chemical management and may also reflect vegetation structure, landscape context, roost proximity, or other site-specific factors.

Although most taxa recorded in this study are currently classified as Least Concern (LC) globally, and *Plecotus* cf. *gaisleri* is not evaluated, global assessments may not fully reflect regional population trends or local pressures associated with agricultural intensification. The legal protection of these taxa in Algeria, together with the limited information available on their use of northern African agroecosystems, highlights the need for regional baseline data. Moreover, agri-environment schemes do not necessarily benefit all bat taxa or biodiversity components in conventional agricultural landscapes, and some management prescriptions may have limited or even negative effects (Fuentes-Montemayor et al. 2011; MacDonald et al. 2012; Park 2015). These considerations underscore the importance of evaluating the effectiveness of farming practices and conservation measures under local conditions.

Monthly activity varied over the survey period, with particularly low values in June and November relative to March. Such variation may reflect seasonal changes in weather, prey availability, reproduction, migration, or torpor. Because these mechanisms were not measured directly and only one annual cycle was sampled, the observed monthly pattern should not be interpreted as evidence that the orchard buffered seasonal environmental stress (Russo & Jones 2003; Adams 2010).

Multivariate analyses indicated site-associated differences in assemblage structure. NMDS suggested partial structuring between orchard and vineyard observations, and the paired PERMANOVA detected a significant Site contrast after restricting permutations within Month (pseudo-$F = 6.26$, $R^2 = 0.281$, $p = 0.004$). The test of multivariate dispersion did not detect a statistically significant difference between sites (PERMDISP: $F = 0.808$, $p = 0.100$). Thus, there was no statistical evidence that the PERMANOVA result was explained solely by unequal dispersion, although the limited number of monthly observations reduces the power of this diagnostic test (Anderson 2001; Legendre & Legendre 2012; Oksanen et al. 2022). These findings describe contrasting assemblage structures at the two sampled sites but should not be interpreted as demonstrating a general effect of orchard versus vineyard habitat because each agricultural context was represented by only one site.

From a conservation perspective, the higher bat activity and diversity observed at the sampled orchard suggest that some low-input perennial agricultural sites may provide favourable conditions for bats. Bats can provide important ecosystem services in agricultural landscapes, particularly insect-pest suppression (Boyles et al. 2011; Kunz et al. 2011; Russo et al. 2018). However, replicated studies are required before this pattern can be generalized to low-input agricultural systems across the region. Maintaining vegetation cover and reducing unnecessary chemical inputs are plausible conservation measures, but their effects should be tested directly in replicated studies.

In addition to the absence of spatial replication, acoustic monitoring may underestimate taxa with low-intensity calls and may not permit definitive species-level identification of acoustically similar taxa. The walked-transect design may also generate taxon-specific differences in detectability. Future studies should include multiple orchard–vineyard pairs and integrate direct measurements of insect abundance, pesticide exposure, vegetation structure, landscape composition, and roost availability.

This preliminary case study revealed consistently higher bat activity, monthly richness, and Shannon diversity at the sampled low-input citrus orchard than at the sampled intensively managed vineyard. The orchard also supported a more compositionally diverse assemblage, whereas activity at the vineyard was dominated by *Pipistrellus kuhlii*. These findings indicate that the two agricultural sites differed substantially in their use by bats during the monitoring period.

Because only one site represented each agricultural context, these differences cannot be attributed specifically to crop type or management intensity. They may also reflect site-specific variation in surrounding landscape, roost proximity, prey availability, microclimate, or detection conditions. The results should therefore be considered baseline evidence and a source of hypotheses rather than a general comparison of orchards and vineyards.

Replicated studies across multiple farms should combine acoustic monitoring with measurements of insect abundance, pesticide exposure, vegetation structure, landscape composition, and roost availability. Such work is needed to determine whether low-input perennial crops consistently contribute to the conservation of protected bat assemblages in northern African agricultural landscapes.

REFERENCES

Adams, R.A. (2010). Bat reproduction declines when conditions mimic climate change projections for western North America. Ecology 91(8): 2437–2445. https://doi.org/10.1890/09-0091.1

Ahmim, M. et al. (2020). First data on the acoustic characteristics of some chiropteran species from northern Algeria. Bioacoustics 29(5): 499–517. https://doi.org/10.1080/09524622.2019.1620634

Ait-Abdesselam, M. et al. (2025). Bat species richness and activity in a Mediterranean area of Northwest Africa: Urban–rural shifts. Animal Taxonomy and Ecology 71(1): 36–50. https://doi.org/10.1556/1777.2024.00018

Ancillotto, L. et al. (2022). Bats as suppressors of agroforestry pests in beech forests. Forest Ecology and Management 522: 120467. https://doi.org/10.1016/j.foreco.2022.120467

Anderson, M.J. (2001). A new method for non-parametric multivariate analysis of variance. Austral Ecology 26(1): 32–46. https://doi.org/10.1111/j.1442-9993.2001.01070.pp.x

Azam, C. et al. (2016). Disentangling the relative effect of light pollution, impervious surfaces and intensive agriculture on bat activity with a national-scale monitoring program. Landscape Ecology 31: 2471–2483. https://doi.org/10.1007/s10980-016-0417-3

Barataud, M. (2012). Écologie acoustique des chiroptères d'Europe: Identification des espèces, étude de leurs habitats et comportements de chasse. Biotope Éditions/Muséum National d'Histoire Naturelle, Mèze/Paris, 344 pp.

Bendjeddou, M.L. et al. (2014). A new locality for *Tadarida teniotis* (Rafinesque, 1814) (Mammalia, Chiroptera, Molossidae) in Algeria. Natura Rerum 3: 37–39.

Bendjeddou, M.L. et al. (2017). Bat ectoparasites (Nycteribiidae, Streblidae, Siphonaptera, Heteroptera, Mesostigmata, Argasidae, and Ixodidae) from Algeria. Journal of Vector Ecology 42: 13–23. https://doi.org/10.1111/jvec.12235

Bendjeddou, M.L. et al. (2020). First photographed record of the naked rumped tomb bat, *Taphozous nudiventris* Cretzschmar, 1830 (Chiroptera: Emballonuridae), in the Grand Maghreb. African Journal of Ecology 58: 852–854. https://doi.org/10.1111/aje.12780

Biondi, A. et al. (2012). Using organic-certified rather than synthetic pesticides may not be safer for biological control agents: Selectivity and side effects of 14 pesticides on the predator *Orius laevigatus*. Chemosphere 87(7): 803–812. https://doi.org/10.1016/j.chemosphere.2011.12.082

Bouchenak, N. (2021). Déséquilibre des marchés mondiaux et économie algérienne: Quelles répercussions pour quelles alternatives? Algerian Scientific Journal Platform 7(1): 780–800.

Boughey, K.L. et al. (2011). Improving the biodiversity benefits of hedgerows: How physical characteristics and the proximity of foraging habitat affect bat use. Biological Conservation 144(6): 1790–1798. https://doi.org/10.1016/j.biocon.2011.02.017

Boukhari, A. et al. (2025). Bat activity in South Mediterranean forests: A seasonal acoustic survey. Diversity 17(11): 750. https://doi.org/10.3390/d17110750

Boyles, J.G. et al. (2011). Economic importance of bats in agriculture. Science 332(6025): 41–42. https://doi.org/10.1126/science.1201366

Brooks, M.E. et al. (2017). *glmmTMB* balances speed and flexibility among packages for zero-inflated generalized linear mixed modeling. The R Journal 9(2): 378–400. https://doi.org/10.32614/RJ-2017-066

Convention on Migratory Species (CMS) (2024). Appendices I and II of the Convention on the Conservation of Migratory Species of Wild Animals. UNEP/CMS Secretariat, Bonn, Germany. https://www.cms.int/en/species. Accessed on 10.vi.2025.

Council of Europe (2024). Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention): Appendices II and III. Council of Europe, Strasbourg, France. https://www.coe.int/en/web/bern-convention/appendices. Accessed on 30.iv.2025.

Dalhoumi, R. et al. (2016). Bat species richness and activity in Bou

Hedma National Park (central Tunisia). Turkish Journal of Zoology 40(6): 864–875. https://doi.org/10.3906/zoo-1505-46
Deutsch, D.A. et al. (2018). Increase in crop losses to insect pests in a warming climate. Science 361(6405): 916–919. https://doi.org/10.1126/science.aat3466
Disca, T. et al. (2014). Caractéristiques acoustiques des cris d'écholocation de 16 espèces de Chiroptères (Mammalia, Chiroptera) du Maroc. Vespère 3: 209–229.
Fahrig, L. et al. (2011). Functional landscape heterogeneity and animal biodiversity in agricultural landscapes. Ecology Letters 18(9): 999–1011. https://doi.org/10.1111/j.1461-0248.2010.01559.x
Farfar, A. et al. (2017). Bats of the El Kala Biosphere Reserve, northeastern Algeria (Chiroptera). Lynx 48: 79–92. https://doi.org/10.2478/lynx-2017-0005
Froidevaux, J.S.P. et al. (2019). Managing hedgerows for nocturnal wildlife: Do bats and their insect prey benefit from targeted agri-environment schemes? Journal of Applied Ecology 56(7): 1610–1623. https://doi.org/10.1111/1365-2664.13412
Fuentes-Montemayor, E. et al. (2011). Pipistrelle bats and their prey do not benefit from four widely applied agri-environment management prescriptions. Biological Conservation 144: 2233–2246. https://doi.org/10.1016/j.biocon.2011.05.015
Geiger, F. et al. (2010). Persistent negative effects of pesticides on biodiversity and biological control potential on European farmland. Basic and Applied Ecology 11(2): 97–105. https://doi.org/10.1016/j.baae.2009.12.001
Gupta, S.S. et al. (2024). Biodiversity: goal and driver of agricultural sustainability, pp. 143–164. In: Dhyani, S. et al. (eds.). Biodiversity and Bioeconomy: Status, Challenges, and Emerging Trends. Elsevier, Amsterdam, 546 pp. https://doi.org/10.1016/B978-0-323-95482-2.00007-9
Gurr, G.M. et al. (2017). Habitat management to suppress pest populations: Progress and prospects. Annual Review of Entomology 62(1): 91–109. https://doi.org/10.1146/annurev-ento-031616-035050
Hamida, L. et al. (2021). First record of existence of *Rhinolophus ferrumequinum* in southwest of Algeria: Morphometric characterization and their ectoparasites. Ukrainian Journal of Ecology 11: 159–166.
Hartig, F. (2016). DHARMa: Residual diagnostics for hierarchical (multi-level/mixed) regression models (R package). https://doi.org/10.32614/CRAN.package.DHARMa
Jung, K. & C.G. Threlfall (2016). Urbanisation and its effects on bats—a global meta-analysis, pp. 13–33. In: Voigt, C.C. & Kingston, T. (eds.). Bats in the Anthropocene: Conservation of Bats in a Changing World. Springer, Cham, 606 pp. https://doi.org/10.1007/978-3-319-25220-9_2
Kunz, T.H. et al. (2011). Ecosystem services provided by bats. Annals of the New York Academy of Sciences 1223: 1–38. https://doi.org/10.1111/j.1749-6632.2011.06004.x
Legendre, P. & L. Legendre (2012). Numerical Ecology, 3rd English edition. Elsevier, Amsterdam, 1006 pp.
Lehmann, P. et al. (2020). Complex responses of global insect pests to climate warming. Frontiers in Ecology and the Environment 18(3): 141–150. https://doi.org/10.1002/fee.2160
Loumassine, H.-E. et al. (2019). Bats of Saoura Valley in Algeria. Africa Conservation Telegraph 15(2): 1–4.
Loumassine, H.-E. et al. (2017a). A new mammal species for Algeria, *Rhinopoma microphyllum* (Chiroptera: Rhinopomatidae): Morphological and acoustic identification. Mammalia 82: 85–88. https://doi.org/10.1515/mammalia-2016-0153
Loumassine, H.-E. et al. (2017b). Premières données sur les populations de chauves-souris de la région de Boukais (Bechar, Sud-Ouest Algérien). Revue Écologie Environnement 13: 27–30.
Loumassine, H.-E. et al. (2020). How arid environments affect spatial and temporal activity of bats. Journal of Arid Environments 180: 104206. https://doi.org/10.1016/j.jaridenv.2020.104206
Maas, B. et al. (2016). Bird and bat predation services in tropical forests and agroforestry landscapes. Biological Reviews 91(4): 1081–1101. https://doi.org/10.1111/brv.12211
MacDonald, M.A. et al. (2012). Effects of agri-environment management for cirl buntings on other biodiversity. Biodiversity and Conservation 21: 1477–1492. https://doi.org/10.1007/s10531-012-0258-6
Marcelino, S.M. et al. (2024). Agricultural practices for biodiversity enhancement: evidence and recommendations for the viticultural sector. AgriEngineering 6(2): 1175–1194. https://doi.org/10.3390/agriengineering6020067
Mokrani, Y. et al. (2018a). Ecology, distribution and diversity of chiropteran fauna in the east of Algeria. World Journal of Environmental Biosciences 7(1): 32–35. https://environmentaljournals.org/storage/models/article/7MXturUmR5OvAjvZ5ZIZRktESWCa2BxvvW73pPSYvDs7Pdwe8649EONkLTDG/ecology-distribution-and-diversity-of-chiropteran-fauna-in-the-east-of-algeria.pdf
Mokrani, Y. et al. (2018b). Rapid assessment of cave-dwelling bat diversity in the Chebket ES-Sellaoua Mountains (Eastern Algeria). Arxius de Miscel·lània Zoològica 16: 112–120. https://doi.org/10.32800/amz.2018.16.0112
Oerke, E.C. (2006). Crop losses to pests. The Journal of Agricultural Science 144(1): 31–43. https://doi.org/10.1017/S0021859605005708
Oksanen, J. et al. (2022). vegan: Community Ecology Package (R package). https://CRAN.R-project.org/package=vegan
Park, K.J. (2015). Mitigating the impacts of agriculture on biodiversity: bats and their potential role as bioindicators. Mammalian Biology 80(3): 191–204. https://doi.org/10.1016/j.mambio.2014.10.004
People's Democratic Republic of Algeria (2012). Executive Decree No. 12-235 of 24 May 2012 establishing the list of protected non-domestic animal species (Décret exécutif n° 12-235 du 3 Rajab 1433 correspondant au 24 mai 2012 fixant la liste des espèces animales non domestiques protégées*).* Journal officiel de la République algérienne démocratique et populaire, No. 35, 10 June 2012, pp. 5–11.
Pretty, J. & Z.P. Bharucha (2014). Sustainable intensification in agricultural systems. Annals of Botany 114(8): 1571–1596. https://doi.org/10.1093/aob/mcu205
R Core Team (2025). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/
Roubos, C.R. et al. (2014). Relative toxicity and residual activity of insecticides used in blueberry pest management: Mortality of natural enemies. Journal of Economic Entomology 107(1): 277–285. https://doi.org/10.1603/EC13191
Russo, D. & L. Ancillotto (2015). Sensitivity of bats to urbanization: a review. Mammalian Biology 80(3): 205–212. https://doi.org/10.1016/j.mambio.2014.10.003
Russo, D. & G. Jones (2003). Use of foraging habitats by bats in a Mediterranean area determined by acoustic surveys: Conservation implications. Ecography 26(2): 197–209. https://doi.org/10.1034/j.1600-0587.2003.03422.x
Russo, D. et al. (2018). Novel perspectives on bat insectivory highlight the value of this ecosystem service in farmland: Research frontiers and management implications. Agriculture, Ecosystems & Environment 266: 31–38. https://doi.org/10.1016/j.agee.2018.07.024
Sánchez-Bayo, F. & K.A.G. Wyckhuys (2019). Worldwide decline of the entomofauna: A review of its drivers. Biological Conservation 232: 8–27. https://doi.org/10.1016/j.biocon.2019.01.020
Shannon, C.E. (1948). A mathematical theory of communication. The Bell System Technical Journal 27(3): 379–423. https://doi.org/10.1002/j.1538-7305.1948.tb01338.x
Tscharntke, T. et al. (2012). Global food security, biodiversity conservation and the future of agricultural intensification. Biological Conservation 151(1): 53–59. https://doi.org/10.1016/j.biocon.2012.01.068
Tuneu-Corral, C. et al. (2023). Pest suppression by bats and management strategies to favour it: A global review. Biological Reviews 98(5): 1564–1582. https://doi.org/10.1111/brv.12967

Wickham, H. (2016). ggplot2: Elegant Graphics for Data Analysis, 2nd edition. Springer, Cham, 260 pp. https://doi.org/10.1007/978-3-319-24277-4_9

Wickramasinghe, L.P. et al. (2004). Abundance and species richness of nocturnal insects on organic and conventional farms: Effects of agricultural intensification on bat foraging. Conservation Biology 18(5): 1283–1292. https://doi.org/10.1111/j.1523-1739.2004.00152.x

Zhu, D. et al. (2024). The consumption and diversity variation responses of agricultural pests and their dietary niche differentiation in insectivorous bats. Animals 14(5): 815. https://doi.org/10.3390/ani14050815

Table S1. Conservation status and legal protection of the bat taxa recorded at the two agricultural study sites in northern Algeria.

Taxon (authority) — Family	Common name	IUCN Red List category	Global population trend	CMS listing[1]	Bern Convention[2]	Legal status in Algeria[3]	Conservation relevance
Rhinolophus hipposideros (Borkhausen, 1797) — Rhinolophidae	Lesser Horseshoe Bat	Least Concern	Decreasing	European populations	Appendix II	Protected	Species with a decreasing global population trend; acoustically detected only at the orchard site
Eptesicus isabellinus (Temminck, 1840) — Vespertilionidae	Isabelline Serotine	Least Concern	Unknown	European populations	Appendix II	Protected	Western Mediterranean and North African taxon; one of the two dominant taxa at the orchard site
Hypsugo savii (Bonaparte, 1837) — Vespertilionidae	Savi's Pipistrelle	Least Concern	Stable	European populations	Appendix II	Protected	Widespread Mediterranean species; recorded only at the orchard site
Pipistrellus kuhlii (Kuhl, 1817) — Vespertilionidae	Kuhl's Pipistrelle	Least Concern	Increasing	European populations	Appendix II	Protected	Widespread generalist and the dominant taxon at the vineyard site
Pipistrellus pipistrellus (Schreber, 1774) — Vespertilionidae	Common Pipistrelle	Least Concern	Stable	European populations	Appendix III	Protected	Widespread species recorded at both study sites
Plecotus cf. *gaisleri* Benda et al., 2004 — Vespertilionidae[4]	Long-eared Bat provisionally assigned to Gaisler's Long-eared Bat	Not Evaluated for *P. gaisleri*	Unknown	Not confirmed for the North African taxon	Appendix II	Protected	Provisional identification of a probable northern African endemic taxon; acoustic data alone do not provide definitive species confirmation

[1] **CMS:** Listings follow Appendices I and II of the Convention on the Conservation of Migratory Species of Wild Animals (CMS 2024). For the families concerned, Appendix II coverage is generally expressed in relation to European populations and should not automatically be interpreted as applying to the Algerian populations recorded in this study.
[2] **Bern Convention:** Listings follow Appendices II and III of the Convention on the Conservation of European Wildlife and Natural Habitats (Council of Europe 2024). Most microchiropteran bats are included in Appendix II, whereas *Pipistrellus pipistrellus* is included in Appendix III. These listings describe the status of the taxa under the Convention and should not be interpreted as the source of their legal protection in Algeria.
[3] **Algerian protection:** National legal status follows Executive Decree No. 12-235 of 24 May 2012 establishing the list of protected non-domestic animal species (*Décret exécutif n° 12-235 du 3 Rajab 1433 correspondant au 24 mai 2012 fixant la liste des espèces animales non domestiques protégées*; People's Democratic Republic of Algeria 2012).
[4] Calls assigned to *Plecotus* could not be unequivocally identified to species level. Because *P. gaisleri* is the expected regional taxon, the records are reported as *Plecotus cf. gaisleri*. This designation indicates probable, but not definitive, species identity.
CMS—Convention on the Conservation of Migratory Species of Wild Animals.

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Author contributions: SM—methodology, field sampling. FZB—conceptualization, methodology, field sampling, data curation, data analysis, validation, supervision, writing-original draft, and writing-review and editing. FB—validation, methodology, and writing-review and editing. AB—data curation, conceptualization, methodology. MA—field sampling, methodology. LB—supervision and writing-review and editing.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 August 2026 | 18(8): 29390–29400

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

https://doi.org/10.11609/jott.9501.18.8.29390-29400

#9501 | Received 21 November 2024 | Final received 31 July 2026 | Finally accepted 11 August 2026

OPEN ACCESS

ARTICLE

Linear power infrastructure and vulture electrocution risk: mitigation through carcass dump relocation in Sudhauwala, Dehradun, India

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Abstract: Vultures are among the most threatened groups of birds globally, having undergone severe population declines across Asia and Africa due to multiple anthropogenic pressures, including poisoning, veterinary non-steroidal anti-inflammatory drugs (NSAIDs), food scarcity, belief-based use, and infrastructure-related mortality. Among these, electrocution from power infrastructure has emerged as an important but underreported threat. This study documents electrocution mortality of vultures in the Sudhauwala region of Dehradun, Uttarakhand, India, based on field observations conducted between May 2011 and February 2014. A total of 34 surveys recorded 743 individual vultures belonging to five species. During this period, 46 vulture carcasses attributable to electrocution were documented in proximity to high-tension power transmission structures. The highest proportion of mortality relative to observations was recorded for Himalayan Griffon *Gyps himalayensis*, followed by Eurasian Griffon *Gyps fulvus*, and Cinereous Vulture *Aegypius monachus*. Although surveys were conducted on a non-systematic basis, the number of mortality events observed suggests that electrocution may represent a significant localized threat, particularly for long-lived scavengers such as vultures. Based on these observations, the carcass dumping site that attracted vultures to the area was relocated approximately 2.4 km away from high-risk infrastructure in coordination with local authorities. Subsequent observations indicated continued use of the new site by vultures, with no mortality events recorded during limited post-relocation monitoring. This study highlights the risk posed by power infrastructure near feeding sites and demonstrates that relocation of carcass dumping sites can serve as a practical mitigation measure to reduce electrocution risk. The findings contribute to improving understanding of infrastructure-related threats to vultures and inform conservation planning in human-dominated landscapes.

Keywords: *Aegypius monachus*, anthropogenic mortality, carcass dumping site, conservation, electrocution, feeding site, *Gyps himalayensis*, *Gyps fulvus*, mitigation, population, power lines, scavengers, transmission infrastructure, uttarakhand.

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

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

Citation: Anver, J., Y.V.S. Sengar, B. Ghimire, V. Ngullie, H.R. Nanda, T.P. Dorji, A. Sharma, A. Jain, Sas Biswas, A. Kumar & M. Muzahed (2026). Linear power infrastructure and vulture electrocution risk: mitigation through carcass dump relocation in Sudhauwala, Dehradun, India. *Journal of Threatened Taxa* 18(8): 29390–29400. https://doi.org/10.11609/jott.9501.18.8.29390-29400

Funding: No specific funding was received for this study. The research was conducted without external financial support.

Competing interests: The authors declare no competing interests.

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

Acknowledgements: We would like to thank the local wildlife conservationists, my colleagues and also the local community (especially Vivek Rawat) for their assistance in field observations and data collection. We would like to present our deepest gratitude to our teachers (Dr. Sas Biswas, Dr. Sandhya Goswami, Dr. Manisha Rani, Dr. Natalaya Krishnamiba, Dr. Tahir Nazir and other faculty members) of our B.Sc. Forestry Department (Dolphin Institute of Bio-Medical and Natural Sciences) for their guidance and support during the field visits. Special thanks to the Uttarakhand Forest department for their efforts to protect vulture habitats in the region and the municipality department of Sudhauwala, Dehradun to support the success of the project.

INTRODUCTION

Vultures are large avian obligatory scavengers (Campbell 2015). In total, there are 23 species of vultures found around the world ranging from the dense Amazon rainforest to the eastern African savannahs, the arid Sahara Desert, to the high-altitude areas of the Himalaya (Buechley et al. 2016).

Globally, the most significant threats to vultures include poisoning from veterinary non-steroidal anti-inflammatory drugs (NSAIDs) such as diclofenac, intentional and unintentional poisoning through poison-baited carcasses, and in Africa, belief-based use (Ogada et al. 2012; Botha et al. 2017). These factors have contributed to the alarming statistic that approximately 61% of vulture species are threatened with extinction, with the most severe declines recorded in Asia and Africa (Ogada et al. 2012). The African-Eurasian Vulture Multi-species Action Plan (MsAP) highlights the pressures as the primary drivers of population declines and emphasizes coordinated international conservation actions to mitigate them (Botha et al. 2017). In addition to these dominant threats, anthropogenic infrastructure such as power lines and electrical distribution systems has emerged as a significant and increasingly recognized cause of mortality in large soaring birds, including vultures. Electrocution and collision incidents have been documented across multiple continents, with records dating back to the early 1970s in South Africa and the United States (Markus 1972; Jarvis 1974; Ledger & Hobbs 1981). Subsequent studies have further demonstrated the risks posed by poorly designed electrical infrastructure, particularly where birds can simultaneously contact energized components, leading to fatal electrocution events (Kagan 2016).

Electrical infrastructure has become an increasingly important source of mortality for large soaring birds worldwide. Electrocution typically occurs when a bird simultaneously contacts two energized conductors, or an energized conductor and a grounded component of a pole or tower, thereby completing an electrical circuit. Large-bodied species with broad wingspans, such as vultures, eagles, and storks, are particularly susceptible because their wings or feet can bridge these components while perching, taking off, or landing (Ferrer & Janss 1999; Kagan 2016). In addition to electrocution, collisions with overhead wires also contribute to mortality, particularly where power infrastructure overlaps with important feeding, roosting, or migration areas (Smallie & Virani 2010).

Recent global assessments have identified power infrastructure as an important and expanding conservation threat to vultures. Infrastructure-related mortality has been documented across Africa, Europe, Asia, and North America, and is expected to increase as electricity networks expand into previously undeveloped landscapes (Ogada et al. 2012; Botha et al. 2017). The African-Eurasian Vulture Multi-species Action Plan (MsAP) recognizes electrocution and collision with power infrastructure as significant threats affecting numerous vulture populations throughout their range, particularly where poorly designed power structures occur close to feeding sites and communal roosts (Lehman et al. 2007; Botha et al. 2017).

Although most evidence has been reported from Africa and Europe, electrocution has also been documented in India. For example, Bohra & Vyas (2021) reported the electrocution of an Egyptian Vulture *Neophron percnopterus* in Rajasthan, highlighting that infrastructure-related mortality is an emerging conservation concern in the country. These observations suggest that localized mortality events may have disproportionate impacts on vulture populations because these species are long-lived, have low reproductive rates, and depend on high adult survival for population persistence (Dwyer 2004; Ogada et al. 2012).

This study aims to analyze the impact of electrocution on vulture populations in Dehradun, focusing on mortality events.

MATERIALS AND METHODS

Study Area

The study was conducted in the Sudhauwala region of Dehradun, Uttarakhand, India. The Sudhauwala is situated at the 30.3330° N, 77.9608° E, in the 15 km southwestern part of Dehradun district on the Dehradun to Chandigarh Highway. Jhajhara range is one of the forest ranges of Dehradun Forest Division. The terrain is characterized by valleys surrounded by human settlements, agricultural land, and infrastructure such as power lines (Kumar et al. 2017).

Data Collection and Survey Effort: The field observations were conducted from May 2011 to February 2014. The survey focused on a livestock carcass dumping site and the surrounding area within a 2–3 km radius, including nearby power transmission infrastructure frequently used by vultures for perching and roosting. A total of 34 surveys were conducted, distributed across multiple seasons-spring, autumn, and winter-with a minimum frequency of about one survey

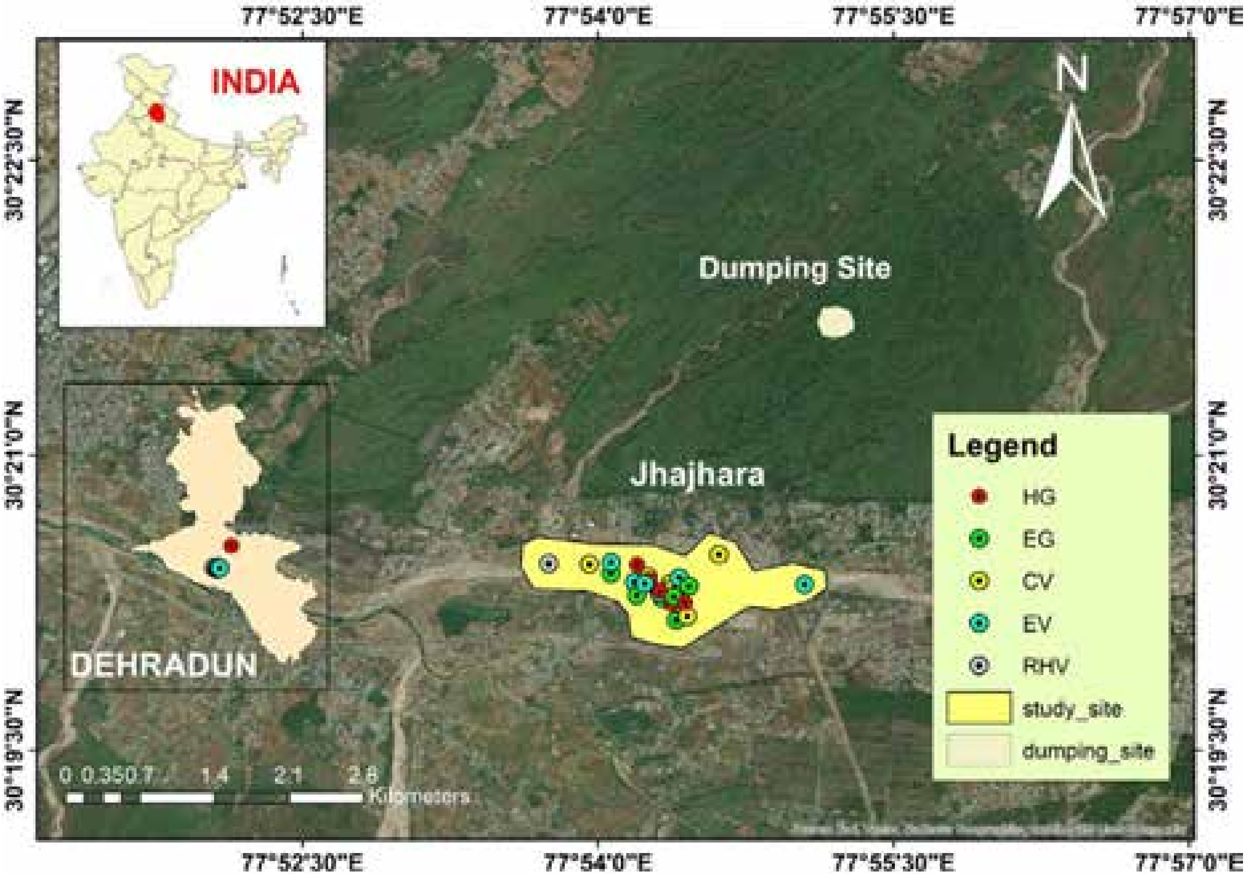

Image 1. Map of the study area highlighting the study area points and the Jhajhara range (new relocated site), the different colored points represent the different species of vultures reported during the study time: HG—Himalayan Griffon | EG—Eurasian Griffon | CV—Cinereous Vulture | EV—Egyptian Vulture | RHV—Red-headed Vulture. Source: Esri, Ventor, Earthstar Geographics, and the GIS User Community.

per month during active periods. The sampling effort was higher during winter months (October to February) when there was increased vulture abundance, resulting in approximately 6–10 visits per year. Each survey lasted 2.6–3.5 hours, mainly conducted in the morning (0630–1230). During each visit, direct counts of vultures present at the dumping site, and surrounding roosting locations were recorded using visual observation. Observations focused on feeding grounds and nearby powerline structures used for perching.

For each survey the following data were collected-

- Date and location
- Species identity (where possible)
- Number of individuals

Surveys were conducted on a non-systematic basis. Survey frequency varied across the study period, with an approximate minimum of 1–2 visits per month during active survey periods, and higher frequency during peak seasons. Overall, this corresponded to approximately 6–10 survey days per year, with 2–5 survey visits per season.

Mortality Recording

During each survey, the area surrounding the livestock carcass dumping site and nearby high-voltage power transmission structures within the 2–3 km survey area was searched on foot for vulture carcasses. Searches focused on the ground beneath transmission towers and powerlines that were frequently used by vultures as perching and roosting sites. The designated search area included the dumping site and adjacent powerline corridor, which were inspected systematically during each survey visit.

For each mortality event, the following information was recorded: (i) species identification, where possible; (ii) GPS location; (iii) photographic documentation; and (iv) visible evidence consistent with electrocution, such as burns or the carcass position beneath power infrastructure. Photographs were used to support species identification and confirm the cause of mortality.

Carcasses were not removed after documentation. To avoid duplicating records during subsequent surveys, each carcass was identified using its GPS location, photographs, species identity, and stage of decomposition. As carcass searches were conducted only during scheduled survey visits and not continuously, the mortality data presented represent minimum confirmed electrocution events, and the actual number of electrocution deaths may have been higher.

Survey Method

Field data were collected opportunistically during repeated surveys conducted between May 2011 and February 2014 at the livestock carcass dumping site in Sudhauwala and adjacent vulture loafing and roosting sites. The study area also included the surrounding high-voltage power transmission corridor, where vultures were frequently observed perching. A total of 34 surveys were undertaken, with greater sampling effort during the winter months (October–February) to coincide with the seasonal increase in vulture abundance. Surveys were conducted primarily between 0630 and 1230 h, with each survey lasting approximately 2.6–3.5 hours.

During each survey, all vultures observed at the dumping site, nearby roosting locations, and associated power transmission structures were identified to species level, where possible, and counted using direct visual observations. Photographic and video records were obtained to support species identification, verify flock composition, estimate the number of individuals present, and document behavioral activities, including feeding, perching, and resting.

The livestock carcass dumping site was surveyed because it represented the primary foraging area for vultures in the region, whereas the adjacent power transmission structures functioned as the principal loafing and roosting sites. Repeated surveys of these locations enabled the documentation of species composition, relative abundance, behavioral observations, and electrocution-related mortality throughout the study period.

Following the relocation of the carcass disposal site, post-relocation monitoring was undertaken at the newly established disposal site at Sudhauwala to assess continued use by vultures and other raptors. Monitoring consisted of two field surveys, conducted on 15 November 2015 and 15 December 2015. During each survey, all raptors observed within and immediately surrounding the disposal site were identified to species level and counted using direct visual observations. For each species, behavioral observations (e.g., feeding, soaring, flying or perching) and associated habitat type were recorded. The same survey approach was used during both visits to facilitate comparison with pre-relocation observations. Because individuals may have been recorded on more than one survey visit, observations from separate visits were treated as independent sampling events and were not combined to estimate population size.

RESULTS

Observations

Across repeated surveys conducted between May 2011 and February 2014, 743 cumulative vulture observations representing five species were recorded. Because these totals represent repeated observations during multiple survey visits, they should not be interpreted as population estimates. The highest number of individuals recorded during a single survey visit was observed for the Eurasian Griffon (85 individuals), followed by the Himalayan Griffon (35 individuals), Egyptian Vulture (21 individuals), and Cinereous Vulture (20 individuals). A single Red-headed Vulture *Sarcogyps calvus* was recorded during the study. A total of 46 electrocution-related mortality events were documented beneath or adjacent to high-voltage power transmission structures.

The Vulture use of the Dumping Site

The number of vultures recorded at the Sudhauwala dumping site varied among survey periods throughout the study. The highest number of individuals recorded during a single survey visit was 161 vultures in March 2013, comprising 85 Eurasian Griffons, 35 Himalayan Griffons, 21 Egyptian Vultures, and 20 Cinereous Vultures *Aegypius monachus*. Lower numbers were recorded during other survey periods, indicating temporal variation in the use of the dumping site by vultures. As survey effort varied over the years, these observations

Table 1. The total observational table of different species of vultures.

Species	Total observations	Maximum count per survey	Range per survey	Electrocution deaths
Eurasian Griffon	404	85	24–85	19
Himalayan Griffon	176	35	10–35	24
Cinereous Vulture	89	20	4–20	3
Egyptian Vulture	72	21	4–21	0
Red-headed Vulture	1	1	1	0
Unknown	1	1	1	0

Table 2. The total observational data representing the seasonal visits to the survey site.

Month	Surveys	Total vultures counted	Temporal coverage (Years)	Seasonal classification	Total mortality events
January	5	84	2014	Winter	3
February	4	59	2014	Winter	6
March	8	264	2012, 2013	Spring	11
April	0	-	-	Summer (early)	-
May	1	1	2011	Summer (early)	1
June	0	-	-	Summer (peak)	-
July	0	-	-	Summer (peak)	-
August	0	-	-	Summer (late)	-
September	4	85	2012	Autumn	6
October	8	187	2011, 2013	Autumn	13
November	0	-	-	Autumn (late)	-
December	4	63	2013	Winter	6

Image 2. The linear infrastructure (electric pole profile- 220 KV power transmission station) images of power plant and power line, these images represent a suitable perching site for the large birds like Vulture, Eagle etc. © B.Sc. Forestry Students (D.I.B.N.S. Dehradun).

represent differences in site use rather than changes in the regional vulture population.

Seasonal and Spatial Patterns

Electrocution incidents and vulture abundance exhibited strong seasonal patterns, with peak values recorded during March and October across multiple years. These periods consistently showed the highest counts of Gyps vultures (e.g., up to 85 individuals in March 2013 and 65 individuals in October 2011), along with the highest number of electrocution events. In contrast, vulture abundance declined sharply outside these peak periods. The only available record from the early summer period (May 2011) documented a single individual, indicating a substantial reduction in local vulture presence following the peak seasons. Although no surveys were conducted during peak summer months (June–July), the observed decline from spring to early summer, combined with the absence of records in subsequent months, suggests a strong seasonal reduction in vulture abundance during this period. This pattern is consistent with the known migratory and dispersal behavior of Gyps vultures, which move away from the region during warmer months.

Table 3. The post relocation data of the new dumping site with the total species observed.

Species	IUCN Red List status	Maximum count recorded during a single post-relocation survey	Survey month of maximum count
Egyptian Vulture *Neophron percnopterus*	Endangered	8	December 2015
Himalayan Griffon *Gyps himalayensis*	Near Threatened	4	November 2015
Eurasian Griffon *Gyps fulvus*	Least Concern	6	December 2015
Black Kite *Milvus migrans*	Least Concern	7	November 2015
Crested Serpent Eagle *Spilornis cheela*	Least Concern	7	December 2015

Image 3. A group of Egyptian Vultures (Endangered) species was reported from the new dumping site. © Ravi Kiran.

DISCUSSION

Electrocution

Electrocution can occur when a bird perches on a cross-arm and completes an electrical circuit with two or more body parts (Shobrak 2012). The lack of roosting trees in the dumping site area and presence of the large amount of tall electric poles attracts the birds to rest, particularly those of the Himalayan Griffon and Eurasian Griffon, make them highly susceptible to contact with overhead power lines. The data from the present study shows a significant effect on the vulture's population, below are the notable effects recorded from the Dehradun.

Electrocution as a Key Mortality Factor

The data clearly indicate that electrocution is a major source of mortality for the different species of vultures in the Dehradun region. These findings are consistent with global studies that identify power lines as a significant hazard for large avian species.

Conservation Concerns

The presence of human settlements and infrastructure in close proximity to key vulture habitats exacerbates the risk. The loss of vultures has broader

Image 4. A decomposing body of vulture was found underneath the power line. © Javed Anver.

ecological consequences, as these scavengers play an essential role in preventing the spread of disease by removing carcasses from the environment.

Image 5. The Eurasian Griffon *Gyps fulvus* dead bodies under the high-tension electric pole (below picture) and another decomposed caracass was photographed during the survey. © Javed Anver.

Electrocution and Conservation Implications

The present study demonstrates that electrocution associated with power transmission infrastructure represents an important source of mortality for vultures in the Sudhauwala region. The majority of electrocution deaths involved Himalayan Griffons and Eurasian Griffons, suggesting that these large-bodied species are particularly vulnerable because they frequently perch and roost on high-voltage transmission structures located adjacent to the carcass dumping site. Similar patterns have been reported elsewhere, where large soaring birds are at increased risk of electrocution due to their body size, wingspan, and use of electrical infrastructure as perching sites (Ferrer & Janss 1999; Biasotto et al. 2022).

The concentration of feeding resources close to power infrastructure is likely to increase the exposure of vultures to electrocution risk. These findings support the implementation of targeted mitigation measures, including relocation of carcass dumping sites away from hazardous electrical infrastructure and modification of high-risk power structures in areas that are regularly used by vultures. Such interventions have the potential to substantially reduce infrastructure-related mortality while maintaining access to important feeding resources.

Although electrocution was the primary focus of this study, vultures in the Indian subcontinent continue to face multiple anthropogenic threats, including poisoning, habitat degradation, and loss of suitable nesting and roosting sites (Prakash et al. 2012; Biju & Mize 2021). Consequently, reducing electrocution mortality should

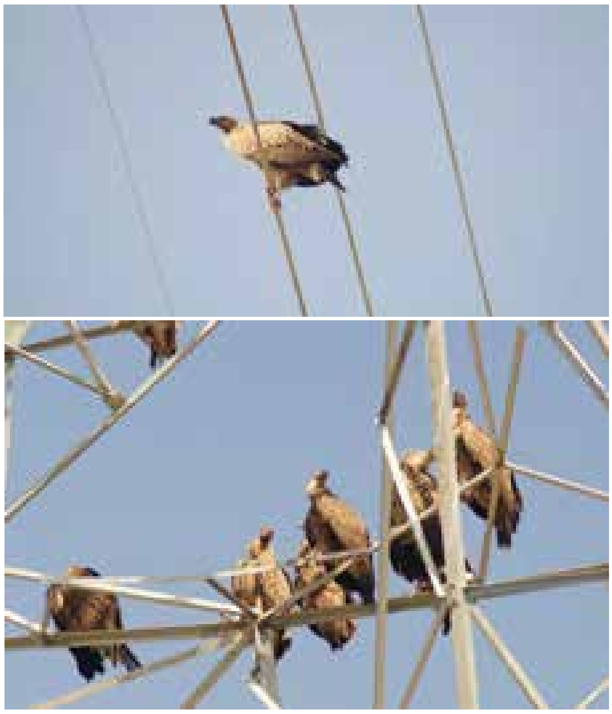

Image 6. The vultures were photographed sitting on the power line. © Javed Anver.

Image 7. A group of vultures were seen sitting on the electric pole, on the below a Red-headed Vulture can be seen from the Sudhauwala area. © Javed Anver.

be considered as one component of an integrated conservation strategy for these threatened scavengers.

Diclofenac Poisoning

Historically, the vulture population in India has suffered dramatic declines due to poisoning from diclofenac, a non-steroidal anti-inflammatory drug used in veterinary medicine. Although diclofenac has been banned, its impact lingers, making vultures more vulnerable to threats such as electrocution.

Mitigation

Given the significance of electrocution as a threat to vultures in Dehradun, we propose the following mitigation measures:

1. Shifting the dumping site: Based on field observations and documented instances of vulture mortality due to electrocution, the authors formally recommended the relocation of the carcass dumping site to reduce exposure to nearby power infrastructure. This recommendation was developed as part of the present study and communicated to the Divisional Forest Office (DFO), Dehradun Forest Division, and the Municipality of Sudhauwala through a written technical report submitted in the year 2014. The report included spatial analysis of mortality locations, photographic evidence of electrocution incidents, and an assessment of the proximity of the existing dumping site to high-risk electrical infrastructure.

Image 8. Two partially decomposed body of the Himalayan Griffon *Gyps himalayensis* were photographed close to a high-tension pole. © Javed Anver.

2. The recommendation emphasized that the existing dumping site, located near expanding power infrastructure, posed a continued risk to scavenging vultures. A proposed alternative site, approximately 2.4 km from the original location and within a relatively undisturbed area, was identified to minimize disruption to vulture movement patterns while reducing electrocution risk.

3. Involving the local Administration/Municipality: The authors were engaged with relevant local authorities, including the Forest Department and the Municipality of Sudhauwala Dehradun, to address the issue. Detailed

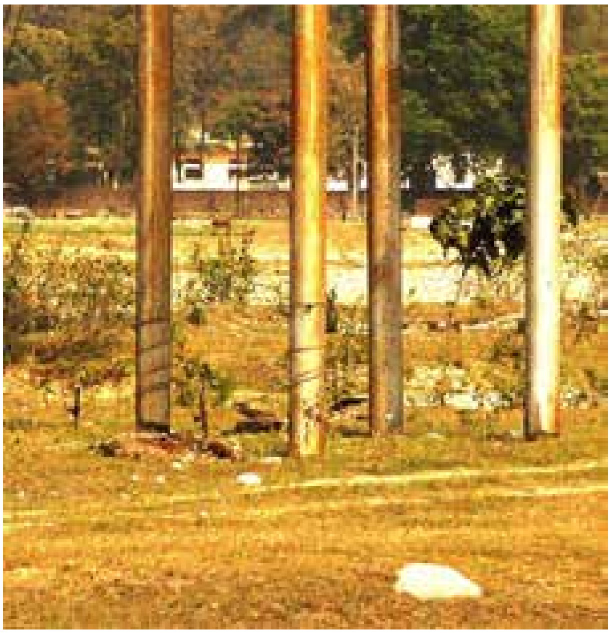

Image 9. On the above picture, two dead vultures were photographed by the team near the high-tension electric pole in Dhalwala and on the below picture two dead vultures were reported under the electric pole. © Javed Anver.

reports and necessary documentation were submitted, highlighting the urgency of relocating the dumping site, which is in close proximity to expanding power infrastructure. In response, the authorities acted promptly, facilitating the relocation of the dumping site to a safer location, thereby reducing the risk of further electrocution-related vulture mortality. This coordinated effort demonstrates the potential for effective conservation action through collaboration between research institutions and local government bodies.

4. Relocation: The relocation was done on 04 April 2015 by notifying the local community with a notice, to those who actively participate in the dumping of their livestock. A warning board from the forest department was installed to ensure the prevention of dumping the caraccas on the site. A new site was allotted to the villagers and local community to dump their carcasses and safeguarding it to prevent any further death in vulture species.

5. Post-relocation: Vultures were observed feeding at the relocated carcass disposal site during both post-relocation surveys, demonstrating continued use of the new feeding area. The relocation was intended to reduce the risk of interactions with nearby power infrastructure, although the limited post-relocation monitoring did not allow a quantitative assessment of changes in activity at the former site. In addition to vultures, other raptor species, including the Black Kite *Milvus migrans* and Crested Serpent Eagle *Spilornis cheela*, were also recorded at the relocated site.

Image 10. The dumping ground surrounding with power line and vultures can be seen in the background, a stray dog can also be observe in this photograph. © Javed Anver.

CONCLUSION

This study documents electrocution as an important source of mortality for vultures using a livestock carcass dumping site located adjacent to high-voltage power transmission infrastructure in the Sudhauwala region of Dehradun, India. During 34 surveys conducted between 2011 and 2014, 46 confirmed electrocution-related mortality events were recorded, with Himalayan Griffons and Eurasian Griffons accounting for most documented deaths. These findings indicate that the proximity of predictable food resources to electrical infrastructure can create localized mortality hotspots for large scavenging birds.

The relocation of the carcass dumping site was done on 04 April 2015, approximately 2.4 km from the original location was implemented as a management intervention to reduce this risk. Limited post-relocation monitoring demonstrated that vultures continued to use the relocated feeding site, suggesting that relocation can maintain access to food resources while potentially reducing exposure to hazardous infrastructure. However, because post-relocation monitoring consisted of only two surveys, the effectiveness of this intervention in reducing long-term electrocution mortality could not be quantitatively evaluated.

The study highlights the importance of incorporating power infrastructure into vulture conservation planning. Locating carcass disposal sites away from hazardous transmission structures, together with retrofitting high-risk power poles and implementing long-term monitoring, should be considered practical conservation measures to reduce infrastructure-related mortality of vultures and other large soaring birds.

REFERENCES

Biju, T. & D. Mize (2021). Distribution, population trend and threats of three critically endangered Gyps vultures in the Indian subcontinent: a review. Dera Natung Government College Research Journal 6(1): 55–65. https://doi.org/10.56405/dngcrj.2021.06.01.06

Biasotto, L.D. et al. (2022). Risk of bird electrocution in power lines: a framework for prioritizing species and areas for conservation and impact mitigation. Animal Conservation 25(2): 285–296. https://doi.org/10.1111/acv.12736

Bohra, D.L. & S. Vyas (2021). A record of electrocution of Egyptian Vulture at Jorbeer, Rajasthan, India. Zoo's Print 36(10): 62–66.

Botha, A. et al. (2017). Multi-species Action Plan to Conserve African-Eurasian Vultures (MsAP). Convention on Migratory Species (CMS), Bonn, Germany.

Buechley, E.R. & C.H. Sekercioglu (2016). Vultures. Current Biology 26(13): R560–R561. https://doi.org/10.1016/j.cub.2016.01.052

Campbell, M.O.N. (2015). Vultures: Their Evolution, Ecology and Conservation. CRC Press, Boca Raton.

Dwyer, J.F. (2004). Investigating and Mitigating Raptor Electrocution in an Urban Environment. PhD Thesis. University of Arizona, Tucson, Arizona.

Ferrer, M. & G.F.E. Janss (1999). Birds and Power Lines. Quercus, Madrid, Spain.

Hutto, R.L. et al. (1986). A fixed-radius point count method for nonbreeding and breeding season use. The Auk 103(3): 593–602. https://doi.org/10.1093/auk/103.3.593

Jarvis, M.J.F. (1974). Further records of vulture electrocution in South Africa. Ostrich 45(2): 77–79.

Kagan, R.A. (2016). Electrocution of raptors on power lines: a review of necropsy methods and findings. Veterinary Pathology 53(5): 1030–1036. https://doi.org/10.1177/0300985816646431

Krüger, R. et al. (2004). Vulture electrocutions on vertically configured medium voltage structures in the Northern Cape Province, South Africa., pp. 437–441. In: Chancellor, R.D. & B.-U. Meyburg (eds.). Raptors Worldwide. WWGBP/MME, Berlin, Germany.

Kumar, Y. et al. (2017). The spectral modelling of above ground forest biomass in Jhajra forest range of Dehradun Forest Division using microwave data. Journal of Plant Development Science 9(10): 917–923.

Ledger, J.A. & J.C. Hobbs (1981). Electrocuted raptors and power lines in South Africa. Biological Conservation 21(1): 7–18.

Lehman, R.N. et al. (2007). The state of the art in raptor electrocution research: a global review. Biological Conservation 136(2): 159–174. https://doi.org/10.1016/j.biocon.2006.09.015

Markus, M. (1972). Mortality of Vultures caused by Electrocution. Nature 238, 228, pp. https://doi.org/10.1038/238228b0

Ogada, D.L. et al. (2012). Dropping dead: causes and consequences of vulture population declines worldwide. Annals of the New York Academy of Sciences 1249(1): 57–71. https://doi.org/10.1111/j.1749-6632.2011.06293.x

Prakash, V. et al. (2012). The population decline of Gyps vultures in India and Nepal has slowed since veterinary use of diclofenac was banned. PLoS ONE 7(11): e49118. https://doi.org/10.1371/journal.pone.0049118

Shobrak, M. (2012). Electrocution and collision of birds with power lines in Saudi Arabia (Aves). Zoology in the Middle East 57(1): 45–52. https://doi.org/10.1080/09397140.2012.10648962

Smallie, J. & M.Z. Virani (2010). A preliminary assessment of the potential risks from electrical infrastructure to large birds in Kenya. Journal of East African Ornithology 30: 32–39.

Swan, G. et al. (2006). Removing the threat of diclofenac to critically endangered Asian vultures. PLoS Biology 4(3): e66. https://doi.org/10.1371/journal.pbio.0040066

Sutherland, W.J. (ed.) (2006). Ecological Census Techniques: A Handbook, 2nd Edition. Cambridge University Press, Cambridge.

Thomas, L. et al. (2010). Distance software: design and analysis of distance sampling surveys for estimating population size. Journal of Applied Ecology 47(1): 5–14. https://doi.org/10.1111/j.1365-2664.2009.01737.x

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Hindi: गिद्ध (Vultures) विश्व स्तर पर सबसे अधिक संकटग्रस्त पक्षी समूहों में से एक हैं। एशिया और अफ्रीका में उनकी आबादी में मानवजनित (Anthropogenic) कारणों से अत्यधिक गिरावट आई है। इसके प्रमुख कारणों में विषाक्तता (Poisoning), पशु-चिकित्सा में प्रयुक्त नॉन-स्टेरॉयडल एंटी-इन्फ्लेमेटरी दवाओं (NSAIDs) का उपयोग, भोजन की कमी, पारंपरिक मान्यताओं के कारण उनका उपयोग तथा विद्युत अवसंरचना (Power Infrastructure) से होने वाली मृत्यु शामिल हैं (Ogada et al. 2012; Botha et al. 2017)। इन सभी कारणों में से विद्युत अवसंरचना से करंट लगने (Electrocution) के कारण होने वाली मृत्यु एक महत्वपूर्ण, किन्तु अपेक्षाकृत कम रिपोर्ट की गई समस्या के रूप में उभरकर सामने आई है।. यह अध्ययन भारत के उत्तराखंड राज्य के देहरादून जनपद के सुधौवाला (Sudhauwala) क्षेत्र में गिद्धों की करंट लगने से हुई मृत्यु का दस्तावेजीकरण प्रस्तुत करता है। यह अध्ययन मई 2011 से फरवरी 2014 के बीच किए गए क्षेत्रीय सर्वेक्षणों पर आधारित है। कुल 34 सर्वेक्षणों के दौरान पाँच प्रजातियों के 743 गिद्धों का अवलोकन किया गया। इसी अवधि में उच्च वोल्टेज (High-Tension) विद्युत संचरण लाइनों एवं उनके टावरों के निकट करंट लगने के कारण मृत पाए गए गिद्धों के कुल 46 शव दर्ज किए गए। अवलोकित गिद्धों की संख्या की तुलना में सबसे अधिक मृत्यु अनुपात हिमालयी ग्रिफॉन (Gyps himalayensis) में दर्ज किया गया, इसके बाद यूरेशियन ग्रिफॉन (Gyps fulvus) तथा सिनेरियस गिद्ध (Aegypius monachus) का स्थान रहा। यद्यपि सर्वेक्षण नियमित एवं व्यवस्थित पद्धति से नहीं किए गए थे, फिर भी दर्ज की गई मृत्यु घटनाओं की संख्या यह संकेत देती है कि करंट लगने की समस्या गिद्ध जैसे दीर्घायु मृतभक्षी पक्षियों के लिए स्थानीय स्तर पर एक गंभीर खतरा हो सकती है।. इन अवलोकनों के आधार पर, स्थानीय प्रशासन के सहयोग से उस मृत पशु निस्तारण स्थल (Carcass Dumping Site), जो गिद्धों को इस क्षेत्र की ओर आकर्षित करता था, को उच्च जोखिम वाली विद्युत अवसंरचना से लगभग 2.4 किलोमीटर दूर स्थानांतरित किया गया। स्थानांतरण के बाद किए गए सीमित अनुवर्ती (Post-relocation) अवलोकनों से यह पता चला कि गिद्ध नए निस्तारण स्थल का उपयोग करते रहे तथा इस अवधि में करंट लगने से किसी भी गिद्ध की मृत्यु दर्ज नहीं की गई।. यह अध्ययन दर्शाता है कि भोजन स्थलों के समीप स्थित विद्युत अवसंरचना गिद्धों के लिए गंभीर जोखिम उत्पन्न करती है। साथ ही, यह भी प्रदर्शित करता है कि मृत पशु निस्तारण स्थलों का सुरक्षित स्थान पर स्थानांतरण करंट लगने से होने वाली मृत्यु के जोखिम को कम करने के लिए एक प्रभावी एवं व्यावहारिक संरक्षण उपाय हो सकता है। इस अध्ययन के निष्कर्ष गिद्धों के लिए अवसंरचना-जनित खतरों की समझ को बेहतर बनाने में योगदान देते हैं तथा मानव-प्रभावित परिदृश्यों (Human-dominated Landscapes) में उनके संरक्षण की योजना बनाने के लिए उपयोगी जानकारी प्रदान करते हैं।

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 August 2026 | 18(8): 29401–29417

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

https://doi.org/10.11609/jott.10045.18.8.29401-29417

#10045 | Received 10 July 2025 | Final received 05 June 2026 | Finally accepted 24 June 2026

ARTICLE

Avifaunal diversity of the central Western Ghats in Uttara Kannada, Karnataka, India

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Abstract: Birds are present across diverse ecosystems and play critical roles as seed dispersers, pest controllers, and indicators of environmental change. Documenting avian diversity in a landscape is essential for recognising its ecological significance, identifying priority areas for conservation, and safeguarding critical habitats. Here, we present a baseline checklist of the avifaunal diversity of the ecologically sensitive areas of the central Western Ghats during the summer season, encompassing the forests of Karwar Forest Division, Yellapur Forest Division, and Kali Tiger Reserve. Using a combination of systematic grid-based point count and opportunistic surveys, we documented a total of 206 species belonging to 66 families and 18 orders. Species richness was highest in the semi evergreen forest, followed by moist deciduous, and tropical evergreen forest. We recorded 20 species endemic to the Indian subcontinent, of which 13 species were exclusively endemic to the Western Ghats. Our findings provide valuable baseline data for future ecological assessments and conservation planning in this ecologically sensitive region of the Western Ghats.

Keywords: Biodiversity hotspot, bird assemblage, conservation, ecologically sensitive areas, endemic, Kali Tiger Reserve, Non-Protected Area, Protected Area, species richness.

Editor: H. Byju, Coimbatore, Tamil Nadu, India. **Date of publication:** 26 August 2026 (online & print)

Citation: Patra, R., N. Rana, S.J.D. Frank & G.V. Gopi (2026). Avifaunal diversity of the central Western Ghats in Uttara Kannada, Karnataka, India. *Journal of Threatened Taxa* 18(8): 29401–29417. https://doi.org/10.11609/jott.10045.18.8.29401-29417

Funding: Nuclear Power Corporation of India Limited (NPCIL).

Competing interests: The authors declare no competing interests.

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Author contributions: Conceptualisation: GVG. Data curation: RP, NR. Formal analysis: RP, NR. Funding acquisition: GVG. Investigation: GVG. Methodology: RP, NR, SJDF, GVG. Supervision: GVG. Project administration: GVG. Validation: GVG, SJDF, RP, NR. Visualisation: GVG, RP, NR, SJDF. Writing – original draft: RP, NR. Writing – review and editing: GVG, SJDF, RP, NR.

Acknowledgements: We thank the director and dean, Wildlife Institute of India for their guidance and support. We extend our sincere thanks to the PCCF (HoFF), PCCF (WL) & CWLW, APCCF (WL), Karnataka Forest Department for the permission to carry out the field survey. We thank the field director, Kali Tiger Reserve, deputy conservators of forests of Karwar and Yellapur forest divisions for the permission and logistical support during the field work. We are thankful to the ACFs, RFOs, DyRFOs, guards, watchers, and other forest department staff of all three forest divisions for their inputs and accompanying us during the field work. We are thankful to Mr. G. Mohandas, Mr. A.L.V.V. Reddy, and Mr. K. Harish from NPCIL Kaiga for their valuable insights on the avian diversity of the Kaiga region. We would also like to thank our teammates Mr. Avinash Yadav, Mr. Toushif P.K., and Mr. Karthy Shivapushnam.

भारतीय वन्यजीव संस्थान Wildlife Institute of India

INTRODUCTION

Birds occupy a wide range of habitats globally and play vital ecological roles such as seed dispersal, pollination, pest control, and scavenging (Ali 2002; Sekercioglu 2006; Whelan et al. 2008; Archana et al. 2024). Due to their mobility and sensitivity to environmental changes, birds serve as key indicators for monitoring habitat quality and biodiversity trends (Menon & Shahabuddin 2021; Aarif et al. 2025). In India, recent assessments indicate that nearly 60% of bird species show long-term declines, with 40% currently experiencing population reductions (State of India's Birds 2023). These trends highlight the urgency of documenting avifaunal diversity, particularly in ecologically sensitive regions.

In particular, tropical and subtropical forests around the world support an exceedingly high number of birds as compared to other regions (Pillay et al. 2021). However, anthropogenic disturbances such as deforestation, logging, and the conversion of forests to agroforests or urban areas have resulted in the disruption of bird communities in forests (Barlow et al. 2006; Sekercioglu 2012; Matuoka et al. 2020). The Western Ghats, one of the eight 'hottest' biodiversity hotspots in the world (Myers et al. 2000), support a rich bird community shaped by diverse topography and climatic variations. Within the Western Ghats, Gadgil et al. (2011) defined ESA as areas "that are ecologically and economically important, but vulnerable even to mild disturbances, and hence demand careful management". The 6th Draft Notification of the Western Ghats ESA identifies an area of 20,668 km^2 in the state of Karnataka to be ecologically sensitive, which majorly encompasses the mountains of the Ghats (Gazette of India 2024). Within this region, the Uttara Kannada district contains the largest contiguous tropical forests in peninsular India and harbours 441 of Karnataka's 556 recorded bird species (Praveen et al. 2025). While several studies have documented avian diversity in different parts of this district (Davidson 1898a,b; Daniels et al. 1990, 1992; Barve & Warrier 2013; Ramachandra et al. 2013; Bhat & Ganesh 2014), very few surveys have been conducted in the Anshi-Dandeli area (Kotangale & Ghosh 2000; Puttaraju 2014), which remains largely unexplored in terms of its avifaunal diversity. Thus, the present study aims to provide an overview of the region's bird diversity and establish a baseline dataset for future studies aimed towards addressing avian conservation efforts within this landscape.

STUDY AREA

The study was carried out in the forests of the central Western Ghats in the Uttara Kannada District of Karnataka. The area spanned across three forest divisions: Karwar Forest Division, Kali Tiger Reserve, and Yellapur Forest Division (bounded by the latitudes 14.691°–15.016° N and the longitudes 74.286°–74.627° E) (Image 1). The landscape is primarily dominated by southern tropical wet evergreen and semi evergreen forests. However, the eastern portion of the Yellapur Forest Division transitions to tropical dry deciduous forests. The Kali Tiger Reserve (KTR) is a critical part of this region, encompassing two key protected areas: Dandeli Wildlife Sanctuary (886.41 km^2) and Anshi National Park (417.34 km^2). Together, these contiguous areas form the "Dandeli-Anshi Tiger Reserve" (DATR), renamed as the KTR, which encompasses a total area of over 1,300 km^2. Kali Tiger Reserve is a part of a larger contiguous forest tract extending over 10,000 km^2 across the states of Karnataka and Goa. The tiger reserve serves as the major catchment for the Kali River and its tributaries, Nagzari and Kaneri. Geographically, KTR shares its northern boundary with Bhimgad Wildlife Sanctuary of Belgaum Division. To the east, it borders the Haliyal Division, while to the south and south-east, it adjoins the reserved forests of Yellapur and Karwar divisions. The western boundary connects to protected areas in Goa.

In addition to the main river Kali, many streams and rivulets drain the heavy rainfall of the area into the Arabian Sea. The climate here is characterised by hot and humid summer and warm winter with the mean annual temperature varying between 25°C and 28°C. The mean annual rainfall exceeds 2,000 mm in most of the areas. The region comprises of predominantly red and laterite soils on the leeward side of the Sahyadris (Western Ghats) and alluvium-derived soils in the coastal plains; however, in regions where the native forest cover remains undisturbed, continuous litter deposition and organic matter accumulation contribute to the humus-rich, well-drained soils that support high levels of plant productivity and overall biodiversity. Based on the classification of Champion & Seth (1968), we classified the vegetation within our study area into three major natural forest types. Additionally, two anthropogenically modified categories—mixed forests (secondary forests) and plantations—were recognised to account for variation in land-use history and vegetation structure across the landscape. Brief descriptions of these categories are given below:

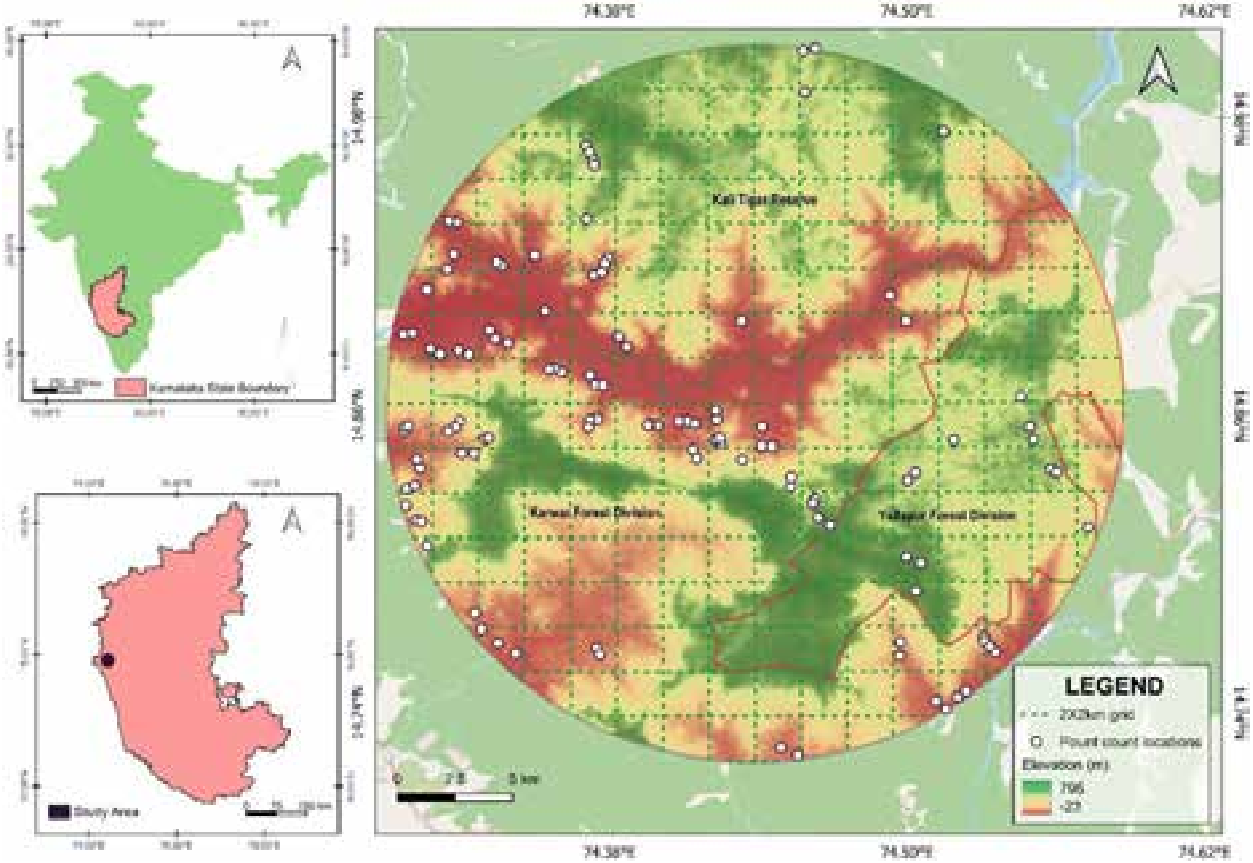

Image 1. Map of the study area showing the forest divisions and point count locations.

Tropical evergreen forests – southern tropical wet evergreen forests (1A/C4: West coast tropical evergreen forests) (Champion & Seth 1968) occur in areas with high rainfall and minimal dry periods, particularly within the KTR and parts of Karwar Division. Characterised by a multi-storied structure with dense canopy cover, they harbour a rich assemblage of evergreen tree species such as *Dipterocarpus indicus*, *Myristica dactyloides, Hopea parviflora*, and *Vateria indica* forming critical habitats for endemic avian and arboreal species.

Semi-evergreen forests – southern tropical semi-evergreen forests (2A/C2: West coast semi evergreen forests) (Champion & Seth 1968) forms an ecotonal zone between evergreen and moist deciduous forests, often found in areas subject to partial disturbance or on lower slopes. Species composition includes a mixture of evergreen and deciduous elements, with characteristic trees such as *Terminalia paniculata, Lagerstroemia microcarpa*, and *Tectona grandis* as common species. They are accompanied by evergreen species like *Diospyros candolleana* and *Cinnamomum malabatrum*, which eventually mix and result in a semi-deciduous canopy. As a result of seasonal canopy dynamics, semi evergreen forests have more diverse understories that consist of light-loving and shade-tolerant species.

Moist deciduous forests – southern Indian moist deciduous forests (3B/C2: Southern moist mixed deciduous forests) (Champion & Seth 1968) are found primarily in the eastern parts of Yellapur Forest Division and lower rainfall zones, these forests are characterised by species such as *Tectona grandis*, *Terminalia tomentosa*, *Xylia xylocarpa*, and *Dalbergia latifolia*. They often occur in a mosaic with semi-evergreen patches. Shrubs, small trees, and saplings are seen dominating the understory layers by species like the Indian gooseberry *Phyllanthus emblica* or the Flame of the Forest *Butea monosperma*. Along with that, the presence of lianas and epiphytes further complements the vertical stratification of these forests. Woody vines, or lianas, such as *Bauhinia racemosa*, are typical components within the tree vegetation. The relatively open canopy structure provides habitat for a different set of avifauna compared to evergreen forests.

Mixed forests (Secondary forests): In several parts of the landscape, especially near villages and degraded tracts, forests have undergone secondary succession, resulting in a heterogeneous 'mixed forest'. These are characterised by a combination of species from the semi evergreen and moist deciduous categories, often regenerating after selective logging, shifting cultivation, or fire. They provide important foraging grounds for generalist bird species.

Plantations

Large patches of monoculture plantations are also present within the study area, particularly of Teak *Tectona grandis*, Acacia *Acacia auriculiformis*, and Eucalyptus *Eucalyptus* spp. While structurally different from natural forests, these habitats nevertheless support certain bird species adapted to modified environments, though overall diversity tends to be lower compared to natural forest types.

METHODS

We conducted bird surveys over a five-month period from February 2024 to June 2024. This period defined the entire summer season (March to May) and the onset of the monsoon (June). A systematic point count survey methodology was employed, following Bibby et al. (2000). The study area was divided into a grid system comprising 225 grids, each measuring 2 x 2 km. Due to the short duration of the survey, logistical challenges and accessibility of dense forests based on the forest department staff availability and recommendations, we randomly chose 40% of the grids for sampling, ensuring coverage across all three forest divisions. Within the selected grids, a total of 118 survey station were established (Image 1, Table 1). At each survey station, point counts were conducted with a fixed radius of 100 m. Each point count was conducted for a standardised duration of 10 min, with a minimum distance of 400 m maintained between survey points to minimise the risk of double counting individuals. Thus, the overall duration of surveys for point count was limited to 1,180 min, which corresponds to approximately 20 h. Additionally, we conducted opportunistic bird surveys across different habitats to maximise sampling effort for forest, riverine and nocturnal birds as well. For this, we specifically relied on daily eBird lists to keep a track of the species recorded during this period when point counts were not being conducted. During this period, a total of 218 eBird lists were created corresponding to a total survey effort of approximately 94 h (approximately 5,626 min). Our surveys were scheduled during peak bird activity periods - early morning (0630 h) and late afternoon (1600 h) to maximise bird detections. All bird species observed or heard during the survey were identified and recorded based on visual and auditory cues. Field observations were conducted using Nikon Prostaff 7s 8 x 42 binoculars, and photographs were taken of most species for documentation with a Nikon P900 and Nikon D5600. To minimise potential observer bias during point count surveys, two trained observers were consistently involved at each sampling location. One observer was responsible for detecting and identifying bird species and documenting detections, while the second observer simultaneously recorded species identity, counts, and associated metadata for each point count station. This division of roles helped reduce errors related to miscounting, double counting, or overlooking individuals, thereby increasing the reliability of the dataset. Species identification was done by standard field guides (Ali 2002; Grimmett et al. 2011; Billerman et al. 2022). For taxonomy and nomenclature, we particularly followed the eBird and Clements et al. (2024) and Praveen et al. (2025). We further categorised the species as Resident (R), Summer Migrant (SM), Winter Migrant (WM) or Local Migrant (LM) based on field observations and descriptions provided in Grimmett et al. (2011) and SoIB (2023). Conservation status and legal protection were determined according to the IUCN Red List of Threatened Species (2024) and the Wildlife (Protection) Amendment Act 2022.

Table 1. Number of point count stations and size of stations sampled for birds in the study area.

Forest Division	Point count plot size	Number of point count stations
Karwar Forest Division	100 m	85
Kali Tiger Reserve (Anshi-Dandeli Area)	100 m	22
Yellapur Forest Division	100 m	11
Total		118

Analysis

We evaluated key metrics such as species richness and total species abundance across the entire survey area by categorising the habitats into different forest types, viz., semi evergreen (Southern tropical semi evergreen forests), tropical evergreen (Southern tropical wet evergreen forests), moist deciduous (Southern Indian moist deciduous forests), mixed forests (Secondary forests), and plantations. In addition to species richness and abundance, we calculated Shannon diversity index to quantify species diversity, taking into account both the abundance and evenness of the species present

(Shannon & Weaver 1963).

Shannon - Wiener index $H' = -\sum pi \times \ln(pi)$

where ∑= Sum, pi = proportion of the entire community made up of species 'i', ln is the natural logarithm, and S is the species richness or the total number of species observed in a community.

We also calculated the maximum possible diversity (Hmax) to determine the theoretical maximum diversity. Furthermore, we used Pielou's evenness Index (Pielou 1966) to assess the evenness of species distribution. The index was calculated as: Pielou's evenness index J = H' /ln(S), where H' is the Shannon diversity index and S is the total number of species. ln(S) is denoted as Hmax or maximum possible diversity. In order to assess the adequacy of our survey effort, we generated a species accumulation curve based on our observed species richness. To examine patterns of species dominance and relative abundance within the bird communities, we also included a rank-abundance curve across different habitat types. Furthermore, we compared the species detection between the communities of different forest types to understand the preliminary ecological patterns associated with habitat variation. All statistical analyses and visualisations were conducted using the R statistical software (R Core Team 2024).

RESULTS

A total of 206 avian species were documented, representing 66 families and 18 orders during the survey (Table 2). Passerines comprised 49.75% (103 species) of the total species recorded. Among the non-Passeriformes, the family Accipitridae exhibited the highest diversity with 12 species, followed by Ardeidae (11) and Picidae (8). Within the Passeriformes, the family Muscicapidae was the most diverse, with 12 species. Notably, 20 of these species are endemic to the Indian subcontinent, and 13 are exclusively endemic to the Western Ghats (Table 3). Based on point-count data (excluding opportunistic records), we recorded 2,674 individuals representing 147 species. The Shannon–Wiener diversity index for the study area was H' = 4.24, and Pielou's evenness Index was J' = 0.85, indicating a relatively even distribution of species rather than dominance by a few taxa. These indices suggest a diverse bird community across the region, but the results should be viewed as preliminary, given the limited temporal coverage and replication. Forest-specific H' and J' are provided in Table 4.

In our dataset, a higher number of species was observed in semi evergreen forests (113 species) compared to moist deciduous (102 species), and tropical evergreen forests (87 species). However, given that the surveys were restricted to one summer season, with incomplete coverage of all grids and replication, these results should be interpreted cautiously as preliminary patterns rather than definitive differences among forest types (Table 4). Further, based on our point-count surveys, we observed a comparatively higher species abundance in the semi evergreen forest (970 individuals), followed by moist deciduous forest (713 individuals), and tropical evergreen forest (701 individuals). The boxplot reflects these preliminary patterns observed within our study area (Image 2). In particular, semi evergreen forests exhibited the highest median and the widest spread of values, including several extreme outliers, suggesting that this forest type may harbour particularly rich bird assemblages and site-level heterogeneity. In contrast, plantations reflected the lower species detections, with a narrow range and low median values, which may be reflective of relatively poor and uniform habitat quality for bird communities, though this could be a result of less sampling effort in these habitats. Moist deciduous forests had a moderately intermediate range of species detection per point with wider variability than mixed forests, suggesting that they may provide important resources for avifauna, but with differences depending on local site conditions.

Additionally, with the help of a species rank abundance curve, we also found that White-cheeked Barbet *Psilopogon viridis* was most abundant in semi evergreen forests and tropical evergreen forests (Image 3). Apart from that, Purple Sunbird *Cinnyris asiaticus* and Greater Racket-tailed Drongo *Dicrurus paradiseus* were the most abundant species in moist deciduous and mixed forest types, respectively. Although these patterns highlight possible differences in richness and abundance among forest types, they are best interpreted as indicative trends. Since the survey was restricted to a single season with incomplete spatial coverage and no replication, our results might limit the robustness of cross-habitat comparisons. Future studies with multi-season sampling and greater replication will be necessary to confirm whether the patterns reported here reflect broader ecological differences among forest types.

Status of Foraging Guilds of Birds

Based on the heterogeneity of the foraging ecology of birds or how different groups of birds exploit the same class of food resources within the study area, the status of birds was assessed. Eight different categories

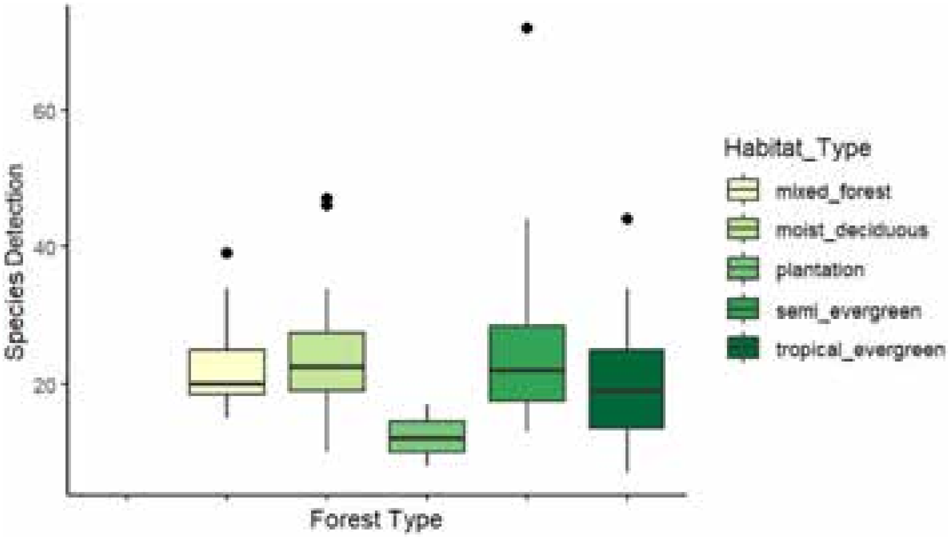

Image 2. Boxplot representing species detection based on the different forest types in the study area.

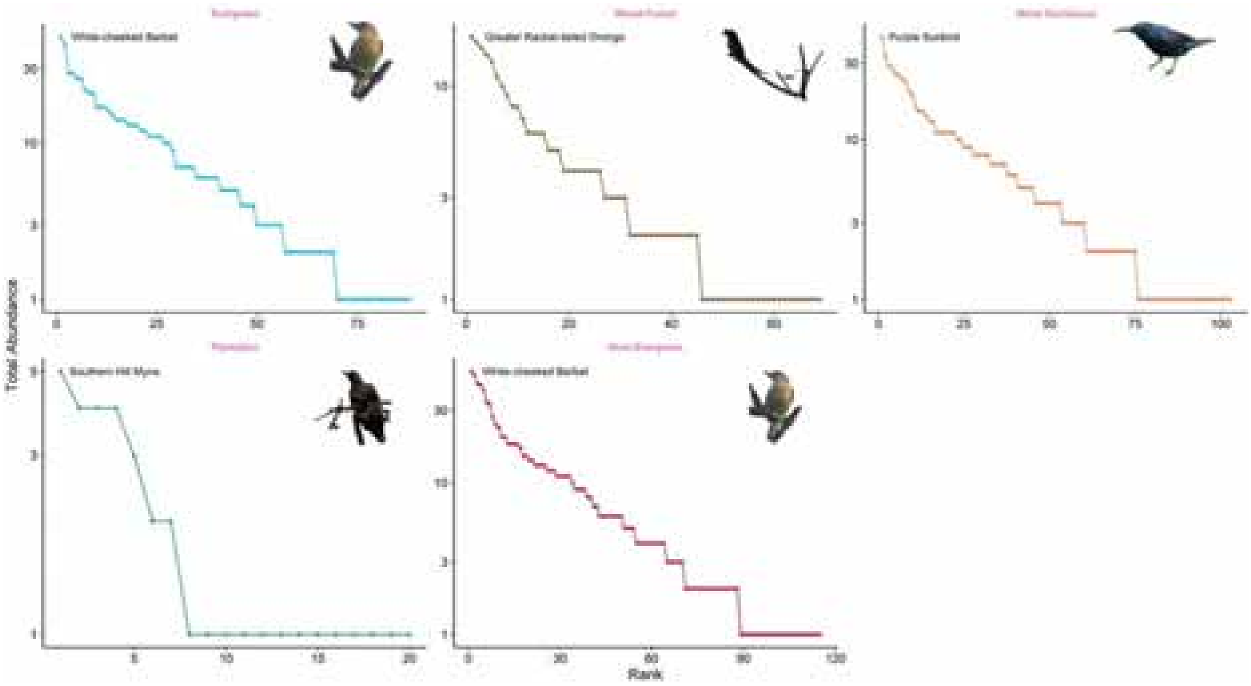

Image 3. Species rank abundance curve for different forest types in the study area.

of foraging guilds were identified, including carnivorous, frugivorous, granivorous, herbivorous, insectivorous, molluscivorous, omnivorous, and piscivorous birds. Of the 206 species, insectivorous birds were detected in the highest numbers (65), followed by omnivorous (51), carnivorous (46), and frugivorous (29) birds (Image 4). Interestingly, only a single species of molluscivore (*Anastomus oscitans*) was recorded, which specialises in feeding extensively on snails, especially apple snails (*Pila*).

Migratory Status of Birds

Karnataka lies along the Central Asian Flyway, a well-defined pathway for migratory birds traveling between their breeding grounds in Siberia and their non-breeding grounds in India and other regions. Based on the survey period, which typically started from the end of February and lasted till June, bird species were classified into four

Table 2. List of avian species recorded from the study area.

Order/Family/Common name	Scientific name	IUCN Red List status	WPA status	MS
Galliformes (1)				
Phasianidae (3)				
Indian Peafowl	*Pavo cristatus* (Linnaeus, 1758)	LC	Sch I	R
Red Spurfowl	*Galloperdix spadicea* (Gmelin, 1789)	LC	Sch II	R
Grey Junglefowl	*Gallus sonneratii* (Temminck, 1813)	LC	Sch I	R
Columbiformes (1)				
Columbidae (8)				
Rock Pigeon	*Columba livia* (Gmelin, 1789)	LC	Not sch	R
Nilgiri Wood-Pigeon	*Columba elphinstonii* (Sykes, 1832)	VU	Sch I	R
Spotted Dove	*Spilopelia chinensis* (Scopoli, 1786)	LC	Sch II	R
Asian Emerald Dove	*Chalcophaps indica* (Linnaeus, 1758)	LC	Sch II	R
Orange-breasted Green-Pigeon	*Treron bicinctus* (Jerdon, 1840)	LC	Sch II	R
Grey-fronted Green-Pigeon	*Treron affinis* (Jerdon, 1840)	LC	Sch II	R
Green Imperial-Pigeon	*Ducula aenea* (Linnaeus, 1766)	NT	Sch II	R
Malabar Imperial-Pigeon	*Ducula cuprea* (Jerdon, 1840)	LC	Sch II	R
Cuculiformes (1)				
Cuculidae (7)				
Greater Coucal	*Centropus sinensis* (Stephens, 1815)	LC	Sch II	R
Blue-faced Malkoha	*Phaenicophaeus viridirostris* (Jerdon, 1840)	LC	Sch II	R
Asian Koel	*Eudynamys scolopaceus* (Linnaeus, 1758)	LC	Sch II	R
Banded Bay Cuckoo	*Cacomantis sonneratii* (Latham, 1790)	LC	Sch II	LM
Fork-tailed Drongo-Cuckoo	*Surniculus dicruroides* (Hodgson, 1839)	LC	Sch II	LM
Common Hawk-Cuckoo	*Hierococcyx varius* (Vahl, 1797)	LC	Sch II	LM
Indian Cuckoo	*Cuculus micropterus* (Gould, 1838)	LC	Sch II	SM
Caprimulgiformes (4)				
Caprimulgidae (2)				
Jerdon's Nightjar	*Caprimulgus atripennis* (Jerdon, 1845)	LC	Sch II	R
Savanna Nightjar	*Caprimulgus affinis* (Horsfield, 1821)	LC	Sch II	R
Podargidae (1)				
Sri Lanka Frogmouth	*Batrachostomus moniliger* (Blyth, 1849)	LC	Sch I	R
Apodidae (4)				
White-rumped Spinetail	*Zoonavena sylvatica* (Tickell, 1846)	LC	Sch II	R
Brown-backed Needletail	*Hirundapus giganteus* (Temminck, 1825)	LC	Sch II	R
Little Swift	*Apus affinis* (Gray, 1830)	LC	Sch II	R
Asian Palm Swift	*Cypsiurus balasiensis* (Gray, 1829)	LC	Sch II	R
Hemiprocnidae (1)				
Crested Treeswift	*Hemiprocne coronata* (Tickell, 1833)	LC	Sch I	R
Gruiformes (1)				
Rallidae (2)				
Common Moorhen	*Gallinula chloropus* (Linnaeus, 1758)	LC	Sch II	R
White-breasted Waterhen	*Amaurornis phoenicurus* (Pennant, 1769)	LC	Sch II	R
Charadriiformes (4)				
Charadriidae (3)				
Red-wattled Lapwing	*Vanellus indicus* (Boddaert, 1783)	LC	Sch II	R
Tibetan Sand-Plover	*Anarhynchus atrifrons* (Wagler, 1829)	LC	Sch II	WM
Greater Sand-Plover	*Anarhynchus leschenaultii* (Lesson, 1826)	LC	Sch II	WM
Scolopacidae (1)				
Common Sandpiper	*Actitis hypoleucos* (Linnaeus, 1758)	LC	Sch II	WM

Order/Family/Common name	Scientific name	IUCN Red List status	WPA status	MS
Turnicidae (1)				
Yellow-legged Buttonquail	*Turnix tanki* (Blyth, 1843)	LC	Sch II	R
Laridae (1)				
River Tern	*Sterna aurantia* (Gray, 1831)	VU	Sch I	R
Ciconiiformes (1)				
Ciconiidae (4)				
Asian Openbill	*Anastomus oscitans* (Boddaert, 1783)	LC	Sch II	R
Black Stork	*Ciconia nigra* (Linnaeus, 1758)	LC	Sch II	WM
Asian Woolly-necked Stork	*Ciconia episcopus* (Boddaert, 1783)	NT	Sch II	R
Lesser Adjutant	*Leptoptilos javanicus* (Horsfield, 1821)	NT	Sch I	R
Suliformes (2)				
Anhingidae (1)				
Oriental Darter	*Anhinga melanogaster* (Pennant, 1769)	LC	Sch II	R
Phalacrocoracidae (2)				
Little Cormorant	*Microcarbo niger* (Vieillot, 1817)	LC	Sch II	R
Indian Cormorant	*Phalacrocorax fuscicollis* (Stephens, 1826)	LC	Sch II	R
Pelecaniformes (2)				
Threskiornithidae (2)				
Glossy Ibis	*Plegadis falcinellus* (Linnaeus, 1766)	LC	Sch II	R
Black-headed Ibis	*Threskiornis melanocephalus* (Latham, 1790)	LC	Sch II	R
Ardeidae (11)				
Black-crowned Night Heron	*Nycticorax nycticorax* (Linnaeus, 1758)	LC	Sch II	R
Malayan Night Heron	*Gorsachius melanolophus* (Raffles, 1822)	LC	Sch II	R
Little Egret	*Egretta garzetta* (Linnaeus, 1766)	LC	Sch II	R
Western Reef-Egret	*Egretta gularis* (Bosc, 1792)	LC	Sch II	R
Striated Heron	*Butorides striata* (Linnaeus, 1758)	LC	Sch II	R
Indian Pond-Heron	*Ardeola grayii* (Sykes, 1832)	LC	Sch II	R
Eastern Cattle-Egret	*Ardea coromanda* (Boddaert, 1783)	NE	Sch II	R
Great Egret	*Ardea alba* (Linnaeus, 1758)	LC	Sch II	R
Intermediate Egret	*Ardea intermedia* (Wagler, 1829)	LC	Sch II	R
Grey Heron	*Ardea cinerea* (Linnaeus, 1758)	LC	Sch II	R
Purple Heron	*Ardea purpurea* (Linnaeus, 1766)	LC	Sch II	R
Accipitriformes (2)				
Pandionidae (1)				
Osprey	*Pandion haliaetus* (Linnaeus, 1758)	LC	Sch I	WM
Accipitridae (12)				
Oriental Honey-buzzard	*Pernis ptilorhynchus* (Temminck, 1821)	LC	Sch II	R
Crested Serpent-Eagle	*Spilornis cheela* (Latham, 1790)	LC	Sch I	R
Changeable Hawk-Eagle	*Nisaetus cirrhatus* (Gmelin, 1788)	LC	Sch I	R
Rufous-bellied Eagle	*Lophotriorchis kienerii* (de Sparre, 1835)	NT	Sch I	R
Black Eagle	*Ictinaetus malaiensis* (Temminck, 1822)	LC	Sch I	R
Crested Goshawk	*Lophospiza trivirgata* (Temminck, 1824)	LC	Sch I	R
Shikra	*Tachyspiza badia* (Gmelin, 1788)	LC	Sch I	R
Black Kite	*Milvus migrans* (Boddaert, 1783)	LC	Sch II	R
Brahminy Kite	*Haliastur indus* (Boddaert, 1783)	LC	Sch I	R
White-bellied Sea-Eagle	*Icthyophaga leucogaster* (Gmelin, 1788)	LC	Sch I	R
Grey-headed Fish-Eagle	*Icthyophaga ichthyaetus* (Horsfield, 1821)	NT	Sch I	R
White-eyed Buzzard	*Butastur teesa* (Franklin, 1831)	LC	Sch I	R
Strigiformes (2)				

Order/Family/Common name	Scientific name	IUCN Red List status	WPA status	MS
Tytonidae (1)				
Eastern Barn-Owl	*Tyto javanica* (Gmelin, 1788)	LC	Sch I	R
Strigidae (5)				
Indian Scops-Owl	*Otus bakkamoena* (Pennant, 1769)	LC	Sch II	R
Brown Fish-Owl	*Ketupa zeylonensis* (Gmelin, 1788)	LC	Sch I	R
Jungle Owlet	*Glaucidium radiatum* (Tickell, 1833)	LC	Sch II	R
Spotted Owlet	*Athene brama* (Temminck, 1821)	LC	Sch II	R
Brown Boobook	*Ninox scutulata* (Raffles, 1822)	LC	Sch II	R
Trogoniformes (1)				
Trogonidae (1)				
Malabar Trogon	*Harpactes fasciatus* (Pennant, 1769)	LC	Sch II	R
Bucerotiformes (2)				
Upupidae (1)				
Eurasian Hoopoe	*Upupa epops* (Linnaeus, 1758)	LC	Sch II	WM
Bucerotidae (3)				
Great Hornbill	*Buceros bicornis* (Linnaeus, 1758)	VU	Sch I	R
Malabar Grey Hornbill	*Ocyceros griseus* (Latham, 1790)	VU	Sch I	R
Malabar Pied-Hornbill	*Anthracoceros coronatus* (Boddaert, 1783)	NT	Sch I	R
Coraciiformes (3)				
Meropidae (3)				
Asian Green Bee-eater	*Merops orientalis* (Latham, 1801)	LC	Sch II	R
Blue-tailed Bee-eater	*Merops philippinus* (Linnaeus, 1767)	LC	Sch II	R
Chestnut-headed Bee-eater	*Merops leschenaulti* (Vieillot, 1817)	LC	Sch II	R
Alcedinidae (3)				
Common Kingfisher	*Alcedo atthis* (Linnaeus, 1758)	LC	Sch II	R
Stork-billed Kingfisher	*Pelargopsis capensis* (Linnaeus, 1766)	LC	Sch II	R
White-throated Kingfisher	*Halcyon smyrnensis* (Linnaeus, 1758)	LC	Sch II	R
Coraciidae (1)				
Indian Roller	*Coracias benghalensis* (Linnaeus, 1758)	LC	Sch II	R
Piciformes (2)				
Megalaimidae (4)				
Malabar Barbet	*Psilopogon malabaricus* (Blyth, 1847)	LC	Sch II	R
Coppersmith Barbet	*Psilopogon haemacephalus* (Müller, 1776)	LC	Sch II	R
Brown-headed Barbet	*Psilopogon zeylanicus* (Gmelin, 1788)	LC	Sch II	R
White-cheeked Barbet	*Psilopogon viridis* (Boddaert, 1783)	LC	Sch II	R
Picidae (8)				
Speckled Piculet	*Picumnus innominatus* (Burton, 1836)	LC	Sch II	R
Heart-spotted Woodpecker	*Hemicircus canente* (Lesson, 1832)	LC	Sch I	R
Brown-capped Pygmy Woodpecker	*Yungipicus nanus* (Vigors, 1832)	LC	Sch II	R
Malabar Flameback	*Chrysocolaptes socialis* (Koelz, 1939)	NE	Sch II	R
Rufous Woodpecker	*Micropternus brachyurus* (Vieillot, 1818)	LC	Sch II	R
Black-rumped Flameback	*Dinopium benghalense* (Linnaeus, 1758)	LC	Sch II	R
Lesser Yellownape	*Picus chlorolophus* (Vieillot, 1818)	LC	Sch II	R
White-bellied Woodpecker	*Dryocopus javensis* (Horsfield, 1821)	LC	Sch II	R
Falconiformes (1)				
Falconidae (2)				
Common Kestrel	*Falco tinnunculus* (Linnaeus, 1758)	LC	Sch II	WM
Peregrine Falcon	*Falco peregrinus* (Tunstall, 1771)	LC	Sch I	R
Psittaciformes (1)				

Order/Family/Common name	Scientific name	IUCN Red List status	WPA status	MS
Psittaculidae (5)				
Alexandrine Parakeet	*Psittacula eupatria* (Linnaeus, 1766)	NT	Sch II	R
Rose-ringed Parakeet	*Psittacula krameri* (Scopoli, 1769)	LC	Sch II	R
Plum-headed Parakeet	*Psittacula cyanocephala* (Linnaeus, 1766)	LC	Sch II	R
Malabar Parakeet	*Psittacula columboides* (Vigors, 1830)	LC	Sch II	R
Vernal Hanging-Parrot	*Loriculus vernalis* (Sparrman, 1787)	LC	Sch II	R
Passeriformes (35)				
Pittidae (1)				
Indian Pitta	*Pitta brachyura* (Linnaeus, 1766)	LC	Sch II	LM
Campephagidae (3)				
Small Minivet	*Pericrocotus cinnamomeus* (Linnaeus, 1766)	LC	Sch I	R
Orange Minivet	*Pericrocotus flammeus* (Forster, 1781)	LC	Sch II	R
Black-headed Cuckooshrike	*Lalage melanoptera* (Rüppell, 1839)	LC	Sch II	R
Oriolidae (2)				
Indian Golden Oriole	*Oriolus kundoo* (Sykes, 1832)	LC	Sch II	R
Black-hooded Oriole	*Oriolus xanthornus* (Linnaeus, 1758)	LC	Sch II	R
Artamidae (1)				
Ashy Woodswallow	*Artamus fuscus* (Vieillot, 1817)	LC	Sch II	R
Vangidae (2)				
Malabar Woodshrike	*Tephrodornis sylvicola* (Jerdon, 1839)	LC	Sch II	R
Bar-winged Flycatcher-shrike	*Hemipus picatus* (Sykes, 1832)	LC	Sch II	R
Aegithinidae (1)				
Common Iora	*Aegithina tiphia* (Linnaeus, 1758)	LC	Sch II	R
Dicruridae (6)				
Black Drongo	*Dicrurus macrocercus* (Vieillot, 1817)	LC	Sch II	R
Ashy Drongo	*Dicrurus leucophaeus* (Vieillot, 1817)	LC	Sch II	R
White-bellied Drongo	*Dicrurus caerulescens* (Linnaeus, 1758)	LC	Sch II	R
Bronzed Drongo	*Dicrurus aeneus* (Vieillot, 1817)	LC	Sch II	R
Hair-crested Drongo	*Dicrurus hottentottus* (Linnaeus, 1766)	LC	Sch II	R
Greater Racket-tailed Drongo	*Dicrurus paradiseus* (Linnaeus, 1766)	LC	Sch II	R
Monarchidae (2)				
Black-naped Monarch	*Hypothymis azurea* (Boddaert, 1783)	LC	Sch II	R
Indian Paradise-Flycatcher	*Terpsiphone paradisi* (Linnaeus, 1758)	LC	Sch II	R
Laniidae (3)				
Brown Shrike	*Lanius cristatus* (Linnaeus, 1758)	LC	Sch II	WM
Bay-backed Shrike	*Lanius vittatus* (Valenciennes, 1826)	LC	Sch II	R
Long-tailed Shrike	*Lanius schach* (Linnaeus, 1758)	LC	Sch II	R
Corvidae (3)				
Rufous Treepie	*Dendrocitta vagabunda* (Latham, 1790)	LC	Sch II	R
House Crow	*Corvus splendens* (Vieillot, 1817)	LC	Not sch	R
Large-billed Crow	*Corvus macrorhynchos* (Wagler, 1827)	LC	Sch II	R
Stenostiridae (1)				
Grey-headed Canary-Flycatcher	*Culicicapa ceylonensis* (Swainson, 1820)	LC	Sch II	R
Paridae (1)				
Cinereous Tit	*Parus cinereus* (Vieillot, 1818)	NE	Sch II	R
Alaudidae (1)				
Malabar Lark	*Galerida malabarica* (Scopoli, 1786)	LC	Sch II	R
Cisticolidae (3)				
Common Tailorbird	*Orthotomus sutorius* (Pennant, 1769)	LC	Sch II	R

Order/Family/Common name	Scientific name	IUCN Red List status	WPA status	MS
Grey-breasted Prinia	*Prinia hodgsonii* (Blyth, 1844)	LC	Sch II	R
Ashy Prinia	*Prinia socialis* (Sykes, 1832)	LC	Sch II	R
Acrocephalidae (1)				
Blyth's Reed Warbler	*Acrocephalus dumetorum* (Blyth, 1849)	LC	Sch II	WM
Hirundinidae (5)				
Dusky Crag-Martin	*Ptyonoprogne concolor* (Sykes, 1832)	LC	Sch II	R
Barn Swallow	*Hirundo rustica* (Linnaeus, 1758)	LC	Sch II	WM
Wire-tailed Swallow	*Hirundo smithii* (Leach, 1818)	LC	Sch II	R
Eastern Red-rumped Swallow	*Cecropis daurica* (Laxmann, 1769)	LC	Sch II	R
Streak-throated Swallow	*Petrochelidon fluvicola* (Blyth, 1855)	LC	Sch II	R
Pycnonotidae (7)				
Yellow-browed Bulbul	*Acritillas indica* (Jerdon, 1839)	LC	Sch II	R
Square-tailed Bulbul	*Hypsipetes ganeesa* (Sykes, 1832)	LC	Sch II	R
Grey-headed Bulbul	*Microtarsus priocephalus* (Jerdon, 1839)	NT	Sch II	R
Flame-throated Bulbul	*Rubigula gularis* (Gould, 1836)	LC	Sch II	R
White-browed Bulbul	*Pycnonotus luteolus* (Lesson, 1841)	LC	Sch II	R
Red-whiskered Bulbul	*Pycnonotus jocosus* (Linnaeus, 1758)	LC	Sch II	R
Red-vented Bulbul	*Pycnonotus cafer* (Linnaeus, 1766)	LC	Sch II	R
Phylloscopidae (5)				
Tickell's Leaf Warbler	*Phylloscopus affinis* (Tickell, 1833)	LC	Sch II	WM
Green Warbler	*Phylloscopus nitidus* (Blyth, 1843)	LC	Sch II	WM
Greenish Warbler	*Phylloscopus trochiloides* (Sundevall, 1837)	LC	Sch II	WM
Large-billed Leaf Warbler	*Phylloscopus magnirostris* (Blyth, 1843)	LC	Sch II	WM
Western Crowned Warbler	*Phylloscopus occipitalis* (Blyth, 1845)	LC	Sch II	WM
Sylviidae (1)				
Lesser Whitethroat	*Curruca curruca* (Linnaeus, 1758)	LC	Sch II	WM
Paradoxornithidae (1)				
Yellow-eyed Babbler	*Chrysomma sinense* (Gmelin, 1789)	LC	Sch II	R
Zosteropidae (1)				
Indian White-eye	*Zosterops palpebrosus* (Temminck, 1824)	LC	Sch II	R
Timaliidae (2)				
Dark-fronted Babbler	*Dumetia atriceps* (Jerdon, 1839)	LC	Sch II	R
Indian Scimitar-Babbler	*Pomatorhinus horsfieldii* (Sykes, 1832)	LC	Sch II	R
Pellorneidae (1)				
Puff-throated Babbler	*Pellorneum ruficeps* (Swainson, 1832)	LC	Sch II	R
Leiothrichidae (3)				
Brown-cheeked Fulvetta	*Alcippe poioicephala* (Jerdon, 1841)	LC	Sch II	R
Jungle Babbler	*Argya striata* (Dumont, 1823)	LC	Sch II	R
Yellow-billed Babbler	*Argya affinis* (Jerdon, 1845)	LC	Sch II	R
Sittidae (1)				
Velvet-fronted Nuthatch	*Sitta frontalis* (Swainson, 1820)	LC	Sch II	R
Sturnidae (7)				
Southern Hill Myna	*Gracula indica* (Cuvier, 1829)	LC	Sch I	R
Rosy Starling	*Pastor roseus* (Linnaeus, 1758)	LC	Sch II	WM
Indian Pied Starling	*Gracupica contra* (Linnaeus, 1758)	LC	Sch II	R
Brahminy Starling	*Sturnia pagodarum* (Gmelin, 1789)	LC	Sch II	R
Malabar Starling	*Sturnia blythii* (Jerdon, 1845)	NE	Sch II	R
Common Myna	*Acridotheres tristis* (Linnaeus, 1766)	LC	Sch II	R
Jungle Myna	*Acridotheres fuscus* (Wagler, 1827)	LC	Sch II	R

Order/Family/Common name	Scientific name	IUCN Red List status	WPA status	MS
Turdidae (2)				
Orange-headed Thrush	*Geokichla citrina* (Latham, 1790)	LC	Sch II	R
Indian Blackbird	*Turdus simillimus* (Jerdon, 1839)	LC	Sch II	R
Muscicapidae (12)				
Dark-sided Flycatcher	*Muscicapa sibirica* (Gmelin, 1789)	LC	Sch II	WM
Asian Brown Flycatcher	*Muscicapa dauurica* (Pallas, 1811)	LC	Sch II	WM
Indian Robin	*Copsychus fulicatus* (Linnaeus, 1766)	LC	Sch II	R
Oriental Magpie-Robin	*Copsychus saularis* (Linnaeus, 1758)	LC	Sch II	R
White-rumped Shama	*Copsychus malabaricus* (Scopoli, 1786)	LC	Sch II	R
Tickell's Blue Flycatcher	*Cyornis tickelliae* (Blyth, 1843)	LC	Sch II	R
Indian Blue Robin	*Larvivora brunnea* (Hodgson, 1837)	LC	Sch II	WM
Malabar Whistling-Thrush	*Myophonus horsfieldii* (Vigors, 1831)	LC	Sch II	R
Taiga Flycatcher	*Ficedula albicilla* (Pallas, 1811)	LC	Sch II	WM
Red-breasted Flycatcher	*Ficedula parva* (Bechstein, 1792)	LC	Sch II	WM
Blue-capped Rock-Thrush	*Monticola cinclorhyncha* (Vigors, 1831)	LC	Sch II	WM
Blue Rock-Thrush	*Monticola solitarius* (Linnaeus, 1758)	LC	Sch II	WM
Dicaeidae (3)				
Thick-billed Flowerpecker	*Pachyglossa agilis* (Tickell, 1833)	LC	Sch II	R
Pale-billed Flowerpecker	*Dicaeum erythrorhynchos* (Latham, 1790)	LC	Sch II	R
Nilgiri Flowerpecker	*Dicaeum concolor* (Jerdon, 1840)	LC	Sch II	R
Nectariniidae (5)				
Purple-rumped Sunbird	*Leptocoma zeylonica* (Linnaeus, 1766)	LC	Sch II	R
Crimson-backed Sunbird	*Leptocoma minima* (Sykes, 1832)	LC	Sch II	R
Purple Sunbird	*Cinnyris asiaticus* (Latham, 1790)	LC	Sch II	R
Loten's Sunbird	*Cinnyris lotenius* (Linnaeus, 1766)	LC	Sch II	R
Little Spiderhunter	*Arachnothera longirostra* (Latham, 1790)	LC	Sch II	R
Irenidae (1)				
Asian Fairy-bluebird	*Irena puella* (Latham, 1790)	LC	Sch II	R
Chloropseidae (2)				
Jerdon's Leafbird	*Chloropsis jerdoni* (Blyth, 1844)	LC	Sch II	R
Golden-fronted Leafbird	*Chloropsis aurifrons* (Temminck, 1829)	LC	Sch II	R
Estrildidae (3)				
Scaly-breasted Munia	*Lonchura punctulata* (Linnaeus, 1758)	LC	Sch II	R
Black-throated Munia	*Lonchura kelaarti* (Jerdon, 1863)	LC	Sch II	R
White-rumped Munia	*Lonchura striata* (Linnaeus, 1766)	LC	Sch II	R
Passeridae (2)				
House Sparrow	*Passer domesticus* (Linnaeus, 1758)	LC	Sch II	R
Yellow-throated Sparrow	*Gymnoris xanthocollis* (Burton, 1838)	LC	Sch II	R
Motacillidae (7)				
Forest Wagtail	*Dendronanthus indicus* (Gmelin, 1789)	LC	Sch I	WM
Grey Wagtail	*Motacilla cinerea* (Tunstall, 1771)	LC	Sch II	R
White-browed Wagtail	*Motacilla maderaspatensis* (Gmelin, 1789)	LC	Sch II	WM
White Wagtail	*Motacilla alba* (Linnaeus, 1758)	LC	Sch II	WM
Paddyfield Pipit	*Anthus rufulus* (Vieillot, 1818)	LC	Sch II	R
Long-billed Pipit	*Anthus similis* (Jerdon, 1840)	LC	Sch II	R
Tawny Pipit	*Anthus campestris* (Linnaeus, 1758)	LC	Sch II	WM

IUCN—International Union for Conservation of Nature | LC—Least Concern | VU—Vulnerable | EN—Endangered | CR—Critically Endangered | NE—Not Evaluated | WPA—Indian Wildlife Protection (Amendment) Act, 2022 | Sch-I—Schedule List I species | Sch-II—Schedule List II species | MS—Migratory status | R—Resident | SM—Summer migrant | WM—Winter migrant | LM—Local migrant.

different categories of migration: residents (present throughout the year), summer migrants, winter migrants, and local migrants (Grimmett et al. 2011; Billerman et al. 2022; SoIB 2023). Of the 206 species observed, 174 (84.54%) were categorised as resident, while 32 species (15.45%) were migratory. The migratory species included 27 winter visitors, one summer visitor, and four locally migrating species. During the survey period, only 27 winter migrants were observed, compared to the total list of 80 recorded thus far (based on secondary sources and the consolidated checklist).

Species of Conservation Significance

The study area hosts a diverse range of bird species, many of which are of significant conservation concern. Table 5 highlights categories under various conservation framework for the 206 species recorded from the study area.

IUCN Red List Categories

Least Concern (LC): A majority of 190 species are classified as 'Least Concern', indicating that they currently face no immediate threat of extinction.

Vulnerable (VU): Four species, namely, Nilgiri Wood Pigeon *Columba elphinstonii*, River Tern *Sterna aurantia*, Malabar Grey Hornbill *Ocyceros griseus*, and Great Hornbill *Buceros bicornis*, are categorised as 'Vulnerable', reflecting a high risk of extinction in the wild.

Near Threatened (NT): Eight species are categorised as 'Near Threatened', meaning they are close to qualifying for a threatened category in the near future.

Not Evaluated (NE): Four species including Cinereous Tit *Parus cinereous*, Eastern Cattle-Egret *Ardea coromanda*, Malabar Starling *Sturnia blythii*, and Malabar Flameback *Chrysocolaptes socialis*, were not currently evaluated or recognised by the IUCN Red List.

National Level Legal Protections

Wildlife (Protection) Amendment Act 2022, Schedule I: According to the recent Wildlife Amendment 2022, 29 species found in the study area are listed under Schedule I. This designation affords them the highest level of protection under Indian law, reflecting their critical conservation status.

State Level Priorities

Apart from the IUCN Red List, based on the latest report of State of India's Birds 2023, species included in the list of high priority, such as the Osprey *Pandion haliaetus*, Blue Rock-Thrush *Monticola solitarius*, and Forest Wagtail *Dendronanthus indicus* are of high conservation concern.

DISCUSSION

Our study represents the first attempt to establish a baseline inventory of avifaunal diversity in the Kaiga-Karwar region of Uttara Kannada District, Karnataka, where 206 species were recorded over the course of the survey period. Furthermore, combining primary data with secondary sources based on eBird and Kaiga Bird Marathon data, we found that the area harbours a total of 325 species belonging to 20 orders and 76 families (Refer to supplementary section for consolidated checklist). This corresponds to 58% of the birds found in the state of Karnataka and 23% of the total number of bird species recorded across the Indian subcontinent (till the last checklist update) (Praveen et al. 2025). Considering the short period of the survey and limitations in accessing certain remote areas within the study area, our baseline survey resulted in (excluding opportunistic sightings) 175 resident species and 20 endemic species, out of which 13 are exclusively endemic to the Western Ghats. In terms of species richness, the species accumulation curve shows that the sampling efforts within the study area appear sufficient to capture most of the species (Image 5). However, there is a likelihood of detecting some more species with additional sampling. The overall Shannon–Wiener diversity index (H' = 4.24) indicates a highly diverse bird community, a finding consistent with the ecological significance of this landscape as part of a global biodiversity hotspot. The relatively high Pielou's evenness value (J' = 0.85) further suggests that bird communities were not dominated by a few species, but rather that abundances were distributed relatively evenly across the recorded assemblages. Together, these indices indicate a preliminary trend towards a structurally balanced community. Based on our dataset, the results from the boxplots revealed higher median detection and wider variability in semi evergreen and tropical evergreen forests, whereas plantations indicated a comparatively lower and more uniform detection. Even though our results are preliminary, they are broadly consistent with earlier studies from the Western Ghats, which demonstrate that structurally complex forest habitats support higher bird assemblages compared to simplified or monoculture landscapes (Raman 2006; Ranganathan et al. 2010; Karanth et al. 2016). Specifically, indications of an elevated number of detections in semi evergreen and evergreen forests within these forested areas also indicate patterns reported by Hariharan et al. (2022), who

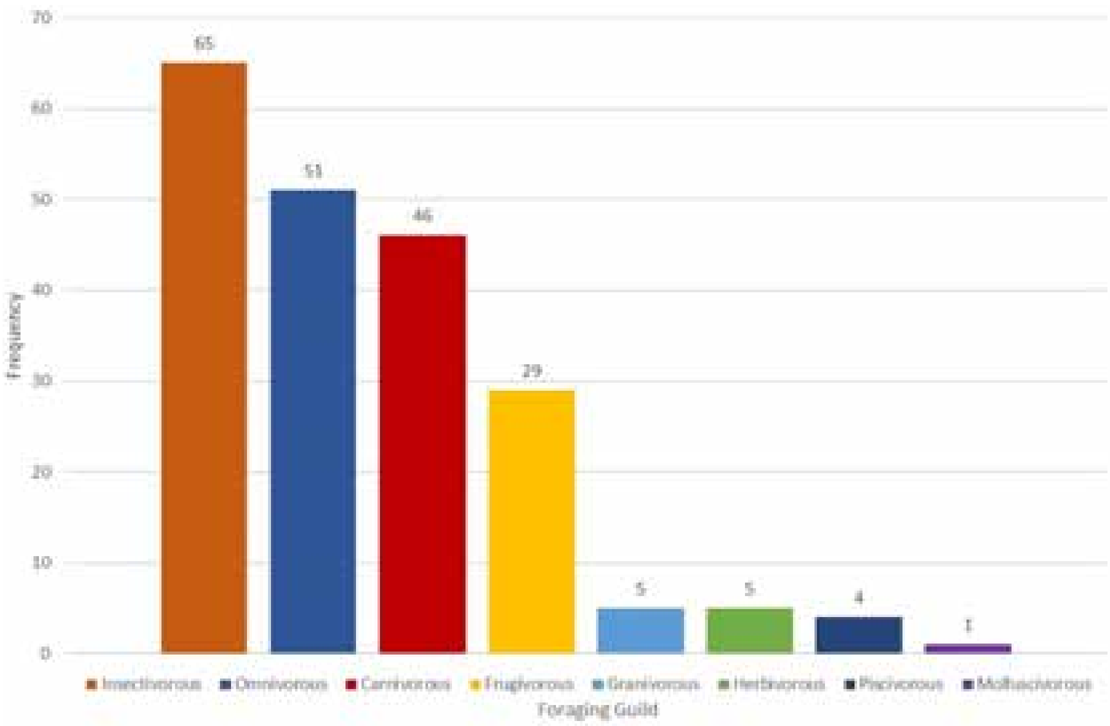

Image 4. Foraging guilds status of birds in the study area constituting both point count and opportunistic data.

Table 3. Birds species endemic to Western Ghats recorded in the study area.

	Common name	Scientific name
1	Nilgiri Wood-Pigeon	*Columba elphinstonii*
2	Grey-fronted Green-Pigeon	*Treron affinis*
3	Malabar Imperial-Pigeon	*Ducula cuprea*
4	Malabar Grey Hornbill	*Ocyceros griseus*
5	Malabar Barbet	*Psilopogon malabaricus*
6	Malabar Flameback	*Chrysocolaptes socialis*
7	Malabar Parakeet	*Psittacula columboides*
8	Malabar Woodshrike	*Tephrodornis sylvicola*
9	Grey-headed Bulbul	*Microtarsus priocephalus*
10	Flame-throated Bulbul	*Rubigula gularis*
11	Malabar Starling	*Sturnia blythii*
12	Nilgiri Flowerpecker	*Dicaeum concolor*
13	Crimson-backed Sunbird	*Leptocoma minima*

found that mixed-species flocks preferentially used semi evergreen and evergreen habitats over more degraded habitats, reflecting the higher resource diversity and structural complexity of these forests. Together, these studies underscore the conservation importance of semi evergreen and evergreen forests in sustaining diverse avian communities within the Western Ghats.

Our rank-abundance curve based on our baseline survey efforts showed the dominance of White-cheeked Barbet *Psilopogon viridis*, an obligate frugivore in both semi evergreen and tropical evergreen forests, while the abundance of Greater Racket-tailed Drongo *Dicrurus paradiseus* was higher in the mixed forests. The dominance of medium-sized frugivore species, such as the White-cheeked Barbet, highlights the importance of fruit-bearing trees, as this species primarily feeds on fruits and plays a key role in seed dispersal. Overall, 29 frugivore species, such as the Malabar Imperial-Pigeon *Ducula cuprea*, Nilgiri Wood-Pigeon, Grey-headed Bulbul *Microtarsus priocephalus*, Flame-throated Bulbul *Rubigula gularis*, were also observed in a variety of habitats within the study area. Although our data are preliminary and limited in temporal and spatial replication, the presence of a diverse frugivore assemblage across multiple habitats suggests that fruiting resources may play an important role in structuring local bird communities. Similar patterns have been reported elsewhere in the Western Ghats, where both forest cover and fruit crop size were shown to influence frugivore visitation and seed dispersal services (Gopal et al. 2020).

Furthermore, the semi evergreen and tropical evergreen forests of the Anshi-Dandeli region are critical

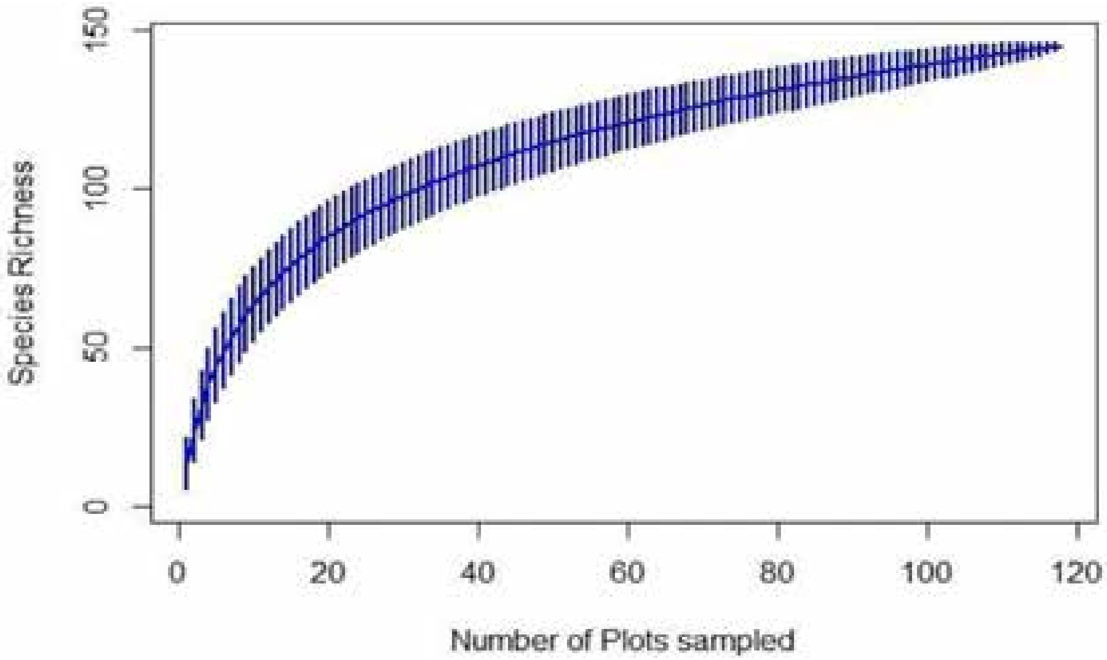

Image 5. Species accumulation curve in the study area based on point count locations.

Table 4. Species richness by forest types in the study area.

Forest type	Shannon-Weiner diversity index (H')	Pielou's evenness index (J')	Species richness	Total abundance of species	Most abundant species	Ratio of the most abundant species/ Total abundance
Mixed forest	3.824	0.663	69	253	grtd (17)	0.067
Moist deciduous	4.102	0.581	102	713	pusu (44)	0.062
Plantation	2.78	0.805	20	37	shmy (5)	0.135
Semi evergreen	4.152	0.557	113	970	wcba (54)	0.056
Tropical evergreen	3.975	0.605	87	701	wcba (48)	0.068

grtd—Greater Racket-tailed Drongo | pusu—Purple Sunbird | shmy—Souther Hill Myna | wcba—White-cheeked Barbet.

habitats for large frugivores such as the Great Hornbill, Malabar Pied Hornbill *Anthracoceros coronatus*, and Malabar Grey Hornbill. According to Mudappa & Raman (2009), the Kali (Anshi-Dandeli) area is one of the key regions for the conservation of the Malabar Pied Hornbill. Besides the protected areas, the Great Hornbills have a stronghold in the Tiger Reserve as well as adjacent reserve forests, where key nesting and feeding habitats are available. During the present survey, a congregation of 14 foraging individuals of Great Hornbills were observed at a time on different *Ficus* spp. near Hartuga Village. Moreover, the trees adjacent to the riverine areas, especially around Kali, act as major roosting sites for Malabar Pied Hornbills (Sneha & Davidar 2011).

The Kali River system further supports a diverse assemblage of riverine bird species, many of which are likely dependent on aquatic invertebrates and fish found within this habitat. Notably, species belonging to the families of Ardeidae, Ciconiidae, and Phalacrocoracidae were also observed during the survey period. Additionally, several riverine raptors, including the Brahminy Kite *Haliastur indus*, White-bellied Sea-Eagle *Icthyophaga leucogaster*, Black Kite *Milvus migrans*, and Osprey, were regularly recorded roosting and hunting across multiple locations. Interestingly, we also observed an intriguing behaviour of mass congregation of these raptors near the Kadra Dam spillway, particularly in the afternoons on weekends, coinciding with the large-scale dumping of poultry waste. This pattern may be suggestive of a strong association between raptor activity and anthropogenic food subsidies in the region, which requires further evaluation in the future.

In addition to our systematic surveys, opportunistic observations yielded records of cryptic species such as

Table 5. Status of species of conservation significance (SCS) in the study area.

SCS	Categories	Frequency
IUCN Red List categories	Least Concern	189
	Near Threatened	10
	Vulnerable	4
	Not Evaluated	3
National & international legal protections	WPA-Schedule I	29
State of India's Birds 2023	High Priority	9
	Moderate Priority	55

Malayan Night Heron *Gorsachius melanolophus*, and the Sri Lankan Frogmouth *Batrachostomus moniliger*. However, some species commonly reported from the region, including Legge's Hawk Eagle *Nisaetus kelaarti*, Black-backed Dwarf Kingfisher *Ceyx erithaca*, and Blue-eared Kingfisher *Alcedo meninting* along with resident-endemic species such as the White-bellied Blue Flycatcher *Cyornis pallidipes*, White-bellied Treepie *Dendrocitta leucogastra*, and Rufous Babbler *Argya subrufa* were not detected during our primary survey. This likely reflects seasonal and methodological limitations rather than a true absence.

Migratory Birds

The Western Ghats, with its diverse forest types and perennial water sources, serve as a critical stopover site for many species. For the birds travelling between their breeding grounds in the Palearctic and wintering habitats in southern and southeastern Asia, the study area acts as a vital migratory corridor. In this study, we documented 32 migratory species, including 27 winter migrants. Notable among them were warblers such as Blyth's Reed Warbler *Acrocephalus dumetorum*, Large-billed Leaf Warbler *Phylloscopus magnirostris*, and Western-crowned Warbler *Phylloscopus occipitalis*. The occurrence of these species in these areas highlights that the region is an important habitat for migratory birds. Although our surveys documented a number of migratory species, the richness observed was lower compared to the 80 species previously reported from the broader region. A likely explanation for this discrepancy is the temporal window of sampling, which was restricted to the summer months (February–June). This period coincides with the northward migration of many winter visitors, thereby reducing their detectability within the study area. Consequently, our data may underrepresent the diversity and habitat use of migratory species. To address this limitation, future studies should adopt a multi-seasonal framework to capture temporal variation in species presence and provide a more robust understanding of migratory dynamics in the region. The study area within the KTR, as well as reserve forests encompassing Karwar forest division and Yellapur forest division, plays a crucial role in safeguarding the avian biodiversity of the Western Ghats. Our baseline surveys documented a rich diversity of bird species across different habitats, ranging from tropical evergreen to moist deciduous forests. Recent landscape-level analyses highlight that the Uttara Kannada district has lost nearly a third of its evergreen forest cover in the past four decades, accompanied by a sharp rise in built-up areas and monoculture plantations (Ramachandra et al. 2024). Such land-use changes alter the structure and functioning of forest ecosystems, threaten resource bases, and reduce habitat quality for forest-dependent species. Additionally, our observations of juvenile Grey-headed Fish Eagles *Icthyophaga ichthyaetus* and White-bellied Sea Eagles *Icthyophaga leucogaster* during boat surveys (as observed by RP, NR on 01st April 2024 and 04th April 2024 respectively) may indicate local breeding, suggesting that the riverine habitats of the Kali river could serve as potential breeding sites for these species. Overall, our findings emphasise that safeguarding the ecological integrity of these habitats within this region is central to conserving the avifaunal diversity of the Western Ghats. However, the current dataset, being restricted to a single season, represents only a preliminary baseline. Given ongoing land-use changes and the ecological sensitivity of this landscape, long-term and multi-seasonal monitoring of bird communities across habitat types is essential to track temporal dynamics, detect early warning signals of change, and inform adaptive conservation strategies.

REFERENCES

Ali, S. (2002). *The Book of Indian Birds, 13th edition.* Bombay Natural History Society & Oxford University Press, Mumbai, 326 pp.

Aarif, K.M., A. Nefla, K.A. Rubeena, Y. Xu, Z. Bouragaoui, M. Nasser, C.T. Shifa, T.R. Athira, K. Jishnu, J. Anand, S. Manokaran, P.P. Moosa, A. Gopinath, O.R. Reshi, K.M. Rajaneesh, H. Byju, T.V. Joydas, K.P. Manikandan, M.I. Naikoo & C. Sonne (2025). Assessing environmental change and population declines of large wading birds in southwestern India. *Environmental and Sustainability Indicators* 25: 100572. https://doi.org/10.1016/j.indic.2024.100572

Archana, T.R., A. Nefla, H. Byju, S. Almaroofi, O.R. Reshi, A.S. Alatawi & K.M. Arif (2024). Effects of plant and avian frugivore interaction networks on landscape patterns and seed dispersal functions in the southern Western Ghats, India. *Ornithological Science* 23(1): 35–43. https://doi.org/10.2326/osj.23.35

Barlow, J., C.A. Peres, L.M.P. Henriques, P.C. Stouffer & J.M. Wunderle (2006). The responses of understorey birds to forest fragmentation, logging and wildfires: An Amazonian synthesis. *Biological*

Conservation 128(2): 182–192. https://doi.org/10.1016/j.biocon.2005.09.028

Barve, S. & R. Warrier (2013). Bird diversity of the Sharavathy landscape, Karnataka. *Indian Birds* 8(3): 57–61.

Bhat, R.A. & C.B. Ganesh (2014). Bird diversity and status in western ghats of Katgal (Uttara Kannada Dist.), Karnataka State. *Ecology Environment and Conservation* 20(1): 181–186.

Bibby, C.J., N.D. Burgess, D.A. Hill & S.H. Mustoe (2000). *Bird Census Techniques*, *2nd edition*. Academic Press Inc, 302 pp.

Billerman, S.M., B.K. Keeney, P.G. Rodewald & T.S. Schulenberg (Eds.) (2022). Birds of the World. Cornell Laboratory of Ornithology, Ithaca, New York, USA. https://birdsoftheworld.org/bow/home. Accessed on 20.xii.2024.

Champion, H.G. & S.K. Seth (1968). *A Revised Survey of the Forest Types of India*. Manager of Publications, Delhi, 404 pp.

Clements, J.F., P.C. Rasmussen, T.S. Schulenberg, M.J. Iliff, T.A. Fredericks, J.A. Gerbracht, D. Lepage, A. Spencer, S.M. Billerman, B.L. Sullivan, M. Smith & C.L. Wood (2024). The eBird/Clements checklist of Birds of the World: v2024. https://www.birds.cornell.edu/clementschecklist/download/. Downloaded on 20.vi.2024.

Daniels, R.J.R., N.V. Joshi & M. Gadgil (1990). Changes in the bird fauna of Uttara Kannada, India, in relation to changes in land use over the past century. *Biological Conservation* 52(1): 37–48. https://doi.org/10.1016/0006-3207(90)90013-F

Daniels, R.J., N.V. Joshi & M. Gadgil (1992). On the relationship between bird and woody plant species diversity in the Uttara Kannada district of south India. *Proceedings of the National Academy of Sciences* 89(12): 5311–5315. https://doi.org/10.1073/pnas.89.12.5311

Davidson, J.A.G. (1898a). The birds of North Kanara. *Journal of the Bombay Natural History Society* 11(4): 652–679.

Davidson, J.A.G. (1898b). The birds of North Kanara. Part II. *Journal of the Bombay Natural History* Society 12(1): 43–72.

Gadgil, M., R.R. Daniels, K.N. Ganeshaiah, S.N. Prasad, M.S.R. Murthy, C.S. Jha, B.R. Ramesh & K.A. Subramanian (2011). Mapping ecologically sensitive, significant and salient areas of Western Ghats: proposed protocols and methodology. *Current Science* 100(2): 175–182.

Grimmett, R., C. Inskipp & T. Inskipp (2011). *Birds of the Indian Subcontinent*, *2nd Edition*. Helm Field Guides, Oxford, UK, 528 pp.

Gopal, A., D. Mudappa, T.R.S. Raman & R. Naniwadekar (2020). Forest cover and fruit crop size differentially influence frugivory of select rainforest tree species in Western Ghats, India. *Biotropica* 52(5): 871–883. https://doi.org/10.1111/btp.12810

Hariharan, P., P. Bangal, H. Sridhar & K. Shanker (2022). Habitat use by mixed-species bird flocks in tropical forests of the Western Ghats, India. *Journal of Tropical Ecology* 38(6): 393–400. https://doi.org/10.1017/S026646742200030X

IUCN (2024). The IUCN Red List of Threatened Species. Version 2024-1. https://www.iucnredlist.org. Accessed on 3.iv.2024.

Karanth, K.K., S. Vishnupriya, S. Dalvi, S. Arjun, P. Ravishankar, S. Sharma, P. Robbins & A. Chhatre (2016). Producing Diversity: Agroforests Sustain Avian Richness and Abundance in India's Western Ghats. *Frontiers in Ecology and Evolution* 4: 111. https://doi.org/10.3389/fevo.2016.00111

Kotangale, J.P. & T.K. Ghosh (2000). Avifauna Diversity in and Around Kaiga in Uttara Kannada District of Karnataka State. *Environment Conservation Journal* 1(1): 1–7. https://doi.org/10.36953/ecj.2000.010101

Matuoka, M.A., M. Benchimol, J.M. de Almeida-Rocha & J.C. Morante-Filho (2020). Effects of anthropogenic disturbances on bird functional diversity: A global meta-analysis. *Ecological Indicators* 116: 106471. https://doi.org/10.1016/j.ecolind.2020.106471

Menon, T. & G. Shahabuddin (2021). Assessing woodpeckers as indicators of bird diversity and habitat structure in managed forests. *Biodiversity and Conservation* 30: 1689–1704. https://doi.org/10.1007/s10531-021-02164-0

Mudappa, D. & T.R.S. Raman (2009). A conservation status survey of hornbills (Bucerotidae) in the Western Ghats, India. *Indian Birds* 5(4): 90–102.

Myers, N., R.A. Mittermeier, C.G. Mittermeier, G.A. Da Fonseca & J. Kent (2000). Biodiversity hotspots for conservation priorities. *Nature* 403(6772): 853–858. https://doi.org/10.1038/35002501

Pielou, E.C. (1966). The measurement of diversity in different types of biological collections. *Journal of Theoretical Biology* 13(1): 131–144. https://doi.org/10.1016/0022-5193(66)90013-0

Pillay, R., M. Venter, J. Aragon-Osejo, P. González-del-Pliego, A.J. Hansen, J.E. Watson & O. Venter (2021). Tropical forests are home to over half of the world's vertebrate species. *Frontiers in Ecology and the Environment* 20(1): 10–15. https://doi.org/10.1002/fee.2420

Praveen, J., S. Subramanya & V.M. Raj (2025). A checklist of the birds of Karnataka, India (v7.0). Website: http://www.indianbirds.in/indian-states/. Accessed on 20.vi.2025.

Puttaraju, K. (2014). Avifaunal diversity of the Southern Western Ghats with special reference to Kaiga - Karwar region - A checklist. *Journal of Aquatic Biology and Fisheries* 2(2): 512–519. https://keralamarinelife.in/JournalofAquaticBiologyandFisheries.html

R Core Team (2024). R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. https://r-project.org

Ramachandra, T.V., S. Bharath, M.D. Subashchandran, G.R. Rao, M. Vishnu & B. Prasanna (2024). Monitoring land use dynamics and diversity of flora in Uttara Kannada district, Karnataka, Central Western Ghats, India, pp 21–46. In: Dutta, D., A. Kundu & N.R. Patel (eds.). *Vegetation Dynamics and Crop Stress*. Academic Press. https://doi.org/10.1016/b978-0-323-95616-1.00002-x

Ramachandra, T.V., S. Chandran, N.V. Joshi & B. Setturu (2013). Land use changes with the implementation of developmental projects in Uttara Kannada District. Sahyadri Conservation Series 31, ENVIS Technical Report 61, ENVIS, Centre for Ecological Sciences, Indian Institute of science, Bangalore, 94 pp.

Raman, T.R.S. (2006). Effects of Habitat Structure and Adjacent Habitats on Birds in Tropical Rainforest Fragments and Shaded Plantations in the Western Ghats, India. *Biodiversity and Conservation* 15(4): 1577–1607. https://doi.org/10.1007/s10531-005-2352-5

Ranganathan, J., J. Krishnaswamy & M.O. Anand (2010). Landscape-level effects on avifauna within tropical agriculture in the Western Ghats: Insights for management and conservation. *Biological Conservation* 143(12): 2909–2917. https://doi.org/10.1016/j.biocon.2010.04.018

Sekercioglu, C.H. (2006). Increasing awareness of avian ecological function. *Trends in Ecology & Evolution* 21(8): 464–471. https://doi.org/10.1016/j.tree.2006.05.007

Sekercioglu, C.H. (2012). Bird functional diversity and ecosystem services in tropical forests, agroforests, and agricultural areas. *Journal of Ornithology* 153(1): 153–161. https://doi.org/10.1007/s10336-012-0869-4

Shannon, C.E. & W. Weaver (1963). *The Mathematical Theory of Communication*, *1st Edition)*. University of Illinois Press, 144 pp.

Sneha, V. & P. Davidar (2011). Status Survey of the Malabar Pied Hornbill in the Dandeli region, Northern Western Ghats, India. *The Raffles Bulletin of Zoology* 24: 45–51.

SoIB (2023). State of India's Birds, 2023: Range, trends, and conservation status. The SoIB Partnership, 119 pp. https://doi.org/10.5281/zenodo.11124590

The Gazette of India (2024). Ministry of Environment, Forest and Climate Change Notification, July 2024. https://moef.gov.in/storage/tender/1723024218.pdf. Downloaded on 31.viii.2024.

Whelan, C.J., D.G. Wenny & R.J. Marquis (2008). Ecosystem services provided by birds. *Annals of the New York Academy of Sciences* 1134(1): 25–60. https://doi.org/10.1196/annals.1439.003

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 August 2026 | 18(8): 29418–29429
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.10539.18.8.29418-29429
#10539 | Received 21 March 2026 | Final received 30 June 2026 | Finally accepted 07 July 2026

ARTICLE

A study on the avifaunal diversity and community dynamics of Karanji Lake, Mysuru, Karnataka, India

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Abstract: We conducted the present field study to record avifaunal diversity at Karanji Lake, Mysuru, Karnataka, from April 2021 to March 2022 on a bimonthly basis. Point count method with a fixed radius was carried out within the lake premises, with 14 grids. A total of 94 bird species were recorded belonging to 16 orders and 47 families. Highest number of birds was represented by order Passeriformes, with 23 families, and the family Ardeidae dominated with eight species. A total of 90 species were 'Least Concern', and two species were 'Near Threatened'. Further, these birds were grouped into omnivorous (33%), insectivorous (27.6%), carnivorous (23.4%), piscivorous (7.4%), frugivorous (3.2%), nectarivores (2.1%), granivorous (2.1%), and herbivorous (1.1%) based on feeding habits. Shannon-Wiener value was $3.1517 \pm 0.31_{SE}$, Simpson diversity was 0.6937, and Pielou's evenness value was 0.694. The different diversity index values revealed the occurrence of a good number of bird species, conveying that the Karanji Lake still has potential to support avifauna. This study will help understand the conservation of birds at the Lake in future, an important biodiversity perspective.

Keywords: Birds, Chamundi Hills, diversity indices, feeding guilds, Mysore Zoo, Near Threatened, waterbody, wetland birds.

Editor: H. Byju, Coimbatore, Tamil Nadu, India. **Date of publication:** 26 August 2026 (online & print)

Citation: Sushanth, S. & K.S. Raghunandan (2026). A study on the avifaunal diversity and community dynamics of Karanji Lake, Mysuru, Karnataka, India. *Journal of Threatened Taxa* 18(8): 29418–29429. https://doi.org/10.11609/jott.10539.18.8.29418-29429

Funding: Self-funded.

Competing interests: The authors declare no competing interests.

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Author contributions: SS—data collection, manuscript writing, analysis; KSR—conceived the study, manuscript editing.

Acknowledgements: Authors thankful to Sri Ajith M. Kulkarni, IFS, executive director, Sri Chamarajendra Zoological Garden, Mysuru for granting the permission to carry out this research work. Special thanks to Ms. Sujosha, education officer and all the staff of Sri Chamarajendra Zoological Garden, Mysuru for their support. Special thanks are also due to the principal, Maharani's Science College for women, Mysuru and Dr. M. Ramyashree, head of the department, and Dr, Nijgal, assistant professor, PG Department of Zoology, JSS College, Mysuru for encouragement.

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INTRODUCTION

Birds are globally widespread and perform ecologically important functions as pollinator, scavengers, predators, and seed dispersers (Sekercioglu 2006). With over 11,000 species worldwide and approximately 1,358 in the Indian subcontinent (Birdlife International 2026), they are among the most studied taxa and serve as valuable bioindicators of environmental changes because they respond rapidly to changes in landscape configuration, composition, and function (Gregory et al. 2004). Monitoring bird diversity therefore provides insights into habitat quality and ecosystem health. Birds also contribute to multiple ecosystem services, such as provisioning, regulating, cultural, and supporting services, which sustain human well-being (Sekercioglu et al. 2016). Despite their importance, bird communities are increasingly threatened by habitat loss, anthropogenic disturbance, urbanisation, and climate change. Monitoring and conserving bird diversity remain critical for maintaining ecosystem function and biodiversity.

Mysuru City is among the few places in India that has detailed bird documentation since the 1940s. In their landmark survey of the Mysore State, Ali & Whistler (1942–43) documented several wetlands in and around the city, providing an early baseline for avian studies. Wetlands are known to provide key habitats for both resident and migratory birds for breeding, drinking, feeding, resting, and for social interactions (Kaur & Brraich 2021). These freshwater bodies often succumb to changes in land use in their catchment areas, resulting in reduced inflows and a declining quality of the “runoff” that passes through agricultural fields and urban areas (Verma et al. 2001). The depletion of wetlands as a result of numerous human activities and/or climate change poses a serious threat to the diversity and number of waterbird species worldwide, with some species becoming extinct across several wetlands (Wetlands International 2012). With this background, the present study was undertaken to assess current avifaunal diversity at Karanji Lake using the point count method. It quantifies species richness, abundance and guilds while evaluating threats. Outcomes will inform urban wetland conservation in Mysuru.

MATERIALS AND METHODS

Study Area

The study was carried out in Karanji Lake (12.3028º N, 76.6736º E; Image 1), located in the Mysuru District, Karnataka, within the Chamundi Hills foothills. It has an altitude ranging 861–944 m, and the surrounding plateau is 1,024–1,057 m high (Mishra et al. 2007). The lake was constructed by the Maharaja of Mysore and is one of the biggest lakes in Karnataka. The total area of the lake is about 36.4 ha. The green cover area measured within the lake premises is about 14 ha. The lake also has a marshy area of about 0.0675 km^2 and a dry area of 0.280 km^2, and has a catchment area of 745 ha. The lake water capacity is 629.2 ML, and the highest flood level is 744.14 m (Kumara et al. 2010; Mysore Nature 2025).

Sampling Method

The present study was conducted from April 2021 to March 2022 on a bimonthly basis, with a total of 24 surveys. Surveys were conducted between 0630 h and 1000 h, as bird activity is known to be highest during morning hours. Point count method (Bibby et al. 2000) was employed to estimate the bird richness and abundance that was present in the sampling site. There were a total of 14 grids with one point count station per grid. We spent 15 minutes at each point (3.5 h per replication of all the grids), yielding ~84 h of total sampling effort. The birds were counted within the fixed radius (100 m) (Buckland et al. 2001) using binoculars (10 x 42) and a digital camera was used to photograph. Minimum three replications of point count surveys at every sampling point were carried out in each season (summer, winter, and monsoon). The birds were identified using a field guide (Grimmett et al. 2016). Bird species were classified into feeding guilds following Ghosh et al. (2022) and Jamakhandi & Kadadevaru (2024).

Data Analysis

To assess the adequacy of sampling for bird diversity and sampling effort sufficiency, species accumulation curves were plotted with the cumulative number of bird species that were recorded across all the sampling sites against cumulative effort using the R software v4.3.1 and RStudio v2025.09.2 + 418 (R core team 2025; RStudio team 2025) with ‘vegan’ package (Oksanen et al. 2025) and all the graphs were created with ‘ggplot2’ package (Wickham 2016). The diversity indices (including species richness, Shannon-Wiener diversity, Simpson diversity, and Pielou’s evenness) were calculated using the same

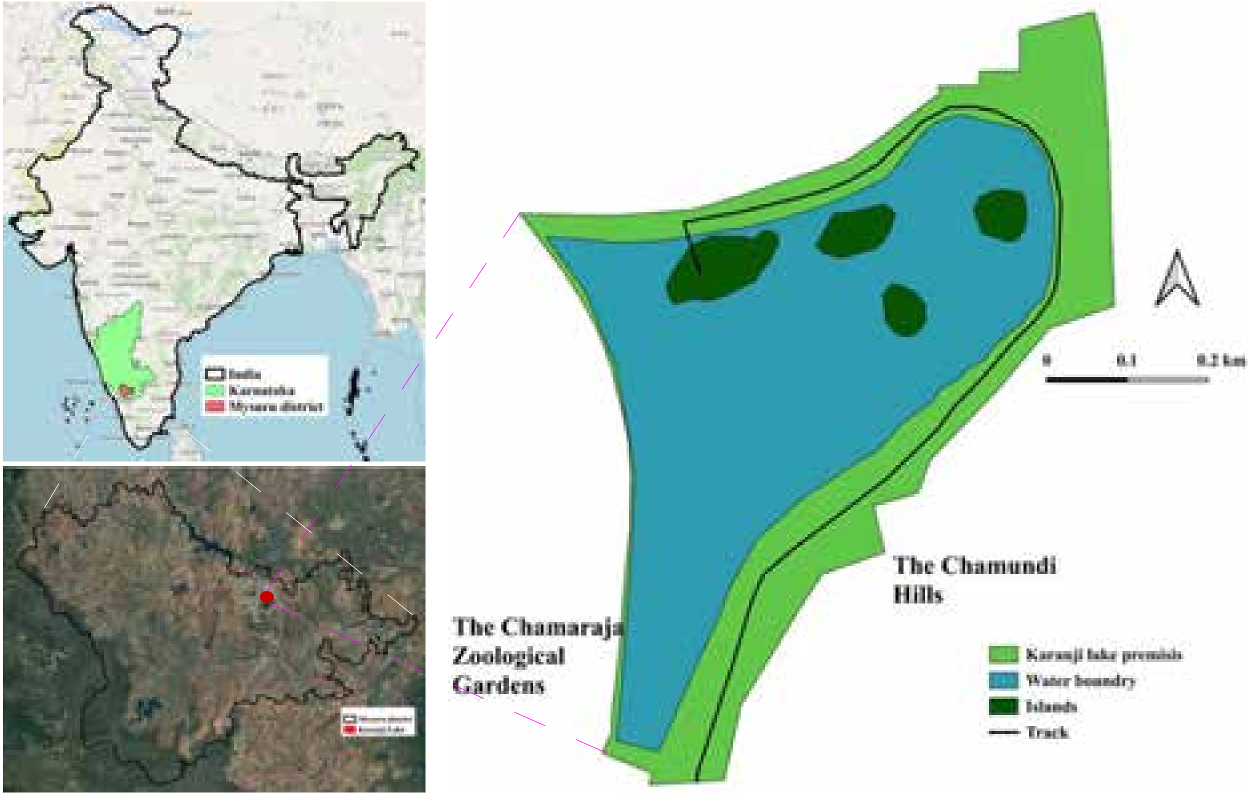

Image 1. The map of the study area, created using QGIS v3.26.2 (https://qgis.org) along with the survey track (from the entrance to the end point—1.5 km).

software with 'vegan' package (Oksanen et al. 2025).

RESULTS AND DISCUSSION

A total of 94 bird species were recorded belonging to 16 orders and 47 families. The order Passeriformes and the family Ardeidae had the highest number of bird species in them, with 43 and eight, respectively. Three Western Ghats endemic birds were recorded (White-spotted Fantail *Rhipidura albogularis*, White-cheeked Barbet *Psilopogon viridis*, and Mottled Wood-Owl *Strix ocellata*). According to their feeding guilds, the birds were categorised into eight groups, viz., omnivorous (31 species), insectivorous (26 species), carnivorous (22 species), piscivorous (7 species), frugivorous (3 species), nectarivores (2 species), granivorous (2 species), and herbivorous (1 species) (Table 1; Image 4). Based on IUCN 2026, there were only two categories: 'Least Concern' (LC) (90 species), 'Near Threatened' (NT) (2 species) (Black-headed Ibis *Threskiornis melanocephalus* and Spot-billed Pelican *Pelecanus philippensis*) and two species are not assessed (Grey-headed Swamphen *Porphyrio poliocephalus* and Cinereous Tit *Parus cinereus*) (Table 1).

The order Passeriformes had the highest number of bird species of 43, with the highest occurrence percentage of 45.75%. The lowest number of species recorded was in four orders (Ciconiiformes, Podicipediformes, Psittaciformes, and Strigiformes) with one species each and with 1.06% occurrence each (Image 5). The family Ardeidae had the highest number of bird species, with eight recorded and the highest occurrence of 8.52%. The least number of bird species was recorded in 21 different families with one species in each and 1.06% occurrence each (Table 2; Image 3).

The species accumulation curve suggested that the sampling effort was adequate, as it reached an asymptote from the tenth month (Image 2). The species richness was 94. The Shannon-Wiener diversity value was $3.1517 \pm 0.31_{SE}$. The Simpson's diversity index value was 0.6937, and the Pielou's evenness value was 0.694 (Table 3).

Karanji Lake serves as a key urban ecology site in Mysuru City, sustaining a wide variety and diversity of birds. It serves as breeding ground for several bird species (Black-headed Ibis *Threskiornis melanocephalus*, Spot-billed Pelican *Pelecanus philippensis*, Greater

Table 1. The updated list of bird species recorded in Karanji Lake, Mysuru.

	Common name	Scientific name	IUCN Red List	Diet
I	Accipitriformes			
i	Accipitidae			
1	Shikra	*Accipiter badius*	LC	CV
2	Black Kite	*Milvus migrans*	LC	CV
3	Brahminy Kite	*Haliastur Indus*	LC	CV
II	Anseriformes			
ii	Anatidae			
4	Indian Spot-billed Duck	*Anas poecilorhyncha*	LC	OV
5	Lesser Whistling-Duck	*Dendrocygna javanica*	LC	OV
iii	Phasianidae			
6	Indian Peafowl	*Pavo cristatus*	LC	OV
III	Bucerotiformes			
iv	Bucerotidae			
7	Indian Grey Hornbill	*Ocyceros birostris*	LC	OV
v	Upupidae			
8	Common Hoopoe	*Upupa epops*	LC	OV
IV	Charadriiformes			
vi	Charadriidae			
9	Red-wattled Lapwing	*Vanellus indicus*	LC	CV
vii	Jacanidae			
10	Bronze-winged Jacana	*Metopidius indicus*	LC	CV
viii	Scolopacidae			
11	Green Sandpiper	*Tringa ochropus*	LC	OV
12	Common Sandpiper	*Actitis hypoleucos*	LC	CV
13	Wood Sandpiper	*Tringa glareola*	LC	CV
V	Ciconiiformes			
ix	Ciconiidae			
14	Painted Stork	*Mycteria leucocephala*	LC	CV
VI	Columbiformes			
x	Columbidae			
15	Rock Dove	*Columba livia*	LC	OV
16	Spotted Dove	*Spilopelia chinensis*	LC	GV
VII	Coraciiformes			
xi	Alcedinidae			
17	Common Kingfisher	*Alcedo atthis*	LC	PV
18	White-throated Kingfisher	*Halcyon smyrnensis*	LC	PV
19	Stork-billed Kingfisher	*Pelargopsis capensis*	LC	PV
VIII	Cuculiformes			
xii	Cuculidae			
20	Greater Coucal	*Centropus sinensis*	LC	OV
21	Asian Koel	*Eudynamys scolopaceus*	LC	OV
22	Common Hawk-Cuckoo	*Hierococcyx varius*	LC	IV
IX	Gruiformes			
xiii	Rallidae			
23	Eurasian Coot	*Fulica atra*	LC	OV
24	Eurasian Moorhen	*Gallinula chloropus*	LC	OV
25	Grey-headed Swamphen	*Porphyrio poliocephalus*	-	OV
26	White-breasted Waterhen	*Amaurornis phoenicurus*	LC	OV
X	Passeriformes			
xiv	Acrocephalidae			
27	Sykes's Warbler	*Iduna rama*	LC	IV
28	Clamorous Reed Warbler	*Acrocephalus stentoreus*	LC	IV
29	Blyth's Reed Warbler	*Acrocephalus dumetorum*	LC	IV
30	Booted Warbler	*Iduna caligata*	LC	IV
xv	Aegithinidae			
31	Common Iora	*Aegithina tiphia*	LC	IV
xvi	Apodidae			
32	Asian Palm Swift	*Cypsiurus balasiensis*	LC	IV
33	Little Swift	*Apus affinis*	LC	IV
xvii	Campephagidae			
34	Small Minivet	*Pericrocotus cinnamomeus*	LC	IV
35	Black-headed Cuckooshrike	*Coracina melanoptera*	LC	IV
xviii	Chloropseidae			
36	Jerdon's Leafbird	*Chloropsis jerdoni*	LC	OV
xix	Cisticolidae			
37	Common Tailorbird	*Orthotomus sutorius*	LC	OV
38	Ashy Prinia	*Prinia socialis*	LC	IV
xx	Corvidae			
39	House Crow	*Corvus splendens*	LC	OV
40	Large-billed Crow	*Corvus macrorhynchos*	LC	OV
xxi	Dicaeidae			
41	Pale-billed Flowerpecker	*Dicaeum erythrorhynchos*	LC	OV
xxii	Dicruridae			
42	Black Drongo	*Dicrurus macrocercus*	LC	IV
43	Ashy Drongo	*Dicrurus leucophaeus*	LC	IV
xxiii	Estrildidae			
44	Scaly-breasted Munia	*Lonchura punctulata*	LC	OV
45	White-rumped Munia	*Lonchura striata*	LC	GV
xxiv	Hirundinidae			

	Common name	Scientific name	IUCN Red List	Diet
46	Red-rumped Swallow	*Cecropis daurica*	LC	IV
47	Barn Swallow	*Hirundo rustica*	LC	IV
xxv	Monarchidae			
48	Indian Paradise Flycatcher	*Terpsiphone paradisi*	LC	IV
xxvi	Motacillidae			
49	Forest Wagtail	*Dendronanthus indicus*	LC	IV
50	Gray Wagtail	*Motacilla cinerea*	LC	CV
51	White-browed Wagtail	*Motacilla maderaspatensis*	LC	IV
xxvii	Muscicapidae			
52	Asian Brown Flycatcher	*Muscicapa dauurica*	LC	IV
53	Indian Robin	*Saxicoloides fulicatus*	LC	OV
54	Oriental Magpie Robin	*Copsychus saularis*	LC	OV
55	Tickell's Blue Flycatcher	*Cyornis tickelliae*	LC	IV
56	White-rumped Shama	*Copsychus malabaricus*	LC	IV
xxviii	Nectariniidae			
57	Purple-rumped Sunbird	*Leptocoma zeylonica*	LC	NV
58	Purple Sunbird	*Cinnyris asiaticus*	LC	NV
xxix	Oriolidae			
59	Indian Golden Oriole	*Oriolus kundoo*	LC	OV
xxx	Paridae			
60	Cinereous Tit	*Parus cinereus*	-	IV
xxxi	Phylloscopidae			
61	Green Warbler	*Phylloscopus nitidus*	LC	IV
xxxii	Pittidae			
62	Indian Pitta	*Pitta brachyura*	LC	CV
xxxiii	Pycnonotidae			
63	Red-whiskered Bulbul	*Pycnonotus jocosus*	LC	OV
64	Red-vented Bulbul	*Pycnonotus cafer*	LC	OV
xxxiv	Rhipiduridae			
65	White-spotted Fantail	*Rhipidura albogularis*	LC	IV
xxxv	Sturnidae			
66	Common Myna	*Acridotheres tristis*	LC	OV
67	Jungle Myna	*Acridotheres fuscus*	LC	OV
68	Chestnut-tailed Starling	*Sturnia malabarica*	LC	OV
xxxvi	Zosteropidae			
69	Indian White-eye	*Zosterops palpebrosus*	LC	HV
XI	Pelecaniformes			
xxxvii	Ardeidae			
70	Purple Heron	*Ardea purpurea*	LC	CV
71	Indian Pond Heron	*Ardeola grayii*	LC	OV

	Common name	Scientific name	IUCN Red List	Diet
72	Little Egret	*Egretta garzetta*	LC	CV
73	Intermediate Egret	*Ardea intermedia*	LC	CV
74	Great White Egret	*Ardea alba*	LC	CV
75	Cattle Egret	*Bubulcus ibis*	LC	CV
76	Gray Heron	*Ardea cinerea*	LC	CV
77	Black-crowned Night Heron	*Nycticorax nycticorax*	LC	OV
xxxviii	Threskiornithidae			
78	Red-naped Ibis	*Pseudibis papillosa*	LC	CV
79	Black-headed Ibis	*Threskiornis melanocephalus*	NT	CV
80	Glossy Ibis	*Plegadis falcinellus*	LC	CV
XII	Piciformes			
xxxix	Megalaimidae			
81	Coppersmith Barbet	*Megalaima haemacephala*	LC	FV
82	White cheeked Barbet	*Psilopogon viridis*	LC	FV
xl	Meropidae			
83	Asian Green Bee-eater	*Merops orientalis*	LC	IV
84	Blue-tailed Bee-eater	*Merops philippinus*	LC	IV
xli	Picidae			
85	Black-rumped Flameback	*Dinopium benghalense*	LC	OV
86	White-naped Woodpecker	*Chrysocolaptes festivus*	LC	OV
XIII	Podicipediformes			
xlii	Podicipedidae			
87	Little Grebe	*Tachybaptus ruficollis*	LC	CV
XIV	Psittaciformes			
xliii	Psittaculidae			
88	Rose-ringed Parakeet	*Psittacula krameri*	LC	FV
XV	Strigiformes			
xliv	Strigidae			
89	Mottled Wood-Owl	*Strix ocellata*	LC	CV
XVI	Sulliformes			
xlv	Anhingidae			
90	Oriental Darter	*Anhinga melanogaster*	LC	CV
xlvi	Pelecanidae			
91	Spot-billed Pelican	*Pelecanus philippensis*	NT	PV
xlvii	Phalacrocoracidae			
92	Great Cormorant	*Phalacrocorax carbo*	LC	PV
93	Little Cormorant	*Microcarbo niger*	LC	PV
94	Indian Cormorant	*Phalacrocorax fuscicollis*	LC	PV

I (Capital roman numerals)—order | I (sentence case roman numerals)—family | 1 (Arabic numerals)—species | LC—Least Concerned | NT—Near Threatened | GV—Granivorous | CV—Carnivorous | OV—Omnivorous | IV—Insectivorous | FV—Frugivorous | HV—Herbivorous.

Table 2. Family-wise bird species recorded in Karanji Lake, Mysuru.

	Name of the family	No. of bird species recorded	% Occurrence		Name of the family	No. of bird species recorded	% Occurrence
1	Accipitridae	3	3.19	25	Monarchidae	1	1.06
2	Anatidae	2	2.13	26	Motacillidae	3	3.19
3	Phasianidae	1	1.06	27	Muscicapidae	5	5.33
4	Bucerotidae	1	1.06	28	Nectariniidae	2	2.13
5	Upupidae	1	1.06	29	Oriolidae	1	1.06
6	Charadriidae	1	1.06	30	Paridae	1	1.06
7	Jacanidae	1	1.06	31	Phylloscopidae	1	1.06
8	Scolopacidae	3	3.19	32	Pittidae	1	1.06
9	Ciconiidae	1	1.06	33	Pycnonotidae	2	2.13
10	Columbidae	2	2.13	34	Rhipiduridae	1	1.06
11	Alcedinidae	3	3.19	35	Sturnidae	3	3.19
12	Cuculidae	3	3.19	36	Zosteropidae	1	1.06
13	Rallidae	4	4.27	37	Ardeidae	8	8.52
14	Acrocephalidae	4	4.27	38	Threskiornithidae	3	3.19
15	Aegithinidae	1	1.06	39	Megalaimidae	2	2.13
16	Apodidae	2	2.13	40	Meropidae	2	2.13
17	Campephagidae	2	2.13	41	Picidae	2	2.13
18	Chloropseidae	1	1.06	42	Podicipedidae	1	1.06
19	Cisticolidae	2	2.13	43	Psittaculidae	1	1.06
20	Corvidae	2	2.13	44	Strigidae	1	1.06
21	Dicaeidae	1	1.06	45	Anhingidae	1	1.06
22	Dicruridae	2	2.13	46	Pelecanidae	1	1.06
23	Estrildidae	2	2.13	47	Phalacrocoracidae	3	3.19
24	Hirundinidae	2	2.13		**Total**	**94**	**100**

Cormorant *Phalacrocorax carbo*, Indian Cormorant *Phalacrocorax fuscicollis*, Little Cormorant *Microcarbo niger*, Grey Heron *Ardea cinerea*, Pond Heron *Ardeola grayii*, Black-crowned Night Heron *Nycticorax nycticorax*, Painted Stork *Mycteria leucocephala*, Indian Spot-billed Duck *Anas poecilorhyncha*, Lesser whistling Duck *Dendrocygna javanica*, Black Kite *Milvus migrans*, Brahminy Kite *Haliastur indus*) (S. Sushanth pers. obs.). Earlier studies on birds from the same area have recorded 135 species of birds (Kumara et al. 2010), which is a decline in bird diversity compared to the present study. The bird diversity is lower than the other two major lakes of Mysuru (Kukkarahalli lake and Lingambudhi lake) with 98 and 213 species, respectively (Kumara et al. 2010). All of these declines, even though there are methodological limitations in different survey periods, underscore its role amid ongoing urbanization pressures. However, index values indicate substantial richness of the wetland's biodiversity; species richness

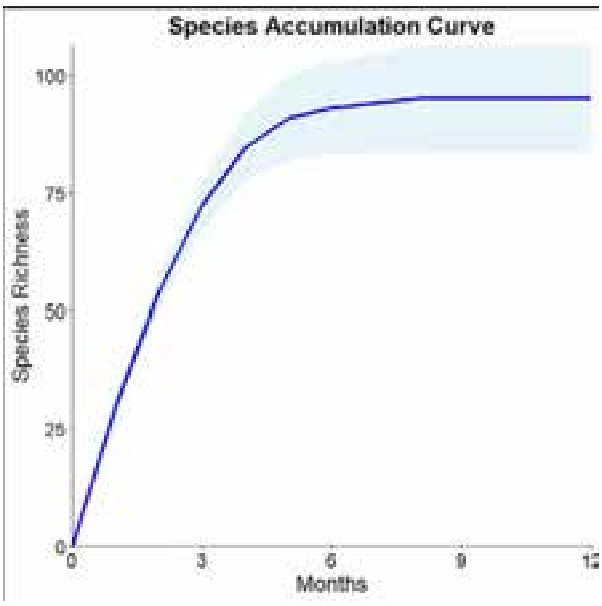

Image 2. Species accumulation curve for birds of Karanji Lake, Mysuru. The feather area indicates 95% confidence intervals.

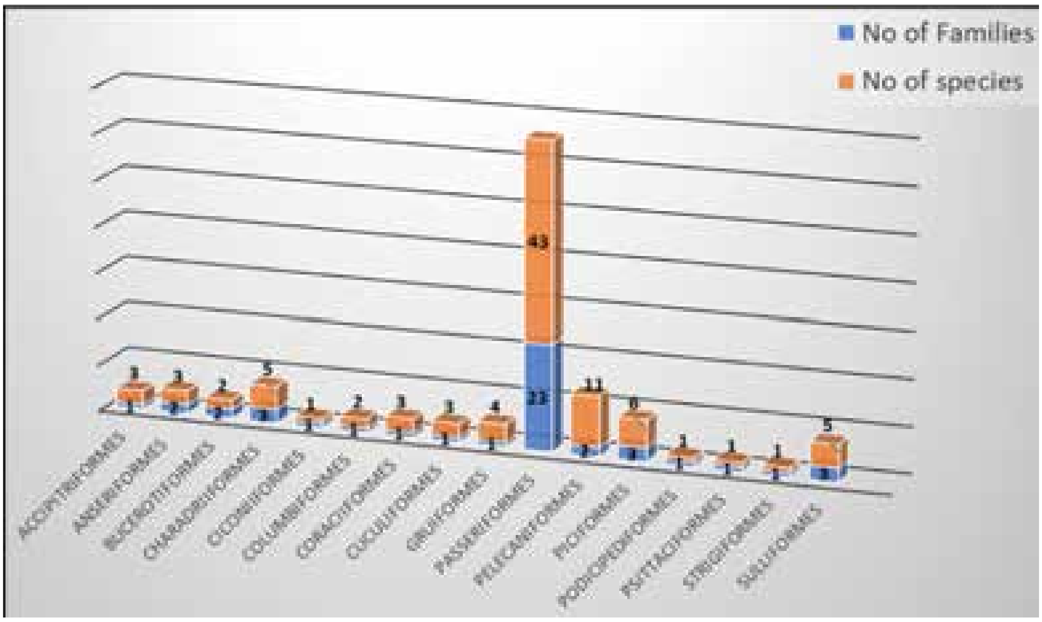

Image 3. Graph representing order-wise families and species recorded at Karanji Lake, Mysuru.

Table 3. Diversity Indices values of birds recorded at Karanji Lake, Mysuru.

	Diversity Indices	Values
1	Species richness	94
2	Shannon-Wiener diversity Index	$3.1517 \pm 0.31_{SE}$
3	Simpson diversity Index	0.6937
4	Pielou's evenness	0.694

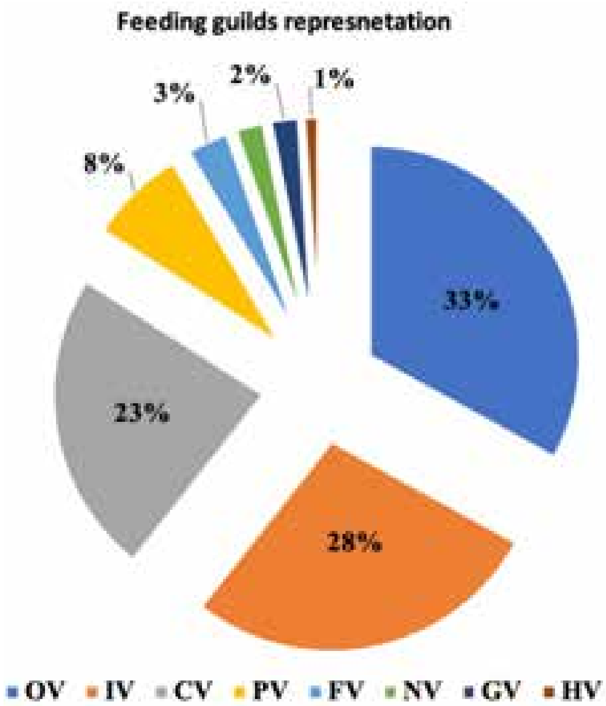

Image 4. Representation of feeding guilds of birds recorded at Karanji Lake, Mysuru: CV—Carnivorous | FV—Frugivorous | GV—Granivorous | HV—Herbivorous | IV—Insectivorous | NV—Nectarivorous | OV—Omnivorous | PV—Piscivorous.

and Shannon-Wiener values reflect robust taxonomic representation along with high community uncertainty driven by even species proportions. Simpson's value signifies low dominance probability among species pairs, wherein Pielou evenness demonstrates equitable abundance distribution supporting stability.

The dominance of certain birds in lake ecosystems is known to reflect habitat structure, food availability, and ecological suitability. The order Passeriformes dominated as they are globally the most species-rich and commonly abundant bird order, dominating mixed lake-edge and adjacent terrestrial habitats, where shrubs, trees, and open ground favour insectivores, omnivores, and generalists, explaining the higher number of omnivores and insectivores (Francl & Schnell 2002; Traut & Hostetler 2004; Schmitt & Edwards 2022; Naveen et al. 2025, 2026). Habitat heterogeneity of lakes (such as open water, shallow margin, aquatic vegetation, and riparian trees) provides a mosaic of complementary habitats for wetland birds (along with food), which are known to be key drivers of waterbird abundance, explaining the elevated presence of Pelecaniformes and Ardeidae (Ramachandran et al. 2017; Ramesh et al. 2020; Meerhoff & González-Sagrario 2022; Nag 2022).

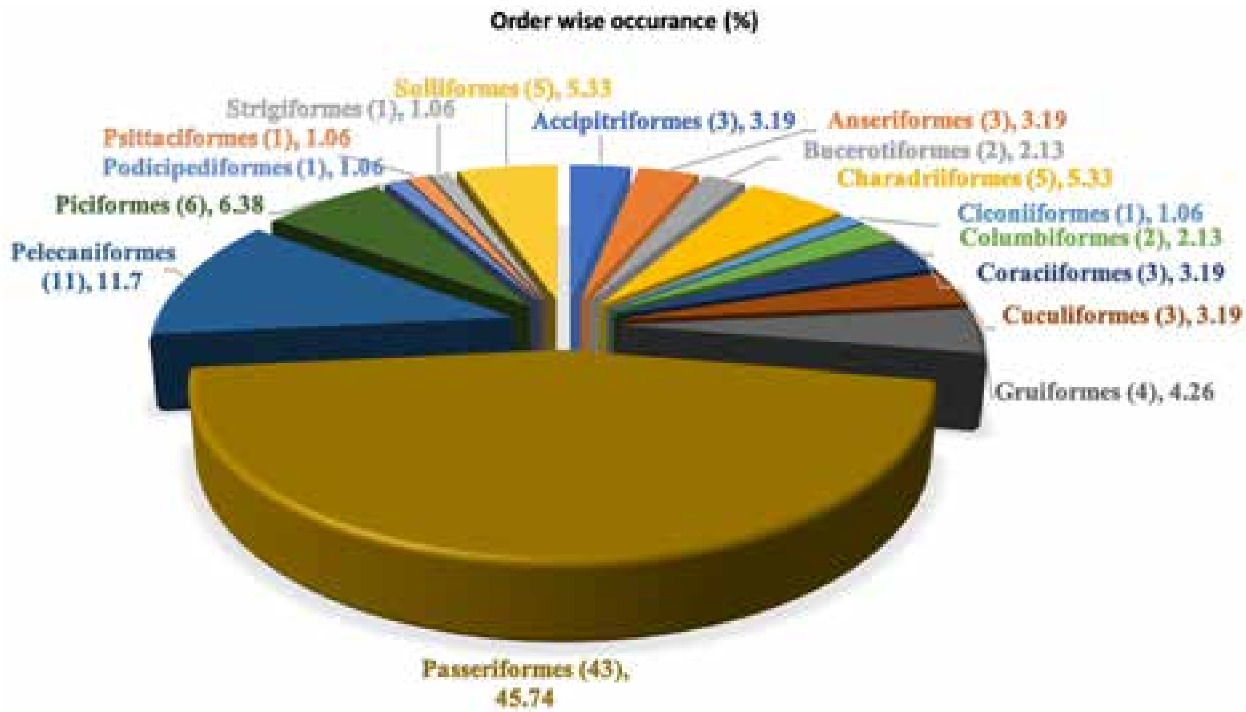

Image 5. Order-wise bird species recorded in Karanji Lake, Mysuru.

Wetland habitat heterogeneity (wooded area, marshes, open water) supports functional diversity through dominant feeding guilds, primarily omnivores, insectivores, and carnivores, that drive pest regulation and nutrient cycling, indicating robust trophic interactions typical of urban refugia (Panda et al. 2021). However, the prevalence of omnivores and insectivores alongside declining representation of other guilds indicates strong ecological filtering and reduced resource heterogeneity (Ahmed & Khan 2022). Such guild patterns favouring broad trophic niches under urban-driven habitat simplification—predictably erode trophic complexity and functional diversity (Hagen et al. 2017; El-Sabaawi 2018; Sol et al. 2020; Panda et al. 2021; Ahmed & Khan 2022). The present study also highlights that there could be a potentially significant relationship between Karanji Lake and Chamundi Hills, as there were personal observations of the movement of birds between both of these places. They are two separate areas, but connected by some of these life forms which are dependent on both of these areas. Further, systematic investigation is required to understand the fine-scale relationship between birds and these areas.

Urban wetlands like Karanji Lake act as an important refugium and help maintain species richness and functional diversity because they provide necessary resources that can support both resident and migratory birds within otherwise heavily built-up landscapes, making them especially valuable where natural wetlands have been lost or degraded. However, during the study, it was found that Karanji Lake is under several threats, falling into i) anthropogenic (sewage intrusion, tourist boating, path alterations) and ii) ecological threats (hyacinth mats, natural siltation, eutrophication), as these threats should be considered to take conservation actions by the concerned authorities. All of these are known to affect the bird community negatively, consistent with regional declines potentially reducing migratory influx (Bhendekar et al. 2024; Nandhini & Jagatheeswari 2024). Detailed studies in future would help to directly assess the effect of these threats on bird populations of the area. Bhatnagar et al. (2007) reported similar findings in India. It was observed that the various decaying weeds in the lakes formed floating vegetation islands/mats, which are known to deteriorate habitat quality and also interfere with foraging activities of waterbirds. These threats are also known to affect the distribution of wetland birds and cause local extinctions (Harisha & Hosetti 2017), which might lead to fewer migratory bird visits to the lake.

Considering these facts, there is a need to create awareness among local people about the richness of this place and take adequate steps and measures towards protection and conservation of the Lake, avifauna and

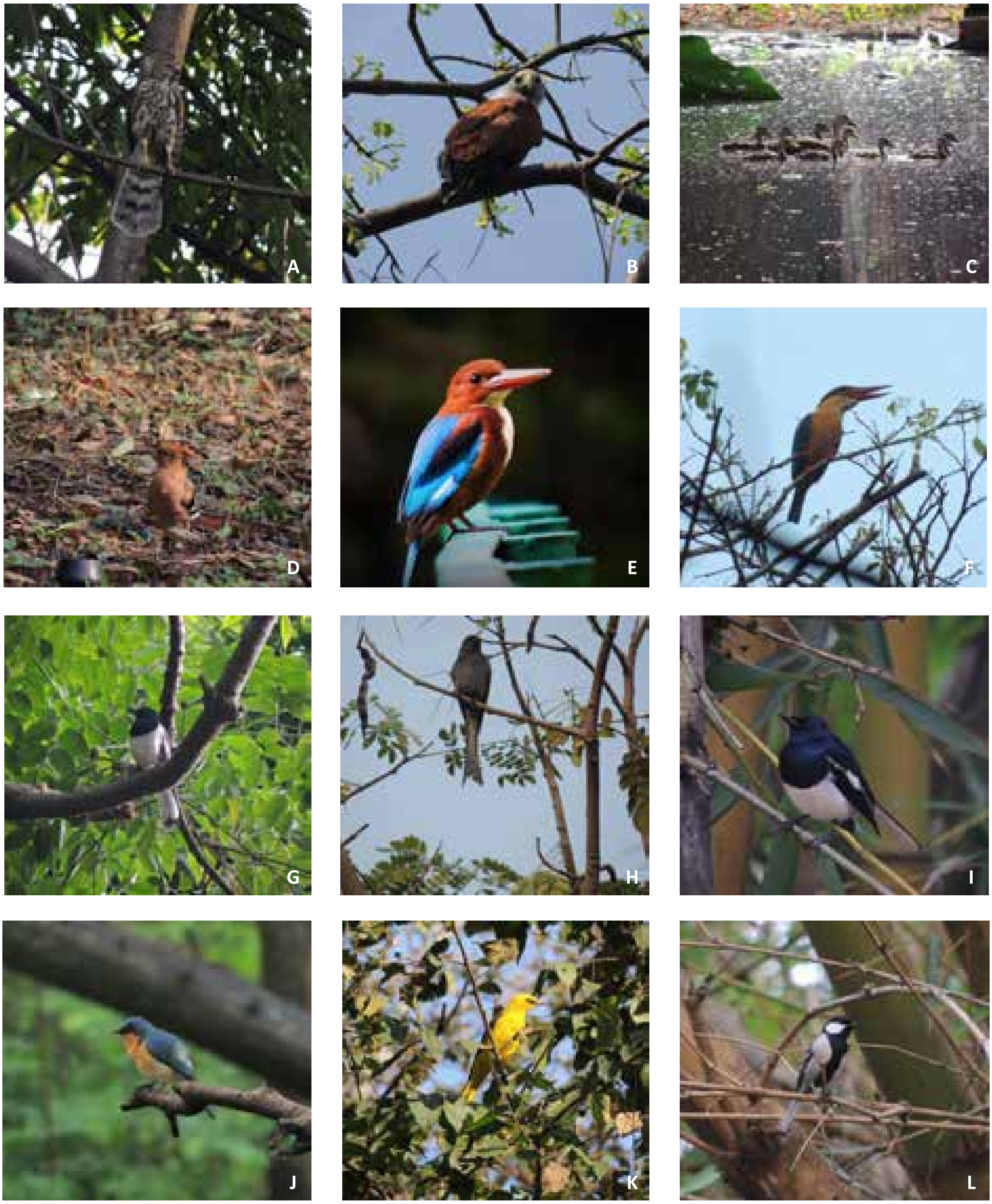

Image 6 A—L. Photographs of select birds recorded at the Karanji Lake, Mysuru during the study period. A—Shikra | B—Brahminy Kite | C—Indian Spot-billed Duck | D—Eurasian Hoopoe | E—White-throated Kingfisher | F—Stork-billed Kingfisher | G—Black-headed Cuckooshrike | H—Ashy Drongo | I—Oriental magpie Robin | J—Tickell's Blue Flycatcher | K—Indian Golden Oriole | L—Cinerous Tit. © S. Sushanth.

Image 6 M—T. Photographs of select birds recorded at the Karanji Lake, Mysuru during the study period. M—Indian Pitta | N—Purple Heron | O—Black-rumped Flameback | P—White-naped Woodpecker | Q—Rose-ringed Parakeet | R—Mottled Wood-Owl | S—Spot-billed Pelican | T—Great Cormorant. © S. Sushanth.

the lake's avian heritage. Conservation via targeted measures such as aquatic de-weeding, wastewater diversion, mechanical/biolocontrol hyacinth eradication, and water aeration by mechanical pumps needs to be carried out from time to time for sustaining aquatic bird populations; more native trees and host plants should be planted, which would attract prey base and increase prey abundance (Grutters et al. 2015; Woo et al. 2018; Peterson et al. 2025). Hence, it is required by the Sri Chamarajendra Zoological Gardens to help restore its biodiversity value, bolster flyway stopovers, and model urban wetland management, with speculated Chamundi Hills connectivity. Further follow-up studies of the same lake for a longer period will help to determine the species-specific aquatic and other bird and habitat conservation. Conservation of such wetlands is essential to sustain migratory bird populations, as it is probably an abode during their migratory route, serving a vital role in the conservation of these species (Harisha & Hosetti 2017). Thus, to have a long-term conservation measure, it is necessary to have knowledge about bird species diversity present in an area. The richness of species diversity in the present study site may be attributed to its geographical location, heterogeneity of land characteristics, and number of tree & shrub species, which makes the place more complex structurally.

CONCLUSION

The outcome of the present study highlights the importance of wetland habitat as refugia for avifaunal diversity in urban ecosystems, with Karanji Lake sustaining 94 species and critical guilds despite urbanization pressures, thereby maintaining ecological regulation via pest control and nutrient cycling. Management must prioritize sewage diversion, hyacinth eradication, and zoned tourism to preserve breeding sites for NT species like Painted Stork, preventing trophic cascades from guild loss. The current study not only acts as baseline data from scientific and systematic effort, but also helps in understanding the value of such urban wetlands. Such studies will also aid in monitoring and conserving bird diversity in and around urban areas. Although the present habitat is providing shelter and acting as a breeding ground for many bird species, there is a need for an awareness campaign and bio-monitoring programmes for maintaining and protecting the avian heritage. However, if proper steps are not taken, the available richness of these glorified birds is under threat due to uncontrolled urbanization constraints. These may severely affect the ecological balance and alter the avian diversity of this Lake. Future research should deploy radio-telemetry for hills-lake connectivity and functional trait analyses to quantify resilience thresholds under climate-urban gradients.

REFERENCES

Ahmed, T. & A. Khan (2022). Avifaunal feeding guilds' response to landscape compositional heterogeneity and their drivers in forest mosaic, Uttarakhand, India. Journal of Tropical Ecology 38(4): 183–193. https://doi.org/10.1017/S0266467422000049

Ali, S. & H. Whistler (1942–43). The birds of Mysore. Part I, II and III. Journal of the Bombay Natural History Society. 43:130–147, 318–341, 573–595; 44: 9–26, 208–220.

Bhatnagar, C.C.B et al. (2007). Vanishing habitats of aquatic birds in the city of lakes, Udaipur: a case study. Indian Forester 133(10): 1395–1402.

Bhendekar, G. et al. (2024). Seasonal bird diversity of an urban lake with the history of eutrophication and restoration. Tropical Ecology 65(4): 592–608. https://doi.org/10.1007/s42965-024-00354-9

Bibby, C.J. et al. (2000). Bird Census Techniques. 2nd Edition. Academic Press, London, 302 pp.

BirdLife International (2026). BirdLife is the world leader in Bird Conservation. https://www.birdlife.org/

Buckland, S.T. et al. (2001). Introduction to distance sampling: estimating abundance of biological populations. Oxford University Press, Oxford, UK.

El-Sabaawi, R. (2018). Trophic structure in a rapidly urbanizing planet. Functional Ecology 32(7): 1718–1728. https://doi.org/10.1111/1365-2435.13114

Francl, K.E. & G.D. Schnell (2002). Relationships of human disturbance, bird communities, and plant communities along the land-water interface of a large reservoir. Environmental Monitoring and Assessment 73(1): 67–93. https://doi.org/10.1023/A:1012615314061

Ghosh, M. et al. (2022). Species composition and classification of guilds in birds with respect to food and feeding behavior: evidences from suburban landscape in Hooghly District, West Bengal. Asian Journal of Conservation Biology 11(1): 143–153. https://doi.org/10.53562/ajcb.67216

Gregory, R.D. et al. (2004). The state of play farmland birds: population trends and conservation status of lowland farmland birds in the United Kingdom. Ibis 146: 1–13. https://doi.org/10.1111/j.1474-919X.2004.00358.x

Grimmett, R. et al. (2013). Birds of the Indian Subcontinent. Oxford University Press.

Grutters, B.M. et al. (2015). Native and non-native plants provide similar refuge to invertebrate prey, but less than artificial plants. PLoS One 10(4): e0124455. https://doi.org/10.5061/dryad.11h73

Hagen, E.O. et al. (2017). Impacts of urban areas and their characteristics on avian functional diversity. Frontiers in Ecology and Evolution 5: 84. https://doi.org/10.3389/fevo.2017.00084

Harisha, M.N. & B.B. Hosetti (2017). Conservation status, threats and diversity of wetland birds of Dyamannana lake (Kere), Bhadravathi Taluk, Shivamogga District, Karnataka, India. Environment and Ecology 35(4): 3071–3076.

IUCN (2026). The IUCN Red List of Threatened Species. Version 2025-2. https://www.iucnredlist.org. Accessed on 02.vii.2026.

Jamakhandi, H.S. & G.G. Kadadevaru (2024). Avifaunal diversity and feeding guild structure in and around Unkal Lake: a semiarid urban wetland in Karnataka, India. Indian Journal of Ecology 51(2): 453–467. https://doi.org/10.55362/IJE/2024/4258

Kaur, R. & O.S. Brraich (2021). Abundance and diversity of threatened birds in Nangal Wetland, Punjab, India. Journal of Threatened Taxa 13(12): 19733–19742. https://doi.org/10.11609/jott.4062.13.12.19733-19742

Kumara, H.N. et al. (2010). Preparation of biodiversity conservation plan for Mysore Forest Division. Technical report submitted to Karnataka Forest Department, Mysore Forest Division, Mysore, Karnataka, India.

Meerhoff, M. & M. de los Ángeles González-Sagrario (2022). Habitat complexity in shallow lakes and ponds: importance, threats, and potential for restoration. Hydrobiologia 849(17): 3737–3760. https://doi.org/10.1007/s10750-021-04771-y

Mishra, D. et al. (2007). Birds of Chamundi Hills Reserve Forest, Mysore, Karnataka. Indian Birds 3(3): 82–86.

Mysore Nature (2025). Mysore Nature website. https://www.mysorenature.org/home. Accessed on 02.vii.2026.

Nag, K.C. (2022). Height variations of Great Cormorant *Phalacrocorax carbo sinensis* nests in response to anthropogenic presence at two lakes in Bengaluru, India. Indian Birds 18(3): 74–78.

Nandhini, M. & J. Jagatheeswari (2024). Diversity and conservation of wetland avifauna in Nanjarayan Lake, Tiruppur, Tamil Nadu, India. Uttar Pradesh Journal of Zoology 45(18): 254–267.

Naveen, K.S. et al. (2026). Waterbird assemblage structure, seasonal dynamics and anthropogenic Ppressures in Sengulam Lake, an urban wetland of the Noyyal River Basin, south India. AgroEnvironmental Sustainability 4(2): 157–171. https://doi.org/10.59983/s2026040206

Naveen, K.S. et al. (2025). Avifaunal diversity of Chinnavedampatti Lake: An urban wetland in Coimbatore, Tamil Nadu, India. Journal of Experimental Zoology India 28: 1383–1395. https://doi.org/10.51470/jez.2025.28.2.1383

Oksanen, J. et al. (2025). vegan: Community ecology package. R package version 2.7-2. https://CRAN.R-project.org/package=vegan

Panda, B.P. et al. (2021). Habitat heterogeneity and seasonal variations influencing avian community structure in wetlands. Journal of Asia-Pacific Biodiversity 14(1): 23–32. https://doi.org/10.1016/j.japb.2020.10.001

Peterson, M.I. et al. (2025). Benefits of aquatic vegetation for fish in an ecosystem dominated by an invasive piscivore. Freshwater Biology 70(5): e70045. https://doi.org/10.1111/fwb.70045

Ramachandran, R. et al. (2017). Hunting or habitat? Drivers of waterbird abundance and community structure in agricultural wetlands of southern India. Ambio 46(5): 613–620. https://doi.org/10.1007/s13280-017-0907-9

Ramesh, T. et al. (2020). Abundance, Assemblage, Habitat Characteristics and Seasonal Diversity of Waterbirds at Kalpakkam, South East Coast of India. Asian Journal of Conservation Biology 9(1): 156–166.

R Core Team (2025). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org

RStudio Team (2025). RStudio: Integrated development for R. RStudio, PBC. http://www.rstudio.com/

Schmitt, C.J. & S.V. Edwards (2022). Passerine birds. Current Biology 32(20): R1149–R1154. https://doi.org/10.1016/j.cub.2022.08.061

Sekercioglu, C.H. (2006). Increasing awareness of avian ecological function. Trends in Ecology & Evolution 21(8): 464–471. https://doi.org/10.1016/j.tree.2006.05.007

Sekercioglu, C.H. et al. (2016). Why Birds Matter: Avian Ecological Function and Ecosystem Services. University of Chicago.

Sol, C. et al. (2020). The worldwide impact of urbanisation on avian functional diversity. Ecology Letters 23(6): 962–972. https://doi.org/10.1111/ele.13495

Traut, A.H. & M.E. Hostetler (2004). Urban lakes and waterbirds: effects of shoreline development on avian distribution. Landscape and Urban Planning 69(1): 69–85. https://doi.org/10.1016/j.landurbplan.2003.08.009

Verma, M. et al. (2001). Economic valuation of Bhoj wetland for sustainable use. Unpublished project report for World Bank assistance to Government of India, Environmental Management Capacity-Building, Indian Institute of Forest Management, 35: 1–32, Bhopal.

Wetlands International (2012). Waterbird Population Estimates (5th ed.). Wetlands International, Wageningen, Netherlands.

Wickham, H. (2016). ggplot2: Elegant Graphics for Data Analysis. Springer-Verlag, New York.

Woo, I. et al. (2018). Enhanced invertebrate prey production following estuarine restoration supports foraging for multiple species of juvenile salmonids (*Oncorhynchus* spp.). Restoration Ecology 26(5): 964–975. https://doi.org/10.1111/rec.12658

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 August 2026 | 18(8): 29430–29446

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

https://doi.org/10.11609/jott.10447.18.8.29430-29446

#10447 | Received 09 February 2026 | Final received 11 July 2026 | Finally accepted 01 August 2026

OPEN ACCESS

ARTICLE

A preliminary checklist and seasonal diversity of wetland-associated birds in Bajali District, Assam, India

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Abstract: Wetlands sustain diverse avian assemblages and provide indispensable habitats for resident and migratory waterbirds; however, many wetlands in northeastern India remain inadequately documented. This study presents the first preliminary checklist and diversity assessment of wetland-associated birds from selected wetlands in Bajali District, Assam, northeastern India, based on systematic point-count surveys conducted across five sites between April 2024 and March 2025. Seasonal variations in species composition, abundance, migratory status, feeding guilds, conservation status, and community diversity were comprehensively evaluated. A total of 44 wetland-associated bird species representing 14 families were recorded. Ardeidae was the most species-rich family (10 species; relative diversity index = 22.72%), followed by Scolopacidae (7 species). Bird abundance exhibited pronounced seasonal fluctuations, peaking during winter (2,835 individuals), followed by monsoon (2,601), autumn (2,064), and summer (2,009). Species richness attained its maximum during autumn and winter (44 species each) but declined markedly during the monsoon (29 species). Diversity metrics consistently revealed greater species richness, diversity, evenness, and community stability during the post-monsoon and winter seasons, whereas monsoon assemblages were characterized by reduced diversity and elevated species dominance. Resident species constituted 65.91% of the recorded avifauna, while 34.09% were winter visitors. Most species (95.46%) were classified as 'Least Concern', whereas the Lesser Adjutant and Asian Woollyneck were categorized as 'Near Threatened', underscoring the conservation significance of the study area. This study provides the first comprehensive documentation of wetland-associated birds in Bajali District and highlights the ecological importance of its wetlands in sustaining diverse resident and migratory bird assemblages. The findings establish a valuable reference for long-term biodiversity monitoring, conservation planning, and sustainable wetland management in the lower Brahmaputra floodplain.

Keywords: Abundance, avian assemblages, biodiversity monitoring, community stability, conservation planning, feeding guild, migratory status, seasonal variation, species richness.

Editor: Aditya Srinivasulu, Zoo Outreach Organisation, Hyderabad, India. **Date of publication:** 26 August 2026 (online & print)

Citation: Das, B.K. (2026). A preliminary checklist and seasonal diversity of wetland-associated birds in Bajali District, Assam, India. *Journal of Threatened Taxa* 18(8): 29430–29446. https://doi.org/10.11609/jott.10447.18.8.29430-29446

Funding: No funding agency or project grant was involved in the study, and the work was completed independently.

Competing interests: The author declares no competing interests.

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Acknowledgements: The author is grateful to the authorities of Nalbari College, Assam, for granting permission to conduct this study and for providing necessary support and encouragement during the course of the research. The author also sincerely thank Mr. Nejib Ahmed, wildlife photographer and birdwatcher, and Mr. Prasanna Kalita, president of the environmental conservation NGO Bonyabondhu, for their valuable assistance in bird identification and for their support in various environmental and conservation-related activities.

INTRODUCTION

Birds significantly contribute to ecosystem functionality through pollination, regulation of insect populations, and modification of the physico-chemical properties of their habitats via diverse ecological interactions (Fraixedas et al. 2020; Basile et al. 2021). Consequently, avian species richness, community composition, habitat utilization patterns, and population dynamics are widely recognized as robust indicators of environmental quality, resource availability, and overall ecosystem health (Lindenmayer et al. 2006; Tanalgo et al. 2015). Birds occupy multiple trophic levels within food webs and play essential roles in ecological networks through predation, seed dispersal, scavenging, nutrient cycling, and other ecosystem functions, thereby contributing to ecosystem stability and resilience (Michel et al. 2020; Tobias et al. 2020; Signa et al. 2021**).**

Within urban landscapes, the availability and management of large green spaces are critical for the long-term persistence and conservation of avian assemblages (Campbell et al. 2022; Choudaj & Shaha 2023). Spatial heterogeneity in avian abundance and species richness can exert cascading effects on both terrestrial and aquatic ecosystems, which are ecologically linked through complex trophic pathways (Turner 2003). Nevertheless, a marked decline in bird populations—particularly within highly urbanized environments—has emerged as a growing ecological concern, closely associated with increasing levels of urban development and environmental pollution (Donaldson et al. 2007). Furthermore, climatic stability and seasonal variability function as key determinants of avian diversity, strongly influencing species distributions and community structure (Graham et al. 2006).

Accelerated urban expansion has substantially transformed natural landscapes, altered ecological processes, and modified ecosystem structure and functioning (Basu & Das 2021; Hersperger et al. 2021). Urbanization results in habitat loss, fragmentation, and degradation, leading to significant reductions in the diversity of plants, insects, and vertebrate taxa, with birds being among the most sensitive to these changes (Carrasco et al. 2018). Mitigating the negative impacts of urban growth on biodiversity and achieving a sustainable balance between anthropogenic development and ecological integrity therefore constitute major objectives of contemporary urban planning and biodiversity conservation research (Canedoli et al. 2018). As the most widespread and ecologically responsive vertebrate group in urban ecosystems, birds serve as reliable bioindicators of environmental conditions and biodiversity status (Shwartz et al. 2014). Given their ecological importance and contributions to human well-being in urban environments (Fuller et al. 2007), avian-focused research is particularly essential in regions experiencing rapid urbanization.

Wetland ecosystems are among the most productive and biologically rich environments on Earth, yet they are highly fragile and sensitive to disturbance (Gibbs 1993; Van der Valk 2006). These ecosystems are primarily structured by hydrological processes, including water availability, hydroperiod, and local water cycles, which strongly influence species composition, habitat structure, and overall biodiversity (Urban 2004; Bronmark & Hansson 2005). Variations in hydrological regimes regulate ecological filtering and species assemblage patterns, making water dynamics a key driver of wetland community organization. Freshwater wetlands, particularly lakes and riverine systems, are of immense ecological and socio-economic importance, supporting agriculture, fisheries, livestock, and drinking water supplies while sustaining high biodiversity. They also provide critical ecosystem services such as flood regulation, groundwater recharge, nutrient retention, sediment control, and erosion mitigation (Mitsch & Gosselink 1986). However, increasing anthropogenic pressures—including agricultural expansion, aquaculture, industrial discharge, waste disposal, land reclamation, and dredging—have severely altered wetland structure and function, threatening both biodiversity and ecosystem services (Balachandran et al. 2002; Naveen et al. 2025).

Waterbirds, defined as bird species ecologically dependent on wetlands, constitute a major faunal component of these ecosystems. They occupy multiple trophic levels within wetland food webs and play an important role in nutrient cycling, prey–predator regulation, and ecosystem stability (Custer & Osborne 1977; Rajashekara & Venkatesha 2010). Because waterbirds respond rapidly to environmental change, their population trends and community structure serve as reliable biological indicators of wetland health and water quality (Grimmett & Inskipp 2007). Their assemblages are regulated by food availability, wetland size, habitat heterogeneity, productivity, and the duration and timing of flooding cycles (Cintra et al. 2007; Gajardo et al. 2009; Khan 2010; Cintra 2012; Rajpar 2022). Temporal factors, such as seasonal variations, tidal cycles, and climatic conditions, influence the quality and resource availability, thereby shaping waterbird abundance and assemblage structure in wetlands (Khan 2010; Pandiyan et al. 2010; Byju et al. 2025c). Wetlands containing diverse microhabitats, such as shallow open water, marshes, mudflats, and aquatic vegetation, generally support higher waterbird diversity by providing essential feeding, nesting, and roosting resources (Paracuellos 2006; Manikannan et al. 2011; Arya et al. 2014; Mathibalan et al. 2026).

In addition to natural wetlands, agricultural and agroforestry landscapes also contribute significantly to bird conservation, as protected areas cover only a limited proportion of land (Sundar & Subramanya 2010). Agroecosystems provide diverse food resources, including grains, seeds, fruits, insects, and small vertebrates, supporting avian communities that function both as crop pests and as natural pest-control agents (O'Connor & Shrubb 1986; Borad et al. 2000; Haslem & Bennett 2008; Asokan et al. 2009). Furthermore, birds contribute to seed dispersal, pollination, scavenging, and nutrient cycling, thereby enhancing ecosystem functioning in both natural and human-modified landscapes (Dhindsa & Saini 1994; Whelan et al. 2008; Sekercioglu 2012). Bird diversity in agricultural systems is strongly influenced by crop type, vegetation structure, land-use practices, and landscape composition, including the presence of wetlands, forest patches, grasslands, and agroforestry trees (Taft & Haig 2006; Bruggisser et al. 2010; Wretenberg et al. 2010).

Although wetland bird communities have been studied in several ecologically important wetlands of Assam and other parts of northeastern India, these investigations are largely restricted to protected areas and a few well-known floodplain wetlands. Consequently, many district-level wetlands remain poorly documented, resulting in limited knowledge of their avifaunal diversity, community composition, seasonal dynamics, and habitat use. Bajali District, situated in the lower Brahmaputra valley of western Assam and adjoining the foothills of Bhutan, contains a network of natural and human-modified wetlands that are likely to provide important habitats for both resident and migratory waterbirds. Despite their ecological significance, these wetlands have received little scientific attention, and baseline information on their bird communities is lacking. The present study was therefore undertaken to prepare the first preliminary checklist of wetland-associated birds and document their diversity, abundance, and seasonal dynamics in selected wetlands of Bajali District, Assam. The findings provide baseline ecological information to support long-term biodiversity monitoring, conservation planning, and sustainable wetland management in this understudied region.

MATERIALS AND METHODS

Study area

Bajali District, located in the western part of Assam, India, was formally established on 12 January 2021 following its separation from Barpeta District, where it previously functioned as a subdivision. The district is bordered by Baksa District to the north, Nalbari District to the east, and Barpeta District to the west and south. The administrative headquarters is situated at Madan Rauta Nagar in Pathsala. Geographically, Bajali lies between 26.7333–26.8333 °N and 91.0667–91.4000 °E, covering a total area of approximately 422.95 km² (163.30 square miles), which is comparable in size to the country of Barbados.

Bajali District is characterized by a heterogeneous landscape comprising low-lying alluvial plains interspersed with gentle uplands and traversed by several minor river systems, including the Palla, Deojara, Pahumara, and Kaldia, which render the area highly flood-prone. The district lies within Seismic Zone V, reflecting a high level of tectonic vulnerability. Its economy is predominantly agrarian, supported by fertile alluvial soils that sustain crops such as rice, mustard, and a variety of vegetables. The climate is tropical monsoonal, with hot and humid summers, heavy rainfall from May to September, and relatively cool, overcast winters. Vegetation is dominated by wet broadleaf forests containing sal, teak, mahogany, bamboo, and diverse fruit-bearing species. The district also hosts ecologically significant wetlands rich in aquatic macrophytes such as lotus and water lilies, underscoring Bajali's role as an important biodiversity reservoir within the Brahmaputra Valley. Bajali experiences a humid subtropical climate with hot, moisture-laden summers and cool, overcast winters. Peak rainfall occurs from May to September, followed by a mild post-monsoon period, while February–April remain comparatively dry. Seasonal flooding of the Kaldiya and Pahumara rivers frequently results in hydrological stress and socio-environmental disruption across the district.

Bird surveys

Surveys of wetland-associated birds in Bajali District were conducted from April 2024 to March 2025 using the point count method (Ralph et al. 1995; Drapeau et al. 1999; Bibby et al. 2000). A total of five-point count stations were established across the landscape (Table 1; Image 1), spaced 1.0–2.5 km apart to minimize the likelihood of double counting (Ralph et al. 1995). The sampling sites were randomly selected from relatively

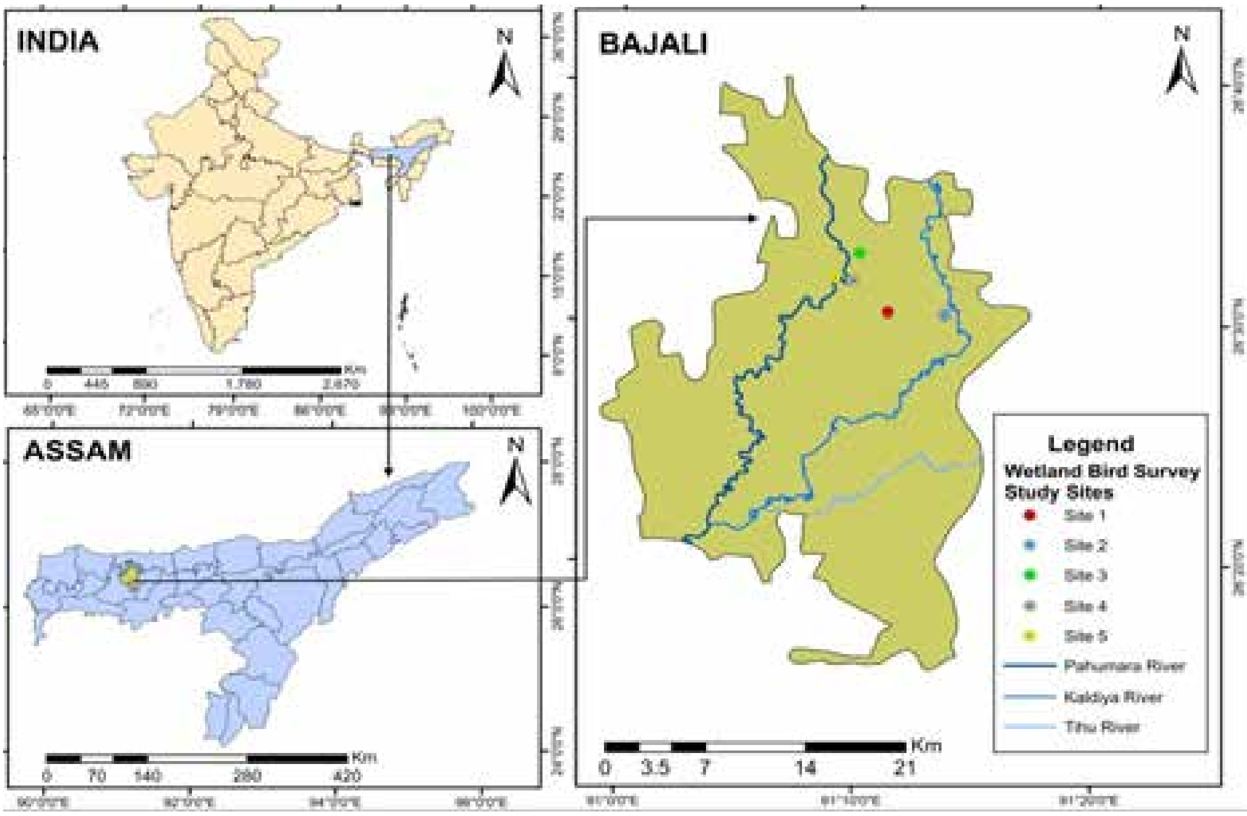

Image 1. Location map of the wetland-associated bird survey sites in Bajali District, Assam, India. Prepared using ArcGIS 10.2.

Table 1. The geographic coordinates, elevation, and habitat characteristics of the five bird survey sites.

	Survey sites	Coordinates		Habitat type and vegetation characteristics	Elevation (in m)
		Latitude (°N)	Longitude (°E)		
1	Site-1	26.5071	91.1876	Grass embankments of village ponds with standing freshwater and emergent aquatic vegetation	44
2	Site-2	26.5055	91.2272	Marshlands with extensive reedbeds fringing permanent wetlands	47
3	Site-3	26.5481	91.1671	Damp grasslands interspersed with cultivated paddy fields	49
4	Site-4	26.5287	91.1625	Seasonally flooded grasslands associated with rice-growing areas	47
5	Site-5	26.5310	91.1500	Riverbank habitats with riparian vegetation	45

species-rich areas, with site selection guided by vegetation structure, food availability, and overall habitat suitability for bird communities. The selected locations represented a range of habitat complexes supporting varying levels of wetland-associated bird species richness and community composition (Table 1). Surveys were conducted two days per week, twice daily between 0600–0900 h and 1500–1700 h under favorable weather conditions, and were postponed during periods of heavy rainfall or strong winds to minimize observational bias. Precise GPS coordinates were recorded for each station to ensure spatial accuracy. At each station, observers allowed a brief acclimatization period before initiating counts to reduce disturbance (Hostetler & Main 2001). Birds were then recorded during a 15-minute observation period, including all individuals detected visually or aurally within an unlimited radius (Drapeau et al. 1999; Bibby et al. 2000). Species identification was carried out using standard field guides (Kazmierczak 2002; Grimmett et al. 2016; Grewal et al. 2018), based on morphological characteristics, size, plumage, and vocalizations. When identification was uncertain, photographic and audio records were obtained for later verification. Observations were made using binoculars (Nikon, Monarch, 10 × 42 mm) and a spotting scope (20 × 60), with additional documentation captured using a Nikon

D7500 camera. Diversity indices were calculated using PAST software (version 4.03). The global conservation status of each species was determined following the IUCN Red List. Species were classified according to their frequency of occurrence during repeated field surveys following the classification proposed by Mackinnon & Phillips (1993) and subsequently adopted by Byju et al. (2024). Species recorded on 6–8 out of every 10 survey visits were categorized as Common (C), those observed on 3–5 out of 10 visits as Uncommon (UC), and those detected on only 1–2 out of every 10 survey visits as Rare (R). In addition, the relative diversity of each bird family was estimated using the relative diversity index (RDi) following Koli (2014), calculated as:

$$\text{RDi} = \frac{\text{Number of species in a family}}{\text{Total number of species recorded}} \times 100$$

Field observations conducted throughout the study period, together with information from standard ornithological literature (Ali et al. 1996; Feijen & Feijen 2008; Grimmett et al. 2016; Billerman et al. 2022), were used to assign all recorded bird species to seasonal occurrence categories comprising resident species, winter visitors, and summer migrants, as well as to feeding guilds comprising granivores, frugivores, nectivores, insectivores, carnivores, and omnivores. Assamese vernacular names were compiled and cross-verified using published regional sources (Gogoi 2006; Dutta 2011; Datta 2017).

RESULTS AND DISCUSSION

Species composition and seasonal abundance of wetland-associated birds

A total of 44 wetland-associated bird species, representing 14 avian families, were recorded from the selected wetlands of the Bajali landscape during the study period (April 2024–March 2025) (Table 2). The recorded assemblage comprised both resident and migratory species occupying diverse ecological niches within the wetland ecosystem, indicating the importance of these habitats in supporting a taxonomically diverse avifaunal community.

Seasonal surveys conducted during summer (pre-monsoon; March–May), monsoon (June–September), autumn (post-monsoon; October–November), and winter (December–February) revealed pronounced temporal variation in bird abundance (Table 3). The total abundance was highest during winter (2,835 individuals), followed by monsoon (2,601 individuals), autumn (2,064 individuals) and summer (2,009 individuals). The marked increase in winter abundance was primarily associated with the seasonal arrival of migratory waterbirds, whereas relatively lower abundance during summer reflected the predominance of resident species prior to the onset of migration.

Seasonal fluctuations were also evident in species richness, reflecting changes in community composition throughout the annual hydrological cycle. Wetland habitats supported a greater diversity of species during autumn and winter, whereas comparatively

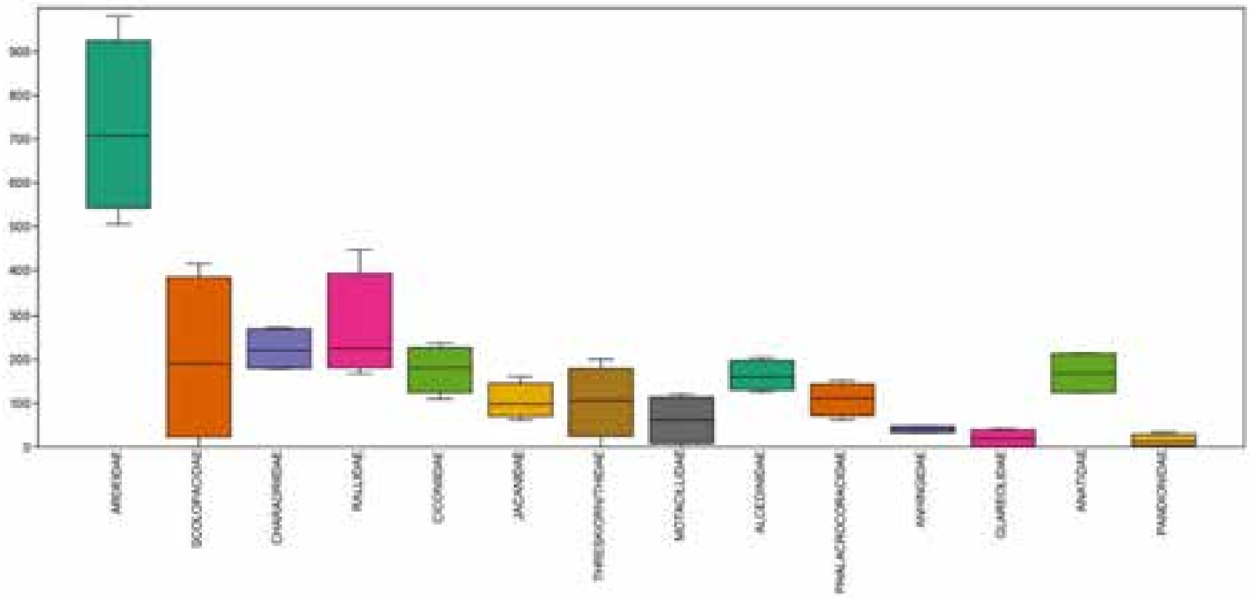

Image 2. Box plots illustrating variation in the abundance of wetland-associated bird families.

Table 2. Checklist of wetland-associated bird species recorded in Bajali District, Assam, with taxonomic details, local names, habitat, feeding guilds, abundance, phenology, and conservation status.

	Family	English name	Scientific name	Local name/ Assamese name	IUCN Red List status	IWPA	Habitat location	Feeding habits/ Feeding guilds	Abundance status	Phenological status
1	Ardeidae	Little Egret	*Egretta garzetta* (Linnaeus, 1766)	টেটেৰী বগ	LC	Schedule II	WE, OW, T	CA	COM	R
2		Grey Heron	*Ardea cinerea* (Linnaeus, 1758)	হালখেদা	LC	Schedule II	WE	CA	COM	R
3		Indian Pond Heron	*Ardeola grayii* (Sykes, 1832).	কণামুচৰি	LC	Schedule II	WE	CA	COM	R
4		Yellow Bittern	*Ixobrychus sinensis* (Gmelin, 1789).	হালধি কণা/ হালধীয়া বগুলা	LC	Schedule II	WE	CA	UNCOM	R
5		Great Egret	*Ardea alba* (Linnaeus, 1758)	বৰ বগ	LC	Schedule II	OW, WE, T	CA	COM	R
6		Cattle Egret	*Bubulcus ibis* (Linnaeus, 1758)	গো বগ	LC	Schedule II	WE	CA	COM	R
7		Purple Heron	*Ardea purpurea* (Linnaeus, 1766)	আজান	LC	Schedule II	OW, WE	CA	UNCOM	R
8		Medium Egret	*Ardea intermedia* (Wagler, 1829.)	মাজু বগ	LC	Schedule II	OW, WE	CA	COM	R
9		Cinnamon Bittern	*Ixobrychus cinnamomeus* (Gmelin, 1789).	ইটাগুড়ীয়া	LC	Schedule II	WE	CA	LOC COM	R
10		Black- crowned Night Heron	*Nycticorax nycticorax* (Linnaeus, 1758)	ৰাক চৰাই	LC	Schedule II	WE	CA	UNCOM	R
11	Scolopacidae	Common Sandpiper	*Actitis hypoleucos* (Linnaeus, 1758).	বালি খোঁচৰা	LC	Schedule II	WE	CA	COM	WM
12		Marsh Sandpiper	*Tringa stagnatilis* (Bechstein, 1803)	বোকাপানী খোঁচৰা / পিতনিৰ বালি খোঁচৰা	LC	Schedule II	OW, WE	CA	UNCOM	WM
13		Common Greenshank	*Tringa nebularia* (Gunnerus, 1767).	পাত ঠেঙী	LC	Schedule I	OW, WE	CA	UNCOM	WM
14		Green Sandpiper	*Tringa ochropus* (Linnaeus, 1758)	বালি বগুৰা/ সেউজীয়া বালি খোঁচৰা	LC	Schedule II	WE	CA	RARE	WM
15		Common Snipe	*Gallinago gallinago* (Linnaeus, 1758)	চেৰেকা চৰাই / বালিটোকা	LC	Schedule II	WE	CA	UNCOM	WM
16		Spotted Redshank	*Tringa erythropus* (Pallas, 1764).	ফুটুকী ৰঙা বালি খোঁচৰা	LC	Schedule II	OW, WE	CA	UNCOM	WM
17		Temminck's Stint	*Calidris temminckii* (Leisler, 1812)		LC	Schedule II	OW, WE	CA	UNCOM	WM
18	Charadriidae	Pacific Golden Plover	*Pluvialis fulva* (Gmelin, 1789)	সোণালী লৰিয়লি	LC	Schedule I	OW, WE	OM	UNCOM	WM
19		Grey-headed Lapwing	*Vanellus cinereus* (Blyth, 1842).	দলঘোঁৰা	LC	Schedule II	WE	INSEC	COM	WM
20		Red-wattled Lapwing	*Vanellus indicus* (Boddaert, 1783)	বালিঘোঁৰা / টিটিহুট	LC	Schedule II	WE	OM	COM	R
21		Little Ringed Plover	*Charadrius dubius* (Scopoli, 1786.)	সৰু লৰিয়লি	LC	Schedule II	WE	CA	UNCOM	R

	Family	English name	Scientific name	Local name/ Assamese name	IUCN Red List status	IWPA	Habitat location	Feeding habits/ Feeding guilds	Abundance status	Phenological status
22	Rallidae	White-breasted Waterhen	*Amaurornis phoenicurus* (Pennant, 1769).	ডাউক	LC	Schedule II	WE	OM	COM	R
23		Watercock	*Gallicrex cinerea* (Gmelin, 1789)	পানী কুকুৰা	LC	Schedule II	WE	OM	UNCOM	R
24		Grey-headed Swamphen	*Porphyrio poliocephalus* (Latham, 1801).	কাম চৰাই	NE	Schedule II	WE	OM	COM	R
25		Common Moorhen	*Gallinula chloropus* (Linnaeus, 1758).	দেশী কোৰা ঢেকৰ	LC	Schedule II	WE	OM	COM	R
26	Ciconiidae	Asian Openbill	*Anastomus oscitans* (Boddaert, 1783).	শামুক ভঙা	LC	Schedule II	WE	CA	COM	R
27		Lesser Adjutant Stork	*Leptoptilos javanicus* (Horsfield, 1821).	বৰটোকোলা/ হদং	NT	Schedule I	WE	CA	LOC COM	R
28		Asian Woollyneck	*Ciconia episcopus* (Boddaert, 1783).	কনুৱা চৰাই	NT	Schedule IV	WE	CA	LOC COM	R
29	Jacanidae	Bronze-winged Jacana	*Metopidius indicus* (Latham, 1790).	দলপুঙা	LC	Schedule II	WE	OM	COM	R
30		Pheasant-tailed Jacana	*Hydrophasianus chirurgus* (Scopoli, 1786).	দলম'ৰা/ জলময়ূৰ	LC	Schedule II	WE	OM	COM	R
31	Threskiornithidae	Black-headed Ibis	*Threskiornis melanocephalus* (Latham, 1790).	আঁকুহী বগ	LC	Schedule II	WE	CA	COM	WM
32		Glossy Ibis	*Plegadis falcinellus* (Linnaeus, 1766).	ইটাগুড়ীয়া আঁকুহী বগ	LC	Schedule II	WE	CA	LOC COM	WM
33	Motacillidae	White Wagtail	*Motacilla alba* (Linnaeus, 1758)	বগা বালিমাহী/ খঞ্জন	LC	Schedule II	WE	INSEC	COM	WM
34		Citrine Wagtail	*Motacilla citreola* (Pallas, 1776)	হালধিমূৰীয়া বালিমাহী	LC	Schedule II	WE, WA	INSEC	COM	WM
35	Alcedinidae	Stork-billed Kingfisher	*Pelargopsis capensis* (Linnaeus, 1766)	বৰটোকোলাঠুঁটীয়া মাছৰোকা	LC	Schedule II	T	CA	LOC COM	R
36		White-throated Kingfisher	*Halcyon smyrnensis* (Linnaeus, 1758)	বগাবুকুৱা মাছৰোকা	LC	Schedule II	T	CA	COM	R
37		Common Kingfisher	*Alcedo atthis* (Linnaeus, 1758)	সাধাৰণ মাছৰোকা	LC	Schedule II	T	CA	COM	R
38		Pied Kingfisher	*Ceryle rudis* (Linnaeus, 1758)	পখৰা মাছৰোকা	LC	Schedule II	T	CA	COM	R
39	Phalacrocoracidae	Little Cormorant	*Phalacrocorax niger* (Vieillot, 1817)	পানী কাউৰী	LC	Schedule II	OW	CA	COM	R
40	Anhingidae	Oriental Darter	*Anhinga melanogaster* (Pennant, 1769)	মণিয়ৰি	LC	Schedule II	OW, WE, T	CA	LOC COM	R
41	Glareolidae	Small Pratincole	*Glareola lacteal* (Temminck, 1820)	তিতিয়লী	LC	Schedule II	OW	INSEC	UNCOM	R
42	Anatidae	Lesser Whistling Duck	*Dendrocygna javanica* (Horsfield, 1821)	শৰালি হাঁহ	LC	Schedule II	OW	OM	COM	R
43		Ruddy Shelduck	*Tadorna ferruginea* (Pallas, 1764)	চাকৈ-চকোৱা	LC	Schedule II	OW	OM	COM	WM
44	Pandionidae	Osprey	*Pandion haliaetus* (Linnaeus, 1758)	চিল কুৰুৱা	LC	Schedule I	OA, WA	**Pisc**	UNCOM	WM

OA—Open Area | OW—Open Water | WE—Water Edge | T—Trees | WA—Water Associated | COM—Common | UNCOM—Uncommon | LOC COM—Locally common | CA—Carnivorous | INSEC—Insectivorous | OM—Omnivorous | Pisc—Piscivorous | R—Resident | WM—Winter Migrant | LC—Least Concern | NT—Near Threatened.

fewer species were encountered during the monsoon. These seasonal differences indicate that hydrological fluctuations strongly influence the availability of suitable foraging and roosting habitats, thereby regulating the distribution and abundance of wetland-associated birds. Similar seasonal patterns have been reported from other wetland ecosystems in India, where post-monsoon habitat stabilization and winter migration substantially enhance bird diversity and abundance (Verma 2008; Nair & Krishna 2013; Kar & Debata 2019).

Overall, the observed seasonal variation demonstrates that the wetland bird community in the Bajali landscape is strongly influenced by annual hydro-climatic conditions. The higher abundance recorded during winter highlights the ecological significance of these wetlands as important seasonal habitats for migratory waterbirds, whereas the persistence of numerous resident species throughout the year emphasizes their role in sustaining breeding and foraging populations under varying environmental conditions. These findings are consistent with studies demonstrating that seasonal abundance, species composition, and migration dynamics of wetland birds are closely regulated by habitat quality, hydrological conditions, prey availability, and anthropogenic disturbances, which collectively determine habitat suitability and community structure (Ellis et al. 2021; Jagadeesan & Pandiyan 2021; Kularatne 2021; Rashiba et al. 2022).

Family composition and seasonal dynamics

The wetland-associated bird assemblage exhibited marked variation in taxonomic composition and seasonal abundance among avian families (Image 2; Table 3). Based on relative diversity (RDi), Ardeidae was the most species-rich family, comprising 10 species (RDi = 22.72%), followed by Scolopacidae with seven species (RDi = 15.90%). Rallidae, Charadriidae, and Alcedinidae were each represented by four species (RDi = 9.09%), while Ciconiidae included three species (RDi = 6.81%). Jacanidae, Threskiornithidae, Motacillidae, and Anatidae each contributed two species (RDi = 4.54%), whereas Phalacrocoracidae, Anhingidae, Glareolidae, and Pandionidae were represented by a single species each (RDi = 2.27%). The predominance of Ardeidae and Scolopacidae indicates that the wetlands provide a broad range of shallow-water and marsh habitats capable of supporting taxonomically diverse wading and shorebird communities.

Pronounced seasonal variation was evident in family-level abundance, although species within individual families differed considerably in their numerical dominance and seasonal occurrence (Image 3). These patterns indicate that family-level abundance was primarily influenced by a limited number of dominant species rather than by uniform contributions from all constituent species.

Among all families, Ardeidae remained the most abundant throughout the study period, with abundance increasing from 758 individuals in summer to a peak of 981 individuals during the monsoon, before declining to 505 individuals in autumn and increasing slightly to 657 individuals in winter. This dominance was largely attributable to the Cattle Egret *Bubulcus ibis* (651 individuals) and Indian Pond Heron *Ardeola grayii* (624 individuals), followed by the Purple Heron *Ardea purpurea* (444 individuals). The remaining species, including the Great Egret *Ardea alba* (228 individuals), Medium Egret *Ardea intermedia* (228 individuals), Little Egret *Egretta garzetta* (215 individuals), Cinnamon Bittern *Ixobrychus cinnamomeus* (156 individuals), Grey Heron *Ardea cinerea* (155 individuals), Black-crowned Night Heron *Nycticorax nycticorax* (109 individuals), and Yellow Bittern *Ixobrychus sinensis* (91 individuals) occurred in comparatively lower numbers. The consistently high abundance of Ardeidae reflects the availability of shallow-water foraging habitats and abundant aquatic prey throughout much of the year, particularly during the monsoon when extensive inundation enhances feeding opportunities for herons and egrets.

In contrast, Scolopacidae exhibited the most pronounced seasonal variation among all recorded families. The family was absent during the monsoon, moderately represented during summer (91 individuals), increased substantially during autumn (290 individuals), and attained its highest abundance during winter (415 individuals). Although the family showed a pronounced seasonal influx, abundance was unevenly distributed among species. The Common Snipe *Gallinago gallinago* (215 individuals) was the dominant representative, followed by the Common Greenshank *Tringa nebularia* (130 individuals), Green Sandpiper *Tringa ochropus* (126 individuals), Common Sandpiper *Actitis hypoleucos* (110 individuals), and Marsh Sandpiper *Tringa stagnatilis* (106 individuals), whereas Temminck's Stint *Calidris temminckii* (66 individuals) and Spotted Redshank *Tringa erythropus* (43 individuals) were comparatively less abundant. The complete absence of Scolopacidae during the monsoon, followed by a substantial increase during autumn and winter, highlights the importance of exposed mudflats and shallow wetlands created after floodwaters recede, providing favourable foraging

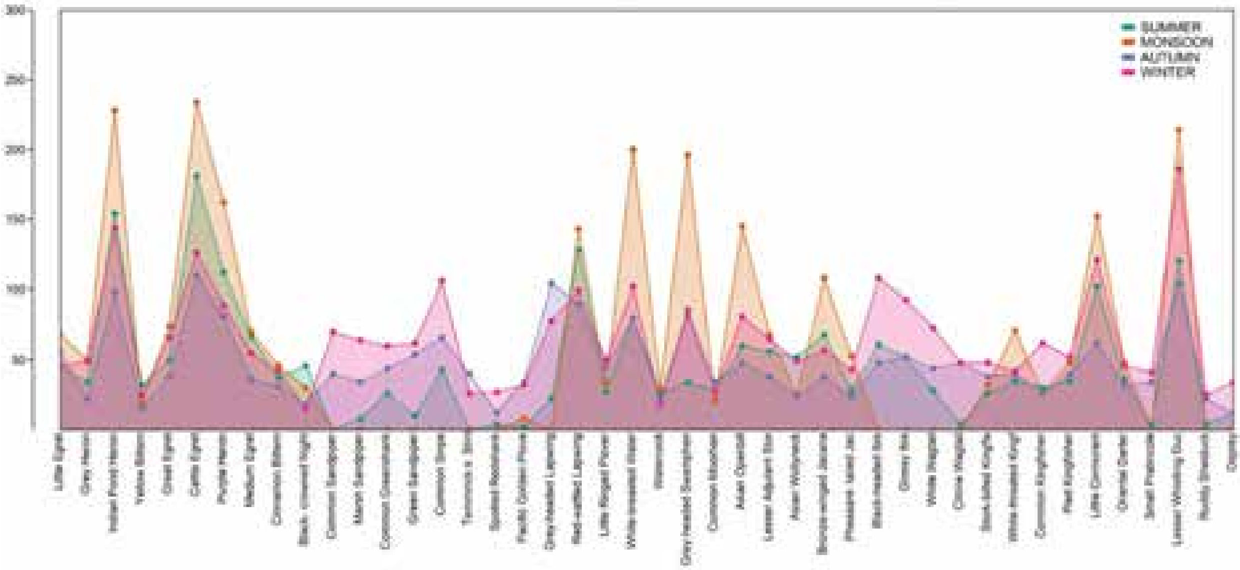

Image 3. Species-wise seasonal variation in the abundance of wetland associated birds recorded from Bajali District, Assam.

Table 3. Seasonal abundance of wetland-associated bird families and their relative diversity in the Bajali District, Assam.

Name of the family	Number of species observed	Relative diversity (%)	Seasons with no of individuals observed			
			Summer (pre-monsoon)	Monsoon	Autumn (post monsoon)	Winter
Ardeidae	10	22.72	758	981	505	657
Scolopacidae	7	15.90	91	0	290	415
Charadriidae	4	9.09	179	184	273	259
Rallidae	4	9.09	168	446	222	230
Ciconiidae	3	6.81	168	238	110	195
Jacanidae	2	4.54	96	161	62	100
Threskiornithidae	2	4.54	113	0	100	201
Motacillidae	2	4.54	32	0	92	121
Alcedinidae	4	9.09	126	177	144	204
Phalacrocoracidae	1	2.27	102	152	62	121
Anhingidae	1	2.27	36	48	32	46
Glareolidae	1	2.27	4	0	34	41
Anatidae	2	4.54	124	214	126	211
Pandionidae	1	2.27	12	0	12	34
Total	**44**		**2009**	**2601**	**2064**	**2835**

habitats for migratory shorebirds.

Rallidae reached its maximum abundance during the monsoon (446 individuals) and declined during autumn (222 individuals), winter (230 individuals), and summer (168 individuals). This seasonal pattern was largely driven by the White-breasted Waterhen *Amaurornis phoenicurus* (462 individuals) and Grey-headed Swamphen *Porphyrio poliocephalus* (398 individuals), whereas the Common Moorhen *Gallinula chloropus* (111 individuals), and Watercock *Gallicrex cinerea* (95 individuals) occurred less frequently. The predominance of these marsh-dependent species during the rainy season corresponds with the expansion of emergent vegetation and shallow inundated habitats, which provide suitable nesting, shelter, and feeding sites.

Charadriidae was recorded throughout the year, with abundance increasing from 179 individuals in summer to 273 individuals in autumn, followed by a slight decline

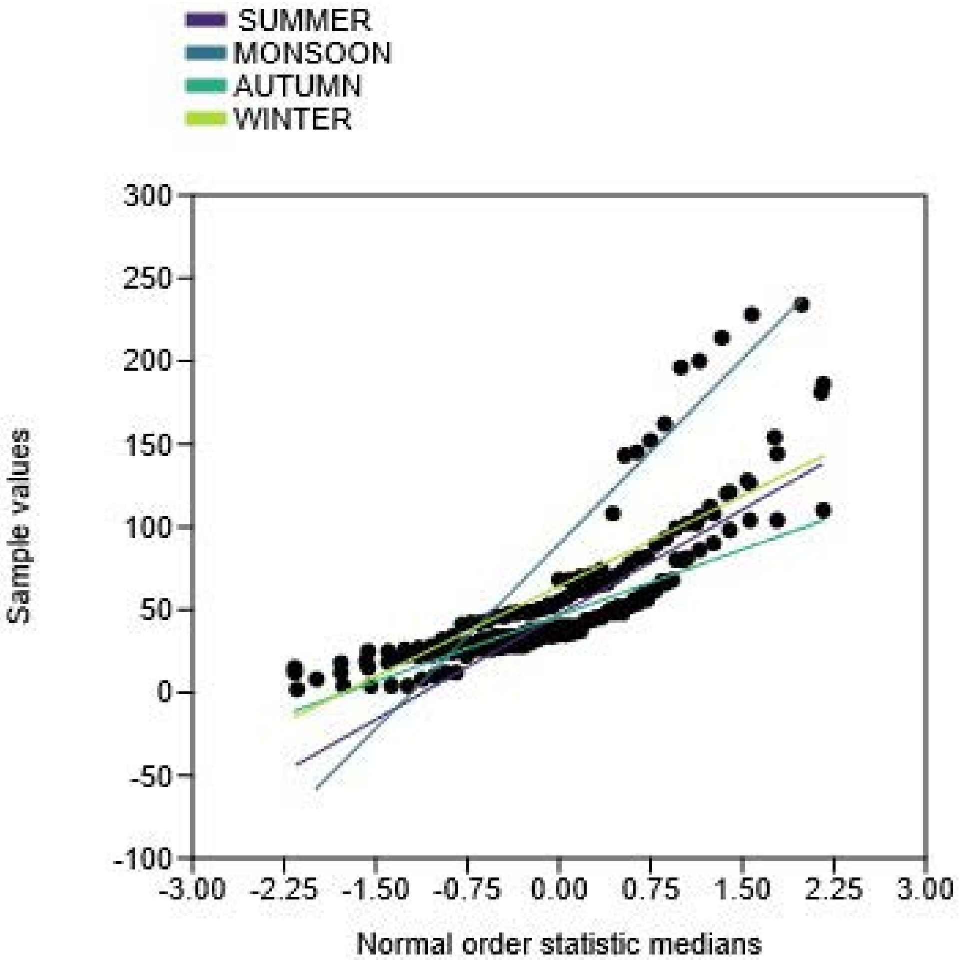

Image 4. Normal quantile–quantile (Q–Q) plot illustrating the distribution of seasonal abundances of wetland-associated bird species.

to 259 individuals in winter. Family abundance was dominated by the Red-wattled Lapwing *Vanellus indicus* (460 individuals), while the Grey-headed Lapwing *Vanellus cinereus* (204 individuals), Little Ringed Plover *Charadrius dubius* (155 individuals), and Pacific Golden Plover *Pluvialis fulva* (76 individuals) were comparatively less abundant. Similarly, Ciconiidae reached its highest abundance during the monsoon (238 individuals) and lowest abundance during autumn (110 individuals). The Asian Openbill *Anastomus oscitans* (334 individuals) was the dominant species within the family, followed by the Lesser Adjutant *Leptoptilos javanicus* (227 individuals) and Asian Woollyneck *Ciconia episcopus* (150 individuals). The seasonal occurrence of these large wading birds reflects fluctuations in water depth and prey availability across the wetlands.

Comparable species-level variation was also observed among the remaining families. Within Jacanidae, the Bronze-winged Jacana *Metopidius indicus* (271 individuals) was more abundant than the Pheasant-tailed Jacana *Hydrophasianus chirurgus* (148 individuals). In Threskiornithidae, the Black-headed Ibis *Threskiornis melanocephalus* (217 individuals) slightly outnumbered the Glossy Ibis *Plegadis falcinellus* (197 individuals). Motacillidae was represented predominantly by the White Wagtail *Motacilla alba* (145 individuals) compared with the Citrine Wagtail *Motacilla citreola* (100 individuals). Among Alcedinidae, the White-throated Kingfisher *Halcyon smyrnensis* (188 individuals) occurred more frequently than the Pied Kingfisher *Ceryle rudis* (175 individuals), Common Kingfisher *Alcedo atthis* 144 individuals), and Stork-billed Kingfisher *Pelargopsis capensis* (144 individuals). Likewise, Anatidae was overwhelmingly dominated by the Lesser Whistling Duck *Dendrocygna javanica* (624 individuals), whereas the Ruddy Shelduck *Tadorna ferruginea* (51 individuals) occurred only occasionally.

Overall, the observed family-level patterns demonstrate that wetland bird assemblages in the Bajali landscape are strongly structured by seasonal

Table 4. Seasonal variation in diversity indices of the wetland-associated bird community in the study area.

Indices	Summer (pre-monsoon)	Monsoon	Autumn (post-monsoon)	Winter
Taxa_S	42	29	44	44
Individuals	2009	2601	2064	2835
Dominance_D	0.0405	0.05524	0.02905	0.0292
Simpson_ 1-D	0.9595	0.9448	0.971	0.9708
Shannon_H	3.426	3.08	3.655	3.654
Evenness_e H/S	0.732	0.7505	0.8791	0.8777
Menhinick	0.937	0.5686	0.9685	0.8264
Margalef	5.391	3.561	5.634	5.409
Fisher_alpha	7.509	4.57	7.9	7.393
Berger-Parker	0.09009	0.08997	0.05329	0.06561

hydrological changes and species-specific ecological requirements. Resident families such as Ardeidae, Rallidae, Jacanidae, Alcedinidae, and Anhingidae persisted throughout the year, whereas migratory families, particularly Scolopacidae, together with Threskiornithidae, Motacillidae, Glareolidae, and Pandionidae, exhibited marked seasonal occurrence, becoming most abundant during the post-monsoon and winter periods. These findings emphasize the complementary ecological roles of permanent wetlands and seasonally exposed mudflats in sustaining both resident and migratory wetland bird communities, supporting previous studies that identified seasonal habitat quality, hydrological variability, and migration dynamics as major drivers of shorebird and waterbird assemblages (Jagadeesan & Pandiyan 2021; Ma et al. 2021).

Community characteristics

The wetland-associated bird community of the Bajali landscape exhibited distinct patterns in species occurrence, migratory status, conservation status, and feeding guild composition (Table 2), reflecting the ecological heterogeneity and seasonal resource availability of the wetland ecosystem.

Based on the frequency of occurrence, the avifaunal community was dominated by common species, comprising 24 species (54.55%), followed by uncommon species (13 species; 29.55%), locally common species (6 species; 13.64%), and a single rare species (1 species; 2.27%). The predominance of common species suggests that the study wetlands provide relatively stable environmental conditions capable of supporting persistent populations of several wetland-associated birds throughout the annual cycle. Conversely, the limited representation of rare species may reflect species-specific habitat preferences, naturally low population densities, or seasonal occurrence within the study area.

Analysis of migratory status showed that resident species constituted the major component of the wetland bird assemblage, accounting for 65.91% (29 species) of the total recorded species, whereas winter visitors comprised the remaining 34.09% (15 species). The dominance of resident species indicates that the wetlands provide suitable breeding, nesting, and foraging habitats throughout the year. In contrast, the substantial contribution of winter migratory species demonstrates the seasonal importance of these wetlands as feeding and resting habitats along regional migratory routes. Similar dominance of resident species accompanied by a pronounced winter influx of migratory waterbirds has been documented from other wetland ecosystems across India (Verma 2008; Nair & Krishna 2013; Kar & Debata 2019), highlighting the importance of maintaining habitat quality for both resident and migratory populations.

Assessment of conservation status based on the IUCN Red List revealed that the majority of recorded species were classified as 'Least Concern' (42 species; 95.46%), whereas only two species (4.54%), namely the Lesser Adjutant *Leptoptilos javanicus* and the Asian Woollyneck *Ciconia episcopus*, were categorized as 'Near Threatened'. Although these threatened species represented only a small proportion of the recorded avifauna, their regular occurrence emphasizes the conservation value of the Bajali wetlands in supporting species of global conservation concern. The presence of Near Threatened waterbirds further highlights the need for continued monitoring and effective habitat management to ensure the long-term persistence of these vulnerable populations.

The wetland-associated bird assemblage was also differentiated according to feeding guilds. Carnivorous species predominated, accounting for 29 species (65.91%), followed by omnivorous species (10 species; 22.72%), insectivorous species (4 species; 9.09%), and a single piscivorous species (1 species; 2.27%). The predominance of carnivorous birds reflects the high availability of aquatic prey, including fishes, amphibians, molluscs, crustaceans, and aquatic invertebrates, within the wetland ecosystem. Such trophic composition is characteristic of productive freshwater wetlands, where abundant food resources support a diverse assemblage of higher trophic-level waterbirds.

Collectively, these community characteristics demonstrate that the wetlands of the Bajali landscape support a structurally diverse avian assemblage composed predominantly of resident and common species, while simultaneously functioning as important seasonal habitats for migratory waterbirds and species of conservation concern. The coexistence of multiple feeding guilds further indicates that these wetlands provide a wide range of ecological resources capable of sustaining diverse functional groups throughout the year, thereby emphasizing their ecological significance within the regional wetland network.

Seasonal variation in diversity indices

The diversity indices revealed pronounced seasonal variation in the structure, composition, and stability of the wetland-associated bird community (Table 4). Observed species richness (Taxa_S) was highest during autumn and winter (44 species each), followed by summer (42 species), whereas the monsoon recorded the lowest richness (29 species). The higher richness during autumn and winter coincided with the arrival of migratory waterbirds and the availability of favourable habitat conditions following the monsoon. In contrast, the reduced richness during the monsoon is likely attributable to extensive flooding, increased water depth, breeding-related behavioural changes, and lower detectability of birds within dense emergent vegetation. Similar seasonal fluctuations have been widely reported in freshwater wetlands, where hydrological regimes strongly regulate habitat availability and bird community composition (Saygili et al. 2011; Kumar & Sharma 2019).

Patterns of species diversity further supported these seasonal differences. The Shannon–Wiener diversity index (H′) reached its highest value during autumn (3.655), followed closely by winter (3.654) and summer (3.426), while the lowest value was recorded during the monsoon (3.080). Likewise, Simpson's diversity index (1−D) was highest during autumn (0.971), followed by winter (0.9708) and summer (0.9595), whereas the monsoon exhibited the lowest diversity (0.9448). Conversely, Simpson's dominance index (D) showed an inverse trend, attaining its highest value during the monsoon (0.05524) and lowest value during autumn (0.02905). The concurrence of high Shannon and Simpson diversity together with low dominance during autumn and winter indicates a comparatively balanced community in which individuals were more evenly distributed among species. Conversely, increased dominance during the monsoon suggests that only a few species contributed disproportionately to total abundance, resulting in a comparatively simplified community structure under seasonally constrained environmental conditions. Similar seasonal responses of diversity indices have been reported in wetland bird communities where hydrological fluctuations influence habitat quality and resource availability (Azizoglu et al. 2023).

Species evenness also varied considerably among seasons. Pielou's evenness (J′) was highest during autumn (0.8791), followed by winter (0.8777) and monsoon (0.7505), while the lowest value occurred during summer (0.7320). Greater evenness during autumn and winter indicates a more equitable distribution of individuals among species, suggesting relatively balanced resource utilization and reduced numerical dominance. In contrast, the lower evenness observed during summer and the monsoon reflects greater dominance by a limited number of abundant species, likely resulting from seasonal variation in habitat conditions and resource availability.

The richness estimators showed remarkable consistency in describing seasonal community structure. Menhinick's index reached its highest value during autumn (0.9685), while Margalef's richness index was also greatest during autumn (5.634), followed by winter (5.409). Similarly, Fisher's alpha attained its maximum value during autumn (7.900) and remained comparatively high during winter (7.393). The agreement among these independent richness estimators provides robust evidence that post-monsoon and winter conditions supported the greatest true species richness within the study wetlands. These periods are characterized by stabilized hydrological conditions, increased habitat heterogeneity, and enhanced availability of aquatic food resources, thereby creating favourable conditions for both resident and migratory waterbirds.

The Berger–Parker dominance index further reinforced these seasonal patterns. The lowest dominance was recorded during autumn (0.05329), whereas comparatively higher values were observed during summer (0.09009) and the monsoon (0.08997). Lower Berger-Parker values indicate that no single species overwhelmingly dominated the assemblage, reflecting a more heterogeneous and balanced bird community during the post-monsoon period. In contrast, increased dominance during summer and the monsoon suggests that environmental conditions favoured relatively few adaptable species, thereby reducing overall community heterogeneity.

The seasonal patterns observed in the diversity indices were further supported by the **Q–Q plot (Image**

Image 5. Photographs of selected wetland-associated bird species recorded in Bajali District, Assam, India. 1—Little Egret | 2—Grey Heron | 3A—Indian Pond Heron (non-breeding plumage) | 3B—Indian Pond Heron (breeding plumage) | 4—Yellow Bittern | 5—Great Egret | 6—Cattle Egret | 7—Purple Heron | 8—Medium Egret | 9—Common Sandpiper | 10—Green Sandpiper | 11—Common Snipe | 12—Spotted Redshank | 13—Temminck's Stint | 14—Pacific Golden Plover | 15—Grey-headed Lapwing | 16—Red-wattled Lapwing | 17—Little Ringed Plover | 18—White-breasted Waterhen | 19—Grey-headed Swamphen | 20—Common Moorhen | 21—Asian Openbill | 22—Lesser Adjutant Stork | 23—Asian Woollyneck. © Bidyut Kumar Das.

Image 5 cont.. Photographs of selected wetland-associated bird species recorded in Bajali District, Assam, India. 24—Bronze-winged Jacana | 25—Black-headed Ibis | 26—Glossy Ibis | 27A—White Wagtail (Hodgson's) | 27B—White Wagtail (Chinese) | 28—Citrine Wagtail | 29—Stork-billed Kingfisher | 30—White-throated Kingfisher | 31—Common Kingfisher | 32—Pied Kingfisher | 33—Little Cormorant | 34—Oriental Darter| 35—Small Pratincole | 36—Lesser Whistling Duck | 37—Ruddy Shelduck. © Bidyut Kumar Das.

4), which demonstrated that bird abundance data generally conformed to normality assumptions across seasons, with only minor deviations at the lower and upper quantiles. Winter and autumn communities exhibited comparatively stable distributional patterns, whereas the steeper gradient observed during the monsoon reflected greater variability in abundance and the influence of a few highly dominant species. These results indicate that seasonal hydrological conditions not only influence species richness and diversity but also affect the overall distributional characteristics of wetland bird assemblages.

Collectively, the diversity analyses demonstrate that the wetland bird community of the Bajali landscape undergoes substantial seasonal reorganization in response to hydrological fluctuations and habitat dynamics. The post-monsoon and winter seasons supported the highest levels of species richness, diversity, and community evenness, primarily owing to improved habitat conditions, greater habitat heterogeneity, enhanced food availability, and the seasonal influx of migratory waterbirds. In contrast, extensive monsoonal inundation reduced habitat suitability for several species, resulting in lower species richness, increased dominance, and a comparatively simplified community structure. These findings are consistent with previous studies demonstrating that seasonal hydrology, water-level fluctuations, habitat quality and heterogeneity, prey availability, and migration dynamics are the principal ecological drivers shaping the diversity, abundance, and community organization of wetland-associated birds across freshwater and coastal wetland ecosystems (Colwell & Dodd 2017; Kumar & Sharma 2018, 2019; Kumar 2019; Ellis et al. 2021; Jagadeesan & Pandiyan 2021; Kularatne 2021; Ma et al. 2021; Rashiba et al. 2022; Byju et al. 2025a,b). Overall, these findings highlight the ecological importance of maintaining natural hydrological regimes, habitat heterogeneity, and wetland integrity to sustain diverse resident and migratory wetland bird communities.

CONCLUSION

This study provides the first comprehensive baseline assessment of the diversity, seasonal dynamics, and community structure of wetland-associated birds in the wetlands of Bajali District, Assam, thereby addressing an important knowledge gap for the lower Brahmaputra floodplain. The documented assemblage of resident and migratory species demonstrates that these wetlands function as ecologically important habitats that support breeding, foraging, and seasonal refuge for a diverse avifaunal community. The marked seasonal variation in species richness, abundance, and community composition confirms that hydrological regimes, habitat heterogeneity, and seasonal resource availability are the principal ecological drivers shaping wetland bird assemblages in the region.

The regular occurrence of the 'Near Threatened' Lesser Adjutant and Asian Woollyneck further highlights the conservation significance of these wetlands and underscores the need to maintain habitat quality amid increasing anthropogenic pressures. Protecting shallow wetlands, marshes, seasonally exposed mudflats, and riparian habitats will be essential for sustaining both resident populations and winter migratory birds that depend on these ecosystems.

Beyond providing the first checklist for Bajali District, this study establishes an important ecological benchmark against which future changes in wetland bird communities can be evaluated. Continued long-term monitoring, combined with habitat restoration, regulation of wetland degradation, and community-based conservation initiatives, will be crucial for safeguarding the ecological integrity of these wetlands under ongoing land-use change and climate variability. The findings presented here provide a scientific foundation for future biodiversity assessments, conservation planning, and sustainable wetland management in the lower Brahmaputra valley.

REFERENCES

Ali, S. (1996). The Book of Indian Birds. 11th ed. Bombay Natural History Society and Oxford University Press, Bombay, 394 pp.

Arya, M.R. et al. (2014). Avifaunal occurrence and distribution of wetland birds in Sakhya Sagar and Madhav lakes in Madhav national park, Shivpuri, India. Journal of Environmental Biology 35: 703–708.

Asokan, S. et al. (2009). Diet of three insectivorous birds in Nagapattinam District, Tamil Nadu, India: a preliminary study. Journal of Threatened Taxa 1(6): 327–330. https://doi.org/10.11609/JoTT.o2145.327-30

Azizoglu, E. et al. (2023). A statistical approach on distribution and seasonal habitat use of waterfowl and shorebirds in Çıldır Lake (Ardahan, Türkiye). Environmental Science and Pollution Research 30(31): 77371–77384. https://doi.org/10.1007/s11356-023-27855-9

Balachandran, P.V. et al. (2002). Wetland agriculture problems and prospects, pp. 50–68. In: Wetland Conservation and Management in Kerala (Ed.) Jayakumar. State Committee on Science Technology and Environment, Thiruvananthapuram.

Basile, M. et al. (2021). Abundance, species richness and diversity of forest bird assemblages – the relative importance of habitat structures and landscape context. Ecological Indicators 133: 108402. https://doi.org/10.1016/j.ecolind.2021.108402

Basu, T. & **A.** Das (2021). Systematic review of how eco-environmental transformation due to urbanization can be investigated in the sustainable development of Indian cities. Environmental Challenges 4**:** 100099. https://doi.org/10.1016/j.envc.2021.100099

Bibby, C. et al. (2000). Bird Census Techniques, 2nd Edition. Academic Press, London, 302 pp.

Billerman, S.M. et al. (2022). Birds of the World. Cornell Laboratory of Ornithology, Ithaca, NY, USA. https://birdsoftheworld.org/bow/home

Borad, C.K. et al. (2000). Conservation of the avian biodiversity in paddy (Oryza sativa) crop agroecosystem. Indian Journal of Agricultural Sciences 70(6): 378–381.

Bronmark, C. & L. Hansson (2005). The Biology of Lakes and Ponds (2nd ed). Oxford University Press, New York, 285 pp.

Bruggisser, O.T. et al. (2010). Effects of vineyard management on biodiversity at three trophic levels. Biological Conservation 143: 1521–8. https://doi.org/10.1016/j. biocon.2010.03.034

Byju, H. et al. (2024). Avifaunal diversity assessment and conservation significance of Therthangal Bird Sanctuary, Ramanathapuram, Tamil Nadu: insights about breeding waterbirds. Journal of Threatened Taxa 16(9): 25802–25815. https://doi.org/10.11609/jott.8999.16.9.25802-25815

Byju, H. et al. (2025a). The avifauna of Ramanathapuram, Tamil Nadu along the Southeast coast of India: waterbird assessments and conservation implications across key sanctuaries and Ramsar sites. PeerJ 13: e18899. http://doi.org/10.7717/peerj.18899

Byju, H. et al. (2025b). Disappearing colonies: temporal decline in abundance and nesting of waterbirds in a key Indian wetland. Wetlands Ecology and Management 33(4): 47. https://doi.org/

Byju, H. et al. (2025c). Temporal patterns in shorebird diversity and abundance at Dhanushkodi Lagoon: a critical wintering ground along India's southeast coast. Thalassas 41(3): 151. https://doi.org/10.1007/s41208-025-00908-1

Campbell, C.E. et al. (2022). How do we study birds in urban settings? a systematic review. Biodiversity and Conservation 31(1): 1–20.

Canedoli, C. et al. (2018). Birds Biodiversity in Urban and Periurban

Forests: Environmental Determinants at Local and Landscape Scale. Urban Ecosystems 16: 193–203. https://doi.org/10.1007/s11252-018-0757-7

Carrasco, L. et al. (2018). Habitat diversity and structure regulate British bird richness: Implications of non-linear relationships for conservation. Biological Conservation 226: 256–263.

Choudaj, K. & C. Shaha (2023). Natural remnants are refuges for rare birds in an urban area: a study from Pune city, India. Ornis Hungarica 31(1): 62–71. https://doi.org/10.2478/orhu-2023-0004

Cintra, R. (2012). Ecological gradients influencing water-bird communities in Black water Lakes in the Anavilhanas Archipelago, Central Amazonia. Inter-national Journal of Ecology 1–21. https://doi.org/10.1155/2012/801683

Cintra, R. et al. (2007). Com-position and structure of the bird communities of seasonally flooded wetlands of western Brazilian Amazonia at high water. Waterbirds 30: 521–540.

Colwell, M.A. & S.L. Dodd (2017). Effects of habitat and prey abundance on foraging shorebirds and their invertebrate prey. Journal of Avian Biology 48(3): 272–280.

Custer, T.W. & R.W. Osborne (1977). Wading birds as biological indicators. Long Survey, US. Fish and Wildlife service, Washington, DC.

Datta, S. (2017). Asomor Jalasar corai. Banalata, Dibrugarh, Assam, 191 pp.

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

Donaldson, M.R. et al. (2007). Assessing the effect of developed habitat on waterbird behaviour in an urban riparian system in Ottawa, Canada. Urban Ecosystems 10(2): 139–151. https://doi.org/10.1007/s11252-006-0015-2

Drapeau, P. et al. (1999). Refining the use of point counts at the scale of individual points in studies of bird-habitat relationships. Journal of Avian Biology 30(4): 367–382. https://doi.org/10.2307/3677009

Dutta, S. (2011). Axamar Charai Parjyabekshnar Hatputhi. Banphool Prakashan, Panbazar, Guwahati, 192 pp.

Ellis, K.S. et al. (2021). Impacts of extreme environmental disturbances on Piping Plover survival are partially moderated by migratory connectivity. *Biological Conservation* 264: 109371.

Feijen, C. & H.R. Feijen (2008). A review of the breeding birds of Bhutan. Forktail 24: 1–24.

Fraixedas, S. et al. 2020). A state-of-the-art review on birds as indicators of biodiversity: advances, challenges, and future directions. Ecological Indicators 118: 106728. https://doi.org/10.1016/j.ecolind.2020.106728

Fuller, R. et al. (2007). Sychological benefits of green space increase with biodiversity. Biology Letters 3: 390–394.

Gajardo, A.G. et al. (2009). Waterbird assemblages and habitat characteristics in wetlands: influence of temporal variability on species habitat relationships. Waterbirds 32(2): 225–233

Gibbs, J.P. (1993). The importance of small wetlands for the persistence of local populations of wetland-associated animals. Wetlands 13: 25–31. https://doi.org/10.1007/BF03160862

Gogoi, P.C. (2006). Axamar Charai. Assam Science Society, Guwahati, 272 pp.

Graham, C.H. et al. (2006). Habitat history improves prediction of biodiversity in rainforest fauna. Proceedings of the National Academy of Sciences of the United States of America 103(3): 632–636. https://doi.org/10.1073/pnas.0505754103

Grewal, B. et al. (2018). A pictorial field guide to Birds of India. Om Books International, New Delhi, India.

Grimmett, R. & T. Inskipp. (2007). Birds of Southern India. Om Books International, New Delhi, India.

Grimmett, R. et al. (2016). Birds of the Indian Subcontinent. Helm Field Guides. Christopher Helm, London, 528 pp.

Haslem, A. & A.F. Bennett (2008). Birds in agricultural mosaics: the influence of landscape pattern and countryside heterogeneity. Ecological Applications 18: 185–196. https://doi.org/10.1890/07-0692.1

Hersperger, A.M. et al. (2021). *Landscape ecological concepts in planning: Review of recent developments.* Landscape Ecology 36**:** 2329–2345. https://doi.org/10.1007/s10980-021-01193-y

Hostetler, M.E. & M.B. Main (2001). Florida Monitoring Program: Point Count Method to Survey Birds. University of Florida Cooperative Extension Service, Institute of Food and Agriculture Sciences, EDIS, Gainesville, 45 pp.

Jagadeesan, R. & J. Pandiyan (2021) Temporal variations of large wading birds in the point Calimere wildlife sanctuary, Tamil nadu, India. Indian Journal of Science and Technology 14(1): 1–7. https://doi.rg/1 0.17485/IST/v14i1.2251

Kar, T. & S. Debata (2019). Assemblage of waterbird species in an anthropogenic zone along the Mahanadi River of Odisha, eastern India: Implications for management. Proceedings of the Zoological Society 72(4): 355–363. https://doi.org/10.1007/s12595-018-0276-9

Kazmierczak, K. (2002). A Field Guide to the Birds of India, Sri Lanka, Pakistan, Nepal, Bhupan, Bangladesh and the Maldives. Om Book Service, New Delhi, 352pp.

Khan, T.N. (2010). Temporal changes to the abundance and community structure of migratory waterbirds in Santragachhi Lake, West Bengal, and their relation-ship with water hyacinth cover. Current Science 99(11): 1570–1577.

Koli, V. (2014). Diversity and status of avifauna in Todgarh-Raoli Wildlife Sanctuary, Rajasthan, India. Journal of Asia-Pacific Biodiversity 7(4): 401–407.

Kularatne, R.K.A. et al. (2021). Use of habitats by aquatic and terrestrial avifauna in tropical coastal lagoons. Regional Studies in Marine Science 47: 101926. https://doi.org/10.1016/j.rsma.2021.101926

Kumar, P. & A. Sharma (2018). Diversity and status of avifauna in man-made sacred ponds of Kurukshetra, India. Journal of Threatened Taxa 10(9): 12173–12193. https://doi.org/10.11609/jott.3729.10.9.12173-12193

Kumar, R. (2019). Wetlands and waterbirds in Central Asian Flyway: An overview of status, management and conservation priorities for India. Journal of Governance 18: 111–121.

Kumar, P. & A. Sharma. (2019). Wetland Birds Assemblages in Man-Made Sacred Ponds of Kurukshetra, India. Proceedings of Zoological Society 72: 61–73. https://doi.org/10.1007/s12595-018-0259-x

Lindenmayer, D.B. et al. (2006). General management principles and a checklist of strategies to guide forest biodiversity conservation. Biological Conservation 131: 433–45. https://doi.org/10.1016/j.biocon.2006.02.019

MacKinnon, J. & K. Philips (1993). A Field Guide to Birds of Sumatra, Java and Bali. Oxford University Press, 512 pp.

Mathibalan, T. et al. (2026). Diversity and composition of avian populations in Sivagalai Wetland, Thoothukudi, India. Journal of Experimental Zoology-India 29: 965–974. https://doi.org/10.51470/jez.2026.29.1.965

Ma, Z. et al. (2021). Coastal wetland loss and the endangered status of migratory shorebirds in the East Asian-Australasian flyway. Conservation Biology 35(4): 1136–1145.

Manikannan, R. et al. (2011). Status, abundance and threats to waterbirds of the Great Vedaranyam Swamp, Point Calimere Wildlife Sanctuary (Ramsar Site), South-east coast of India. *Journal of Research in Biology 2*: 93–100

Michel, N.L. et al. (2020). *Ecosystem services provided by Neotropical birds.* Ornithological Applications 122(3). https://doi.org/10.1093/condor/duaa022

Mitsch, W.I. & I.G. Gosselink (1986). Wetlands. Van Nostrand Reinhold, New York.

Sivaperuman, C. & E.A. Jayson (2000). Birds of Kole wetlands, Thrissur, Kerala. Zoos' Print Journal 15(10): 344–349. https://doi.org/10.11609/JoTT.ZPJ.15.10.344-9

Nair, T. & Y.C. Krishna (2013). Vertebrate fauna of the Chambal River basin, with emphasis on the National Chambal Sanctuary, India. Journal of Threatened Taxa 5(2): 3620–3641. https://doi.org/10.11609/JoTT.o3238.3620-41

Naveen, K. et al. (2025). Avifaunal diversity of Chinnavedampatti

Lake: An urban wetland in Coimbatore, Tamil Nadu, India. Journal of Experimental Zoology India 28: 1383–1395. https://doi.org/10.51470/jez.2025.28.2.1383

O'Connor, R. & M. Shrubb (1986). Farming and birds. Cambridge: Cambridge University Press, Cambridge, 539 pp.

Pandiyan, J. et al. (2010). Habitat utilization and assemblage patterns of migratory shorebirds at stop-over sites in Southern India. Stilt 58: 36–44.

Paracuellos, M. (2006). How can habitat selection affect the use of a wetland complex by waterbirds. Biodiversity and Conservation 15: 4569–4582. https://doi.org/10.1007/s10531-005-51820-z

Rajashekara, S. & M.G. Venkatesha (2010). The diversity and abundance of waterbirds in lakes of Bangalore city, Karnataka, India. Biosystematica 4(2): 63–73.

Rajpar, M.N. et al. (2022). Artificial wetlands as alternative habitat for a wide range of waterbird species. *Ecological Indicators 138*: 108855. https://doi.org/10.1016/j.ecolind.2022.108855

Ralph, C.J. et al. (1995). Managing and monitoring birds using point counts: standards and applications. In: Ralph, C.J., J.R. Sauer & S. Droege (technical editors). Monitoring Bird Populations by Point Counts. Gen. Tech. Rep. PSW-GTR-149. Albany, CA: US Department of Agriculture, Forest Service, Pacific Southwest Research Station, 149 pp.

Rashiba, A.P. et al. (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

Saygili, F.N. et al. (2011). The spatial and temporal distributions of waterbirds in Lakes Akşehir-Eber and Lake Köyceğiz in western Anatolia, Turkey-a comparative analysis. Turkish Journal of Zoology 35(4): 467–480. https://doi.org/10.3906/zoo-0911-99

Sekercioglu, C.H. (2012). Bird functional diversity and ecosystem services in tropical forests, agroforests and agricultural areas. Journal of Ornithology 153(Suppl. 1): S153–S161. https://doi.org/10.1007/s10336-012-0869-4

Shwartz, A. et al. (2014). Enhancing urban biodiversity and its influence on city–Dwellers: An experiment. Biological Conservation 171: 82–90. https://doi.org/10.1016/j.biocon.2014.01.009

Signa, G. et al. (2021). *Seabird influence on ecological processes in coastal marine ecosystems: An overlooked role? A critical review.* Estuarine, Coastal and Shelf Science 250**:** 107164. https://doi.org/10.1016/j.ecss.2020.107164

Sundar, K.S.G. & S. Subramanya (2010). Bird use of rice fields in the Indian subcontinent. Waterbirds 33 (Special Publication) 1: 44–70

Taft, O.W. & S.M. Haig (2006). Landscape context mediates influence of local food abundance on wetland use by wintering shorebirds in an agricultural valley. Biological Conservation 128: 298–307. https://digitalcommons.unl.edu/usgsstaffpub/575

Tanalgo, K.C. et al. (2015). Bird diversity and structure in different land-use types in lowland south-central Mindanao, Philippines. Tropical Life Science Research 26: 85.

Tobias, J.A. et al. (2020). Avian diversity: Speciation, macroevolution, and ecological function. *Annual Review of Ecology, Evolution, and Systematics* 51: 533–560. https://doi.org/10.1146/annurev-ecolsys-110218-025023]

Turner, W.R. (2003). Citywide biological monitoring as a tool for ecology and conservation in urban landscapes: the case of the Tucson Bird Count. Landscape and Urban Planning 65(3): 149–166. https://doi.org/10.1016/s0169-2046(03)00012-4

Urban, M.C. (2004). Disturbance heterogeneity determines freshwater metacommunity structure. Ecology 85: 2971–2978. https://doi.org/10.1890/03-0631

Van der Valk, A.G. (2006). The Biology of Freshwater Wetlands. Oxford University Press, Oxford, 173 pp.

Verma, A. (2008). Occurrence and abundance of waterbirds at Bundh Baretha reservoir, Bharatpur, north-western India. Indian Birds 4: 150–153.

Whelan, C.J. et al. (2008). Ecosystem services provided by birds. Annals of the New York Academy of Sciences 11343: 25–60. https://doi.org/10.1196/annals.1439.003

Wretenberg, J. et al. (2010). Changes in local species richness of farmland birds in relation to land-use changes and landscape structure. Biological Conservation 143: 375–381. https://doi.org/10.1016/j.biocon.2009.11.001

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 August 2026 | 18(8): 29447–29458

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

https://doi.org/10.11609/jott.10279.18.8.29447-29458

#10279 | Received 27 November 2025 | Final received 08 June 2026 | Finally accepted 03 July 2026

OPEN ACCESS

ARTICLE

Fish diversity and conservation status across habitat guilds in the river Rupnarayan, West Bengal, India

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Abstract: The Rupnarayan River, a major tributary of the Hugli in West Bengal, extends approximately 75 km and exhibits distinct hydrological and morphological characteristics, including tidal influence, dynamic salinity gradients, and a meandering channel. The river transitions from a freshwater system upstream to a brackish estuarine environment downstream, supporting diverse floodplain habitats, fisheries, nutrient cycling, and sediment transport. A comprehensive assessment of ichthyofaunal diversity recorded 55 fish species belonging to 31 families, based on field surveys, fishers' interviews, and secondary literature. Cyprinidae and Bagridae were the most species-rich families. The highest Shannon diversity index (H' = 3.28) was recorded at the Denan canal confluence, indicating spatial variation in fish community composition. The assemblage included freshwater, brackish, and euryhaline species, reflecting the river's transitional salinity regime and ecological connectivity. The river also provides important habitat for migratory fishes, including the anadromous Hilsa Shad *Tenualosa ilisha* and Toli Shad *Tenualosa toli*, and the catadromous Indian Mottled Eel *Anguilla bengalensis*. Several native species, such as catfishes and snakeheads, contribute to ecosystem regulation by preying on insect larvae, including mosquitoes, thereby offering natural pest control services. Fish species showed varied spatial distributions, with some restricted to specific microhabitats and others widely distributed throughout the river. Assessment against IUCN Red List categories indicated that while most recorded species were classified as Least Concern (LC), several were categorised as Near Threatened (NT), Vulnerable (VU), Data Deficient (DD), or Not Evaluated (NE). The co-occurrence of native, migratory, and exotic species highlights the complex conservation challenges associated with environmental change, fishing pressure, and species introductions. These findings provide an important baseline for developing evidence-based conservation and management strategies to maintain fish diversity, ecological integrity, and the livelihoods of communities dependent on the Rupnarayan River.

Keywords: Aquatic biodiversity, biodiversity assessment, community structure, estuarine fish, freshwater conservation, fish assemblages, inland fisheries, ichthyofauna, threatened species, tidal river ecology.

সারসংক্ষেপ: রূপনারায়ণ নদী পশ্চিমবঙ্গের হুগলি নদীর একটি প্রধান উপনদী যা প্রায় ৭৫ কিলোমিটার দীর্ঘ। এই নদীতে জোয়ার-ভাটা, লবণাক্ততার তারতম্য এবং সর্পিল বা আঁকাবাঁকা গতিপথের মতো সুনির্দিষ্ট বৈশিষ্ট্য দ্রষ্টব্য। নদীটি জোয়ারের সময় উৎসের দিকে মিঠাজল থেকে ক্রমশ নোনাজল মোহনা-পরিবেশে রূপান্তরিত হয়। ফলে উর্বর পলিমাটি যুক্ত প্লাবনভূমি তৈরি হয় যা পুষ্টি চক্রায়ণ, পলি পরিবহন এবং মৎস্য-নির্ভর জীবিকার মতো গুরুত্বপূর্ণ পরিষেবা প্রদান করে। এই গবেষণাপত্রে পূর্ববর্তী গবেষণার তথ্য, প্রাথমিক সমীক্ষা এবং মৎস্যজীবীদের সাক্ষাৎকারের মাধ্যমে রূপনারায়ণের মৎস্য বৈচিত্র্য মূল্যায়ন করা হয়েছে। ৩১টি গোত্রের মোট ৫৫টি প্রজাতির উপস্থিতি নথিভুক্ত হয়েছে, যার মধ্যে সর্বোচ্চ বৈচিত্র্য পাওয়া গেছে *Cyprinidae* ও *Bagridae* গোত্রে। নদীর বিভিন্ন অংশে মাছের বৈচিত্র্য আলাদা। উদাহরণস্বরূপ দেনান খালের সঙ্গমস্থল সর্বাধিক বৈচিত্র্যময় (শ্যানন সূচক H' = ৩.২৮)। এই নদীতে মিঠাজলের মাছ, নোনাজলের মাছ এবং নোনা সহনশীল (euryhaline) মাছ – সব ধরনেরই দেখা মেলে, যা নদীর পরিবর্তনশীল লবণাক্ততা এবং বাস্তুতান্ত্রিক সংযোগের প্রতীক। এই নদী পরিযায়ী মাছেদের জন্যও একটি গুরুত্বপূর্ণ বাসস্থান। সমুদ্র থেকে নদীতে গমনকারী (anadromous) মাছেদের মধ্যে রয়েছে ইলিশ (*Tenualosa ilisha*) এবং চন্দনা ইলিশ (*Tenualosa toli*), আবার নদী থেকে সমুদ্রে গমনকারী (catadromous) মাছেদের মধ্যে রয়েছে ভারতীয় বাইন মাছ (*Anguilla bengalensis*)। শিং, মাগুরের মতো ক্যাটফিশ এবং শোল জাতীয় মাছ মশা-সহ নানা পোকামাকড়ের লার্ভা খেয়ে প্রাকৃতিক কীটনাশকের ভূমিকা পালন করে, যা নদীর বাস্তুতন্ত্রের ভারসাম্য বজায় রাখে। কিছু প্রজাতি নদীর নির্দিষ্ট অংশেই সীমাবদ্ধ থাকে, আবার কিছু প্রজাতি গোটা নদী জুড়েই বিচারণ করে ।IUCN রেড লিস্টের মানদণ্ড অনুযায়ী বেশিরভাগ প্রজাতিই ন্যূনতম উদ্বেগজনক (Least Concern) শ্রেণিতে পড়লেও, উল্লেখযোগ্য সংখ্যক প্রজাতি প্রায়-বিপন্ন (Near Threatened), সংকটাপন্ন (Vulnerable), তথ্য-অপ্রতুল (Data Deficient) অথবা এখনও মূল্যায়ন-না-হওয়া (Not Evaluated) শ্রেণিতেও রয়েছে। পরিবেশগত পরিবর্তন, মাছ ধরার চাপ এবং নতুন প্রজাতির অনুপ্রবেশের পরিপ্রেক্ষিতে বিভিন্ন ধরণের (দেশীয়, পরিযায়ী এবং বহিরাগত) মাছের উপস্থিতি সংরক্ষণের কাজটিকে জটিল করে তুলেছে। এই গবেষণায় প্রাপ্ত তথ্য রূপনারায়ণ নদীতে মাছের বৈচিত্র্য রক্ষা, নদীর পরিবেশগত ভারসাম্য বজায় রাখা এবং নদীর উপর নির্ভরশীল স্থানীয় মানুষদের জীবিকা টিকিয়ে রাখার মতো কাজে তথ্য ভিত্তিক সংরক্ষণের পরিকল্পনায় ও তার বাস্তবায়নে গুরুত্বপূর্ণ ভূমিকা নেবে।

Editor: C. Sudhan, Dr. MGR Fisheries College and Research Institute, Ponneri, India.

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

Citation: Kar, M.K., M.S. Khan, A.A. Danda & K.D. Joshi (2026). Fish diversity and conservation status across habitat guilds in the river Rupnarayan, West Bengal, India. *Journal of Threatened Taxa* 18(8): 29447–29458. https://doi.org/10.11609/jott.10279.18.8.29447-29458

Funding: WWF-USA.

Competing interests: The authors declare no competing interests.

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

INTRODUCTION

Freshwater ecosystems are among the most biodiverse yet highly threatened habitats on Earth. In India, riverine systems play a pivotal role in sustaining ecological processes, supporting biodiversity, and promoting human well-being. Despite covering only 2.7% of India's geographical area, the state of West Bengal contributes 13.6% of the country's total inland fisheries production, recording 1.652 million tonnes in 2021–22 (Department of Fisheries 2022). This disproportionately high contribution underscores both the ecological productivity of West Bengal's freshwater systems and the intensive anthropogenic dependence on fish resources. While inland fisheries form the economic backbone of many rural and riverine communities, increasing exploitation pressures necessitate a transition from production-oriented approaches to long-term conservation and sustainability frameworks.

Fish in West Bengal hold not only nutritional and economic value but also deep-rooted cultural and social significance, particularly among Bengali communities (Thapa et al. 2025). Beyond their human utility, fish serve as fundamental components of aquatic food webs, sustaining higher trophic levels including piscivorous birds, otters, riverine reptiles, and freshwater cetaceans (Bashir et al. 2010; Khan et al. 2014; Iglesias et al. 2023). Fish diversity in the Rupnarayan River plays a pivotal role in maintaining ecosystem integrity and supporting species of high conservation significance. A diverse and stable fish community forms the primary prey base for threatened taxa such as the Ganges River Dolphin *Platanista gangetica*, India's National Aquatic Animal, the Irrawaddy Dolphin *Orcaella brevirostris*, and the Critically Endangered Gharial *Gavialis gangeticus*. It also sustains a range of piscivorous birds, including cormorants and other waterbirds, whose foraging success is closely linked to fish availability. Fish also contribute to key ecosystem processes, including nutrient cycling, sediment bioturbation, and the regulation of algal and benthic communities (Matthews 1998; Moore 2006; Vanni et al. 2006). Furthermore, their migratory behaviours enhance ecological connectivity and facilitates nutrient flows across ecosystem boundaries (Cederholm et al. 1999; Flecker et al. 2010).

In this context, conserving fish diversity is integral not only to maintaining aquatic biodiversity but also to sustaining the health and resilience of freshwater ecosystems and the livelihood of fishers. Ecosystem-based conservation efforts help stabilise food webs, protect threatened species, and uphold the services these ecosystems provide to human societies. The Rupnarayan River, a significant tributary of the lower Ganges Basin in eastern India, is a crucial habit supporting a rich diversity of fish and serving as a critical migratory corridor for anadromous and catadromous species. Despite its ecological value and role in supporting inland fisheries, the river faces significant challenges due to pollution, habitat degradation, and invasive species. Notably, shifts in fish catch composition and declining yields have been observed by local fishers, indicating ecological imbalance and socio-economic vulnerabilities. Given this context, a comprehensive understanding of species diversity and conservation status across habitat guilds is essential for effective ecosystem-based management. This study, therefore, aims to document the diversity and conservation status of fish species in the river Rupnarayan, an important tributary of the river Hugli in West Bengal. Some limited literature exists on the fish diversity of the Rupnarayan, based on studies conducted at different times (Ghorai 2018; Dey & Panigrahi 2023), which recorded 30 to 38 fish species separately. The present study compiles all previously available data and additionally reports 11 fish species recorded for the first time from the river Rupnarayan. The findings are based on field data collected during the "Pinger project," conducted between November 2023 and January 2024 at Harishpur, Paschim Medinipur. By consolidating new and existing data, this paper seeks to enhance our understanding of fish assemblages in the Rupnarayan and to support informed conservation planning for this ecologically significant river system of Rupnarayan-Hugli.

Study area

The Rupnarayan River is a major spring-fed tributary of the river Hugli. It originates from the confluence of two rain-fed rivers, Shilabati and Dwarakeswar, which both flow from the Chhota Nagpur Plateau in Purulia (Das 2024). The confluence is located at coordinates 22.671° N, 87.777° E, approximately 6 km downstream of Ghatal City in Paschim Medinipur. The Rupnarayan River flows through four districts in West Bengal: Paschim Medinipur, Purba Medinipur, Hooghly, and Howrah (WII-GACMC 2022). It travels around 75 km from its origin to the Hugli River confluence near Geonkhali in Purba Medinipur, at 22.202° N, 88.032° E. Thirteen tributaries contribute to the River Rupnarayan during its course from origin to end, major tributaries are Dwarakeswar, Shilabati, and Mundeswari (Das 2023).

The Rupnarayan River is an ecologically significant system that supports a rich assemblage of aquatic

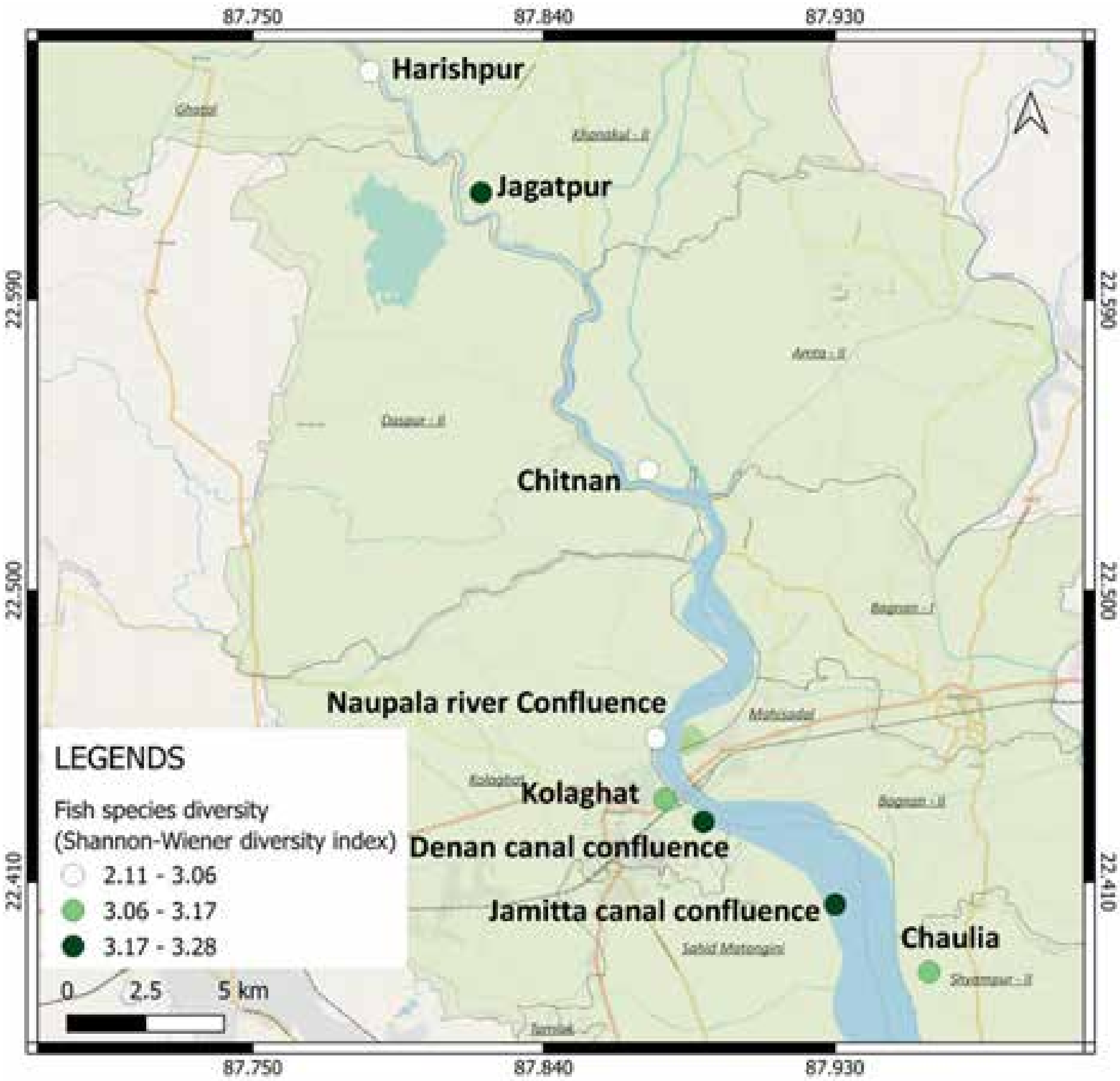

Image 1. Fish species diversity at different locations along river Rupnarayan, West Bengal, India.

and semi-aquatic taxa. Its diverse habitats, including deep channels, sandbars, mudflats, and riparian zones, provide critical feeding, breeding, and resting/nesting or basking grounds for a wide range of species. The Rupnarayan River is a recognised hotspot for the Ganges River Dolphin population, with occasional records of the 'Critically Endangered' Gharial and Northern River Terrapin *Batagur baska*, as well as the 'Endangered' Irrawaddy Dolphin and 'Vulnerable' Indo-Pacific Humpback Dolphin *Sousa chinensis* (WII-GACMC 2022; Qureshi et al. 2024; George et al. 2025). Beyond these flagship species, the river functions as an ecologically significant habitat supporting a diverse assemblage of aquatic and semi-aquatic taxa. Its dynamic habitats sustain a wide range of waterbirds, including cormorants, herons, and migratory species, as well as semi-aquatic fauna such as the Common Water Monitor *Varanus salvator* and other riverine reptiles. Collectively, these attributes underscore the importance of the Rupnarayan River as a critical biodiversity refuge and an integral component of the region's riverine ecosystem.

The river is also essential for the West Bengal Power Development Corporation Limited (WBPDCL), a thermal power plant situated on the riverbank at Kolaghat. The river is famous for its Hilsa Fish *Tenualosa ilisha*, which is a popular fish in Bengali cuisine. The river is very unique owing to its origin as a smaller spring-fed stream that traverses through a narrow-embanked gorge in the upstream stretch and turns into the mighty river downstream, influenced by extreme tidal cyclic changes and frequent mixing of fresh and brackish water in tidal reaches. The tidal variation, in terms of water level fluctuations and salinity changes, is noticeable along the entire length of the river (Das 2023). As a result, both freshwater and brackish water fish species are found in the river Rupnarayan. Although the river stretch in the upper reaches is narrower, the embanked gorge makes it deeper, forming a congenial habitat for river dolphins.

METHODS

Data collection

Method of fish sampling: The fish sampling took place daily from 21 November 2023 to 31 January 2024 at Harishpur (22.660° N, 87.786° E) in Paschim Medinipur, West Bengal. Situated just downstream of the confluence of the Shilabati and Dwarakeswar rivers, where the Rupnarayan River originates, the Harishpur sampling site represents the river's uppermost reach. Previous studies of the Rupnarayan's ichthyofauna have been restricted to its lower stretches, leaving this upper section largely unexplored. Owing to its considerable distance from the estuary, the site experiences minimal tidal influence and considering the confluence habitat, we therefore hypothesised that fish diversity at this location would differ significantly from that of the lower reaches.

A nylon monofilament gill net with a mesh size of 40 mm, a length of 50 m, and a width of 2 m was used, following local fishing practices. The net was deployed in the river cross-section with the assistance of local fishers and was retrieved and cleaned each morning (0500–0600 h) and evening (1730–1830 h). When the net was retrieved, the local fishers collected the fish catch, and a researcher recorded the data on the number of species. Since the fish sampling was conducted only in the winter months, the interviews of 12 local fishers were undertaken to include the number of fish species that may be found in the river during other seasons (such as summer and monsoon). They were asked about the species of fish found in the river during the summer and monsoon months of the year.

Literature review: A systematic literature review to gather, evaluate, and summarize all available empirical evidence on fish species occurrence and diversity in river Rupnarayan was conducted. We made an exhaustive effort using the Google search engine to include all relevant studies published to date on Rupnarayan fisheries. However, there is very limited information on the fisheries of river Rupnarayan, with almost all relevant studies conducted after 2014. Therefore, we reviewed secondary data available on fish occurrence and diversity in river Rupnarayan from the last decade, specifically between 2014 and 2024, which includes research papers focusing on seven river sites, namely Jagatpur, Chitnan, Naupala river confluence, Kolaghat, Denan canal confluence, Jamitta canal confluence and Chaulia. Eight river sites, including Harishpur, collectively represent the fish diversity of the entire river. Harishpur served as the primary data collection site, while secondary information for the remaining nine sites was gathered through a literature review.

Data analysis

The fish species were listed according to the Talwar & Jhingran (1991) taxonomic classification, which is based on an evolutionary sequence, and taxonomic discrepancies were also resolved using the FishBase database (Froese & Pauly 2010). The fish number data, comprising primary data for Harishpur and secondary data for the remaining nine river sites, were used to calculate the fish diversity index using the Shannon diversity index approach (Image 1). Each recorded and reported fish species conservation status category based on the IUCN Red List was collated. The species were also categorised into the habitat guilds. Based on reports and records from the river site, species distribution was categorised into Clumped, Aggregate, Random, and Hyperdispersed (Khan et al. 2013). Species reported/recorded only from one or two sites were categorised into clumped with only 25% of all sites usage, species found in 3–4 sites were labelled as aggregate distribution with 26–50 % of available monitored sites usage, similarly, species with a usage of 5–6 sites were categorised as random distribution with 51–75 % of available sites use while the species using more than 75% of the sites were categorised into random distribution with 76–100 % usage of available habitat.

RESULTS

A total of 55 fish species, belonging to 13 orders and 31 families, were documented in the Rupnarayan River. One additional shellfish species, the Giant River Prawn *Macrobrachium rosenbergii*, was also recorded but excluded from finfish analyses. Data were compiled through direct sampling, fisher interviews, and literature review. Several species identified during the study are of conservation concern. These include the 'Near Threatened' — Butter Catfish *Ompok bimaculatus*, Indian Mottled Eel *Anguilla bengalensis*, and Pabdah Catfish *Ompok pabda* (Table 1). Additionally, three species—Mozambique Tilapia *Oreochromis mossambicus*, Toli Shad *Tenualosa toli*, and Wallago *Wallago attu*, are listed as 'Vulnerable' according to the IUCN Red List. Although Mozambique Tilapia is classified as VU globally. It is native to Africa, specifically the Mozambique region, and is considered an exotic species in the Indian river systems (Table 1). The Olive Flathead-gudgeon *Butis humeralis* and Philippine Catfish *Clarias batrachus* are also non-native species found in the Rupnarayan River. The Spotted Catfish *Arius maculatus* is categorised as 'Data Deficient', indicating insufficient information to assess its conservation status. The Olive Flathead-gudgeon *Butis humeralis* and Goldspot Mullet *Planiliza parsia* were the two species that are not assessed by the IUCN (Table 1). One fish species of *Synbranchidae* family was reported as *Amphipnous* sp., indicating that the exact species within that genus- *Amphinous* is unknown/ unidentified.

The fish population is dominated by the presence of five species each from the Cyprinidae and the Bagridae families. Both families are commercially important fish families (Image 2). Notably, a comprehensive sampling at Harishpur identified 20 fish species, while local fishermen specifically reported nine different species found in the Rupnarayan River at Harishpur (Table 1). This makes up the list of 29 species from the Harishpur site. Of these 29 species of fish, 11 species were not reported from the river Rupnarayan, namely Indian Glassy Fish *Chanda ranga,* Long-whiskered Catfish *Sperata aor,* Olive Flathead-gudgeon *Butis humeralis,* Toli Shad *Tenualosa toli,* Rosy Barb *Pethia conchonius,* Large Razorbelly Minnow *Salmophasia bacaila,* Spiny Eel *Mastacembelus armatus,* Gangetic leaffish *Nandus nandus,* Garua Bachcha *Clupisoma garua,* Oriental Sole *Brachirus orientalis*, and Crocodile-tooth Pipefish *Microphis cuncalus*. Among these newly recorded species, Toli Shad is classified as 'Vulnerable'.

The Giant River Prawn *Macrobrachium rosenbergii* (locally known as *Chingri*) was recorded during the present study and has also been previously reported from the river by Ghorai (2018). These authors included the species in their ichthyofaunal diversity index calculations. However, as a shellfish rather than a finfish, this species was excluded from the species list and subsequent analyses in the present study.

The fish diversity index of the Harishpur site was calculated as 2.113 (Shannon diversity index, Image 1). The fish diversity of the Rupnarayan River was found to vary from 2.1 (Shannon diversity index) in Harishpur (the highest point covered during the present study) to 3.09

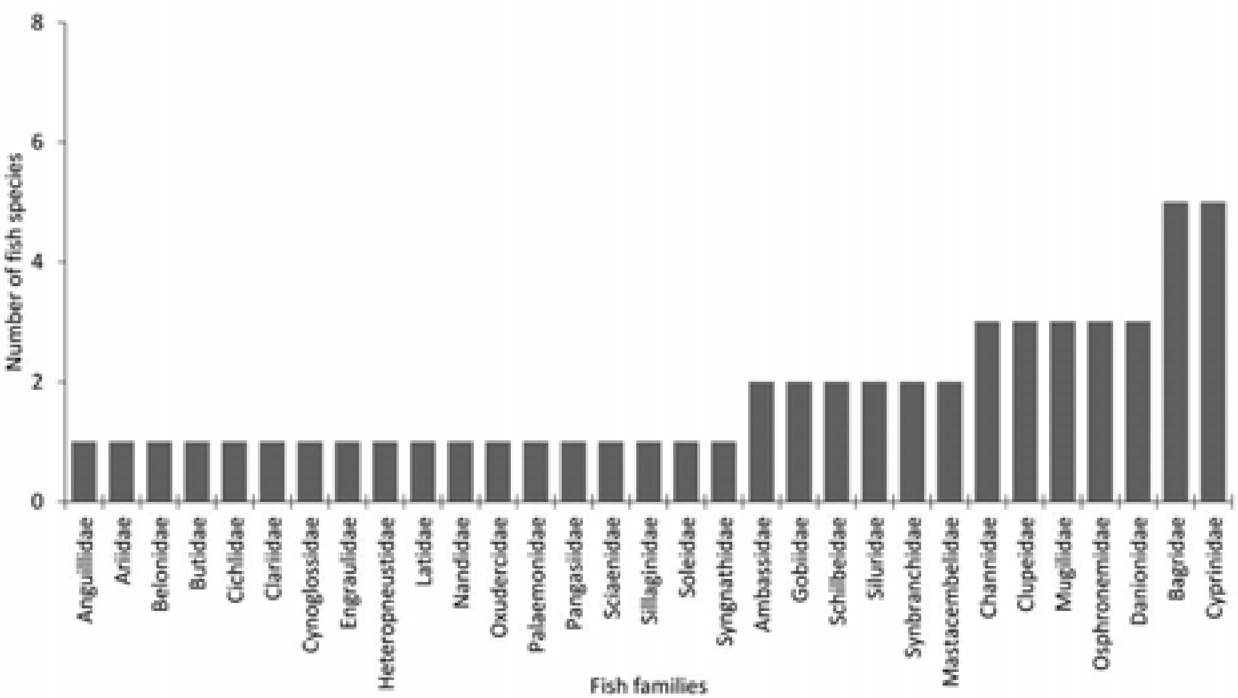

Image 2. Family-wise number of fish species found in the Rupnarayan River, West Bengal, India.

Table 1. Fish species composition, conservation status and distribution in the river Rupnarayan, West Bengal, India.

	Family	Scientific name	English name	Bengali name	Conservation status[1]	Harishpur[2]	Jagatpur[3]	Chitnan[3]	Naupala River confluence[4]	Kolaghat[5]	Denan Canal confluence[6]	Jamitta Canal confluence[4]	Chaulia[3]
1	Anguillidae	*Anguilla bengalensis*	Indian Mottled Eel	--	NT	-	-	-	+	-	+	+	-
2	Clupeidae	*Tenualosa ilisha*	Hilsa Shad	Ilish	LC	-	+	+	+	+	+	+	+
3		*Gudusia chapra*	Indian River Shad	Khoira	LC	+	+	+	+	+	+	+	+
4		*Tenualosa toli*	Toli Shad	Khoka Ilish/ Chandana-Ilish	VU	+	-	-	-	-	-	-	-
5	Engraulidae	*Setipinna phasa*	Gangetic Hairfin Anchovy	Phasa/Phansa	LC	+	+	+	+	+	+	+	+
6	Cyprinidae	*Pethia ticto*	Ticto Barb	Tituputi	LC	-	+	+	+	+	+	+	+
7		*Puntius vittatus*	Green-stripe Barb	--	LC	-	+	+	+	+	+	+	+
8		*Systomus sarana*	Olive Barb	Selim Puti/ Sar Puti	LC	+	+	+	+	+	+	+	+
9		*Labeo bata*	Minor Carp	Bhangan Bata	LC	+	-	-	-	-	-	-	-
10		*Pethia conchonius*	Rosy Barb	Deshi Puti/ Kanchan Puti	LC	+	-	-	-	-	-	-	-
11	Danionidae	*Chela cachius*	Silver Hatchet Chela	--	LC	-	+	+	+	+	+	+	+
12		*Amblypharyngodon mola*	Mola Carplet	Mourala	LC	-	+	+	+	+	+	+	+
13		*Salmophasia bacaila*	Large Razorbelly Minnow	Chela/Swui	LC	+	-	-	-	-	-	-	-
14	Bagridae	*Sperata seenghala*	Giant River-Catfish	Aoyeer	LC	-	+	+	+	+	+	+	+
15		*Mystus tengara*	Tengara Catfish	Bajri Tengra	LC	-	+	+	+	+	+	+	+
16		*Mystus vittatus*	Striped Dwarf Catfish	Lal Tengra	LC	-	+	+	+	+	+	+	+
17		*Mystus cavasius*	Gangetic Mystus	Tengra	LC	+	+	+	+	-	-	+	+
18		*Sperata aor*	Long-Whiskered Catfish	Aar	LC	+	-	-	-	-	-	-	-
19	Siluridae	*Ompok bimaculatus*	Butter Catfish	Pabda	NT	+	+	+	+	+	+	+	+
20		*Wallago attu*	Wallago	Boyal/Boyali	VU	+	+	+	+	+	+	+	-
21		*Ompok pabda*	Pabdah Catfish	--	NT	-	+	+	+	+	+	+	+
22	Schilbeidae	*Silonia silondia*	Silond Catfish	Farse/Silon	LC	+	+	+	+	+	+	+	+
23		*Clupisoma garua*	Garua Bachcha	Bachi/Ghaura	LC	+	-	-	-	-	-	-	-
24	Pangasiidae	*Pangasius pangasius*	Pangas Catfish	Pangas	LC	-	+	-	+	+	+	-	+

	Family	Scientific name	English name	Bengali name	Conservation status[1]	Harishpur[2]	Jagatpur[3]	Chitnan[3]	Naupala River confluence[4]	Kolaghat[5]	Denan Canal confluence[6]	Jamitta Canal confluence[4]	Chaulia[3]
25	Clariidae	*Clarias batrachus*	Philippine Catfish	Magur	LC	-	+	+	+	+	+	-	+
26	Heteropneustidae	*Heteropneustes fossilis*	Stinging Catfish	Singee	LC	-	+	+	+	-	+	+	-
27	Ariidae	*Arius maculatus*	Spotted Catfish	--	DD	-	+	+	+	+	+	+	+
28	Belonidae	*Xenentodon cancila*	Freshwater Garfish	Gang Dhara(Kankle)	LC	+	+	-	+	-	-	-	+
29	Syngnathidae	*Microphis cuncalus*	Crocodile-tooth Pipefish	Daton Kathi	LC	+	-	-	-	-	-	-	-
30	Synbranchidae	*Amphipnous sp*		--	---	-	-	-	+	-	+	+	-
31		*Monopterus cuchia*	Gangetic Mudeel	Kuchia	LC	-	+	-	+	+	+	+	+
32	Ambassidae	*Chanda nama*	Elongate Glass Perchlet	Chanda	LC	+	+	+	+	+	+	+	+
33		*Chanda ranga*	Indian Glassy Fish	Chanda	LC	+	-	-	-	-	-	-	-
34	Sillaginidae	*Sillaginopsis panijus*	Flathead Sillago	Tool-belle	LC	-	-	-	-	+	-	-	-
35	Sciaenidae	*Johnius coitor*	Coitor Croaker	--	LC	+	+	+	+	-	+	+	+
36	Nandidae	*Nandus nandus*	Gangetic Leaffish	Ledus/Nadus	LC	+	-	-	-	-	-	-	-
37	Cichlidae	*Oreochromis mossambicus*	Mozambique Tilapia	--	VU	-	+	+	+	+	+	-	+
38	Mugilidae	*Rhinomugil corsula*	Corsula	Tarui/ Kharsula/Urul	LC	+	-	-	-	-	-	-	-
39		*Planiliza parsia*	Goldspot Mullet	--	NE	-	+	+	+	+	+	+	+
40		*Mugil cephalus*	Flathead Mullet	Ain	LC	-	-	-	+	-	+	-	-
41	Polynemidae	*Polynemus paradiseus*	Paradise Thread fin	Tapsee-machh	LC	-	+	+	+	+	+	+	+
42	Gobiidae	*Odontamblyopus rubicundus*	Red Eel Goby	Lal Chengo	LC	+	-	-	-	-	-	-	-
43		*Glossogobius giuris*	Bareye Goby	Sada Bhola/ Belay	LC	+	+	+	+	+	+	+	+
44	Oxudercidae	*Apocryptes bato*	--	Sada Chengo/ Cheeng	LC	+	-	-	-	-	-	-	-
45	Butidae	*Butis humeralis*	Olive Flathead-gudgeon	Kalo Bhola	NE	+	-	-	-	-	-	-	-
46	Osphronemidae	*Trichogaster chuna*	Honey Gourami	--	LC	-	+	+	+	+	+	+	+
47		*Trichogaster fasciata*	Banded Gourami	Kholisha	LC	+	-	-	+	-	+	+	-

	Family	Scientific name	English name	Bengali name	Conservation status[1]	Harishpur[2]	Jagatpur[3]	Chitnan[3]	Naupala River confluence[4]	Kolaghat[5]	Denan Canal confluence[6]	Jamitta Canal confluence[4]	Chaulia[3]
48		*Channa striatus*	Striped Snakehead	Shoal	LC	-	-	+	-	+	+	+	+
49	Channidae	*Channa marulius*	Great Snakehead	Sal/Gajal	LC	+	-	-	-	-	-	-	-
50		*Channa punctata*	Spotted Snakehead	Lata	LC	-	+	-	+	+	+	+	+
51	Mastacembelidae	*Mastacembelus armatus*	Spiny Eel	Baim/Ban	LC	+	-	-	-	-	-	-	-
52		*Macrognathus pancalus*	Barred Spiny Eel	Baim	LC	-	+	+	+	+	+	-	+
53	Cynoglossidae	*Cynoglossus cynoglossus*	Bengal Tonguesole	Kukur Jiv	LC	+	+	+	+	+	+	+	+
54	Soleidae	*Brachirus orientalis*	Oriental Sole	Kathal Pata	LC	+	-	-	-	-	-	-	-
55	Latidae	*Lates calcarifer*	Barramundi	Bhetki	LC	-	+	+	+	+	+	-	+

*—Not identified at species level | [1] LC—Least Concern | VU—Vulnerable | NT—Near Threatened | DD—Data Deficient | NE—Not Evaluated | [2]—Present study | [3]—Dey & Panigrahi 2023 | [4]—Ghorai 2018 | [5]—Dey & Panigrahi 2023 | [6]—Ghorai 2018.

(Shannon diversity index) in Kolaghat (approximately the middle section of the river) and 3.28 Shannon diversity index at Chaulia (lowest assessment point in the river) (Image 1, Table 2).

The majority of fish species in the River Rupnarayan, as recorded at the Harishpur site and reported in the literature and by fishers, are categorised as 'Least Concern' by the IUCN Red List of Threatened Species. Between 6.1% and 10% of the species are classified as 'Near Threatened', while 3.1% to 6.7% are categorised as VU across the sites. There are 1.9% of species with DD status, and 3.7% of fish species are not assessed for their conservation status by the IUCN Red List (Table 1, Image 3).

The fish population of the river Rupnarayan is primarily composed of species that inhabit freshwater and brackish water habitats. Approximately 18.2% of the population consists of exclusive freshwater fishes, 52.7% live in freshwater and brackish waters, and 29.1% fish species, capable of surviving in various salinity levels, including freshwater, brackish water, and marine water (Image 4). This distribution of fish habitat guild composition was consistent across all sites in the river Rupnarayan (Image 4).

An analysis of habitat distribution revealed that 17 species exhibited highly clumped distribution, utilising only 25% of the available habitats (Image 5). Four fish species demonstrated aggregate distribution by utilising up to 50% of the available habitat (Image 5). Additionally, 10 fish species exhibited random distribution by utilising 51–75 % of the available habitat, while 24 species were widely dispersed, utilising 76–100 % of the available habitat across sites (Image 5).

DISCUSSIONS

The Rupnarayan River supports a diversity of 55 fish species, which is comparable to other tributaries of the river Hooghly within West Bengal, such as the Damodar River (68 species; Das et al. 2013) and the Churni River (64 species; Das et al. 2014). Although the tidal freshwater stretch of the Hooghly estuary reports a higher diversity (155 species; Roshith et al. 2013), this includes a broader estuarine influence and migratory species. Thus, within the context of West Bengal's riverine systems, the Rupnarayan River exhibits a moderately high level of fish diversity, underscoring its ecological significance among similar river stretches in the region. These findings suggest that the Rupnarayan River plays a vital role in maintaining regional fish diversity

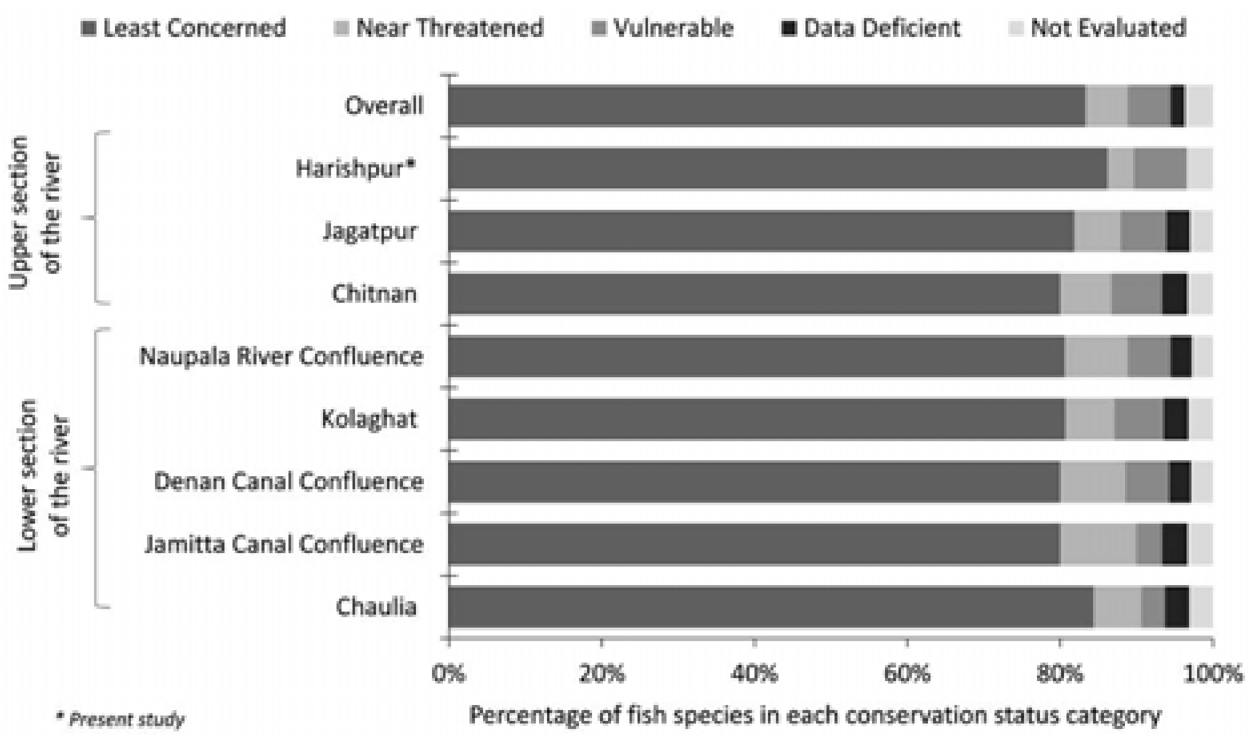

Image 3. Conservation status of the fishes of Rupnarayan River, West Bengal, India.

Table 2. Fish diversity table to assess the Shannon index in the river Rupnarayan of present and past studies.

Location	Habitat description	Shannon Index	Reference
Harishpur, Paschim Medinipur (22.66058° N, 87.78616° E)	The site is located approximately 6 km downstream from the confluence point of Dewakeshwar and Shilabati rivers. The river at this site is narrow, about 100 m wide, but deep, reaching 3–4 m at low tide. It remains narrow until it meets the Mundeshwari at Bakshi. The riverbanks are steep and covered with dense vegetation, mostly tall grasses. There is a broad meander near the site. Both banks of the river are embanked and have human settlements.	2.113	Primary study
Jagatpur, Hooghly (22.623° N, 87.8206° E)	The river at the site is narrow, about 100 m wide, and deep, reaching 3–4 m at low tide. The river channel is straight at Jagatpur, with steeply sloped banks, and there are visible signs of soil erosion at a few points. About 1 km upstream of the site, a small canal flows into the river.	3.172	Dey & Panigrahi 2023
Chitnan, Howrah (22.5373° N, 87.87219° E)	The Chitnan area features a narrow river, approximately 300 m wide and 3–6 m deep at low tide. The site is in downstream from where the river Mundeswari meets the river Rupnarayan, the river widens significantly compared to the upper two sites. The riverbanks are characterized by narrow floodplains and dense vegetation, while small mid-channel islands emerge during low tide.	3.040	Dey & Panigrahi 2023
Naupala River Confluence, Howrah (22.45440° N, 87.87476° E)	The river at this site varies in width 500–1,000 m and forms meander, with many small islands visible during low tide. The river's depth is 3–4 m at low tide.	3.052	Ghorai 2018
Kolaghat, Purba Medinipur (22.4352° N, 87.8607° E)	The river at Kolaghat is straight and deep, measuring 3–8 m during low tide. It is approximately 600–700 m wide and embanked on both sides. A mid-channel island emerges during low tide. There are railway and roadway bridges as well as other riverside developmental activities at this location.	3.09	Dey & Panigrahi 2023
Denan canal inlet, Purba Medinipur (22.42851° N, 87.88941° E)	The Denan Canal connects to the river Rupnarayan, and thermal fly ash can be observed mixed in the river water at this location. The river is straight at this point and features a large mid-channel island. In terms of stream habitat, the river width is approximately 550 m and the depth ranges from 3–6 m during low tide.	3.28	Ghorai, 2018
Jamitta canal inlet, Purba Medinipur (22.40293° N, 87.93011° E)	The Jamitta canal connects to the river Rupnarayan, where thermal fly ash can be seen mixed in the river water. The river has a meander at this location. The depth of the river is about 2–3 m at low tide, and the width of the river is 800–850 m.	3.195	Ghorai 2018
Chaulia, Paschim Medinipur (22.3821° N, 87.95920° E)	The river channel splits into two separate channels due to a large mid-channel island. The main channel is approximately 850 m wide and is bordered by extensive flood plains on both banks. The river runs straight and has a depth of 2–4 m during low tide.	3.158	Dey & Panigrahi 2023

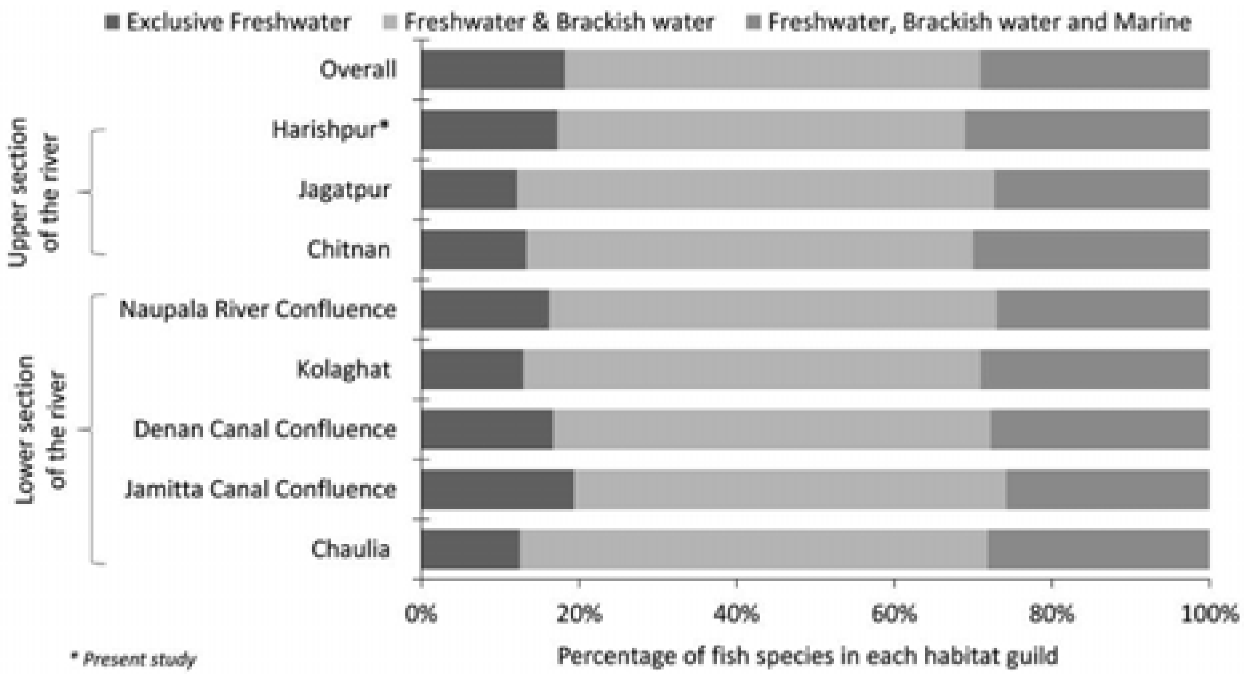

Image 4. Habitat guild of the fishes of Rupnarayan River, West Bengal, India.

and may serve as an important corridor for migratory and estuarine-dependent species. Its conservation is therefore crucial for sustaining the broader ecological integrity of the Hooghly riverine system. The integration of direct observations, local ecological knowledge, and literature synthesis enabled a robust understanding of the ichthyofaunal assemblage within a relatively short study period. However, the diversity also highlights underlying conservation challenges, especially the coexistence of native, migratory, and exotic species. While many species were categorised as LC, this does not imply ecological security. Several species with restricted distribution or facing local pressures—such as habitat degradation, overfishing, and pollution—require urgent conservation attention. The presence of NT and VU species, particularly in tidal zones that act as breeding grounds, calls for immediate protection measures. Notably, the exotic species add another layer of complexity, as their introduction to Indian rivers poses potential ecological risks due to competition for resources with indigenous species, habitat alteration, and potential spread of diseases (Saha et al. 2022). This also illustrates the anthropogenic influence on the river's biodiversity (Milardi et al. 2022).

The river's fish community is predominantly composed of species belonging to the *Cyprinidae* and *Bagridae* families, which are commercially important and widely distributed in Indian freshwater systems. The dominance of *Cyprinidae*, with eight identified species, underscores its adaptability to the river's environment. Differences in fish species diversity across sites, with the Shannon diversity index ranging from 2.1 at Harishpur to 3.28 at Denan canal confluence, suggest that environmental conditions, such as water quality, habitat structure, and salinity gradients, influence species distribution. The higher diversity observed at Denan canal inlet and Jamitta canal inlet could be attributed to the river's transition from freshwater to brackish water, providing a more diverse range of ecological niches (Kark 2017).

Species such as Elongate Glass Perchlet *Chanda nama*, Striped Snakehead *Channa striatus*, Great Snakehead *Channa marulius*, Spotted Snakehead *Channa punctata*, Tengara Catfish *Mystus tengara*, Striped Dwarf Catfish *Mystus vittatus*, Gangetic Mystus *Mystus cavasius*, Mola Carplet *Amblypharyngodon mola*, Barramundi *Lates calcarifer*, Spiny Eel *Mastacembelus armatus*, Barred Spiny Eel *Macrognathus pancalus*, Honey Gourami *Trichogaster chuna*, Banded Gourami *Trichogaster fasciata*, Gangetic Leaf-fish *Nandus nandus*, Wallago *Wallago attu*, Pabdah Catfish *Ompok pabda*, and Gangetic Mudeel *Monopterus cuchia* play important ecological roles by controlling insect larvae populations, including vectors of human diseases. These ecosystem services offer indirect public health benefits, further reinforce the need for their conservation (Farswan et al.

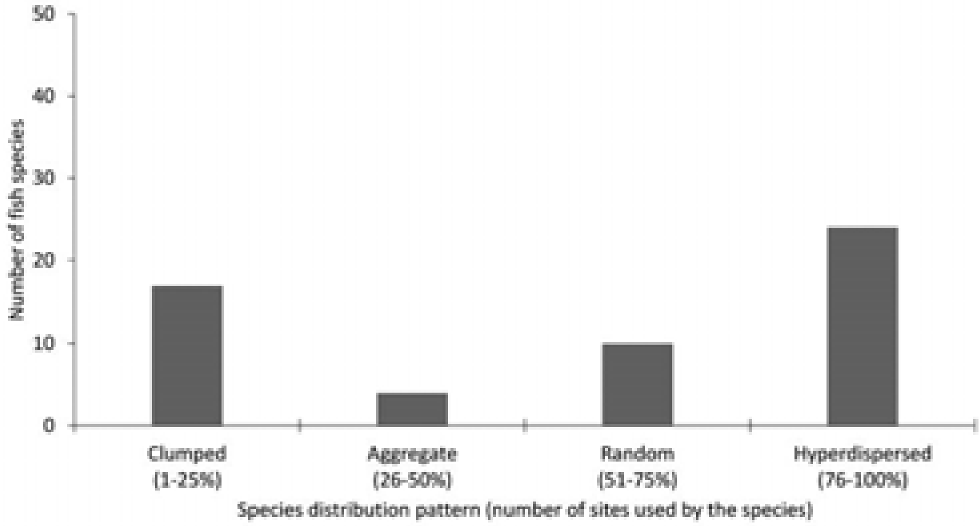

Image 5. Distribution pattern of the fishes of Rupnarayan River, West Bengal, India.

2019).

The species distribution analysis reveals that a substantial proportion of fish species (24 out of 55) are widely dispersed across habitats, indicating ecological adaptability. Conversely, clumped or narrowly distributed 16 species may be more vulnerable to habitat disturbance. The coexistence of freshwater, brackish water, and euryhaline species demonstrates the river's role as a transition zone between different aquatic environments. This ecological connectivity allows for a diverse array of fish species to thrive but also makes the river sensitive to changes in salinity and hydrological dynamics. The high proportion of species that utilise both freshwater and brackish water habitats (52.7%) suggests a reliance on stable salinity conditions, making the ecosystem potentially vulnerable to activities such as dam construction, which could alter natural salinity gradients. Owing to its unique geographical location and habitat due to the ingression of cyclic tide, the river supports many migratory species of fishes. The presence of anadromous migrants such as Hilsa Shad *Tenualosa ilisha*, Toli Shad *Tenualosa toli*, Corsula *Rhinomugil corsula*, and Oriental Sole *Brachirus orientalis* indicates the importance of the River Rupnarayan as a viable breeding ground. Furthermore, the unique habitat of River Rupnarayan also supports a substantial population of various catadromous species, including the Indian Mottled Eel *Anguilla bengalensis*. While the current study provides valuable baseline data, limitations such as taxonomic ambiguities (e.g., *Amphipnous* sp.) and seasonal data gaps must be acknowledged. Genetic barcoding and longer-term monitoring are recommended to improve species resolution and track population trends.

This study underscores the ecological significance of the Rupnarayan River as a biodiversity-rich yet vulnerable freshwater ecosystem. The documentation of 55 fish species, including threatened and exotic taxa, highlights the need for immediate conservation action. Ecosystem-based management approaches that integrate biodiversity protection with sustainable livelihood strategies are essential. Continued research, habitat restoration, and participatory governance involving local communities will be key to securing the future of this vital riverine ecosystem. Changes in fish catch patterns, as reported by local fishers, suggest a declining abundance of certain native and economically important species and an increasing presence of exotics. This shift has direct implications for livelihoods dependent on traditional capture fisheries. Conservation strategies must, therefore, integrate socio-economic perspectives to ensure sustainable fisheries while restoring ecological balance. Management actions could include regulating fishing practices, protect breeding habitats, and establishing community-based monitoring systems. Conservation strategies should consider the management of non-native species, monitoring of fish population trends, and protection of critical habitats to maintain the ecological balance (Britton et al. 2011). Additionally, the presence of species that are either DD or NE for their conservation status further highlights the need for ongoing research to fill knowledge gaps and inform conservation priorities.

Disclaimer

The map used in the article is not a legal description or a reflection of any expression or opinion or advise of any nature and do not warrant correctness, current situation, limitations and accuracy. The depictions are strictly representational.

REFERENCES

Bashir, T. et al. (2010). Abundance and prey availability assessment of Ganges River dolphin (*Platanista gangetica*) in a stretch of Upper Ganges River, India. Aquatic Mammals 36(1): 19–26.

Britton, J.R. et al. (2011). Managing non-native fish in the environment. Fish and Fisheries 12(3): 256–274.

Cederholm, C.J. et al. (1999). Pacific salmon carcasses: Essential contributions of nutrients and energy for aquatic and terrestrial ecosystems. Fisheries 24(10): 6–15. https://doi.org/10.1577/1548-8446(1999)024<0006:PSC>2.0.CO;2

Das, M.K. et al. (2014). Assessment of fishery and ecological integrity of the anthropogenically stressed river Churni, India. Journal of the Inland Fisheries Society of India 46(1): 09–28.

Das, M.K. et al. (2013). Environment and Fisheries of River Damodar. ICAR-CIFRI Bulletin No. 183, 68 pp.

Das, G.K. (2024). Environmental Morphodynamics of Rupnarayan River. In: *River Systems of West Bengal: Water and Environments.* Springer, Cham. https://doi.org/10.1007/978-3-031-53480-5_7

Department of Fisheries (2022). Handbook on Fisheries Statistics. Ministry of Fisheries, Animal Husbandry & Dairying, Government of India.

Dey, S. & A.K. Panigrahi (2023). Current status and diversity of ichthyofauna in the River Rupnarayan. Research Journal of Agricultural Sciences 14(6): 1933–1936. http://rjas.org/Article/Article/5712

Farswan, S. et al. (2019). A study on the occurrence of larvivorous fishes (Pisces) in Doon Valley (Uttarakhand). Journal of Experimental Zoology India 22(1): 183–187.

Flecker, A.S. et al. (2010). Migratory fishes as material and process subsidies in riverine ecosystems. In American Fisheries Society Symposium 73: 559–592. https://doi.org/10.47886/9781934874141.ch28

Froese, R. & D. Pauly (eds.) (2010). FishBase. Accessed on 02.x.2025.

George, D. et al. (2025). First photographic evidence of Indo-Pacific Humpback Dolphin (*Sousa chinensis* Osbeck, 1765) from tidal river Rupnarayan, West Bengal, India. *Journal of Wildlife Science* 2(2): 62–65. https://doi.org/10.63033/JWLS.WCCA6033

Ghorai, M. (2018). Diversity and present conservation status of fish fauna in the Rupnarayan River at Kolaghat of Purba Medinipur district of West Bengal, India. International Journal of Scientific Development and Research 3(2): 2455–2631.

Iglesias, I.S. et al. (2023). Mesopelagic fishes are important prey for a diversity of predators. Frontiers in Marine Science 10: 1220088. https:// doi.org/10.3389/fmars.2023.1220088

IUCN (2025). The IUCN Red List of Threatened Species. https://www.iucnredlist.org/ Accessed on 07.x.2025.

Kark, S. (2017). Effects of ecotones on biodiversity, pp. 142–148. In: Reference Module in Life Sciences. Elsevier. https://doi.org/10.1016/B978-0-12-809633-8.02290-1

Khan, M.S. et al. (2013). Composition and conservation status of avian species at Hastinapur Wildlife Sanctuary, Uttar Pradesh, India. Journal of Threatened Taxa 5(12): 4714–4721. https://doi.org/10.11609/JoTT.o3419.4714-21

Khan M.S. et al. (2014). Habitat use and conservation status of Smooth-coated Otters *Lutrogale perspicillata* in Upper Gangetic Basin, India. Animal Biodiversity Conservation 37(1): 69–76. https://doi.org/10.32800/abc.2014.37.0069

Matthews, W.J. (1998). *Patterns in Freshwater Fish Ecology.* Chapman & Hall, New York, 756 pp. https://doi.org/10.1007/978-1-4615-4066-3

Milardi, M. et al. (2022). Natural and anthropogenic factors drive large-scale freshwater fish invasions. Scientific Reports 12: 10465. https://doi.org/10.1038/s41598-022-14556-5

Moore, J.W. (2006). Animal ecosystem engineers in streams. *BioScience* *56*(3): 237–246. https://doi.org/10.1641/0006-3568(2006)056[0237:AEEIS]2.0.CO;2

Qureshi, Q. et al. (2024). *Population Status of River Dolphins in India 2021–23.* Ministry of Environment, Forest & Climate Change, New Delhi & Wildlife Institute of India, Dehradun, 294 pp.

Roshith, C.M. et al. (2013). Ichthyofaunal diversity, assemblage structure and seasonal dynamics in the freshwater tidal stretch of Hooghly estuary along the Gangetic delta. Aquatic Ecosystem Health & Management 16(4): 445–453. https://doi.org/10.1080/14634988.2013.857561

Saha, N.C. et al. (2022). Invasive fish species in India: Challenges, threats and impacts. Research & Reviews: Journal of Ecology 11(1): 7–14. https://sciencejournals.stmjournals.in/index.php/RRJoE/article/view/3263

Talwar, P.K. & A.G. Jhingran (1991). Inland Fishes of India and Adjacent Countries, Vols. 1 & 2. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi.

Thapa, A. et al. (2025). Non-consumptive value of hilsa fishery restoration in West Bengal, India: An application of contingent valuation method. *Journal of Environmental Management 373*: 124016. https://doi.org/10.1016/j.jenvman.2024.124016

Vanni, M.J. et al. (2006). Nutrient cycling by fish supports relatively more primary production as lake productivity increases. Ecology 87(7): 1696–1709. https://doi.org/10.1890/0012-9658(2006)87[1696:ncbfsr]2.0.co;2

WII-GACMC (2022). *Rupnarayan River: Ecological Status and Trends.* Ganga Aqualife Conservation Monitoring Centre and Wildlife Institute of India, Dehradun, 28 pp.

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Acknowledgements: We sincerely thank the local fisher community of Harishpur, particularly the fishers Mr. Uttam Dolui, and Mr. Subho Dolui, who assisted in conducting interviews and fish sampling, without whom this study would not have been possible. We extend our heartfelt appreciation to Mr. Ravi Singh (SG & CEO, WWF-India), Dr. Sejal Worah (Director Programmes, WWF-India), Mr. Suresh Babu (Senior Director – Ecological Footprint, WWF-India), and Mr. Nitin Kaushal (Director – Rivers and Wetlands, WWF-India) for their dedicated oversight and support, which were instrumental in the successful completion of this study. We are also grateful to our colleagues in the Sundarbans Delta Programme, particularly Ms. Debolina Banerjee and Ms. Mahashweta Ghoshal, for their significant contributions to the research process.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 August 2026 | 18(8): 29459–29469

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

https://doi.org/10.11609/jott.10360.18.8.29459-29469

#10360 | Received 02 January 2026 | Final received 22 July 2026 | Finally accepted 04 August 2026

OPEN ACCESS

ARTICLE

Community structure and environmental determinants of amphibians in the Western Ghats watersheds of eastern Goa, India

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Abstract: We studied the amphibian diversity and the influence of abiotic factors across 12 watershed zones in the Western Ghats region of Goa, India. Surveys conducted at 102 sampling sites recorded 22 amphibian species, including eight Western Ghats endemics. Species richness and diversity were highest in watersheds with intermediate canopy cover and deeper leaf litter. Pearson correlation analysis identified leaf litter depth, humidity, and temperature as key factors influencing amphibian diversity. The findings highlight the importance of forest floor microhabitats and microclimatic conditions in shaping amphibian communities and emphasize the need to conserve structurally diverse forest habitats in the Western Ghats.

Keywords: Abiotic factors, alpha diversity, canopy cover, ecology, leaf litter depth, microclimate, species richness.

Editor: Anonymity requested. **Date of publication:** 26 August 2026 (online & print)

Citation: Gawas, M.M., S.S. Sawal & N.S. Sawant (2026). Community structure and environmental determinants of amphibians in the Western Ghats watersheds of eastern Goa, India. *Journal of Threatened Taxa* 18(8): 29459–29469. https://doi.org/10.11609/jott.10360.18.8.29459-29469

Funding: None.

Competing interests: The authors declare no competing interests.

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Author contributions: MG—field data collection, data analysis, manuscript preparation and writing. SS—field data collection. NSS—conceptualization of the research, research methodology and study design, manuscript preparation, review, proofreading and supervision.

Acknowledgements: We sincerely thank the Goa Forest Department for granting necessary permissions, Honourable MLA Smt. Deviya Rane for support in facilitating permissions, and our fellow colleagues for their valuable assistance during fieldwork.

INTRODUCTION

The Western Ghats is recognised as one of the world's 34 biodiversity hotspots and supports high amphibian diversity and endemism (Myers et al. 2000). Goa forms part of the Goa Gap, a bioclimatic and vegetational transition zone within the Western Ghats (Pascal 1988; Qureshi 1965; Barboni et al. 2003; Reddy et al. 2016; Ramachandran et al. 2017; Biswas & Karanth 2021; Chaitanya & Meiri 2022). Despite the rich amphibian diversity of the Western Ghats, Goa remained comparatively understudied for many decades because the state was under Portuguese rule during the period when extensive faunal surveys were being conducted in British India (Kulkarni et al. 2013).

The earliest published accounts of amphibians from Goa were provided by Abdulali & Sekar (1988), followed by studies by Sekar (1991, 1992), Das & Whitaker (1997, 1998), Bhat & Desai (1998), and Sarkar & Ray (2004). Kamble (2008) carried out one of the last detailed taxonomic studies on Goan amphibians. Later, Kulkarni et al. (2013) reported 36 species from Goa, while Dinesh et al. (2015) updated the checklist and reported 34 species from the state. Although these studies contributed significantly to the knowledge of amphibians in Goa, information regarding amphibian community structure, spatial distribution, and the influence of abiotic factors on amphibian assemblages remains limited.

Understanding amphibian diversity, habitat associations, and community structure is therefore essential for developing effective conservation strategies (Sawant & Jadhav 2013; Bowalkar & Sawant, in press). Therefore, the present study was conducted to document amphibian species from the forests in the study area, examine their community structure, and assess the influence of selected abiotic factors on their communities.

METHODS

The study was carried out in the Western Ghat region of Goa covering Mhadei Wildlife Sanctuary, Bhagwan Mahavir Wildlife Sanctuary, Mollem National Park, Netravali Wildlife Sanctuary, Cotigao Wildlife Sanctuary, and parts outside these sanctuaries amounting to a total geographical area of 1335.95 km^2 (Image 1). The surveys were conducted across watersheds associated with Valvanti river (W1), Kotrachi nadi (W2), Madhei river – Satrem tributary (W3), Madhei river (Main) (W4), Ragada river (W5), Dudhsagar river (W6), Uguem river (W7), Netravali river (W8), Kushawati river (W9), Agonda river (W10), Talpona river (W11), and Kali river tributary (W12) (Table 1). The study was carried out during the monsoon season from June–September in dense forested areas, defined as regions having tree canopy cover greater than 40% (Forest Survey of India 2023). The entire study area is divided into 12 watershed zones (W1–W12) using QGIS software and SRTM data from U.S. Department of the Interior (Image 2). Each watershed zone was further subdivided into three elevational zone low (0–200 m), mid (200–400 m), and high (above 400 m) and sampling was conducted uniformly in each of the elevational zone to minimize sampling bias. In total, 102 sampling sites were established (three sites per elevation in each watershed) (Image 1, table 1). At each site, three replicate line transects (30 × 20 m; 10 m on either side) were laid. Amphibians were surveyed using standardized visual and acoustic encounter surveys for 30 minutes per observer, covering all available microhabitats (Crump 1994; Rödel & Ernst 2004). Surveys were conducted at night between 2000 h and 0300 h, coinciding with peak amphibian activity.

Along with species data, environmental, climatic, and habitat-related variables were collected to understand the relationship between amphibian communities and environmental factors. Seven key abiotic variables were recorded: tree cover (%) using a densitometer, leaf litter temperature (^{0}C) using an infrared thermometer, leaf litter depth (cm) using a scale, leaf litter ratio by counting number of leaves, twigs and fruits in 1 m^2, understory vegetation (count in 5 m^2), ambient temperature (^{0}C) using a thermometer, and relative humidity (%) using a hygrometer.

RESULTS

A total of 22 amphibian species were recorded from the study area. Of these, two species are classified as 'Endangered', two as 'Vulnerable', one as 'Near Threatened', one as 'Data Deficient', and 16 species as 'Least Concern' according to the IUCN Red List of Threatened Species. Eight of the recorded species are endemic to the Western Ghats of India, highlighting the region's unique and irreplaceable biodiversity (Image 2; Table 2).

Alpha diversity

Species richness ranged from 9–19 species, with least species in W12 (9 species) and highest species in W3 (19 species) (Image 3A; Table 3). The Shannon diversity

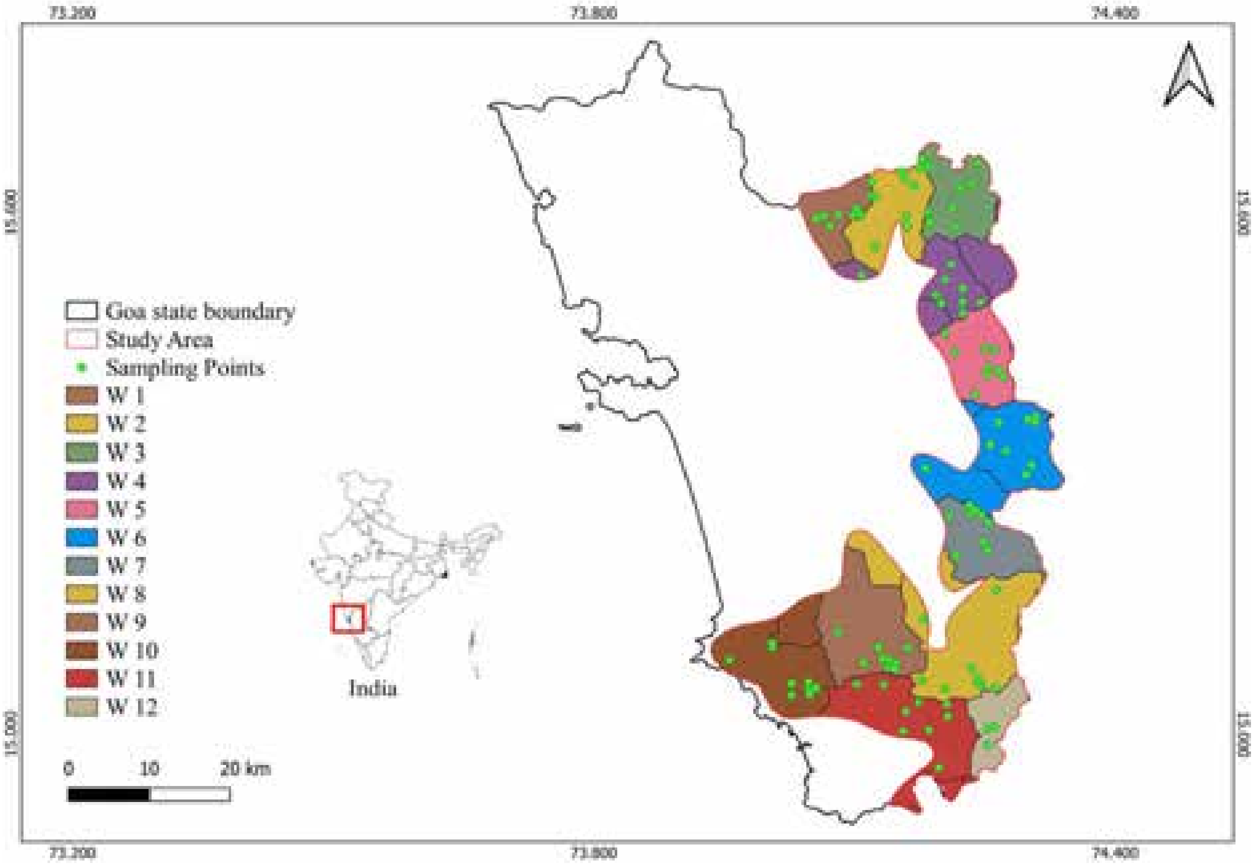


Image 1. Watershed zones (W1–W12) and sampling sites in the study area.

Table 1. Details of sampling sites, elevation categories, associated watersheds, and hill ranges surveyed in the Western Ghats region of Goa.

Watershed code	Site names			Watershed/river basin	Hill range
	Low elevation (0–200 m)	Mid elevation (200–400 m)	High elevation (above 400 m)		
W1	1_A1, 1_A2, 1_A3	1_B1, 1_B2, 1_B3	1_C1, 1_C2, 1_C3	Valvanti river basin	Morlegad and vagheri hill range
W2	2_A1, 2_A2, 2_A3	2_B1, 2_B2, 2_B3	2_C1, 2_C2, 2_C3	Kotrachi Nadi river basin	Chorla ghat range
W3	3_A1, 3_A2, 3_A3	3_B1, 3_B2, 3_B3	3_C1, 3_C2, 3_C3	Madhei river – Satrem tributary basin	Surla ghat range
W4	4_A1, 4_A2, 4_A3	4_B1, 4_B2, 4_B3	4_C1, 4_C2, 4_C3	Madhei river basin	Sosogad hill range
W5	5_A1, 5_A2, 5_A3	5_B1, 5_B2, 5_B3	5_C1, 5_C2, 5_C3	Ragada river basin	Anmod ghat range
W6	6_A1, 6_A2, 6_A3	6_B1, 6_B2, 6_B3	6_C1, 6_C2, 6_C3	Dudhsagar river basin	Dudhsagar-Kuveshi hill range
W7	7_A1, 7_A2, 7_A3	7_B1, 7_B2, 7_B3	7_C1, 7_C2, 7_C3	Uguem river basin	Dhargini-Patiem hill range
W8	8_A1, 8_A2, 8_A3	8_B1, 8_B2, 8_B3	8_C1, 8_C2, 8_C3	Netravali river basin	Netravali-Ravon dongor Hill range
W9	9_A1, 9_A2, 9_A3	9_B1, 9_B2, 9_B3	9_C1, 9_C2, 9_C3	Kushawati river basin	Corla hill range
W10	10_A1, 10_A2, 10_A3	10_B1, 10_B2, 10_B3	10_C1, 10_C2, 10_C3	Agonda river basin	Karmal ghat range
W11	11_A1, 11_A2, 11_A3	11_B1, 11_B2, 11_B3	11_C1, 11_C2, 11_C3	Talpona river basin	Cotigao-Ravon dongor hill range
W12	Nil	Nil	12_C1, 12_C2, 12_C3	Kali river tributary basin	Netravali-Ravon dongor Hill range

index (H') was highest at W1 1 (2.35) and lowest at W12 (1.82), with elevated H' values at Sites 1 and 11 indicating a diverse and well-distributed amphibian community in these watersheds (Image 3B; Table 3). Simpson Index (1–D) ranged from 0.79 in W12 to 0.89 in W11, watersheds such as W5 and W11 which exhibited high

Table 2. Table showing presence (1) absence (0) of species across watersheds, * Endemic to Western Ghats of India.

	Species	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12
1	*Duttaphrynus melanostictus*	1	1	1	1	1	1	1	1	1	1	1	0
2	*Pedostibes tuberculosus**	0	0	1	1	0	1	0	0	1	0	0	0
3	*Euphlyctis cyanophlyctis*	0	0	1	1	0	1	1	1	1	1	1	1
4	*Minervarya gomantaki*	1	1	1	1	1	1	1	1	1	1	1	0
5	*Minervarya goemchi*	0	1	1	0	0	0	0	0	0	0	0	1
6	*Minervarya cepfi*	1	1	1	1	1	1	0	1	1	1	1	1
7	*Hoplobatrachus crassus*	1	1	1	1	0	1	1	1	1	1	1	1
8	*Sphaerotheca maskeyi*	1	1	1	1	1	1	1	1	1	1	1	1
9	*Microhyla ornata*	1	0	1	0	1	0	0	1	0	1	1	0
10	*Uperodon globulosus*	1	0	0	0	0	0	0	0	0	0	0	0
11	*Uperodon mormorata*	1	1	1	1	1	1	1	1	0	1	1	0
12	*Nyctibatrachus petraeus**	1	0	1	0	1	0	1	1	1	0	1	1
13	*Clinotarsus curtipes**	0	0	1	0	0	0	0	0	0	0	0	0
14	*Hydrophylax bahuvistara*	0	1	1	0	0	0	0	1	0	1	1	0
15	*Indosylvirana caesari**	1	0	1	0	0	0	1	0	0	0	0	0
16	*Indirana salelkari**	1	1	1	0	1	0	1	1	1	1	1	1
17	*Polypedates maculatus*	1	1	1	1	1	1	1	1	1	1	1	0
18	*Pseudophilautus amboli**	1	1	1	1	1	1	1	1	1	1	1	1
19	*Raorchestes bombayensis**	1	1	1	1	1	1	1	1	1	1	1	1
20	*Rhacophorus malabaricus**	1	1	1	0	1	0	1	0	1	0	1	0
21	*Ichthyophis davidi*	0	0	0	0	0	1	0	0	0	0	0	0
22	*Ichthyophis bombayensis*	0	0	0	0	0	0	0	0	1	0	0	0

Simpson values, indicates low dominance and higher probability of encountering different species (Image 3C; Table 3). Evenness (J') was highest at W5 (0.92), showing a balanced species distribution, while W3 (0.74) had lower evenness despite high richness possible due to dominance by few species (Image 3D; Table 3).

Environmental Variation

Tree cover: Tree canopy cover was generally high across all watersheds, ranging from 71.11% SE = 6.33 at W10 to 100% at W5 and W12. Watersheds in the northern and central regions (W1–W7) consistently exhibited dense canopy cover (>90%), whereas southern watersheds showed variable tree canopy cover between 71% in W10 to 100% in W12, indicating canopy openness or disturbance in south (Image 4A; Table 4).

Leaf Litter Temperature: This was relatively stable across the sites, ranging from 22.70 ^{0}C SE = 0.65 in W8 to 24.76 ^{0}C SE = 0.19 (W11) (Image 4B; Table 4).

Leaf litter depth: It varied across the gradients, with W3 recording the highest mean depth (3.50 cm SE = 0.54), followed by W2 (3.22 cm SE = 0.67), and W9 (3.11 cm SE = 0.46) (Image 4C; Table 4).

Leaf Litter Ratio: ratio remained consistent across watersheds, generally ranging between 0.73 and 0.80, except in W10 (0.67 SE = 0.05), which had the lowest value. Most northern and central watersheds had a ratio of 0.76–0.80, indicating high-quality litter habitats (Image 4D; Table 4).

Understory Vegetation: This showed high spatial variability. The densest vegetation was observed in W6 (173.33 SE = 12.69), and W3 (160 SE = 17.16), while W10 had the sparsest understory (82.78 SE = 14.89). Northern watersheds such as W1–W6 also had moderate to dense understory with an average of 140.04, contributing to microhabitat complexity (Image 4E; Table 4).

Ambient Temperature: This varied significantly along the gradient. The coolest site was W8 (23.53 ^{0}C, SE = 0.49), while the warmest was W7 (28.90 ^{0}C, SE = 1.08), and W10 (28.14 ^{0}C, SE = 0.30). Southern watersheds, particularly W7–W12, exhibited higher temperatures compared to northern ones (Image 4F; Table 4).

Humidity: This was generally high across the watersheds. W4 and W9 recorded the highest mean humidity (92.33% SE = 1.48 and 91.11% SE = 1.44) while W7 recorded the lowest (74.56% SE = 5.40) (Image 4G;

Image 2. Amphibians recorded in the study area. A—*Duttaphrynus melanostictus* | B—*Pedostibes tuberculosus* | C—*Euphlyctis cyanophlyctis* | D—*Minervarya gomantaki* | E—*Minervarya goemchi* | F—*Minervarya cepfi* | G—*Hoplobatrachus crassus* | H—*Sphaerotheca maskeyi* | I—*Microhyla ornata* | J—*Uperodon globulosus* | K—*Uperodon mormorata* | L—*Nyctibatrachus petraeus* | M—*Clinotarsus curtipes* | N—*Hydrophylax bahuvistara* | O—*Indosylvirana caesari*. © Mayur Gawas.

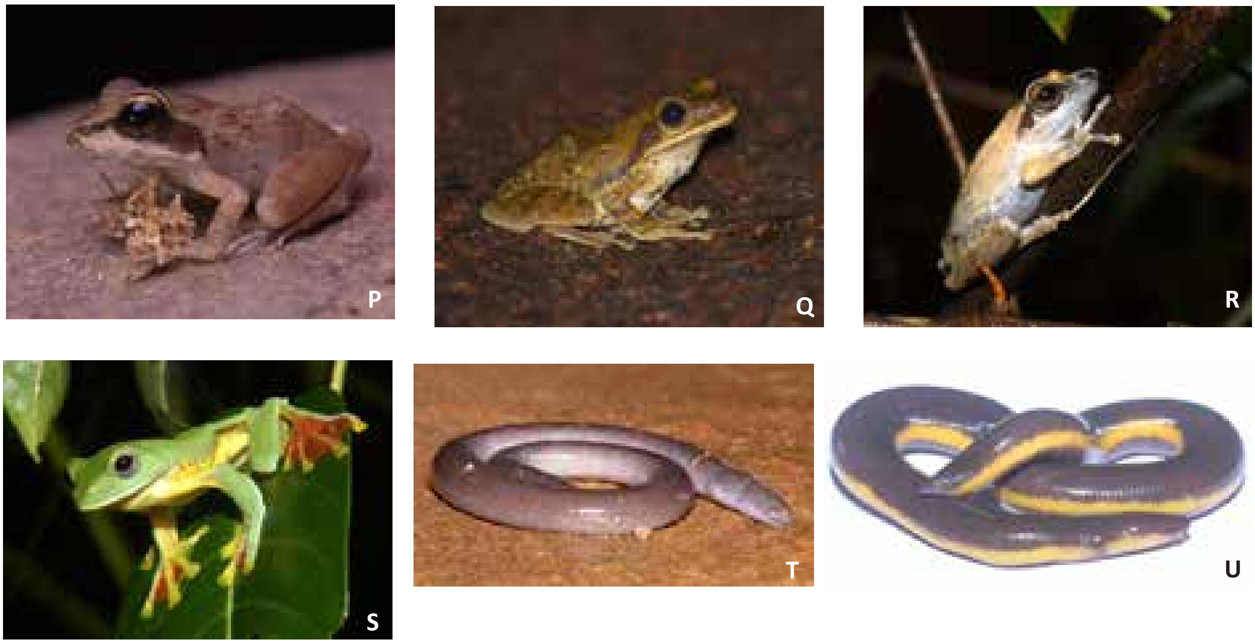


Image 2 continued. Amphibians recorded in the study area. P—*Indirana salelkari* | Q—*Polypedates maculatus* | R—*Pseudophilautus amboli* | S—*Rhacophorus malabaricus* | T—*Ichthyophis bombayensis* | U—*Ichthyophis davidi.* © Mayur Gawas.

Table 3. Table showing alpha diversity indices across watersheds.

Site	Richness	Shannon	Simpson	Evenness
W1	15	2.35	0.88	0.87
W2	13	2.10	0.85	0.82
W3	19	2.19	0.85	0.74
W4	11	1.92	0.81	0.80
W5	12	2.28	0.88	0.92
W6	12	1.98	0.81	0.80
W7	13	2.07	0.85	0.81
W8	14	2.32	0.88	0.88
W9	14	2.17	0.86	0.82
W10	13	2.09	0.85	0.81
W11	15	2.32	0.89	0.86
W12	9	1.82	0.79	0.83

Table 4).

Overall, southern watersheds were characterized by higher ambient temperatures, variable humidity, and relatively sparse vegetation, whereas northern and central watersheds exhibited denser canopy cover, cooler microclimates, and deeper litter layers. These environmental gradients likely influence the observed patterns in amphibian community composition and beta diversity.

Pearson correlation

Pearson correlation analysis revealed leaf litter depth as the strongest driver of amphibian alpha diversity across 12 Western Ghats watersheds (Image 5). Species richness was strongly positively correlated with leaf litter depth ($r = 0.65$) and humidity ($r = 0.37$), but negatively with temperature ($r = -0.35$) and tree cover ($r = -0.27$). Shannon and Simpson indices were highly intercorrelated ($r = 0.97$) and moderately tied to richness ($r = 0.67, 0.57$), with weak negative links to temperature and understory vegetation. Pielou's evenness showed a strong negative correlation with leaf litter depth ($r = -0.47$), indicating dominance in deeper litter, and weak positive ties to tree cover ($r = 0.21$) and leaf litter ratio ($r = 0.21$). Environmental variables were tightly linked: tree cover & leaf litter ratio ($r = 0.82$), understory & leaf litter ratio ($r = 0.63$), and temperature & humidity ($r = -0.54$). Overall, leaf litter depth, humidity, and temperature were the primary predictors, with depth exerting opposing effects on richness (+ve) and pielou's evenness (-ve).

Intermediate canopy cover (80–95 %) and deeper leaf litter emerge as key drivers of amphibian alpha diversity across Western Ghats watersheds, with peak richness occurring where microclimatic conditions optimize the litter–forest floor interface. While full canopy closure maintains evenness through generalist dominance, it reduces habitat suitability via litter compression and

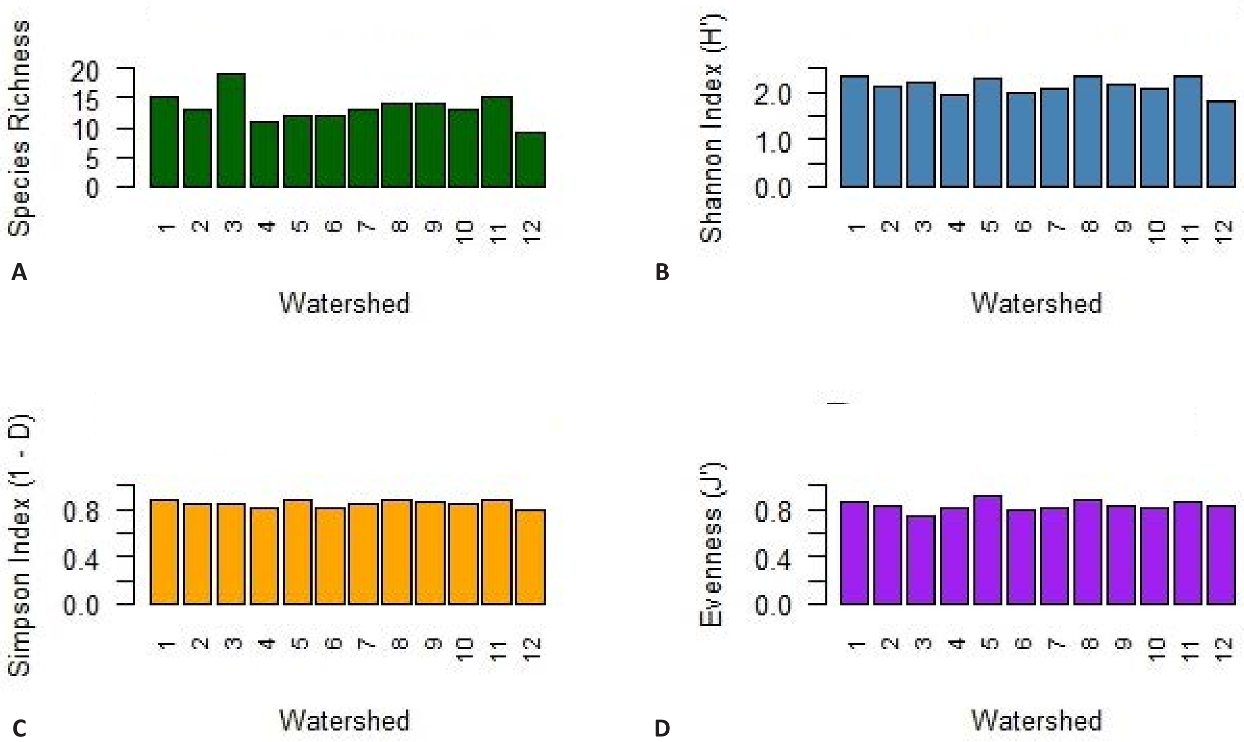


Image 3. Alpha diversity indices: A—Species richness | B—Shanon diversity index | C—Simpson diversity index | D—Pielou's evenness.

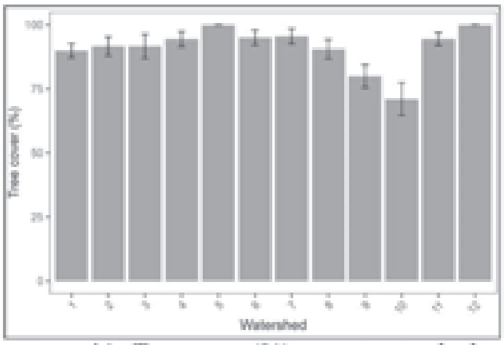
thermal stress. These findings highlight the value of mid-successional forest patches for conserving anuran biodiversity amidst ongoing habitat alteration in this global biodiversity hotspot. To safeguard anuran biodiversity amid escalating climate change and habitat fragmentation, conservation priorities must emphasize preserving undisturbed leaf litter layers and intermediate vegetation structure in tropical montane streams, ensuring both species coexistence and long-term community stability.

DISCUSSION

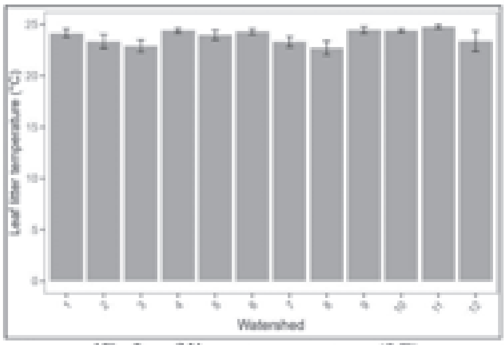
Amphibian alpha diversity across the 12 Western Ghats watersheds exhibited moderate variation, with species richness ranging from 9 (W12) to 19 (W3) and Shannon diversity from 1.82 (W12) to 2.35 (W1). Highest richness and Shannon values occurred in watersheds with intermediate canopy cover (80–95 %) and deeper leaf litter (W1, W9, W3, W8, W11), consistent with studies showing that canopy closure and litter depth are key predictors of anuran diversity in Western Ghats forests (Katwate et al. 2013) and that amphibian richness tends to decline under very dense canopy in forested wetlands (Skelly et al. 2005).

In contrast, full-canopy, shallow-litter sites (W5, W12) supported lower richness despite occasionally high Pielou's evenness (W5 = 0.92), a pattern similar to sites with low richness but evenly distributed abundances reported from Phansad Wildlife Sanctuary (Katwate et al. 2013). Simpson diversity remained consistently high across watersheds (0.79–0.89), indicating low dominance and relatively even assemblages; this is in line with work showing that elevated local alpha diversity and evenness can persist across habitat conditions while masking underlying shifts in species composition and regional diversity (Dehling & Dehling 2023). Together, these results suggest that fine-scale variation in canopy structure and forest-floor litter depth modulates local richness within broadly forested catchments, whereas community evenness remains high, as expected for assemblages dominated by a mix of habitat generalists and a smaller set of specialists.

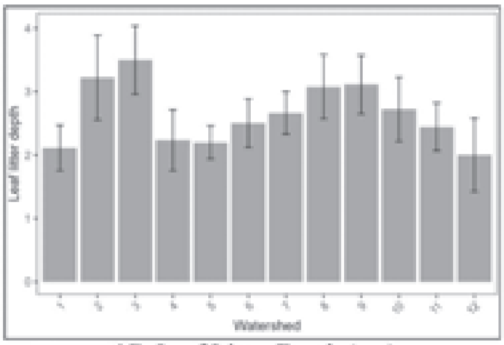
Pearson correlation analysis confirmed leaf litter depth as the strongest predictor, positively driving richness ($r = 0.65$) but reducing evenness ($r = -0.47$), indicating that greater forest-floor microhabitat complexity promotes species accumulation while fostering dominance by leaf-litter specialists (Scott 1976; Kouamé et al. 2018).



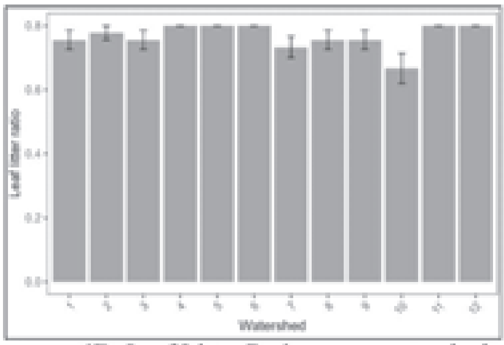
4A: Tree cover (%) across watersheds



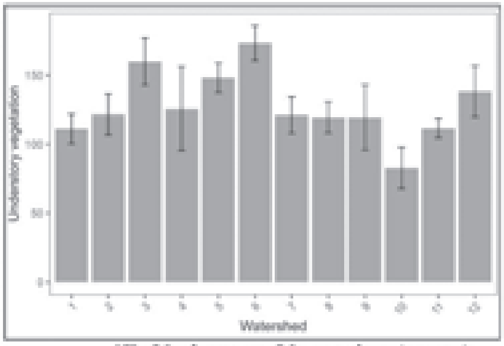
4B: Leaf litter temperature (°C) across watersheds



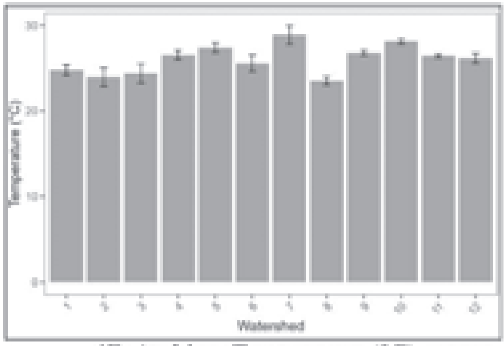
4C: Leaf Litter Depth (cm) across watersheds



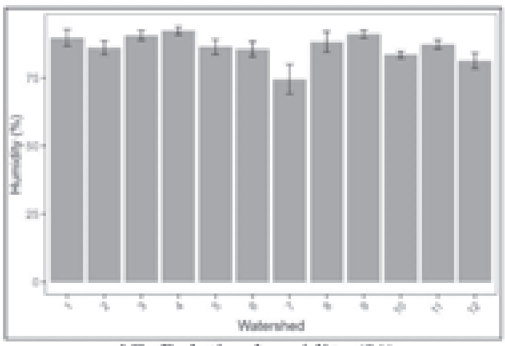
4D: Leaf Litter Ratio across watersheds



4E: Understory Vegetation (count) across watersheds



4F: Ambient Temperature (°C) across watersheds



4G: Relative humidity (%) across watersheds

Image 4. Environmental variables across watersheds.

Table 4. Environmental variables across watersheds.

watershed	Tree Cover			Leaf Litter Temperature			Leaf Litter Depth			Leaf Litter Ratio			Understory Vegetation			Temperature			Humidity		
	Mean	SD	SE	Mean	SD	SE	Mean	SD	SE	Mean	SD	SE	Mean	SD	SE	Mean	SD	SE	Mean	SD	SE
1	90	8.29	2.76	24.14	1.25	0.42	2.11	1.08	0.36	0.76	0.09	0.03	111.11	32.29	10.76	24.79	1.85	0.62	89.78	9.11	3.04
2	91.67	11.18	3.73	23.35	1.98	0.66	3.22	2.00	0.67	0.78	0.07	0.02	121.67	44.51	14.84	23.98	3.20	1.07	86.11	7.49	2.50
3	91.67	14.14	4.71	22.89	1.72	0.57	3.50	1.62	0.54	0.76	0.09	0.03	160.00	51.48	17.16	24.40	3.29	1.10	90.67	5.17	1.72
4	94.44	8.82	2.94	24.39	0.73	0.24	2.23	1.45	0.48	0.80	0.00	0.00	125.78	91.36	30.45	26.56	1.61	0.54	92.33	4.44	1.48
5	100	0.00	0.00	23.96	1.36	0.45	2.20	0.78	0.26	0.80	0.00	0.00	148.33	32.21	10.74	27.40	1.69	0.56	86.44	8.22	2.74
6	95	8.66	2.89	24.29	0.79	0.26	2.50	1.15	0.38	0.80	0.00	0.00	173.33	38.08	12.69	25.59	2.89	0.96	85.67	8.19	2.73
7	95.56	8.82	2.94	23.31	1.57	0.52	2.67	1.00	0.33	0.73	0.10	0.03	121.11	39.43	13.14	28.90	3.25	1.08	74.56	16.19	5.40
8	90.56	11.30	3.77	22.70	1.96	0.65	3.08	1.52	0.51	0.76	0.09	0.03	119.44	33.95	11.32	23.53	1.46	0.49	88.33	11.24	3.75
9	80	13.23	4.41	24.45	0.95	0.32	3.11	1.39	0.46	0.76	0.09	0.03	119.44	70.73	23.58	26.80	0.96	0.32	91.11	4.31	1.44
10	71.11	19.00	6.33	24.38	0.50	0.17	2.72	1.52	0.51	0.67	0.14	0.05	82.78	44.66	14.89	28.14	0.90	0.30	83.56	3.68	1.23
11	94.44	7.26	2.42	24.76	0.57	0.19	2.44	1.13	0.38	0.80	0.00	0.00	111.67	21.07	7.02	26.44	0.61	0.20	87.33	4.66	1.55
12	100	0.00	0.00	23.38	1.74	1.00	2.00	1.00	0.58	0.80	0.00	0.00	138.33	32.15	18.56	26.17	0.96	0.55	81.33	4.93	2.85

Humidity positively influenced richness and Shannon indices (r = 0.37, 0.32), and temperature showed negative associations (r = −0.35, −0.26), consistent with amphibians' reliance on cool, moist microclimates, and narrow physiological tolerances to desiccation and heat (Wells 2007). The strong inverse relationship between temperature and humidity (r = −0.54) therefore highlights a key microclimatic trade-off, where drier, warmer conditions are likely to restrict activity and occupancy of many forest-floor anurans despite otherwise suitable structural habitat (Wells 2007).

Environmental variables show some distinct patterns. Tree cover ranged from 71.11% (W10) to 100% (W5, W12), with leaf litter depth peaking (3.0–3.5 cm) under moderate canopy and declining under dense closure (~2.2 cm) due to compression and reduced litterfall (Wells 2007; Cardelús 2010). Understory vegetation was densest in closed-canopy sites (W6, W5, W12), potentially impeding amphibian movement or prey access as reported from Western Ghats forests. Ambient temperature was elevated (>27 ^{0}C) in high-canopy watersheds, likely from reduced ventilation and heat trapping (Spranger et al. 2024), while humidity dipped lowest in W7 and W5, coinciding with moderate canopy and high thermal stress (Wells 2007; Seshadri 2014).

Despite structural roles in habitat provision, tree cover, and understory vegetation showed weak or negative correlations with amphibian diversity metrics, as dense canopies suppressed leaf litter depth (r = -0.40) and elevated temperature, indirectly constraining occupancy. This pattern supports tropical studies documenting peak anuran diversity in mid-successional habitats rather than closed-canopy forests, where intermediate structural complexity optimizes microclimate, litter accumulation, and foraging opportunities (Skelly et al. 2005; Wells, 2007). The near-perfect correlation between Shannon and Simpson indices (r = 0.97) across watersheds confirms their redundancy for characterizing these assemblages, with Pielou's evenness contributing only modestly to overall diversity variation (Magurran 2003). These integrated findings demonstrate that intermediate canopy cover optimizes the litter–microclimate interface, maximizing species richness and functional stability (Skelly et al. 2005). Full canopy closure, while enhancing evenness in some cases, reduces habitat suitability through litter compression and thermal elevation (Wells 2007; Rödel & Ernst 2004).

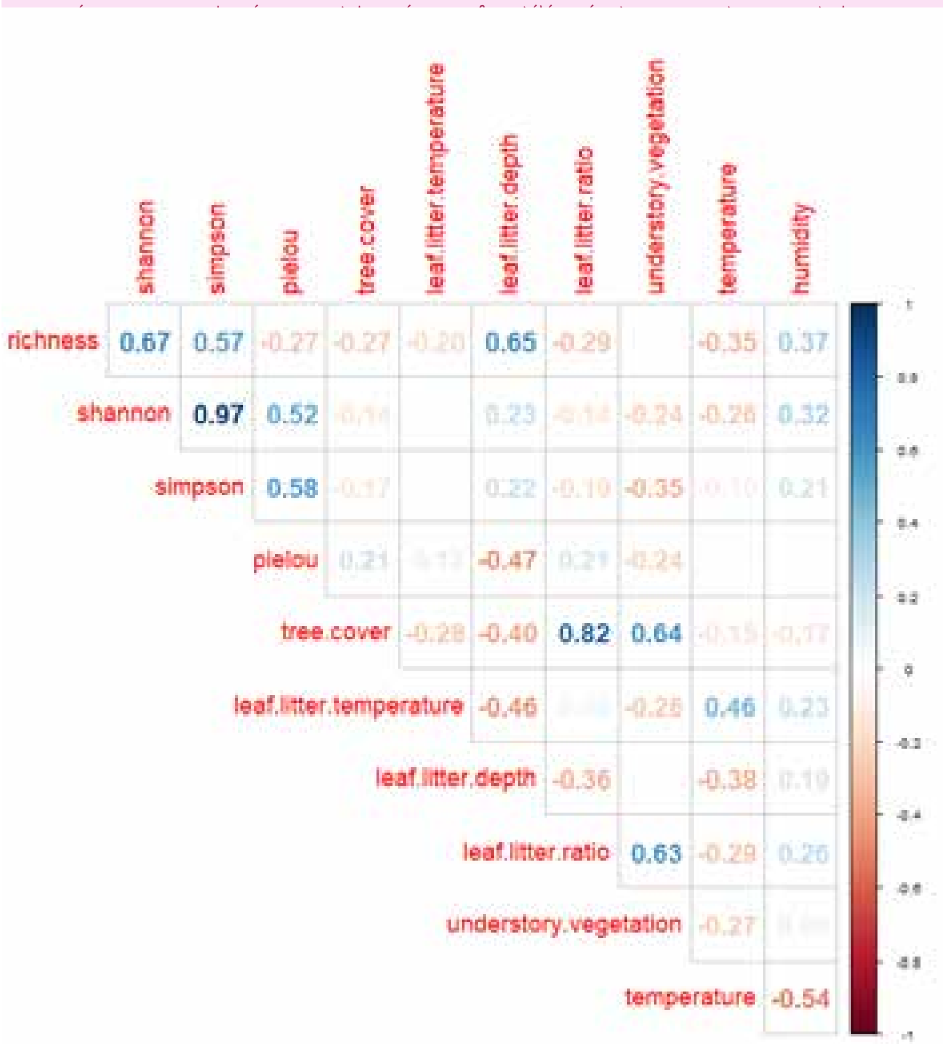


Image 5. Correlation matrix of alpha diversity and environmental variables.

REFERENCES

Abdulali, H. & A.G. Sekar (1988). On a small collection of amphibians from Goa. Journal of the Bombay Natural History Society 85: 202–205.

Barboni , D. et al. (2003). Variation in modern pollen from tropical evergreen forests and the monsoon seasonality gradient in SW India. Journal of Vegetation Science 14(4): 551–562. https://doi.org/10.1111/j.1654-1103.2003.tb02182.x

Bhat, N.R. & P.V. Desai (1998). Ecology of some amphibians in the state of Goa. Frogleg 3(1): 2.

Bowalkar, D.Y. & N.S. Sawant (accepted – in press). Microhabitat associations and seasonal dynamics of amphibians in the lateritic rocky outcrops along west coast of Goa, India. Journal of Threatened Taxa.

Crump, M.L. (1994). Visual encounter surveys, pp. 84–92. In: Heyer, W.R. et al. (eds.). Measuring and monitoring biological diversity: Standard methods for amphibians. Smithsonian Institution Press, Washington, DC.

Cardelús, C.L. (2010). Litter decomposition within the canopy and forest floor of three tree species in a tropical lowland rain forest, Costa Rica. Biotropica 42(3): 300–308. https://doi.org/10.1111/j.1744-7429.2009.00590.x

Das, I. & R. Whitaker (1997). A re-description of *Ramanella mormorata* Rao, 1937 (Anura: Microhylidae). Alytes 15(3): 127–132.

Das, I. & R. Whitaker (1998). Geographical distribution: *Pedostibes tuberculosus* (Malabar Tree Toad). Herpetological Review 29: 173.

Dehling, D.M. & J.M. Dehling (2023). Elevated alpha diversity in disturbed sites obscures regional decline and homogenization of amphibian taxonomic, functional and phylogenetic diversity. Scientific Reports 13: 1710. https://doi.org/10.1038/s41598-023-27946-0

Dinesh, K.P. et al. (2015). Checklist of amphibians of India. Mhadei Research Center, Valpoi, Goa. http://mhadeiresearchcenter.org/wp-content/uploads/2014/01/2017_April_Checklist-of-Amphibians-of-India.pdf. Accessed on 23.i.2026.

Dinesh, K.P. et al. (2020). A checklist of amphibians of India with IUCN conservation status. Version 3.0. Zoological Survey of India, Pune, 19 pp. https://zsi.gov.in/uploads/documents/importantLinks/hindi/10.pdf

Forest Survey of India (2023). India State of Forest Report 2023. Ministry of Environment, Forest and Climate Change, Government of India, Dehradun, 183 pp.

Kamble, S.S. (2008). Amphibia, pp. 273–280. In: Fauna of Goa, State Fauna Series 16. Zoological Survey of India, Kolkata,

Katwate, U. et al. (2013). CEPF Western Ghats Special Series: Diversity and distribution of anurans in Phansad Wildlife Sanctuary (PWS), northern Western Ghats of India. Journal of Threatened Taxa 5(2): 3589–3602. https://doi.org/10.11609/JoTT.o3038.3589-602

Kouamé, N.G.G. et al. (2018). Spatio-temporal distribution of five species of West African leaf-litter frogs. Salamandra 54(1): 21–29.

Kulkarni, N. et al. (2013). Checklist of amphibians of Goa. Frogleg 19: 7–12

Magurran, A.E. (2003). Measuring Biological Diversity. John Wiley & Sons, 248 pp.

Myers, N. et al. (2000). Biodiversity hotspots for conservation priorities. Nature 403(6772): 853–858. https://doi.org/10.1038/35002501

Pascal , J.P. (1988). Wet evergreen forests of the Western Ghats of India. Tropical Ecology 45: 281–292.

Qureshi , I.M. (1965). Tropical Rain Forests of India and their silvicultural and ecological aspects. Symposium on Ecological Research in Humid Tropics Vegetation, Kuching, Sarawak, 1963: 120–136.

Reddy , C.S. et al. (2016). Assessment and monitoring of long-term forest cover changes (1920–2013) in Western Ghats biodiversity hotspot. Journal of Earth System Science 125(1): 103–114. https://doi.org/10.1007/s12040-015-0645-y

Rödel, M.O. & R. Ernst (2004). Measuring and monitoring amphibian diversity in tropical forests. I. An evaluation of methods with recommendations for standardization. Ecotropica 10(1): 1–14.

Sarkar, A.K. & S. Ray (2004). A synopsis of the amphibian fauna of Goa. Hamadryad 28: 7–18.

Sawant, N.S. & T.D. Jadhav (2013). Factors influencing habitat selection by arboreal pit vipers. Zoological Science 30(1): 21–26. https://doi.org/10.2108/zsj.30.21

Scott, N.J. Jr. (1976). The abundance and diversity of the herpetofaunas of tropical forest litter. Biotropica 8(1): 41–58. https://doi.org/10.2307/2387818

Sekar, A.G. (1991). Key to the amphibian fauna of Goa. Herpeton 4: 14–15.

Sekar, A.G. (1992). Additions to the list of amphibian fauna of Goa. Journal of the Bombay Natural History Society 89: 134–135.

Seshadri, K.S. (2014). Effect of fragmentation and microclimatic changes on amphibian assemblages in the Western Ghats. Conservation Leadership Programme Final Technical Report.

Skelly, D.K. et al. (2005). Canopy closure and amphibian diversity in forested wetlands. Wetlands Ecology and Management 13(3): 261–268. https://doi.org/10.1007/s11273-004-7520-y

Spranger, R.R. et al. (2024). Canopy coverage, light, and moisture affect thermoregulatory trade-offs in an amphibian breeding habitat. Journal of Thermal Biology 122: 103864. https://doi.org/10.1016/j.jtherbio.2024.103864

Wells, K.D. (2007). The ecology and behavior of amphibians. University of Chicago Press, Chicago, USA, 693 pp.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 August 2026 | 18(8): 29470–29482
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.10009.18.8.29470-29482
#10009 | Received 19 June 2025 | Final received 22 July 2026 | Finally accepted 04 August 2026

ARTICLE

Microhabitat associations and seasonal dynamics of amphibians in the lateritic rocky outcrops along the western coast of Goa, India

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Abstract: A total of 12 lateritic rocky outcrops in Goa were studied throughout the wet season (May to November) to understand amphibian occurrence and their microhabitat associations. Microhabitat association and seasonal trend were analysed using indicator species value (IndVal) and Hill number analysis. The findings show microhabitats such as ephemeral vegetation, ephemeral pool, and peripheral ecotone vegetation are critical components of outcrops and harbour high IndVal Scores, although seasonal changes significantly influence species distribution and abundance. The findings conclude strong habitat and seasonal association of anurans. This research contributes to conservation strategies for this unique ecosystem of Goa.

Keywords: Anuran, ecotone vegetation, ephemeral pool, ephemeral vegetation, habitat heterogeneity, hill numbers, hydroperiod, indicator species value, plateau ecosystem, seasonal breeding.

Konkani: सारांश: गोंयांतल्या एकूण १२ चिऱ्या फातराच्या सड्यांचो पावसाळ्याच्या हंगामांत (मे ते नोव्हेंबर) अभ्यास केलो. उभयचर प्राण्यांची उपस्थिती आनी तांचो सूक्ष्म अधिवासांशी आशिल्लो संबंध समजून घेवप हो ह्या अभ्यासाचो उद्देश आशिल्लो. निदर्शक प्रजाती मूल्य (IndVal) आनी हिल संख्या विश्लेषण वापरून सूक्ष्म अधिवासांशी आशिल्लो संबंध आनी ऋतुमानानुसार दिसपी कल हांचें विश्लेषण केलें. निष्कर्षांवरून अल्पकालीन वनस्पतीसमूह, अल्पजीवी उदकाचीं तळीं आनी तळपाच्या देगेवयल्या संक्रमण क्षेत्रांतलो वनस्पतीसमूह हे सड्यांचे म्हत्वाचे सूक्ष्म अधिवास आसून, तांकां चड IndVal गुण मेळ्ळे; मात ऋतुमानांत जावपी बदलांचो प्रजातींचें वितरण आनी विपुलता हांचेर लक्षणीय परिणाम जाता. निष्कर्षांवरून बेबकांचो अधिवास आनी ऋतुमान हांचेकडेन घट्ट संबंध आसा, हें दिसून येता. गोंयच्या ह्या वैशिष्ट्यपूर्ण परिसंस्थे खातीर संवर्धन धोरणां तयार करपाक हो अभ्यास उपेगी थारता.

Editor: Anonymity requested.

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

Citation: Bowalkar, D.Y. & N.S. Sawant (2026). Microhabitat associations and seasonal dynamics of amphibians in the lateritic rocky outcrops along the western coast of Goa, India. *Journal of Threatened Taxa* 18(8): 29470–29482. https://doi.org/10.11609/jott.10009.18.8.29470-29482

Funding: Ministry of Environment, Forest and Climate Change (MoEF&CC), Government of India, and the Goa State Research Foundation (GSRF), Government of Goa.

Competing interests: We declare that we have no known competing financial interests or personal relationships that could have appeared to influence this work.

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Author contributions: DYB—field data collection, data analysis, manuscript preparation and writing. NSS—conceptualization of the research, research methodology and study design, manuscript preparation, review, proofreading and supervision.

Acknowledgements: The authors sincerely acknowledge the Ministry of Environment, Forest and Climate Change (MoEFCC), Government of India and Goa State Research Foundation (GSRF), Government of Goa, for providing financial assistance and institutional support for this research. We sincerely thank Dr. Purnanand Chari, President, Goa Konkani Akademi, Goa Sanchar Bhavan, BSNL Building, Patto, Panaji, Goa, and Head, Department of Konkani, DPM's SHREE MALLIKARJUN & Shri Chetan Manju Desai College, Delem, Canacona, Goa, for his valuable assistance with the Konkani translation.

INTRODUCTION

Lateritic rocky outcrops are highly weathered, iron-rich geological landscapes occurring as open, exposed ferricretes with a thickness of 6–30 m capped over basaltic bedrocks (Widdowson & Cox 1996). The ecological studies on amphibians inhabiting low-altitude coastal lateritic outcrops remain limited, particularly niche specificity within the naturally occurring microhabitats available on these landscapes (Thorpe et al. 2018; Mudke et al. 2020; Jithin & Naniwadekar 2025; Jithin et al. 2025).

While several amphibian studies in the Western Ghats have been primarily focused on forested landscapes and broad-scale environmental determinants of diversity (Gawas et al. in press; Biju et al. 2008), the present study is situated within low-altitude lateritic rocky outcrops, which represent distinct geomorphological systems along coastal and midland regions of Goa (Widdowson 2009). These outcrops are characterised by heterogeneous microhabitats and function as terrestrial habitat islands with unique hydrological and vegetation dynamics (Thorpe & Watve 2015), thereby necessitating a fine-scale, microhabitat-based ecological approach.

METHODS

Study Area

The lateritic rocky outcrops are highly disintegrated patches forming tabletop plateau landscapes representing a mosaic habitat along the west coast of Goa. For the present study, all coastal outcrop complexes in Goa were pre-surveyed and selected 12 unique sites (Table 1; Image 1) belonging to four plateaux complexes and having the least anthropogenic disturbance based on absence of mining, major infrastructure, intensive agriculture and visible recent land-use conversion, verified through field reconnaissance and regional land use maps (Widdowson 2009).

Sampling

The microhabitats on outcrops for the present study were classified based on the availability of following factors: (1) Water (aquatic habitat); (2) Vegetation; (3) Exposed outcrop; (4) Slope, and (5) Soil layer (Lekhak & Yadav 2012; Watve 2013; Mudke et al. 2020). The microhabitats documented from Goan lateritic outcrops closely resemble those described from Maharashtra and Karnataka (Datar & Watve 2018). Accordingly, a total of eight microhabitats (Image 2) were selected based on classification and ecological description provided in earlier studies from the outcrops of Maharashtra and Karnataka (Lekhak & Yadav 2012; Watve 2013; Rahangdale & Rahangdale 2014; Thorpe & Watve 2015; Sreejith et al. 2016; Datar & Watve 2018; Thorpe et al. 2018; Mudke et al. 2020; Jithin et al. 2025). Microhabitats were defined based on water availability, vegetation type, soil depth, and slope angle (Table 2). Some authors also recognise naturally occurring other microhabitats such as loose rocks and rock crevices which were merged as a part of exposed rocks plains and slopes for the present study (Lekhak & Yadav 2012; Thorpe et al. 2018; Jithin et al. 2023). The high-elevation outcrops associated microhabitats such as steep clips and lateritic cave were absent or not uniformly available in the present study sites (Datar & Watve 2018), hence not included in the study. The human-influenced or altered habitats such as paddy fields, orchards, acacia plantation, cashew plantation and sacred groves were not considered in the present the study to minimise the anthropogenic effect (Rahangdale & Rahangdale 2014; Mudke et al. 2020; Jithin et al. 2025).

Weather data collected from nasa.gov between 1981–2023 for all study sites reveals irregular showers in the months of May and November (Image 4). Hence, the study was conducted between the two monsoon cycles of seven months (May–November) of the years 2023 and 2024. At each of the study sites, line transects of 100-m long and 6-m wide were plotted that would cover all microhabitats and minimal anthropogenic stress. A time-constrained visual count method was employed to document the number of sightings of amphibians within the transect. The sampling was done between 1900 h and 2200 h when amphibian activity is highest (Crump & Scott Jr. 1994; Rodda et al. 2005). The same transect was reused for the next year. The amphibian activity and their abundance in each of the microhabitats were recorded separately. Amphibian species encountered during the study were photographed using an Olympus TG-6 camera and calls recorded using a Sony ICD-PX470 digital voice recorder in the field, while cryptic species were examined by capturing using latex-free gloves. Prior approval from the Institutional Animal Ethics Committee (IAEC), Goa University, was obtained before the study (Approval No. GUZ/IAEC/23-24/17), and all efforts were made to minimise disturbance to animals and their habitats as per guidelines given the Study of Amphibians and Reptiles (SSAR) code of practice. Species were identified using available standard identification keys (Gururaja 2012; Dinesh et al. 2015, 2024; Modak et al. 2015; Padhye et al. 2015, 2017; Gururaja & Hebbar

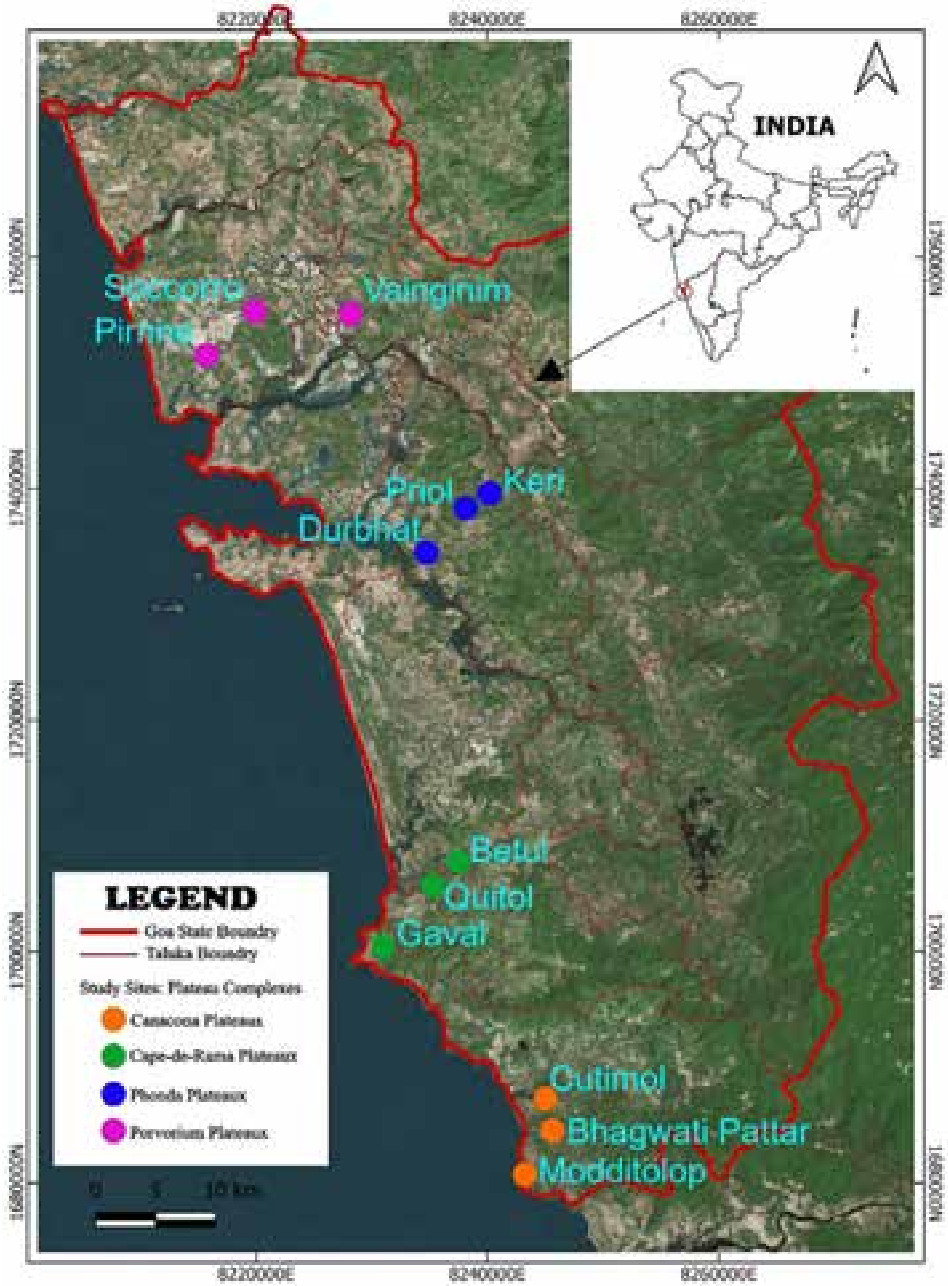

Image 1. Map of Goa with study sites within the colour-coded plateaux marked.

2016; Garg & Biju 2016, 2017, 2021; Garg et al. 2018; Sanchez et al. 2018; Dufresnes et al. 2022; Yadav et al. 2024). Taxonomic nomenclature is followed as per the Amphibian Species of the World 6.2 database (Frost 2024).

Analysis

All statistical analyses were performed using R (version 4.4.1; R Core Team 2024) implemented in RStudio. The indicator of species analysis (IndVal) was carried out to understand the association of each species with microhabitats on the outcrop by cumulating all the monthly observations of each microhabitat across all study sites. To minimise the effect of chance, a randomised analysis with N = 999 was performed, and the associations only with a significance level less than or equal to 0.05 were considered valid. IndVal with 999 Permutations were performed across all species for their microhabitat association, reporting five microhabitats with strong association with amphibian species. The "indicspecies package" was used to compute Indicator of species analysis, while the "permute packages" was

Table 1. Details of the study site used for the present study. Land use type is based on the Regional Plan for Goa 2021 (RDP-2021) prepared by the Goa Town & Country Planning Department.

Study Site	Latitude	Longitude	Area (km^2)	Land Use type
A: Canacona Plateaux				
A1: Cutimol	14.9830° N	74.0663° E	12.43	Grazing Ground, Orchard, Natural Cover
A2: Bhagwati Pattar	14.9592° N	74.0716° E	12.70	Orchard, Protected / reserve forest, Natural Cover
A3: Modditolop	14.9263° N	74.0503° E	14.32	Orchard, Natural Cover, Settlement
B: Cape-de-Rama Plateaux				
B1: Gaval	15.0973° N	73.9406° E	7.46	Orchard, Natural Cover, Settlement, Paddy Fields
B2: Quitol	15.1428° N	73.9790° E	11.68	Orchard, Natural Cover, Settlement, Paddy Fields
B3: Betul	15.1607° N	73.9986° E	13.31	Orchard, Natural Cover, Settlement, Paddy Fields
C : Phonda Plateaux				
C1: Durbhat	15.3924° N	73.9739° E	8.67	Natural Cover, Orchard
C2: Priol	15.4255° N	74.0044° E	5.66	Orchard, Natural Cover, Settlement
C3: Keri	15.436889° N	74.023028° E	9.62	Orchard, Natural Cover,
D: Porvorium Plateaux				
D1: Pirnne	15.540250° N	73.802861° E	3.66	Orchard, Natural Cover, Settlement
D2: Soccorro	15.573139° N	73.840361° E	3.87	Orchard, Natural Cover, Quarry, Settlement
D3: Vainginim	15.571000° N	73.914889° E	2.13	Orchard, Natural Cover

Table 2. Microhabitats used for the present study with their characterization.

	Microhabitat type	Availability of water	Type of vegetation	Thickness of soil	Angle of slope
1	Exposed rocky flats	Low	No vegetation, lichens, mosses, blue-green algae. grass.	Absent to thin	Gentle, plain
2	Exposed rocky slope	Low	No vegetation, lichens, mosses, blue-green algae. grass.	Absent to thin	Acute, steep slope
3	Seasonal surface channels	High, Lotic water	Aquatic plants, blue-green algae.	Thin	Depression, drainage.
4	Ephemeral pools	High, Lentic water	Herbaceous plants, aquatic plants, blue-green algae.	Thin	Depression, pool.
5	Ephemeral vegetation	Moderate	Herbaceous ephemeral plants, grasses	Thin to moderate	Gentle
6	Shrubland patches	Moderate	Herbaceous plants, bushes, woody plants	Moderate to thick	Gentle, plain
7	Peripheral ecotone vegetation	Moderate	Herbaceous plants, bushes, woody plants	Moderate to thick	Acute, steep slope
8	Soil-filled depression	Moderate	Herbaceous plants, bushes	Moderate to thick	Gentle, plain

used for significance testing with permutation. The visualisation of these associations between anuran species and microhabitats was done by using a Sankey plot with the "networkD3 package". Further, alpha diversity were analysed by performing Hill number analysis for each microhabitat to estimate different aspects of biodiversity with q values 0, 1, 2 and 3. The q0 value is an indicator of species richness encountered in each microhabitat. To understand the relationship between each microhabitat with respect to anuran species, alpha diversity was analysed with Hill number (q = 0, 1, 2, 3) computation using the "hillR package". To understand the pattern of anuran occurrence during the hydration period, all microhabitat observations were accumulated by month and visualised using a heat map and violin plot using "ggplot2" and "geom_tile" package.

RESULTS

A total of 15,574 amphibian sightings belonging to seven families, 12 genera, and 14 species (Image 3) were reported from 12 low-altitude lateritic outcrops from the state of Goa with a sampling effort conducted during two consecutive years (May–November) of 2023 and 2024. It was observed that 41% of amphibian species

Image 2. Microhabitats associated with lateritic rocky outcrops: M1—exposed rocky flats | M2—exposed rocky slope | M3—seasonal surface channel | M4—ephemeral pools | M5—ephemeral vegetation | M6—shrubland patches | M7—peripheral ecotone vegetation | M8—soil filled depression. © Dipak Bowalkar.

were documented from the state on the lateritic rocky outcrops. One Vulnerable species and three Schedule II species under the Indian Wildlife (Protection) Act, 1972 were reported from the present study (Table 3). More than 70% of the species documented in the present study are listed by IUCN for association with forest, inland wetland, artificial terrestrial habitats, artificial aquatic habitats and marshlands (Table 3).

Image 3. References images of anurans from study sites: a—*Duttaphrynus melanostictus* | b—*Euphlyctis cyanophlyctis* | c—*Hoplobatrachus tigerinus* | d—*Minervarya cepfi* | e—*Minervarya gomantaki* | f—*Minervarya syhadrensis* | g—*Phrynoderma* cf. *konkani* | h—*Sphaerotheca dobsoni* | i—*Microhyla ornata* | j—*Uperodon mormoratus* | k—*Hydrophylax bahuvistara* | l—*Indirana salelkari* | m—*Polypedates maculatus* | n—*Pseudophilautus amboli*. © Dipak Bowalkar.

The encounter rate of amphibians across the seven-months study period increased from mid-May and peaked during August, followed by a sharp decrease towards November (Image 5). This seasonal pattern reflects variation in detectability and breeding activity associated with the southwestern monsoon. *Euphlyctis cyanophlyctis* exhibited the highest encounter rate among all species during August, coinciding with peak

Table 3. Species-wise analysis of microhabitat association and IUCN inventories. IndVal: Indicator value of species with 999 permutations (p = 0.01) | LC—Least Concern | VU—Vulnerable | NE—Not Evaluated | *—endemic to the Western Ghats | #—Schedule-II species under WPA, 1972.

Species	IndVal%	Associated microhabitat	IUCN Red List status	IUCN population trend	IUCN Habitat type								
					Forest	Savanna	Shrubland	Grassland	Rocky areas	Wetlands	Artificial/ terrestrial	Artificial/ aquatic	Marine
Family: Bufonidae													
Duttaphrynus melanostictus	7.17	Peripheral vegetation	LC	↑se	+		+	+		+	+	+	+
Family: Dicroglossidae													
*Euphlyctis cyanophlyctis**#	43.6	Ephemeral pools	LC	Stable	+					+	+	+	+
Hoplobatrachus tigerinus#	16.4	Exposed rock	LC	Stable	+	+		+		+	+	+	+
*Minervarya cepfi**	38.8	Exposed rock	LC	↓se	+			+	+	+	+		
*Minervarya gomantaki**	44.8	Ephemeral vegetation	LC	↓se	+					+	+	+	+
Minervarya syhadrensis	14.3	Ephemeral vegetation	LC	↓se		+	+			+	+	+	+
Phrynoderma cf. *konkani**	3.6	Ephemeral pools	NE	-						-		-	-
*Sphaerotheca dobsoni**	10.9	Exposed rock	LC	↓se	+		+			+	+	+	+
Family: Microhylidae													
Microhyla ornata	30.3	Ephemeral vegetation	LC	Stable	+	+	+	+		+	+	+	+
*Uperodon mormoratus**	3.39	Peripheral vegetation	LC	↓se	+					+	+	+	+
Family: Ranidae													
Hydrophylax bahuvistara	7.86	Shrubs and bushes	LC	↓se	+					+	+	+	+
Family: Ranixalidae													
*Indirana salelkari**	11	Peripheral vegetation	VU	↓se	+					+	+		
Family: Rhacophoridae													
Polypedates maculatus	13.9	Ephemeral vegetation	LC	Unknown	+		+	+		+	+	+	+
*Pseudophilautus amboli**	37.6	Peripheral vegetation	LC	↓se	+						+		

monsoonal breeding activity (Image 8).

Ephemeral vegetation and peripheral ecotone vegetation showed the highest number of significant indicator species (four each), followed by exposed rocky plains, ephemeral pool, and shrubland patches, with three, two and one, respectively (Image 6). The microhabitats exposed rocky slope, surface runoff channel and soil-filled depression showed no significant correlation with any anuran species. Two species, *Minervarya gomantaki* and *Euphlyctis cyanophlyctis*, achieved maximum IndVal values of 44.8% and 43.6%, respectively, while *Phrynoderma* cf. *konkani* and *Uperodon mormoratus* exhibited the lowest IndVal values of 3.6% and 3.3%, respectively (Table 3).

The Hill number analysis revealed q = 0 values between 7 and 13 across all microhabitats associated with lateritic outcrops (Image 7). The sequence of q0 in decreasing order was observed to be shrubland patches -> ephemeral vegetation -> soil-filled depression -> peripheral ecotone vegetation -> ephemeral pool -> exposed rocky plains -> exposed rocky slopes -> runoff channels.. The q1 value is an indicator of effective species diversity and measures the exponential of Shannon entropy. Here, it was evaluated that q1 was highest in shrubland patches of 8.4, while lowest in the runoff channel and ephemeral pool with q1 of 2.4 for both. The Hill numbers q2 and q3 provide strong evidence regarding dominating species in a microhabitat by minimising the effect of rare species. Microhabitat types with woody plants and vegetation like shrubland

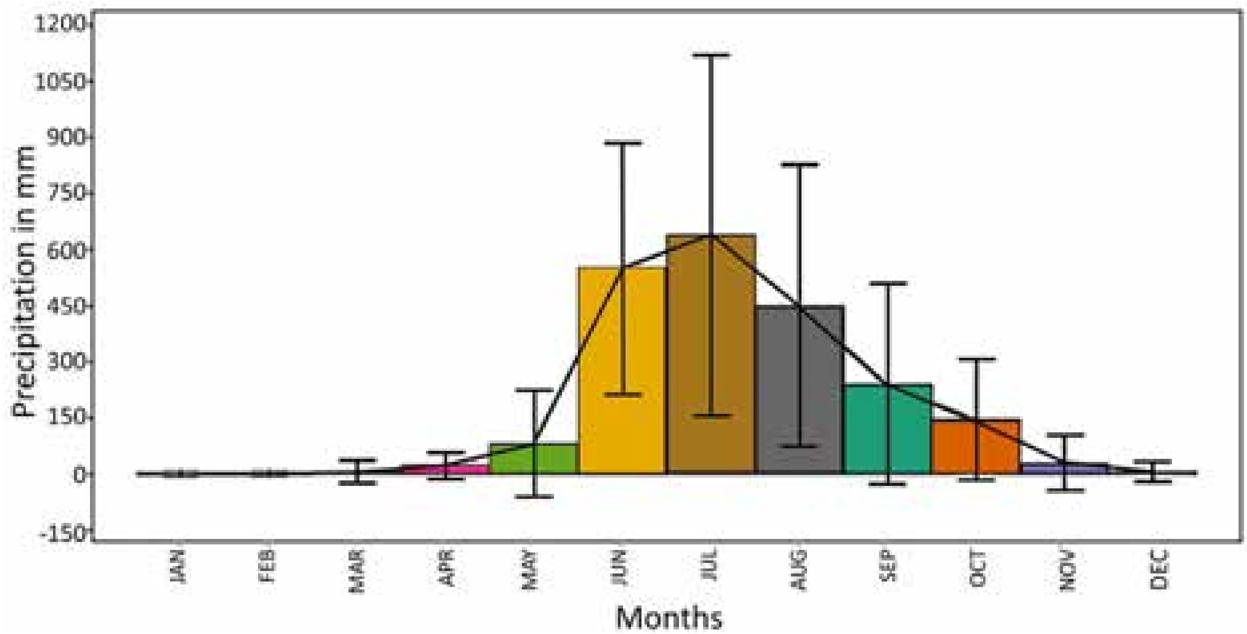

Image 4. Annual precipitation trend for study sites with cumulative average from 1981–2023.

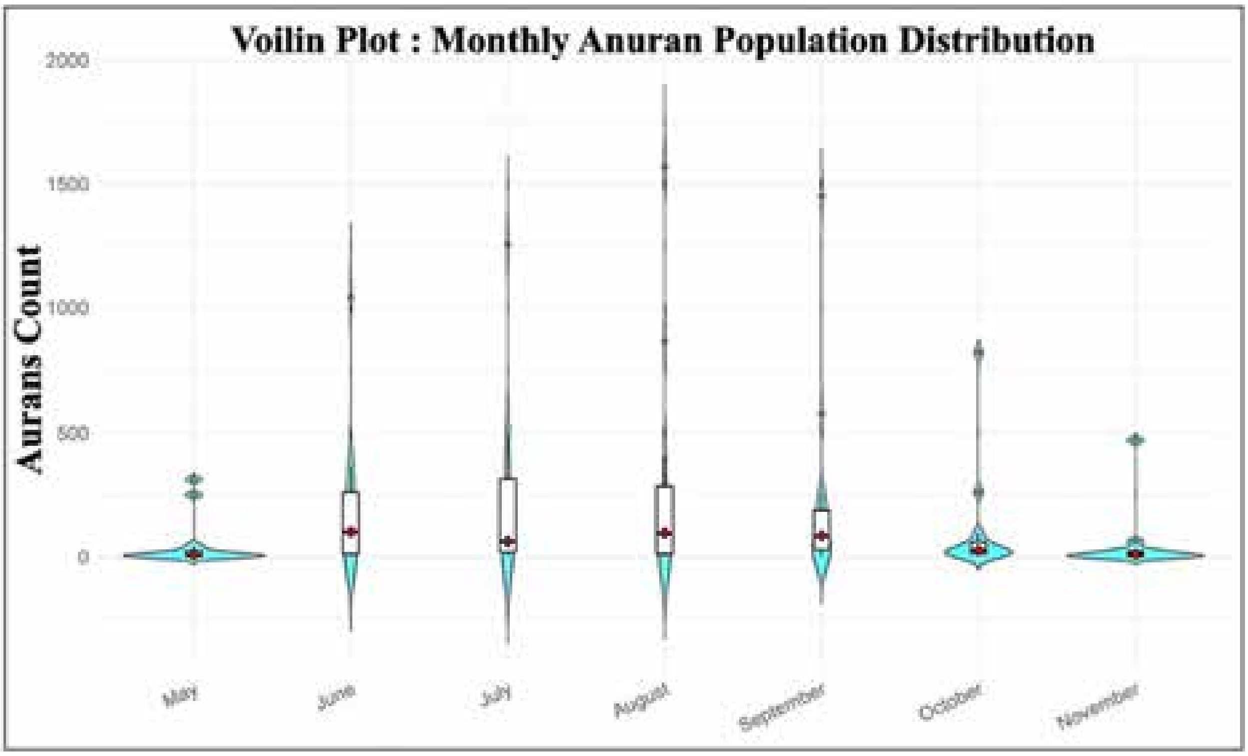

Image 5. Violin plot showing a monthly trend of anuran encounter cumulative of all study sites.

patches demonstrate the highest q2 and q3 of 6.6 and 5.8 measurements, respectively, while aquatic environments on outcrops, the surface runoff channels (q2 1.17; q3 1.12) and ephemeral pools (q2 1.16; q3 1.11) had the lowest measurements.

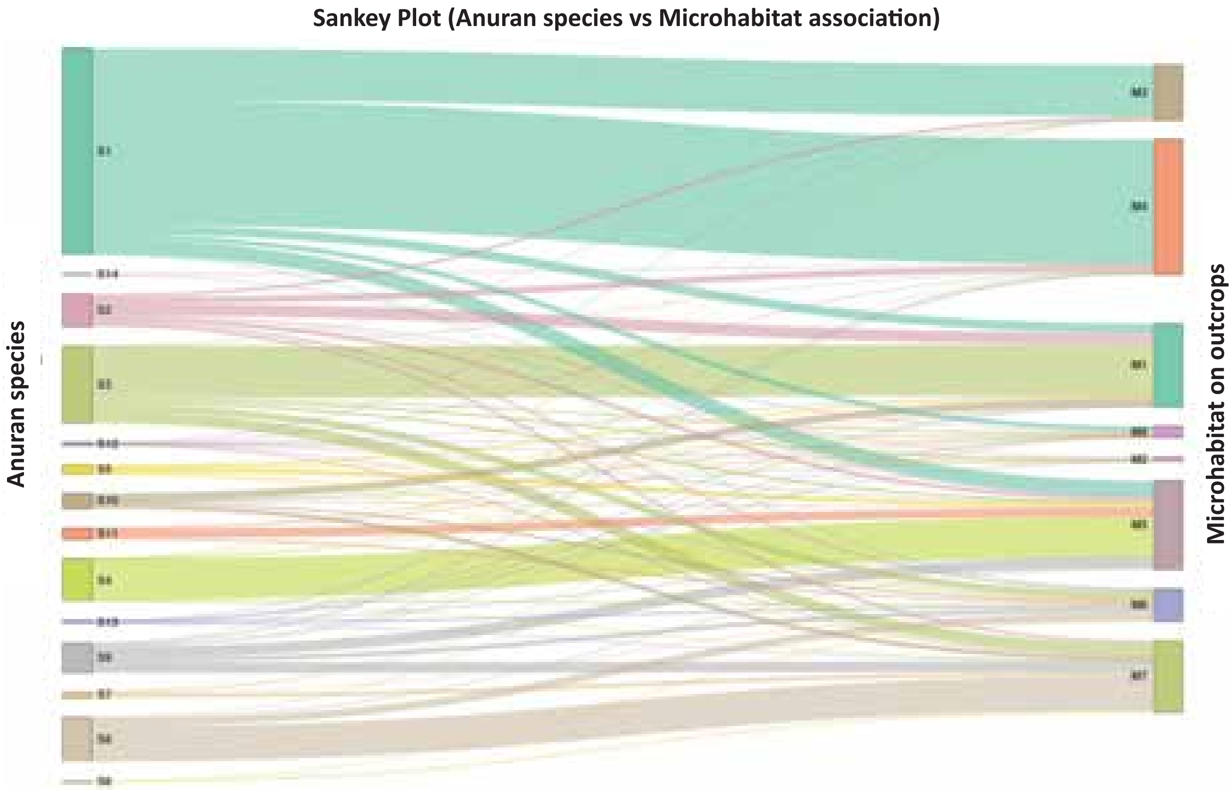

Image 6. Sankey plot visualising association of anuran species with respective microhabitats: S1—*Euphlyctis cyanophlyctis* | S2—*Hoplobatrachus tigerinus* | S3—*Minervarya cepfi* | S4—*Minervarya gomantaki* | S5—*Polypedates maculatus* | S6—*Uperodon mormoratus* | S7—*Indirana salelkari* | S8—*Pseudophilautus amboli* | S9—*Minervarya syhadrensis* | S10—*Sphaerotheca dobsoni* | S11—*Microhyla ornata* | S12—*Duttaphrynus melanostictus* | S13—*Hydrophylax bahuvistara* | S14—*Phrynoderma* cf. *konkani* | M1—Exposed rocky flats | M2—Exposed rocky slope | M3—Seasonal surface channel | M4—Ephemeral pools | M5—Ephemeral vegetation | M6—Shrubland patches | M7—Peripheral ecotone vegetation | M8—Soil-filled depression.

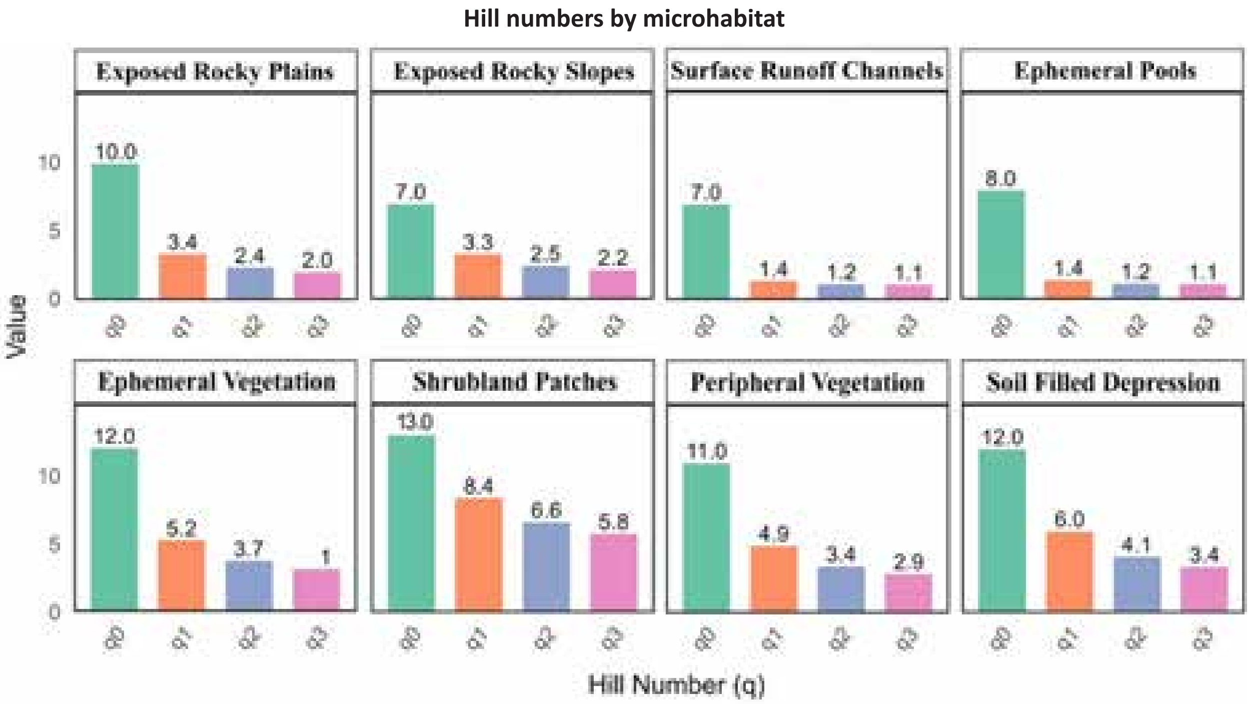

Image 7. Alpha diversity; Hill numbers (q_0–q_3) for eight microhabitats on Goa lateritic outcrops.

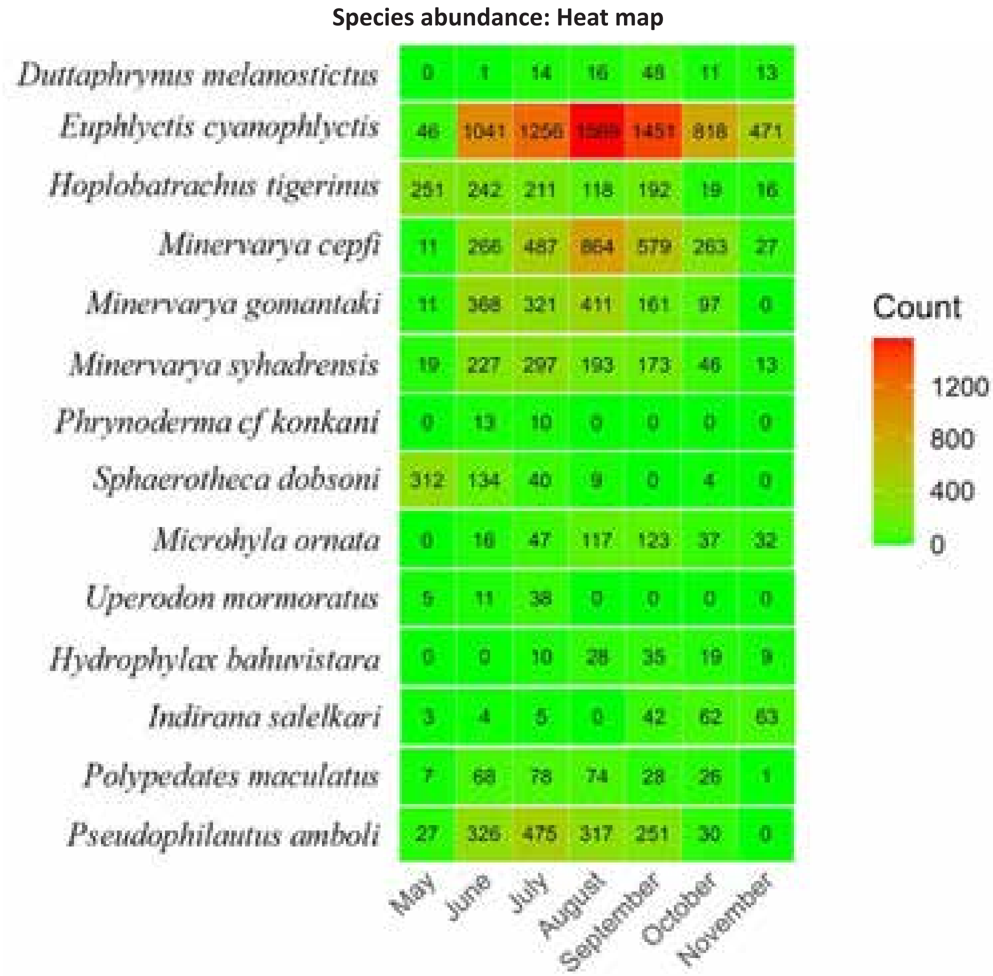

Image 8. Heatmap showing anuran species distribution across wet months on the plateau (May–November).

DISCUSSION

Previous anuran ecological studies have largely treated outcrop landscapes as a single unit (Jithin et al. 2025), while the present study examines here the microhabitat level studies on lateritic rocky outcrops in Goa. The study of these suggests that a few amphibian species are strongly associated with specific microhabitats (Thorpe et al. 2018; Mudke et al. 2020). The two aquatic anuran species *Euphlyctis cyanophlyctis* and *Phrynoderma* cf. *konkani* were observed to have a strong association with ephemeral pools (Mudke et al. 2020). *Euphlyctis cyanophlyctis* was previously been reported to shift from permanent water sources to rain fed shallow waterholes such as roadside ditches, paddy field and vernal water for breeding, which signifies their strong association with Ephemeral pools on the outcrop (Chowdhury et al. 2021). *Phrynoderma* cf. *konkani* also show similar habitat preference with more restriction to low lying wetlands and plateaus in coastal regions while this species was observed only from Socorro plateau in present study (Yadav et al. 2024). The small streams formed due to surface runoff cut through the outcrops and make channel towards periphery of outcrop in direction of slope and dries up faster while the ephemeral pools retain water for longer period (Porembski et al. 2016; Kulkarni et al. 2022). The observation in the field shows anurans such as *Minervarya cepfi* and *Euphlyctis cyanophlyctis* and *Hoplobatrachus tigerinus* optionally use this microhabitat to reduce competition. Due to lack of predators such as fishes, the shallow ephemeral pool is most preferred habitat for anurans tadpoles (Jithin & Naniwadekar 2025). The aquatic vegetation in this ephemeral pool gradually covers entire pools which provides shelter for anuran tadpoles (Kulkarni et al. 2022).

The ephemeral vegetation covers the short-length endemic herbaceous plants including grasses (Sreejith et al. 2016). It was found that this habitat was dominatingly used by *Minervarya gomantaki, Minervarya syhadrensis* and *Microhyla ornata*. The dense mesh of herbaceous plants in ephemeral vegetation also provide protection from predators for amphibians (Burrow & Maerz 2022). In the present study, it was observed that males of these species croak while hiding in the carpet of ephemeral vegetation. *Polypedates maculatus*, even though is of arboreal nature, was reported to breed and lay foam nests in ephemeral vegetation near ephemeral pools (Mudke et al. 2020). The rocky exposed laterites are periodically separated by shrubland patches composed of small bushes along with few woody plants are important microhabitat which act as a refuge to avoid the harsh temperature of day time for most of the anurans (Lekhak & Yadav 2012; Burrow & Maerz 2022). *Sphaerotheca dobsoni* and *Duttaphrynus melanostictus*, the ground-dwelling terrestrial anurans, were found foraging mostly on ground foliage in shrubland patches on the outcrops (Mudke et al. 2020).

The peripheral ecotone vegetation also serves as an important refuge for multiple anurans, while *Pseudophilautus amboli* and *Duttaphrynus melanostictus* was found to be the most dominant anuran species in this microhabitat. *Indirana* due to their primitive semi-terrestrial breeding strategy is strongly associated with forest and forest edges (Gaitonde & Giri 2014; Komanduri et al. 2023). Similar findings were reported in this study for *Indirana salelkari* which was strictly found in the peripheral ecotone vegetation. Studies show that *Uperodon mormoratus* is an early monsoon aquatic breeder that prefers forest habitat over the outcrops (Katwate & Apte 2019), which is consistent with our study, as this species was only reported from peripheral ecotone vegetation.

The exposed rocky plains during heavy precipitation temporarily submerge with surface flooding while merging with ephemeral pools, water channels and ephemeral vegetation (Thorpe et al. 2018). This microhabitat is strongly associated with *Minervarya cepfi* where males show mass accumulation during the peak monsoon at night while they take refugia under loose rocks and shrubland patches during daytime (Garg & Biju 2017). The exposed slope showed the least association with any anurans during the present study likely due to rapid drainage, reduced water retention and higher exposure to thermal stress compared to other microhabitats. However, the small crevices on the exposed rocky plains and slopes were used by males of *Hoplobatrachus tigerinus* and *Sphaerotheca dobsonii* to reduce predation risk during the peak activity period (Mudke et al. 2020; Komanduri et al. 2023).

Effect of Hydroperiod

Based on the hydroperiod on lateritic outcrops, two distinct seasonal patterns can be identified: the dry season from December to mid-May and the wet season from May to November (Jithin et al. 2025). Amphibians show periodic migration between their breeding habitat and refuge habitat (Snodgrass et al. 2000). Most amphibians show an explosive breeding strategy during the wet season on plateau outcrops, while during the dry season they either undergo aestivation or their population shifts to lowlands where water is available to return with the onset of monsoon (Burrow & Maerz 2022). Different species have evolved in response to changing hydroperiod often categorised as early explosive breeders, prolonged breeders and late seasonal breeders. Explosive breeders mate for a short duration when conditions are favourable, whereas prolonged breeders reproduce over an extended season (Soni et al. 2025). Though most anurans synchronise themselves with the precipitation trend across the wet period, from the present study we observed that anurans use these three selective strategies to breed while occupying different microhabitats on the outcrop. *Euphlyctis cyanophlyctis*, *Minervarya cepfi*, *Minervarya gomantaki*, *Polypedates maculatus*, *Pseudophilautus amboli*, and *Microhyla ornata* shows prolonged breeding activity with peak population in July to August when precipitation is high. *Hoplobatrachus tigerinus* and *Sphaerotheca dobsoni* appear on plateaus during pre-monsoon (May–July) showers and show early explosive breeding. *Indirana salelkari* is found to be active during late-monsoon (September–November) preferring late seasonal breeding strategy. This differential use of time by anurans acts as an important factor for temporal niche differentiation on the outcrops to maximise best utilisation of resources (Borzée et al. 2016).

Anthropogenic stress on outcrops

The present study scope is only restricted to naturally occurring microhabitats while the majority of these microhabitats are constantly altered due to anthropogenic activities. Mining, laterite stone quarrying and infrastructure development on outcrops at both domestic and commercial scale remains the biggest threat to loss of microhabitats (Thorpe & Watve 2015; Porembski et al. 2016; Jithin et al. 2025). The ephemeral pools on outcrops are altered with cemented water tank for cattle drinking and domestic use. Ephemeral vegetation like *Senecio belgaumensis*, *Utricularia* spp. and *Eriocaulon* spp. are mass exploited for ornamental and religious purposes (Ghate et al. 2023). The high demand for residential land with boom of tourism along with unplanned urbanisation in the state of Goa has forced to convert these lateritic rocky outcrops into urbanisation hubs (Sutheeshna 2021). Few lateritic outcrops of Goa due to their complex land ownership status are still retained with minimal disturbance while peripheral slopes of these outcrops are intensely exploited for cashew plantation and commercial residential projects (Nigam et al. 2024).

Conservation Status of Anurans and Outcrops

Based on the IUCN Red Data list, nine of the anuran species reported form the present study have declining population trend (Table 3). According to the IUCN habitat type, the lateritic outcrops are designated as rocky areas. While only *Minervarya cepfi* documented from the present study has been assigned to this habitat type. Other studies, along with our observation reports *Minervarya cepfi* having a strong association with exposed rocky plain microhabitats on the outcrops (Thorpe et al. 2018; Mudke et al. 2020).

Amphibians are declining worldwide, while loss of their habitat remains one of the prime contributing factors for this loss (Alford & Richards 1999; Catenazzi 2015; Luedtke et al. 2023). These habitats are declining due to their rapid land use, land cover change for human needs (Alford & Richards 1999; Catenazzi 2015; Nakazawa 2015). Outcrops can parallelly act as an alternate breeding ground for these anurans. According to the Town and Planning Survey of Goa, the status of these lateritic outcrops is of mixed nomenclature, classified mostly as wasteland, barren land, pasture land, while outcrops which show partial succession were termed as shrubland, grasslands, orchards, grazing grounds, and open natural cover. There is an urgent need for revision of this classification for the conservation of these outcrops.

REFERENCES

Alford, R.A. & S.J. Richards (1999). Global amphibian declines: a problem in applied ecology. Annual Review of Ecology and Systematics 30: 133–165. https://doi.org/10.1146/annurev.ecolsys.30.1.133

Biju, S.D. et al. (2008). Diversity and conservation status of the Western Ghats amphibians, pp. 80–82. In: Stuart, S.N. et al. (eds.). Threatened Amphibians of the World. Lynx Edicions, Barcelona.

Borzée, A. et al. (2016). Temporal and spatial differentiation in microhabitat use: implications for reproductive isolation and ecological niche specification. Integrative Zoology 11(5): 375–387. https://doi.org/10.1111/1749-4877.12200

Burrow, A. & J. Maerz (2022). How plants affect amphibian populations. Biological Reviews 97(5): 1749–1767. https://doi.org/10.1111/brv.12861

Catenazzi, A. (2015). State of the world's amphibians. Annual Review of Environment and Resources 40(1): 91–119. https://doi.org/10.1146/annurev-environ-102014-021358

Chowdhury, M.A.W. et al. (2021). Temporary water holes may benefit the breeding of the common skipper frog *Euphlyctis cyanophlyctis* (Anura: Dicroglossidae). Ecologies 2(1): 138–149. https://doi.org/10.3390/ecologies2010007

Crump, M.L. & N.J. Scott Jr. (1994). Visual encounter surveys, pp. 84–92. In: Heyer, W.R. et al. (eds.). Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonian Institution Press, Washington, DC.

Datar, M.N. & A.V. Watve (2018). Vascular plant assemblage of cliffs in northern Western Ghats, India. Journal of Threatened Taxa 10(2): 11271–11284. https://doi.org/10.11609/jott.3611.10.2.11271-11284

Dinesh, K.P. et al. (2024). Checklist of Fauna of India: Animalia: Chordata: Amphibia. Version 1.0. Zoological Survey of India. https://doi.org/10.26515/Fauna/1/2023/Chordata:Amphibia

Dinesh, K.P. et al. (2015). Systematic status of *Fejervarya* (Amphibia, Anura, Dicroglossidae) from South and SE Asia with the description of a new species from the Western Ghats of Peninsular India. Zootaxa 3999(1): 79–94. https://doi.org/10.11646/zootaxa.3999.1.5

Dufresnes, C. et al. (2022). Shedding light on taxonomic chaos: Diversity and distribution of South Asian skipper frogs (Anura, Dicroglossidae, *Euphlyctis*). Systematics and Biodiversity 20(1): 2102686. https://doi.org/10.1080/14772000.2022.2102686

Frost, D.R. (2024). Amphibian Species of the World: An Online Reference. Version 6.2 (accessed on 20.v.2025). American Museum of Natural History, New York, USA. Electronic database. https://amphibiansoftheworld.amnh.org/index.php. https://doi.org/10.5531/db.vz.0001

Gaitonde, N. & V. Giri (2014). Primitive breeding in an ancient Indian frog genus *Indirana*. Current Science 107(1): 109–112.

Garg, S. & S.D. Biju (2016). Molecular and morphological study of leaping frogs (Anura, Ranixalidae) with description of two new species. PLOS ONE 11(11): e0166326. https://doi.org/10.1371/journal.pone.0166326

Garg, S. & S.D. Biju (2017). Description of four new species of burrowing frogs in the *Fejervarya rufescens* complex (Dicroglossidae) with notes on morphological affinities of *Fejervarya* species in the Western Ghats. Zootaxa 4277(4): 451–490. https://doi.org/10.11646/zootaxa.4277.4.1

Garg, S. & S.D. Biju (2021). DNA barcoding and systematic review of minervaryan frogs (Dicroglossidae: *Minervarya*) of Peninsular India: resolution of a taxonomic conundrum with description of a new species. Asian Herpetological Research 12(4): 345–370. https://doi.org/10.16373/j.cnki.ahr.210023

Garg, S. et al. (2019). Systematic revision of *Microhyla* (Microhylidae) frogs of South Asia: a molecular, morphological, and acoustic assessment. Vertebrate Zoology 69(1): 1–71. https://doi.org/10.26049/VZ69-1-2019-01

Gawas, M. et al. (In press). Community structure and environmental determinants of amphibians in the Western Ghats watersheds of eastern Goa, India. Journal of Threatened Taxa.

Ghate, P. et al. (2023). Matvi: an eco-cultural tradition of wildflower decoration from Rajapur Tehsil, Ratnagiri District, Maharashtra, India. Journal of Ecological Society 34(1): 1–11. https://doi.org/10.54081/JES.028/03

Gururaja, K.V. (2012). Pictorial guide to frogs and toads of the Western Ghats. Gubbi Labs LLP, Gubbi, Karnataka, India, xviii + 154 pp.

Gururaja, K.V. & P. Hebbar (2016). A new species of *Euphlyctis* (Amphibia, Anura, Dicroglossidae) from the west coastal plains of India. Asian Herpetological Research 7(4): 229–241. https://doi.org/10.16373/j.cnki.ahr.160020

IUCN SSC Amphibian Specialist Group (2023). *Pseudophilautus amboli*. The IUCN Red List of Threatened Species 2023: e.T58910A3074893. https://doi.org/10.2305/IUCN.UK.2023-1.RLTS.T58910A3074893.en. Accessed on 24.viii.2026.

IUCN SSC Amphibian Specialist Group (2023). *Minervarya cepfi*. The IUCN Red List of Threatened Species 2023:

e.T121370255A121370272. https://doi.org/10.2305/IUCN.UK.2023-1.RLTS.T121370255A121370272.en. Accessed on 24.viii.2026.

Jithin, V. & R. Naniwadekar (2025). Effects of abiotic and biotic factors on tadpole occurrence and abundance in seasonal rock pools of rock outcrops, northern Western Ghats. Aquatic Ecology 59(2): 797–803. https://doi.org/10.1007/s10452-025-10195-w

Jithin, V. et al. (2023). Between a rock and a hard place: Comparing rock-dwelling animal prevalence across abandoned paddy, orchards, and rock outcrops in a biodiversity hotspot. Global Ecology and Conservation 46: e02582. https://doi.org/10.1016/j.gecco.2023.e02582

Jithin, V. et al. (2025). Orchards and paddy differentially impact rock outcrop amphibians: Insights from community- and species-level responses. Ecological Applications 35(1): e3058. https://doi.org/10.1002/eap.3058

Katwate, U. & D. Apte (2019). Amphibian diversity in two different landscapes of Konkan Region, northern Western Ghats, India. Journal of the Bombay Natural History Society 116: 9–21. https://doi.org/10.17087/jbnhs/2019/v116/115359

Komanduri, K.P.K. et al. (2023). Abundance and composition of forest-dwelling anurans in cashew plantations in a tropical semi-evergreen forest landscape. Biotropica 55(3): 594–604. https://doi.org/10.1111/btp.13210

Kulkarni, A. et al. (2022). Vanishing waters: water chemistry of temporary rock pools of the Western Ghats, India. Water Practice and Technology 17(1): 234–245. https://doi.org/10.2166/wpt.2021.107

Lekhak, M.M. & S.R. Yadav (2012). Herbaceous vegetation of threatened high altitude lateritic plateau ecosystems of Western Ghats, southwestern Maharashtra, India. Rheedea 22(1): 39–61. https://doi.org/10.22244/rheedea.2012.22.01.12

Luedtke, J.A. et al. (2023). Ongoing declines for the world's amphibians in the face of emerging threats. Nature 622(7982): 308–314. https://doi.org/10.1038/s41586-023-06578-4

Modak, N. et al. (2015). Indirana salelkari, a new species of leaping frog (Anura: Ranixalidae) from Western Ghats of Goa, India. Journal of Threatened Taxa 7(9): 7493–7509. https://doi.org/10.11609/jott.2175.7493-7509

Mudke, M. et al. (2020). Annotated list of anurans from the lateritic plateau of western India with notes on malformations. Check List 16(3): 685–698. https://doi.org/10.15560/16.3.685

Nakazawa, T. (2015). Ontogenetic niche shifts matter in community ecology: a review and future perspectives. Population Ecology 57(2): 347–354. https://doi.org/10.1007/s10144-014-0448-z

Nigam, R. et al. (2024). Evaluation of efficiency of the index of potential anthropic geomorphology at meso level: a case study of Goa State, India. The Geographical Journal 190(1): e12540. https://doi.org/10.1111/geoj.12540

Padhye, A.D. et al. (2015). *Hydrophylax bahuvistara*, a new species of fungoid frog (Amphibia: Ranidae) from peninsular India. Journal of Threatened Taxa 7(11): 7744–7760. https://doi.org/10.11609/jott.2318.7744-7760

Padhye, A. et al. (2017). *Sphaerotheca pashchima*, a new species of burrowing frog (Anura: Dicroglossidae) from western India. Journal of Threatened Taxa 9(6): 10286–10296. https://doi.org/10.11609/jott.2877.9.6.10286-10296

Porembski, S., et al. (2016). Worldwide destruction of inselbergs and related rock outcrops threatens a unique ecosystem. Biodiversity and Conservation 25(13): 2827–2830. https://doi.org/10.1007/s10531-016-1171-1

Rahangdale, S.S. & S.R. Rahangdale (2014). Plant species composition on two rock outcrops from the northern Western Ghats, Maharashtra, India. Journal of Threatened Taxa 6(4): 5593–5612. https://doi.org/10.11609/JoTT.o3616.5593-612

R Core Team (2024). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/

Rodda, G.H. et al. (2005). The predictive power of visual searching. Herpetological Review 36(3): 259–264.

Sanchez, E. et al. (2018). Phylogeny and classification of fejervaryan frogs (Anura: Dicroglossidae). Salamandra 54(2): 109–116.

Snodgrass, J.W. et al. (2000). Relationships among isolated wetland size, hydroperiod, and amphibian species richness: implications for wetland regulations. Conservation Biology 14(2): 414–419. https://doi.org/10.1046/j.1523-1739.2000.99161.x

Soni, S.P. et al. (2025). Barking up the wrong frog: global prevalence of misdirected amplexus in anuran amphibians. Biological Journal of the Linnean Society 145(1): blae062. https://doi.org/10.1093/biolinnean/blae062

Sreejith, K.A. et al. (2016). Microhabitat diversity in a lateritic hillock of northern Kerala, India. Vegetos 29(3): 100. https://doi.org/10.5958/2229-4473.2016.00074.4

Sutheeshna, B.S. (2021). Tourism, Urbanization and Spatial Reorganization: Some Reflections on Tourism Development in Goa, India, pp. 219–242. In: Jaglan, M.S. & Rajeshwari (eds.) Reflections on 21st Century Human Habitats in India: Felicitation Volume in Honour of Professor M.H. Qureshi. Springer Nature Singapore Pte Ltd., Singapore. https://doi.org/10.1007/978-981-16-3100-9_9

Thorpe, C.J. & A. Watve (2015). Lateritic Plateaus in the northern Western Ghats, India; a review of bauxite mining restoration practices. Journal of Ecological Society 28(1): 25–44. https://doi.org/10.54081/JES.024/03

Thorpe, et al. (2018). Micro-habitat distribution drives patch quality for sub-tropical rocky plateau amphibians in the northern Western Ghats, India. PLOS ONE 13(3): e0194810. https://doi.org/10.1371/journal.pone.0194810

Watve, A. (2013). Status review of rocky plateaus in the northern Western Ghats and Konkan region of Maharashtra, India with recommendations for conservation and management. Journal of Threatened Taxa 5(5): 3935–3962. https://doi.org/10.11609/JoTT.o3372.3935-62

Widdowson, M. (2009). Evolution of laterite in Goa, pp. 35–68. In: Mascarenhas, A. & G. Kalavampara (eds.) Natural Resources of Goa: A Geological Perspective. Geological Society of Goa, Miramar, Goa, India.

Widdowson, M. & K.G. Cox (1996). Uplift and erosional history of the Deccan Traps, India: evidence from laterites and drainage patterns of the Western Ghats and Konkan Coast. Earth and Planetary Science Letters 137(1–4): 57–69. https://doi.org/10.1016/0012-821X(95)00211-T

Yadav, O. et al. (2024). A new species of pond frog *Phrynoderma* (Anura: Dicroglossidae) from the coastal plains of Maharashtra, Western India. Journal of Asia-Pacific Biodiversity 17(4): 601–610. https://doi.org/10.1016/j.japb.2024.03.008

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 August 2026 | 18(8): 29483–29492

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

https://doi.org/10.11609/jott.9819.18.8.29483-29492

#9819 | Received 07 April 2025 | Final received 03 August 2026 | Finally accepted 11 August 2026

ARTICLE

Distribution, population status, associations, and biotic challenges of *Sanjappa cynometroides,* an endemic legume tree (Leguminosae: Caesalpinioideae) in the southern Western Ghats, Kerala, India

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Abstract: *Sanjappa cynometroides* (Bedd.) E.R.Souza & Krishnaraj, an unique species indigenous to the lush environs of the southern Western Ghats, India, epitomises the intricate interplay between flora, fauna, and conservation challenges. This tree was earlier categorized as Critically Endangered; however, no updated status is available. Extensive field surveys resulted in locating two new populations in Kathipara and Kambimood parts of the southern Western Ghats, Kerala and these population consist of about 20 and 70 mature trees respectively. The Kambimood population is distinct with epicormic branching, cauliflory, and stem galls. This study also offers a meticulous examination of its associations with other taxa, like epiphyllous lichens, such as *Racoplaca subtilissima* Fée, *Byssoloma chlorinum* (Vain) Zahlbr, *Tricharia vainioi* R. Sant; Corticolous lichens, *Hemithecium* sp., and *Trichothelium* sp.; leafy liverwort, *Cololejeunea lanciloba* Steph.; Corticolous bryophytes including *Meteoriopsis squarrosa* (Hook. ex Harv.) M.Fleisch and *Actinodontium rhaphidostegum* (Müll.Hal.) Bosch & Sande Lac.; a snail belonging to the *Beddomea* genus; and a preying mantis *Indomenella indica* Ghate & Mukherjee. In addition to restricted seedling regeneration in their natural habitat, they also suffer from leaf infestations caused by whiteflies, flower bud infestations by mealybugs & aphids, and fruit & seed predation by Bonnet Macaques. Moreover, the downward-growing branches of the tree touch the soil and subsequently form roots, facilitating vegetative propagation; even fallen trees do the same. This natural vegetative propagation is observed in the wild as a survival strategy in their natural habitat.

Keywords: Cauliflory, epicormic branching, fabaceae, new populations, phenology, plant-animal interactions, restricted seedling establishment, riparian, threats, vegetative propagation.

Editor: V. Sampath Kumar, Formerly Botanical Survey of India, Coimbatore, India. **Date of publication:** 26 August 2026 (online & print)

Citation: Gopika, S. & M.V.N. Krishnaraj (2026). Distribution, population status, associations, and biotic challenges of *Sanjappa cynometroides*, an endemic legume tree (Leguminosae: Caesalpinioideae) in the southern Western Ghats, Kerala, India. *Journal of Threatened Taxa* 18(8): 29483–29492. https://doi.org/10.11609/jott.9819.18.8.29483-29492

Funding: This work was supported by the Council of Scientific and Industrial Research-University Grants Commission (CSIR-UGC), Government of India (NTA Ref. No.:211610063886).

Competing interests: We declare that we have no known competing financial interests or personal relationships that could have appeared to influence this work.

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Author contributions: Gopika Suresh—conceptualization, field investigation, methodology, data collection, data analysis, writing-original draft. MKV—conceptualization, methodology, validation, supervision, manuscript review and editing.

Acknowledgements: We want to express our deep gratitude to the Kerala Forest Department, Government of India, for permitting us to conduct the present study. We are indebted to Dr Siljo Joseph (junior scientist/scientist B, Department of Forest Botany, Kerala Forest Research Institute, Peechi, Kerala) for the identification of epiphyllous lichens and Dr Stephen Sequeira (assistant professor, Postgraduate Department of Botany, Maharaja's College, Ernakulam, Kerala) for the identification of Corticolous lichens. We are grateful to Dr Manju C. Nair (associate professor, Department of Botany, University of Calicut, Kerala) for identifying the epiphyllous and corticolous bryophytes. We immensely thank Dr Sankararaman H. (assistant professor, Entomology, Vanavarayar Institute of Agriculture, Pollachi, Tamil Nadu) for identifying and giving valuable information about Apefly, Mealybugs, and Treehoppers. We are pleased to thank Ancy Raju (research scholar, Department of Zoology, Government College for Women, Thiruvananthapuram, Kerala) for the identification of the preying mantis and Aleena Elizabeth Cyril (research scholar, PG and Research Department of Zoology, Nirmala College, Muvattupuzha, Kerala) for the genus level identification of snail.

INTRODUCTION

Leguminosae is the third largest angiosperm family after Asteraceae and Orchidaceae with 796 genera and 22,450 species, and the recent Legume Phylogeny Working Group re-classified the family to six monophyletic subfamilies, viz., Caesalpinioideae DC. (Including Mimosoideae DC.), Cercidoideae LPWG, Detarioideae Burmeist., Dialioideae LPWG, Duparquetioideae LPWG, and Papilionoideae DC. (https://www.legumedata.org/; LPWG 2017). In India, the family is represented with 273 genera and 1510 species (Sanjappa & Pusalkar 2024). Kerala harbours 115 genera and 449 species, of which 17 species are strictly endemic to the state (Vajravelu & Kabeer 2016; Balan & Predeep 2021).

Sanjappa cynometroides (Image 1) is an endemic tree legume in the southern Western Ghats, Kerala, India. Beddome (1873) described the species, *Calliandra cynometroides* based on his collection from Tinnevelly and Travancore mountains at an elevation of about 760 m. Although Bentham (1875), while revising the suborder Mimoseae, treated it under *Calliandra* Benth.*,* Baker (1878) and Kuntze (1891) transferred it to the genus *Inga* Mill. (*Inga cynometroides* (Bedd.) Baker), and *Feuilleea* Kuntze (*Feuilleea cynometroides* (Bedd.) Kuntze) respectively. After thorough morphological and molecular phylogenetic studies by de Souza et al. (2016), the taxonomic identity of this enigmatic taxon, previously placed in the genera *Calliandra*, *Inga*, and *Feuilleea* was clarified, and a new genus *Sanjappa* E.R. Souza & Krishnaraj was erected to accommodate the same. Recently, Thulin (2023) expanded the genus by adding two more species, viz., *Sanjappa umbrosa* (Wall.) Thulin and *Sanjappa vietnamica* Thulin. However, Sanjappa & Pusalkar (2024) described a new genus *Kanjilalia* Sanjappa & Pusalkar comprising two species viz., *Kanjilalia griffithii* (Baker ex Benth.) Sanjappa & Pusalkar and *Kanjilalia umbrosa* (Wall.) Sanjappa & Pusalkar, based on the characters of flowers, stipular spines, and distribution pattern. Hence, presently the genus *Sanjappa* E.R. Souza & Krishnaraj comprises only two species.

In the present work, apart from the discovery of two new populations of *Sanjappa cynometroides*, provided an overview of the current population status, floral-faunal associations, and the threats in its natural habitat.

MATERIALS AND METHODS

Field exploration was conducted during 2022–2024 in parts of the Agasthyamalai Biosphere Reserve. Continuous field surveys and the collection of various plant parts, including leaves, inflorescences with flower buds & flowers, fruits, and seeds, were made in populations located at Rosemala (part of Shendurney Wildlife Sanctuary), Kallar, Kathipara, and Kambimood (part of Agasthyamalai Biosphere Reserve), southern Western Ghats, Kerala. Preliminary morphological observations of the vegetative and reproductive parts for floral, faunal associations and infestations were examined using a 15x hand lens in the field. Unidentified biological specimens were later identified with the help of experts in the respective fields. The epiphyllous lichen specimens and bryophytes were deposited at Kerala Forest Research Institute (KFRI) Herbarium and Herbarium of the Department of Botany, Calicut University (CALI), respectively. Photographs of the specimens were taken using a stereo microscope MSZ-Tr LED with Magcam DC10MP camera, manufactured by Magnus Opto Systems, India, and a macro lens (SKYVIK Signi 15x macro lens). The geographic coordinates of study sites were recorded using a handheld device of Garmin eTrex 10.

RESULTS AND DISCUSSION

Population status

Sanjappa cynometroides is an endemic species to the southern Western Ghats and was thought to be extinct until Sasidharan (1998) rediscovered it after a lapse of 125 years from Rosemala (Kollam District, Kerala). After almost 20 years, Somen et al. (2017) found another population of this species in Kallar (Thiruvananthapuram district, Kerala). Diminishing to less than 40 mature individuals and restricted seedling regeneration in Rosemala, present a bleak picture of it in the wild and earlier was categorized under Critically Endangered (IUCN 2012). While the present study was going on, six new seedlings were found in the Rosemala population in July 2024, however, only three out of the six survived (50%). The Kallar population has 4–10 mature trees, but no seedlings could be traced. Both populations have an area of occupancy of less than 1 km^2 each, and they inhabit areas close to streams (Image 2). During this field study, we found two new populations in the wild, Kathipara and Kambimood (Image 2). The population at Kathipara (8.6922^o N, 77.1353^o E, at an altitude of

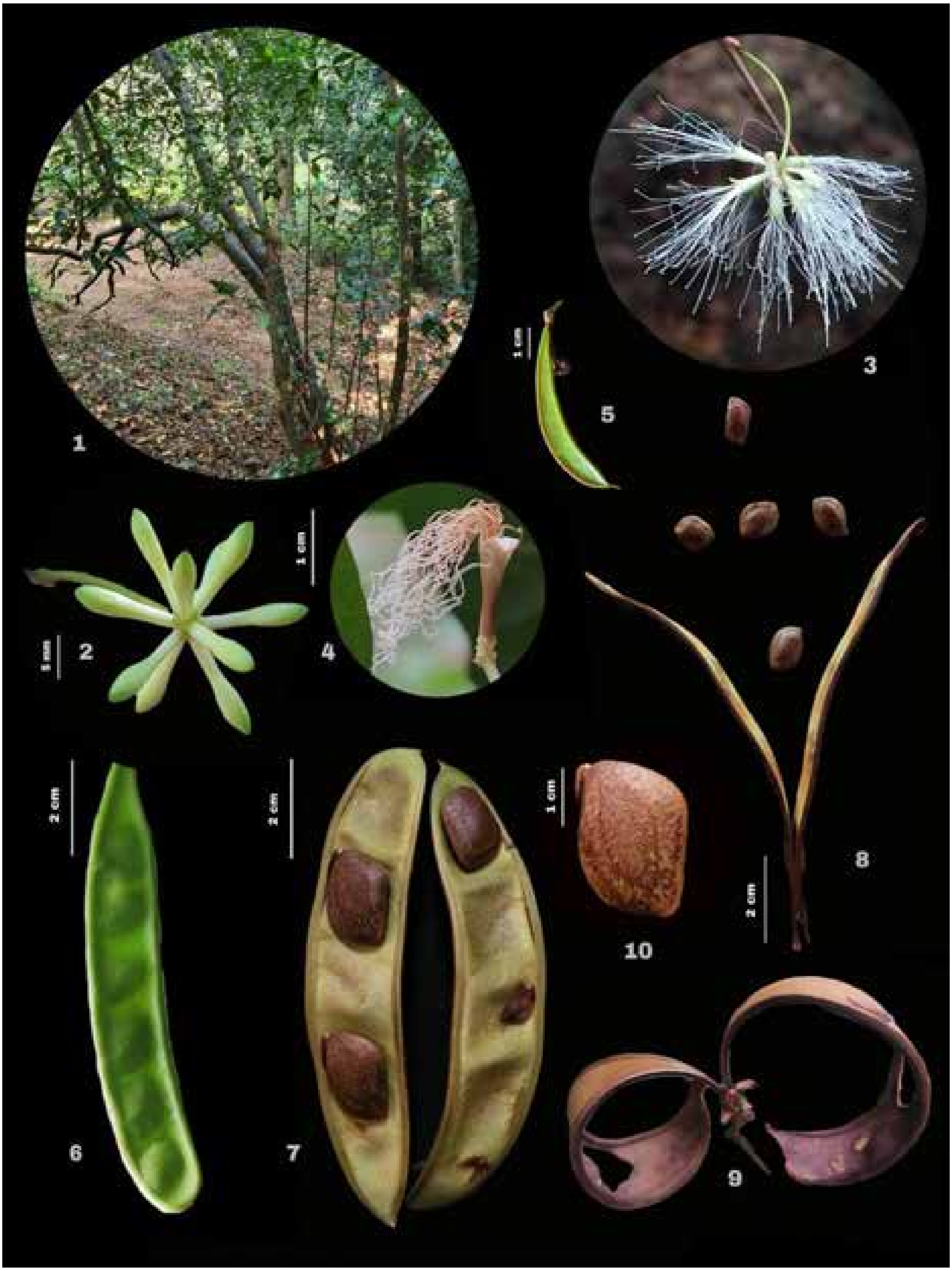

Image 1. ***Sanjappa cynometroides*** **(Bedd.) E.R. Souza & Krishnaraj: 1—Habit | 2–3—Inflorescence Pre-anthesis & Post-anthesis stage | 4—Post-pollination change | 5—Immature fruit | 6—Mature fruit | 7—Pod with seeds | 8–9—Stages of fruit dehiscence | 10—Seed. © Gopika Suresh.**

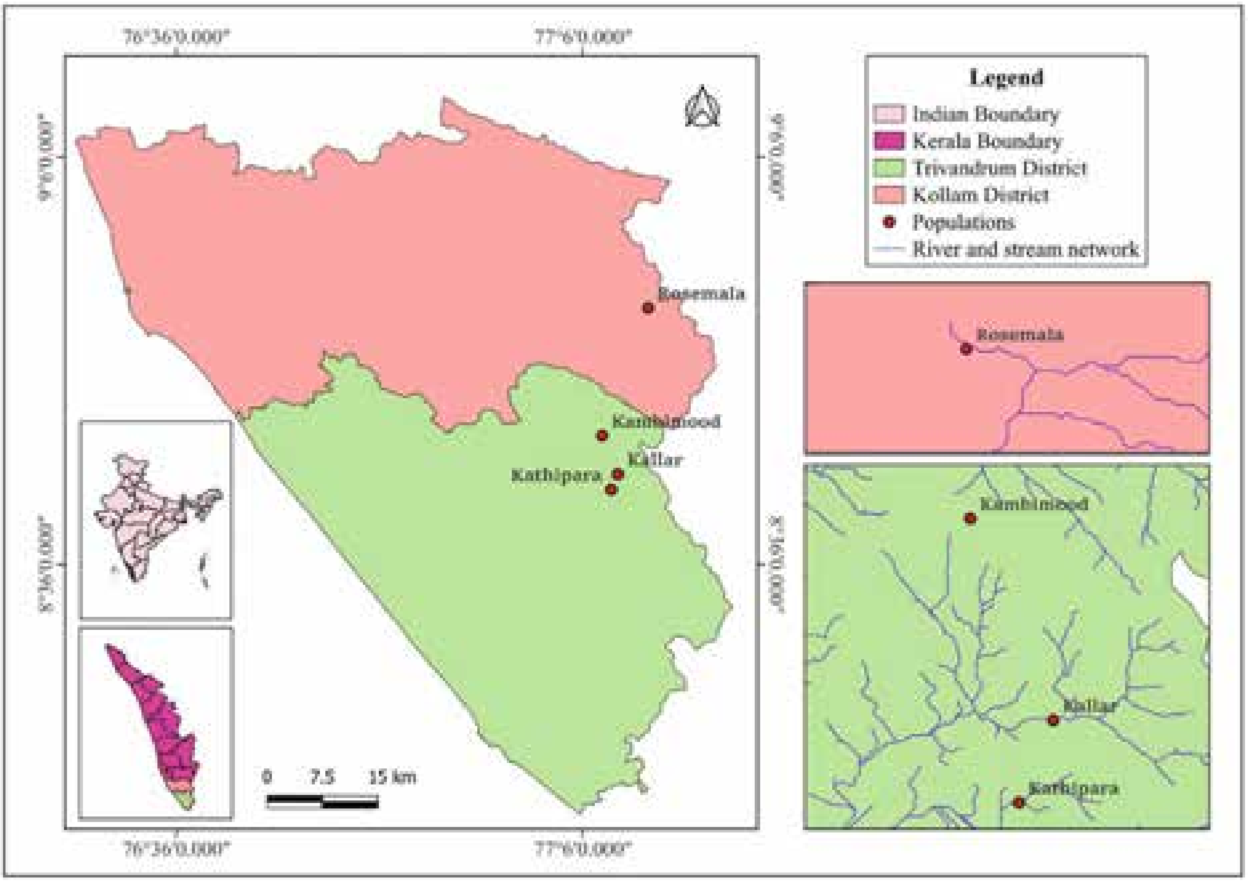

Image 2. Map showing the geographic locations of the presently known populations of *Sanjappa cynometroides* and associated river and stream networks. (Map prepared by using QGIS software).

114 m) (Image 3A) is riparian and 2–3 km farther from the Kallar population, with lesser exposure to human habitation. In this population, *S. cynometroides* survives with seedlings, saplings, and mature trees. Seedlings and saplings range from 4–5, and mature individuals are 20–25 in number, including fallen trees. However, the fallen trees are successfully alive through vegetative propagation (Image 3B). The second population is at Kambimood (8.757011^0 N, 77.124298^0 E) (Image 3C), near the Ponmudi hilltop, Thiruvananthapuram. This population is found near to tea plantation at an altitude of 770 m, and interestingly, this is the only one not inhabited close to a stream (see Image 2). This one is the largest population comprising 70–80 mature trees and a few saplings without any seedlings. Moreover, the morphology of the tree trunk is much more varied than that of the other three populations and shows epicormic branching throughout (Image 3D). The plant's epicormic branching is a survival mechanism against environmental disturbances to recover its damaged shoot system (de Campos et al. 2021). Anthropogenic disruption is low in this population, and forest fire activities are not reported in this area. So, further investigation is essential to find the reason behind epicormic branching.

The bud bank is a collection of buds that includes axillary and adventitious buds in dormant form, which act as a reserve and play a crucial role in the regeneration of the shoot system. When any disturbance (like injury) happens, these buds are actively grown, leading to vegetative regeneration (Klimesˇová & Klimeš 2007). In the Kambimood population, we have noticed bud growth in the main trunk, even though the tree was completely damaged (Image 3E). Cauliflory, an intimately related phenomenon to epicormic branching, is reported for the first time in *S. cynometroides* (Image 3F); here, the number of cauliflorous inflorescences is more than axillary inflorescences in the branches. In the Rosemala population, one tree showed an epicormic branching–like pattern, and another showed cauliflory.

Phenology

The phenological behaviour of the species in the

Image 3. New Population and its characteristics: A—Population at Kathipara | B—Fallen trees showing vegetative propagation at Kathipara | C—Population at Kambimood | D—Epicormic branching at Kambimood | E—New bud proliferation from the completely damaged tree | F—Cauliflory at Kambimood tree. © Gopika Suresh.

Rosemala population shows relatively narrow variation. Floral bud initiation occurs during July–August, followed by peak flowering between late August and early October. Although the flowering period of individual trees is brief (4–5 days), flowering is highly synchronous within the population. Fruiting commences in November, with fruits maturing in December and January.

Floral-Faunal associations

In the Kallar population, the adaxial surface of the leaf is intensely colonized with epiphyllous lichens such as *Racoplaca subtilissima* Fée (Image 4A), *Byssoloma* *chlorinum* (Vain) Zahlbr (Image 4B) and *Tricharia vainioi* R. Sant (Image 4C). This is the first report of epiphyllous lichens from *Sanjappa cynometroides.* As per the study of Randive et al. (2017), the abundant proliferation of lichens on foliage indicates minimal human disturbances. Despite the high level of human interference, the epiphyllous lichens are growing abundantly on trees in the Kallar population. Additionally, we found two corticolous lichens, *Hemithecium* sp. (Graphidaceae) and *Trichothelium* sp. (Porinaceae), associated with the twigs of *Sanjappa cynometroides* from the Kambimood population.

It is also observed that *S. cynometroides* as a host plant of an epiphyllous liverwort called *Cololejeunea lanciloba* Steph. of the family Lejeuneaceae (Image 4D). Leafy liverworts exhibit sensitivity to changes in moisture and temperature levels, making them reliable indicators of climate change and forest fragmentation (Jiang et al. 2018). The trees growing at the Kambimood population are home to Corticolous bryophytes, *Meteoriopsis squarrosa* (Hook. ex Harv.) M.Fleisch (Meteoriaceae) (Image 4E) and *Actinodontium rhaphidostegum* (Müll. Hal.) Bosch & Sande Lac. (Hookeriaceae) (Image 4F). During the field surveys, observed a snail belonging to the genus *Beddomea* of the family Camaenidae (Image 4G) found attached to the leaves of *Sanjappa cynometroides*. Due to the lack of studies on arboreal snails in the Western Ghats, not able to identify it up to the species level. It would be interesting to study the interaction between the snails and the trees. In addition, the Ootheca (egg mass) of the praying mantis, *Indomenella indica* Ghate & Mukherjee was observed, which is attached to the lower surface of many leaves, even on stems (Images 4H,I), and also spotted the nymphs and mature ones frequently in the Rosemala population. Additionally, it was interesting to notice *I. indica* displayed egg mass guarding behaviour that lasts for 5–10 days. The researchers in this field did not observe any plant-specific egg-laying mechanisms. However, the site selection for capturing prey and the deposition of ootheca are essential for their reproduction and survival. Habitat selection is also influenced by camouflaging dense foliage, prey availability, predators, microclimatic conditions, and various other elements (Balakrishnan 2012). A wide range of butterflies, moths, beetles, bees, flies, and ants were also observed on the tree across flowering and non-flowering seasons. However, we have not found any pollination-like behaviour during the daytime so far.

Natural threats in the wild

Natural threats that have a negative impact on the population of *Sanjappa cynometroides* are infestation and predation of leaves, flower buds, fruits, and seeds. In Rosemala and Kallar, severe leaf infestation is caused by the Whiteflies (Image 5A). Whiteflies are highly invasive, exotic, phytophagous insect species belonging to Hemiptera: Aleyrodidae. It is infested on the lower surface of the leaves and causes damage to the host plants by sucking the plant sap and interfering the normal growth. Furthermore, the whiteflies cause indirect damage by excreting honeydew and producing wax (Selvaraj et al. 2024). Sundararaj et al. (2021) assessed the intensity of damage caused by whiteflies using the following parameters: "Low (less than ten live egg spirals or adults/leaflet), Medium (11–20 live egg spirals or adults/leaflet), and Severe (more than 20 live egg spirals or adults/leaflet)". In the case of *S. cynometroides*, the whitefly population and intensity of damage are low in the Kallar population. However, it was observed more than 20 adults/leaflets at Rosemala in January, indicating a severe population and damage caused by whiteflies. Although the tree showed signs of recovery through leaf flushing, this process was not immediate. Also observed empty pupa shells hidden under the leaves, which seem to be either a butterfly or moth pupa; more evidence is needed to confirm this.

The Kambimood population is distinctive due to the numerous stem galls on the trees (Image 5B). Usually, galls are formed due to abnormal tissue growth caused by biological agents such as viruses, bacteria, nematodes, and insects. The interaction between gall-inducing insects and their host plant species is highly species-specific (Silva & Urso-Guimarães 2021). The causative organism for the stem galls in *S. cynometroides* has not been studied. Additionally, within the same population spotted the nymph of the treehopper (Membracidae, Hemiptera) associated with the stem gall (Image 5C). Treehoppers are phytophagous insects that cause damage to host plants by sucking large amounts of plant sap, and the honeydew they excrete is an alternative nectar to other organisms such as ants, bees, wasps, and even to butterflies (Bartlett et al. 2018).

Interestingly, a prey-predator (mealybug-apefly) relationship as part of flower bud infestation in *S. cynometroides* in the Kallar population is an interesting to record. Mealybugs are pests that feed on plant sap and reduce plant vigour. Here, it attacks the flower bud, causing stunted growth, leading to the malformation of the flower (Image 5D). The butterfly larvae of *Spalgis epeus* (Apefly) (Image 5E) were also found within the

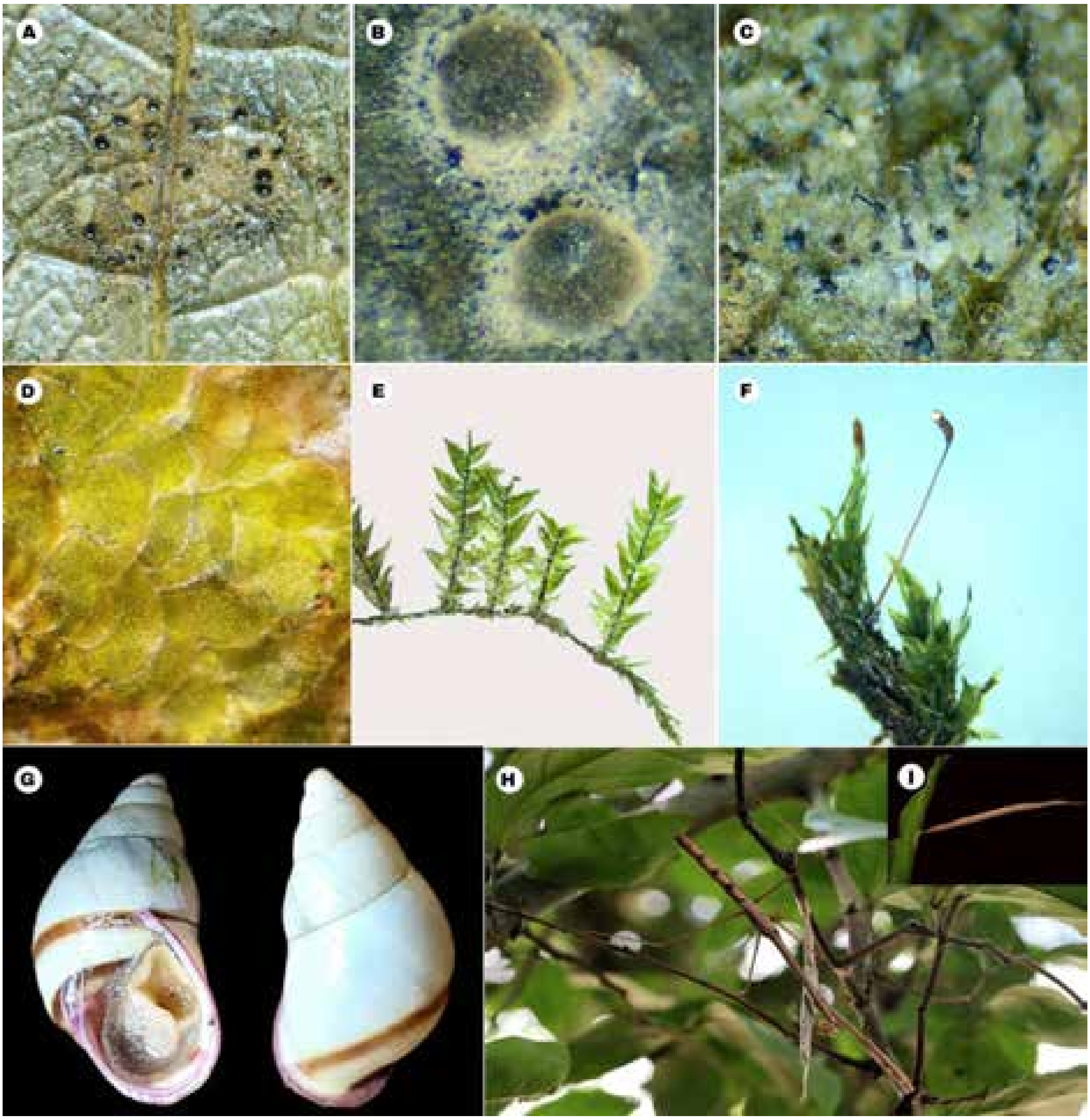

Image 4. Floral–faunal associations found in *Sanjappa cynometroides*: A—*Racoplaca subtilissima* Fée | B—*Byssoloma chlorinum* (Vain) Zahlbr | C—*Tricharia vainioi* R.Sant | D—*Cololejeunea lanciloba* Steph. | E—*Meteoriopsis squarrosa* (Hook. ex Harv.) M.Fleisch | F—*Actinodontium rhaphidostegum* (Müll.Hal.) Bosch & Sande Lac | G—A snail species of *Beddomea* | H—*Indomenella indica* Ghate & Mukherjee with ootheca | I—Ootheca. © Gopika Suresh.

same inflorescence. Apefly larvae are recognized as predators of mealybugs (Saengyot & Burikam 2012).

In Rosemala population, aphids (Aphidoidea, Hemiptera) exclusively attack flower buds in the late monsoon and post-monsoon periods (usually August–November). This significantly affects the reproductive mechanisms of the plant, resulting in a limited number of healthy flower buds and flowers suitable for pollination and fruit development. It was also observed that an ant-aphid mutualistic relationship associated with *Sanjappa cynometroides* (Image 5F) in the same population. Aphids ingest the phloem sap using stylets and excrete sugary honeydew. Ants use this honeydew as food; in return, they protect the aphids from predation, parasitism, and fungal infections (Phillips & Willis 2005). As the infestation progresses, the host

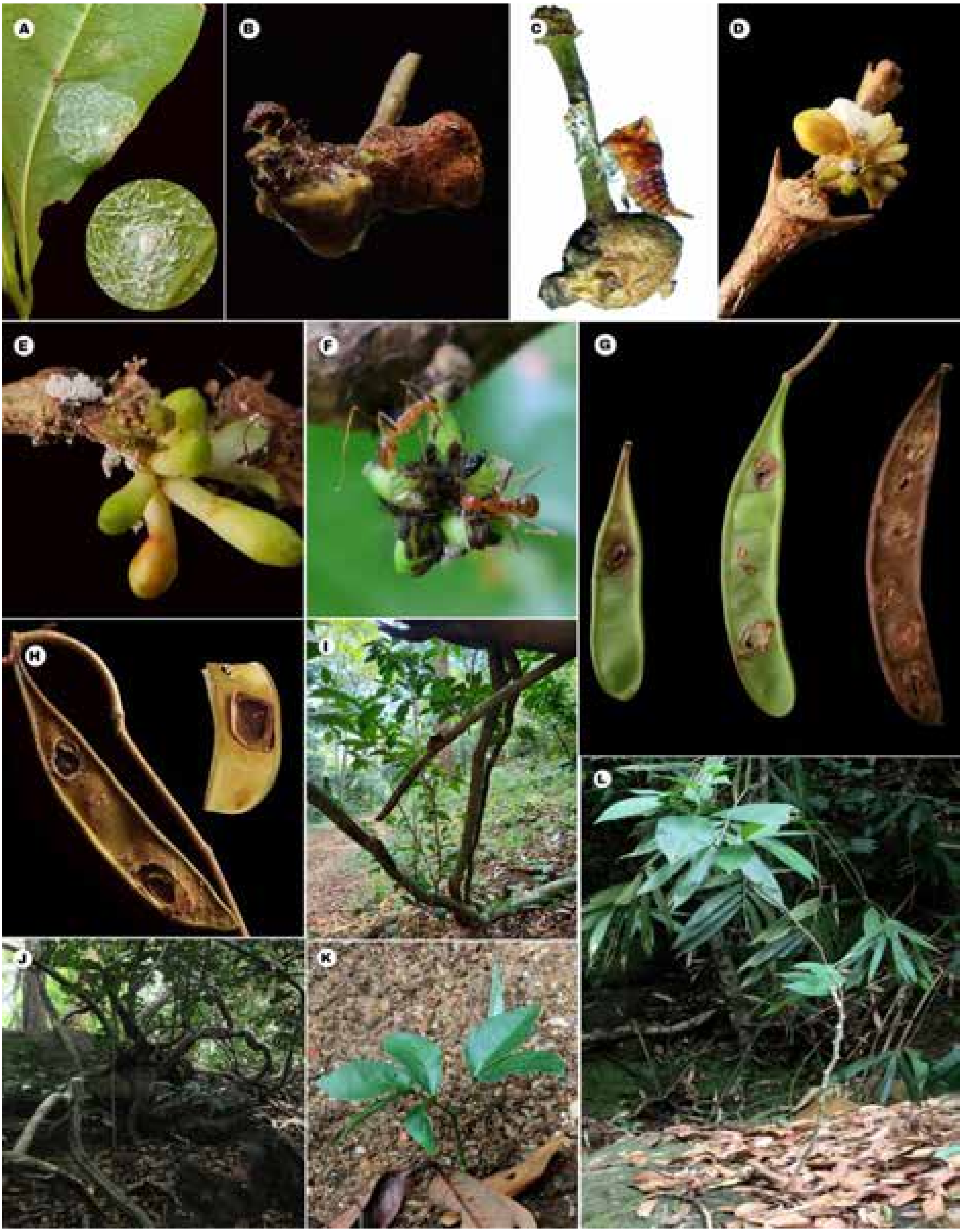

Image 5. Natural and anthropogenic threats: A—Leaf infestation by whiteflies | B—Stem gall | C—Nymph of treehopper associated with stem gall | D—Flower bud infestation by mealybug | E—Larvae of *Spalgis epeus* (Apefly) associated with mealybug infected flower bud | F—Ant-aphid mutualistic relationship leading to flower bud infestation | G—Predation-like act on immature, mature and dried pods | H—Fully consumed seed condition by unknown organism | I—Vegetative propagation at Rosemala | J—Vegetative propagation at Kathipara | K—Seedling growing in stream bed at Kathipara | L—Sapling growing on the rock within the stream bed at Kathipara. © Gopika Suresh.

plant may develop a morphological barrier or attract natural enemies of aphids. Meanwhile, natural enemies have started to use honeydew produced by the aphids as food (Guerrieri & Digilio 2008). So, this mutualistic relationship has a negative impact on the plants' health.

Some notable infestations on fruits include reddish patches on immature fruit surfaces. Moreover, infestation, the signs of the predation-like act, are seen on immature, mature, and even dried fruit surfaces at Rosemala (Image 5G). Additionally, part of the fruit wall, where the seeds occur, appears as an ample vacant space with fully consumed empty seeds (Image 5H); nevertheless, the dehiscence mechanism is carried out without fail at maturity. The infestations are more prominent on the trees near the stream at Rosemala.

Ramachandran (1995) recorded 23 feeding plants of Bonnet Macaque *Macaca radiata* from Shendurney Wildlife Sanctuary and observed monthly variations in the diet. During this study it is observed that Bonnet macaques consume young fruits of *Sanjappa cynometroides* and themselves serve as seed dispersers after fruit maturity. Their movement across the tree branches, coupled with the elastically dehiscent character of fruits from the apex downwards, favours effective seed dispersal. However, only a few seeds were found on the forest floor, indicating further predation.

Apart from infestation and predation, some trees were washed out during the flood at the Kallar River. In Rosemala, strong winds cause large woody trees to fall onto *S. cynometroides*. In the new Kathipara population, more fallen trees are observed due to flooding in the stream. However, roots are formed from the fallen branches of *S. cynometroides*, indicating a change in their reproductive strategy towards vegetative propagation in reaction to difficulties encountered in their natural environment. This changing reproductive strategy is more prominent at Rosemala (Image 5I) and Kathipara (Image 5J). Moreover, at Kathipara, because tree branches extend over the stream, seeds can fall directly into the water. Under low streamflow conditions, the seeds may be deposited in the sandy streambed, where they can germinate and grow into seedlings (Image 5K), even on large rocks within the streambed as saplings (Image 5L). As a result, seedlings are more likely to be washed out during the rainy season or periods of heavy streamflow; conversely, this flow may help the seeds spread farther.

Anthropogenic threats

The populations at Rosemala and Kallar are concentrated around the pedestrian routes, and they are popular tourist destinations in southern Kerala. In Rosemala, the trail acts as a path for vehicles, mostly Jeeps used by the local people and tourists. Consequently, to prevent travelling issues, the branches of *Sanjappa cynometroides* along the path are chopped down. The neighbouring local community uses the branches of this tree to produce domestic items like handles of pick-axes, etc., without having enough awareness of its taxonomic or conservation significance, which negatively affects the population. In Ponmudi, the local people called *S. cynometroides* as 'Penarakam' in their mother tongue, Malayalam. According to them, in earlier times, the leaves were boiled in water along with leaves of other medicinal plants (not revealed their exact local names), and bathing in this decoction was believed to alleviate arthritic problems.

CONCLUSION

Through continuous field surveys, two new populations in the wild and expanded distribution of *Sanjappa cynometroides* were reported in this work and believe that this new reports will have an impact on their IUCN threat status. The field surveys indicate that all the populations have restricted seedling regeneration, and the species is undergoing considerable risks including natural calamities and man-made disasters. It is also witnessed that the plant adopt vegetative propagation to survive in its natural environment. The reason for the shift in reproductive strategy is currently under study. The stem cuttings were directly planted in the humus-rich soil of the population at Rosemala, as a trial, resulting in the successful regeneration of the plant. To conclude, this species grapples with various challenges despite its taxonomic novelty and ecological significance, underscoring the necessity for comprehensive conservation strategies.

REFERENCES

Balakrishnan, P. (2012). Ambush and oviposition site selection by giant Asian mantis *Hierodula membranacea* Burmeister (Mantodea: Mantidae) in tropical wet evergreen forests. Western Ghats, India. The Journal of Tropical Asian Entomology 01: 13–19.

Balan, A.P. & S.V. Predeep (2021). Legumes of Kerala, India: a checklist. Journal of Threatened Taxa 13(5): 18257–18282. https://doi.org/10.11609/jott.6475.13.5.18257-18282

Baker, J.G. (1878). Leguminosae: Mimosoideae, pp. 56–306. In: Hooker J.D. (ed.). The Flora of British India, Vol. 2. L. Reeve and Co., London.

Bartlett, C.R. et al. (2018). The Diversity of the True Hoppers (Hemiptera: Auchenorrhyncha), pp. 501–590. In: Foottit, R.G. & P.H. Adler (eds.). Insect Biodiversity: Science and Society (1st ed.). Wiley.

Beddome, R.H. (1873). The flora sylvatica for southern India. Gantz Brothers.

Bentham, G. (1875). Revision of the suborder Mimoseae. Transactions of Linnean Society London 30: 335–664.

de Campos, B.H. et al. (2021). Epicormic bud protection traits vary along a latitudinal gradient in a neotropical savanna. The Science of Nature 108 (2): 1–16. https://doi.org/10.1007/s00114-021-01722-4

de Souza, E.R. et al. (2016). *Sanjappa*, a new genus in the tribe Ingeae (Leguminosae: Mimosoideae) from India. Rheedea 26(1): 1–12. https://doi.org/10.22244/rheedea.2016.26.01.01

Guerrieri, E. & M.C. Digilio (2008). Aphid–plant interactions: a review. Journal of Plant Interactions 3(4): 223–232. https://doi.org/10.1080/17429140802567173

IUCN (2012). IUCN Red List Categories and Criteria. Version 3.1. IUCN Species Survival Commission Gland.

Jiang, Y. et al. (2018). Past distribution of epiphyllous liverworts in China: The usability of historical data. Ecology and Evolution 8(15): 7436–7450. https://doi.org/10.1002/ece3.4274

Klimesˇová, J. & L. Klimeš (2007). Bud banks and their role in vegetative regeneration–A literature review and proposal for simple classification and assessment. Perspectives in Plant Ecology, Evolution and Systematics 8(3): 115–129. https://doi.org/10.1016/j.ppees.2006.10.002

Kuntze, O. (1891). Revisio generum plantarum: vascularium omnium atque cellularium multarum secundum leges nomenclaturae internationales cum enumeratione plantarum exoticarum in itinere mundi collectarum. Leipzig Arthur Felix [etc.]. Vol. 1.

LPWG (2017). A new subfamily classification of the Leguminosae based on a taxonomically comprehensive phylogeny. Taxon 66(1): 44–77. https://doi.org/10.12705/661.3

Phillips, I.D. & C.K.R. Willis (2005). Defensive behavior of ants in a mutualistic relationship with aphids. Behavioral Ecology and Sociobiology 59(2): 321–325. https://doi.org/10.1007/s00265-005-0046-3

Ramachandran, K.K. (1995). Status survey of primates in Shendurney Wildlife Sanctuary and adjacent areas. KFRI Research Report No.106, Peechi, 34 pp.

Randive, P. et al. (2017). Notes on Foliicolous Lichens from Western Ghats Part of Goa, India. Indian Journal of Forestry 40(3): 217–221. https://doi.org/10.54207/bsmps1000-2017-SO7E69

Saengyot, S. & I. Burikam (2012). Bionomics of the apefly, Spalgis epius (Lepidoptera: Lycaenidae), predatory on the papaya mealybug, Paracoccus marginatus (Hemiptera: Pseudococcidae), in Thailand. Songklanakarin. Journal of Science & Technology 34(1): 1–7.

Sanjappa, M. & P.K. Pusalkar (2024). Fabaceae (Leguminosae)–Part–1, pp. 258–262. In: Sanjappa, M., P. K. Pusalkar & A.A. Mao (eds.). Flora of India, Vol. 6. Botanical Survey of India, Kolkata.

Sasidharan, N. (1998). Rediscovery of four threatened and possibly extinct endemic tree legumes from Kerala. In: Higher plants of Indian Subcontinent. Indian Journal of Forestry 10: 205–213.

Selvaraj, K. et al. (2024). Guide on Diagnosis of Invasive Whiteflies and Their Natural Enemies. Technical Bulletin No. 01/2021, Revised 2024 ICAR-National Bureau of Agricultural Insect Resources, Hebbal, Bengaluru, Karnataka, India, vi + 42 pp.

Silva, E.A.M. & M.V. Urso-Guimarães (2021). New records and expansion of the geographic distribution of gall inducers of the family Cecidomyiidae (Diptera) associated to Andira Lam. (Fabaceae) species in Brazil. Revista Brasileira de Entomologia 65(4): e20210071. https://doi.org/10.1590/1806-9665-RBENT-2021-0071

Somen, C.K. et al. (2017). Population evaluation and development of propagation protocol for three Rare, Endangered, and Threatened (RET) trees from the Kerala part of Western Ghats. KFRI Research Report No. 526, Peechi, 63 pp.

Sundararaj, R. et al. (2021). Invasion and expansion of exotic whiteflies (Hemiptera: Aleyrodidae) in India and their economic importance. Phytoparasitica 49(5): 851–863. https://doi.org/10.1007/s12600-021-00919-7

Thulin, M. (2023). Studies of Asian 'Calliandra' lead to expansion of Sanjappa (Fabaceae–Caesalpinioideae). Nordic Journal of Botany e04241. https://doi.org/10.1111/njb.04241

Vajravelu, E. & K.A.A. Kabeer (2016). Fabaceae, pp.1–296. In: Murthy, G.V.S. & V.J. Nair (eds.). The Flora of Kerala, Vol. 2. Botanical Survey of India.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 August 2026 | 18(8): 29493–29506
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.10608.18.8.29493-29506
#10608 | Received 13 April 2026 | Final received 13 July 2026| Finally accepted 24 July 2026

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ARTICLE

Lichen diversity of Churdhar Wildlife Sanctuary and adjacent areas of Himachal Pradesh, India

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Abstract: Himachal Pradesh supports a rich diversity of both cryptogams and phanerogams including lichens owing to its diverse physiography, climatic heterogeneity and wide elevational range. However, several protected areas including Churdhar Wildlife Sanctuary (CWS) remain unexplored for lichen diversity. The present study provides the first systematic inventory of the lichen biota of CWS based on approximately 230 specimens collected during field surveys conducted in 2024. A total of 102 species belonging to 42 genera and 16 families were identified, including the description of 15 lichen species reported for the first time from the state. The study highlights CWS as an important reservoir of western Himalayan lichen diversity and emphasize the need for continued floristic surveys in protected areas.

Keywords: Ascomycetes, biodiversity, biomonitoring, climate change, corticolous, lichenized fungi, Indian mycota, parmeliaceae, taxonomy, western Himalaya.

सारांश: हिमाचल प्रदेश अपनी विविध भौगोलिक संरचना, जलवायवीय विषमता तथा विस्तृत ऊँचाई के कारण लाइकेन (शैक) सहित क्रिप्टोगैम (अपुष्पी) एवं फेनेरोगैम (पुष्पी) पादपों की समृद्ध विविधता पायी जाती है। तथापि, चूरधार वन्यजीव अभयारण्य सहित राज्य के कई संरक्षित क्षेत्र अभी भी शैक विविधता के दृष्टिकोण से अपेक्षाकृत अन्वेषित हैं। प्रस्तुत अध्ययन में वर्ष 2024 के दौरान किए गए क्षेत्रीय सर्वेक्षणों में एकत्रित लगभग 230 नमूनों के आधार पर CWS की शैक जैवविविधता का प्रथम सर्वेक्षण एवं सूचीकरण प्रस्तुत किया गया है। अध्ययन में कुल 16 कुलों तथा 42 वंशों से संबंधित 102 शैक प्रजातियों की पहचान की गई। इनमें 15 शैक प्रजातियाँ ऐसी हैं जिन्हें पहली बार हिमाचल प्रदेश राज्य से अभिलिखित किया गया है। यह अध्ययन चूरधार वन्यजीव अभयारण्य की शैक विविधता के महत्व को रेखांकित करता है।

Editor: Vishal Chauhan, University of Jammu, Jammu, India.

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

Citation: Devi, A., G.K. Mishra & M. Srivastava (2026). Lichen diversity of Churdhar Wildlife Sanctuary and adjacent areas of Himachal Pradesh, India. *Journal of Threatened Taxa* 18(8): 29493–29506. https://doi.org/10.11609/jott.10608.18.8.29493-29506

Funding: The author GKM and MS is grateful to CSIR for in house project ULIP-MMP002628. First author (AD) is thankful to Indian Council of Medical Research, New Delhi for providing financial assistance in the form of Senior Research Fellowship (SRF).

Competing interests: The authors declare no competing interests.

Author details: See end of this article.

Author contributions: The authors GKM and MS authenticated the specimens and critically reviewed the manuscript. AD carried out segregation, identification, prepared hand-cut sections, compiled the photo plates, and drafted the initial manuscript.

Acknowledgements: The authors are thankful to the director of CSIR-National Botanical Research Institute, Lucknow, for providing laboratory facilities under MMP002628. The authors, GKM and MS, are grateful to CSIR for in house project ULIP-MMP002628. Co-author AD is thankful to the Indian Council of Medical Research, New Delhi, for providing financial assistance in the form of a junior research fellowship (JRF).

INTRODUCTION

Protected areas play a crucial role in conserving biological diversity by providing refugia for numerous plant, animal and fungal taxa. In the Himalaya, these landscapes encompass a wide range of habitats and microclimatic conditions that support a rich lichen flora. However, despite their ecological significance, the lichen diversity of many protected areas remains inadequately documented. The state of Himachal Pradesh is located in the western Himalayan region. Despite its relatively small geographical area (55,673 km^2), the state harbours rich biodiversity. Its diverse climatic and geographic conditions support the growth and development of various flora and fauna. Due to its excellent lichen diversity, the state is considered a hotspot of lichen diversity in India (Nayaka et al. 2002). Upreti & Nayaka (2000) have enumerated 309 species from the state. Later, Yadav (2005) enumerated 504 lichen species from 12 districts of Himachal Pradesh. According to Sinha et al. (2024), 716 lichen species were recorded from Himachal Pradesh. At present, the state comprises five National Parks, 26 Wildlife Sanctuaries, and three Conservation Reserves (Himachal Pradesh forest department 2026). However, floristically, many of these protected areas remain unexplored. The Churdhar Wildlife Sanctuary (CWS) is one of the unexplored protected areas of Himachal Pradesh, lying in 30.8108°–30.9108° N and 77.4922°–77.4969° E, covering a wide altitude varying 1,500–3,647 m. The area of CWS falls into two districts of the state, i.e., Sirmaur and Shimla, while the present study was conducted in the area of CWS, which falls into the district of Shimla. The vegetation of CWS is classified into two major types: (I) sub-tropical mixed deciduous and coniferous forest, and (II) temperate to sub-alpine forest. Some of the phorophytes of the sanctuary are; *Abies spectabilis*, *Acer caesium*, *A. acuminatum*, *A. pentapomicum*, *Aesculus indica, Betula utilis*, *Berberis aristata*, *B. coriaria*, *B. jaeschkeana*, *Buxus wallichiana*, *Cedrus deodara*, *Cornus macrophylla*, *Picea smithiana*, *Pinus wallichiana*, *Juglans regia*, *Rhododendron anthopogon*, *R. lepidotum*, *Quercus leucotrichophora*, *Q. semecarpifolia Syringa emodi*, and *Taxus wallichiana* (Subramani et al. 2014; Thakur et al. 2021). These phorophytes have a luxuriant growth of lichens in the region. Although several floristic investigations have been conducted in CWS, no dedicated lichenological survey has been undertaken (Upreti & Nayaka 2000; Yadav 2005; Bajpai et al. 2022). Therefore, this is the first attempt to enumerate and document the lichen biota of CWS.

MATERIALS AND METHODS

The present study is based on approximately 230 freshly collected specimens from CWS. Two field surveys were made during the months of April 2024 and November 2024 (28–30 April 2024 and 04–05 November 2024) (Image 1). Specimens were collected from different substrates, including bark, rock, wood, soil, moss and on leaves. After shade drying for one week in the processing room, the specimens were examined morphologically, anatomically and chemically. The morphological examination of the specimens was done under a stereo zoom microscope (Leica S8 APO). Anatomy of the thallus and spores was studied by thin hand-cut sections observed under a compound microscope (Leica DM500). Chemistry of the specimens was studied by performing spot tests using routine reagents K (10%), C (Calcium hypochlorite), and P (Paraphenylenediamine), Thin Layer Chromatography (TLC) was performed in solvent systems A (Toluene: 1–4, dioxane: acetic acid in ratio of 180: 60: 8 ml) and C (Toluene: 1–4, dioxane: acetic acid in ratio of 180: 60: 8 ml), following Orange et al. (2001). Identification of the specimens up to species level was done following Awasthi (1991, 2007), Sinha et al. (2024) and Wijayawardene et al. (2022) is followed for classification. The identified specimens are preserved in the lichen herbarium of CSIR-National Botanical Research Institute, Lucknow (LWG). Maps of the study area were created using QGIS (version 3.34.9) software.

RESULTS AND DISCUSSION

A total of 102 lichen species representing 42 genera and 16 families were recorded from CWS, including 15 species newly reported for Himachal Pradesh (Table 1; Image 2B). With respect to substrate preference, 79 species were corticolous, followed by seven saxicolous, five lignicolous, four muscicolous, two ramicolous, and one foliicolous species. One species occurred on both soil and bark, while another was recorded from both rock and bark (Image 1C). On the basis of growth forms 62 species were foliose, followed by 23 crustose, 16 fruticose, and one leprose species (Image 2A). Among the families, Parmeliaceae was dominant, comprising 11 genera and 25 species, followed by Physciaceae (5 genera, 23 species), Ramalinaceae (3 genera, 8 species), Caliciaceae (3 genera, 5 species), and Teloschistaceae (4 genera, 4 species). In contrast, Opegraphaceae, Stereocaulaceae, and Strigulaceae were each represented by a single species.

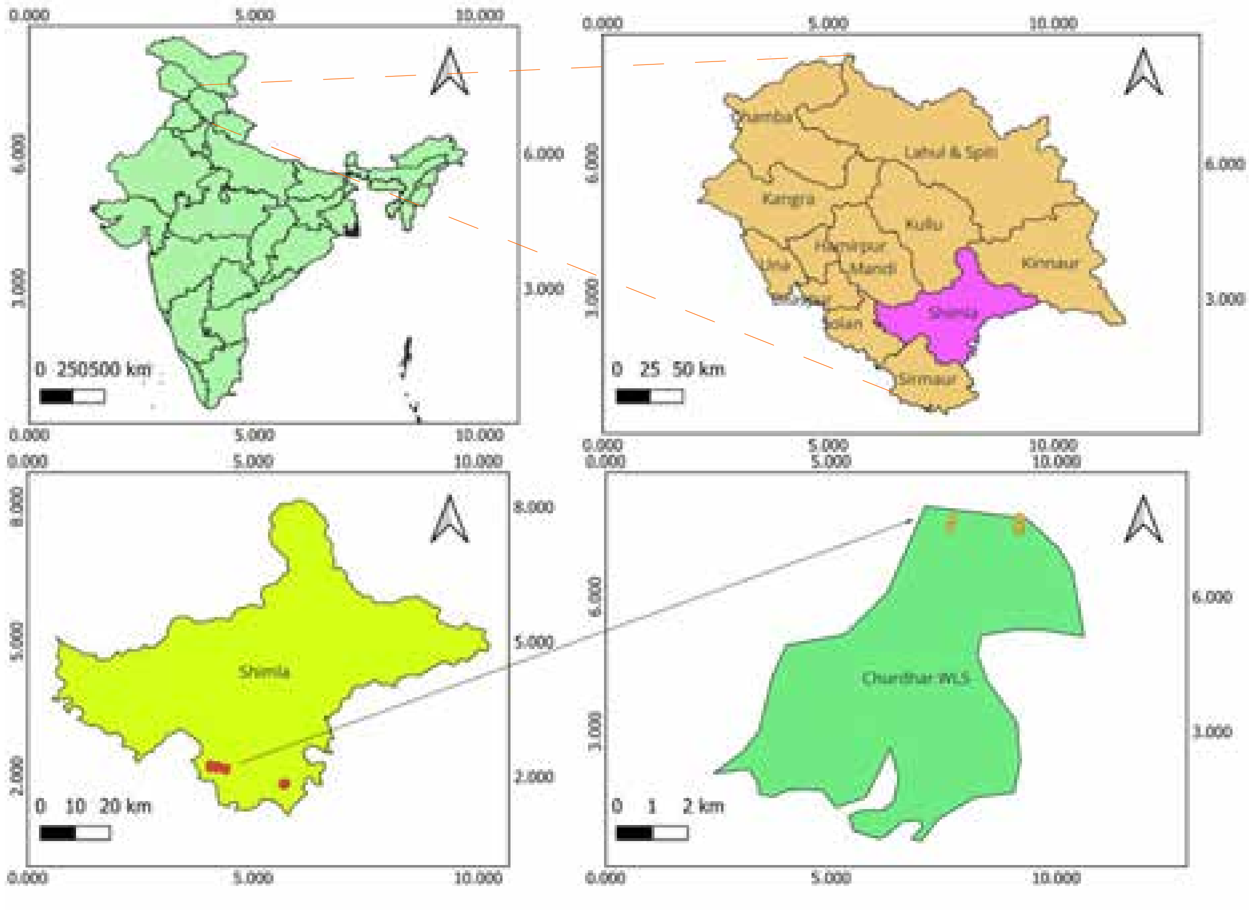

Image 1. A—India | B—Himachal Pradesh highlighting district Shimla | C—Collection sites in and around Churdhar Wildlife Sanctuary District Shimla | D—Collection sites with in the Sanctuary.

The species *Amandinea montana*, *Heterodermia obscurata*, and *H. hypochraea*, *Parmotrema nilgherrense*, and *P. reticulatum*, were common across all sampling localities. Species of *Phaeophyscia, Physcia, Dirinaria,* and *Lepraria* were abundant in the subtropical forests, whereas *Heterdermia, Punctelia, Flavoparmelia, Flavopunctelia, Myelochroa, Lobaria*, and *Ramalina* species were common in the temperate zone, while the alpine zone features diversity of *Acarospora, Aspicillia, Lecanora, Xanthoria*, and *Xanthoparmelia* species.

The present investigation additionally records *Bacidia rufescens*, *Bulbothrix setschwanensis, Cladonia didyma, C. fimbriata, C. fruticulosa, C. rei, Cetrelia collata, C. cetrarioides*, *Lobaria isidiosa*, *L. pindarensis, Myelochroa upretii*, *Phaeophyscia endococcina, P. endococcinodes, P. exornatula*, *P. pyrrhophora*, *P. tribacioides, Physconia detersa, Ramalina baltica, Sticta limbata*, and *Trapelia coarctata* as new additions to the Shimla district.

Among the western Himalayan states, Uttarakhand harbours the highest lichen diversity with 1,034 species followed by Himachal Pradesh with 716 species and Jammu & Kashmir including Ladakh with 457 species (Sinha et al. 2024). Compared with Uttarakhand, Himachal Pradesh exhibits less number of lichen species, which may reflect limited lichenological exploration together with increasing anthropogenic disturbances associated with tourism rather than an actual paucity of species. The state encompasses diverse habitats ranging from tropical to alpine ecosystems, and includes numerous protected areas, that provide favourable conditions for lichen colonization and diversification. Srivastava (2005) documented 263 lichen species from the Great Himalayan National Park. The present study provides the first preliminary assessment of the lichen diversity of CWS and reports 15 species as new records for Himachal Pradesh. These findings indicate that even relatively small protected areas can serve as important reservoirs of lichen diversity and emphasize the need for continued systematic surveys to better improve our understanding, conservation and long-term monitoring

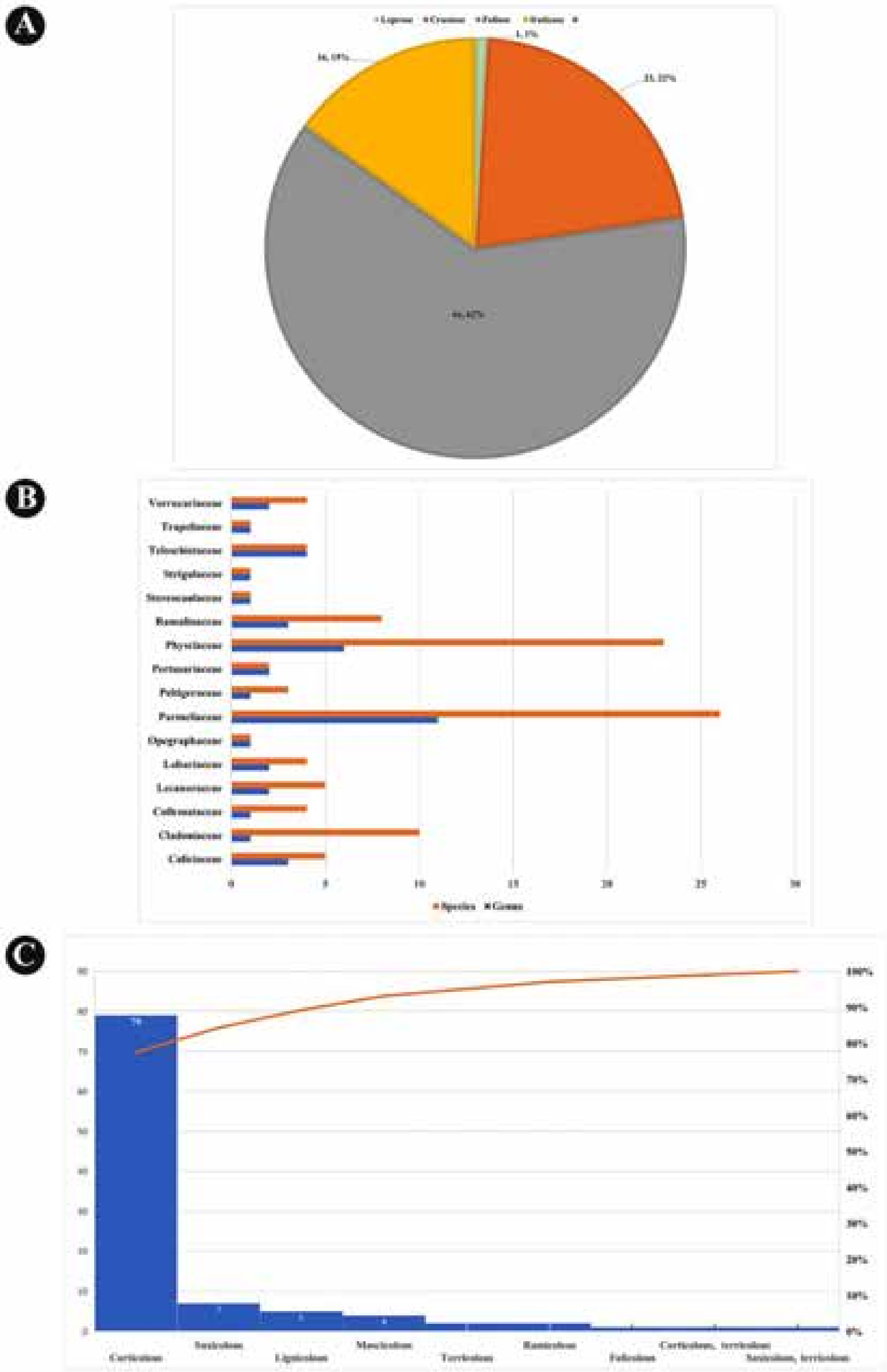

Image 2. A—Percentage of different lichen growth forms | B—Graph representing families, genus and total number of species | C—Clustered bar chart of lichens found on their respective substratum.

Table 1. List of lichen taxa reported from Churdhar Wildlife Sanctuary.

	Name of taxa	GF	Sub	Localities	Altitude (m)	Field No.
I	**Caliciaceae**					
1	*Amandinea montana* (H.Magn.) Marbach	Cr	C	HL CWS SR	2200–2250 3200 2209	24-367574 24-369900 24-369833
2	*A. punctata* (Hoffm.) Coppins & Scheid	Cr	C	HL	2000–2100	24-369832
3	*Calicium adspersum* ssp. *himalayense* G.Pant & D.D.Awasthi	Cr	C	HL	2015	24-369842
4	*Pyxine berteroana* (Fée) Imshaug	Fo	C	HL	2015	24-369457
5	*P. reticulata* (Vain.) Vain.	Fo	C	HL	2015	24-369806
II	**Cladoniaceae**					
6	*Cladonia coniocraea* (Flörke) Spreng	Fr	C	CWS	2753	24-369864
7	*C. corniculata* Ahti & Kashiw.	Fr	L	CWS	3200	24-369871
8	*C. didyma* (Fée) Vain.	Fr	L	CWS	2673	24-369870
9	*C. fimbriata* (L.) Fr.	Fr	M	CWS	2673	24-369867
10	*C. fruticulosa* Kremp.	Fr	L	CWS	2753	24-369865
11	*C. macilenta* Hoffm.	Fr	L	CWS	2700	24-369869
12	*C. ochrochlora* Flörke	Fr	L	CWS CWS	2700 2673	24-369868 24-369881
13	*C. pocillum* (Ach.) Grognot	Fr	M	CWS	2673	24-369882
14	*C. rei* Schaer.	Fr	T	CWS	2700	24-369883
15	*C. pyxidata* (L.) Hoffm.	Fr	M	CWS	4300	24-369866
III	**Collemataceae**					
16	*Leptogium burnetiae* C.W.Dodge	Fo	C	HL HL CWS CWS	2200–2250 1658 2706 2673	24-369440 24-369439 24-369467 24-369888
17	*L. denticulatum* Nyl. *	Fo	C	CWS	2673	24-369877
18	*L. pedicellatum* P.M.Jørg.	Fo	C	HL CWS	2200–2250 2579 2579 2605 2753 2753 2700 2706 2700 2673	24-369436 24-369437 24-369438 24-369442 24-369855 24-369854 24-369856 24-369816 24-369874 24-371407
19	*L. saturninum* (Dicks.) Nyl.	Fo	C	CWS HL CWS	1658 2706 2673	24-369439 24-369468 24-369876
IV	**Lecanoraceae**					
20	*Lecanora achroa* Nyl.	Cr	C	CWS	2605	24-367585
21	*L. alba* Lumbsch	Cr	C	CWS	2579	24-367593
22	*L. campestris* (Schaer.) Hue	Cr	S	HL	2200–2250	24-367587
23	*L. helva* Stizenb.	Cr	R	CWS	2753	24-369894
24	*Lecidella elaeochroma* (Ach.) M.Choisy	Cr	R	CWS	2753	24-369894
V	**Lobariaceae**					
25	*Lobaria isidiosa* (Müll.Arg.) Vain.	Fo	C	CWS	2579	24-369469
26	*L. pindarensis* Räsänen	Fo	C	CWS	2579	24-369444
27	*L. retigera* (Bory) Trevis.	Fo	C	CWS CWS CWS CWS CWS	2579 2605 2700 2673 2673	24-369445 24-367590 24-369858 24-369859 24-369899

	Name of taxa	GF	Sub	Localities	Altitude (m)	Field No.
28	*Sticta limbata* (Sm.) Ach.	Fo	C	CWS	2673	24-369849
VI	**Opegraphaceae**					
29	*Opegrapha simplicior* (Nyl.) Nyl. *	Cr	C	HL HL	2015 2200–2250	24-369831 24-369830
VII	**Parmeliaceae**					
30	*Bulbothrix isidiza* (Nyl.) Hale*	Fo	C	CWS	2605	24-369818
31	*B. meizospora* (Nyl.) Hale	Fo	C	CWS	2706	24-369824
32	*B. setschwanensis* (Zahlbr.) Hale	Fo	C	CWS HL	2706 2200–2250	24-369810 24-369452
33	*Cetrelia braunsiana* (Müll.Arg.) W.L.Culb. & C.F.Culb.	Fo	C	CWS CWS HL CWS	2605 2579–2710 1658 2605	24-367567 24-367566 24-369449 24-369817
34	*C. collata* (Nyl.) W.L.Culb. & C.F.Culb.	Fo	C	CWS	2706	24-369823
35	*C. cetrarioides* (Duby) W.L.Culb. & C.F.Culb	Fo	C	SR HL HL CWS CWS	2209 2605 2200–2250 2605 2673	24-369430 24-367565 24-367570 24-367569 24-371413
36	*C. olivetorum* (Nyl.) W.L.Culb. & C.F.Culb.	Fo	C	HL HL CWS HL	2200–2250 2200–2250 2605 1658	24-369805 24-367568 24-369428 24-369454
37	*C. pseudolivetorum* (Asahina) W.L.Culb. & C.F.Culb.	Fo	C	CWS CWS CWS CWS	2706 2605 2706 2605	24-369451 24-369402 24-369816 24-369403
38	*Flavoparmelia caperata* (L.) Hale	Fo	C	CWS HL CWS CWS CWS	2706 2200–2250 2605 2700 2673	24-369432 24-369455 24-369825 24-371401 24-371406
39	*Flavopunctelia flaventior* (Stirt.) Hale	Fo	C	CWS SR	2605 2209	23-369827 24-369433
40	*Hypotrachyna cirrhata* (Fr.) Divakar, A.Crespo, Sipman, Elix & Lumbsch	Fo	C	CWS	2706	24-368946
41	*H. nepalensis* (Taylor) Divakar, A.Crespo, Sipman, Elix & Lumbsch	Fo	C	CWS	2579	24-369429
42	*H. sinensis* (J.B.Chen & J.C.Wei) Divakar, A.Crespo, Sipman, Elix & Lumbsch	Fo	C	CWS	2706	24-369427
43	*Myelochroa aurulenta* (Tuck.) Elix & Hale	Fo	C	CWS CWS	2706 2605	24-369809 24-369826
44	*M. upretii* Divakar & Elix	Fo	C	HL	2200–2250	24-369448
45	*Parmelia meiophora* Nyl.	Fo	C	SR CWS CWS	2209 3200 3200	24-369435 24-371402 24-371414
46	*Parmelinella wallichiana* (Taylor) Elix & Hale	Fo	C	CWS	2706	24-369813
47	*Parmotrema nilgherrense* (Nyl.) Hale	Fo	C	SR CWS HL CWS CWS	2209 2605 2200–2250 2605 3200	24-369812 24-369808 24-369446 24-369820 24-371409
48	*P. praeisidiosum* Fleig	Fo	C	CWS	2673	24-369873
49	*P. rampoddense* (Nyl.) Hale*	Fo	C	CWS	2605	24-369828
50	*P. reticulatum* (Taylor) M.Choisy	Fo	C	SR HL HL CWS CWS	2209 2015 1658 2706 2763	24-369434 24-369447 24-369456 24-369819 24-371403
51	*P. stuppeum* (Taylor) Hale*	Fo	C	HL	2200–2250	24-369459
52	*Punctelia borreri* (Sm.) Krog	Fo	C	CWS	3200	24-371410

	Name of taxa	GF	Sub	Localities	Altitude (m)	Field No.
53	*P. subrudecta* (Nyl.) Krog	Fo	C	CWS CWS CWS	2605 2605 2605	24-367585 24-369401 24-369844
54	*Usnea orientalis* Motyka	Fr	C	CWS CWS CWS	2579 2700 2753	24-369470 24-369884 24-371411
55	*U. spinosula* Stirt. *	Fr	C	HL	2200–2250	24-369471
VIII	**Peltigeraceae**					
56	*Peltigera elisabethae* Gyeln.	Fo	C	CWS CWS CWS CWS	2706 2706 2605 2706	24-369443 24-367591 24-367586 24-369801
57	*P. polydactylon* (Neck.) Hoffm.	Fo	T	CWS	3200	24-369889
58	*P. praetextata* (Flörke ex Sommerf.) Zopf	Fo	C	HL CWS CWS CWS CWS CWS CWS CWS CWS	2015 2673 2753 3200 3200 2700 2753 2753 2673	24-369441 24-369851 24-369853 24-369852 24-369848 24-369857 24-369878 24-371412 24-371404
IX	**Pertusariaceae**					
59	*Lepra albescens* (Huds.) Hafellner	Cr	C	HL HL	2015 2200–2250	24-367600 24-369802
60	*Pertusaria punctata* Nyl.	Cr	C	HL	2015	24-367595
X	**Physciaceae**					
61	*Heterodermia diademata* (Taylor) D.D.Awasthi	Fo	T, C	CWS HL	2579 1658	24-367582 24-369413
62	*H. firmula* (Linds.) Trevis.	Fo	C	CWS CWS	2706 2579–2710	24-367562 24-367580
63	*H. incana* (Stirt.) D.D.Awasthi	Fo	C	CWS	2579 2605 2706	24-367561 24-367583 24-367581
64	*H. isidiophora* (Nyl.) D.D.Awasthi	Fo	C	HL CWS CWS	2015 2579 2700	24-367579 24-369495 24-369886
65	*H. hypochraea* (Vain.) Swinscow & Krog	Fo	C	CWS HL HL SR CWS HL CWS CWS CWS CWS CWS CWS	2605 2200–2250 2200–2250 2209 2706 2015 2579 2579 2700 2700 2700 2700	24-367558 24-367559 24-367560 24-369410 24-369411 24-369412 24-367581 24-369418 24-367561 24-36924 24-369879 24-369887
66	*H. obscurata* (Nyl.) Trevis	Fo	C	HL HL HL SR CWS HL	1658 2200–2250 2200–2250 2209 2579 2200–2250	24-369416 24-369421 24-369409 24-367577 24-367563 24-369415
67	*H. pseudospeciosa* (Kurok.) W.L. Culb	Fo	C	HL HL CWS CWS CWS	2015 2250 2579 2579 2100	24-367557 24-369414 24-369425 24-369862 24-369847
68	*H. speciosa* (Wulfen) Trevis.	Fo	C	CWS, HL	2000–2100 2605	24-367578 24-369423
69	*H. tremulans* (Müll. Arg.) W.L.Culb.*	Fo	C	CWS	2579	24-369422
70	*Leucodermia boryi* (Fée) Kalb.	Fo	M	CWS CWS CWS	2700 2706 2700	24-369885 24-369861 24-369885

	Name of taxa	GF	Sub	Localities	Altitude (m)	Field No.
71	*Phaeophyscia endococcina* (Körb.) Moberg	Fo	C	CWS	2706	24-369822
72	*P. endococcinodes* (Poelt) Essl.	Fo	C	HL	2015	24-367548
73	*P. exornatula* (Zahlbr.) Kashiw.	Fo	C	HL CWS	2200–2250 2579	24-367555 24-367552
74	*P. hispidula* (Ach.) Moberg	Fo	C	CWS CWS CWS HL CWS CWS CWS CWS	2579 2579 2605 2200–2250 2706 2673 2700 2673	24-367551 24-367544 24-357541 24-367539 24-369821 24-369893 24-369892 24-371405
75	*P. laciniata* Essl. *	Fo	C	CWS HL CWS	2579 2200–2250 2706	24-367550 24-367542 24-367543
76	*P. primaria* (Poelt) Trass*	Fo	C	HL	2200-2250	24-367538
77	*P. pyrrhophora* (Poelt) D.D.Awasthi & M.Joshi	Fo	C	HL	1658	24-367540
78	*Physcia dilatata* Nyl.	Fo	C	CWS HL HL HL HL	2579 2200–2250 2000–2100 1658	24-367547 24-367549 24-367546 24-367545
79	*P. tribacioides* Nyl.	Fo	C	HL	1658	24-367545
80	*Physconia detersa* (Nyl.) Poelt	Fo	S, C	CWS CWS	2700 2700	24-369890 24-369891
81	*P. distorta* (With.) J.R.Laundon	Fo	C	SR	2209	24-367576
82	*P. enteroxantha* (Nyl.) Poelt	Fo	C	HL	1658	24-367554
83	*Polyblastidium japonicum* (M. Satô) Kalb	Fo	C	CWS CWS CWS CWS CWS	2605 2605 2605 2579 2700	24-367556 24-369426 24-369420 24-369419 24-369880
XI	**Ramalinaceae**					
84	*Bacidia convexula* (Müll.Arg.) Zahlbr.*	Cr	C	HL	2200–2250	24-367588
85	*B. rufescens* (Müll.Arg.) Zahlbr.	Cr	C	HL	2200–2250	24-367575
86	*B. submedialis* (Nyl.) Zahlbr.	Cr	C	HL	2015	24-367589
87	*Biatora vernalis* (L.) Fr.*	Cr	C	HL	2000–2100	24-367584
88	*Ramalina baltica* Lettau	Fr	S	SR	2209	24-369466
89	*R. conduplicans* Vain.	Fr	C	HL HL CWS CWS	2000–2100 2200–2250 3200 2700	24-369472 24-369476 24-369850 24-369872
90	*R. pacifica* Asahina	Fr	C	CWS	2706	24-369481
91	*R. sinensis* Jatta	Fr	C	CWS HL CWS HL CWS CWS	2706 2200–2250 2706 2015 3200 3200	24-369478 24-369463 24-369477 24-369464 24-369860 24-369895
XII	**Stereocaulaceae**					
92	*Lepraria isidiata* (Llimona) Llimona & A.Crespo	Le	C	CWS	2579	24-369845
XII	**Strigulaceae**					
93	*Strigula subelegans* Vain. *	Cr	F	HL	2000–2100	24-369898
XIV	**Teloschistaceae**					
94	*Caloplaca himalayana* Y.Joshi & Upreti	Cr	C	HL CWS	2200–2250 2605	24-367575 24-367585
95	*Opeltia flavorubescens* (Huds.) S.Y.Kondr. & Hur	Cr	C	CWS	2605	24-367585
96	*Sanguineodiscus haematites* (Chaub. ex-St.-Amans) I.V.Frolov & Vondrák*	Cr	C	CWS	2673	24-369896
97	*Polycauliona candelaria* (L.) Frödén, Arup & Søchting	Fo	C	HL	2200–2250	24-369476

	Name of taxa	GF	Sub	Localities	Altitude (m)	Field No.
XV	**Trapeliaceae**					
98	*Trapelia coarctata* (Turner) M. Choisy	Cr	S	CWS	2605	24-367598
XVI	**Verrucariaceae**					
99	*Dermatocarpon miniatum* (L.) W.Mann	Fo	S	HL	2200–2250	24-369480
100	*D. miniatum* var. *compactum* (Lamy) Zahlbr. *	Fo	S	CWS	3200	24-369875
101	*Verrucaria margacea* (Wahlenb.) Wahlenb	Cr	S	HL	2015	24-369839
102	*V. muralis* Ach. *	Cr	S	HL	2250	24-369840

CWS—Churdhar Wildlife Sanctuary | SR—Srain | HL—Halau | GF—growth form | Cr—crustose | Fo—foliose | Fr—fruticose | Sub—Substratum | C—corticolous | F—folicolous | L—lignicolous | S—saxicolous | M—muscicolous | R—ramicolous | T—terricolous | *—New to state.

of the lichen biota of the western Himalaya.

DESCRIPTION OF THE SPECIES NEWLY RECORDED FOR HIMACHAL PRADESH

1. *Bacidia convexula* (Müll. Arg.) Zahlbr., Cat. Lich. Univers. 4: 188 (1926) [1927]. (Image 3A).

The species is characterised by crustose, grey thallus with numerous apothecia, corticated at base, apothecia disc brownish red ascospores ellipsoid, transversely septate with 5-6 septa (Awasthi & Mathur 1987).

Chemistry: Thallus K–, C–, KC–, P–; No chemical seen in TLC.

Ecology and distribution: The species was found growing on tree bark in the district Shimla at an elevation of 2,200–2,250 m. The species was previously reported from Arunachal Pradesh, Assam, Madhya Pradesh, Manipur, Meghalaya, Tamil Nadu, Uttar Pradesh, Uttarakhand, and West Bengal (Sinha et al. 2024).

Specimen examined: India, Himachal Pradesh, Shimla District, village Shalan Forest, alt. 2,200–2,250 m, on tree bark, P. Maurya & A. Devi 24-367588 (LWG).

2. *Biatora vernalis* (L.) Fr., K. svenska Vetensk-Akad. Handl., ser. 3: 271 (1822). (Image 3B).

The species is characterized by crustose, granulose, upper surface grey thallus, having sessile biotorine ascomata, ascospores narrowly ellipsoid, aseptate and monocular. Photobiont *Trebouxia* species (Printzen et al. 2023).

Chemistry: Thallus K–, C–, KC–, P–; No chemical seen in TLC.

Ecology and distribution: The species was found growing on tree bark in district Shimla at the elevation of 2,000–2,100 m. This species was previously reported from Arunachal Pradesh, Manipur, Mizoram, and Uttarakhand (Sinha et al. 2024).

Specimens examined: India, Himachal Pradesh, Shimla District, village Shalan Forest, alt. 2,000–2,100 m on tree bark, A. Devi & P. Maurya 24-367584, 24-369466 (LWG).

3. *Bulbothrix isidiza* (Nyl.) Hale, Phytologia 28(5): 480 (1974). (Image 3C).

The diagnostic characters of the species include foliose thallus, having bulbate cilia along the margins, maculate with coralloid isidia, lower side pale brown (Awasthi 2007).

Chemistry: Medulla K+ yellow turning red, C–, KC–, P+ orange red; salazinic acid seen in TLC

Ecology and distribution: The species was found growing on tree bark in the district Shimla at an elevation of 2605 m. The species was previously reported from Andhra Pradesh, Arunachal Pradesh, Assam, Chhattisgarh, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Mizoram, Meghalaya, Nagaland, Odisha, Sikkim, Tamil Nadu, Tripura, Uttar Pradesh, Uttarakhand and West Bengal (Sinha et al. 2024).

Specimen examined: India, Himachal Pradesh, Shimla District, CWS, alt. 2,605 m, on tree bark, A. Devi & P. Maurya 24-369818 (LWG).

4. *Dermatocarpon miniatum var. compactum* (Lamy) Zahlbr., Cat. Lich. Univers. 1: 226 (1921) [1922]. (Image 3D).

The species has polyphyllous, squamulose, upper side grey thallus, lower side wrinkled and lacking rhizines (Awasthi 2007).

Chemistry: Thallus K–, C–, KC–, P–; No chemical seen in TLC.

Ecology and distribution: The species was found growing on rock in the district Shimla at an elevation of 2200–2250 m. The species was previously reported from Uttarakhand (Sinha et al. 2024).

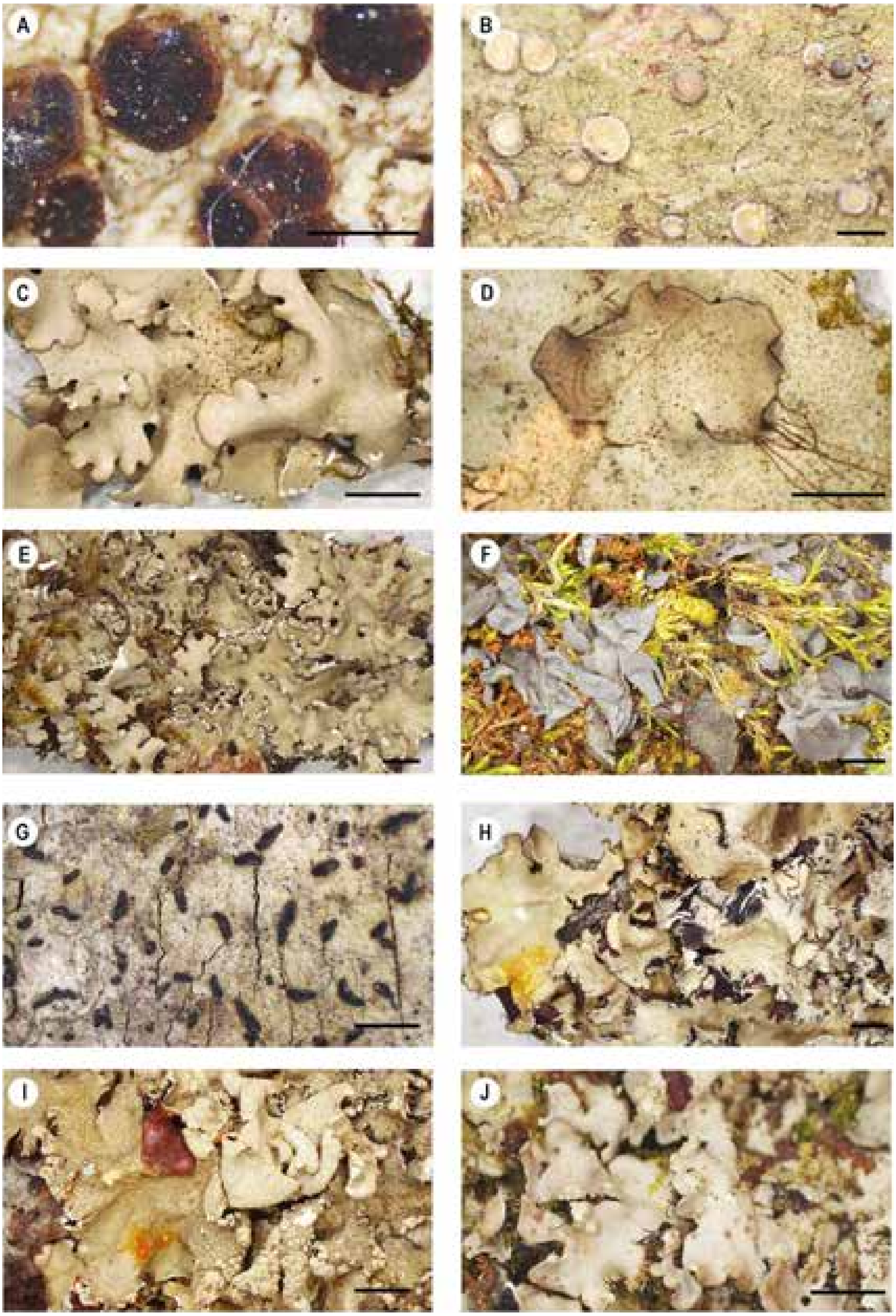

Image 3. New additions of lichens to the state of Himachal Pradesh: A—*Bacidia convexula* | B—*Biatora vernalis* | C—*Bulbothrix isidiza* | D—*Dermatocarpon miniatum* var. *compactum* | E—*Heterodermia tremulans* | F—*Leptogium denticulatum* | G—*Opegrapha simplicior* | H—*Parmotrema rampoddense* | I—*Parmotrema stuppeum* | J—*Phaeophyscia laciniata*. Scale: A–C—1 mm, D—1 cm, E–J—1 mm. © A. Devi.

Specimen examined: India, Himachal Pradesh, Shimla District, CWS, alt. 2,200–2,250 m, on rock, A. Devi 24-369875 (LWG).

5. *Heterodermia tremulans* (Müll. Arg.) W.L. Culb., Bryologist 69: 485 (1967). (Image 3E).

The species is characterized by corticolous, adnate, upper side greyish thallus, with small and narrow lobes, lower side white to daker with concolorous rhizines (Awasthi 2007).

Chemistry: Medulla K–, C–, KC–, P+ pale yellow; atranorin and zeorine seen in TLC.

Ecology and distribution: The species was found growing on tree bark in district Shimla at an elevation of 2579 m. The species was previously reported from Kerala, Madhya Pradesh, Nagaland, Rajasthan, Sikkim, Tamil Nadu, Uttarakhand, and West Bengal (Sinha et al. 2024).

Specimen examined: India; Himachal Pradesh, Shimla District, CWS, alt. 2,579 m, on tree bark, P. Maurya & A. Devi 24-369422 (LWG).

6. *Leptogium denticulatum* Nyl., *Annls Sci. Nat.*, Bot., sér. 5 7: 302 (1867). (Image 3F).

The species is characterised by the foliose, corticolous, adnate with irregular lobes, upper surface grey to medium grey with no wrinkles thallus, isidia on margin, apothecia rare, lower surface smooth with scattered tufts of white hair (Awasthi 2007).

Chemistry: Thallus K–, C–, KC–, P–; No chemical seen in TLC.

Ecology and distribution: The species was found growing on tree bark in district Shimla at an elevation of 2673 m, in Himachal Pradesh. The species was previously reported from Andaman and Nicobar Islands, Andhra Pradesh, Arunachal Pradesh, Assam, Goa, Jammu and Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Mizoram, Meghalaya, Nagaland, Sikkim, Tamil Nadu, Uttarakhand, and West Bengal (Sinha et al. 2024).

Specimen examined: India, Himachal Pradesh**,** Shimla District, CWS, alt. 2,673 m, on tree bark, A. Devi 24-369877 (LWG).

7. *Opegrapha simplicior* (Nyl.) Nyl., Bull. Soc. linn. Normandie, sér. 2 2: 94 (1868). (Image 3G).

The species has a crustose, white to grey surface thallus, cracked at places with scattered, slightly curved and black lirellate ascomata, asci 8-spored, ascospores elliopsoid, hyaline 3-spetate, 12–16 × .7–1.1 µm (Joseph & Sinha 2011).

Chemistry: Thallus K–, C–, KC–, P–; No chemical seen in TLC.

Ecology and distribution: The species was found growing on tree bark in district Shimla at an elevation of 2015–2250 m,. The species was previously reported from Assam, Madhya Pradesh and West Bengal (Sinha et al. 2024).

Specimens examined: India, Himachal Pradesh, Village Shalan Forest, alt. 2,015–2,250 m, on tree bark, A. Devi & P. Maurya 24-369830, 24-369831 (LWG).

8. *Parmotrema rampoddense* (Nyl.) Hale, Phytologia 28(4): 338 (1974). (Image 3H).

The species has a corticolous thallus withlarge lobes and emaculate, greyish upper side, marginally sorediate in central parts of thallus, lower side tan, marginal zone erhizinate and involute central lobes (Awasthi 2007).

Chemistry: Medulla K–, C–, KC+ red, P–; alectoronic, α-collatolic acids and skyrin seen in TLC.

Ecology and distribution: The species was found growing on tree bark in district Shimla at an elevation of 2605 m. Earlier, the species was reported from Jammu & Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Mizoram, Nagaland, Sikkim, Tamil Nadu, Uttarakhand and West Bengal (Sinha et al. 2024).

Specimen examined: India, Himachal Pradesh, Shimla District, CWS, alt. 2,605 m, on tree bark, A. Devi & P. Maurya 24-369828 (LWG).

9. *Parmotrema stuppeum* (Taylor) Hale [as '*stuppea*'], *Phytologia* 28(4): 339 (1974). (Image 3I).

The species is characterised by foliose, large crenate dentate lobes, ciliate, greyish upper side, emaculate thallus, marginal sorelia on central part, involute sorediate lobes, lower side marginal zone brown, central zone black and medulla white in colour (Awasthi 2007).

Chemistry: Medulla K+ yellow turning red, C–, KC–, P+ orange red; salazinic and consalazinic acids seen in TLC.

Ecology and distribution: The species found growing on tree bark in district Shimla at the elevation of 2,200–2,250 m, The species was previously reported from Andaman & Nicobar Islands, Arunachal Pradesh, Karnataka, Kerala, Mizoram, Nagaland, and Tamil Nadu (Sinha et al. 2024).

Specimen examined: India, Himachal Pradesh, Shimla District, village Shalan Forest, alt. 2,200–2,250 m, on tree bark, A. Devi & P. Maurya 24-369459 (LWG).

10. ***Phaeophyscia laciniata*** Essl., Mycologia 70(6): 1247 (1979) [1978]. (Image 3J).

The species has foliose thallus with short lobes and lobulate margins, brownish grey in colour thallus, lower surface black with simple rhizines; bright orange medulla due to the presence of skyrine (Maurya et al. 2024).

Chemistry: Medulla K+ purple, KC–, C–, P–; skyrine seen in TLC.

Ecology and distribution: The species was found growing on tree bark in district Shimla at an elevation of 2,200–2,250 m. The species was previously reported from Kerala and Uttarakhand (Sinha et al. 2024).

Specimens examined: India, Himachal Pradesh, Shimla District, village Halau, alt. 2,200–2,250 m, on tree bark, P. Maurya & A. Devi 24-367542, 24-367543, 24-367550 (LWG).

11. ***Phaeophyscia primaria*** (Poelt) Trass, *Folia cryptog. Estonica* 15: 2 (1981). (Image 4K).

The species is characterized by corticolous, upper side grey thallus, isidia and soredia absent, rhizines projecting beyond lobes (Maurya et al. 2024).

Chemistry: Thallus K–, C–, KC–, P–; No chemical seen in TLC.

Ecology and distribution: The species was found growing on tree bark in district Shimla at the elevation of 2200–2250 m, in Himachal Pradesh. The species was previously reported from Manipur, Meghalaya, Odisha, Rajasthan, Tamil Nadu and Uttarakhand (Sinha et al. 2024).

Specimen examined: India, Himachal Pradesh, Shimla District, village Shalan Forest, alt. 2,200–2,250 m, on tree bark, P. Maurya & A. Devi 24-367538 (LWG).

12. ***Sanguineodiscus haematites*** (Chaub. ex-St.-Amans) I.V. Frolov & Vondrák, , J. Syst. Evol. 59(3): 471 (2020). (Image 4L).

The species is corticolous, crustose, grey, unevenly areolate towards centre, blood red apothecial discs, ascospores ellipsoid with thick septum (Mishra et al. 2020).

Chemistry: Thallus K+ purple, C–, KC–, Pd–; parietin seen in TLC.

Ecology and distribution: The species was found growing on tree bark in district Shimla at an elevation of 2673 m. The species was previously reported from Jammu & Kashmir (Sinha et al. 2024).

Specimen examined: **Ind**ia, Himachal Pradesh, Shimla District, CWS, alt. 2,673 m, on tree bark, A. Devi 24-369896 (LWG).

13. ***Strigula subelegans*** **Vain.**, Ann. Acad. Sci. Fenn., Ser. A 19(no. 15): 23 (1923)**.** (Image 4M).

The species is characterized by epiphyllous thallus having irregular and scattered patches, sometimes round, white, with many small black pycnidia, colourless crystals are commonly dispersed with fungal hyphae, perithecia black, immersed partially, with unequal ascospores (Singh & Pinokiyo 2014).

Chemistry: Thallus K–, C–, KC–, P–; No chemical seen in TLC.

Ecology and distribution: The species was found growing on leaves in district Shimla at an elevation of 2000–2100 m. The species was previously reported from Andaman and Nicobar Islands, Arunachal Pradesh, Assam, Goa, Karela, Manipur, Meghalaya, Nagaland, Sikkim, Tamil Nadu and West Bengal (Sinha et al. 2024).

Specimen examined: India, Himachal Pradesh, Shimla District, village Halau, alt. 2,000–2,100 m, on leaves, A. Devi & P. Maurya 24-369898 (LWG).

14 ***Usnea spinosula*** Stirt., Scott. Natural. 6(3): 107 (1881) [1881–1882]. (Image 4N).

The species has a fruticose thallus with solid central axis,, contains spinules, and among the spinules, lateral branches are present, isidia and soredia are absent (Awasthi 2007).

Chemistry: Medulla K+ yellow, then turning red, C-, P+ yellow; usnic acid seen in TLC.

Ecology and distribution: The species was found growing on tree bark in District Shimla at an elevation of 2200–2250 m. The species was previously reported from Arunachal Pradesh, Kerala, Tamil Nadu, and Uttarakhand (Sinha et al. 2024).

Specimen examined: India, Himachal Pradesh, Shimla district, village Shalan Forest, alt. 2,200–2,250 m, on tree bark, A. Devi & P. Maurya 24-369471 (LWG).

15. ***Verrucaria muralis*** Ach., Methodus, Sectio prior (Stockholmiæ): 115 (1803). (Image 4O).

The species is characterised by crustose, superficial, slightly cracks and with minute pits present, grey to brown in colour thallus, having numerous perithecia, immersed but prominent, black with a clearly visible ostiole; ascospores are colourless, simple and ellipsoid (Joshi et al. 2009).

Chemistry: Thallus K–, C–, KC–, P–; No chemical seen in TLC.

Ecology and distribution: The species was found growing on rock in district Shimla at an elevation of 2200–2250 m. The species was previously reported from Tamil Nadu (Sinha et al. 2024)

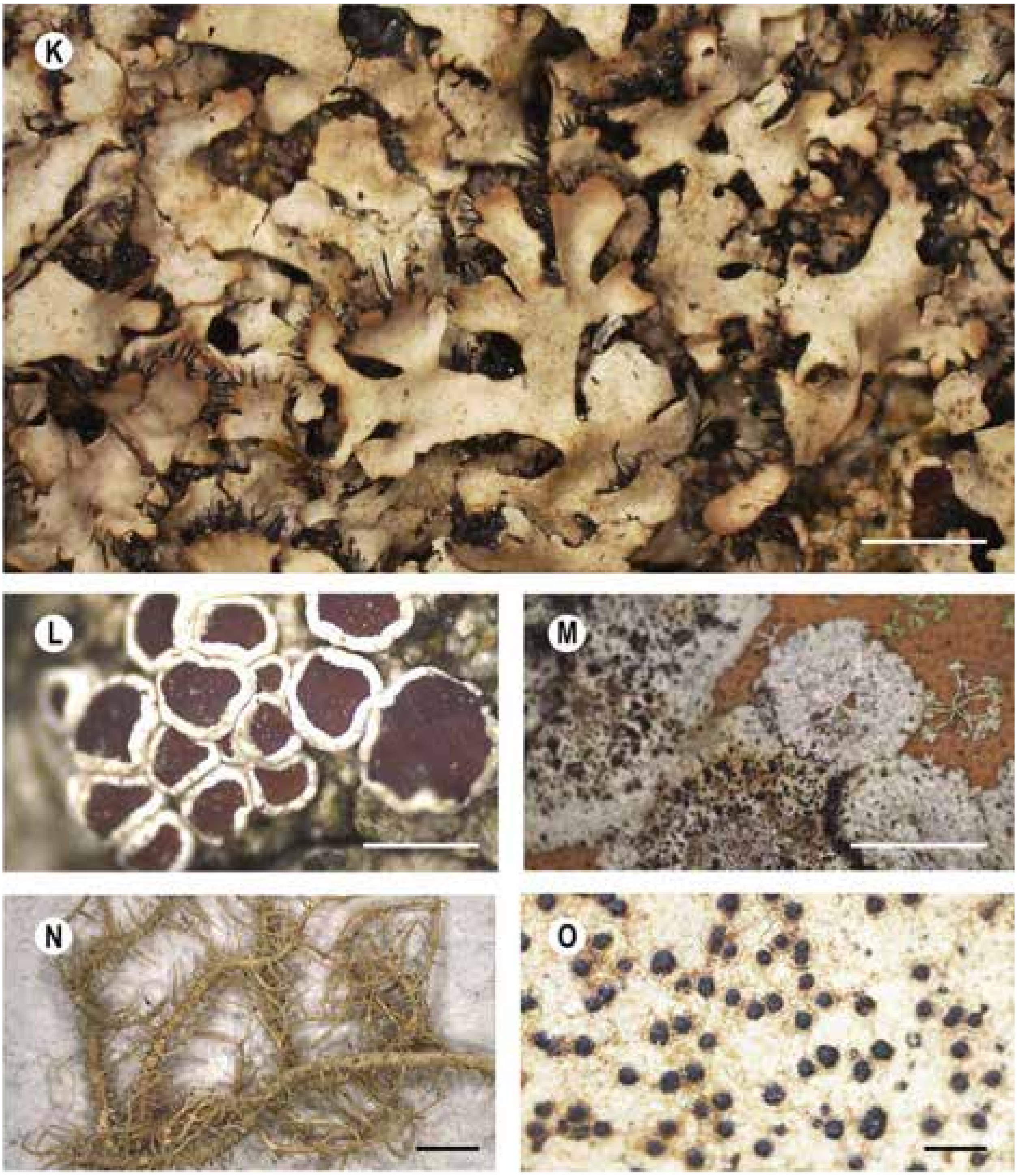

Image 4. New additions of lichens to the state of Himachal Pradesh: K—*Phaeophyscia primaria* | L—*Sanguineodiscus haematites* | M—*Strigula subelegans* | N—*Usnea spinosula* | O—*Verrucaria muralis* | Scale: K–N—2 mm. © A. Devi.

Specimen examined: India, Himachal Pradesh, Shimla District, village Halau Shalan forest, alt. 2,200–2,250 m, on tree bark, P. Maurya & A. Devi 24-369840 (LWG).

REFERENCES

Awasthi, D.D. & R. Mathur (1987). Species of the lichen genera *Bacidia*, *Badimia*, *Fellhanera* and *Mycobilimbia* from India, pp. 481–503. In: Proceedings of the Indian Academy of Sciences, Vol. 97, issue 6. Springer India, New Delhi.

Awasthi, D.D. (1991). A key to the microlichens of India, Nepal and Sri

Lanka. Bibliotheca Lichenologica, 40: 1–377.
Awasthi, D.D. (2007). A compendium of the macrolichens from India, Nepal and Sri Lanka, pp. 31–34. Bishen Singh Mahendra Pal Singh, Dehra Dun, India, 580 pp.
Bajpai et al. (2022). Refining the picture of lichen biota of Himachal Pradesh together with new distributional records to the state. 64(1): 171–247. https://doi.org/10.20324/nelumbo/v64/2022/167350
Joseph, S. & G.P. Sinha (2011). Two species of corticoulus Opergraph Ach. (lichenized Ascomycota) new to India. Geophytology 40(1–2): 83–86.
Joshi, Y. et al. (2009). *Thelotrema subtile* and *Verrucaria muralis* new to South Korea. Mycobiology 37(4): 302–304. https://pmc.ncbi.nlm.nih.gov/articles/PMC3749422/
Himachal Pradesh Forest Department (2026). Protected Area Network of Himachal Pradesh. Government of Himachal Pradesh. https://hpforest.gov.in/protected-area-network
Maurya, P. et al. (2024). A taxonomic revision of the lichen genus *Phaeophyscia* Moberg (Physciaceae) with new records from India. Journal of Asia-Pacific Biodiversity 17(1): 43–53. https://doi.org/10.1016/j.japb.2023.10.005
Mishra, G.K. et al. (2020). Current taxonomy of the lichen family Teloschistaceae from India with descriptions of new species. Acta Botanica Hungaricae 62(3–4): 309–391. https://doi.org/10.1556/034.62.2020.3-4.5
Nayaka, S. et al. (2002). An enumeration and new records of lichens from Solan district, Himachal Pradesh, India. Biological Memoirs 28(1): 25–33.
Orange, A. et al. (2001). Microchemical Methods for the Identification of Lichens. British Lichen Society, London, 1–101 pp.
Printzen, C. et al. (2023). DNA barcoding indicates the presence of unrecognized species and phylogenetic diversity within the *Biatora vernalis* and *B. meiocarpa* groups. Plant and Fungal Systematics 68(2): 262–279. https://doi.org/10.35535/pfsyst-2023-0011
QGIS Development Team (2023). QGIS Geographic Information System. Open Source Geospatial Foundation.
Singh, K.P. & A. Pinokiyo (2014). Foliicolous lichens of India. Bishen Singh Mahendra Pal Singh.
Sinha, G.P. et al. (2024). A comprehensive checklist of lichens from India – 2024. Cryptogam Biodiversity and Assessment 8(02): 1–134.
Srivastava, R. (2005). Distribution, Diversity and Pollution Status of Lichens in Great Himalayan National Park, Kullu District, Himachal Pradesh. PhD Thesis. Dr Ram Manohar Lohia Avadh University, Faizabad, U.P., India.
Subramani, S.P. et al. (2014). Additions to the floral wealth of Sirmaur district, Himachal Pradesh from Churdhar Wildlife Sanctuary. Journal of Threatened Taxa 6(11): 6427–6452. https://doi.org/10.11609/JoTT.o2845.6427-52
Thakur M. et al. (2020). An assessment of lichen diversity from Mandi district, Himachal Pradesh, India. International Journal of Plant and Environment 6(4): 277–282. https://doi.org/10.18811/ijpen.v6i04.06
Thakur U. et al. (2021). Influence of altitude on diversity and distribution pattern of trees in Himalayan temperate forests of Churdhar Wildlife Sanctuary, India. Water, Air & Soil Pollution 232(5): 205. https://doi.org/10.1007/s11270-021-05162-8
Upreti, D.K. & S. Nayaka (2000). An enumeration of lichens from Himachal Pradesh. Professor D.D. Nautiyal Commemoration Volume Recent Trends in Botanical Researches, 15–31 pp.
Yadav, V. (2005). Lichen flora of Himachal Pradesh. PhD Thesis. University of Lucknow.
Wijayawardene N.N. et al. (2022). Outline of Fungi and fungus-like taxa – 2021. Mycosphere 13(1): 53–453. https://doi.org/10.5943/mycosphere/13/1/2

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Journal of Threatened Taxa | www.threatenedtaxa.org | 26 August 2026 | 18(8): 29507–29514
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.10197.18.8.29507-29514
#10197 | Received 04 October 2025 | Final received 26 July 2026 | Finally accepted 08 August 2026

COMMUNICATION

New record of the Malayan Porcupine (Rodentia: Hystricidae: *Hystrix brachyura* Linnaeus, 1758) in Tripura, India

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Abstract: First confirmed evidence of the Malayan Porcupine *Hystrix brachyura* from Sepahijala Wildlife Sanctuary and the Clouded Leopard National Park, Tripura, India, is documented in the study. The findings were between 12–22 February 2024, wherein 14 camera traps were deployed across eight camera-trap stations. Two trap stations documented *H. brachyura*, yielding five independent captures represented by 20 images. This marks the first documented photographic evidence of the species from a protected area in Tripura, which shall lead to bridging gaps in its recorded distribution in northeastern India.

Keywords: Bushmeat, camera trap, Clouded Leopard National Park, geography, mammal, northeastern India, poaching, range extension, rapid assessment, rubber plantation, Sepahijala Wildlife Sanctuary.

Editor: Anonymity requested.

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

Citation: Patil, O., A. Joshi & R. Digaskar (2026). New record of the Malayan Porcupine (Rodentia: Hystricidae: *Hystrix brachyura* Linnaeus, 1758) in Tripura, India. *Journal of Threatened Taxa* 18(8): 29507–29514. https://doi.org/10.11609/jott.10197.18.8.29507-29514

Funding: This study was funded by The Habitats Trust.

Competing interests: The authors declare no competing interests.

Author details: Omkar Patil is an ecologist whose work primarily revolves around carnivore & landscape ecology and human animal interactions. Dr. Ashutosh Joshi functions as a research advisor to the wildlife research division of the Vivek PARC Foundation. He holds a PhD in environmental sciences. Rutuja Digaskar is an ecologist whose work focuses on wild carnivores in high altitude landscapes and unprotected forest areas.

Author contributions: OP and AJ contributed to data collection. Study conception, study design, preparation, data collection and analysis were performed by OP & AJ. The first draft of the manuscript was written by OP and all authors contributed to refining & revising the manuscript.

Acknowledgements: We thank the Tripura Forest Department for research permits, opportunity, and continuous support during the study. We are grateful to The Habitats Trust for funding, camera traps and technical assistance. Field support from the ground staff, Banmitras, and field facilitators was invaluable. We thank the directors and team of Vivek PARC Foundation for their guidance. Special thanks to our team members Amey Parkar, Divyajit Bal, Ninad Ajanikar, Arthur Lewis, Raj Jadhav, Kartheek Thevar, Sherly Barbosa, and Shrikar Ashtaputre for their efforts during fieldwork and data compilation.

INTRODUCTION

Order Rodentia is the largest order within the class Mammalia and is represented by 2,277 species globally belonging to 481 genera & 33 families (Wilson & Reeder 2005). Rodents include mice, squirrels, rats, gerbils, and hamsters. Although rodents are highly diverse, numerous species across the globe are poorly studied, leading to ecological data deficiencies (Fleming & Bateman 2016).

Among rodents, porcupines are considered an iconic species, evidently due to their distinctive morphology. Porcupines are divided into two families: the family Hystricidae, known as the Old-World porcupines (Eurasia, Africa, southern & southeastern Asia) and the family Erethizontidae, which are known as the New World porcupines (North & South America) (Voss et al. 2013; Rovie-Ryan et al. 2017). The family Hystricidae consists of four genera namely, *Hystrix, Atherurus, Thecurus*, and *Trichys,* which are represented by 11 species globally (Rovie-Ryan et al. 2017). The presence of Malayan Porcupine *Hystrix brachyura*, Indian Crested Porcupine *Hystrix indica*, and Asiatic Brush-tailed Porcupine *Atherurus macrourus* has been reported across India (Molur et al. 2005).

The Malayan Porcupine is classified as 'Least Concern' in the IUCN Red List of Threatened Species and is listed under Schedule I of the Indian Wildlife Protection Act, 1972. It is found across southern Asia including India, Nepal, & Bangladesh, in central and southern China, Myanmar, Thailand, Laos, Cambodia, Viet Nam, Malaysia, Singapore, Indonesia, and Borneo (Molur et al. 2005). In India, the Malayan Porcupine is distributed extensively in the north-east (Alfred et al. 2002; Molur et al. 2005).

Also known as the Himalayan Crestless Porcupine, it is found along various forested and agricultural areas with rocky outcrops and bordering forest areas (Lunde 2016). It is a fossorial and nocturnal small mammal and is said to be more active during the winters (Akash et al. 2025). It lives in family units and feeds on fruits, roots, and tubers (Jnawali et al. 2011; Mallick 2012). It is mainly threatened by illegal trade and hunting for medicinal use and consumption. In southeastern Asia, especially in Malaysia, the species is harvested for food and medicinal purposes (Molur et al. 2005). Porcupine farming in Malaysia is heavily regulated; however, captive breeding is unlikely to reduce poaching pressures as they are associated with wild-sourced bezoars, which are high in value (Gomez & Khoo 2024). Habitat loss due to infrastructure development also contributes to threats. Despite having a wide distribution in the regions of southern and southeastern Asia, it is ecologically understudied (Hasan & Neha 2019; Akash et al. 2025). This study documents, for the first time, the Malayan Porcupine in Sepahijala Wildlife Sanctuary and Clouded Leopard National Park with photographic evidence, providing new insight into its distributional extension in Tripura.

The current record is the result of a rapid assessment survey conducted in all the protected areas (PAs) of Tripura. While this study may add up to a small region in the global distribution of Malayan Porcupine, it underscores the importance of conducting research in parts of India which are rich in biodiversity yet remain understudied. By underscoring the importance and necessity of short yet intensive surveys in regions where long-term studies are challenging, this work simultaneously draws attention to a lesser-known and poorly documented species, bringing it into the conservation spotlight.

MATERIALS AND METHODS

Study Area

The Sepahijala Wildlife Sanctuary (SWS) and Clouded Leopard National Park (CLNP) (23.6167°–23.7000° N, 91.2833°–91.3500° E) combined cover an area of 18.5 km^2 in the Sepahijala District of Tripura (Figure 1). Due to its proximity to the state capital, Agartala, it is a popular tourist attraction. The SWS was established in 1987; further, in 2007, the CLNP was established as an effort to enhance conservation efforts for the vulnerable Clouded leopard *Neofelis nebulosa*. As the CLNP is situated within the SWS, both protected areas were treated as a single entity for data collection, analysis, and documentation of the Malayan Porcupine record in this study. The Sepahijala Zoological Park is encompassed within the SWS.

Based on the forest classification of Champion & Seth (1968), the forest type of SWS is classified as moist mixed deciduous, with secondary moist bamboo brakes. Additionally, numerous man-made forests featuring Sal *Shorea robusta*, Teak *Tectona grandis*, and patches of Acacia *Acacia auriculiformis*, along with abandoned rubber plantations, remain within and around SWS (Adimallaiah et al. 2014; Patil & Joshi 2024). The terrain is characterized by small hillocks with an average altitude of 50 m. The region faces threats from extraction of timber and non-timber forest products (NTFP), road-kills and unregulated tourism. National Highway 8 (NH8), a vital route connecting various parts of Tripura,

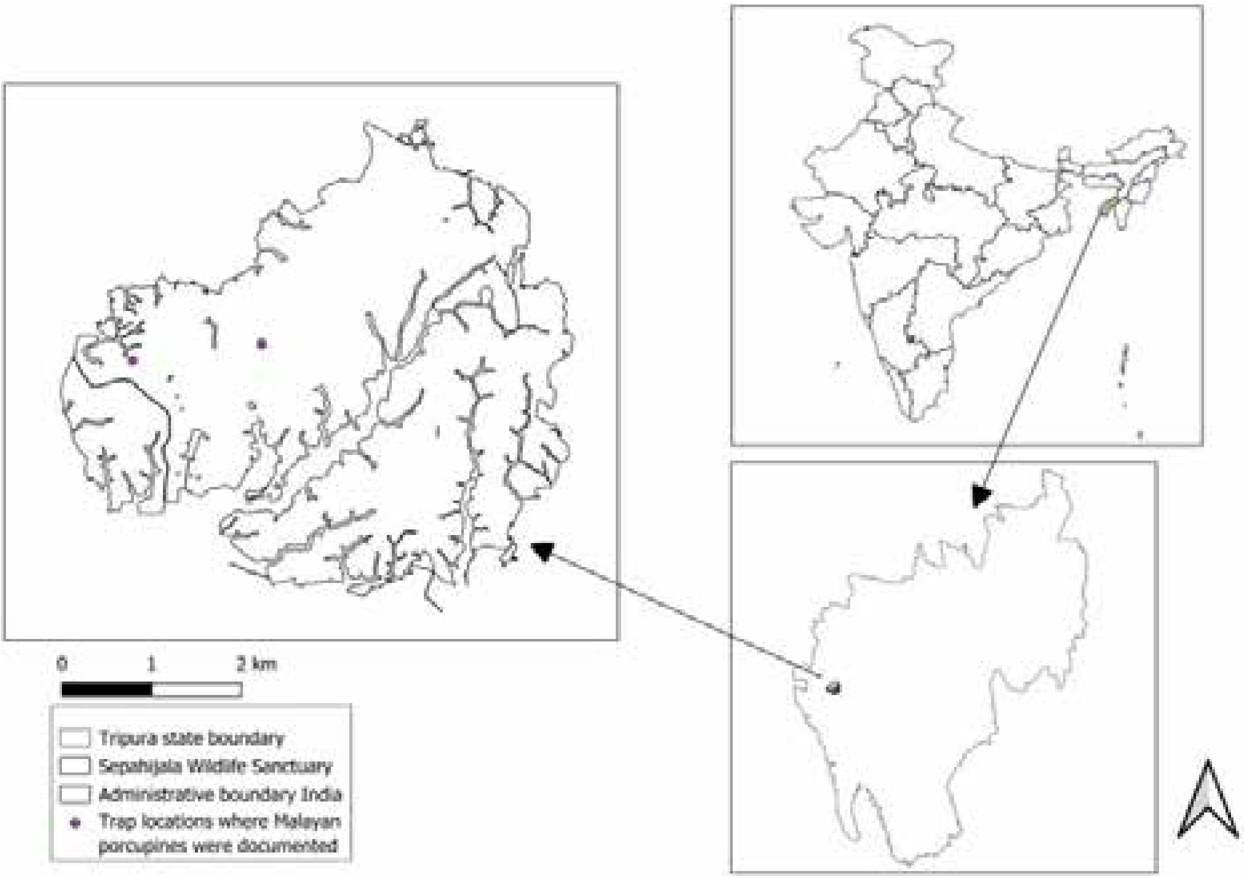

Image 1. Location of Sepahijala Wildlife Sanctuary on the map of Tripura along with locations where Malayan Porcupine was recorded.

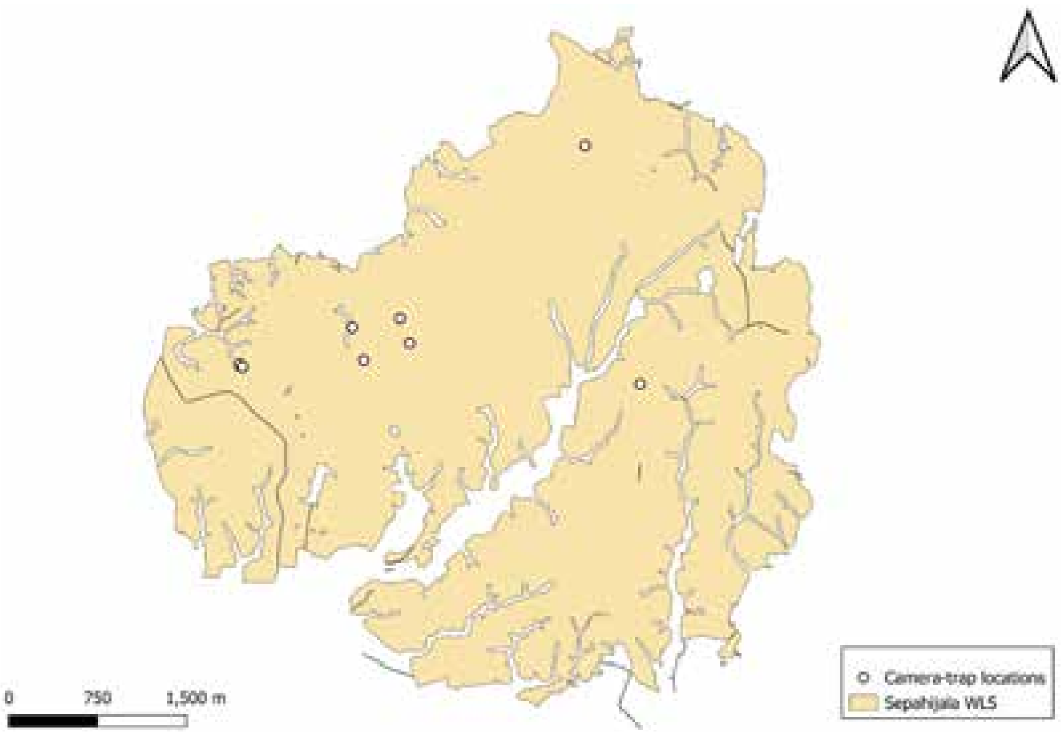

Image 2. Camera trap locations within Sepahijala Wildlife Sanctuary, Tripura, India.

passes through the SWS, which, despite its economic importance, causes significant habitat fragmentation within the sanctuary (Patil & Joshi 2024). Additionally, the PA is surrounded by villages, rice fields alternating with patches of rubber plantations.

Method

A total of 14 camera traps (Cuddeback Xchange C1 with an infrared flash along with Spartan Lumen (white flash)) were deployed in eight camera trap stations using single & double-sided techniques, accounting for 77 trap nights between 12–22 February 2024 in SWS. Trap nights were calculated by summing the number of 24-hour periods for which each camera-trap station remained operational, with one operational station for one night considered as one trap night; paired cameras deployed at the same station were treated as a single sampling unit (Meek et al. 2014). Camera traps were deployed along trails, water bodies, dry rivulets and stream beds showing mammalian signs. Within SWS, stations were pragmatically selected to minimize vandalism and theft, and chosen using Google Earth Pro and QGIS (v.3.30.2) based on forest cover, vegetation, and low anthropogenic disturbance. Distance between two camera-trap locations ranged 30 m–2 km. Cameras were placed at a height of 0.3 m from the ground on trees. There was no delay between two image triggers, and that successive images were programmed to be captured as fast as possible. Local forest staff, Banmitras (friends-of-forests) & field facilitators helped in the camera-trapping exercise.

RESULTS

During the course of deployment in SWS, we documented the presence of Malayan Porcupine in two camera trap locations (SEP-CT1 and SEP-CT2) (Table 1; Image 2). Both of the camera-trap locations were situated near a small waterbody within the PA, with a distance of 1.45 km from each other. Across the two camera-trap stations, 20 photographs of the Malayan Porcupine were obtained over 10 and nine trap-nights respectively, yielding a total of five independent capture events (Table 2).

The species was identified as *Hystrix brachyura* after examining the morphological characters visible in the photographs (Images 3a,b). Key distinguishing characteristics include a short dorsal crest and long dorsal quill, which has a single dark band, unlike *Hystrix indica,* which possesses two or more dark bands on the quills. Additionally, the individual also possesses a relatively shorter tail than *Hystrix indica* (Menon 2023). These diagnostic characteristics confirm that the individuals captured in the images belong to *Hystrix brachyura*. The images were recorded during the nocturnal and crepuscular times of the day, aligning with the findings of Akash et al. (2025) which studied the nocturnal activity patterns of *Hystrix brachyura*. This confirms the first record of the Malayan Porcupine from the state of Tripura, thereby contributing to an extension of its known global distribution range (Image 4).

Other species such as the Large Indian Civet *Viverra zibetha*, Asian Palm Civet *Paradoxurus hermaphroditus*, Small Indian Civet *Viverricula indica*, Northern Red Muntjac *Muntiacus vaginalis*, Rhesus Macaque *Macaca mulatta*, Northern Pig-tailed Macaque *Macaca leonina*, and Wild Pig *Sus scrofa* were documented by the same camera-trap stations.

Table 1. Camera trap locations in Sepahijala Wildlife Sanctuary, Tripura, India.

Camera-trap location ID	Latitude	Longitude	Height (in m)
SEP-CT1	23.661° N	91.295° E	6
SEP-CT2	23.661° N	91.295° E	17
SEP-CT3	23.665° N	91.308° E	36
SEP-CT4	23.678° N	91.324° E	41
SEP-CT5	23.664° N	91.305° E	26
SEP-CT6	23.663° N	91.309° E	22
SEP-CT7	23.660° N	91.328° E	37
SEP-CT8	23.661° N	91.306° E	23

DISCUSSIONS

Porcupines are known to play a key role in ecosystem functioning through soil disturbance, seed dispersal and their interactions with vegetation and predators (Ilse & Hellgren 2001). Social associations, including stable reproductive pairs and family groups, have been documented among porcupines of the genus *Hystrix* (Corbet & Van Aarde 1996; Mori et al. 2025). This social behaviour corresponds with our observations, in which pairs of Malayan Porcupines were documented during two independent capture events. In addition to the camera-trap records, porcupine droppings and burrows were observed at several locations within the protected area, indicating continued use of the landscape by the species. Despite their protective quills, porcupines serve

Image 3a. A camera trap image of a pair of Malayan Porcupine *Hystix brachyura* from Sepahijala Wildlife Sanctuary, Tripura, India.

Image 3b. An image of Malayan Porcupine *Hystix brachyura* from Sepahijala Wildlife Sanctuary, Tripura, India.

Table 2. Details of Malayan Porcupine *Hystrix brachyura* recorded during the camera trapping survey of mammals in February 2024 in Sepahijala Wildlife Sanctuary, Tripura, India.

Date	Time (from) (hhmmss)	Time (to) (hhmmss)	Total number of camera trap images	Camera-trap station	Remarks
15.ii.24	034500	--	1	SEP-CT1	The porcupine walks across the open area.
15.ii.24	234800	235400	2	SEP-CT1	A pair of porcupines walk across the open area.
16.ii.24	020740	022812	7	SEP-CT2	A porcupine was repeatedly observed traversing the trail, likely foraging.
16.ii.24	192600	192800	3	SEP-CT2	A pair of porcupines walk across the open area.
21.ii.24	051232	051254	7	SEP-CT2	A porcupine was observed on the trail, likely foraging.

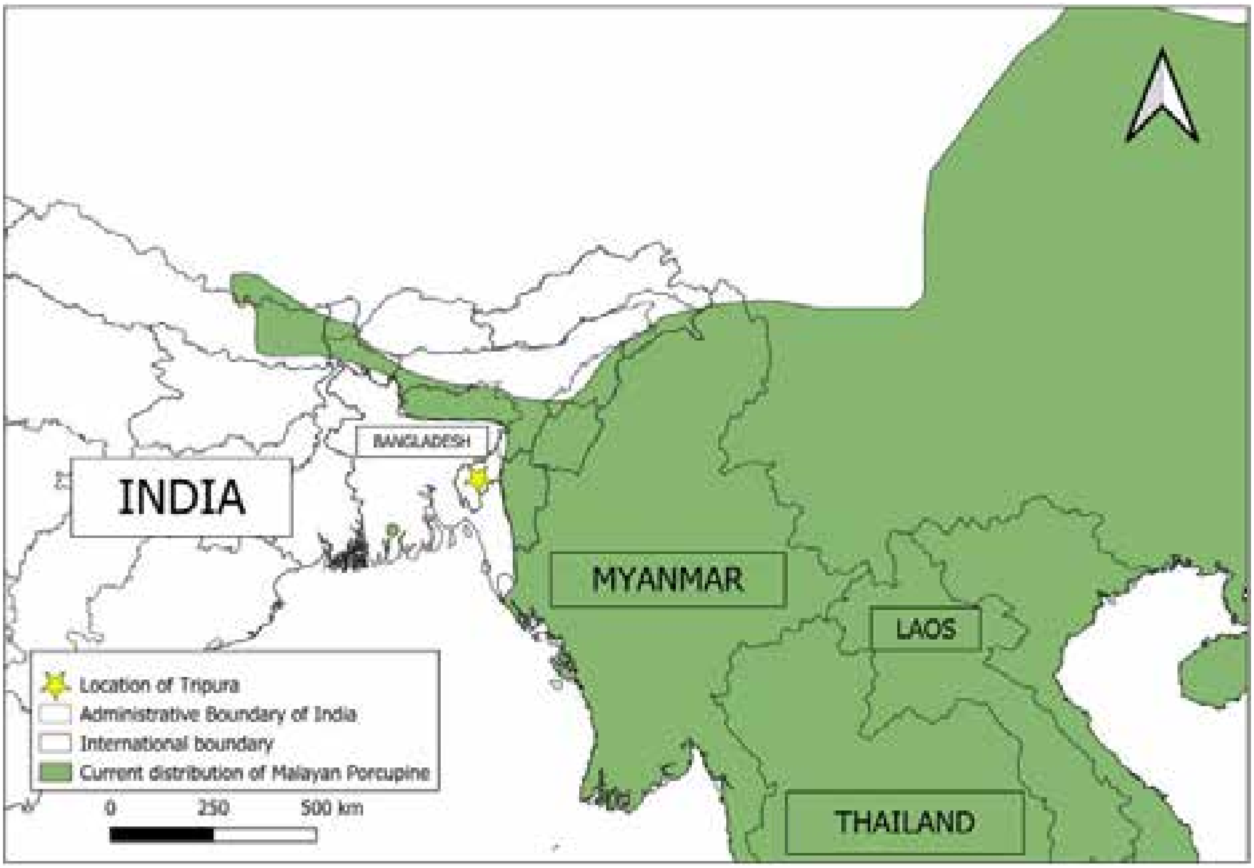

Image 4. Geographical distribution of Malayan porcupine and location of Tripura.

as prey for major carnivores such as leopards and lions. They are also actively hunted for their meat by humans. Che Dah (2017) reports that porcupine meat is consumed as a source of protein in China. Multiple studies document herbivory in porcupines, yet Nowak (1999) mentions that members of *Hystrix* feed on carcasses, thus suggesting that it could be an opportunistic feeder.

The Malayan Porcupine is widely distributed in the Indo-Malayan region and has been reported extensively from the states of northeastern India. Precise detections have been noted from Sikkim, Assam, Arunachal Pradesh, Manipur, Mizoram, Meghalaya, and West Bengal (Molur et al. 2005; Talukdar et al. 2019). Records in proximity to Tripura include observations from Aizawl in Mizoram & Bangladesh (Agrawal 2000; Hasan & Neha 2019). The occurrence of the species in Tripura had previously been considered likely because the state supports habitats similar to those in the adjoining regions where the species has been recorded (Mazumdar et al. 2011). The present photographic records therefore provide evidence supporting its occurrence in the state. The CLNP is situated within the SWS, with no physical boundary separating the two protected areas. Consequently, animals can move across the landscape without restriction, and the two protected areas were treated as a single sampling and analytical unit during the study. The records reported here therefore represent the combined SWS–CLNP landscape rather than two ecologically separate sites.

The limited duration and spatial extent of the camera-trap survey do not allow an assessment of the population size, density or trend of the Malayan Porcupine within the SWS landscape. However, repeated camera-trap detections, records of pairs and the presence of droppings and burrows indicate that the species currently occurs across multiple parts of the protected area. These observations should not be interpreted as evidence of a stable population, and systematic long-term monitoring is required to assess its population status. No cases of porcupine hunting were recorded in and around the protected area during the study. Nevertheless, habitat loss, fragmentation and disturbance remain potential threats, while hunting for meat and medicinal use is known to affect the species elsewhere in its range (Molur et al. 2005; Kumawat et al. 2013).

Despite its wide occurrence, *Hystrix brachyura* remains poorly studied, and information about its ecology, abundance and local population trends remains limited. The species is affected by habitat destruction and hunting for food; and is not listed under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (Molur et al. 2005; CITES 2023). Owing to this, the Malayan Porcupine is more prone to being poached and hunted for bushmeat and medicinal purposes. In several regions of Java, porcupines are still hunted from the wild to supply food stalls selling delicacies made with their meat (Farida et al. 2019). This persistent hunting to meet culinary demand exerts heavy pressure on wild populations, contributing to their continued decline. Effective monitoring, control, and captive-breeding efforts are therefore essential to prevent further depletion. Molur et al. (2005) suggest that all of the Indian species of porcupines have declined by 20% and are showing a downward trend.

Conservation measures within the SWS landscape should therefore focus on reducing disturbance and maintaining connectivity between forest patches. Practical measures may include restricting non-essential vehicular movement during nocturnal hours, enforcing speed limits along the section of National Highway 8 passing through the protected area, identifying frequently used wildlife-crossing locations and installing appropriate warning signs or traffic-calming measures. Strict enforcement against littering, regulation of tourist movement and control of unrestricted access from peripheral villages would further reduce disturbance. Continued camera trapping, monitoring of indirect signs and documentation of road mortality or hunting incidents are required to determine changes in the occurrence and conservation status of the Malayan Porcupine within the protected area.

REFERENCES

Agrawal, V.C. (2000). Taxonomic Studies on Indian Muridae and Hystricidae (Mammalia: Rodentia). Records of Zoological Survey of India, Occasional Paper No. 180. Zoological Survey of India, Calcutta, 159 pp.

Adimallaiah, D. et al. (2014). Population status of Phayre's Langur *Trachypithecus phayrei* in Sepahijala Wildlife Sanctuary, Tripura, Northeast India. Primate Conservation 28: 159–163. https://doi.org/10.1896/052.028.0101

Akash, M. et al. (2025). Malayan porcupines in moonlight: assessing nocturnal activity patterns, with a review of porcupine distributions in Bangladesh. Global Ecology and Conservation 58: e03486. https://doi.org/10.1016/j.gecco.2025.e03486

Alfred, J.R.B. et al. (2002). Checklist of Mammals of India. Records of Zoological Survey of India, Occasional Paper No. 199. Zoological Survey of India, Kolkata, 288 pp.

Champion, H.G. & S.K. Seth (1968). A Revised Survey of the Forest Types of India. Government of India Press, New Delhi, 404 pp.

Che, D.F. (2017). Nutrient Content and Sensory Analysis in Four Dishes Based on Porcupine and Deer Meat. M.Sc. Thesis. Universiti Sains Malaysia, Penang, Malaysia, 161 pp.

CITES (2023). Appendices I, II and III. Convention on International Trade in Endangered Species of Wild Fauna and Flora, Geneva, Switzerland. Valid from 25.xi.2023. Accessed on 26.vii.2026.

Corbet, N.U. & R.J. Van Aarde (1996). Social organization and space use in the Cape porcupine in a southern African savanna. African Journal of Ecology 34(1): 1–14. https://doi.org/10.1111/j.1365-2028.1996.tb00589.x

Farida, W. et al. (2019). Observations of behavioral development on common porcupines *Hystrix brachyura* undergoing domestication. IOP Conference Series: Earth and Environmental Science 308: 012076. https://doi.org/10.1088/1755-1315/308/1/012076

Fleming, P.A. & P.W. Bateman (2016). The good, the bad, and the ugly: which Australian terrestrial mammal species attract most research? Mammal Review 46(4): 241–254. https://doi.org/10.1111/mam.12066

Gomez, L. & M.S. Khoo (2024). The trade of porcupines in Malaysia with international trade links. Tropical Conservation Science 17: 1–15. https://doi.org/10.1177/19400829241236311

Hasan, M.A.U. & S.A. Neha (2019). The Himalayan Crestless Porcupine *Hystrix brachyura* Linnaeus, 1758 (Mammalia: Rodentia: Hystricidae): first authentic record from Bangladesh. Journal of Threatened Taxa 11(12): 14624–14626. https://doi.org/10.11609/jott.4861.11.12.14624-14626

Ilse, L.M. & E.C. Hellgren (2001). Demographic and behavioral characteristics of North American Porcupines *Erethizon dorsatum* in pinyon-juniper woodlands of Texas. The American Midland

Naturalist 146(2): 329–338. https://doi.org/10.1674/0003-0031(2001)146[0329:DABCON]2.0.CO;2

Jnawali, S.R. et al. (2011). The Status of Nepal Mammals: The National Red List Series. Department of National Parks and Wildlife Conservation, Kathmandu, Nepal, 169 pp.

Kumawat, M.M. et al. (2013). Threatened rodent species of Arunachal Pradesh. International Journal of Agriculture, Environment and Biotechnology 6(4): 657–662. https://doi.org/10.5958/j.2230-732X.6.4.046

Lunde, D. (2016). *Hystrix brachyura*. The IUCN Red List of Threatened Species 2016. Accessed on 21.v.2025.

Mallick, J.K. (2012). Mammals of Kalimpong Hills, Darjeeling District, West Bengal, India. Journal of Threatened Taxa 4(11): 3103–3136. https://doi.org/10.11609/JoTT.o2418.3103-36

Mazumdar, K. et al. (2011). Mammalian diversity of degraded forest habitats around Assam University Campus, Cachar, Assam, India, with notes on conservation status. Our Nature 9(1): 119–127. https://doi.org/10.3126/on.v9i1.5742

Meek, P.D. et al. (2014). Recommended guiding principles for reporting on camera trapping research. Biodiversity and Conservation 23: 2321–2343. https://doi.org/10.1007/s10531-014-0712-8

Menon, V. (2023). Indian Mammals: A Field Guide. Hachette India, Gurugram, 544 pp.

Molur, S. et al. (2005). Status of South Asian Non-volant Small Mammals. Zoo Outreach Organisation & CBSG South Asia, Coimbatore, India, 618 pp.

Mori, E. et al. (2025). Social behaviour of the crested porcupine in urban and rural areas. Acta Ethologica 28: 109–117. https://doi.org/10.1007/s10211-025-00459-x

Nowak, R.M. (1999). Walker's Mammals of the World. 6th Edition. The Johns Hopkins University Press, Baltimore, 936 pp.

Patil, O. & A. Joshi (2024). Status of Mammals in the Protected Areas of Tripura: A Rapid Assessment. Vivek PARC Foundation, Mumbai. Submitted to the Tripura Forest Department. Supported by The Habitats Trust.

Rovie-Ryan, J. et al. (2017). Molecular phylogeny of the Old World porcupines (Family Hystricidae) using mitochondrial cytochrome B gene. Journal of Sustainability Science and Management 12: 1–11.

Talukdar, N.R. et al. (2019). Current records of porcupine in northeast India: distribution, habitat preference and conservation. Tropical Ecology 60(1): 41–51. https://doi.org/10.1007/s42965-019-00005-4

Voss, R.S. et al. (2013). Phylogenetic relationships of New World porcupines (Rodentia: Erethizontidae): implications for taxonomy, morphological evolution and biogeography. American Museum Novitates 3769: 1–36. https://doi.org/10.1206/3769.2

Wilson, D.E. & D.M. Reeder (eds.) (2005). Mammal Species of the World: A Taxonomic and Geographic Reference. 3rd Edition. Johns Hopkins University Press, Baltimore, 2142 pp.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 August 2026 | 18(8): 29515–29520
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.9722.18.8.29515-29520
#9722 | Received 27 February 2025 | Final received 23 June 2026 | Finally accepted 04 August 2026

OPEN ACCESS

COMMUNICATION

Fishermen-led documentation of bycatch of sea snakes (Serpentes: Elapidae: Hydrophiinae) on the Malabar coast of southwestern India

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Abstract: Sea snakes are prominent among marine fishery bycatch and few studies have examined the gravity of this problem in Indian coastline fisheries. We examine sea snake bycatch on the Malabar Coast in southwestern India during a study period from September 2024 to January 2025 that was conducted in eight harbours in southern Karnataka and northern Kerala over a 15-week period. Sea snake bycatch photos were obtained directly from fishermen aboard vessels, and among 22 photos we identified three sea snake species: Short Sea Snake *Hydrophis curtus* (13 dead, 4 live), Annulated Sea Snake *H. cyanocinctus* (4 dead), and Hook-nosed Sea Snake *H. schistosus* (1 dead). We also interacted with fishermen and shared e-posters on sea snake bycatch issues during awareness outreach efforts in the study area.

Keywords: Awareness outreach, dead snake, fishermen, Karnataka, Kerala, Indian coastline fisheries, live snake, photo sharing, posters, snake bycatch.

Editor: Anonymity requested.

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

Citation: Vishnu, R.S. & S.R. Ganesh (2026). Fishermen-led documentation of bycatch of sea snakes (Serpentes: Elapidae: Hydrophiinae) on the Malabar coast of southwestern India. *Journal of Threatened Taxa* 18(8): 29515–29520. https://doi.org/10.11609/jott.9722.18.8.29515-29520

Funding: Zooreach Conservation Seed Grant (24ZCSG02H).

Competing interests: The authors declare no competing interests.

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Author contributions: SVR conducted fieldwork and networked with the fishing community and prepared the Malayalam version poster. SRG envisaged and developed this project and its modalities, in consultation with SVR and trained SVR initially regarding on-site project data collection.

Acknowledgements: This study was supported by Zooreach Conservation Seed Grants (ZCSG). We thank the Zoo Outreach Organisation team for positively considering and funding this project, its director Dr. Sanjay Molur and grants coordinator Ms. Trisa Battacharjee. SRG thanks the 1Ocean Program head Mrs. Priyanka Iyer and researcher Ms. Tandrali Baruah for productive academic discussions on sea snake bycatch and fishermen perceptions. We acknowledge that Dr. Kartik Shanker lab collaborations paved the way for our ventures together, especially Dr. Titus Immanuel who introduced us to one another. We thank the fishermen of Karnataka harbours for sharing snake photos that are reproduced here. We thank Drs. S. Suresh Kumar and Limna Mol, KUFOS (Kochi), Sujitha Thomas, CMFRI (Mangalore), P. Padmanabhan, ZSI/MBRC (Chennai), and V. Deepak Samuel, NCSCM (Chennai) for their suggestions on some aspects of the project. We are grateful to the founder director and trustees of our organisation Kalinga Foundation for encouraging our research activities. Thanks to G. Pradeep for Kannada translation.

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INTRODUCTION

Marine bycatch refers to the incidental death and debilitation of marine life that is not within the legal remit of regulated fisheries (Davies et al. 2009). Marine bycatch of non-target fauna and their consequent entanglements lead to unnecessary mortality (Salagrama 1998; Mahesh et al. 2017, 2019). This problem is poorly studied for Indian coastal fisheries (Dineshbabu et al. 2022), especially those involving deep-sea trawling (Dineshbabu et al. 2010, 2012, 2014). Depletion of marine biodiversity is a widespread anthropogenic threat (Kumar & Deepthi 2006; Velip & Rivonker 2015; Madhu et al. 2017), and studies aimed at finding solutions are sparse (Azeez et al. 2021). Commercialisation and non-human consumption of bycatch are reported to be directly incentivising intensive fishing (Lobo et al. 2010; Aulia et al. 2024).

Sea snakes are commonly encountered air-breathing fauna that drown in submerged nets cast for fishing operations (Dsouza et al. 2021; Rao et al. 2021; Jana et al. 2024; Ganesh et al. 2026). The Indian coastline is home to 20 species of front-fanged, marine elapid snakes of the subfamilies Hydrophiinae, the true sea snakes, and Laticaudinae, the sea kraits (Ganesh et al. 2019). Sea snakes are not target species of fisheries as they are neither suitable for human consumption nor for poultry feed, hence snake bycatch is typically discarded. Sea snake bycatch is not well-studied in general, and little is known about this issue on the western Indian coast (Kumar et al. 2007; Iburahim et al. 2019; Patel et al. 2022, 2024). To this end, we studied the frequency of sea snake bycatch in Malabar Coast, southwestern India and conducted awareness drives in attempts to improve the situation.

MATERIALS AND METHODS

Study Area

The study was conducted on the Malabar coast of southwestern India, politically covering parts of Kerala and Karnataka state jurisdictions, with sampling sites extended across Chombala harbour (Kannur District, Kerala) to Malpe harbour (Udupi District, Karnataka), across a distance of about 230 km (Table 1; Image 1). Samplings were concentrated in eight harbours (south to north) namely: Chombala, Mahe, Thalassery, Kannur, Nileshwaram, Kasaragod, Mangalore, and Malpe harbours.

Field Surveys

From September 2024 to January 2025, for five months, field surveys were conducted on the Malabar Coast, southwestern India, focussing on sea snake bycatches. A total of 15 weeks of field surveys were conducted across all the eight harbours. One and a half to two weeks with 2–3 hours per day were spent on field surveys in each harbour, based on the spatial expanse of harbour, fishing intensity, fishermen visitations and boating frequencies. We networked with fishermen to source photos of sea snakes on board and to circulate local language (Malayalam, Kannada) posters depicting awareness messages on sea snakes. Sea snake species were identified from photographs received following Ganesh et al. (2019).

RESULTS

During this five month-survey, lasting for 15 weeks of field days in eight harbours, we interacted with 141 fishermen and shared posters on 47 occasions. We also obtained photographic records of sea snake bycatches amounting to a total of 22 sightings comprising three species namely: Short Sea Snake *Hydrophis curtus* (n = 17), Annulated Sea Snake *Hydrophis cyanocinctus* (n = 4), and Hook-nosed Sea Snake *Hydrophis schistosus* (n = 1). Details of the awareness and photographic data collection aspects are detailed in the following.

i. Sea snake bycatch (Table 2; Image 2)

From all the harbour visits and awareness drives on sea snake bycatch, we received photographic records of a total of 22 bycatch of sea snakes, both dead and alive, from two harbours namely Malpe and Mangalore, both in Karnataka. Based on the photographs received from the fishermen, it was found that *Hydrophis curtus* was the most dominant species here, commoner than both *Hydrophis cyanocinctus* and *Hydrophis schistosus*. There were no records of sea snake bycatches based on the photographs shared by the fishermen, from all the six harbours in Kerala. Only those in the two harbours in Karnataka, shared sea snake photos. Just 1 (*H. cyanocinctus*) photo record was from Mangalore while the remaining 21 were all from Malpe harbour. The fishermen we engaged with used siene nets, gill nets, and cast nets usually deployed for half a day at roughly 0.7 km depth. About one fifth of the snakes that got caught were alive, while the vast majority were dead, as seen in the photos shared and also stated by fishermen. In Malpe, a case of mass mortality, with 10 dead snakes

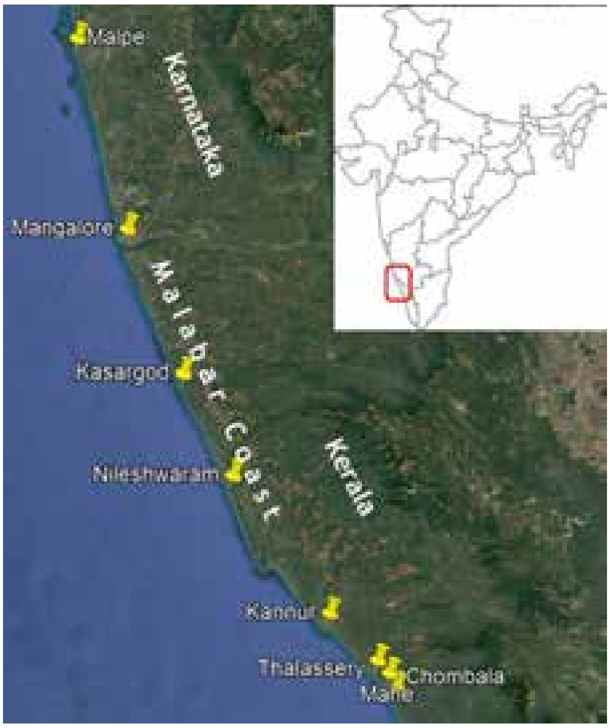

Image 1. Map of southwestern India showing the eight harbours sampled in Malabar Coast, with inset showing the sampled area within India (earmarked in red).

Table 1. Sampling sites of the eight harbours in Malabar Coast, Kerala and Karnataka, India.

Harbour name	District, State	Latitude °N	Longitude °E
Chombala	Kannur, Kerala	11.6658	75.5500
Mahe	Puducherry, Puducherry	11.7022	75.5311
Thalassery	Kannur, Kerala	11.7351	75.5006
Kannur	Kannur, Kerala	11.8574	75.3726
Nileshwaram	Kasargod, Kerala	12.2145	75.1160
Kasaragod	Kasargod, Kerala	12.4772	74.9832
Mangalore	Dakshina Kannada, Karnataka	12.8508	74.8335
Malpe	Udupi, Karnataka	13.3482	74.6958

Table 2. Details of dead and live sea snakes recorded as bycatches in sites where seen.

Site/Snake species	*H. curtus*	*H. cyanocinctus*	*H. schistosus*
Mangalore live	0 (0%)	0 (0%)	0 (0%)
Mangalore dead	0 (0%)	1 (4.5%)	0 (0%)
Malpe live	4 (18.1%)	0 (0%)	0 (0%)
Malpe dead	13 (59.0%)	3 (13.6%)	1 (4.5%)

belonging to two species (*H. curtus, H. cyanocinctus*), was noted. The sea snakes caught in the bycatch all appeared to be adults, approaching 1 m in total length, as deduced from the photographs. To the best of our knowledge, no evident injuries could be seen on the snakes from the photographs.

ii. Awareness Events with Posters (Table 3)

During the interactions, many fishermen misidentified eels as sea snakes, especially the younger inexperienced people. They noted that they greatly benefited from the posters and photographs of the marine snakes shown during the discussions. Many fishermen were unaware of the toxic and venomous nature of sea snakes and their differences in appearance compared to other marine snakes like acrochordids and homalopsids, both of which have normal tapering cylindrical tails just like any other snake.

A total of 141 fishermen were interviewed and posters were shared with 47 fishermen across the different harbours. The number of fishermen interactions per harbour ranged from 6 (4.2%) in Kasargod harbour, to 49 (34.7%) in Thalassery harbour; and that of poster shares per harbour ranged from 2 (4.2%) in Kasargod to nine (19.1%) in Mangalore. There were differences in the maximum numbers of both the aspects studied. The

Table 3. Details of the fishermen interacted and posters shared in each site.

Harbours surveyed	No. of weeks surveyed	No. of fishermen interacted (in %)	No. of posters shared (in %)
Chombala	1.5 weeks	21 (14.8%)	8 (17.2%)
Mahe	1.5 weeks	20 (14.1%)	8 (17.2%)
Thalassery	2 weeks	49 (34.7%)	6 (12.7%)
Kannur	2 weeks	12 (8.5%)	4 (8.5%)
Nileshwaram	2 weeks	12 (8.5%)	8 (17.2%)
Kasargod	2 weeks	6 (4.2%)	2 (4.2%)
Mangalore	2 weeks	13 (9.2%)	9 (19.1%)
Malpe	2 weeks	8 (5.6%)	4 (8.5%)
Total: 8 sites	15 weeks	141	47

maximum number of fishermen that were interacted with by our team were 49, while the second and third highest ones numbered less than half the first value (i.e., n = 21, 20). During interactions, the fishermen reported no sea snake bite instances at least within the last three decades, in the sampled areas.

The maximum percentage of fishermen community that engaged with the awareness posters was at Mangalore harbour (19.1%), followed by Chombala,

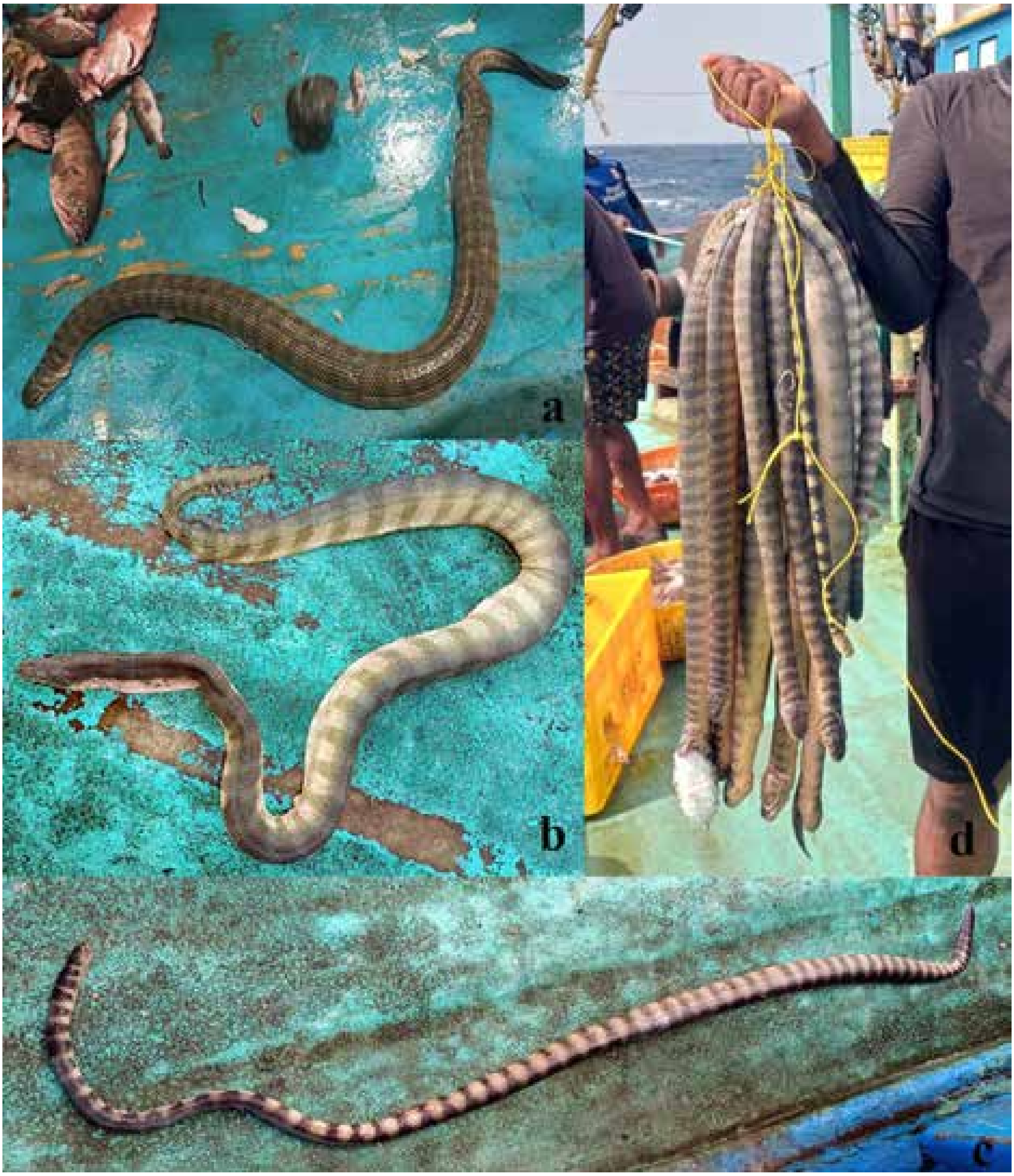

Image 2. Sea snake bycatch photos forwarded by fishermen during the present study. © 2a—Sreedhar | b & d—Raviraj | c—Kumar.

Mahe, and Nileshwaram (17.2% each), with the lowest at Kasargod (4.2%) (Table 3). The numbers of poster shares were rather constant, with the topmost one logging nine shares, while the second and third highest ones were comparable values with marginal differences (n = 8, 6). One third (47 out of 141; 33.33%) of the fishermen engaged with the survey team well enough and shared contacts to enable mutual sharing of posters and bycatch photos. Despite the limited time allocated to each harbour (< 2 weeks), and the first-time contact of the survey team with the fishermen community, it is remarkable to get an engagement level 33.33%. There was no direct positive correlation between the harbours having the highest interviewees, poster shares, and sea snake bycatch photo shares.

DISCUSSION

Kumar et al. (2007) reported Cochin Banded Sea Snake *H. ornatus* from central and southern Kerala Coast and Palot & Radhakrishnan (2010) recorded Yellow-bellied Sea Snake *H. platurus* from northern Kerala. There is a record of Viperine Sea Snake *H. vieprinus* from the northern Karnataka Coast (Mondal et al. 2023). However, in our study, these species were not recorded. During our survey we found, *H. curtus* was the commonest among the three species that we recorded during the study. Padate et al. (2009), Dsouza et al. (2021), and Rao et al. (2021) reported *H. schistosus* to be more common than *H. curtus* in Goa and the northerly Malvan beach, of southern Maharashtra, in Konkan Coast, respectively. However, Lobo et al. (2004) reported that *H. curtus* outnumbered the records of *H. schistosus*, from studies done in the more northern coast of Goa.

Kumar et al. (2007) studied sea snake bycatches associated with trawl fisheries in five harbours in central and southern Kerala Coast and reported 62 instances of four species, as follows: *H. schistosus* (n = 43), *H. cyanocinctus* (n = 10), *H. ornatus* (n = 1), and *H. curtus* (n = 8). This is perhaps one of the very few studies that reported other snake species, apart from *H. schistosus* and *H. curtus*. A study was done on the trophic ecology of *H. curtus* in Goa Coast (Lobo et al. 2005). As for *H. schistosus*, three studies, one from Kerala (Jeyabaskaran et al. 2015), one from Goa (Tambre et al. 2020), and one from south Maharashtra (Dsouza & Rao 2021) coasts reported this species. Dsouza & Rao (2021) even remarked that *H. schistosus* to be a rather resilient species as regards the bycatch problem, based on their sampling in Malvan beach. These studies were done in beaches situated further north of Malabar Coast and it is understandable to get varied results, given the inter-regional variations.

Some studies on sea snake bycatches have been conducted in northern (Patel et al. 2022, 2024) and southern parts (Padate et al. 2009; Tambre et al. 2020; Dsouza et al. 2021; Dsouza & Rao 2021; Rao et al. 2021) of Konkan Coast and southern part of Malabar Coast (Kumar et al. 2007; Jeyabaskaran et al. 2015). To the best of our knowledge, there is no such study from northern part of Malabar Coast covering southern Karnataka and northern Kerala. Those that exist are not based on bycatch problems of sea snakes but generally on sighting records. Citizen science posts of sea snakes also reported the same three species, viz., *H. schistosus, H. curtus* and *H. cyanocinctus* from southern Karnataka–northern Kerala coasts (Blessy & Ganesh 2026). Hence this study fills the void in research bycatch kills of sea snakes.

This study gathered insights into the status of sea snake bycatch and local perceptions of it. The one case of mass mortality involving the commonest species *H. curtus* and a rarer species *H. cyanocinctus* constituting over 10 dead snakes within a single net, raises conservation concern. As our major focus during the present survey was to make first-time contact and create awareness among the fishermen community regarding sea snakes and their mortality in marine bycatch, we did not collect morphometric data, the gender, the reproductive status nor the presence of young ones inside the dead snakes. More data on net type, haul duration would also hint of their potential correlation if any with the bycatch. More such studies on sea snake bycatch and awareness drives need to be conducted along the coastline of India for the conservation of sea snakes and other fauna that get into the marine bycatch.

REFERENCES

Auliya, M. et al. (2024). Challenges of regulating commercial use of marine elapid snakes in the Indo-Pacific. Conservation Biology 38(5): e14336. https://doi.org/10.1111/cobi.14336

Azeez, P.A. et al. (2021). Species composition and spatio-temporal variation of bycatch from mid-water trawlers operating in the Arabian Sea along north-west coast of India. Regional Studies in Marine Science 43: p.101692. https://doi.org/10.1016/j.rsma.2021.101692

Blessy, J. & S.R. Ganesh (2026). Sea snake occurrences along the Mainland Indian coastline in two decades–a preliminary study using citizen science photo posts. Species 27: e11s3271. https://doi.org/10.54905/disssi.v27i79.e11s3271

Davies, R.W. et al. (2009). Defining and estimating global marine fisheries bycatch. Marine Policy 33(4): 661–672.

Dineshbabu, A.P. et al. (2010). Bycatch from trawlers with special reference to its impact on commercial fishery, off Mangalore, pp. 327–334. In: Meenakumari, B. et al. (eds.). Coastal fishery resources of India - Conservation and sustainable utilisation. Central Institute of Fisheries Technology, Kochi.

Dineshbabu, A.P. et al. (2014). An appraisal of trawl fisheries of India with special reference on the changing trends in bycatch utilization. Journal of Marine Biological Association of India 55(2): 69–78. https://doi.org/10.6024/JMBAI.2013.55.2.01765-11

Dineshbabu, A.P. et al. (2012). Spatio-temporal analysis and impact assessment of trawl bycatch of Karnataka to suggest operation based fishery management options. Indian Journal of Fisheries 59: 27–38.

Dineshbabu, A.P. et al. (2022). Bycatch in Indian trawl fisheries and some suggestions for trawl bycatch mitigation. Current Science 123(11): 1372–1380. http://eprints.cmfri.org.in/id/eprint/16524

Dsouza, S. et al. (2021). Resource use and the impacts of fisheries on two sympatric sea snake species on the west coast of India. Marine Biology 168(9): 146. https://doi.org/10.21203/rs.3.rs-328406/v1

Dsouza, S. & C. Rao (2021). Demographics and reproductive biology of

Hydrophis schistosus may make it more resilient to bycatch effects than other sea snakes. Regional Studies in Marine Science 47: 101948. https://doi.org/10.1016/j.rsma.2021.101948

Ganesh, S.R. et al. (2019). Marine snakes of Indian coasts: historical resume, systematic checklist, toxinology, status, and identification key. Journal of Threatened Taxa 11(1): 13132–13150. https://doi.org/10.11609/jott.3981.11.1.13132-13150

Ganesh, S.R. et al. (2026). A preliminary study on the sea snake bycatches (Serpentes: Hydrophis) across time and space in the Coromandel Coast of southeastern India. Hamadryad 42(1&2): 1–15. https://hamadryad.org/index.php/journal/article/view/167

Iburahim, S.A. et al. (2019). Occurrence of venomous aquatic organisms as bycatch and their suggested management measures in dolnets operated in selected creeks of Maharashtra. Journal of Aquaculture in the Tropics 34: 37–43. http://doi.org/10.32381/JAT.2019.34.01.4

Jana, S. et al. (2024). Quantitative Assessment and Temporal Fluctuation of a Multiday Shrimp Trawl Bycatch off Digha Coast, West Bengal, India: Assessment of Bycatch from a Shrimp Trawler off Digha Coast. Fishery Technology 61(3): 222–236. https://doi.org/10.56093/ft.v61i3.148763

Jeyabaskaran, R. et al. (2015). Some observations on the beaked sea snake Enhydrina schistosa (Daudin, 1803) in the mudbank area, off Alapuzha, Kerala, southwest coast of India. Journal of the Marine Biological Association of India 57(2): 109–112. https://eprints.cmfri.org.in/10742/

Kumar, A.B. & G.R. Deepthi (2006). Trawling and by-catch: Implications on marine ecosystem. Current Science 90(8): 922–931.

Kumar, A.B. et al. (2007). Sea snakes associated with trawl by-catch of Kerala Coast, India. Cobra 1(1): 1–4.

Lobo, A. et al. (2004). Weight-length relationships in two species of marine snakes along the coast of Goa, Western India. Hamadryad 29(1): 89–93.

Lobo, A.S. et al. (2005). Trophic ecology of *Lapemis curtus* (Hydrophiinae) along the western coast of India. Copeia (3): 637–641.

Lobo, A.S. et al. (2010). Commercializing bycatch can push a fishery beyond economic extinction. Conservation Letters 3(4): 277–285. https://doi.org/10.1111/j.1755-263X.2010.00117.x

Madhu, V.R. et al. (2017). Status of bycatch from commercial trawlers operated off central Kerala. Fishery Technology 54: 162–169. https://epubs.icar.org.in/index.php/FT/article/view/74490

Mahesh, V. et al. (2017). Occurrence of low value bycatch in trawl fisheries off Karnataka, India. Fishery Technology 54 (2017): 1–10. https://epubs.icar.org.in/index.php/FT/article/view/75351

Mahesh, V. et al. (2019). Characterization of low value bycatch in trawl fisheries off Karnataka coast, India and its impact on juveniles of commercially important fish species. Indian Journal of Geo Marine Sciences 48(11): 1733–1742. https://nopr.niscpr.res.in/handle/123456789/52151

Mondal, S. et al. (2023). Some rare species of sea snakes (Squamata: Serpentes: Elapidae: Hydrophiinae: Hydrophis, Microcephalophis) from the Indian Coasts and nearby waters, lodged in major systematic Indian zoological collections. Bonn Zoological Bulletin 72(2): 209–222.

Padate, V.P. et al. (2009). Biological aspects of sea snakes caught incidentally by commercial trawlers off Goa, West Coast of India. Journal of Threatened Taxa 1(12): 609–616. https://doi.org/10.11609/JoTT.o2253.609-16

Palot, M.J. & C. Radhakrishnan (2010). First record of Yellow-bellied Sea Snake Pelamis platurus (Linnaeus, 1766) (Reptilia: Hydrophiidae) from a riverine tract in northern Kerala, India. Journal of Threatened Taxa 1175–1176. https://doi.org/10.11609/JoTT.o2284.1175-6

Patel, A. et al. (2024). Bycatch of sea snakes from Surwada Beach, Gujarat, India. Zoo's Print 39(8): 1–4.

Patel, A. et al. (2022). Threat to Sea Snakes from Bycatch through Imperilled Fishing Nets Utilization, Report on Rescue of Sea Snakes from by Catch at Kundi, Gujarat. Entomology, Ornithology & Herpetology: Current Research 11: 294.

Rao, C. et al. (2021). Fisheries induced shift in sea snake community assemblages along the Konkan coast, India. Aquatic Conservation: Marine and Freshwater Ecosystems 31(9): 2402–2411. https://doi.org/10.1002/aqc.3658

Salagrama, V. (1998). Bycatch utilisation in Indian fisheries: an overview, pp. 21–23. Report and proceedings of FAO/DFID expert consultation on bycatch utilisation in tropical fisheries, Beijing, China.

Tambre, G. et al. (2020). By-catch mortality of beaked Sea Snake Hydrophis schistosus (Daudin, 1803) by entanglement in shore-seine operation in Goa-India. Acta Biologica (27): 67–76. https://doi.org/10.18276/ab.2020.27-07

Velip, D.T. & C.U. Rivonker (2015). Trends and composition of trawl bycatch and its implications on tropical fishing grounds off Goa, India. Regional Studies in Marine Science 2: 65–75. https://doi.org/10.1016/j.rsma.2015.08.011

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 August 2026 | 18(8): 29521–29531
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.9581.18.8.29521-29531
#9581 | Received 25 December 2024 | Final received 03 July 2026| Finally accepted 20 July 2026

COMMUNICATION

Checklist of the plants of Radhabai Kale Mahila Mahavidyalaya Campus, Ahilyanagar, Maharashtra, India

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Abstract: The present study aimed to determine the plant species richness of an urban green space — the Radhabai Kale Mahila Mahavidyalaya campus in Ahilyanagar, Maharashtra. A total of 325 plant species (including five infraspecific taxa) from 255 genera and 81 families were documented. The dominant plant families were Fabaceae (24 species), Asteraceae (22), Euphorbiaceae (19), Apocynaceae (18), Asparagaceae (15), and Poaceae (14). In addition to the 314 angiosperms species, the study also recorded eight gymnosperms species, and three pteridophytes species. The majority of the recorded plants were planted for academic purposes, contributing to the green space and biodiversity of the college. These plants have various uses: many are ornamental, some have medicinal or edible properties.

Keywords: Angiosperms, biodiversity, conservation, ecology, environment, floristics, gymnosperms, native, pteridophytes, urban green space.

Editor: Avinash Ramchandra Gholave, K.V.N. Naik Arts, Commerce & Science College, Nashik, India. **Date of publication:** 26 August 2026 (online & print)

Citation: Bhagwat, M.G. & S.S. Kambale (2026). Checklist of the plants of Radhabai Kale Mahila Mahavidyalaya Campus, Ahilyanagar, Maharashtra, India. *Journal of Threatened Taxa* 18(8): 29521–29531. https://doi.org/10.11609/jott.9581.18.8.29521-29531

Funding: (i) Rayat Shikshan Sanstha's Radhabai Kale Mahila Mahavidyalaya, Ahilyanagar under the SEED MONEY Scheme. (ii) ASPIRE Research Mentorship Grant, Savitribai Phule Pune University, Pune.

Competing interests: We declare that we have no known competing financial interests or personal relationships that could have appeared to influence this work.

Author details Dr. Manjushree Gokul Bhagwat, a botanist and academician is currently serving as assistant professor and head of the Department of Botany at Rayat Shikshan Sanstha's Radhabai Kale Mahila Mahavidyalaya, Ahilyanagar. She has extensive teaching and research experience in the field of Botany, with a special interest in flowering plants and biodiversity studies.Dr. Sharad Suresh Kambale is a trained taxonomist and described 25 new species of flowering plants. Currently he is serving in the Maratha Vidya Prasarak Samaj's K.R.T. Arts, B.H. Commerce and A.M. Science (KTHM) College, Nashik as an assistant professor in Botany. His expertise is plant nomenclature and biodiversity conservation.

Author contributions: MGB: Conceptualization (equal); Data curation (equal); Formal analysis (lead); Funding acquisition (lead); Investigation (equal); Methodology (equal); Resources (lead); Visualization (lead); Writing – original draft (lead). SSK: Conceptualization (equal); Data curation (equal); Formal analysis (supporting); Investigation (equal); Methodology (equal); Project administration (equal); Validation (equal); Writing – review and editing (equal).

Acknowledgements: Authors are thankful to the principal Dr. Shankar Thopate and Dr. Kalpana Ahire for necessary facilities. Authors are thankful to Dr. Arun Chandore (principal, Rayat Shikshan Sanstha's Loknete Ramsheth Thakur ASC College, Mokhada), Dr. Kumar Vinod Gosavi (assistant professor, Gokhale Education Society's H.P.T. Arts and R.Y.K. Science College, Nashik) for confirming the identities of the grasses and sedges. Authors are grateful towards the colleagues of Radhabai Kale Mahila Mahavidyalaya, Ahilyanagar viz. Dr. Kaveri Sable, Dr. Anjali Khilari, MS. Rutuja Pansare and Dr. Rupali Endait for their support throughout the work. SSK thanks the Savitribai Phule Pune University, Pune, for awarding the ASPIRE Research Mentorship Grant.

INTRODUCTION

Ahilyanagar (formerly known as Ahmednagar) is a district located in the state of Maharashtra, India. It is located in the north-central part of the state. The district covers an area of around 17,048 km^2, making it one of the largest districts in Maharashtra. It has a varied landscape and vegetation, influenced by the semi-arid climate, geography, and seasonal rainfall. The region is characterized by a mix of dry deciduous forests, grasslands, and cultivated land. It experiences a semi-arid climate, with hot summers, a moderate monsoon, and mild winters. The average rainfall in the region ranges from 450–800 mm annually, primarily during the monsoon season (June–September). The dry conditions influence the type of vegetation found in the area.

With increasing urbanisation, there is an expansion of infrastructure, buildings, and roads. This has a significant impact on the environment, including vegetation. It also leads to the loss of natural habitats, resulting in the decline of native vegetation and the destruction of wildlife habitats. Increased pollution levels also have a negative effect on plant health. This leads to changes in plant phenology. Urbanisation has profound and often negative impacts on vegetation, but these impacts can be mitigated through thoughtful planning and conservation strategies. Efforts to preserve natural habitats, promote biodiversity, and reduce pollution can help protect and restore vegetation in urban areas. In recent years, studies focusing on urban ecology have developed rapidly (Celesti 2006). Many researchers have studied the flora of college campuses (Sanyal & Chattopadhyay 2014; Nerlekar et al. 2016; Khan et al. 2019; Dar 2020; Kadam et al. 2020; Naik 2020). Aher (2015) studied the floristic diversity of Parner Tahsil in Ahilyanagar. It was reported that there were 410 taxa belonging to 295 genera and 91 families, which indictaes the rich biodiversity of the Tahsil. The flora of the Radhabai Kale Mahila Mahavidyalaya campus has not been documented so far. Such documentation is essential for understanding the plant diversity of this urban green space and for providing baseline information for future ecological studies and conservation.

In cities, urban green spaces are of great importance because of the multiple ecosystem services they provide (Nehru et al. 2012). Radhabai Kale Mahila Mahavidyalaya (RKMM) is one such green space located in Ahilyanagar City. Therefore, the present study was undertaken to document the plant species occurring on the campus, assess their taxonomic diversity, record their native/non-native status and uses, and provide baseline information for future documentation and conservation of the college campus flora.

MATERIAL AND METHODS

Study site

Radhabai Kale Mahila Mahavidyalaya is a private urban-based government-aided educational institution established in 1989. The college is located in the city of Ahilyanagar, Maharashtra, India (19.104° N, 74.741° E) and is spread over 6.866 ac of land (Image 1).

Data collection

Frequent visits and surveys were undertaken in different seasons from January 2024–December 2024. The entire college campus, including the botanical garden, was surveyed and studied to record the different plant species. Plants were photographed with the help of a Vivo V21e 5G mobile phone (Images 3,4). The specimens were also collected to prepare herbarium specimens representing different families. These specimens are deposited in the herbarium of the Department of Botany, RKMM. Plants were identified using pertinent literature, viz., Cooke (1958); Pradhan & Singh (1999). Ornamental plants were identified using Bailey (1924). Nomenclature of the species was confirmed using online databases such as International Plant Names Index (IPNI), Plants of the World Online (POWO), and Tropicos.org. The angiosperm families in the present study have been arranged according to APG IV (2016). The genera and species are arranged alphabetically. A total of 325 species with their accepted names are listed in Table 1.

RESULT AND DISCUSSIONS

During the present study, a total of 325 species, including five infraspecific taxa belonging to 255 genera and 81 families, have been recorded. In the clade monocots, the families Asparagaceae Juss. and Poaceae Barnhart are dominant. Families such as Fabaceae Lindl., Asteraceae Bercht. & J. Presl, Euphorbiaceae Juss. and Apocynaceae Juss. are dominant in the clade Eudicots. Fabaceae is the dominant family with 24 species, followed by Asteraceae Bercht. & J.Presl (22), Euphorbiaceae Juss. (19), Apocynaceae Juss. (18), Asparagaceae Juss. (15) and Poaceae Barnhart (14) (Image 2).

As part of this total flora, non-angiosperm groups of plants such as pteridophytes and gymnosperms

Image 1. Satellite image of Radhabai Kale Mahila Mahavidyalaya, Ahilyanagar.

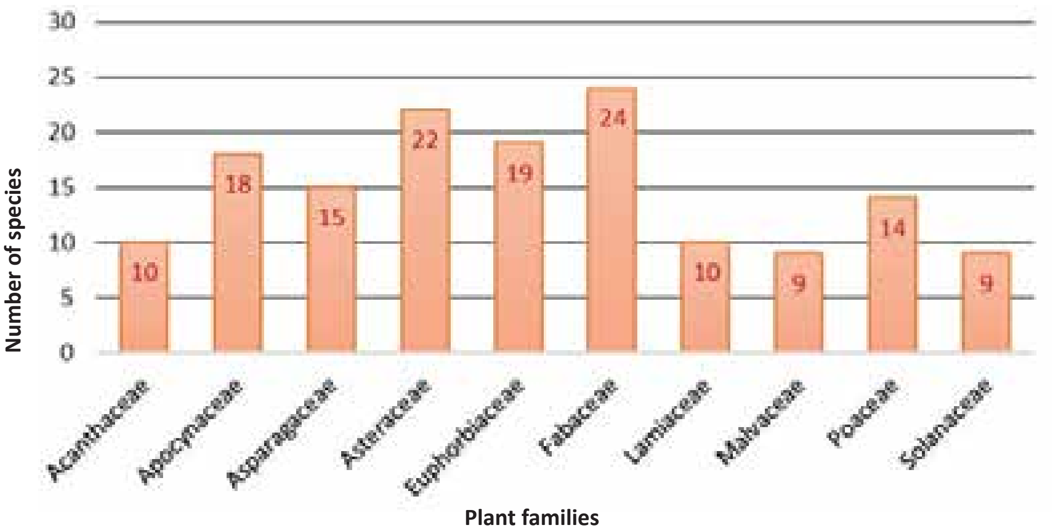

Image 2. Bar graph showing dominant families with their number of species.

were also recorded from the campus. Eight species of gymnosperms belonging to seven genera and four families were recorded. Three species of pteridophytes belonging to three genera and two families were recorded.

Out of the total 325 species recorded, 142 species were native to India, whereas 183 species were non-native (POWO). Most of the plants recorded during the

Table 1. Checklist of RKMM campus flora of Ahilyanagar, Maharashtra.

	Botanical name	Native/ Non-native	Uses
A.	Pteridophytes		
Pteridaceae E.D.M. Kirchn.			
1	*Adiantum capillus-veneris* L.	Native	Ornamental
2	*Pteris vittata* L.	Native	Ornamental
Salviniaceae Martinov			
3	*Salvinia molesta* D.Mitch.	Non-native	Ornamental
B.	Gymnospermae		
Araucariaceae Henkel & W.Hochst.			
4	*Araucaria columnaris* (G.Forst.) Hook.	Non-native	Ornamental
Cycadaceae Pers.			
5	*Cycas circinalis* L.	Native	Ornamental
6	*Cycas rumphii* Miq.	Non-native	Ornamental
Cupressaceae Gray			
7	*Cupressus* sp.	Non-native	Ornamental
8	*Juniperus chinensis* L.	Non-native	Ornamental
9	*Platycladus orientalis* (L.) Franco	Non-native	Ornamental
Zamiaceae Horan.			
10	*Dioon spinulosum* Dyer ex Eichl.	Non-native	Ornamental
11	*Zamia furfuracea* L.f. ex Aiton	Non-native	Ornamental
C.	Angiosperms		
Nymphaeaceae Salisb.			
12	*Nymphaea nouchali* Burm.f.	Native	Ornamental
13	*Nymphaea pubescens* Willd.	Native	Ornamental
Piperaceae Giseke			
14	*Piper betle* L.	Non-native	Medicinal
Magnoliaceae Juss.			
15	*Magnolia champaca* (L.) Baill. ex Pierre	Native	Ornamental
Annonaceae Juss.			
16	*Annona reticulata* L.	Non-native	Planted for its edible fruits
17	*Annona squamosa* L.	Non-native	Planted for its edible fruits
18	*Artabotrys hexapetalus* (L.f.) Bhandari	Native	Ornamental
19	*Monoon longifolium* (Sonn.) B.Xue & R.M.K.Saunders	Native	Avenue tree
Araceae Juss.			
20	*Caladium bicolor* (Aiton) Vent.	Non-native	Ornamental
21	*Dieffenbachia seguine* (Jacq.) Schott	Non-native	Ornamental
22	*Epipremnum aureum* (Linden & André) G.S.Bunting	Non-native	Ornamental
23	*Sauromatum venosum* (Aiton) Kunth	Native	Ornamental
24	*Syngonium podophyllum* Schott.	Non-native	Ornamental
25	*Zamioculcas zamiifolia* (G.Lodd.) Engl.	Non-native	Ornamental
Hydrocharitaceae Juss.			
26	*Hydrilla verticillata* (L.f.) Royle	Native	Phytoremediation
Dioscoreaceae R.Br.			
27	*Dioscorea alata* L.	Native	Medicinal
28	*Dioscorea bulbifera* L.	Native	Medicinal
Orchidaceae Juss.			
29	*Aerides maculosa* Lindl.	Native	Ornamental
30	*Crepidium resupinatum* (G.Forst.) Szlach.	Non-native	Ornamental
31	*Cymbidium aloifolium* (L.) Sw.	Native	Ornamental
Asphodelaceae Juss.			
32	*Aloe vera* (L.) Burm.f.	Non-native	Medicinal
33	*Haworthiopsis attenuata* var. *radula* (Jacq.) G.D.Rowley	Non-native	Ornamental
Amaryllidaceae J.St.-Hil.			
34	*Allium sativum* L.	Non-native	Medicinal
35	*Crinum asiaticum* L.	Native	Ornamental
36	*Hymenocallis caribaea* (L.) Herb.	Non-native	Ornamental
37	*Hymenocallis caroliniana* (L.) Herb.	Non-native	Ornamental
38	*Pancratium maritimum* L.	Non-native	Ornamental
39	*Scadoxus multiflorus* (Martyn) Raf.	Non-native	Ornamental
40	*Zephyranthes candida* Herb.	Non-native	Ornamental
41	*Zephyranthes carinata* Herb.	Non-native	Ornamental
42	*Zephyranthes citrina* Baker	Non-native	Ornamental
Asparagaceae Juss.			
43	*Agave americana* L.	Non-native	Ornamental
44	*Agave amica* (Medik.) Thiede & Govaerts	Non-native	Ornamental
45	*Asparagus adscendens* Roxb.	Native	Ornamental
46	*Asparagus densiflorus* (Kunth) Jessop	Non-native	Ornamental
47	*Asparagus gonoclados* Baker	Native	Ornamental
48	*Asparagus setaceus* (Kunth) Jessop	Non-native	Ornamental
49	*Chlorophytum comosum* (Thunb.) Jacques	Non-native	Ornamental
50	*Cordyline fruticosa* (L.) A.Chev.	Non-native	Ornamental
51	*Dracaena angolensis* (Welw. ex Carrière) Byng & Christenh.	Non-native	Ornamental
52	*Dracaena angustifolia* (Medik.) Roxb.	Non-native	Ornamental
53	*Dracaena fragrans* (L.) Ker Gawl.	Non-native	Ornamental
54	*Dracaena reflexa* Lam.	Non-native	Ornamental

	Botanical name	Native/ Non-native	Uses
55	*Dracaena reflexa* var. *angustifolia* Baker	Non-native	Ornamental
56	*Dracaena trifasciata* (Prain) Mabb.	Non-native	Ornamental
57	*Furcraea foetida* (L.) Haw.	Non-native	Ornamental
Arecaceae Bercht. & J.Presl			
58	*Areca catechu* L.	Non-native	Planted for its edible fruits
59	*Caryota urens* L.	Native	Ornamental
60	*Chrysalidocarpus lutescens* H.Wendl.	Non-native	Ornamental
61	*Cocos nucifera* L.	Non-native	Planted for its edible fruits
62	*Hyophorbe lagenicaulis* (L.H.Bailey) H.E.Moore	Non-native	Ornamental
63	*Phoenix sylvestris* (L.) Roxb.	Native	Ornamental
64	*Roystonea regia* (Kunth) O.F.Cook	Non-native	Ornamental
65	*Wodyetia bifurcata* A.K.Irvine	Non-native	Ornamental
Commelinaceae Mirb.			
66	*Callisia repens* (Jacq.) L.	Non-native	Ornamental
67	*Commelina benghalensis* L.	Native	Forage
68	*Cyanotis fasciculata* (B.Heyne ex Roth) Schult. & Schult.f.	Native	Medicinal
69	*Tradescantia pallida* (Rose) D.R.Hunt	Non-native	Ornamental
70	*Tradescantia spathacea* Sw.	Non-native	Ornamental
Pontederiaceae Kunth			
71	*Pontederia crassipes* Mart.	Non-native	Phytoremediation
Heliconiaceae Vines			
72	*Heliconia rostrata* Ruiz & Pav.	Non-native	Ornamental
Musaceae Juss.			
73	*Musa paradisiaca* L.	Non-native	Planted for its edible fruits
Cannaceae Juss.			
74	*Canna generalis* L.H.Bailey	Non-native	Ornamental
Zingiberaceae Martinov			
75	*Curcuma longa* L.	Native	Medicinal
Cyperaceae Juss.			
76	*Cyperus alternifolius* L.	Non-native	Ornamental
77	*Cyperus dubius* Rottb.	Native	Forage
78	*Cyperus rotundus* L.	Native	Medicinal
79	*Fimbristylis ferruginea* (L.) Vahl	Native	Fibre-yielding
Poaceae Barnhart			
80	*Cenchrus pedicellatus* (Trin.) Morrone	Native	Fodder
81	*Chloris barbata* Sw.	Native	Medicinal
82	*Coix lacryma-jobi* L.	Native	Ornamental
83	*Cymbopogon citratus* (DC.) Stapf	Native	Medicinal
84	*Cynodon dactylon* (L.) Pers.	Native	Medicinal

	Botanical name	Native/ Non-native	Uses
85	*Dactyloctenium aegyptium* (L.) Willd.	Native	Forage
86	*Dendrocalamus strictus* (Roxb.) Nees	Native	Timber-yielding
87	*Digitaria ciliaris* (Retz.) Koeler	Native	Forage
88	*Dinebra retroflexa* (Vahl) Panz.	Native	Forage
89	*Echinochloa colona* (L.) Link.	Native	Fodder
90	*Eleusine indica* (L.) Gaertn.	Native	Forage
91	*Eragrostis gangetica* (Roxb.) Steud.	Native	Forage
92	*Eragrostis viscosa* (Retz.) Trin.	Native	Forage
93	*Setaria intermedia* Roem. & Schult	Native	Fodder
Papaveraceae Juss.			
94	*Argemone mexicana* L.	Non-native	Medicinal
Menispermaceae Juss.			
95	*Tinospora cordifolia* (Willd.) Hook.f. & Thomson	Native	Medicinal
Proteaceae Juss.			
96	*Grevillea robusta* A.Cunn. ex R.Br.	Non-native	Ornamental
Crassulaceae J.St.-Hil.			
97	*Crassula ovata* (Mill.) Druce	Non-native	Ornamental
98	*Kalanchoe pinnata* (Lam.) Pers.	Non-native	Ornamental
Vitaceae Juss.			
99	*Cissus quadrangularis* (L.) Wall. ex Wight	Native	Medicinal
100	*Cissus rotundifolia* Lam.	Non-native	Medicinal
Zygophyllaceae R.Br.			
101	*Tribulus terrestris* L.	Native	Medicinal
Fabaceae Lindl.			
102	*Abrus precatorius* L.	Native	Ornamental
103	*Acacia auriculiformis* A.Cunn. ex Benth	Non-native	Ornamental
104	*Bauhinia purpurea* L.	Native	Ornamental
105	*Bouffordia dichotoma* (Willd.) H.Ohashi & K.Ohashi	Native	Forage
106	*Caesalpinia pulcherrima* (L.) Sw.	Non-native	Ornamental
107	*Cassia fistula* L.	Native	Ornamental
108	*Clitoria ternatea* L.	Non-native	Ornamental
109	*Crotalaria hebecarpa* (DC.) Rudd	Native	Medicinal
110	*Crotalaria juncea* L.	Native	Ornamental
111	*Dalbergia sissoo* Roxb. ex DC.	Native	Ornamental
112	*Delonix regia* (Bojer ex Hook.) Raf.	Non-native	Ornamental
113	*Indigofera cordifolia* B. Heyne ex Roth	Native	Forage
114	*Lysiloma latisiliquum* (L.) Benth.	Non-native	Ornamental
115	*Mimosa pudica* L.	Non-native	Ornamental

	Botanical name	Native/ Non-native	Uses
116	*Pithecellobium dulce* (Roxb.) Benth.	Non-native	Ornamental
117	*Prosopis cineraria* (L.) Druce	Native	Ornamental
118	*Rhynchosia minima* (L.) DC.	Native	Fodder
119	*Samanea saman* (Jacq.) Merr.	Non-native	Ornamental
120	*Senegalia megaladena* (Desv.) Maslin, Seigler & Ebinger	Native	Insecticidal
121	*Senna siamea* (Lam.) H.S.Irwin & Barneby	Non-native	Ornamental
122	*Senna tora* (L.) Roxb.	Non-native	Medicinal
123	*Senna uniflora* (Mill.) H.S.Irwin & Barneby	Non-native	Medicinal
124	*Tamarindus indica* L.	Non-native	Planted for its edible fruits
125	*Vigna dalzelliana* (Kuntze) Verdc.	Native	Forage
Rosaceae Juss.			
126	*Rosa indica* L.	Non-native	Ornamental
Rhamnaceae Juss.			
127	*Ziziphus mauritiana* Lam.	Native	Planted for its edible fruits
Moraceae Gaudich.			
128	*Ficus benghalensis* L.	Native	Ornamental
129	*Ficus carica* L.	Non-native	Planted for its edible fruits
130	*Ficus holosericea* Schott	Non-native	Ornamental
131	*Ficus racemosa* L.	Native	Ornamental
132	*Ficus religiosa* L.	Native	Ornamental
Casuarinaceae R.Br.			
133	*Casuarina equisetifolia* L.	Native	Ornamental
Cucurbitaceae Juss.			
134	*Cucumis maderaspatanus* L.	Native	Vegetable
135	*Cucumis melo* L.	Native	Planted for its edible fruits
136	*Lagenaria siceraria* (Molina) Standl.	Non-native	Vegetable
137	*Momordica charantia* L.	Native	Vegetable
Oxalidaceae R.Br.			
138	*Oxalis corniculata* L.	Native	Medicinal
Putranjivaceae Meisn.			
139	*Putranjiva roxburghii* Wall.	Native	Ornamental
Malpighiaceae Juss.			
140	*Galphimia gracilis* Bartl.	Non-native	Ornamental
Passifloraceae Juss. ex Roussel			
141	*Passiflora foetida* L.	Non-native	Ornamental
Euphorbiaceae Juss.			
142	*Acalypha indica* L.	Native	Medicinal
143	*Acalypha wilkesiana* Müll. Arg.	Non-native	Ornamental
144	*Codiaeum variegatum* (L.) Rumph. ex A.Juss.	Non-native	Ornamental
145	*Croton bonplandianus* Baill.	Non-native	Ornamental

	Botanical name	Native/ Non-native	Uses
146	*Euphorbia cyathophora* Murray	Non-native	Ornamental
147	*Euphorbia heterophylla* L.	Non-native	Medicinal
148	*Euphorbia heyneana* Spreng.	Native	Medicinal
149	*Euphorbia hirta* L.	Non-native	Medicinal
150	*Euphorbia lactea* Haw.	Non-native	Ornamental
151	*Euphorbia milii* Des Moul.	Non-native	Ornamental
152	*Euphorbia pulcherrima* Willd. ex Klotzsch	Non-native	Ornamental
153	*Euphorbia tirucalli* L.	Non-native	Ornamental
154	*Euphorbia tithymaloides* L.	Non-native	Ornamental
155	*Euphorbia umbellata* (Pax) Bruyns	Non-native	Ornamental
156	*Jatropha curcas* L.	Non-native	Ornamental
157	*Jatropha gossypiifolia* L.	Non-native	Medicinal
158	*Jatropha integerrima* Jacq.	Non-native	Ornamental
159	*Jatropha podagrica* Hook.	Non-native	Ornamental
160	*Ricinus communis* L.	Non-native	Oil-yielding
Phyllanthaceae Martinov			
161	*Phyllanthus acidus* (L.) Skeels	Non-native	Planted for its edible fruits
162	*Phyllanthus amarus* Schumach. & Thonn.	Non-native	Medicinal
163	*Phyllanthus emblica* L.	Native	Planted for its edible fruits
Combretaceae R.Br.			
164	*Combretum indicum* (L.) De Filipps	Native	Ornamental
165	*Terminalia arjuna* (Roxb. ex. DC.) Wight & Arn.	Native	Medicinal
166	*Terminalia bellirica* (Gaertn.) Roxb.	Native	Medicinal
167	*Terminalia chebula* Retz.	Native	Medicinal
Lythraceae J.St.-Hil.			
168	*Cuphea hyssopifolia* Kunth	Non-native	Ornamental
169	*Lawsonia inermis* L.	Native	Dye-yielding
170	*Punica granatum* L.	Non-native	Planted for its edible fruits
Myrtaceae Juss.			
171	*Eucalyptus globulus* Labill.	Non-native	Avenue tree
172	*Melaleuca citrina* (Curtis) Dum. Cours.	Non-native	Ornamental
173	*Psidium guajava* L.	Non-native	Planted for its edible fruits
174	*Syzygium cumini* (L.) Skeels	Native	Planted for its edible fruits
Anacardiaceae R.Br.			
175	*Mangifera indica* L.	Native	Planted for its edible fruits
Sapindaceae Juss.			
176	*Cardiospermum halicacabum* L.	Native	Medicinal
177	*Sapindus trifoliatus* L.	Native	Medicinal
Rutaceae Juss.			
178	*Aegle marmelos* (L.) Corrêa	Native	Medicinal

	Botanical name	Native/ Non-native	Uses
179	*Bergera koenigii* L.	Native	Edible
180	*Citrus × limon* (L.) Osbeck	Non-native	Edible
181	*Limonia acidissima* L.	Native	Edible
182	*Ruta graveolens* L.	Non-native	Medicinal
Meliaceae Juss.			
183	*Azadirachta indica* A.Juss.	Native	Medicinal
Muntingiaceae C.Bayer et al.			
184	*Muntingia calabura* L.	Non-native	Edible
Malvaceae Juss.			
185	*Abutilon bidentatum* (Hochst.) A. Rich.	Native	Medicinal
186	*Ceiba pentandra* (L.) Gaertn.	Non-native	Fibre-yielding
187	*Corchorus olitorius* L.	Native	Fibre-yielding
188	*Dombeya burgessiae* Gerrard ex Harv.	Non-native	Ornamental
189	*Hibiscus × rosa-sinensis* L.	Non-native	Ornamental
190	*Hibiscus × rosa-sinensis* L. 'Red Dragon'	Non-native	Ornamental
191	*Hibiscus sabdariffa* L.	Non-native	Ornamental
192	*Malvastrum coromandelianum* (L.) Garcke	Non-native	Medicinal
193	*Sida angustifolia* Mill.	Native	Medicinal
Moringaceae Martinov			
194	*Moringa oleifera* Lam.	Native	Vegetable
Caricaceae Dumort.			
195	*Carica papaya* L.	Non-native	Planted for its edible fruits
Brassicaceae Burnett			
196	*Brassica juncea* (L.) Czern.	Non-native	Oil-yielding
Santalaceae R.Br.			
197	*Santalum album* L.	Non-native	Medicinal
Plumbaginaceae Juss.			
198	*Plumbago zeylanica* L.	Native	Ornamental
Amaranthaceae Juss.			
199	*Achyranthes aspera* L.	Native	Medicinal
200	*Alternanthera ficoidea* (L.) P.Beauv.	Non-native	Medicinal
201	*Alternanthera pungens* Kunth	Non-native	Medicinal
202	*Amaranthus viridis* L.	Non-native	Vegetable
203	*Digera muricata* (L.) Mart.	Native	Medicinal
204	*Gomphrena globosa* L.	Non-native	Ornamental
205	*Spinacia oleracea* L.	Non-native	Vegetable
Aizoaceae Martinov			
206	*Trianthema portulacastrum* L.	Native	Medicinal
Nyctaginaceae Juss.			
207	*Boerhavia erecta* L.	Non-native	Medicinal
208	*Boerhavia diffusa* L.	Native	Medicinal
209	*Bougainvillea spectabilis* Willd.	Non-native	Ornamental

	Botanical name	Native/ Non-native	Uses
210	*Mirabilis jalapa* L.	Non-native	Ornamental
Molluginaceae Bartl.			
211	*Glinus lotoides* L.	Native	Medicinal
Basellaceae Raf.			
212	*Basella alba* L.	Native	Ornamental
Portulacaceae Juss.			
213	*Portulaca grandiflora* Hook.	Non-native	Ornamental
214	*Portulaca oleracea* L.	Non-native	Ornamental
215	*Portulaca umbraticola* Kunth.	Non-native	Ornamental
Cactaceae Juss.			
216	*Cereus spegazzinii* F.A.C.Weber	Non-native	Ornamental
217	*Epiphyllum oxypetalum* (DC.) Haw.	Non-native	Ornamental
218	*Nyctocereus serpentinus* (Lag. & Rodr.) Britton & Rose	Non-native	Ornamental
219	*Opuntia elatior* Mill.	Non-native	Ornamental
220	*Opuntia microdasys* (Lehm.) Pfeiff.	Non-native	Ornamental
Lecythidaceae A.Rich.			
221	*Couroupita guianensis* Aubl.	Non-native	Ornamental
Sapotaceae Juss.			
222	*Manilkara zapota* (L.) P.Royen	Non-native	Planted for its edible fruits
223	*Mimusops elengi* L.	Native	Ornamental
Rubiaceae Juss.			
224	*Gardenia jasminoides* J.Ellis	Non-native	Ornamental
225	*Hamelia patens* Jacq.	Non-native	Ornamental
226	*Ixora coccinea* L.	Native	Ornamental
227	*Mussaenda erythrophylla* Schumach. & Thonn.	Non-native	Ornamental
228	*Neolamarckia cadamba* (Roxb.) Bosser	Native	Ornamental
229	*Oldenlandia corymbosa* L.	Native	Medicinal
230	*Pentas lanceolata* (Forssk.) Deflers	Non-native	Ornamental
Apocynaceae Juss.			
231	*Adenium obesum* (Forssk.) Roem. & Schult.	Non-native	Ornamental
232	*Allamanda blanchetii* A.DC.	Non-native	Ornamental
233	*Allamanda cathartica* L.	Non-native	Ornamental
234	*Alstonia scholaris* (L.) R.Br.	Native	Ornamental
235	*Asclepias curassavica* L.	Non-native	Ornamental
236	*Calotropis procera* (Aiton) W.T.Aiton	Native	Medicinal
237	*Carissa macrocarpa* (Eckl.) A.DC.	Non-native	Planted for its edible fruits
238	*Cascabela thevetia* (L.) Lippold	Non-native	Ornamental
239	*Catharanthus roseus* (L.) G.Don	Non-native	Ornamental
240	*Cryptostegia grandiflora* Roxb. ex R.Br.	Non-native	Ornamental
241	*Nerium oleander* L.	Native	Ornamental

	Botanical name	Native/ Non-native	Uses
242	*Pentatropis capensis* (L.f.) Bullock	Native	Ornamental
243	*Pergularia daemia* (Forssk.) Chiov.	Native	Ornamental
244	*Plumeria alba* L.	Non-native	Ornamental
245	*Plumeria pudica* Jacq.	Non-native	Ornamental
246	*Plumeria rubra* L.	Non-native	Ornamental
247	*Rauvolfia tetraphylla* L.	Non-native	Medicinal
248	*Tabernaemontana divaricata* (L.) R.Br. ex Roem. & Schult.	Native	Ornamental
Boraginaceae Juss.			
249	*Cordia sinensis* Lam.	Native	Medicinal
250	*Euploca ovalifolia* (Forssk.) Diane & Hilger	Native	Medicinal
251	*Trichodesma inaequale* Edgew.	Native	Medicinal
252	*Trichodesma zeylanicum* (Burm.f.) R.Br.	Native	Medicinal
Convolvulaceae Juss.			
253	*Evolvulus alsinoides* (L.) L.	Native	Ornamental
254	*Ipomoea nil* (L.) Roth	Non-native	Ornamental
255	*Ipomoea obscura* (L.) Ker Gawl.	Native	Ornamental
256	*Ipomoea triloba* L.	Non-native	Ornamental
257	*Rivea wightiana* R.R.Mill	Native	Ornamental
Solanaceae Juss.			
258	*Capsicum annuum* L.	Non-native	Vegetable
259	*Cestrum nocturnum* L.	Non-native	Ornamental
260	*Petunia atkinsiana* (Sweet) D.Don ex W.H.Baxter	Non-native	Ornamental
261	*Solanum americanum* Mill.	Non-native	Medicinal
262	*Solanum diphyllum* L.	Non-native	Medicinal
263	*Solanum lycopersicum* L.	Non-native	Vegetable
264	*Solanum melongena* L.	Native	Vegetable
265	*Solanum tuberosum* L.	Non-native	Vegetable
266	*Withania somnifera* (L.) Dunal	Native	Medicinal
Oleaceae Hoffmanns. & Link			
267	*Jasminum laurifolium* var. *laurifolium* Roxb. ex Hornem.	Native	Ornamental
268	*Jasminum officinale* L.	Non-native	Ornamental
269	*Jasminum sambac* (L.) Aiton	Native	Ornamental
270	*Nyctanthes arbor-tristis* L.	Native	Ornamental
Plantaginaceae Juss.			
271	*Angelonia salicariifolia* Bonpl.	Non-native	Ornamental
Scrophulariaceae Juss.			
272	*Leucophyllum frutescens* (Berland.) I.M.Johnst.	Non-native	Ornamental
273	*Verbascum coromandelianum* (Vahl) Hub.-Mor.	Native	Medicinal

	Botanical name	Native/ Non-native	Uses
Acanthaceae Juss.			
274	*Asystasia gangetica* (L.) T.Anderson	Native	Ornamental
275	*Barleria cristata* L.	Native	Ornamental
276	*Barleria cuspidata* F.Heyne ex Nees	Native	Ornamental
277	*Barleria prionitis* L.	Native	Ornamental
278	*Crossandra infundibuliformis* (L.) Nees	Native	Ornamental
279	*Justicia adhatoda* L.	Native	Medicinal
280	*Justicia brandegeeana* Wassh. & L.B.Sm.	Non-native	Ornamental
281	*Pseuderanthemum maculatum* (G.Lodd.) I.M.Turner	Non-native	Ornamental
282	*Rostellularia diffusa* (Willd.) Nees	Native	Medicinal
283	*Ruellia tuberosa* L.	Non-native	Ornamental
Bignoniaceae Juss.			
284	*Dolichandra unguis-cati* (L.) L.G.Lohmann	Non-native	Ornamental
285	*Jacaranda mimosifolia* D.Don	Non-native	Ornamental
286	*Spathodea campanulata* P.Beauv.	Non-native	Ornamental
287	*Tecoma stans* (L.) Juss. ex Kunth	Non-native	Ornamental
288	*Tecomaria capensis* (Thunb.) Spach	Non-native	Ornamental
Verbenaceae J.St.Hil.			
289	*Duranta erecta* L.	Non-native	Ornamental
290	*Lantana camara* L.	Non-native	Medicinal
291	*Phyla nodiflora* (L.) Greene	Native	Ornamental
292	*Verbena tenera* Spreng.	Non-native	Ornamental
Lamiaceae Martinov			
293	*Callicarpa tomentosa* (L.) L.	Native	Ornamental
294	*Clerodendrum thomsoniae* Balf.f.	Non-native	Ornamental
295	*Coleus scutellarioides* (L.) Benth.	Non-native	Ornamental
296	*Gmelina arborea* Roxb. ex Sm.	Native	Ornamental
297	*Mentha arvensis* L.	Native	Medicinal
298	*Mesosphaerum suaveolens* (L.) Kuntze	Non-native	Medicinal
299	*Ocimum basilicum* L.	Native	Medicinal
300	*Ocimum tenuiflorum* L.	Native	Medicinal
301	*Tectona grandis* L.f.	Native	Timber-yielding
302	*Vitex leucoxylon* L.f.	Native	Medicinal
Asteraceae Bercht. & J.Presl			
303	*Ageratum conyzoides* L.	Non-native	Medicinal
304	*Bidens biternata* (Lour.) Merr. & Sherff	Native	Medicinal
305	*Blumea axillaris* (Lam.) Dc.	Native	Medicinal
306	*Blumea obliqua* (L.) Druce	Native	Medicinal
307	*Blumea sinuata* (Lour.) Merr.	Native	Medicinal

	Botanical name	Native/ Non-native	Uses
308	*Blumea virens* DC.	Native	Medicinal
309	*Calyptocarpus vialis* Less.	Non-native	Cover crop
310	*Chrysanthemum indicum* L.	Non-native	Ornamental
311	*Crossostephium chinense* (L.) Makino	Non-native	Ornamental
312	*Cyanthillium cinereum* (L.) H.Rob.	Native	Medicinal
313	*Eclipta prostrata* (L.) L.	Non-native	Medicinal
314	*Erigeron bonariensis* L.	Non-native	Medicinal
315	*Helianthus annuus* L.	Non-native	Ornamental
316	*Jacobaea maritima* (L.) Pelser & Meijden	Non-native	Ornamental
317	*Kleinia grandiflora* (DC.) N.Rani	Native	Ornamental
318	*Launaea procumbens* (Roxb.) Ramayya & Rajagopal	Native	Medicinal
319	*Parthenium hysterophorus* L.	Non-native	Herbicidal
320	*Pseudoconyza viscosa* (Mill.) D'Arcy	Native	Medicinal
321	*Sonchus brachyotus* DC.	Native	Medicinal
322	*Sphagneticola trilobata* (L.) Pruski	Non-native	Ornamental
323	*Tithonia rotundifolia* (Mill.) S.F.Blake	Non-native	Ornamental
324	*Tridax procumbens* L.	Non-native	Medicinal
Araliaceae Juss.			
325	*Polyscias balfouriana* (Andre) L.H.Bailey	Non-native	Ornamental

investigation are planted with a view of landscaping and academic purposes. The recorded plants show a wide range of utility; they include ornamental, medicinal, and edible species. In addition to the cultivated species, 76 species of weeds were also recorded during the present study. The college harbours a wide range of angiosperms, which adds to the green space of the city. The botanical garden contributes to the green cover of the college.

CONCLUSION

This study records 325 species of flowering plants within the college campus which highlights the noteworthy floristic diversity existing in this semi-urban environment. Such species richness highlights the role of a college campus as a repository of regional biodiversity. Furthermore, the recorded plant diversity provides a baseline for future ecological monitoring, enabling assessments of floristic changes in response to anthropogenic pressures and climatic variability. Other than its ecological significance, the campus flora serves as a living laboratory for the students of life sciences. This provides an opportunity for education, interdisciplinary research, and creating an awareness regarding the environment among the students. Thus, this study highlights the necessity of preserving plant diversity as an integral component of urban biodiversity conservation policy.

REFERENCES

Aher, S.K. (2015). Floristic diversity assessment of Parner Tahsil, Maharashtra (India). Indian Journal of Applied & Pure Biology 30(2): 123–130.

APG IV (2016). An update of the angiosperm phylogeny group classification for the orders

and the families of flowering plants: APG IV. Botanical Journal of Linnean Society 181(1): 1–20. https://doi.org/10.1111/boj.12385

Bailey, L.H. (1924). Manual of Cultivated Plants: A Flora for the Identification of the Most Common or Significant Species of Plants Grown in the Continental United States and Canada, for Food, Ornament, Utility, and General Interest, Both in the Open and Under Glass. MacMillan, New York, 851 pp.

Celesti, G.L. et al. (2006). Determinants of native and alien species richness in the urban flora of Rome. Diversity and Distributions 12(5): 490–501. https://doi.org/10.1111/j.1366-9516.2006.00282.x

Cooke, T. (1958). *The Flora of the Presidency of Bombay*. Vol. I–III. Reprint ed. Botanical Survey of India, Calcutta, India, xiv + 632 pp; 615 pp & 649 pp.

Dar, M.H. (2020). Floristic diversity at Hamedia College Campus of Bhopal, Madhya Pradesh. Our Heritage 67(5): 520–528.

Kadam, S.S. et al. (2020). Campus flora of Dr DY Patil Arts, Commerce and Science College, Pune, India. Studies in Indian Place Names 40(50): 3480–3486.

Khan, R.Y. et al. (2019). Campus flora of Shri. Shivaji College, Kandhar, District Nanded, Maharashtra. Think India Journal 22(31): 129–142.

Naik, S.S. (2020). Floristic studies on the Deccan College Campus, Pune. Bulletin of the Deccan College 80: 67–81.

Nehru, P. et al. (2012). Angiosperms of Nanmangalam Reserve Forest, an urban forest in metropolitan Chennai, India. Check List 8: 057–076. https://doi.org/10.15560/8.1.057

Nerlekar, A.N. et al. (2016). Flora of Fergusson College campus, Pune, India: monitoring changes over half a century. Journal of Threatened Taxa 8(2): 8452–8487. https://doi.org/10.11609/jott.1950.8.2.8452-8487

POWO (2024). Plants of the World Online. Facilitated by the Royal Botanic Gardens, Kew. Published on the Internet. https://powo.science.kew.org/. Accessed on 30.vi.2024.

Pradhan, S.G. & N.P. Singh (1999). Flora of Ahmednagar District (Maharashtra). Botanical Survey of India, Western Circle, Pune, 707 pp.

Sanyal, S. & D. Chattopadhyay (2014). Angiospermic flora of Bethune College Campus, Kolkata, West Bengal. Heritage 1: 133–142.

Image 3. a—*Nymphaea nouchali* Burm.f. | b—*Nymphaea pubescens* Willd. | c—*Magnolia champaca* (L.) Baill. ex Pierre | d—*Artabotrys hexapetalus* (L.f.) Bhandari | e—*Cymbidium aloifolium* (L.) Sw. | f—*Commelina benghalensis* L. | g—*Abrus precatorius* L. | h—*Bauhinia purpurea* L. | i—*Rhynchosia minima* (L.) DC. © Bhagwat M.G.

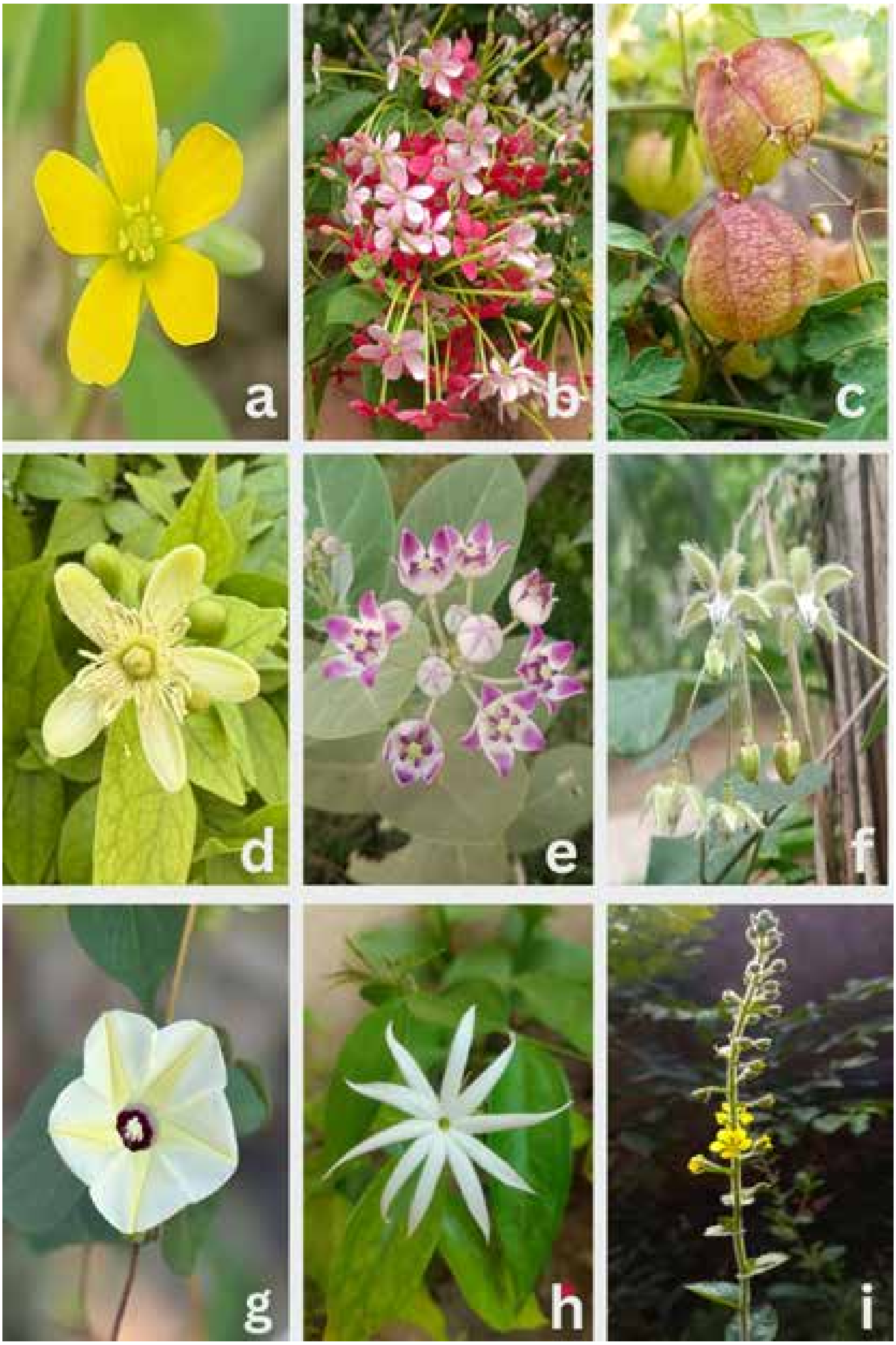

Image 4. a—*Oxalis corniculata* L. | b—*Combretum indicum* (L.) De Filipps | c— *Cardiospermum halicacabum* L. | d—*Aegle marmelos* (L.) Corrêa | e—*Calotropis procera* (Aiton) W.T.Aiton | f—*Pergularia daemia* (Forssk.) Chiov. | g—*Ipomoea obscura* (L.) Ker Gawl. | h—*Jasminum laurifolium* var. *laurifolium* Roxb. ex Hornem | i—*Verbascum coromandelianum* (Vahl) Hub. Mor. © Bhagwat M.G.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 August 2026 | 18(8): 29532–29543

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

https://doi.org/10.11609/jott.10518.18.8.29532-29543

#10518 | Received 10 March 2026 | Final received 19 June 2026 | Finally accepted 20 July 2026

REVIEW

Exploring the agarwood trade in India and its promising horizon

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Abstract: Agarwood, often referred as "liquid gold," is a valuable aromatic resinous substance with longstanding significance in cultural and religious practices, being utilized in perfumes, incense, medicines, and funeral pyres in some communities. Agarwood is one of the major cash crops in northeastern India, and plays a vital role in the livelihood of local people. The commonest cultivated agarwood source is *Aquilaria malaccensis* Lam., and we found that large quantities of *Aquilaria malaccensis*, and small quantities of *Aquilaria crasna* and *Aquilaria filaria* were also imported and re-exported after value addition. Agarwood is listed in Appendix II of the CITES, hence its international trade is regulated by the CITES Management Authority. However, few instances of proper export with a CITES permit are observed despite there being an export quota since 2021. At the same time, the ongoing monopoly in the Agarwood industry and informal trade is adversely impacting Agarwood cultivation and trade in India. A lack of knowledge of government policies, marketing, CITES regulations, and procedures for obtaining CITES permits is contributing to market inefficiency. India has a significant gap between Agarwood production capacity and actual exports. This presents a strong opportunity to shift from a re-export hub to a primary exporter. This article aims to inform stakeholders at all levels about the production and consumption of Agarwood in India, trade factors associated with its derivatives in the global market, and trade issues arising from restrictions, government policies and regulations in India.

Keywords: *Aquilaria malaccensis,* artificial inoculation, CITES, country of origin (CoO), export, illegal logging, import, legal procurement certificate (LPC), non-detrimental findings (NDFs), livelihoods, policy, re-export, smuggling.

Editor: Anonymity requested.

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

Citation: Girisha, H.V., A. Maletha, S.P. Goyal, M. Tangjang, A. Bhattacharjee, S. Chakraborty, M.R.R. Layola, S. Sardar, S. Bandyopadhyay, B. Mallick, O. Chakraborty, S. Sengupta, T. Shil, S. Chakraborty, R. Shaw & F. Banu (2026). Exploring the agarwood trade in India and its promising horizon. *Journal of Threatened Taxa* 18(8): 29532–29543. https://doi.org/10.11609/jott.10518.18.8.29532-29543

Funding: Wildlife Division, MoEF& CC, Govt. India.

Competing interests: The authors declare no competing interests.

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

Acknowledgements: We sincerely thank the MoEF&CC (Wildlife Division), GoI, New Delhi, for financial support under the project, entitled 'Non-detriment Findings (NDFs) of *Aquilaria malaccensis* Lam. (Agarwood) in India'. We are grateful to senior officials of MoEF&CC, Shri S.P. Yadav (IFS), Shri R. Raghu Prasad (IFS), Shri Rakesh Kumar Jagenia (IFS), Shri C. Sasikumar, technical officer, and Shri Prasenjeet Navgire, technical expert (Consultant), CITES Cell, for their immense support. We sincerely thank Director, BSI, Kolkata for his encouragement and technical support . Also, thanks to Dr R.K. Gupta, scientist-in-charge, Central National Herbarium (CNH), BSI, Howrah. The scientist-in-charge of BSI Eastern Regional Centre (ERC), Shillong, Arunachal Pradesh Regional Centre (APRC), Itanagar, BSI Deccan Regional Centre (DRC), Telangana are thankfully acknowledged for extending help.

INTRODUCTION

Agarwood, also known as 'Gaharu' or 'Oud', is an aromatic resinous product obtained from the heartwood of infected trees of the genus *Aquilaria* Lam. and *Gyrinops* Gaertn. (Thymalaeceae). Agarwood, often referred to as 'liquid gold', is cherished for its fragrance and is utilized in perfumes, incense, and medicines. It has also gained importance in cultural and religious practices, and is utilized by different communities in funeral rites (Chakrabarty et al. 1994; Yaacob 1999). The major commercial product derived from Agarwood are resinous wood chips and agarwood essential oil (Images 1E,F). The resinous chips are primarily burned as incense owing to their distinctive fragrances, whereas agarwood oil is widely used as a high-value ingredient in perfumes, air fresheners, cosmetics, aromatherapy products, and pharmaceutical formulations (Chakrabarty et al. 1994). Besides these products, other plant parts also possess commercial value. The dried leaves of Agarwood (*Aquilaria malaccensis*) are processed into herbal tea, while the bark is used for making ropes and the wood serves as fuel for fumigation (TRAFFIC 2005). In addition, 'Boya', an oil extracted from non-resinous wood, is commonly used in the manufacture of smokeless flavoured tobacco products.

Globally, approximately 13 agarwood-producing species belonging to the family Thymelaeaceae are known to yield commercially valuable resin and its derivatives (Lee & Mohamed 2016; Tan et al. 2019). Among these, *A. malaccensis* and *A. crassna* are the two most economically important species cultivated for the commercial purposes (Rasool & Mohamed 2016). In India, the most widely cultivated species is *Aquilaria malaccensis* Lam. (Image 1A), which ranges throughout Bangladesh, Borneo, Bhutan, India, Indonesia, Malaysia, Myanmar, Philippines, Singapore, and Thailand. In India, *A. malaccensis* is distributed throughout the northeastern states, with major cultivation in Assam and Tripura, followed by Manipur, Nagaland, Meghalaya, Mizoram, and Arunachal Pradesh. Apart from the north-east, it is also cultivated in Karnataka, Kerala, West Bengal and Telangana. In addition to *A. malaccensis*, an endemic species *A. khasiana* Hallier f. is found in the Khasi Hills of Meghalaya in India (Barden et al. 2000; Wilson & Kitto 2012; RFRI 2021).

The agarwood industry in India has historically been dominated by a few trading families, particularly in Assam. Before the partition of the Indian subcontinent, traders from Dakshinbagh in Sylhet (now in Bangladesh) played a major role in the agarwood trade by leasing designated forest areas, locally known as 'Assam Agar Mahals', for agarwood extraction and processing (Chakrabarty et al. 1994). In the post-independence era, commercial distillation units were established as cottage/micro industries in upper Assam, especially in Hojai, Naharani, Kakajan, Namti, and Charaidew regions. Over time, the industry expanded across the northeastern states and more recently into southern India. Excessive and largely unregulated harvesting of wild agarwood trees during the 20th Century severely depleted natural populations across northeastern India. Wild populations in Assam and Tripura were considered nearly extirpated due to indiscriminate felling (Chakrabarty et al. 1994). Extensive harvesting between 1950 and 1980 resulted in a significant decline of natural populations in Arunachal Pradesh. This trend of depletion extended to Manipur and Nagaland, where wild populations are now critically diminished. Presently, the wild population of agarwood are confined mostly to some protected areas and very few to remote non-forest areas. As a consequence, *A. malaccensis* was listed in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) in 1995. CITES, an international agreement among countries to regulate or ban the international trade of species under threat, had legally banned the export of agarwood from India until November 2021 due to insufficient documentation of the wild and cultivated stocks of agarwood. The absence of an export quota until November 2021 and other trade restrictions affected the livelihood of people associated with the agarwood trade and led to illegal practices. However, the import of agarwood, value addition and re-export was continued by a few select business people.

According to CITES, the international trade of specimens of species included in Appendix II, is allowed only if the scientific authority of the state advises that the export will not be detrimental to the survival of the species. Based on the non-detriment findings (NDFs) and advice of the scientific authority, the export of the species is either banned or allowed through quota. The export quota is fixed by the scientific authority and approved by the management authority of the respective parties. In India, the first NDF assessment of *A. malaccensis* was done by the Rain Forest Research Institute (RFRI), Jorhat in 2021. In 2023, the Botanical Survey of India (BSI), Kolkata conducted the second NDF and updated the export quota. However, despite high export potential, only a few export instances have happened in India through the proper channel by obtaining CITES export permit. Whereas, imports and re-exports continued as usual. Considering this, we

Image 1. A—*Aquilaria malaccensis* cultivation in Mon District, Nagaland | B—Naturally infected tree | C—Artificially induction by nailing | D—Resinous wood | E—Agarwood chip | F—Agarwood oil. © BSI NDF team.

have collected information on the scope of agarwood cultivation in India, government policies, regulatory mechanism and procedures for international trade.

Potential for Agarwood Cultivation and Agroforestry

The growing international demand for agarwood, coupled with the rapid depletion of natural populations due to overexploitation, has necessitated the large-scale cultivation of *A. malaccensis* as a sustainable alternative to harvesting from wild sources (Rasool & Mohamed 2016). *A. malaccensis* is a fast-growing and adaptable tree species that can attain a diameter at breast height (DBH) of approximately 25–40 cm within 5–7 years under favourable environmental conditions. The species can be cultivated across a wide range of soil types, including marginal lands; however, optimum growth is achieved in well-drained, fertile soils receiving adequate rainfall and moisture. In northeastern India, one-year-old seedlings are generally transplanted during the monsoon season to maximize establishment and survival. Agarwood-based agroforestry systems include home gardens, plantations as cash crops, block plantations, and boundary plantations (Sarkar 2019). The introduction of agarwood trees to home gardens in upper Assam has resulted in high economic returns (Saikia & Khan 2012). Integrating the plantation of agar trees with other crops provides enormous additional income to farmers. Intercropping of agarwood with various native and non-native species like Tea *Camellia sinensis* (L.) Kuntze, Patchouli *Pogostemon cablin* (Blanco) Benth., Sarpagandha *Rauvolfia serpentina* (L.) Benth. ex Kurz, Physic Nut *Jatropha curcas* L., Pepper *Piper longum* L., Pineapple *Ananas comosus* (L.) Merr., Turmeric *Curcuma longa* L., and Arecanut *Areca catechu* L. has also been practiced in India (Chaudhari 1993). Tea cultivation combined with agarwood trees is a very common agroforestry model of cash crop plantation which is widely popular, especially in northeastern parts of India (Saikia & Khan 2012). According to Shinde et al. (2019), agarwood trees are quite suitable to be planted as boundary trees on the banks of ponds, canals, roads, and even on hilly slopes to reduce soil erosion and prevent landslides.

Formation of Agarwood

The crucial stage in the agarwood production is formation of resinous substance (Image 1D). The quality of the agarwood depends mainly on the formation of resin inside the tree. The agar is formed in the tree due to fungus-host interaction, which generally occurs after boring (Image 1B) by the larvae of stem borer *Neurozerra conferta* Walker and fungi species, like *Fusarium* sp., *Rhizophora* sp., *Aspergillus* sp., and *Mucor* sp., are responsible for the interaction. Generally, trees above the age of seven years are vulnerable to infection by fungus, but sometimes infected plants less than one year old are also observed. Agarwood formation is often linked with physical wounding or damage of the trees caused by thunder strikes, animal grazing, predator, and disease infestations (Rasool & Mohamed 2016; Wu et al. 2017). Thus, the inner part of the trees is exposed to pathogenic microbes, which activate the defense mechanism of *Aquilaria* to initiate resin production (Tan & al. 2019). The resin deposited around the wounds over the years, where the accumulation of the volatile compounds eventually forms agarwood (Subasinghe & Hettiarachchi 2013).

Agar production can also be induced artificially by several techniques, which may be broadly classified into physical, chemical, and biological methods or in combinations. Physical injuries are done with hammers or nails (Image 1C) and inoculation with fungal strains. Different types of artificial infection methods like DTII (Direct trunk injection of inoculum), TIIC (Trunk injection of inoculum through cannula), and PIBR (Pasting of inoculum through bark removal) provided by several private companies, are also observed in other parts of the country where natural infection is less or absent. However, the quality and price of chips and oil from agarwood obtained by the artificial infection method are much lesser than the natural ones.

Agarwood Production in India

India is one of the major cultivators of agarwood in the world. The recent NDF study estimated that more than 13 crores of agarwood plants are under cultivation in India (Bhattacharjee et al. 2024). Assam State leads with more than 11 crores of plants, followed by Tripura, Manipur, and Nagaland. Karnataka is one of the major states in southern India that holds more than 20 lakhs of plants. Naturally infected/ artificially inoculated trees that are more than seven years of age are harvested for good-quality agarwood chips and oil. Out of 13 crores of plants, 2.5 crores are estimated to be infected. Among these, around 25 lakhs of trees are in harvestable condition. Agar chips are obtained by nibbling the infected wood manually. Agar oil is of two types, i.e., 'Malor' and 'Boya'. Malor is the oil obtained from the distillation of infected wood is of high quality. Boya is the low-grade oil obtained from the infected wood residues/non-infected woods. A single harvestable tree can produce up to 3 kg of agarwood chips and 10–40 g of agarwood oil (including Boya), depending on the quality of wood. Based on currently available harvestable trees, India can export up to 1,51,080 kg of agarwood chips and powder/sawdust (non-exhausted) and 7,050 kg of agarwood oil, which is much higher than the existing export quota (Bhattacharjee et al. 2024).

International Trade of Agarwood

Two major global market zones for agarwood consumption are eastern Asia (including markets of Taiwan, Japan, and the Republic of Korea) and western Asia or Middle East (which includes the countries of the Arabian Peninsula). Although there is no known agarwood-producing plant west of India, it has been traded for more than 2,000 years, being sourced from India and further east.

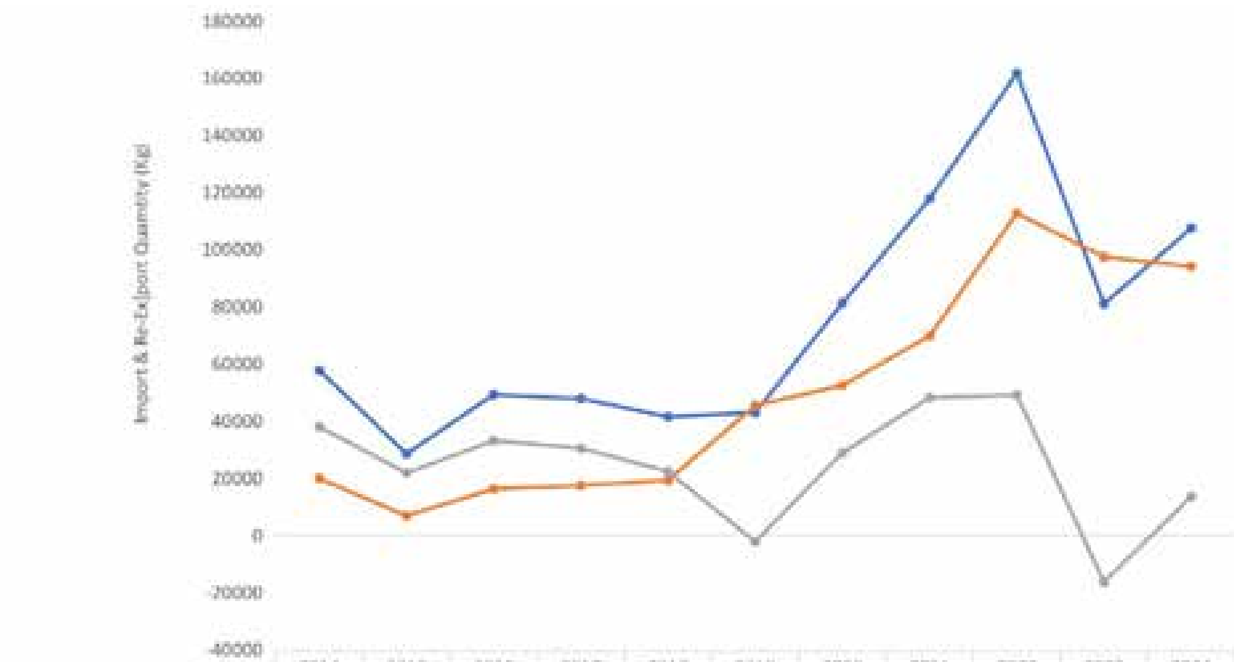
According to the CITES trade database (2019–2023), the United Arab Emirates and Saudi Arabia are the major importing and re-exporting countries of agarwood products worldwide. These countries imported an estimated 1,800 tons of agarwood derivatives during this period. Apart from these countries, Thailand, Singapore, Kuwait and many other countries have also imported more than 200 tonnes of agarwood products. Indonesia, Singapore, and Thailand are major exporters of agarwood derivatives and export around 400 tonnes of agarwood. As per the study by Persistence Market Research, from 2018 to 2022, the global agarwood chips market grew at a compound annual growth rate (CAGR) of 7.7%, reaching a valuation of USD 44,050.7 million in 2023. In the global market, a litre of pure oud oil can fetch up to USD 80,000. Global agarwood trade is predicted to be USD 64 billion by the end of 2029, from an estimated USD 32 billion in 2018 (Kumar et al. 2023). By the end of 2033, the global market for agarwood chips is projected to grow at a 7.1% CAGR, with a total value of USD 87,467.6 million (https://www.persistencemarketresearch.com).

According to the CITES trade database, from 2019 to 2023, India re-exported over 240 tonnes of agarwood derivatives. Major destination countries include the United Arab Emirates, Kuwait, Oman, Qatar, Saudi Arabia, Singapore, and Thailand. At the same time, India imported more than 220 tonnes of agarwood and derivatives from Australia, Saudi Arabia, Qatar, Lao People's Democratic Republic, United Arab Emirates, Malaysia, Thailand, Singapore, Indonesia, Bhutan, Switzerland, France, and Vietnam; out of which, one-third of the agarwood was imported solely from Indonesia and Singapore (TRAFFIC 2023). Agarwood imports and re-export data pertaining to India for the last decade (2014–2024) recorded in the CITES trade database is provided in Image 2. In the global market, India has been currently identified as a re-export hub. The market mechanisms in India needs to be strictly regulated in consonance with the legislation and policy framework to strengthen its position as a primary exporter commensurate with its production potential.

Illegal Logging and Smuggling Issues

India has long agarwood trade relationships (during 1974–91) with Saudi Arabia, Kenya, Bahrain, United Kingdom, Qatar, Dubai, Kuwait, United Arab Emirates, Oman, Singapore, the United States of America, Netherlands, and German F. Republic. More than 1,500 tonnes of agarwood (including chips and dust) were exported from India during this period (Chakrabarty et al. 1994). However, after enlisting *A. malaccensis* in CITES Appendix II in 1995, the export of agarwood and its derivatives was restricted. The absence of an export quota for a long period and other trade-related restrictions in India lead to increase in informal trade/export. More than 1.25 tonnes of chips and 6 l of oil/derivatives were reportedly seized in six states of India from 2017 to 2021 (TRAFFIC 2023). Assam, Delhi, Kerala, Maharashtra, Telangana, and West Bengal reported incidents of agarwood smuggling destined to Bahrain, Saudi Arabia, Kuwait, Thailand, and the United Arab Emirates (TRAFFIC 2023). As per WCCB data base, different forms of agarwood derivatives and products were seized at Delhi, Kolkata and Mumbai airports (Image 3).

Though India has an export quota since November 2021, informal trade is continuing due to complex process of fulfilling official formalities for legal trade and export. The villagers/growers of major harvesting states planted agarwood on private lands, sometimes on leased lands, for their livelihood. However, due to several legal restrictions imposed during the last few decades on harvesting and trading of agarwood and complicacy in obtaining CITES export permits, the growers/ farmers could not trade/export agarwood legally which compelled them to sell their trees and derivatives to informal traders. The formal process of agarwood export with a CITES permit involves about 16 steps starting from obtaining a legal procurement certificate (LPC)/ certificate of cultivation (CoC) from the DFO to getting clearance from DGFT (Director General of Foreign Trade) through the MoEF&CC (Ministry of Environment, Forest and Climate Change). Therefore, the majority of the growers and traders are still inclined towards informal trade which is much more convenient for them due to the well-established, decades-long informal system of trade chain. The informal trade is



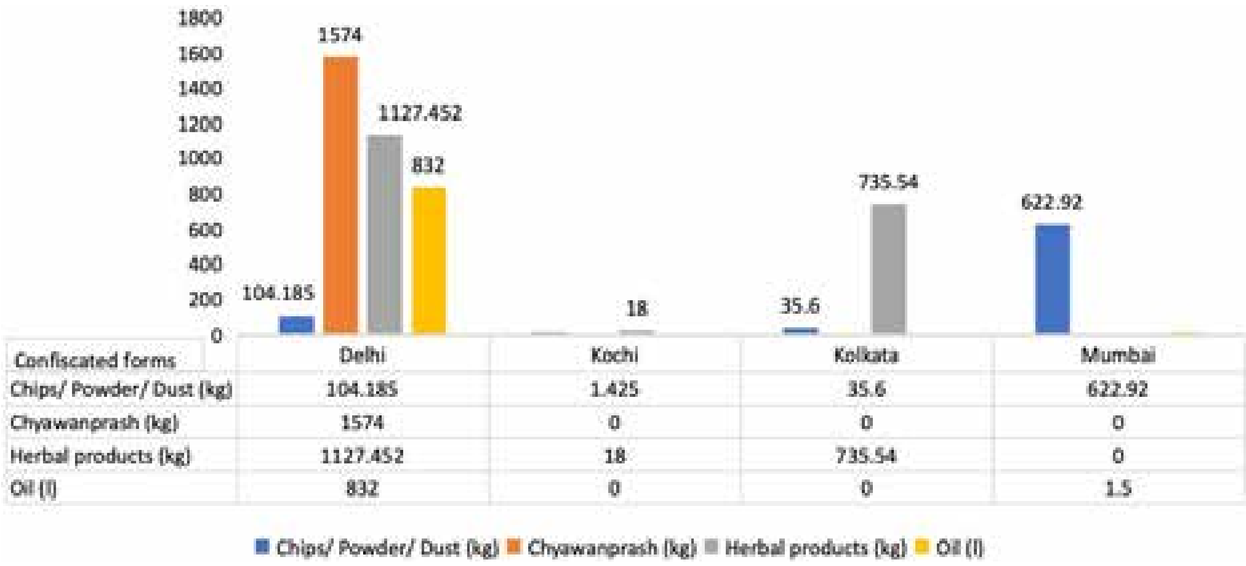
	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Import of Agarwood (Kg)	57628.01	28388.65	49113.1	47676.4	41328.58	42862.96	81118.18	117674.6	161530.4	80865.85	107305.6
Re-Export of Agarwood (Kg)	19800.36	6682.4	16105.85	17332.41	19115.49	45253	52348.16	69621	112536.0	97296.86	93948.46
Difference	37827.65	21706.25	33007.25	30343.99	22213.09	-2390.04	28770.01	48053.6	48994.41	-16431.01	13357.16

Image 2. The import and re-export of Agarwood during 2014-2024 in India based on export country report (Source: CITES Trade Database).

facilitated through importing low-quality agarwood derivatives, logs etc. and replacing these with high-quality derivatives from India in the name of re-export. Pure agar oil is often mixed with some other perfumes, or some volatile solvent to bypass the legal restriction for export. Sometimes, the low-quality agarwood chips are painted and polished to enhance as high-quality chips. Also, the broken or smaller chips are sometimes fixed with glue to sell at a higher price. The agarwood is sometimes exported illegally through postal/ courier services (Bhattacharjee et al. 2024).

Role of Government Policies and Regulations

The Government of India (GoI) and state governments have framed legislations to facilitate formal trade. Agarwood harvesting and transportation within and across states are regulated under the Indian Forest Act (1927) and the Transit Rules. The collection of agarwood plants from any protected area, artificial propagation, stock declaration and international trade of agarwood is regulated by The Wildlife (Protection) Act, 1972 (WPA) and CITES. The agarwood is listed under chapter – III A of the WPA, which contains the primary provisions and regulatory controls such as, licensing and permits that govern cultivation and international trade of this specified plant. As agarwood is protected under Schedule IV of WPA and Appendix - II of CITES, the international trade is regulated through the provisions of section 49 H, 49 I and 49 K of WPA and Wildlife (Protection) International Trade of Specimens Rules, 2023. The state forest departments oversee the collection of cultivated agarwood plants from non-forest regions. Once a plantation reaches the age of five, it must be registered with the Plantation Registering Authority to be eligible for rewards under the state government's promotion policy. Trees from plantations and non-forest areas have to be felled with authorization. The transportation of agarwood will only be allowed by railways in compliance of the directives of the Supreme Court of India and/ or any orders, notifications, or guidelines issued from time to time by the MoEF&CC, GoI. The Ministry of Commerce, GoI, formulated the Export & Import (EXIM) Policy, which forbade the export of agarwood from 1992 to 1997. The DGFT, GoI, published the Negative List of Plant Species for Export, which included *A. malaccensis*. Consequently, it was forbidden to export any part of the species that were harvested from the wild, including extracts, and derivatives of *A. malaccensis*. Later, according to EXIM Policy (2009–2014) published by the DGFT, the export of agarwood and its derivatives



Confiscated forms	Delhi	Kochi	Kolkata	Mumbai
Chips/ Powder/ Dust (kg)	104.185	1.425	35.6	622.92
Chyawanprash (kg)	1574	0	0	0
Herbal products (kg)	1127.452	18	735.54	0
Oil (l)	832	0	0	1.5

Image 3. Details of agarwood derivatives seized at major cargos and airports in India in the form of different products/ as raw items during 2007–2023 (Source: WCCB).

is restricted and is subjected to the provisions of CITES due to its listing in Appendix II of CITES in 1995. The DGFT vide notification No. 52/2024-25, New Delhi, dated 20.ii.2025 has earmarked annual limits for export of agarwood chips and powder obtained from artificially propagated sources (Cultivated outside forest areas) for three financial years from 01.iv.2024 till 31.iii.2027. The application for obtaining authorization to export agarwood sourced from artificially propagated plantations include 1. Attested copy of Certificate of Origin (COO) issued by a authorized forest officer, 2. A coloured photograph of the stock certified by the designated forest officer, 3. An undertaking from the exporter that agarwood derivatives proposed to be exported have been harvested from plantation complying CITES conditions and they shall be exported only upon submission of a valid CITES export permit at the time of export. The state-wise annual export limits for agarwood chips and powder obtained from artificially propagated sources increased from 25,000 kg in 2021 to 1,51,080 kg in 2025 subject to export policy. The state-wise annual export limit for agarwood obtained from artificially propagated sources has been tabulated in Table 1.

Assam and Tripura forest departments have recently taken several initiatives to promote agarwood cultivation and trade to support the economy of farmers and people associated with agarwood industry. *A. malaccensis* is listed in Schedule III of the Assam Trees Outside Forest (Sustainable Management) Rules, 2022. It is exempted from obtaining prior permission for felling, conversion and transportation of outturn from non-forest areas when they are meant for consumption within the state. However, permission is required to establish a chain of custody if the out-turn is transported outside the state. According to the Assam Wood-Based Industries (Promotion and Development) Rules, 2022, no agarwood processing and agar-oil extracting unit can be established or operational without a valid registration. The law provided that all the existing unit holders should get registered under these rules with the divisional forest officer (DFO) concerned within three months of the notification of these rules (12 January 2023). The Forest Department of Assam took initiative to legalise existing agarwood industries through a license under these rules and facilitated through the WBI portal (https://wbi.assam.gov.in). The Assam Agarwood Promotion Policy 2020 aims at promoting agarwood-based industries by providing subsidies and incentives to the distillation units, perfumery, chipping, packaging units, artificial inoculation units (both government and private) and also for creating market facilities. The Forest Department of Assam distributed around 4.54 million saplings of *A. malaccensis* freely in different parts of Assam on 17 September 2023 under the campaign 'Amrit Brikshya Andolan' (Amrit Briskshya Andolan 2024).

Similarly, the Government of Tripura implemented the 'Tripura Agarwood Policy 2021' to ensure the sustainability of the agarwood by taking into account all the aspects of cultivation, harvesting, processing, value additions, transit and trade. It also aims at promoting agarwood trade by easing procedures of procurement, processing and selling of various products, within the

Table 1. State-wise annual export limit for Agarwood (*Acquilaria malaccensis*) from artificially propagated sources.

	State	Agarwood chips/powder/sawdust (non-exhausted) (Kg)	Agar Oil (Kg)
1	Assam	1,19,400	5,560
2	Tripura	22,500	1,047
3	Manipur	4,000	200
4	Nagaland	3,400	180
5	Karnataka	1,200	35
6	Meghalaya	200	09
7	Kerala	80	04
8	Others *	300	15
	Total	1,51,800	7,050

* The state-wise limits for all other states is collectively included in "Others" because the harvest in these states is comparatively very less (Source: DGFT Notification 52/2024-25, dated 20.ii.2025)

country and export subject to the provisions of CITES. All eligible new industrial units for the distillation of agar oil, perfumery, and packaging are provided with capital investment incentives as applicable by relevant provisions under the Tripura Industrial Promotion Scheme and Northeast Industrial & Investment Promotion Policy (NEIPP) of the GoI. Through "Ghar Ghar Agar – Har Ghar Agar" campaign, Tripura Forest Department is promoting private plantations to ensure monetary benefits to thousands of potential agarwood growers of the state by creating awareness on economic potential of agar plantations, intercropping for interim returns, artificial inoculation and registration of each tree grown on private land. The Tripura Wood-Based Industries (Establishment and Regulation) Rules, 2006, encourage registration of the existing and new agarwood processing units. The Non-Timber-Forest-Produce (NTFP) Centre of Excellence is facilitating research on inoculation and planting materials and has collaborated with the Fragrance and Flavour Development Centre to launch the 'Tri Agar' brand. In 2023, the M/S Mamon Enterprise of North Tripura exported 2.5 kg agar oil to M/S Fragrance Force General Trading LLC, Dubai with a valid CITES export permit and approval of MoEF&CC (SU Division) F.no. 5-24/2023-SU dated 4th October 2023. In November 2023, the Ministry of Development of Northeastern Region (DoNER), GoI has constituted the Inter-Ministerial Task Force for promoting trade in agarwood.

India has a robust legislative and policy framework governing agarwood cultivation and trade, however, its implementation at the field level remains inadequate. Challenges associated with registration of plantation, authorization of harvesting, maintenance and submission of stock registers, maintenance of a transparent chain-of-custody from growers to traders for exports, issuance of LPC and COO continue to hinder the acquisition of CITES permits for indigenous cultivated agarwood.

How to Obtain a Valid CITES Permit?

To obtain a CITES permit for the export of agarwood in India, one needs to follow a specific process overseen by the State Forest Department, State Tax Department, DGFT, MoEF&CC, CITES Management Authority, WCCB (Wildlife Crime Control Bureau) and Indian Customs. The exporter must get a valid export license from DGFT by submitting necessary documents, including quota validation and proof of legal acquisition. The legal acquisition is ensured by obtaining legal felling and transit permits from the authorized officer of the forest department, as per the state legislation. The duly completed CITES permit application form is submitted to the designated office of the regional deputy director (RDD) of WCCB, MoEFCC, along with all supporting documents. The authorities will then inspect and verify the details provided. Once approved, the Export/Re-Export CITES permit is issued with a unique identification number in accordance with international standards laid down by the CITES Secretariat. The export permit is valid for specific period, exporter, destination, port of export, nature and quantity of agarwood derivative. The exporter shall ensure strict compliance with all permit conditions and maintain proper records. Along with the shipping bill, the consignment of agarwood derivative shall invariably be accompanied by a CITES export/re-export permit issued by the CITES MA. The authorized officer from WCCB will endorse the CITES export permit in the Customs area before the consignment is loaded in cargo for export. Therefore, starting the application process early and consulting experts can help navigate it efficiently. A framework for obtaining CITES export permits was suggested by the WCCB (Image 4). A flowchart depicting each step of the agarwood trade from planting to export is presented in Image 5.

Future Prospects and Opportunities for the Agarwood Industry

The agarwood industry faces numerous challenges, from the artificial inoculation process till export of agarwood derivatives. One of the major challenges, the artificial inoculation process is influenced by factors such as the age of trees, inoculation methods, and environmental conditions that contribute to the alteration of resin quality and composition. This

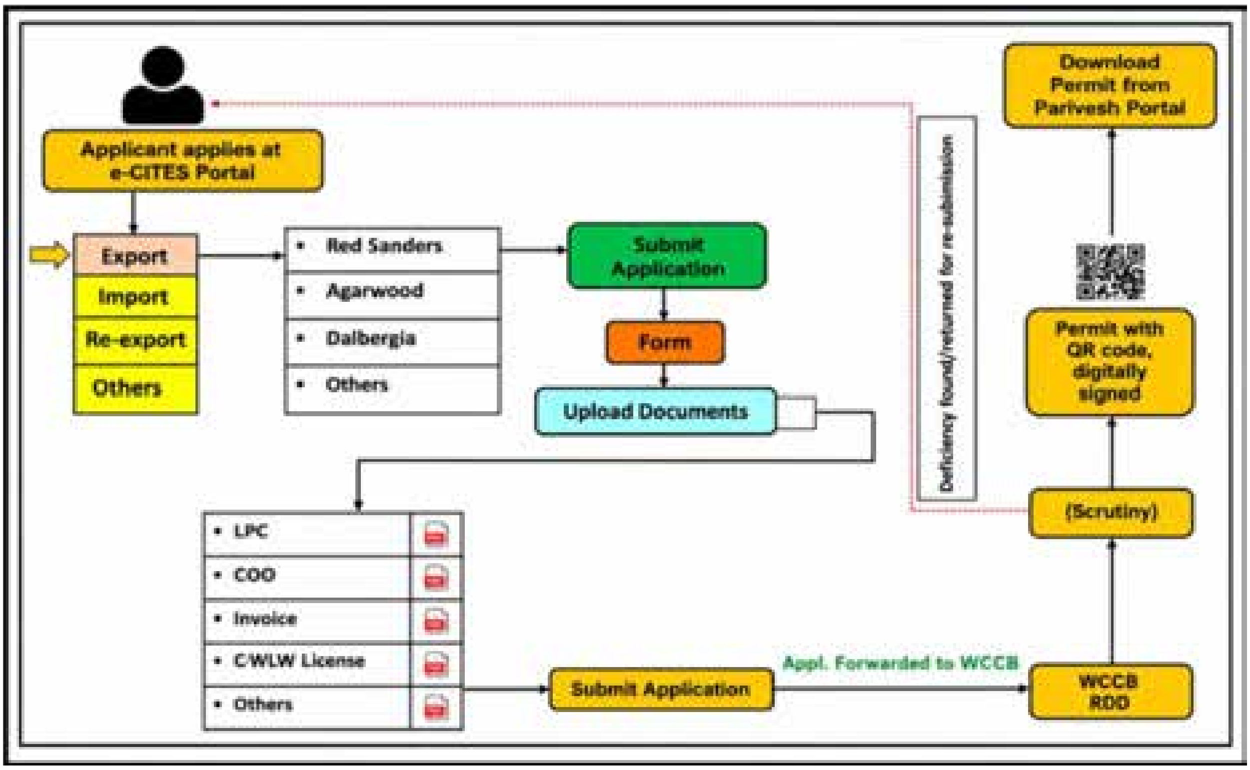


Image 4. Flowchart of the procedure to get CITES export permit through WCCB.

inconsistency poses difficulties in meeting market demands and maintaining product standards (Azren et al. 2019). Improper inoculation techniques or ineffective post-inoculation care may lead to irreversible harm, including harmful infections, stunted growth, or even tree mortality (Herath & Jinendra 2023). Therefore, studies are needed to optimize the inoculum dose and inoculation techniques to increase the chances of infection and standard of agarwood.

The training institutions and skill development centers need to provide training on plantation techniques, artificial inoculation, as well as online marketing. National-level research organizations and private institutions are to be funded for agar-related projects. In October 2023, the chief minister of Assam laid the foundation stone of the Assam Agar International Trade Centre (ITC) in Golaghat, which is the first of its kind in the entire country. The Centre would have facilities for agar plantation, research and training, an industrial shed, exhibition space, a laboratory with tissue culture facility and B2B facilities. The ITC aims to promote the business growth of agarwood entrepreneurs. Such models are worth emulating by all other major agarwood-growing states in India.

Agarwood plantations have potential to improve economic conditions and livelihood of the cultivators, especially in rural areas. Owing to pollarding and coppicing ability, many researchers have recommended agarwood trees as an important component in agroforestry systems (Sarkar 2019).

The intervention of state governments is required to further formalize the informal agarwood trade to create a fair and efficient trade atmosphere. The State Forest Development Corporations (SFDCs) need to come forward to establish a buying and selling mechanism to ensure participation of all agarwood farmers and break the monopoly in agarwood export from India.

As per CITES trade database, global demand for agar products is steadily increasing. For example, the import of agarwood chips to the UAE rose from 56 tonnes in 2004 to 162 tonnes in 2007 (TRAFFIC 2010). Malaysia and Indonesia are two major sources as per the country-of-origin for agarwood imported to the UAE. However, agarwood cargoes get there from three major countries, viz., Singapore, India, and Malaysia. Agarwood from Indonesia largely arrive as re-export from Singapore. Therefore, GoI needs to encourage market research on trade data in the CITES and Customs database in order to understand the global market scenario and cope up with global supply strategy. Lack of data consistency between data held with CITES MA and the Customs in India also needs to be harmonized. Based on analysis of seizure

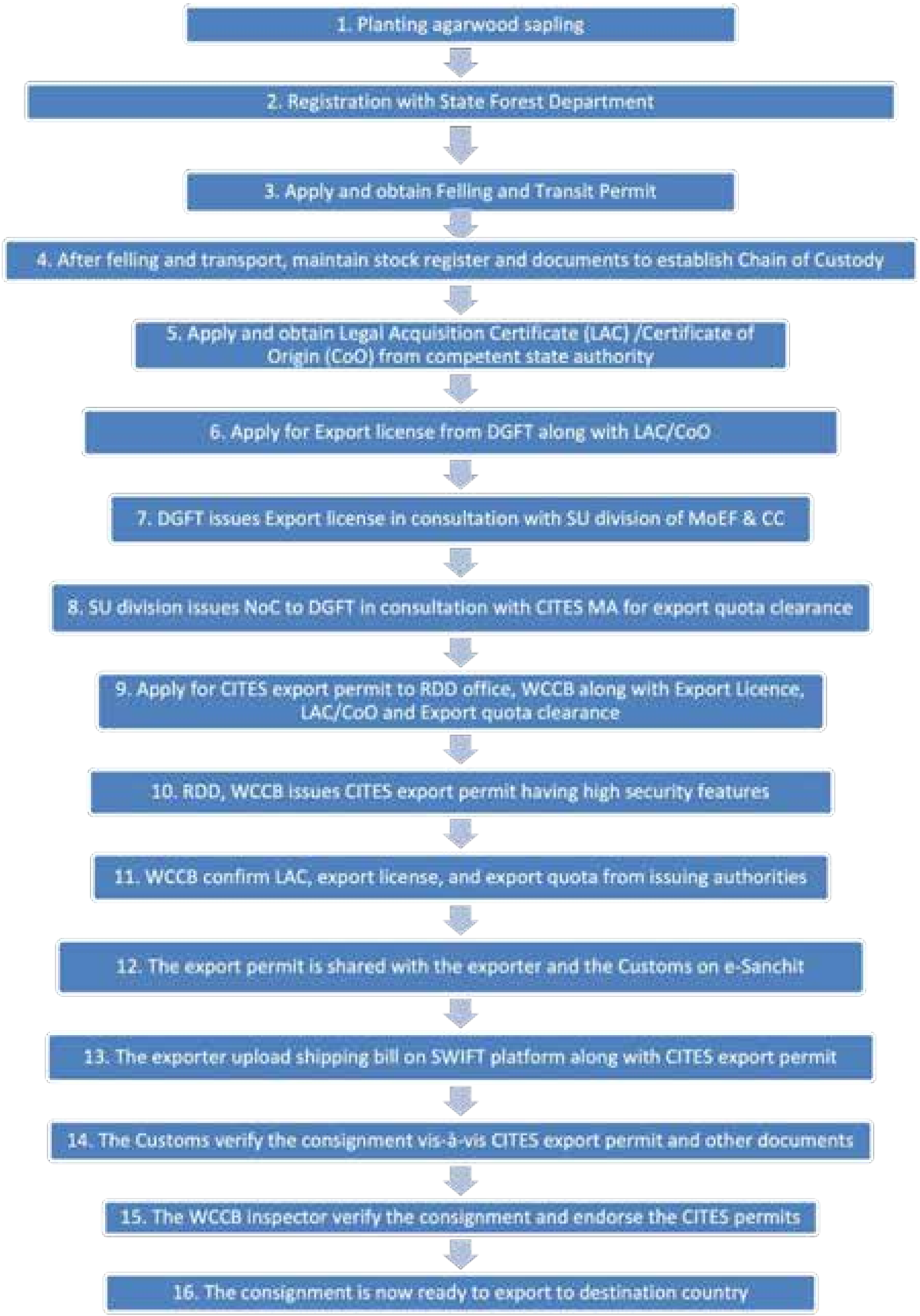


Image 5. Flowchart - steps involved in export of agarwood through CITES export permit.

data, India needs to communicate frequently with destination countries and take measures to discourage the smuggling of Agarwood derivatives and formalize the international trade.

Among trading communities, CITES is perceived as a trade barrier and business impediment. As India is the global forerunner in SDG (Sustainable Development Goals) compliance, the CITES MA India and authorities in range States should be encouraged to take up awareness campaigns to educate all stakeholders. There is already an established mechanism for the export of Red-Sanders *Pterocarpus santalinus*, which is also listed in Appendix II of CITES. The range state authorities in India should observe and adopt similar mechanisms and procedures for agarwood also and encourage global traders to participate through e-auctions.

CONCLUSION

The study provides an overview of the production, consumption, transport, international trade, other challenges associated with agarwood, as well as the regulatory policies in India. The GoI and state governments have taken measures to comply with CITES requirements to ensure the sustainability, traceability, and legality of agarwood derivatives in international trade. The primary reason for the informal trade is the limited bargaining power of agarwood growers and limited awareness of the requirements for obtaining a valid CITES export permit. The continued monopoly in the agarwood export trade is also affecting small-scale farmers' ability to market their agarwood derivatives. India has a robust legislative and policy framework governing agarwood cultivation and trade, with inadequate implementation at the field level. India has a vast scope to scale up export quantity to commensurate with its production capacity. Therefore, the study will be useful for understanding government policies and CITES regulations related to agarwood and for identifying ways to obtain a CITES export permit. The Management Authorities/ State Forest Departments are suggested to conduct awareness programmes and campaigns to educate the growers, traders and exporters about the process of obtaining a CITES export permit and its economic benefits. By encouraging agarwood growers and strengthening the agarwood industry, the local people associated with this industry get benefited, thereby significantly contribute to India's foreign currency earnings.

REFERENCES

Amrit Brikshya Andolan (2024). https://aba.assam.gov.in Electronic version accessed 21.i.2026

Azren, P.D., S.Y. Lee, D. Emang & R. Mohamed (2019). History and perspectives of induction technology for Agarwood production form cultivated Aquilaria in Asia: a review. Journal of Forestry Research 30(1): 1–11. https://doi.org/10.1007/s11676-018-0627-4

Barden, A. et al. (2000). Heart of the matter: Agarwood Use and Trade and CITES Implementation for Aquilaria malaccensis. TRAFFIC International, Cambridge.

Bhattacharjee, A. et al. (2024). Non-detriment Findings (NDFs) of Aquilaria malaccensis Lam. (Agarwood) in India. Botanical Survey of India, Kolkata, 151 pp.

Chakrabarty, K. et al. (1994). Trade in Agarwood. WWF-India/ TRAFFIC-India, New Delhi.

Chaudhari, D.C. (1993). Agarwood from Aquilaria malaccensis (A. agallocha, Roxb.). MFP News 3(4): 12–13.

CITES (2026). Convention on International Trade of Endangered Species of Wild Fauna and Flora. https://cites.org. Accessed on 20.vi.2026.

DGFT (2025). DGFT Notification No. 52/2024-25, dated 20.ii.2025. https://worldtradescanner.com/52-Ntfn-DGFT-20.01.2025.htm. Electronic version accessed 20 June 2026.

Environment & Forest Department Government of Assam (2022). https://wbi.assam.gov.in. Electronic version accessed 10.i.2026.

Herath, H.M.W.A.I. & B.M.S. Jinendra (2023). Recent advancement in Agarwood induction technology: a comprehensive review for the transformation of artificial agar resin induction methods. Journal of Agro-Technology and Rural Sciences 3(1): 6–17. https://doi.org/10.4038/atrsj.v3i1.46

Kumar, S. et al. (2023). FAQs on Agroforestry. Indian Council of Forestry Research and Education, 48 pp.

Lee, S.Y. & R. Mohamed (2016). The origin and domestication of Aquilaria, an important Agarwood-producing genus, 1–20 pp. In: Mohamed, R. (ed.). Agarwood. Tropical Forestry. Springer, Singapore. https://doi.org/10.1007/978-981-10-0833-7_1

Persistence Market Research (2026). https://www.persistencemarketresearch.com Electronic version accessed 20.i.2026.

Rain Forest Research Institute (RFRI) (2021). Report on Non-Detriment Findings of *Aquilaria malaccensis* in India. Rain Forest Research Institute, Jorhat.

Rasool, S. & R. Mohamed (2016). Understanding Agarwood formation and its challenges, pp. 39–56. In: Mohamed, R. (ed.). Agarwood. Tropical Forestry. Springer, Singapore. https://doi.org/10.1007/978-981-10-0833-7_3

Saikia, P. & M.L. Khan (2012). Agar (Aquilaria malaccensis Lam.): a promising crop in the homegardens of Upper Assam, northeastern India. Journal of Tropical Agriculture 50(1): 8–14.

Sarkar, P.K. (2019). Improving livelihood through Agarwood (Aquilaria malaccensis Lam.) based agroforestry systems: an option. Agriculture & Food: e-Newsletter 1(6): 140–147.

Shinde, R. et al. (2019). Soil conservation: Today's need for sustainable development. Agriculture & Food: e-Newsletter 1(5): 175–183.

Subasinghe, S.M.C.U.P. & D.S. Hettiarachchi (2013). Agarwood resin production and resin quality of Gyrinops walla Gaertn. International Journal of Agricultural Sciences 3: 357–362.

Tan, C.S. et al. (2019). Agarwood induction: current developments and future perspectives. Frontiers in plant science 10: 122. https://doi.org/10.3389/fpls.2019.00122

The Indian Forest Act (1927). https://www.indiacode.nic.in/bitstream/123456789/19313/1/the_indian_forest_act%2C_1927.pdf

The Wild Life (Protection) Act (1972). https://www.indiacode.nic.in/bitstream/123456789/1726/1/aA1972-53.pdf

The Wild Life (Protection) International Trade of Specimens Rules (2023). S.O.5408 (E), dated 21.12.2023 https://forest.cg.gov.in/cms/media/4cb1243f-6fe0-46a8-ac1c-6241a7ce59fc_WL-01052023_

Gazzete_Notification_Rules.pdf

TRAFFIC (2005). Report on the trade and use of Agarwood in Taiwan, Province of China. TRAFFIC East Asia-Taipei & TRAFFIC Southeast Asia.

TRAFFIC (2010). Report on the trade and use of Agarwood (oudh) in the United Arab Emirates. TRAFFIC Southeast Asia, Malaysia.

TRAFFIC (2023). Agarwood, factsheet on India's Agarwood in illegal wildlife trade. TRAFFIC, New Delhi.

Wilson, J.J. & M.R. Kitto (2012). Aquilaria malaccensis Lam.: a red-listed and highly exploited tree species in the Assamese home garden. Current Science 102(4): 546.

Wu, Z.Q. et al. (2017). Analysis of gene expression and quality of Agarwood using Agar-bit in Aquilaria sinensis. Journal of Tropical Forest Science 29: 380–388. https://doi.org/10.26525/jtfs2017.29.3.380388

Yaacob, S. (1999). Report of Agarwood: Trade and CITES Implementation in Malaysia. TRAFFIC Southeast Asia, Malaysia.

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Author contributions: HVG conceptualised, collected and analysed the data, interpreted the results, and drafted the manuscript. AM organised and edited the manuscript. SPG reviewed the manuscript. MT reviewed and edited the manuscript. AB designed the research, conducted field surveys of NDF studies, drafted the NDF report, data curation, drafted the manuscript, and reviewed, edited, and approved the manuscript. SC conducted field surveys of NDF studies, drafted the NDF report, data curation, drafted the manuscript, and reviewed and approved the manuscript. MRRL conducted field surveys of NDF studies, drafted the NDF report, drafted the manuscript, edited, and reviewed and approved the manuscript. SS conducted field surveys of NDF studies, drafted the NDF report, drafted the manuscript, and reviewed and approved the manuscript. SB conducted field surveys of NDF studies, drafted the NDF report, drafted the manuscript, and reviewed and approved the manuscript. BM conducted field surveys of NDF studies, drafted the NDF report, drafted the manuscript, and reviewed and approved the manuscript. OC conducted field surveys of NDF studies, drafted the NDF report, drafted the manuscript, and reviewed and approved the manuscript. SS conducted field surveys of NDF studies, drafted the NDF report, drafted the manuscript, and reviewed and approved the manuscript. TS conducted field surveys of NDF studies, drafted the NDF report, drafted the manuscript, and reviewed and approved the manuscript. SC conducted field surveys of NDF studies, drafted the NDF report, drafted the manuscript, and reviewed and approved the manuscript. RS conducted field surveys of NDF studies, drafted the NDF report, drafted the manuscript, and reviewed and approved the manuscript. FB conducted field surveys of NDF studies, drafted the NDF report, drafted the manuscript, and reviewed and approved the manuscript.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 August 2026 | 18(8): 29544–29547
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.10498.18.8. 29544-29547
#10498 | Received 28 February 2026 | Final received 09 June 2026 | Finally accepted 28 July 2026

SHORT COMMUNICATION

Nesting of Shikra *Accipiter badius* on *Gliricidia sepium* (Jacq.) Kunth (Leguminosae)

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Abstract: The raptor bird, Shikra *Accipiter badius,* generally builds its nests on native trees and raises its young ones. In the present communication, it is recorded for the first time that Shikra has built a nest on the *Gliricidia sepium* tree and nurtured its two generations in consecutive years. However, *G. sepium* is not a suitable tree for Shikra to build its nest on because of its low height and nests built on it may collapse even in the slightest storm. Also, it is difficult for birds to find prey in the premises of the trees. The selection of *G. sepium* for nesting by Shikra is probably due to the unavailability of suitable trees.

Keywords: Breeding, fledglings, generation, legume tree, lizard, nestlings, raptor, Shivaji University.

Many species of birds and plants have an inseparable relationship. Birds depend on trees for food and shelter or for both. The Shikra *Accipiter badius* Gmelin, 1788 is one of the most commonly occurring Indian raptors in the family Accipitridae. This carnivorous bird is an important component of the food chain and feeds on rodents, squirrels, small birds, small reptiles, and insects (Ali & Ripley 1978). These birds are very selective about nesting sites and build nests on trees. *Gliricidia sepium* (Jacq., 1842) Kunth is a medium-sized legume tree of the Leguminosae family. It is an important multipurpose legume tree (Batish et al. 2007), originating from Mexico to Colombia, but is now widely known in other tropical regions (Biddulph 1937). On perusal of the literature, it was found that the information on the relationship of *G. sepium* with Shikra is lacking. Hence, we claim that the present report as a first from India about nesting and breeding of Shikra on *G. sepium*. So far, no published record found that *G. sepium* was used by any bird for nesting. In this communication, we not only document the first report of nesting but also its breeding and successful completion of two breeding attempts in two consecutive years. The main objective of the present study is to highlight that due to the cutting down of large native trees, carnivorous birds like Shikra are choosing exotic trees for nesting as an alternative.

Material and Methods

During the summers of both 2020 and 2021 (February to May), observations on the nesting and breeding of Shikra on *G. sepium* tree were made on the Shivaji University, Kolhapur campus (16.6780° N, 74.2555° E), India, in the morning between 0800 h and 1100 h. Identification of the bird was confirmed by using Ali (2002) and Grewal et al. (2016), and the plant by Yadav & Sardesai (2002). The distance from where the nest was located down to the ground was measured using a measuring tape. The activity of the bird was captured using a Nikon D500 DSLR with a 200–500 mm lens.

Editor: H. Byju, Coimbatore, Tamil Nadu, India. **Date of publication:** 26 August 2026 (online & print)

Citation: Gaikwad, S.M. & M.M. Lekhak (2026). Nesting of Shikra Accipiter badius on *Gliricidia sepium* (Jacq.) Kunth (Leguminosae). *Journal of Threatened Taxa* 18(8): 29544–29547. https://doi.org/10.11609/jott.10498.18.8. 29544-29547

Funding: Shivaji University, Kolhapur.

Competing interests: The authors declare no competing interests.

Acknowledgements: The authors would like to thank the head, Department of Zoology, Shivaji University, Kolhapur for providing laboratory facilities and Shivaji University, Kolhapur for providing financial assistance under the 'Research Strengthening Scheme'.

Results and Discussion

While conducting a bird survey in Shivaji University, Kolhapur campus during 2020–2021, Shikra, has successfully reared young in two consecutive breeding seasons in a row by building a nest on the *G. sepium* tree. However, the last chick of the second generation died before it could fully grow up due to the falling of the nest.

During the last week of February 2020, a male and a female Shikra gathered small twigs and tree bark pieces to construct a nest on the *G. sepium* tree. They selected a specific place in the *G. sepium*, situated approximately 8 m above the ground, where three long branches diverged. From the second to the third week of March, both the male and the female took turns sitting in the nest to incubate the eggs (Image 1A). However, the female played a primary big role in the incubation process; as the female remained continuously seated in the nest throughout the incubation period, the male was observed at the nest occasionally. In the third week of April, a pure white chick was seen peeking out from the nest, and the very next day, a second white chick appeared inside. Both chicks were nurtured by the parents, who fed them in the mornings with prey they had hunted and brought back to the nest (Images 1B,C). For hunting, either the male or the female goes out, while the other partner remains perched on a different tree located approximately 8–9 m away from the nest to keep a watchful eye on the chicks. Meanwhile, the nestlings were peeking out of the nest while observing their surroundings. As the chicks grew older, they began venturing out of the nest to stand on its edge; however, at the slightest sign of danger, they would retreat into the nest to hide and find out the situation

Image 1. Nesting and breeding of Shikra *Accipiter badius* on *Gliricidia sepium* (first generation): A—The male (left, note the red iris) and female (right, note the golden yellow iris) incubating the eggs in the nest | B—Female caring for the first-generation nestlings | C—Female Shikra feeding her nestling | D—The early-stage fledgling moves near the nest. © Sunil Gaikwad.

outside. After 12–15 days, the nestlings transformed into 'fledglings' (turning creamy grey and brown) (Image 1D), and typically after 15–20 days, these young birds began to fly. The period from the commencement of nest construction to the first observed flights of the young was approximately 50 days.

Once again, during the second week of April in the second year (2021), the female was observed sitting in the same nest. This indicated that the female had laid eggs in the nest for a second time and that the incubation process was underway. Since the nest was already constructed, there was no need to gather the material typically required for building it. Subsequently, in the last week of April, three chicks were spotted peeking out of the nest (Image 2A), implying that the female had laid at least three eggs on this occasion. However, the three chicks differed noticeably in body size (Image 2B). Consequently, the chicks varied in size, being large, medium, and small. Among these chicks, one was noticeably smaller in size compared to the other two. Just as in the previous year, the tasks of hunting for the chicks, feeding them, and protecting them resumed. After 15–20 days, the two larger fledglings began to fly and started hunting the garden lizard (Image 2C). However, the smallest chick, which was somewhat frail, had not yet left the nest; consequently, its parents continued to hunt for it and feed it. Meanwhile (during the second week of May), heavy rain and a storm struck, causing a portion of the nest to fall from the tree. Following this event, the small fledgling was nowhere to be seen in the vicinity; however, five days later, it was found lying dead beneath the very same tree (Image 2D). Most of its body had been consumed by some animal, leaving behind nothing but feathers. During this study, it was not possible to directly observe the female laying eggs; furthermore, due to the difficulty in accessing the nest, the eggs inside could not be directly examined. Therefore, in this study, the total number of eggs (clutch size) has been merely estimated based on the number of chicks found in the nest.

Biddulph (1937) reported that the pair of Indian Shikra nested on the Banyan tree, and the same pair chose another tree for nesting in the second year. In the third year, the same pair built the nest again on the same Banyan tree on which the nest was built in the first year, but by choosing a different branch. Lamba (1964) reported Shikra's breeding season, clutch size, incubation, young in the nest, etc. According to him, the Shikras are very selective about the breeding locality as well as the nesting site. They prefer a well-screened shady tree with three or more-pronged forks to build a nest, and April and May are the breeding season in Pune, Maharashtra, which is only 240 km away from Kolhapur. He also reports that Shikra has a normal clutch with 3–4 eggs and an incubation period of 18 days. According to Idrisovich & Jumanov (2023), usually, the Shikra builds a nest in a tall tree in the last week of April and the first week of May, and the female incubates the eggs alone, while the male guards the nest and feeds the female. In India, the breeding season of Shikra occurs from March to June, and both sexes contribute to building the nest in which typically lay a clutch of 3–4 eggs (Birda species guide 2024). The observations in the present study are almost consistent with the above workers, as the recorded breeding season of the Shikra is February and April, and the number of eggs they lay was two in the first year and three in the second year. It was observed that both the male and female participate in the nest building, as mentioned by Suryavanshi (2021).

Shikra is known to feed on a variety of insects, lizards, small birds and mammals (Muni & Hegde 1998; Suryavanshi 2021). Upadhyay et al. (2023) observed three chicks in a nest built by a Shikra on an *Eucalyptus* tree in May and reported that both the male and female were involved in feeding them by hunting *Calotes versicolor* and other small animals. This means that the period of their nest building is almost the same as the period of nests built in our area. The males and females we studied also hunt and bring food to the chicks, feed them and raise them. Similarly, it was observed that the fledglings of Shikra started hunting the Garden lizard *Calotes versicolor* when they left the nest and started to fly. According to Gangalmale et al. (2026), small animals such as scorpions, lizards, and trapdoor spiders were not found in the area where the *Gliricidia* plantation was present. Lamba (1964) reported that Shikra chicks die due to two reasons, namely, starvation, accidents, diseases and natural calamities. Similarly, it was found that one of the three chicks fell out of the nest and died due to heavy storms and rain.

Looking at the information and criteria of the trees selected for nest construction mentioned above, *Gliricidia* selected by Shikra during the present study does not fit anywhere except for the presence of three or more pronged forks for nest building.

Conclusion

The Shikra *A. badius* likely selects the *G. sepium* tree for nesting and breeding purposes primarily due to the unavailability of large native trees. Due to rampant deforestation and the removal of native trees, birds that nest in tall trees may face increasing difficulties in finding suitable nesting sites (Byju et al. 2023). The non-native *G. sepium* tree is unsuitable for nesting by carnivorous birds

Image 2. Breeding of the second generation in the same nest and tree *Gliricidia sepium*: A—Note three nestlings move around in the nest | B—The growth difference among fledglings | C— Fledgling hunts a garden lizard | D— Remains of the youngest fledgling after falling and dying in a storm. © Sunil Gaikwad.

like the Shikra, as nests built upon it tend to collapse even in the face of minor natural disturbances. Furthermore, since prey is scarce in areas dominated by *G. sepium* plantations, these birds are forced to travel long distances in search of food.

References

Ali, S. & S.D. Ripley (1978). Handbook of the Birds of India and Pakistan, 2nd edition, Vol 1. Oxford University Press, London, 382 pp.

Ali, S. (2002). The Book of Indian Birds. 13th edition. Bombay Natural History Society, Oxford University Press, 326 pp.

Idrisovich, Y.A. & M.A. Jumanov (2023). Material on the ecology of Shikra (*Accipiter badius*) in the lower stretches of the Amudarya. European Sciences Review 1: 9–12.

Batish, D.R. et al. (2007). Allelopathic Tree-Crop Interactions under Agroforestry Systems. In Ecological Basis of Agroforestry. CRC Press, 400 pp.

Biddulph, C.H. (1937). Number of eggs laid by the Indian Shikra [*Astur badius dussumieri* (Temm. & Lang.)]. Journal of Bombay Natural History Society 39(2): 406.

Birda species guide (2024). Shikra (*Accipiter badius*) identification and ecology. https://app.birda.org/species-guide/45747/Shikra. Downloaded on 26.ii.2026.

Byju, H. et al. (2023). Powerline pylons: an unusual nesting success of White-bellied Sea-Eagle *Haliaeetus leucogaster* (Gmelin, 1788) (Aves: Accipitriformes: Accipitridae) from Ramanathapuram, southeastern coast of India. Journal of Threatened Taxa 15(7): 23610–23614. https://doi.org/10.11609/jott.8460.15.7.23610-23614

Gangalmale, S. et al. (2026). A new species of the trapdoor spider genus *Titanidiops* Simon (Araneae: Idiopidae) from western Maharashtra, India. Journal of Natural History, 60(5–8): 399–419. https://doi.org/10.1080/00222933.2025.2603654

Grewal, B. et al. (2016). A Pictorial Field Guide to Birds of India, Pakistan, Nepal, Bhutan, Sri Lanka and Bangladesh. Om Books International, Delhi, 792 pp.

Lamba, B.S. (1964). Nidification of some common Indian Birds. No.8. The Shikra, *Accipiter badius* (Gmelin). Records of the Zoological Survey of India 62(1–2): 11–20.

Muni, M. & V. Hegde (1998). Indian Shikra preying on Short-nosed Fruit Bats. Journal of Bombay Natural History Society 2: 338–339.

Suryavanshi, K. (2021). Nesting behaviour and diet of the Shikra *Accipiter badius* in Ajanta, Maharashtra. Indian Birds 17(2): 50–53.

Upadhyay, K. et al. (2023). Observation of a Leucistic female Shikra *Accipiter bandius* at a nest near Pavagadh Hill, Gujarat. Flamingo Gujarat - Bulletin of Gujarat Birds 6(2): 54–60.

Yadav, S.R. & M.M. Sardesai (2002). Flora of Kolhapur district. Shivaji University, Kolhapur, 679 pp.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 August 2026 | 18(8): 29548–29551

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

https://doi.org/10.11609/jott.10706.18.8.29548-29551

#10706 | Received 30 May 2026 | Final received 26 June 2026 | Finally accepted 08 July 2026

SHORT COMMUNICATION

New addition to the Odonata fauna of India: *Gynacantha basiguttata* Selys, 1882 (Odonata: Aeshnidae) from Arunachal Pradesh – a rectification

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Abstract: The present study highlights the first record of *Gynacantha basiguttata* Selys, 1882 from India, and significantly indicates a range extension and extends its known geographical distribution. Also known as the Spoon-tailed Duskhawker, the species was identified by dorsal diagnostic morphological characters and spoon-shaped cerci with on-site photographs taken on 16 October 2024 alongside a road-side vegetation about the Miao-Vijaynagar road on a cloudy day at Namdapha National Park and Tiger Reserve, in Arunachal Pradesh, India. Based on photographic evidence for same date, Mahesh et al. (2026) also reported the first confirmed sighting (after 110 years) of *Gynacantha khasiaca* (MacLachlan, 1896), from Arunachal Pradesh with inclusion of 3 photographs. One of the images from it is herein reassigned to *Gynacantha basiguttata* Selys, 1882, thereby indicating a self-rectification.

Keywords: Biodiversity, diagnostic, distribution, dragonfly, morphological, Namdapha National Park, new record, range extension, Spoon-tailed Duskhawker.

Situated in Arunachal Pradesh (India), Namdapha National Park and Tiger Reserve with an elevation range of 200 m to over 4,571 m, supports diverse habitats inclusive of tropical rainforests, subtropical forests, and alpine meadows (Upadhaya et al. 2026). Benevolently, it supports a vast biodiversity including the dragonflies and damselflies (Mahesh et al. 2025). The global diversity of Odonata comprises 6,442 species across 693 genera (Paulson et al. 2026), with India being a habitat for 514 species and 27 subspecies from 159 genera and 19 families (Subramanian & Babu 2025). The species count for Arunachal Pradesh is 113 with 12 species being endemic to the state (Subramanian & Babu 2025). Recently with two new species being discovered, the count has increased to 115 (Joshi et al. 2026a). The genus *Gynacantha* Rambur, 1842, includes large-sized dragonflies with predominantly brown and blue-green colouration and crepuscular behaviour (Fraser 1936). This genus comprises 92 species globally, with 17 species documented in India (Joshi et al. 2026b). With current discovery, the tally rises to 18.

Scientific rectifications are critical towards ensuing accuracy and integrity of published records, when inadvertent errors are identified. Mahesh et al. (2026) in the form of a short communication, reported first confirmed sighting of *Gynacantha khasiaca* MacLachlan,

Editor: Anonymity requested. **Date of publication:** 26 August 2026 (online & print)

Citation: Mahesh, R., R. Gopinath, D. Sawant, G. Joshi & R. Upadhaya (2026). New addition to the Odonata fauna of India: *Gynacantha basiguttata* Selys, 1882 (Odonata: Aeshnidae) from Arunachal Pradesh – a rectification. *Journal of Threatened Taxa* 18(8): 29548–29551. https://doi.org/10.11609/jott.10706.18.8.29548-29551

Funding: This study was self-funded, and a citizen science initiative by the authors. No fund has been received from any external agency for this study.

Competing interests: The authors declare no competing interests.

Acknowledgements: The authors would like to thank the staff of Forest Department at Namdapha National Park and Tiger Reserve (Arunachal Pradesh), for their valuable support and assistance during the fieldwork.

1896, in Arunachal Pradesh. Sighted on 16 October 2024 (after a gap of 110 years), the communication included three photographs. While two inserted photographs (Image 2) and (Image 3) correctly represents *G. khasiaca*, the third photograph (Image 4) constitutes a misidentification and is herein reassigned to *Gynacantha basiguttata* Selys, 1882. Notably, the sighting of *G. basiguttata* is the first verifiable photographic record from India, and the current manuscript highlights this finding, along with diagnostic details, as a rectification.

Materials and Methods

The photograph was taken with Sony Cyber-shot DSC-RX10 Mark IV camera, equipped with 24–600 mm f/2.4-4 ZEISS zoom lens, 20.1 MP 1-inch Exmor RS sensor and 0.03-second autofocus. The re-validation (for species identification) was confirmed with ID keys from literature (Selys-Longchamps 1882). No physical specimens were collected in strict adherence to forest norms, and compliance with the Indian Wildlife Protection (Amendment) Act, 2022.

Observations and findings

The discovery was made at an elevation of 600 m along the Miao-Vijaynagar road (Image 1) within the coordinates 27.46694^0–27.48361^0 N and 96.40027^0 E. A single male individual of *G. basiguttata* was spotted perching while hanging vertically downward (Image 2) around 0810 h on a cloudy day within a densely shaded vegetated area.

The specimen was identified as *G. basiguttata* by following characteristics (Image 1–5): a) black t-mark on frons (Image 2,4); b) olivaceous green thorax without any stripes on lateral; c) dark brown pigmentation in subcostal space at base of both forewing and hindwing extending in medial space, triangle of wings traversed by 7–8 cells, anal triangle 3-celled, anal loop 10–11 celled (Image 3); d) prominent constrict of segment 3; e) segment 2 with greenish-yellow vertical mark on mid-dorsum with greenish-yellow annular mark at anterior end and bluish markings at posterior end (Image 2); f) segment 3 with dorsal greenish-yellow spots on mid part with a pair of dorso-lateral spots near posterior end; g) segments 4–8 with slightly oblique dorsal greenish-yellow markings on mid-part and a pair of small greenish-yellow spots at dorso-lateral aspect of posterior end (Image 2); h) cerci brownish-black, narrow at base, expanded at apex giving a spoon-like appearance in dorsal view, hairs on medal border (Image 6); epiproct short, blackish-brown, half the length of cerci, triangular, broad at base, progressively narrows towards apex, apex of epiproct slightly bulged (Image 6).

Scope of Discovery

Gynacantha basiguttata is listed as 'Least Concern' by the IUCN Red List of Threatened Species (Dow 2020). It was originally described from Philippines and is widely distributed across southeastern Asia, with verifiable records from China, Brunei, Indonesia, Peninsular Malaysia, Philippines, Myanmar, Singapore, Thailand, and Vietnam (Steinmann 1997; Dow 2020). Based on female specimens present in the Indian Museum, Fraser

Image 1. Location of Miao-Vijaynagar road within Namdapha National Park and Tiger Reserve (Source: Google Earth).

Image 2. Dorsal view of *Gynacantha basiguttata* (male) individual, highlighting its terminal abdominal appendages. © Rajesh Gopinath.

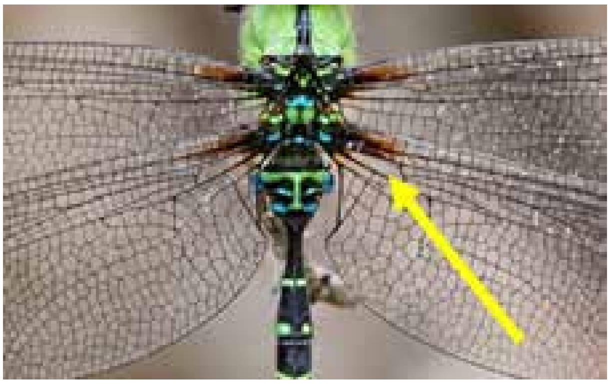

Image 3. Wings of *Gynacantha basiguttata* showing basal wing pigmentation with multi-celled anal loop and anal triangle. © Rajesh Gopinath.

Image 4. Frons of *Gynacantha basiguttata* showing black t-mark. © Rajesh Gopinath.

(1936) had stated the distribution of *G. basiguttata* from Bengal (India), Assam (India) Burma, Malaysia, Indo-China, and Sundaic Archipelago. This geographical distribution was also adopted by Subramanian (2009) and Mitra (2002). Fraser (1936) noted the species to be a very rare insect in Indian limits. As this record from India appeared highly doubtful, the species was excluded from the IUCN checklist of Indian Odonata (Dow 2020), checklist of South Asia (Kalkman et al. 2020) and from the checklist of India (Subramanian & Babu 2025). Further studies have since then followed the same taxonomic arrangement, including the recently updated Indian checklist detailing the distribution records of Gynacantha spp. (Sawant & Kambli 2023). Therefore, with this photographic record, the study presents strong evidence of *G. basiguttata* within the Indian limits and further recommends inclusion of the species in the checklist of India, the Indian subcontinent and South Asia.

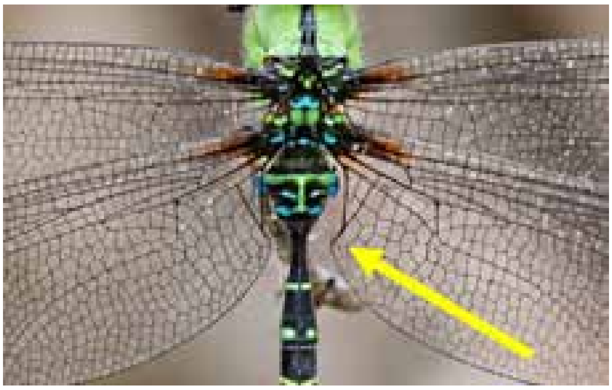

Image 5. Constrict of segment 3 and characteristic markings of *Gynacantha basiguttata*. © Rajesh Gopinath.

Image 6. Anal appendages showing spoon-shaped cerci and short epiproct (half the length of cerci) of Gynacantha basiguttata. © Rajesh Gopinath.

Conclusion

Gynacantha basiguttata Selys, 1882 was historically mentioned in Odonata checklists, for its presence within Indian limits. However, as the inclusion was based solely on female specimens, it was subsequently removed from the recent checklists. The present study provides the first photographic evidence of a male individual from India, thereby supporting its inclusion in the checklists of India, the Indian subcontinent, and South Asia. The study details this discovery and derives it in the form of a self-rectification.

References

Dow, R.A. (2020). *Gynacantha basiguttata*. The IUCN Red List of Threatened Species, e.T167287A176402482. Accessed on 7.vii.2026. https://doi.org/10.2305/IUCN.UK.2020-3.RLTS.T167287A176402482.en

Fraser, F.C. (1936). The Fauna of British India, including Ceylon and Burma: Odonata. Vol. III, 1–461. Taylor & Francis, London. https://doi.org/10.26515/rzsi/v8/i1/1912/163133

Joshi, S. et al. (2026a). Three new species of *Sarasaeschna Karube* & Yeh, 2001 (Odonata: Anisoptera: Aeshnidae) from northeastern India; with a new record of *Sarasaeschna khasiana* (Lieftinck, 1968). Zootaxa 5796(2): 261–288. https://doi.org/10.11646/zootaxa.5796.2.3

Joshi, S. et al. (2026b). A Taxonomic Catalogue Of Indian Odonata. In: Joshi, S. et al. (eds.). Odonata of India, v 1.57. Indian Foundation for Butterflies. https://www.indianodonata.org/. Accessed on 7.vii.2026.

Kalkman, V.J. et al. (2020). Checklist of the dragonflies and damselflies (Insecta: Odonata) of Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka. Zootaxa 4849(1): 1–84. https://doi.org/10.11646/zootaxa.4849.1.1

Mahesh, R. et al. (2025). First record of the *Coeliccia svihleri* Asahina, 1970 (Odonata: Platycnemididae) in Arunachal Pradesh, India. Journal of Threatened Taxa 17(8): 27363–27370. https://doi.org/10.11609/jott.9533.17.8.27363-27370

Mahesh, R. et al. (2026). First time in 110 years: Sighting of *Gynacantha khasiaca* Maclachlan, 1896 (Odonata: Aeshnidae) in Arunachal Pradesh, India. Journal of Threatened Taxa 18(5): 28982–28987. https://doi.org/10.11609/jott.9839.18.5.28982-28987

Mitra, T.R. (2002). Geographical distribution of Odonata of Eastern India. Memoirs of Zoological Survey of India 19: 1–208.

Paulson, D. et al. (2026). World Odonata List. Odonata Central, University of Alabama. https://www.odonatacentral.org/app/#/wol/. Accessed on 7.vii.2026.

Sawant, D. & A. Kambli (2023). *Gynacantha anandmati*, a new species of dragonfly (Odonata: Anisoptera: Aeshnidae) from Maharashtra, India. Zootaxa 5239(4): 537–550. https://doi.org/10.11646/zootaxa.5239.4.5

Selys-Longchamps, E. de (1882). Odonates de Sumatra et de quelques autres îles de l'Archipel Indien. Anales de la Sociedad Española de Historia Natural 11: 5–32.

Steinmann, H. (1997). World catalogue of Odonata. Volume II: Anisoptera (Das Tierreich, Part 111). Walter de Gruyter, Berlin & New York. https://doi.org/10.1515/9783110824445

Subramanian, K.A. & R. Babu (2025). Checklist of Fauna of India: Arthropoda: Insecta: Odonata. Version 2.0. Zoological Survey of India. https://doi.org/10.26515/Fauna/2/2025/Arthropoda:Insecta:Odonata

Subramanian, K.A. (2009). Dragonflies of India: A Field Guide. Vigyan Prasar, New Delhi, 168 pp.

The Wildlife (Protection) Amendment Act (2022). Ministry of Law and Justice. https://ntca.gov.in/ Accessed on 7.vii.2026.

Upadhaya, R. (2026). First photographic record of *Chitoria sordida sordida* (Moore, 1866) (Insecta: Lepidoptera: Nymphalidae: Apaturinae) from Arunachal Pradesh, India. Journal of Threatened Taxa 18(3): 28600–28603. https://doi.org/10.11609/jott.9480.18.3.28600-28603

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 August 2026 | 18(8): 29552–29554
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.10690.18.8.29552-29554
#10690 | Received 26 May 2026 | Final received 04 July 2026 | Finally accepted 31 July 2026

NOTE

Breeding tern colonies in Valinokkam Lagoon, Tamil Nadu, India: additional records from the Gulf of Mannar region

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Terns (family Laridae) comprise 43 globally distributed species (AviList Core Team 2025), of which 18 are recorded in India, and nine breed along Indian coasts and sandbars (Byju et al. 2025a). Historical breeding records of Little Tern *Sternula albifrons* from Rameswaram by Abdulali (1942) lack evidence. Subsequent breeding records in India are from Chilika, Odisha (Balachandran et al. 2005; Li et al. 2009) and Kodiyakkarai, Tamil Nadu (Holloway 1993). More recently, breeding colonies of Little Tern and Saunders's Tern *Sternula saundersi* have been reported on the sandbars of Adam's Bridge along the Indian coast (Byju et al. 2025a). The present note extends these breeding records to the coastal lagoons of the Gulf of Mannar region of Tamil Nadu by providing the first documentation of breeding colonies of both species from Valinokkam Lagoon.

Valinokkam Lagoon (9.1661° N, 78.6141° E), is a man-made coastal lagoon bordered by state-operated saltpans, covering approximately 1,146 ha and extending over 10.12 km. Extensive mudflats and shallow saline habitats are created by periodic seawater pumping and evaporation for salt production. Byju et al. (2023; 2025b) have conducted ornithological studies earlier at this site.

Breeding populations of both terns (April–May 2026) were observed as part of a long-term coastal bird monitoring program at Valinokkam Lagoon. The colony size was estimated through total counts of active nests and direct observations of incubating adults and associated breeding activity within nesting areas (Image 1).

A total of 30 active nests of Little Tern was recorded from two colonies comprising 12 and 18 nests, respectively, on open sand flats. Nests consisted of shallow, moist scrapes lined with fragmented shell material and lacked surrounding vegetation, consistent with earlier observations from arid coastal habitats (Panagoda et al. 2020; AlRashidi 2025). Clutch size varied from one to three eggs (Cheah & Ng 2008), although two-egg clutches dominated. Eggs were olive-green with prominent brown blotches (Image 2). Egg laying was observed during the first week of April, and chicks were recorded during the first week of May. Four nests contained two chicks each, while one nest contained both an egg and a chick, indicating asynchronous hatching. Most nests were located within 30 m of nearby water sources.

Breeding behaviour included aerial displays, chasing flights, and one partner carrying fish to the incubating partner. Biparental incubation was observed throughout the nesting period. Incubating adults frequently wet their ventral plumage by dipping into the nearby water, presumably as a thermoregulatory adaptation to hot

Editor: Bhargavi Srinivasulu, Zoo Outreach Organisation, Hyderabad, India. **Date of publication:** 26 August 2026 (online & print)

Citation: Maitreyi, H., H. Byju, N. Raveendran & S. Ravichandran (2026). Breeding tern colonies in Valinokkam Lagoon, Tamil Nadu, India: additional records from the Gulf of Mannar region. *Journal of Threatened Taxa* 18(8): 29552–29554. https://doi.org/10.11609/jott.10690.18.8.29552-29554

Funding: None.

Competing interests: The authors declare no competing interests.

Image 1. Map showing the breeding colonies of Little and Saunders's Terns in Valinokkam Lagoon, Tamil Nadu, India.

ambient temperatures (AlRashidi 2025). One nest contained a damaged egg, although the cause could not be determined.

Eight nests of Saunders's Tern (four each in two colonies) were documented on elevated mud bunds within active saltpan areas. Nests were shallow, moist scrapes containing fragmented shell material. All nests had a single egg. Eggs were paler and sandier in colouration, with smaller brown speckles compared to those of Little Tern (Image 3). Nests were situated only a few metres from water and lacked vegetation cover. Both adults participated in incubation, and courtship feeding behaviour was similar to that observed in Little Terns.

The occurrence of breeding colonies of both sympatric tern species within the saltpan-associated landscape highlights the importance of Valinokkam Lagoon as a potential breeding habitat for small coastal terns. Breeding habitats at the lagoon are particularly vulnerable to increasing human disturbance, including fishing, livestock grazing, and vehicular movement. Long-term monitoring and protection of the wetland are crucial for conservation of breeding populations.

References

Abdulali, H. (1942). The distribution of the Rosy Tern. Journal of the Bombay Natural History Society 43: 104.

AlRashidi, M. (2025). Breeding ecology and incubation behaviours of Little Tern *Sternula albifrons* in the Sabkhat Al-Fasl Lagoons, Saudi Arabia. Marine Ornithology 53(2): 235–241. https://doi.org/10.5038/2074-1235.53.2.1642

AviList Core Team (2025). AviList: The Global Avian Checklist, v2025. https://doi.org/10.2173/avilist.v2025. Accessed on 7.vii.2026.

Balachandran, S. et al. (2005). Habitat evaluation of Chilika Lake with

Image 2. A—Adult Little Tern | B—Eggs and nest | C—Chicks in the nest. © H. Maitreyi.

Image 3. A—Adult Saunders's Terns | B—Egg and nest. © H. Maitreyi.

special reference to birds as bioindicators. Final Report (2001–2005), Bombay Natural History Society, Mumbai. 141 pp.

Byju, H. et al. (2023). Importance of conserving a critical wintering ground for shorebirds in the Valinokkam Lagoon—a first study of the avifaunal distribution of the southeastern coast of India. Journal of Threatened Taxa 15(8): 23696–23709. https://doi.org/10.11609/jott.8494.15.8.23696-23709

Byju, H. et al. (2025a). Breeding tern colonies on the sandbars of Adam's Bridge, India: new records and significance. Journal of Threatened Taxa 17(3): 26680–26689. https://doi.org/10.11609/jott.9591.17.3.26680-26689

Byju, H. et al. (2025b). Temporal dynamics of shorebird assemblages in Valinokkam Lagoon, southeast India: a new wintering site along the Central Asian Flyway. Ornis Hungarica 33(2): 22–42. http://doi.org/10.2478/orhu-2025-0018

Cheah, J.W.K. & A. Ng (2008). Breeding ecology of the little tern, S*terna albifrons* Pallas, 1764 in singapore. Nature in Singapore 1: 69–73.

Holloway, M. (1993). The variable breeding success of the Little Tern *Sterna albifrons* in south east India and protective measures needed for its conservation. Biological Conservation 65: 1–8. https://doi.org/10.1016/0006-3207(93)90189-8

Li, Z.W.D. et al. (2009). Status of Waterbirds in Asia—Results of the Asian Waterbird Census: 1987–2007. Wetlands International, Kuala Lumpur, 35 pp.

Panagoda, B.G. et al. (2020). Sympatric breeding of two endangered *Sternula* terns, Saunders's *S. saundersi* and Little *S. albifrons* Terns, in the Rama's Bridge of Sri Lanka. BirdingAsia 34: 76–83.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 August 2026 | 18(8): 29555–29558

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

https://doi.org/10.11609/jott.9697.18.8.29555-29558

#9697 | Received 19 February 2025 | Final received 16 June 2026| Finally accepted 14 July 2026

NOTE

Addition of *Athyrium rhachidosorum* (Hand.-Mazz.) Ching, 1934 (Polypodiales: Woodsiaceae) to the pteridophyte diversity of India

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Athyrium Roth is a large and complex pteridophyte genus with many taxonomically critical species. This genus has been assigned to a separate family Athyriaceae (PPG I 2016). We here consider it to be under the family Woodsiaceae (Fraser-Jenkins 2008; Fraser-Jenkins et al. 2018). A total of 50 species and 17 hybrids of Athyrium were reported to occur in India in 2018 (Fraser-Jenkins et al. 2018), whereas in Arunachal Pradesh, 28 species of Athyrium were reported to occur (Chanda et al. 2024).

A. rhachidosorum was first reported from Myanmar but predominantly occur in China. So far, it was known to occur from these two countries only. The present paper reports the occurrence of *A. rhachidosorum* in India.

The species was collected from forest of Dibang Wildlife Sanctuary of Dibang Valley District of Arunachal Pradesh. It was found to grow in a subtemperate forest with lavish vegetation, in a high-altitude area (2,800 m). This forest is on the way to 'Seven Lake' area inside the Wildlife Sanctuary.

Collection: Several field survey tours were undertaken by the first author in Dibang Wildlife Sanctuary for the 'Flora of India' project, titled 'Ferns and Fern-allies of Dihang-Dibang Biosphere Reserve of Arunachal Pradesh'. *A. rhachidosorum* was collected along with many other ferns during those field trips (Image 1).

Identification: The specimens were dried and mounted on herbarium sheets following the standard methods. Later, these were scanned with an Epson scanner, studied under a stereo microscope and photographed. During the process of identification of the collected specimens, the first author misidentified it to be *Athyrium pectinatum*. Later on, the second author identified it as *A. rhachidosorum*.

Athyrium rhachidosorum (Hand.-Mazz.) Ching, Index Filic. (C.Chr.), Suppl. Tert. 43. 1934 (as 'rhachidisorum') (Image 2).

Holotype: Northwestern Yunnan: in rainforest of the Burmese monastery in the valley below the Gomba-la Pass, in the Salwin-Irrawaddy catchment above Tschamutong, granite, 2,900 m, H. Handel-Mazzetti 4595, 12.vii.1916 (Wang et al. 2013).

Basionym: *Asplenium rhachidosorum* Hand.-Mazz., Symb. Sin. 6: 33. 1929.

Synonyms: *Athyrium densisorum* X.C.Zhang, Bull. Bot. Res., Harbin 11(3): 8. 1991.

Athyrium wuliangshanense Ching, Acta Bot. Boreal.-Occid. Sin. 6: 15. 1986.

Description: Rhizome erect, scaly. Fronds tufted, tripinnate to quadripinnatifid; stipe brown, scaly at

Editor: Anonymity requested. **Date of publication:** 26 August 2026 (online & print)

Citation: Chanda, C. & C.R. Fraser-Jenkins (2026). Addition of *Athyrium rhachidosorum* (Hand.-Mazz.) Ching, 1934 (Polypodiales: Woodsiaceae) to the pteridophyte diversity of India. *Journal of Threatened Taxa* 18(8): 29555–29558. https://doi.org/10.11609/jott.9697.18.8.29555-29558

Funding: The study was funded by The Ministry of Environment, Forest & Climate Change, Government of India.

Competing interests: The authors declare no competing interests.

Acknowledgements: The authors are grateful to Dr. A.A. Mao, director, Botanical Survey of India, for providing necessary logistical support. We are also grateful to the Department of Environment and Forests, Government of Arunachal Pradesh, for providing necessary permission. We thank Emudu Trekkers of Anini for assistance in survey work and exploration. We also acknowledge the cooperation of Mr. Rohan Maity, senior preservation assistant, Botanical Survey of India, during this work.

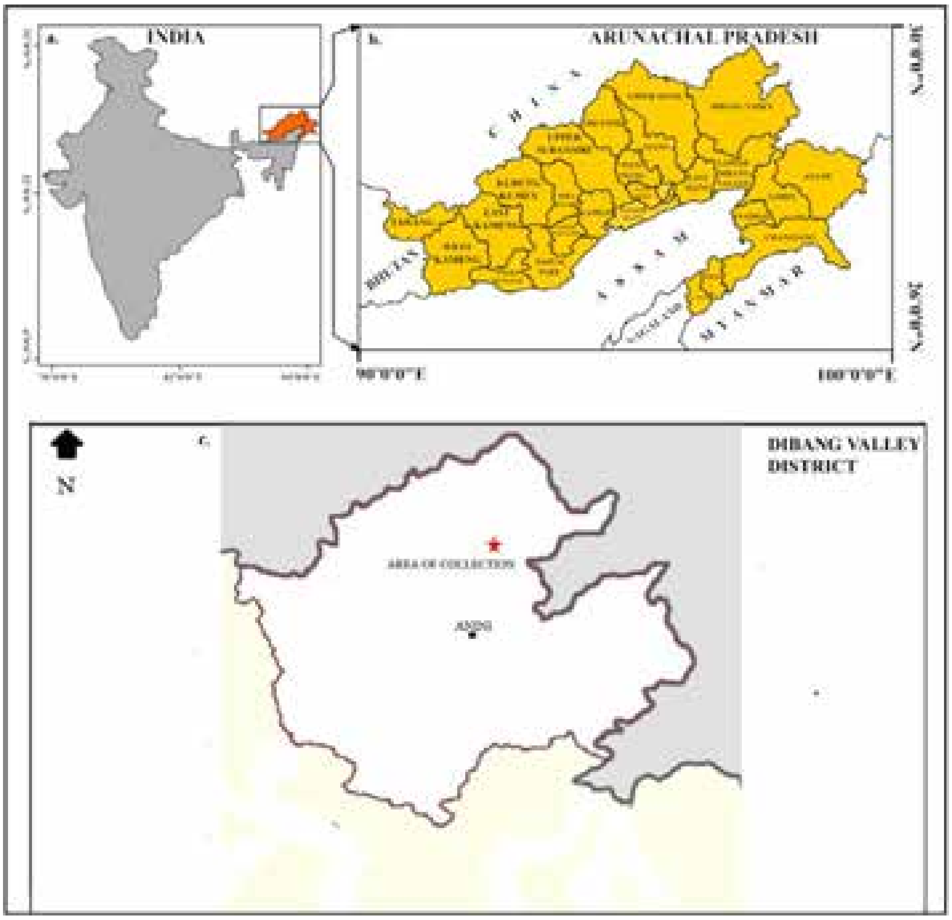

Image 1. Map of the area: a—Position of Arunachal Pradesh in the map of India | b—Map of Arunachal Pradesh showing its districts | c—Map of Dibang Valley District showing the area of collection.

lower half, dorsally grooved, 37–45 × 0.35–0.4 cm; scales dark brown with a pale brown margin, basifixed, lanceolate to ovate-lanceolate, base truncate, margin entire, apex acuminate to caudate, 3–6 × 1–2 mm; rachis stramineous, glabrous; lamina oblong-lanceolate, herbaceous, 40–45 cm × 15–18 cm; pinnae bipinnate to tripinnatifid, subopposite to alternate, stalked, triangular-lanceolate, apex caudate, 7–18 × 1.7–4 cm, lower 2 pairs slightly shorter; costae stramineous, often very narrowly winged; pinnules pinnate to bipinnatifid, subopposite to alternate, stalked, lanceolate, asymmetrical with slightly larger acroscopic pinnulets, base truncate acroscopically and cuneate basiscopically, apex obtuse to acute, with minute dentation, 1–2.5 × 0.35–0.6 cm, few pairs of lower pinnules in lower pinnae gradually shortened; costules with 2–3 short setae; pinnulets simple to pinnatifid, alternate, sessile, oblong-lanceolate, anadromous, base adnate, margin entire to lobed, apex obtuse, dentate, 2–4 × 1–1.5 mm, basal acroscopic one largest; ultimate lobes linear, apex obtuse to acute, up to 2 × 0.7 mm; veins inconspicuous, forked, free. Sori oblong, indusiate, central, one at the base of each pinnulet; indusia thin; spores brown, monolete, reniform, surface irregularly tuberculate, perispore absent, 38–42 × 25–28 µm (Image 2).

Note: This species can be circumscribed by the following characters – erect rhizome; tripinnate to quadripinnatifid fronds; oblong-lanceolate lamina with slightly shorter basal pairs of pinnae; asymmetrical pinnule bases; slightly larger acroscopic pinnulets than basiscopic ones; linear ultimate segments; 2–3 setae on costules and centrally arranged, oblong sori.

Habitat: A very rare, high-altitude, terrestrial species, growing on forest floor, in dense forests.

Distribution: India (Arunachal Pradesh), China (Sichuan, Xizang, & Yunnan), and Myanmar (Flora of China 2013).

Specimen examined: India, Arunachal Pradesh, Dibang Valley, Dibang Wildlife Sanctuary, north-east of Emuli Village, towards 2nd camp, c. 2,800 m, 17.xi.2021, C. Chanda 43661, ARUN (Image 3).

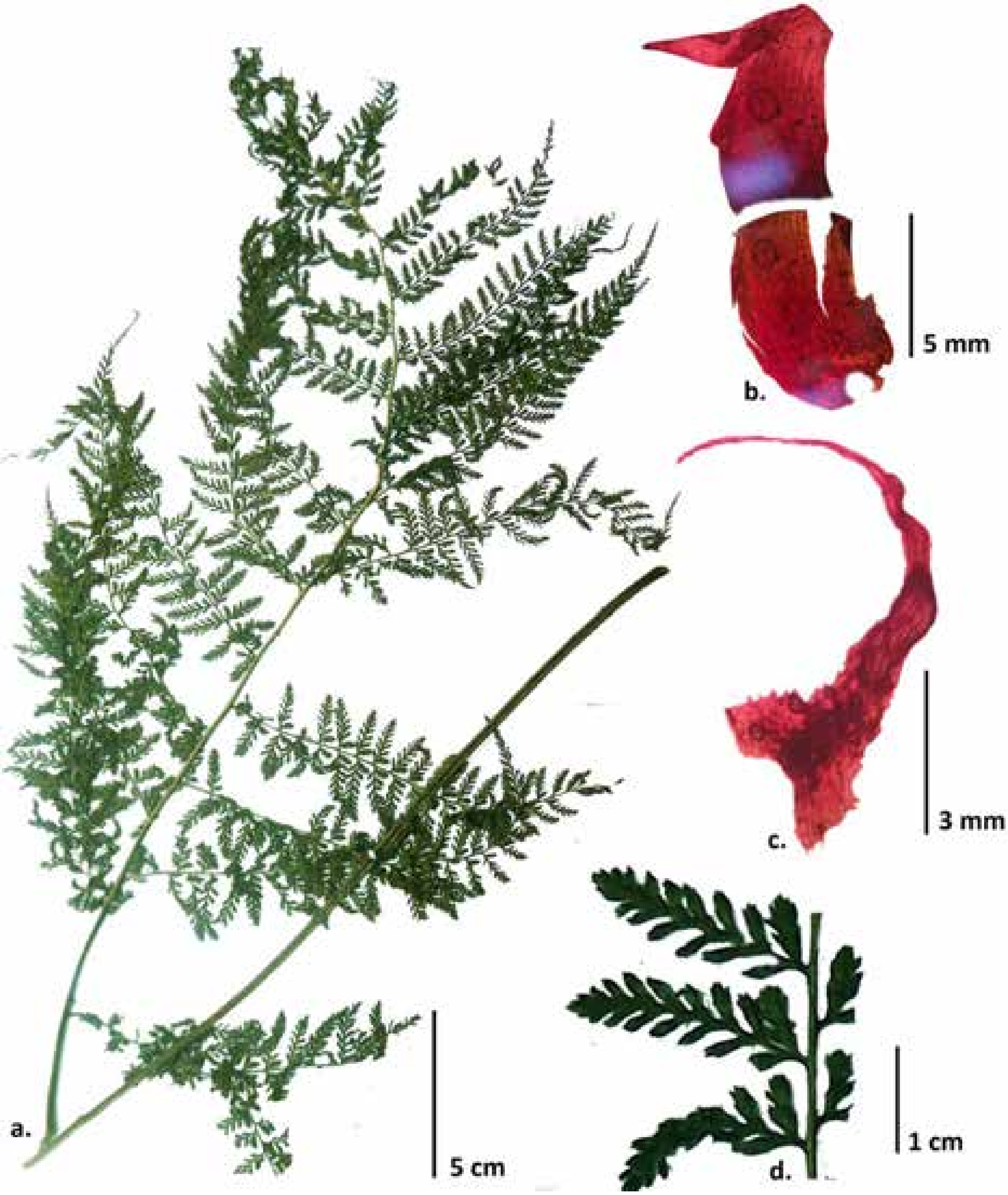

Image 2. Habit and different parts of *Athyrium rhachidosorum* (Hand.-Mazz.) Ching: a—Habit of the plant | b— Rhizome scale | c—Stipe-base scale | d—Part of a pinna showing pinnules and pinnulets. © C. Chanda.

References

Chanda, C. et al. (2024). The genus *Athyrium* in Arunachal Pradesh state, India. Phytotaxa 636(4): 262–278. https://doi.org/10.11646/phytotaxa.636.4.1

Fraser-Jenkins, C.R. (2008). Taxonomic Revision of Three Hundred Indian Subcontinental Pteridophytes with a Revised Census-list. Bishen Singh Mahendra Pal Singh, Dehra Dun, 685 pp.

Fraser-Jenkins, C.R. et al. (2018). An Annotated Checklist of Indian Pteridophytes, Part-2. Bishen Singh Mahendra Pal Singh, Dehra Dun,

Image 3. Herbarium specimen of *Athyrium rhachidosorum* (Hand.-Mazz.) Ching. © C. Chanda.

573 pp.

Schuettpelz, E. & H. Schneider (PPG I) (2016). A community-derived classification for extanlycophytes and ferns. Journal of Systematics and Evolution 54(6): 563–603. https://doi.org/10.1111/jse.12229

Wang, Z. et al. (2013). Athyriaceae. In: Wu, Z.Y. et al. (eds.). Flora of China, Volume 20–21.

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NAAS rating (India) 5.64

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Tamil Nadu 641006, India
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Journal of Threatened Taxa

OPEN ACCESS

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

www.threatenedtaxa.org

August 2026 | Vol. 18 | No. 8 | Pages: 29375–29558
Date of Publication: 26 August 2026 (Online & Print)
DOI: 10.11609/jott.2026.18.8.29375-29558

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Review

Short Communications

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