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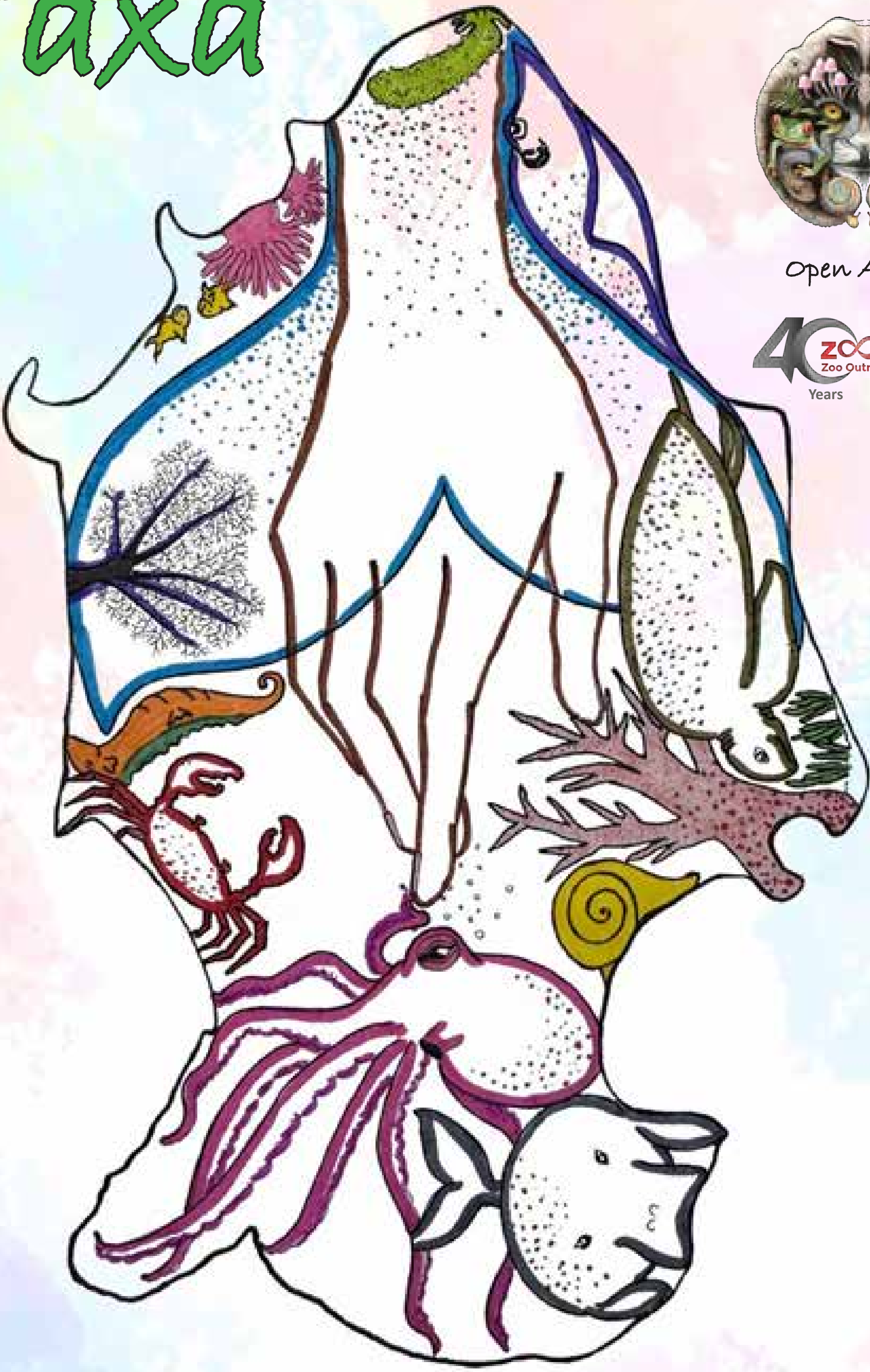

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Cover: Little Andaman is part of the island chain with incredible biodiversity, but these amazing species are threatened by development projects, and need our support. Pen and ink artwork by Priyanka Iyer.

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ARTICLE

Taxonomic studies and breaking seed dormancy of *Hibiscus lobatus* (Murray) Kuntze, 1898 (Magnoliopsida: Malvales: Malvaceae) — a native plant of the central Western Ghats

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Abstract: *Hibiscus lobatus* (Murray) Kuntze is a medicinal plant of the Malvaceae family, very sparsely and seasonally distributed, particularly in the Western Ghats of Karnataka. This species, known for its ethnopharmacological uses, especially in wound healing, faces a declining population due to habitat loss, overexploitation, and poor seed germination. Seed dormancy has been identified as a major factor limiting its natural regeneration. In this study, the distribution, habitat, and taxonomic diagnostic features of *Hibiscus lobatus* were investigated across different floristic regions of the central Western Ghats. Seed viability and dormancy-breaking treatments were assessed both in the field and in vitro. Tetrazolium testing confirmed seed viability, but field germination rates were low (4–6%), indicating strong dormancy. Among the treatments tested, sulfuric acid scarification combined with GA_3 application proved most effective, substantially enhancing germination and reducing germination time. These findings establish an optimised protocol for overcoming seed dormancy in *Hibiscus lobatus*, which can be applied to conserve and propagate this important medicinal species, addressing its declining population.

Keywords Annual herb, ethnobotanical survey, Gibberellic acid (GA_3), native flora conservation, propagation techniques, scarification, seasonal germination, seed viability, tetrazolium test, Western Ghats biodiversity.

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Author contributions: KTD—conducted plant taxonomical study in the Central Western Ghats of Karnataka and studied the morphometric feature of Hibiscus lobatus, designed and performed seed dormancy-breaking experiments. KV—mentor, corresponding author, overseeing the study's conceptualization and coordination. SGBU— Conducted ethnobotanical survey and explored traditional medicine uses of *Hibiscus lobatus*. RK—assisted in evaluating the in vivo seed dormancy-breaking experiments of *Hibiscus lobatus*.SAS—Assisted in evaluating the in vitro seed dormancy-breaking experiments of *Hibiscus lobatus*.

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INTRODUCTION

Global ecological changes driven by human activity and climate shifts have significantly impacted plant biodiversity. Ecological degradation and its consequent biodiversity loss, pose a serious threat to the natural distribution of plant species. Intensive plant exploration studies conducted across various floristic regions have helped taxonomists recognise the vulnerable status of many native species, often impacted by habitat disturbance, and the spread of exotic species. In recent years, habitat loss, overexploitation, pollution, and illegal trade of plant resources have further contributed to biodiversity decline, pushing several species toward threatened status (Tali et al. 2015). These growing stresses are also linked to climate change (Urban 2015; Bachman et al. 2018; Hamid et al. 2020). Therefore, extensive plant surveys and identification of threat status are crucial for assessing extinction risks, formulating conservation strategies, and raising awareness to protect declining habitats. Continuous plant exploration and conservation assessments are essential for understanding species vulnerability, formulating protective strategies, and promoting sustainable use. This is particularly important for lesser-studied native species like *Hibiscus lobatus* (Murray) Kuntze, which faces seasonal growth constraints and germination barriers, making it a valuable candidate for conservation and regenerative studies.

Hibiscus lobatus (Murray) Kuntze (Synonyms: *Hibiscus solandra* L'Hér, *Solandra lobata* Murray, *Hibiscus torulosus* Salisb., *Hibiscus pumilus* Roxb., and *Laguna lobata* Willd.) (WFO 2025) is an annual herb of Malvaceae, primarily growing in the seasonally dry tropical biome of the world. This species was recorded in several monumental taxonomic publications, including flora of the Presidency of Madras (Gamble 1915), flora of Tamil Nadu Carnatic (Matthew 1983), flora of Karnataka (Saldahna 1984), flora of South Kanara (Bhat 2014), flora of Sri Venkateswara National Park and Andhra Pradesh (Benjamin & Murthy 2013). In addition to climatic changes, anthropogenic pressures such as road construction, resort development, mega power projects, deforestation, and agricultural activities in the core forest regions of the Central Western Ghats have severely disturbed natural habitats, pushing the native herbaceous species *Hibiscus lobatus* to the threshold of extinction (Noori et al. 2025). Intensive plant exploration studies in various floristic provinces of the central Western Ghats of Karnataka, such as, flora of Shimoga District (Ramaswamy et al. 2001), flora of Davanagere District (Manjunatha et al. 2004), flora of British India (Hooker 1875), have not listed *Hibiscus lobatus*. Furthermore, detailed morphometric studies, and diagnostic characteristics of this species have not been thoroughly investigated. Hence, the present work is undertaken.

Seed dormancy is an adaptation that helps plants to survive unfavourable environmental conditions by coordinating germination and establishment with the surrounding environment (Donohue et al. 2010). Environmental factors such as soil temperature and humidity play a crucial role in controlling dormancy in mature seeds, serving as key determinants for dormancy cycling (Leubner 2006). Previous studies have investigated the seed viability of various *Hibiscus* species, including *Hibiscus acetosella* Welw. ex Fic., *H. calyphyllus* Cav., *H. surattensis* L., *H. lobatus* Kuntze, *H. radiatus* Cav., *H. vitifolius* L., and *H. panduriformis* Burm. F (Kak et al. 2015); as well as *Hibiscus waimeae* ssp. *hannerae*, and *Hibiscus waimeae* ssp. *waimeae* (Wolkis et al. 2018).

In the present study, field surveys, and ethnobotanical investigations were conducted to explore the distribution, and traditional uses of *Hibiscus lobatus* (Murray) Kuntze in the central Western Ghats, particularly in the forest regions of Tirthahalli (Shivamogga District) and Narasimharajapura Taluk (Chikkamagaluru District). These surveys revealed valuable traditional knowledge, with local practitioners using whole-plant extracts for various skin-related treatments. Notably, these traditional uses have not been recorded in official pharmacopeia or documented in previous scientific literature. Although anti-aging properties have been reported in related species such as *Hibiscus syriacus* (Di Martino et al. 2017; Yang et al. 2019), *H. manihot* L., and *H. abelmoschus* L. (Luan et al. 2020), such properties in *H. lobatus* remain unexplored, and neglected in terms of scientific investigation. This study aims to document the morphological characteristics and distribution of *Hibiscus lobatus* in the central Western Ghats, assess its seed viability, and dormancy status, and develop effective in vivo, and in vitro dormancy-breaking protocols. These efforts are intended to overcome regeneration barriers and support the conservation of this native, and underutilised species.

MATERIALS AND METHODS

Study area

Western Ghats in Karnataka State, India, is a global biodiversity hotspot covering an area of approximately 20,668 km^2, popularly known as the Sahyadri Hills. This region encompasses the largest portion of the Western Ghats, accounting for about 37% of its total area, and is located between 13.769°–15.732° N and 74.124°–75.169° E. The mountain range runs parallel to the western coast of India. The climate is semi-arid and cooler, the mountain range runs parallel to the western coast of India. The climate is semi-arid to temperate, with higher elevations averaging around 15°C (60°F) annually, while lower elevations record mean annual temperatures varying from 20°C (68°F) in the south to 24°C (75°F) in the north (Ramachandra et al. 2019). The geographical habitat of *Hibiscus lobatus* in different study locations within the Sahyadri Hills includes both moist and dry forests.

Taxonomy

The standard herbarium method (Bridson & Forman 1992) was followed during the collection, processing, and preparation of the herbarium specimens. Voucher specimens have been deposited at Kuvempu University, DBT-BUILDER Herbarium (KUDBH- Mal 21-Hb). An ethnobotanical survey was conducted in the study area to document the traditional use of this plant species. The survey typically began with the interview of authorised traditional medicine practitioners residing in and around Sahyadri Hills.

Evaluation of seed viability

a) Tetrazolium Method: Tetrazolium method (Patil & Dadlani 2009) was followed to test the viability of seeds of *Hibiscus lobatus.* Three groups of seeds, aged 10 months, five months, and one month old, were prepared with 100 seeds per group, and were divided into four replicates of 25 seeds each. For hydration, seeds were placed on the moist paper towels, and were soaked directly in distilled water for 12 hours. Following pre-soaking, seed coats were removed, and a small puncture was made near the embryonic axis to facilitate better staining. The seeds were then treated in 1% tetrazolium chloride solution for 4 hours at diurnal room temperature, allowing the solution to react with viable seeds, which stained red or pink. After staining, seeds were rinsed with distilled water, and viability was assessed based on colour intensity in the embryo, with red or pink indicating viable cells. The viability of each seed group was recorded by counting stained (viable) versus unstained (non-viable) seeds in each replicate. Viability percentage for each group was calculated using:

Viability Percentage = (Number of Viable Seeds/ Total Number of Seeds Tested) *100

b) Seed germination test: Seed germination test under field condition (Pace et al. 2016) was conducted to assess germination rates of 12 hr hydrated seeds of 10 months, 5 months, and 1 month old. Seeds were sown in manually prepared plots using humus-rich topsoil corresponding to the O horizon, and regular watering was provided to create conditions favourable for seed germination. In each plot, 25 seeds from each age group were sown, with four replicates per group, totalling 100 seeds per age group. Germination percentages were recorded based on seedling emergence over time under natural environmental conditions in the experimental garden.

Breaking of seed dormancy

To break the dormancy of *Hibiscus lobatus* seeds, experiments were conducted using two pretreatment methods: hot water stratification (Benedito et al. 2019) and acid stratification (Dilaver et al. 2017) were employed. Seeds were divided into triplicates of 30 seeds for each treatment group. For hot water stratification, seeds were immersed in hot water (60–70°C) for 10 min. Acid scarification involves treating the seeds with sulphuric acid (H_2SO_4) at concentrations ranging from 5% to 20% for 5 min. Following these treatments, seeds were sown in vivo in the field condition and cultured in vitro on Murashige and Skoog (MS) medium supplemented with gibberellic acid (GA_3) at concentrations of 0.75–1.5 mg/L (Zhang et al. 2020).

RESULTS AND DISCUSSION

Morphometric studies

Annual, erect, herbaceous plant attaining 50–70 cm in height. Stems fibrous, branched; branchlets hairy; scabrid or stellate trichomes; glabrescent on maturity. Leaves dimorphic, alternate, membranous; lower leaves ovate-cordate, 1.5–3 cm long; middle leaves trifoliolate, up to 9 cm; upper leaves either deeply lobed or trifoliolate, with roundly dentate margins. Lamina lanceolate, villous, up to 8 cm long; petiole equal to or slightly longer than the lamina. Flowers axillary, solitary or in sparse racemes, 1–1.5 cm across; pedicel 0.7–0.9 cm long; flower diameter 2.2–2.5

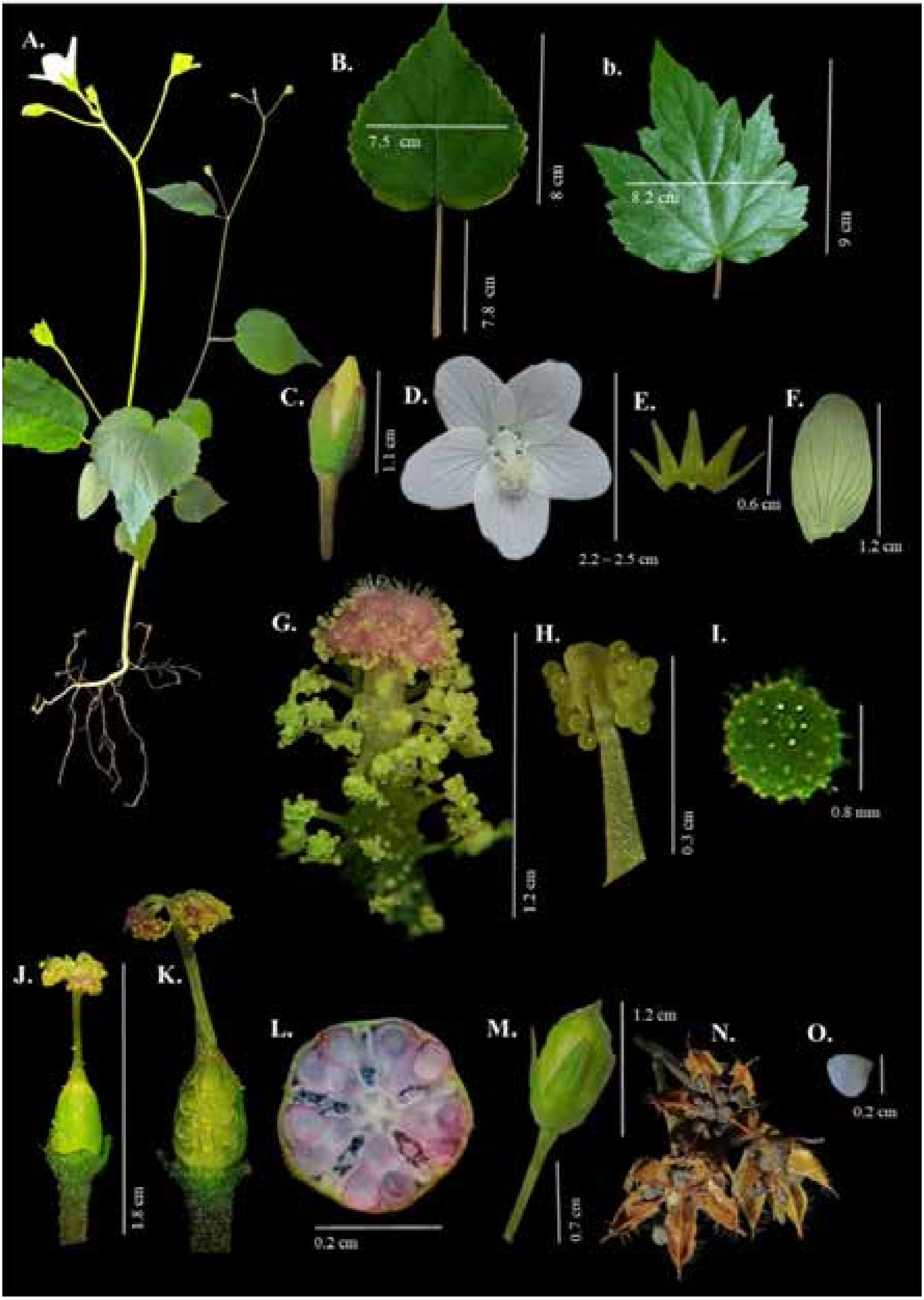

Image 1. Morphometric analysis and diagnostic feature of *Hibiscus lobatus*: A—*Hibiscus lobatus* habitat | B—Leaf | C—Flower bud | D—Blossomed flower | E—Sepals | F—Insect wing like petal | G—Staminal tube | H—Staminal branchlet | I—Pollen grain | J—Pistil | K—LS of ovary | L—TS of ovary | M—Capsule | N—Opened capsule | O—Seeds with hairs. © Karthik T.D.

cm. Calyx cup-shaped, 0.6 mm long, membranous, 5-lobed; lobes lanceolate, pilose, and strigose abaxially, persistent. Petals 5, white, 1.2–1.4 cm long, insect wing-like in appearance. Staminal tube 1.2 cm long; staminal branches up to 0.3 cm, staminal column bearing numerous monadelphous stamens with apical hairs. Pollen grains spheroidal, polycolporate, echinate, approximately 0.8 mm in diameter. Gynoecium with a superior ovary, ellipsoid, 1.3–1.8 cm long and 0.1–0.3 cm wide, 5-locular (occasionally up to 10), with axile placentation and multiple ovules per locule. Stigma 5, free, pinkish, arising from a single style column. Capsule broadly ovoid to cylindrical, 0.8 cm long, beaked at apex; fruit composed of five mericarps; endocarp thin, villous along the ventral side. Seeds minute, 0.2 mm, with scale-like hairs (Image 1).

Distribution

Hibiscus lobatus is distributed in the dry deciduous forests of India, tropical Africa, Madagascar, tropical and southeastern Asia, Sri Lanka, and Malaysia (Rao et al. 2019).

Distribution in India

Hibiscus lobatus is distributed in the forests of Andhra Pradesh, Bihar, Delhi, Gujarat, Himachal Pradesh, Jammu & Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Punjab, Rajasthan, Sikkim, Tamil Nadu, Uttar Pradesh, Uttarakhand, West Bengal, and Assam (India Biodiversity Portal 2025).

The ethnobotanical survey in the central Western Ghats of Karnataka, India, revealed that *Hibiscus lobatus* is very sparsely distributed in the moist deciduous forests of Belagavi, Uttara Kannada, Shivamogga, Chikkamagaluru, Hassan, Dakshina Kannada, Kodagu, and Mysuru districts. The sites of herbarium specimen collection, along with their latitude and longitude, are shown in Image 2, and Table 1. This species is found only in two sites in the Shivamogga region, namely Kuruvalli Village, of Tirthahalli Taluk, and Thammadihalli Village, of Bhadravathi Taluk, in the form of small pockets during the spring season. In other localities, a sparse distribution was observed due to the spread of invasive species such as *Eupatorium odoratum*, *Lantana camara*, *Parthenium hysterophorus*, *Hyptis suaveolens*, *Senna siamea*, *Borreria stricta*, and *Amaranthus spinosa*.

Traditional medicinal value

The traditional medicine practitioners residing in the Tirthahalli Taluk of Shivamogga District and Narasimharajapura Taluk of Chikkamagaluru grind the leaves of *Hibiscus lobatus* and *Terminalia arjuna* in a 3:1 ratio. The fine paste is then boiled with coconut water for 10 to 15 minutes. The oil content is filtered and used as a cosmetic for glowing skin. It is also used for epithelization and the cosmetic treatment of burnt wounds. The anti-aging property of *Hibiscus sabdariffa* L. (Li et al. 2020) and *H. rosa-sinensis* L. (Dos et al. 2021) has been investigated. The extracts and compounds from many species of *Hibiscus* are used in the cosmetic industry to produce various skin-glowing creams and lotions, such as plant science Hibiscus night cream and Saint Jane hydrating petal cream.

Seed viability

Seed viability of *Hibiscus lobatus* was evaluated using the tetrazolium method across three age groups: 1 month old, 5 month old, and 10 month old seeds. A gradual decline in viability was observed with increasing seed age. The 1 month old seeds exhibited the highest viability at 72.6±2.2%, followed by the 5 month old seeds at 69.8±1.8%, and the 10 month old seeds at 65.2±2.3%. Staining patterns revealed that 1month old and 5 month old seeds were uniformly stained and showed minimal necrosis, reflecting healthy, and active embryonic tissues. In contrast, the 10 month old seeds displayed superficial staining in some seeds, particularly at the distal tip of the radicle, along with slightly higher necrosis. Despite these differences, the variation among seed groups was minor, highlighting that seeds of *Hibiscus lobatus* retain viability, and physiological integrity effectively over the time. This resilience is consistent with the plant's annual growth cycle, ensuring the seeds remain robust, and capable of germination in subsequent growing seasons.

Seed germination test in the field

Viable seeds of *H. lobatus*, confirmed through the tetrazolium test, were sown in fertile soil under optimal environmental conditions during the post-fruiting months of October to December, which align closely with the plant's natural growth cycle. Germination was monitored over 45 days, and the results showed that 1 month old seeds had a germination percentage of 25.8±2.6%, 5 month old seeds 18.6±2.4%, and 10 month old seeds 17.2±2.2% as shown in Figure 1. Although the seeds were viable and in healthy condition, their germination potential under field conditions was low, confirming the presence of dormancy. The minimal variation in germination percentages between seed age groups indicates that seed age is not a major influencing factor in this context. These results emphasize the

Table 1. Distribution sites and geographical locations of *Hibiscus lobatus* in the central Western Ghats, Karnataka.

Observation Sites (S)	Location	Forest type	Latitude (Decimal)	Longitude (Decimal)
S1	Alavalli Village, Siddapur Taluk, Uttara Kannada	Semi Evergreen	14.308° N	74.764° E
S2	Chamundi Hill, Mysore	Deciduous	12.288° N	76.688° E
S3	Bhutaramanahatti Village, Belgaum Taluka, Belgaum.	Deciduous	15.993° N	74.517° E
S4	Kuruvalli Village, Tirthahalli Taluk, Shivamogga	Evergreen	13.684° N	75.249° E
S5	Thammadihalli Village, Bhadravathi Taluk, Shivamogga	Moist deciduous	13.741° N	75.624° E
S6	Monnageri Village, Madikeri Taluk, Kodagu	Evergreen	12.426° N	75.716° E
S7	Kodekkal, Beltangadi Taluk, Dakshina Kannada	Evergreen	13.013° N	75.323° E
S8	Thendihalli, Hassan Taluk, Hassan	Deciduous	12.999° N	76.173° E
S9	Balekoppa, Narasimharajapura Taluk, Chikkamagaluru	Moist deciduous	13.614° N	75.506° E

Table 2. Effect of seed pre-treatments on germination of *Hibiscus lobatus* under field conditions.

Treatments	Concentrations	Germination (%)			Number of days to germinate		
		1 month	5 months	10 months	1 month	5 months	10 months
Control (No pretreatment)		25.8±2.6	18.6±2.4	17.2±2.2	32–36	32–36	32–36
Hot water Treatment (°C)	20	26.5±1.4	18.8±1.2	18.6±1.4	28–31	28–31	28–31
	40	27.4±2.4	21.8±2.4	20.5±1.2	28–31	28–31	28–31
	60	**32.6±2.2**	**30.6±1.5**	**29.4±1.2**	**24–28**	**24–28**	**24–28**
	80	18.6±1.2	17.8±1.2	17.4±1.2	32–36	32–36	32–36
Sulphuric acid concentration (%)	5	25.4±1.4	19.4±1.2	19.2±1.2	28–31	28–31	28–31
	10	30.8±1.6	29.2±2.1	26.5±1.4	29–32	29–32	29–32
	15	**38.5±1.4**	**35.6±1.2**	**32.8±1.5**	**22–26**	**22–26**	**22–26**
	20	21.8±1.6	19.5±1.4	19.2±1.2	28–31	28–31	28–31

The value: mean of ± SE four replicates of 25 seeds of each group.

dormancy mechanism in *H. lobatus*, which ensures the seeds remain synchronized with favourable environmental conditions, a crucial adaptation in its annual life cycle (Harel et al. 2011).

Reliable method for assessing seed germination, dormancy, and mortality of seeds is under field conditions. The result indicated that highest percentage of seed germination was noticed between 30–45 days (Figure 1). In this period, the average germination percentage of 1 month old, 5 month old, and 10 month old seeds was 13.3 ± 0.83, 10.8 ± 0.83, and 10.7 ± 0.86, respectively, which were higher than those recorded during the other observation phases (0–15, 15–30, and 45–60 days). Several environmental factors control seed germination success under field conditions**.** Pradhan et al. (2011) also evaluated the effects of microhabitat, light, and temperature on seed germination of a critically endangered Himalayan medicinal herb, *Swertia chirayita* (Roxb.) H. Karst. for conservation implications.

Breaking of seed Dormancy

In vivo method of breaking of seed dormancy

Experiments to break dormancy of seeds conducted *in vivo* under field condition following the method of Tiwari et al. (2018). The results revealed significant differences in germination percentages among seeds treated with hot water and sulphuric acid (Table 2). A decline in germination percentage was observed with increasing seed age. The control group, without any pretreatment, exhibited germination percentages of

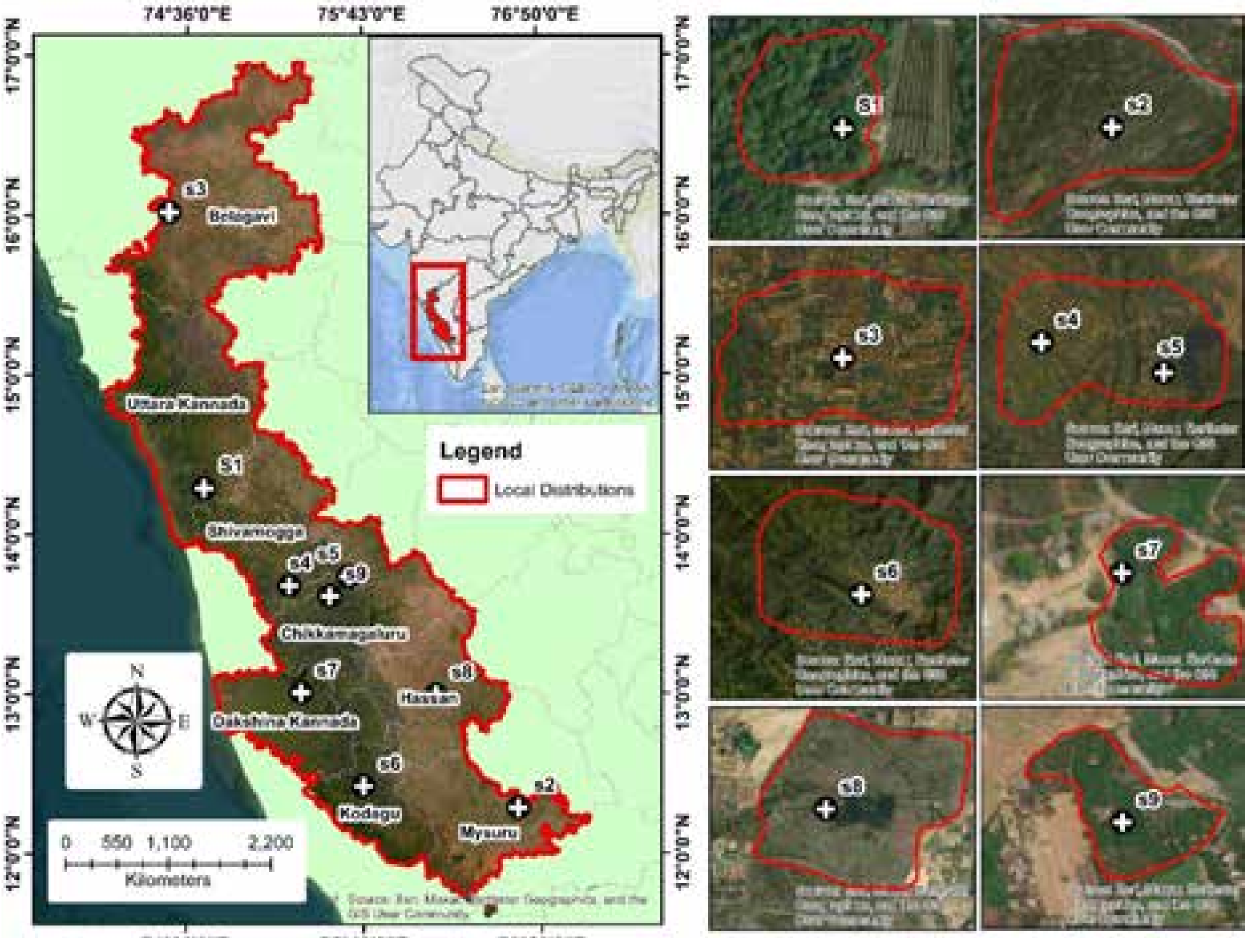

Image 2. Distribution of *Hibiscus lobatus* in the central Western Ghats of Karnataka.

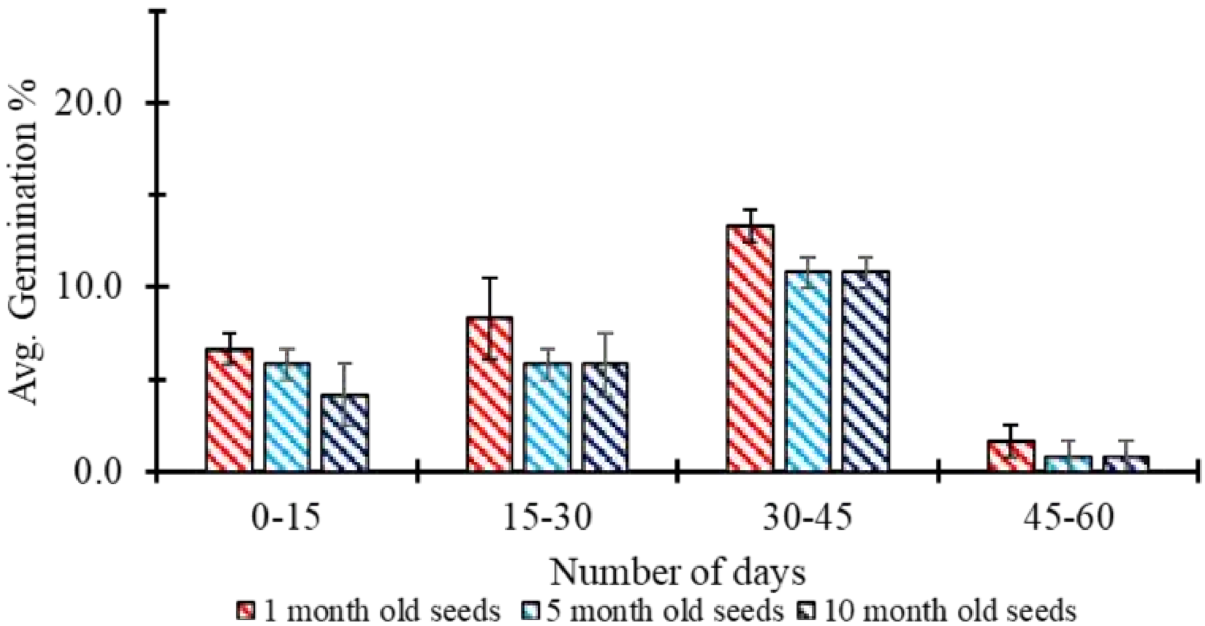

Figure 1. Percentage of *Hibiscus lobatus* seed germination under field condition.

Table 3. Effect of GA_3 treatment on breaking seed dormancy of *Hibiscus lobatus* under in vitro conditions.

	Concentrations	Germination (%)			Number of days to germinate		
		1 month	5 month	10 month	1 month	5 month	10 month
GA_3 (mg/ml)	0.75	35.6±2.2	24.3±2.1	18.3±2.1	24–28	24–28	24–28
	1	58.8±3.6	56.6±3.2	55.5±3.2	16–20	16–20	16–20
	1.25	48.8±1.2	48.6±1.4	46.6±2.4	17–21	17–21	17–21
	1.5	40.6±2.4	38.6±2.2	36.8±2.2	28–31	29–32	29–32
Hot water Treatment (°C) + 1 mg/ml GA_3	20	34.2±2.2	31.4±2.2	29.2±2.1	22–25	22–25	22–25
	40	68.8±4.6	65.8±3.6	59.8±3.4	15–18	15–18	15–18
	60	69.4±4.8	66.8±3.4	63.5±3.2	11–15	11–15	11–15
	80	28.6±2.2	23.8±1.8	16.4±1.2	18–21	19–21	19–21
Sulphuric acid (%) + 1 mg/ml GA_3	5	38.8±2.4	34.8±1.2	34.6±1.3	21–25	21–25	21–25
	10	74.5±4.4	68.6±3.2	66.4±3.2	13–15	13–15	13–15
	15	76.3±4.2	72.5±5.3	71.5±5.3	10–13	10–13	10–13
	20	28.8±1.6	21.6±1.2	19.6±1.2	17–20	17–20	17–20

The value: mean of ± SE three replicates of 30 seeds of each group.

25.8±2.6% for 1 month old, 18.6±2.4% for 5 month old, and 17.2±2.2% for 10 month old seeds. Germination in the control group occurred between 32–36 days, reflecting the persistence of dormancy of seeds of *H. lobatus* .

Hot water scarification treatments of seeds moderately enhanced germination rates compared to the control group. The highest germination percentage of 32.6±2.2% was observed at 60°C, with germination times reduced to 24–36 days. Sulphuric acid scarification showed a more pronounced effect, particularly at a concentration of 15%, achieved percentages of germination of seeds was 38.5±1.4%, 35.6±1.2%, and 32.8±1.5% for 1 month old, 5 month old, and 10 month old seeds respectively. Germination of seeds was observed between 22–26 days, demonstrating its relative effectiveness in overcoming seed dormancy.

Despite these improvements, the overall germination rates remained low, indicating that these treatments partially alleviated seed dormancy, but they were insufficient to fully overcome it under field conditions. These results suggest that more targeted or refined dormancy-breaking methods may be necessary to achieve optimal germination. To address these limitations, in vitro approaches were undertaken. These methods aim to explore controlled environments and specific treatments to achieve higher germination success, and provide a more effective solution for breaking dormancy in *Hibiscus lobatus* seeds.

In vitro method of breaking of seed dormancy

The in vitro methods of breaking of seed dormancy experiments were employed to know the conjugative effect of pretreated seeds cultured *in vitro* on MS medium (Murashige & Skoog 1962) supplemented with 0.75–1.25 mg/L of GA_3. The result of the experiment showed that pretreatment of seeds with either hot water or sulphuric acid and cultured on MS medium fortified with GA_3 showed improved seed germination in *Hibiscus lobatus* (Table 3).

In the culture of untreated seeds, GA_3 at the concentration of 1 mg/L was found to be effective to induce germination of 58.8±3.6% for 1 month old seeds, 56.6±3.2% for 5 month old seeds, and 55.5±3.2% for 10 month old seeds between 16–20 days of culture. Pretreatment of seeds with 15% sulphuric acid when cultured on 1 mg/L of GA_3 showed the highest germination percentages: 76.3±4.2% for 1 month old seeds, 72.5±5.3% for 5 month old seeds, and 71.5±5.3% for 10 month old seeds, respectively. These findings indicate the most effective in vitro approach, offering significantly higher percentage of germination, and shorter germination periods compared to other treatments. The combination of hot water treatment (60°C) and 1 mg/L of GA_3 also showed increased percentage of germination as compared to individual treatments and the germination time was reduced to 11–15 days. Similar results were also observed in breaking of seed dormancy of *Hibiscus coddii* ssp. *barnardii* (du Plessis et al. 2019).

CONCLUSION

The present study highlights the taxonomic, ethnobotanical, and ecological significance of *Hibiscus lobatus* in the central Western Ghats. Traditional medicinal knowledge confirmed its therapeutic potential in skin healing and anti-aging applications, reinforcing its relevance in pharmaceutical, and cosmetic industries. Seed dormancy was identified as a critical factor limiting natural regeneration. Pretreatment with sulphuric acid followed by culture on MS medium fortified with GA_3 significantly improved seed germination, demonstrating an effective dormancy-breaking strategy. These findings provide a foundation for large-scale propagation.

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ARTICLE

Environmental drivers of zooplankton diversity and composition of Pargwal Wetland, Jammu & Kashmir, India

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Abstract: This study investigates temporal and spatial variability in zooplankton abundance within Pargwal wetland, the largest wetland in the Jammu region. Water samples were collected from three strategically selected stations and analyzed for physico-chemical parameters including temperature, pH, dissolved oxygen, carbonates, nutrients, and ions. A total of 27 zooplankton species spanning five groups were recorded. Rotifera dominated in terms of abundance and diversity with 15 species, followed by Cladocera with five species, Protozoa with three, and two species each of Ostracoda and Copepoda. Key environmental factors contributing to the dominance of rotifers and cladocerans were high levels of nutrients (nitrates and phosphates), water transparency, and light penetration (due to shallow water depth), and resilience to pollution-induced stress. Rotifers are also known to outcompete other groups when resources are limited or of poor quality. The abundance of pollution-tolerant species indicated overall degradation of this important wetland driven by anthropogenic pressures. This highlights the need for integrated management strategies to safeguard biodiversity for future generations.

Keywords: Abundance, degradation, revival efforts, spatial, temporal, variability, wetland.

Hindi: यह अध्ययन जम्मू क्षेत्र की सबसे बड़ी आर्द्रभूमि परगवाल आर्द्रभूमि के भीतर जूप्लांकटन की प्रचुरता में अस्थायी और स्थानिक परिवर्तनशीलता की जांच करता है। तीन रणनीतिक रूप से चयनित स्टेशनों से पानी के नमूने एकत्र किए गए और तापमान, पीएच, घुलित ऑक्सीजन, कार्बोनेट, पोषक तत्व और आयनों सहित भौतिक-रासायनिक मापदंडों के लिए विश्लेषण किया गया। पांच समूहों में फैली कुल 27 जूप्लैंक्टन प्रजातियों को दर्ज किया गया था। 15 प्रजातियों के साथ प्रचुरता और विविधता के मामले में रोटिफेरा का वर्चस्व रहा, इसके बाद पांच प्रजातियों के साथ क्लाडोसेरा, तीन के साथ प्रोटोजोआ और ओस्ट्राकोडा और कोपेपोडा की दो-दो प्रजातियों का स्थान रहा। रोटिफर्स और क्लैडोसेरेंस के प्रभुत्व में योगदान देने वाले प्रमुख पर्यावरणीय कारक उच्च स्तर के पोषक तत्व (नाइट्रेट और फॉस्फेट) जल पारदर्शिता, और प्रकाश प्रवेश (उथले पानी की गहराई के कारण) और प्रदूषण-प्रेरित तनाव के प्रति लचीलापन थे। रोटिफर्स को अन्य समूहों को पछाड़ने के लिए भी जाना जाता है जब संसाधन सीमित होते हैं या खराब गुणवत्ता के होते हैं। प्रदूषण-सहिष्णु प्रजातियों की प्रचुरता मानवजनित दबावों द्वारा संचालित इस महत्वपूर्ण आर्द्रभूमि के समग्र क्षरण का संकेत देती है। यह भावी पीढ़ियों के लिए जैव विविधता की रक्षा के लिए एकीकृत प्रबंधन रणनीतियों की आवश्यकता पर प्रकाश डालता है।

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Author contributions: Neha Jamwal- carried out the fieldwork, sampling, species identification, data collection, analysis & interpretation and manuscript writing. Arti Sharma- study design, supervision and guidance in sample collection, careful examination and final approval to the manuscript.

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INTRODUCTION

Zooplankton play vital roles in the aquatic food chain making them essential elements of the aquatic ecosystem. They serve as natural water purifiers, energy transferrers from lower to higher trophic levels (Steinberg & Condon 2009), recyclers of nutrients and energy in their surroundings, and the primary natural fish food source, which is directly related to fish survival and growth (Miah et al. 2013). They also serve as crucial determiners of water quality as they are influenced by the constantly shifting environmental conditions; and subsequently, their distribution, and diversity is influenced by seasonal changes in the physicochemical characteristics of the water (Saba & Sadhu 2015). They are also known to play a handy role in determining the status of pollution in any water body (Contreras et al. 2009).

Discrete ecological niches are found in wetlands, which contribute significantly to the biological variety. Every freshwater ecosystem on earth is home to zooplankton, and within the population, their density, and variety vary widely (Golmarvi et al. 2018). Among zooplanktons, Copepoda, Cladocera, and Rotifera are better suited to examine the community structure of these organisms in relation to environmental heterogeneity (Toruan 2021). Due to their sensitivity to any unfavourable environmental change, zooplankton population composition, and abundance are negatively impacted by continuously declining water quality (Razak & Sharip 2019). Most zooplankton move away from direct sunlight in a pronounced vertical diurnal migration. In response to angular light distributions, copepods exhibit migration away from littoral areas through behavioural swimming while the spatial horizontal distribution of cladocerans sometimes seems patchy, and uneven (Wetzel 2001). Conversely, ostracods are bottom-dwelling animals that mostly consume dead & detritus phytoplankton, which in turn provide food for fish, and other macroinvertebrates. Because of their ease of identification, ability to adapt to environmental gradients, and important function in the food web, cladocerans may be considered the best indicators of biodiversity (Jeppesen et al. 2011). The capacity of certain crustacean zooplankton, such as copepods, to restrict mosquito larvae makes them extremely important. Alekseev (2002) also recognized copepods as the intermediary host for a variety of parasitic diseases, including worms.

Ecology, diversity, and distribution patterns of zooplankton has been reviewed from India by Sreenivasan (1967) in Madras, Sivakumar & Altaff (2004) in Tamil Nadu, Mathivanan et al. (2007) in Cauvery River, Manickam et al. (2012, 2014) in Goa and southern India, while globally by Ezz et al. (2014) from Mediterranean Sea, de Puelles et al. (2014) from Baleares archipelago & Ziadi et al. (2015) from a Mediterranean lagoon. Although, from Jammu region of J&K, many lentic, and lotic waterbodies have been exploited for the zooplankton diversity but among wetlands, this largest Pargwal wetland has remained unexplored.

Due to the ecological significance, short life cycles, and susceptibility to the environmental changes, zooplankton community structure (which includes diversity indices, species richness and dominance pattern) is anticipated to differ greatly depending upon the water quality factors of Pargwal Wetland, hence, revealing the water quality, and ecological well-being of this wetland due to region's continuous anthropogenic disturbances, including waste discharge, sand mining, and agricultural runoff. This will make them an efficient tool for tracking the wetland's ecological status and restoration potential.

MATERIAL AND METHODS

Study area

The present study encompasses Pargwal Wetland located at 32.87°N & 75.03°E in tehsil Akhnoor of Jammu District, J&K, India. This wetland is a humid subtropical riverine type and is surrounded by human habitation, and agricultural fields on one side, and mighty river Chenab on the other side (Image 1) covering a total area of 12,154 acres making it the largest wetland in terms of area. Since this wetland is of riverine kind, three study sites were identified based on anthropogenic activities, and accessibility around the area which are about 1–2.5 km apart from one another (Image 2a–c). All the three sampling stations were equally positioned by the humans but station I (Image 2a) and station III (Image 2c) are highly impacted by the ease of disposing, and adulterating the water body. The main occupation of the inhabitants includes farming and cattle rearing. Station II (Image 2b) is least impacted by human intervention.

Methods

Seasonal sampling of water quality (in triplicates from each station per season) and zooplankton diversity was done quarterly for a period of one year (2021–2022) that included Spring (February–April), Summer (May–June), Monsoon (July–September), and Winter (November–

Image 1. The satellite view of study stations (Inset: Jammu & Kashmir; Location of Pargwal). Source: Google Maps.

Image 2. Study stations: a—Station | b—Station | c—Station III. © Neha Jamwal

January). Water quality parameters, i.e., air & water temperature (using mercury bulb thermometer), pH (Hanna digital pH meter), dissolved oxygen (modified Winkler method), free carbon dioxide (titrimetric method), bicarbonates, chloride (Argentometric method using potassium chromate as indicator was used for determination of chlorides), calcium & magnesium (EDTA-titrimetric method), nitrates (Phenoldisulphonic acid method), phosphates (Stannous chloride method), and sulphates (Turbiditimetric method), were assessed as prescribed by A.P.H.A. (2017), and Adoni (1985). Zooplankton samples were collected by filtering 50 L of water from the study stations using a plankton net having mesh size 40 µm. The filtrate was then preserved by adding 10% formalin. The samples were analyzed using light microscope Magnus MLX under 40x magnification.

Quantitative estimation of zooplankton

Quantitative analysis was done using drop count method and calculated using below mentioned formula:

$$\text{Individuals / litre} = A \times 1/L \times n/v$$

Where, A = number of organisms per drop.

L = volume of original sample (l).

N = total volume of concentrated sample (ml).

V = volume of one drop (ml).

The identification was done using keys by Ward & Whipple (1959), Edmondson & Winberg (1971), Pennak (1978), and Adoni (1985).

Data Analysis

Community structure was assessed using various diversity indices like Shannon-Wiener index (H), evenness index (E), and dominance (C) and calculated using PAST software while Pearson correlations and one-way ANOVA were done using SPSS 29.0.2.0 software.

RESULTS

Water Quality

The water quality parameters of selected study stations of Pargwal Wetland were assessed seasonally and their mean values have been depicted in Table 1 and Figure 1. The air temperature values in the study varied from the lowest value (13°C) recorded at station III during winter to the highest value (39°C) recorded at station II during summer while the water temperature values varied from (10°C) at station III during winter to the highest value of (36°C) observed at station I during summer. The annual mean values of air and water temperature were recorded as 26.83°C and 24.5°C, respectively. The water body remained neutral to moderately alkaline with minimum pH values ranging from 7.2 noted at station III during summer to maximum value of 8.0 recorded at station II during winter. The annual mean pH value was recorded as 7.71. The values of dissolved oxygen (DO) were relatively low having minimum value of 1.6 mg/l reported during summer to 9.6 mg/l during winter at station II, with annual mean 5.07 mg/l ± 0.6. Free carbondioxide (FCO_2) values were comparatively high varying spatially from a minimum 5.28 mg/l during winter to maximum 9.2 mg/l during summer at station II and station I respectively with annual mean value recorded as 6.99 mg/l ± 1.5. Bicarbonates (HCO_3-) were recorded high during entire period of investigation with values fluctuating from minimum 170.8 mg/l at station II during summer to maximum 488 mg/l during winter at station I. The annual mean value of bicarbonates was recorded 276.93 mg/l ± 35.19.

Lowest values of Cl^- (5.81 mg/l) were observed during spring at station II while highest (18.02 mg/l) at station I during summer. The annual mean Cl^- concentration was observed to be 10.91 ± 2.8. The present study showed that the highest values of calcium (84.11 mg/l) and magnesium (72.76 mg/l) were recorded from station I during winter, while the lowest values of calcium (48.78 mg/l) and magnesium (26.6 mg/l) were recorded at station II during summer. The annual mean concentration of Calcium and Magnesium was observed to be 62.41 ± 5.8, and 45.96 ± 6.3, respectively.

All the minerals were well within the permissible limits (as prescribed by WHO 1992; BIS 1998) but values of phosphates were dangerously high (WHO

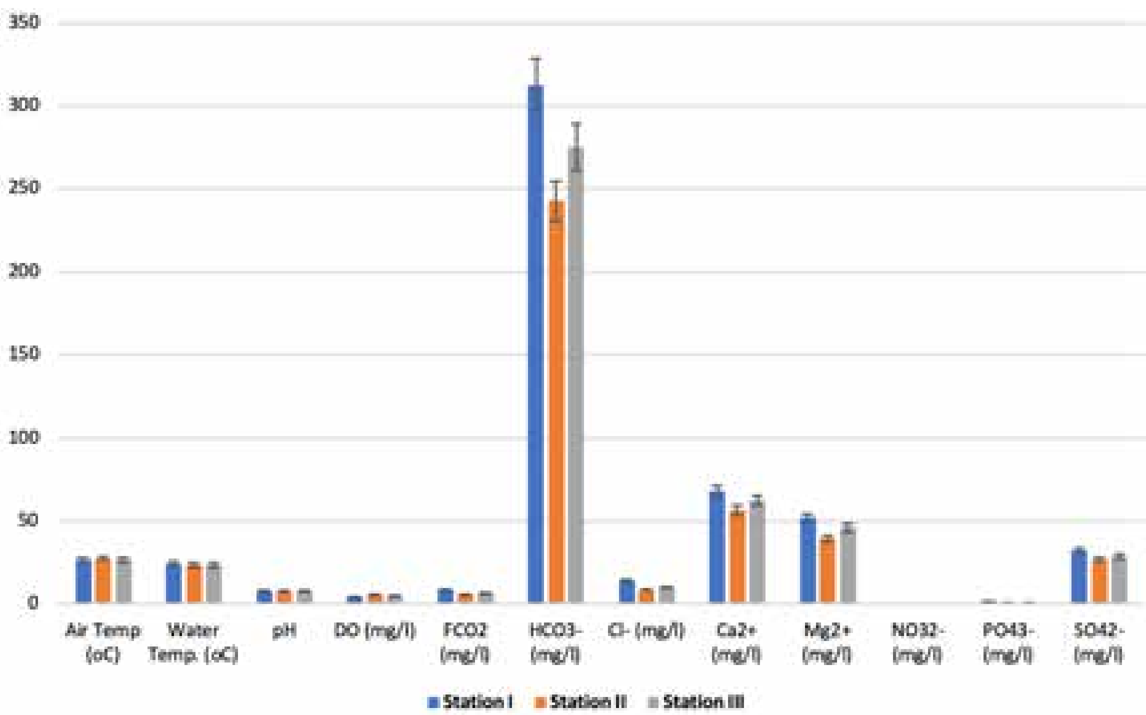

Figure 1. Variations in the physical and chemical parameters of Pargwal Wetland during 2021–2022.

Table 1. Physicochemical parameters of water at different stations of Pargwal Wetland (2021–2022).

Parameters		Station I	Station II	Station III	P-value
Air Temp. (^{O}C)	Min	15	15	13	0.994
	Max	38	39	38	
	Mean ± S.D.	27 ± 9.4	27.25 ± 9.8	26.5 ± 10.5	
Water Temp. (^{O}C)	Min	13	14	10	0.500
	Max	36	35	35	
	Mean ± S.D.	24.5 ± 9.5	23.75 ± 8.8	23.75 ± 10.3	
pH	Min	7.6	7.4	7.2	0.860
	Max	7.9	8.0	7.9	
	Mean ± S.D.	7.73 ± 0.2	7.73 ± 0.3	7.68 ± 0.3	
DO (mg/l)	Min	2.0	1.6	2.6	0.986
	Max	7.2	9.6	9.6	
	Mean ± S.D.	4.48 ± 2.5	5.6 ± 4.2	5.15 ± 3.1	
FCO2 (mg/l)	Min	7.5	5.28	5.4	0.923
	Max	9.2	7	7.2	
	Mean ± S.D.	8.66 ± 0.8	5.87 ± 0.8	6.45 ± 0.8	
HCO_3^- (mg/l)	Min	244	170.8	187.9	
	Max	488	336	430	0.968
	Mean ± S.D.	312.9 ± 116.9	242.6 ± 68.6	275.3 ± 106.2	
Cl^- (mg/l)	Min	9.15	5.81	7.61	0.633
	Max	18.02	10.01	12.01	
	Mean ± S.D.	14.05 ± 3.7	8.52 ± 1.9	10.17 ± 1.9	
Ca^{2+} (mg/l)	Min	60.56	48.78	57.19	0.914
	Max	84.11	60.56	66.52	
	Mean ± S.D.	68.13 ± 10.8	56.62 ± 5.6	62.47 ± 3.9	
Mg^{2+} (mg/l)	Min	35.5	26.6	30.43	0.815
	Max	72.76	50.46	63.92	
	Mean ± S.D.	52.15 ± 15.4	39.59 ± 9.8	46.15 ± 13.8	
$NO3^{2-}$ (mg/l)	Min	0.13	0.096	0.31	
	Max	1.17	0.42	0.58	0.509
	Mean ± S.D.	0.48 ± 0.5	0.19 ± 0.2	0.45 ± 0.1	
$PO4^{3-}$ (mg/l)	Min	0.79	0.72	0.78	0.084
	Max	2.43	1.74	1.36	
	Mean ± S.D.	1.55 ± 0.8	1.23 ± 0.5	1.24 ± 0.4	
$SO4^{2-}$ (mg/l)	Min	18.27	12.77	15.31	0.796
	Max	46.29	41.65	41.79	
	Mean ± S.D.	32.71 ± 13.3	26.92 ± 16.2	28.87 ± 14.5	

1992) except for station I where the value was above permissible limit. The annual mean value of nitrates was 0.4 mg/l ± 0.2 which varied between a minimum of 0.096 mg/l during winter at station II to a maximum 1.17 mg/l during summer at station I, while annual mean phosphate values was 1.34 mg/l ± 0.2, that ranged from lowest value of 0.72 mg/l during summer at station II to highest value of 2.43 mg/l during winter at station I. Sulphates ranged from a minimum 12.77 mg/l during winter at station II to a maximum 46.29 mg/l during summer at station I.

Zooplankton Composition and Abundance

A total of 27 zooplankton species were collected

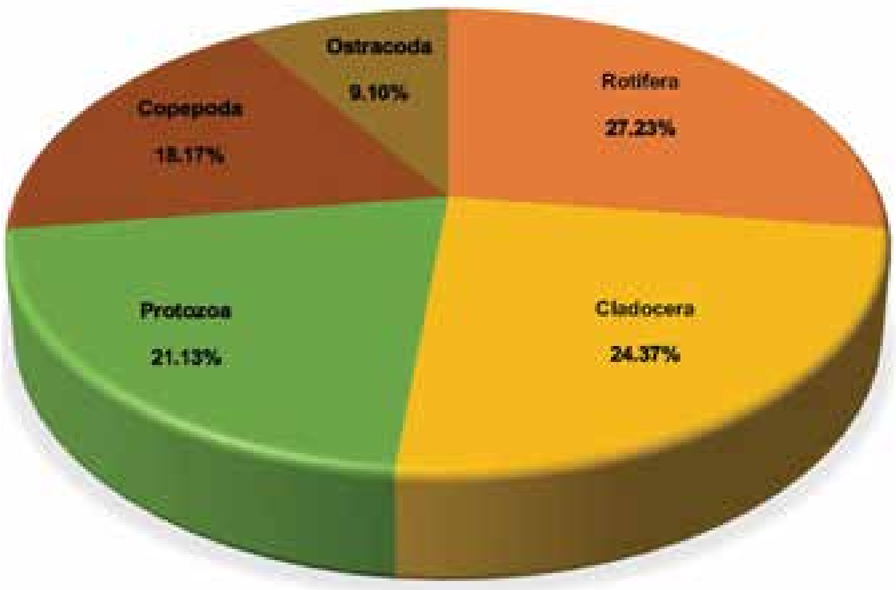

Figure 2. Relative abundance of different zooplankton groups in Pargwal Wetland.

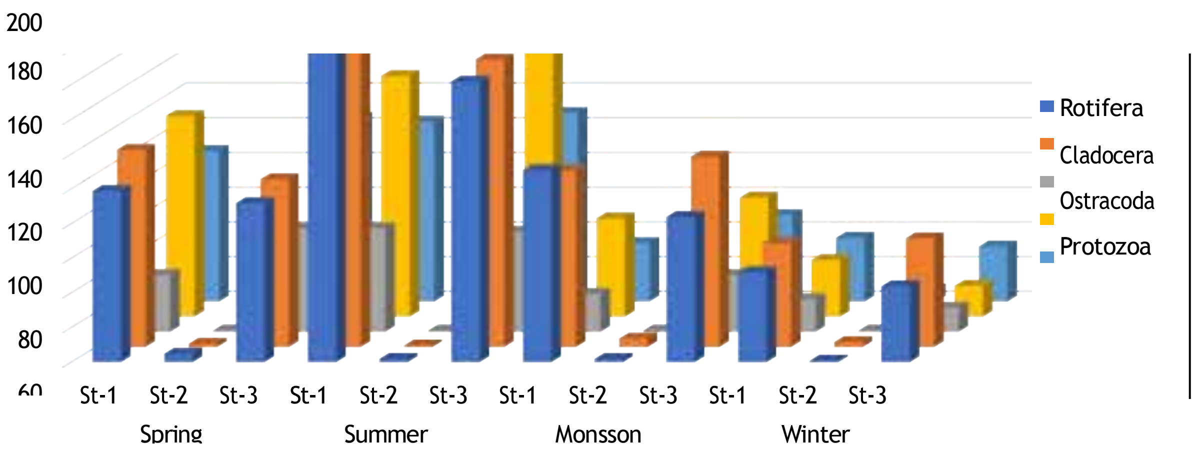

Figure 3. Variations in species richness of zooplankton in Pargwal Wetland.

from the study stations (Table 2, Image 3) and divided into six groups: Rotifera, Cladocera, Ostracoda, Amoebozoa, Copepoda, and Ciliophora. Rotifera topped the table with 15 species (102.7 ind./L; 27.23%) out of all the groupings, followed by Cladocera with five species (91.9 ind./L; 24.37%), Protozoa with three species (79.7 ind./L; 21.13%), Copepoda with two species (68.5 ind./L; 18.17%), and Ostracoda with two species (34.3 ind./L; 9.10%) (Table 3; Figure 2).

The overall temporal abundance of zooplankton followed the following trend:

Summer (42.33%) > Spring (29.14%) > Monsoon (20.68%) > Winter (7.85%)

The summer peak and the winter decline can also be clearly seen in the Table 3. The values of various diversity indices have been depicted in Table 4. Figure 3 depicts Rotifera as the highly diversified group with high abundance of *Euchlanis dilatata*, *Lepadella ovalis*, *Asplanchna* sp., *Brachionus calyciflorus*, *Brachionus quadridentatus*, *Cephalodella* sp., and *Platiyas platulus* which indicates its pollution status.

The review of Table 3 also highlights various dominant species of the zooplankton found in the wetland area which include, Brachionus *calyciflorus*, *Brachionus quadridentatus*, *Arcella discoides*, *Mesocyclops leukarti*, *Cyclops* sp., *Stenocypris* sp., and *Eucypris* species at

Table 2. List of zooplankton reported from all the study stations of Pargwal Wetland (2021–2022).

Phylum	Name of the species
Rotifera	*Euchlanis dilatata* (Ehrenberg, 1830)
	Keratella tropica (Apstein, 1907)
	Lepadella ovalis (Muller, 1786)
	Asplanchna sp.
	Brachionus calyciflorus (Pallas, 1776)
	Brachionus quadridentatus (Hermann, 1783)
	Trichocerca longiseta (Schrank, 1802)
	Trichocerca porcellus (Gosse, 1851)
	Trichotria sp.
	Cephalodella sp.
	Colurella adriatica (Ehrenberg, 1831)
	Monostyla bulla (Gosse, 1851)
	Monostyla hamata (Stokes, 1896)
	Philodina sp.
	Platyias platulus (Muller, 1786)
Arthropoda (Cladocera)	*Macrothrix* sp.
	Pleuroxus sp.
	Simocephalus sp.
	Alona costata (Sars, 1862)
	Alonella sp.
	Stenocypris sp.
Arthropoda (Ostracoda)	*Oncocypris pustulosa* (Vavra, 1891)
Amoebozoa (Protozoa)	*Arcella discoides* (Ehrenberg, 1832)
	Centropyxis aculeata (Ehrenberg, 1832)
Ciliophora (Protozoa)	*Epistylis* sp.
Copepoda	*Mesocyclops leukarti* (Claus, 1857)
	Cyclops sp.

station III, while *Macrothrix* sp., *Simocephalus* sp., and *Alona costata* at station I. Station II was the least species rich among all the stations, with little to no diversity at all, because this area was extremely disturbed by the constant anthropogenic activities.

DISCUSSIONS

High values of air and water temperatures were recorded during summer due to elongated photoperiod, and abundant vegetation cover the surface of water which traps the heat (Sharma 2018; Singh 2022), while lower temperatures during winters result from less diffusion of heat from air to water. The limited range of pH values seen in all study stations in this investigation is explained by the high alkalinity of water which regulates hardness (Goldman & Horne 1983). It is possible to explain the low DO values in summer because high temperature reduces DO solubility in water, therefore, decreasing oxygen carrying capacity (Dallas 2008; Sahni & Yadav 2012). Also, the wetland is frequently filled by waste products, such as household and agricultural runoff, which results in nutrient enrichment and lower DO, elevating BOD. High DO values were observed during winter as low temperature leads to elevated oxygen holding capacity (Sharma 2018). High FCO2 levels during summer may be due to high decomposition rate which consumes more DO (Harney et al. 2013) while its low value during winter may be due to consumption of FCO2 that exceeds its production (Sharma 2018). High HCO3 levels during winter may be because bicarbonate ions accumulate when not taken up by macrophytes, while its low value during summer may be assigned to utilization by macrophytes, and phytoplankton during photosynthesis (Singh 2022). The elevation in bicarbonates could also be attributed to the ease of access to wetland water by people for carrying out their daily chores like bathing, cleaning, and washing.

According to the present findings, values of chlorides were maximum during summer which may be accorded to higher chloride solubility discharged from catchment area (Umamaheshwari & Sarvanan 2009) and due to increased rate of decomposition of organic matter while minimum values during spring were recorded which may be due to its uptake by growing macrophytic biomass (Singh 2004, 2022). High nitrate values during summer may be accredited to evaporation, leading to more nitrate build-up and bacteria causing aerobic decomposition of organic matter (Mustapha et al. 2013) while low values of nitrates during winter may be because of slow decomposition rate at low temperature (Tamot & Sharma 2006). Less phosphate values in summer can be attributed to intense phytoplankton blooms that readily take up phosphate ions (Nassar et al. 2014; Abdulwahab & Rabee 2015), while highest level during winter can be because of low mineralization of organic matter at reduced temperature (Mushtaq et al. 2016). Summer maxima in the values of sulphates may be attributed to biogenic inputs, increased microbial activity (Munawar 1970; Hill-Falkenthal et al. 2013).

In the present studies, Zooplankton peaked in summer which may probably be due to the encouraging environmental conditions (Sharma 2018), increased organic matter content due to higher rate of decomposition in warmer temperatures (Holcik & Olah

Table 3. Seasonal population density (ind./litre) of the zooplankton species reported from Pargwal Wetland, Jammu, J&K.

Phylum	Species		Spring			Summer			Monsoon			Winter	
		St-1	St-2	St-3	St-1	St-2	St-3	St-1	St-2	St-3	St-1	St-2	St-3
Rotifera	*Euchlanis dilatata.*	1.1	-	0.6	2.1	-	1.4	0.6	-	-	0.6	-	-
	Keratella tropica	0.2	-	-	1.0	-	0.9	-	-	-	-	-	-
	Lepadella ovalis	1.7	-	0.9	3.1	-	2.9	1.7	-	0.6	0.3	-	-
	Asplanchna sp.	0.2	0.2	0.1	1.6	-	0.8	0.7	-	0.1	0.1	-	-
	Brachionus calyciflorus	2.1	0.3	3.2	2.9	-	4.3	3.4	-	3.2	0.3	-	0.4
	Brachionus quadridentatus	1.4	-	1.7	2.2	-	2.9	1.7	-	2.2	0.7	-	0.4
	Trichocerca longiseta	1.1	-	2.1	2.1	-	0.3	0.9	-	1.4	0.1	-	0.1
	Trichocerca porcellus	-	-	0.3	0.3	-	0.6	-	-	-	-	-	-
	Trichotria sp.	0.3	-	0.1	0.1	-	-	-	-	-	-	-	-
	Cephalodella sp.	4.2	-	1.5	5.1	0.2	4.6	0.5	0.2	0.2	0.2	-	0.2
	Colurella adriatica	-	-	0.3	-	-	-	-	-	-	-	-	-
	Monostyla bulla	0.6	-	-	0.3	-	0.1	0.7	-	-	0.6	-	0.4
	Monostyla hamata	1.1	-	0.5	1.7	-	2.1	1.4	-	0.5	0.4	-	0.3
	Philodina sp.	0.3	-	-	1.1	-	0.6	0.2	-	0.6	0.2	-	-
	Platyias platulus	0.6	-	0.1	1.1	-	0.3	0.9	-	0.9	0.8	-	0.5
Total Rotifera		**14.9**	**0.5**	**11.4**	**24.7**	**0.2**	**21.8**	**12.7**	**0.2**	**9.7**	**4.3**	**-**	**2.3**
Arthropoda	*Macrothrix* sp.	3.1	0.1	1.5	3.3	-	3.6	3.2	0.2	2.1	0.1	0.1	0.3
(Cladocera)	*Pleuroxus* sp.	0.6	0.1	1.3	0.9	-	0.5	0.6	0.1	0.7	0.5	0.1	-
	Simocephalus sp.	3.3	0.3	1.9	6.4	1.4	5.6	1.5	0.2	2.2	1.1	0.1	0.1
	Alona costata	3.6	-	3.7	5.1	-	4.9	3.5	-	3.4	0.4	-	0.5
	Alonella sp.	2.2	-	2.5	3.2	0.1	3.4	2.9	-	3.2	0.7	-	0.6
Total Cladocera		**12.8**	**0.4**	**10.9**	**18.9**	**1.5**	**18.0**	**11.7**	**0.5**	**12.6**	**2.8**	**0.3**	**1.5**
Arthropoda	*Stenocypris* sp.	1.7	-	3.9	3.9	-	2.9	2.2	-	1.3	1.3	-	1.6
(Ostracoda)	*Eucypris* sp.	2.1	-	3.4	3.4	-	3.8	1.0	-	0.9	0.9	-	-
Total Ostracoda		**3.8**	**-**	**7.3**	**7.3**	**-**	**6.7**	**3.2**	**-**	**2.2**	**2.2**	**-**	**1.6**
Amoebozoa	*Arcella discoides*	3.7	-	5.1	3.4	-	5.4	3.1	-	5.0	1.3	-	-
(Protozoa)	*Centropyxis aculeata*	1.9	-	2.3	2.2	0.1	2.7	1.4	0.1	1.1	0.7	0.1	-

Table 4. The species diversity indices of zooplankton observed in Pargwal Wetland, Akhnoor, Jammu.

Group	Indices	Spring			Summer			Monsson			Winter		
		St-1	St-2	St-3	St-1	St-2	St-3	St-1	St-2	St-3	St-1	St-2	St-3
Rotifera	Taxa_S	13	2	12	14	1	13	11	1	9	11	1	7
	Individuals	99	5	92	181	2	162	111	2	84	52	1	44
	Dominance_D	0.1016	0.4	0.1663	0.09159	1	0.1275	0.1333	1	0.1922	0.1139	-	0.1892
	Simpson_1-D	0.8984	0.6	0.8337	0.9084	-	0.8725	0.8667	-	0.8078	0.8861	-	0.8108
	Shannon_H	2.408	0.773	2.073	2.476	-	2.262	2.206	-	1.875	2.267	-	1.768
	Evenness_e^H/S	0.8546	1.083	0.6622	0.8498	1	0.7385	0.8257	1	0.7242	0.8776	1	0.8371
Cladocera	Taxa_S	5	2	5	5	1	5	5	3	5	5	3	4
	Individuals	114	2	97	182	1	166	102	5	110	60	3	63
	Dominance_D	0.2383	-	0.2489	0.2384	-	0.241	0.239	0.2	0.2252	0.2475	0	0.2401
	Simpson_1-D	0.7617	1	0.7511	0.7616	-	0.759	0.761	0.8	0.7748	0.7525	1	0.7599
	Shannon_H	1.493	0.9431	1.456	1.49	-	1.464	1.491	1.255	1.528	1.5	1.432	1.406
	Evenness_e^H/S	0.8904	1.284	0.8576	0.8874	1	0.8646	0.8887	1.169	0.9214	0.8959	1.396	1.02
Ostracoda	Taxa_S	2	1	2	2	1	2	2	1	2	2	1	1
	Individuals	33	1	60	60	1	58	22	1	33	19	1	14
	Dominance_D	0.4886	-	0.4938	0.4938	-	0.5009	0.4935	-	0.4886	0.4854	-	1
	Simpson_1-D	0.5114	-	0.5062	0.5062	-	0.4991	0.5065	-	0.5114	0.5146	-	-
	Shannon_H	0.7042	-	0.6993	0.6993	-	0.6922	0.6993	-	0.7042	0.7069	-	-
	Evenness_e^H/S	1.011	1	1.006	1.006	1	0.9991	1.006	1	1.011	1.014	1	1
Protozoa	Taxa_S	3	1	3	3	1	3	3	1	3	3	1	1
	Individuals	116	1	96	139	1	166	57	1	69	33	1	18
	Dominance_D	0.4262	-	0.3607	0.4808	-	0.4251	0.3571	-	0.4672	0.3598	-	1
	Simpson_1-D	0.5738	-	0.6393	0.5192	-	0.5749	0.6429	-	0.5328	0.6402	-	-
	Shannon_H	0.9624	-	1.057	0.8916	-	0.9623	1.064	-	0.9131	1.057	-	-
	Evenness_e^H/S	0.8726	1	0.9596	0.813	1	0.8726	0.9655	1	0.8307	0.9597	1	1
Copepoda	Taxa_S	2	2	2	2	2	2	2	2	2	2	2	2
	Individuals	87	15	106	104	11	109	34	7	50	37	7	32
	Dominance_D	0.4948	0.5238	0.4997	0.4968	0.6727	0.4964	0.492	0.4286	0.4931	0.4895	0.4286	0.4859
	Simpson_1-D	0.5052	0.4762	0.5003	0.5032	0.3273	0.5036	0.508	0.5714	0.5069	0.5105	0.5714	0.5141
	Shannon_H	0.6983	0.6698	0.6934	0.6963	0.5196	0.6967	0.7009	0.7543	0.6999	0.7034	0.7543	0.7068
	Evenness_e^H/S	1.005	0.977	1	1.003	0.8407	1.004	1.008	1.063	1.007	1.01	1.063	1.014
	Confidence Intervals	6.95	1.28	3.31	8.00	1.21	9.04	6.14	0.79	6.92	1.46	0.57	1.54

1992; Hans & Anj 2007; Mishra et al. 2009; Golmarvi et al. 2018; Sharma 2018), thereby increasing food availability, increased productivity of phytoplankton owing to elevated concentrations of nutrients like nitrates (Breitburg et al. 1999). Similar upsurging trend of zooplankton during summers was observed by El-Sherbiny et al. (2011), Pradhan (2014), Vasanthkumar et al. (2015), Golmarvi et al. (2018), Sharma (2018). Decline in zooplankton abundance was witnessed during winters probably due to low temperature and high pH which reduces the overall zooplankton abundance (El-Sherbiny et al. 2011; Liu et al. 2023), increased predatory pressure (Shchapov & Ozersky 2023), weak water column stratification, and reduced phytoplankton biomass, and dilution in mineral & salt concentration in the wetland water (Hoyer & Jones 1983; Sivakami et al. 2013; Sharma & Kour 2021).

The number of species in the sample and the distribution of individuals within these species are indicated by biodiversity indices, therefore differences in biodiversity are a sign of changes in the characteristics of the water. A high Shannon-Weiner index value denotes

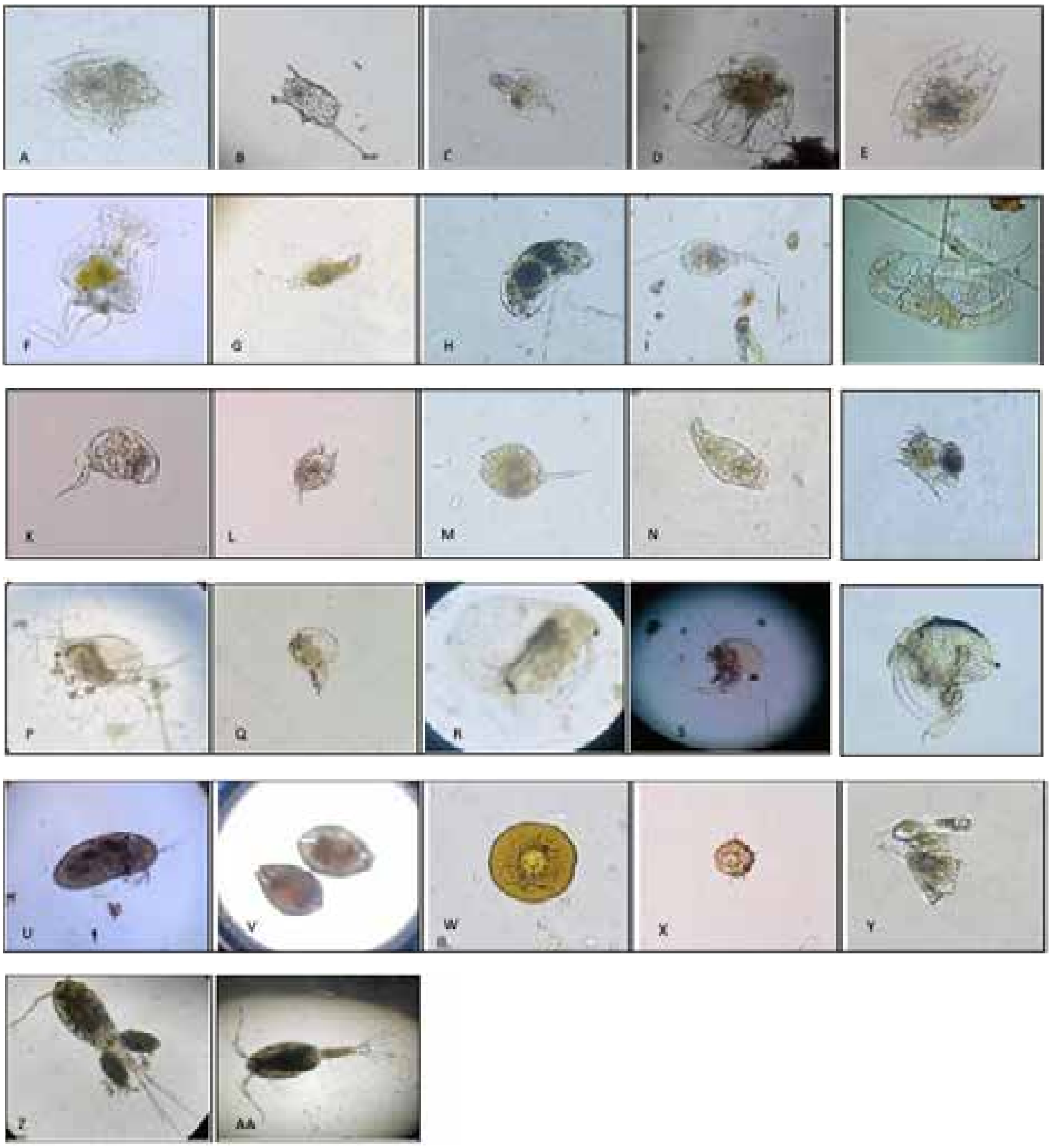

Image 3 (A–AA). Zooplankton species recorded from Pargwal wetland: A—*Euchlanis dilatata* | B—*Keratella tropica* | C—*Lepadella ovalis* | D—*Asplanchna* sp. | E—*Brachionus calyciflorus* | F—*Brachionus quadridentatus* | G—*Trichocerca longiseta* | H—*Trichocerca porcellus* I—*Trichotria* sp. | J—*Cephalodella* sp. | K—*Colurella adriatica* | L—*Monostyla bulla* | M—*Monostyla hamata* | N—*Philodina* sp. | O—*Platiyas platulus* | P—*Macrothrix* sp. | Q—*Pleuroxus* sp. | R—*Simocephalus* sp. | S—*Alona costata* | T—*Alonella* sp. | U—*Stenocypris* sp. | V—*Oncocypris pustulosa* | W—*Arcella discoides* | X—*Centropyxis aculeata* | Y—*Epistylis* sp. | Z—*Mesocyclops leukarti* | AA—*Cyclops* sp. © Neha Jamwal.

a higher level of diversity while a diversity score of three or higher denotes pure water, and between one–three imply significant pollution (Abdulwahab & Rabee 2015). Since rotifers thrive better in organic matter rich environment and thus are recognized as effective indicators of organic pollution (Karabin 1985; Paleolog et al. 1997; El-Sherbiny et al. 2011). Therefore, on applying the diversity indices, high mean value of Shannon-Wiener index (H) was recorded which follows, Rotifera (1.509) > Cladocera (1.288) > Copepoda (0.691) > Protozoa

Table 5. Pearson's correlation coefficient values between various physico-chemical parameters of water and zooplankton community.

Parameters	Rotifera	Cladocera	Copepoda	Protozoa	Ostracoda
AT	-0.794	**-0.843***	-0.922	-0.871	**-0.941***
WT	0.608	0.537	0.387	0.491	0.338
PH	-0.383	-0.462	-0.605	-0.509	-0.645
DO	-0.875	-0.829	-0.723	-0.798	-0.686
FCO2	0.753	0.693	0.561	0.653	0.517
HCO_3^-	**0.908***	0.868	0.771	**0.840***	0.737
Cl^-	0.813	0.759	0.639	0.723	0.594
Ca^{2+}	0.927	0.891	0.802	**0.866***	0.769
Mg^{2+}	0.933	0.899	0.812	0.874	0.780
NO_3^{2-}	**0.999***	**0.999***	0.976	0.995	0.363
$PO4^{3-}$	0.630	0.560	0.412	0.515	0.365
$SO4^{2-}$	0.837	0.786	0.671	0.752	0.630

*Correlation is significant at the 0.05 level (2-tailed).

(0.576) > Ostracoda (0.409) while Simpson index (1-D) followed the order as Rotifera > Cladocera > Protozoa > Ostracoda > Copepoda. The high number of Rotifers, i.e., *Euchlanis dilatata*, *Lepadella ovalis*, *Asplanchna* sp., *Brachionus calyciflorus*, *Brachionus quadridentatus*, *Cephalodella* sp., and *Platiyas platulus* reported in the presently studied wetland indicates mesosaprobity that clearly depicts their presence in moderate oxygenated conditions with considerable organic matter, and bacteria while the presence of less number of other rotifers like, *Keratella tropica*, *Trichocerca longiseta*, *Trichocerca porcellus*, *Colurella adriatica*, *Monostyla bulla*, *Monostyla hamata*, and *Philodina* sp. indicate them as oligosaprobic, which indicates the organisms live in highly oxygenated condition in which little organic matter is present (Slâdeček 1983). High abundance of cladocerans reported in the wetland clearly indicate pollution caused majorly by accumulation of phosphorus but low concentration of contaminants like, heavy metal ions (Aslam et al. 2012; Hosmani 2013. Abundance of *Mesocyclops leuckarti* (Copepod) and *Eucypris* sp. (Ostracod) also indicate slight to moderate pollution in Pargwal Wetland.

Based on Pearson's correlations (Table 5), temperature, pH, and DO remain prime factors that restricted the abundance, and diversity of zooplankton communities in Pargwal Wetland. Correlations were significantly positive for phosphates as follows: Rotifer ($r = 0.999^*$), Cladocera ($r = 0.999^*$), Copepoda ($r = 0.976$), Protozoa ($r = 0.995$), and Ostracoda ($r = 0.963$). The results of one-way ANOVA showed a less significant difference in the physicochemical parameters ($p > 0.05$; 0.960) and with zooplankton diversity ($p > 0.05$; 0.451).

When compared with other internationally important wetlands/reservoirs in Jammu and Kashmir like from Dal Lake, authors like Jeelani & Kour (2014), deciphered 40 zooplankton species (27 rotifers and 13 crustaceans). Pargwal Wetland along with many other important wetlands like Gharana wetland (an International Bird Area, recognized by Birdlife International UK and Bombay Natural History Society) in the Jammu province, crave attention for their revival, and replenishment. No significant work has been done on the wetlands of Jammu province due to the inadvertent neglect and immaculate anthropogenic influence that have turned these important sources into wastelands. Although recent government interventions on the upliftment of Gharana Wetland has led to its substantial revival, others desperately fight for their existence.

It is a universal fact that zooplankton are the driving force which propel an aquatic food chain. They play a crucial role in the transmission of energy from lower to higher trophic levels because of a variety of characteristics, including stress resistance, enormous diversity, density, and drifting behavior (Dutta & Mondal 2020). Because of their brief lifespan, they frequently show abrupt and dramatic changes in reaction to changes in the physicochemical characteristics of water, which greatly enhances the freshwater ecosystem's biological production (Sultana et al. 2023). With a strong association between zooplankton dynamics and important physical & chemical properties of water, this study highlights the critical importance of zooplankton conservation within the setting of this very important wetland. The study deciphered that even minor changes in water quality can have a big impact on zooplankton populations and consequently, the larger aquatic food web, by looking at factors like pH, temperature, and nutrient concentrations. Conservation of zooplankton is important for maintaining water quality and ecosystem resilience as well as for safeguarding aquatic life since they are sensitive bioindicators that offer early warning indications of ecological stress.

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ARTICLE

Cypris decaryi Gauthier, 1933 (Crustacea: Ostracoda: Cyprididae): a new record for Maharashtra, India, with a note on its distribution

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Abstract: Specimens of *Cypris decaryi* Gauthier, 1933 were collected from riverine potholes in the semi-arid zone of Maharashtra, India. The species has previously been recorded from various states in India. This is the first confirmed occurrence from Maharashtra, accompanied by a detailed description and notes on its distribution.

Keywords: Basaltic rocky outcrop, diversity, freshwater, microcrustaceans, Nighoj, riverine potholes, taxonomy.

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INTRODUCTION

Ostracods are enormously diverse bivalved crustaceans occurring in different types of aquatic habitats ranging from 0.2–3 mm in body size. The updated list of the present freshwater ostracods contains 2,420 species worldwide, under the order Podocopida Sars, 1866 (Meisch et al. 2024) belonging to superfamilies like Cypridoidea Baird, 1845 ; Cytheroidea Baird, 1850 ; Darwinuloidea Brady & Robertson, 1885; and Terrestricytheroidea Schornikov, 1969 , with the first two leading in species diversity (Meisch et al. 2019) including 154 species from India (Karuthapandi & Tilak 2023), whereas ostracod fauna of Maharashtra has 38 species belonging to 15 genera (Patil & Talmale 2005).

One of the oldest known genera *'Cypris'* from the superfamily Cypridoidea, is the most diverse group in tropical regions with the highest species diversity in Afrotropical, and Oriental regions, characterised by large body size, and sub-globular appearance as described by Müller in 1776 (Mesquita-Joanes et al. 2020). Seventeen species of the genus *Cypris* were reported worldwide (Meisch et al. 2019), whereas eight species were reported from India (Karuthapandi et al. 2014).

Cypris decaryi was described for the first time by Gauthier (1933) from Androy Island near Madagascar. It was reported from 22 localities between 1932 and 2021. The species was first reported by Victor & Fernando (1979) in India, followed by Jain (1979) from Gujarat, and Battish in 1986 (Battish 2000) from Punjab.

This paper presents the first report of *Cypris decaryi* from Maharashtra, sampled for the first time in the riverine potholes of Nighoj, including a detailed description of the species along with a note on its distribution.

MATERIALS AND METHODS

The specimens of *Cypris decaryi* were sampled from the riverine pothole (approximately 1.2 m in length, 0.7 m in width, maximum depth 0.6 m), located at coordinates 18.932° N, 74.262° E (Figure 1) in Nighoj, Maharashtra, a state in India that occupies a substantial portion of the Deccan Plateau in the peninsular part of the Indian subcontinent. Ostracods were collected during a survey on 29 September 2024 using a simple hand net with a 150 µ mesh size, stored in 100 ml containers, and fixed in 4% formaldehyde immediately in the field. Subsequently, the samples were washed with tap water and preserved in 70% alcohol. *Cypris decaryi* was observed, sorted, identified, and dissected under the Magnus MS24 stereomicroscope. Five specimens were used for the study. Dissection was carried out in polyvinyl lactophenol medium using tungsten needles, and drawings were done by camera Lucida which was attached to Lawrence and Mayo LM-52-1802 microscope. Scanning electron microscopic images were taken on JEOL analytical scanning electron microscope at the Department of Physics, Savitribai Phule Pune University, at an accelerating voltage of 10 kV. Terminologies for the soft part anatomy and chaetotaxy are after Broodbakker & Danielopol (1982) and Meisch (2000).

Specimens were deposited at the Department of Zoology, Modern College, Pune, Maharashtra.

RESULTS

Systematic account

Class Ostracoda Latreille, 1802
Subclass Podocopa G.W.Müller, 1894
Order Podocopida Sars, 1866
Suborder Podocopina Sars, 1866
Superfamily Cypridoidea Baird, 1845
Family Cyprididae Baird, 1845
Subfamily Cypridinae Baird, 1845
Genus *Cypris* O.F.Müller, 1776

***Cypris decaryi* Gauthier, 1933**

1933, *Cypris decaryi* Gauthier, 1933: Gauthier 209–215
1979, *Cypris decaryi* Gauthier, 1933: Victor & Fernando 162–163
1990, *Cypris decaryi* Gauthier, 1933: Martens 136–139

Synonymies

Cypris ravenala Brehm, 1934(7): (Martens & Behen 1994)
Cypris labiata Rome, 1962 (128–132): (Martens 1990)

Measurements (µm)

Carapace (n = 5) L(length) = 1680–1685, W(width) = 1230–1245.

Left valve (n = 5) L = 1514–1640, H(height) = 1050–1150.

Right valve (n = 5) L = 1510–1640, H = 1000–1150.

Carapace (Figure 1A–F) — globular, subovate, valve surface covered with fine granules and hairs, valve margin hairy. The dorsum was highly arched, the ventral margin somewhat sinuated, the anterior margin broadly rounded than the posterior, the greatest height situated in the mid or slightly in front of the mid-length. Right

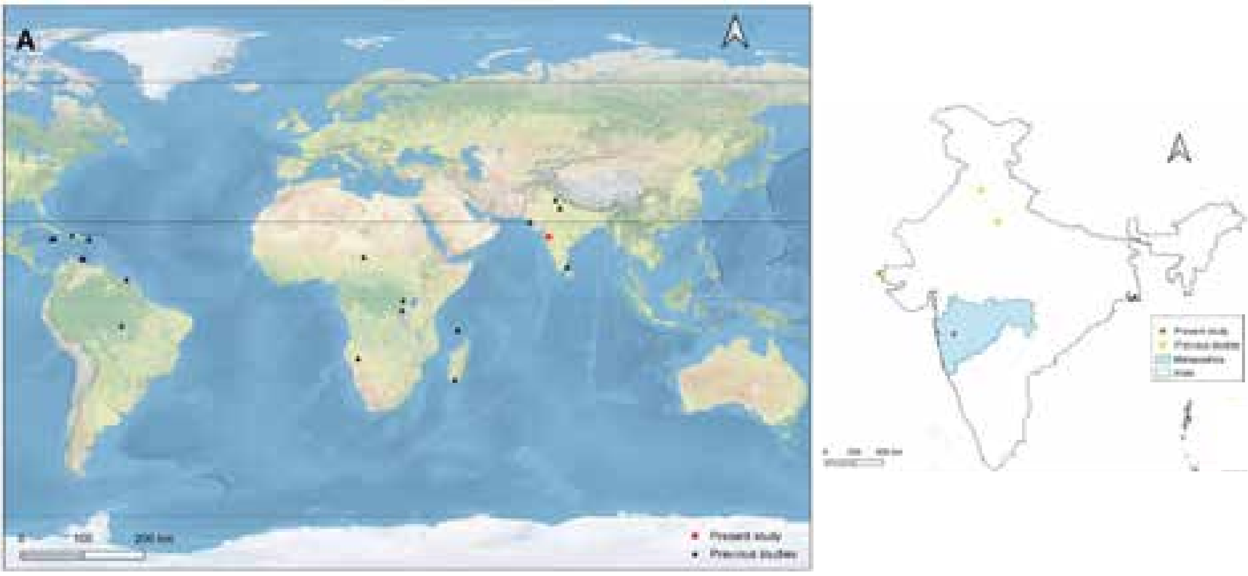

Image 1. a—map showing global distribution of the *Cypris decaryi* | b—distribution of *Cypris decaryi* in India.

valve (RV) was larger than left valve (LV), both valves with flange, and selvage displaced inwardly from the dorsal view, and the anterior end appears beak-like while the posterior LV slightly overlaps RV.

RV (Figure 1B,C) — with large flange, selvage largely displaced inwardly, at the posteroventral side, fine small tubercles present. The inner calcified lamella at the posterior end is broad.

LV (Figure 1A,D) – with a small flange, selvage displaced inwardly, posteroventral tubercles are absent, additional inner list present, inner calcified lamella at the posterior end slightly shorter than RV.

Antennule (A1) (Figure 1A,A′) — seven segmented, first segment with one dorso-subapical seta, wouters organ absent, on proximal side at ventro-apical two long setae present. The second segment is short and wide, with one seta dorso-apically reaching half the length of the next segment; on the other side, a short Rome organ is present. The third segment is the longest among all the segments, carrying two setae, one dorso-apical reaching beyond the fourth segment, and one ventro-apical short, slightly hairy, reaching the tip of the fourth segment. The fourth segment dorsally has two long setae, ventrally two setae of unequal length (inner most is short reaching tip of the next segment other one is long, reaching beyond the sixth but not reaching up to the tip of the terminal segment). Fifth segment with four long setae: two dorsally, two ventrally. The sixth segment with four long and one short seta. The seventh segment has two long setae, aesthetasc Y, and one short seta.

Antenna (A2) (Figure 1B,B′) — first protopodal segment consists of three setae (one most proximal and two situated ventro-laterally). The second protopodal segment has one seta situated ventro-apically reaching the tip of the first endopodal segment. Exopod reduced plate-like structure having three setae (one long, two short setae).

Endopod — first endopod segment with two segmented aesthetasc Y (position unclear), ventro-apical setae reaching the tip of the penultimate segment and with 5+1 natatory setae (five long feathered setae reaching just behind the tip of the terminal claw and one short accompanying seta, length of this accompanying seta reaching halfway along the length of the penultimate segment. The penultimate segment, undivided medially on the ventral side four "t" setae (t1–t4) (t1 reaching beyond the tip of the terminal segment, and t4 reaches the base of the z2 seta, t2 and t3 are very long and reach around 90% of the length of claw G3 and on dorsal side at the same position two setae of unequal length. Distally of the same segment, three serrated claws (G1, G2, G3). G1 is the longest among all, behind these claws, three long z setae (z1, z2, z3), z3 is the longest of all, reaching just beyond the tip of the apical claw. Terminal segment with two serrated claws, claw Gm is more than half the length of GM, presence of long g seta, and aesthetasc Y3, which is half the length of g seta.

Mandible (Figure 1C) — as shown in the figure.

Mandibular palp (Figure 1D,D') — four segmented. The first segment has two long hairy S1 and S2 setae, one long and one short, slim, slender, smooth, called alpha seta. The second segment dorsally has three apical

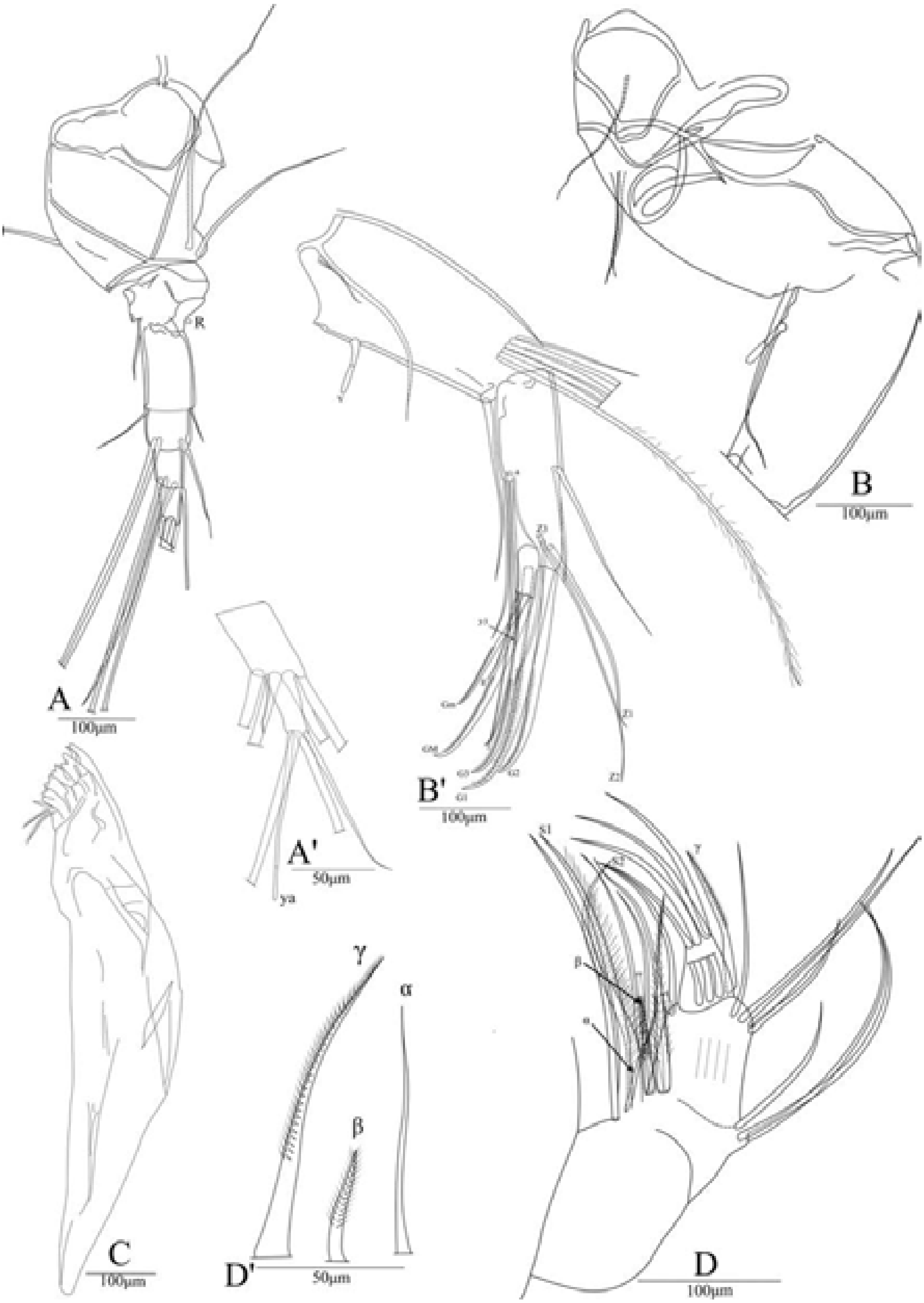

Figure 2. ***Cypris decaryi*****: A—maxillula | B'—first thoracopod | C—second thoracopod | C'—details of last segment of second thoracopod | D—third thoracopod | D'—details of distal part of third thoracopod | E—caudal ramus | F—caudal ramus attachment. Scale bar: B, C, C', D, E, F—100 µm | A, D'—50 µm.**

Image 2. a—study area riverine potholes from Nighoj | b & c—*Cypris decaryi* sampled from these potholes.

setae of unequal length (innermost is shorter), ventrally with group of three long smooth setae of varying length, one long hairy seta, and one very short hairy seta with pointed tip known as beta setae. On the third segment, there is a group of three setae, on the dorsal side four subapical setae (two short and two long setae), ventrally two subapical setae, laterally with three apical smooth setae and gamma setae, gamma setae approximately twice as long as the fourth segment. The fourth segment has four claws and one seta.

Maxillary palp (Figure 2A) — two- segmented, basal segment with a group of six apical setae, one medial seta reaching beyond the tip of the terminal segment, and one dorso-subapical seta, all setae are long. The second segment is longer than twice the width. There are three maxillary endites present, Zahnborsten (tooth-bristles) of the third endite are strongly serrated

First thoracopod (T1) (Figure 2B) — Protopodite with two proximal "a" seta, two long "b" and "d", and distally a group of 14 apical setae, and two subapical setae. Endopodite with three unequal apical setae.

Second thoracopod (T2) (Figure 2C,C') — first segment with two seta, "d1" and "d2" ("d1" is larger than "d2"). The second segment has a long "e" seta reaching beyond the mid length of the next segment, third segment has a medial long "f" setae reaching the tip of the terminal segment, and apically has a short "g" seta reaching just beyond the tip of the terminal segment. The terminal segment is short and triangular with two setae ("h1" and "h3") and one claw ("h2" serrated at the distal end). Seta "h1" is larger than "h2" (length of seta 'h1' compared with claw i.e., 'h2').

Third thoracopod (T3) (Figure 2D,D') — known as the cleaning limb. First segment with three setae ("d1, d2, d3") of different lengths. The second segment with long apical e setae reaching two-third of the next segment. The third segment bears "f "setae reaching the tip of the segment. On the terminal segment, the "h2" setae are transformed into the pincer organ, there is also one short "h1" seta, and subapical h3 (reflected) seta.

Caudal ramus (CR) (Figure 2E) — well developed and symmetrical, with two claws ("Ga" and "Gp") and two setae ("Sa" and "Sp").

Caudal ramus attachment (CR attachment) (Figure 2F) — strong and distally bifurcated.

Taxonomic remarks

Cypris decaryi varies from other species in valve

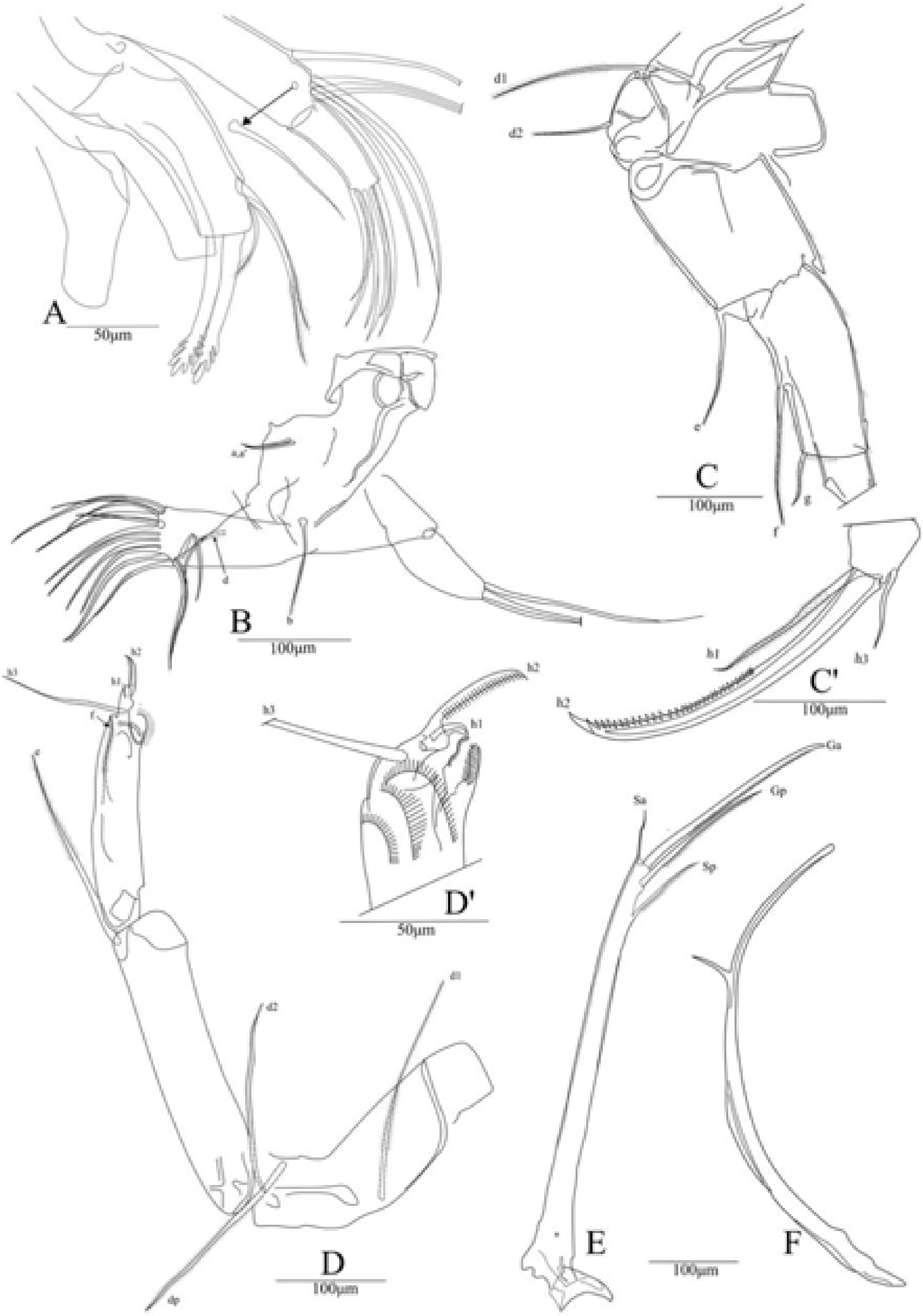

Figure 2. ***Cypris decaryi*: A—maxillula | B'—first thoracopod | C—second thoracopod | C'—details of last segment of second thoracopod | D—third thoracopod | D'—details of distal part of third thoracopod | E—caudal ramus | F—caudal ramus attachment. Scale bar: B, C, C', D, E, F—100 µm | A, D'—50 µm.**

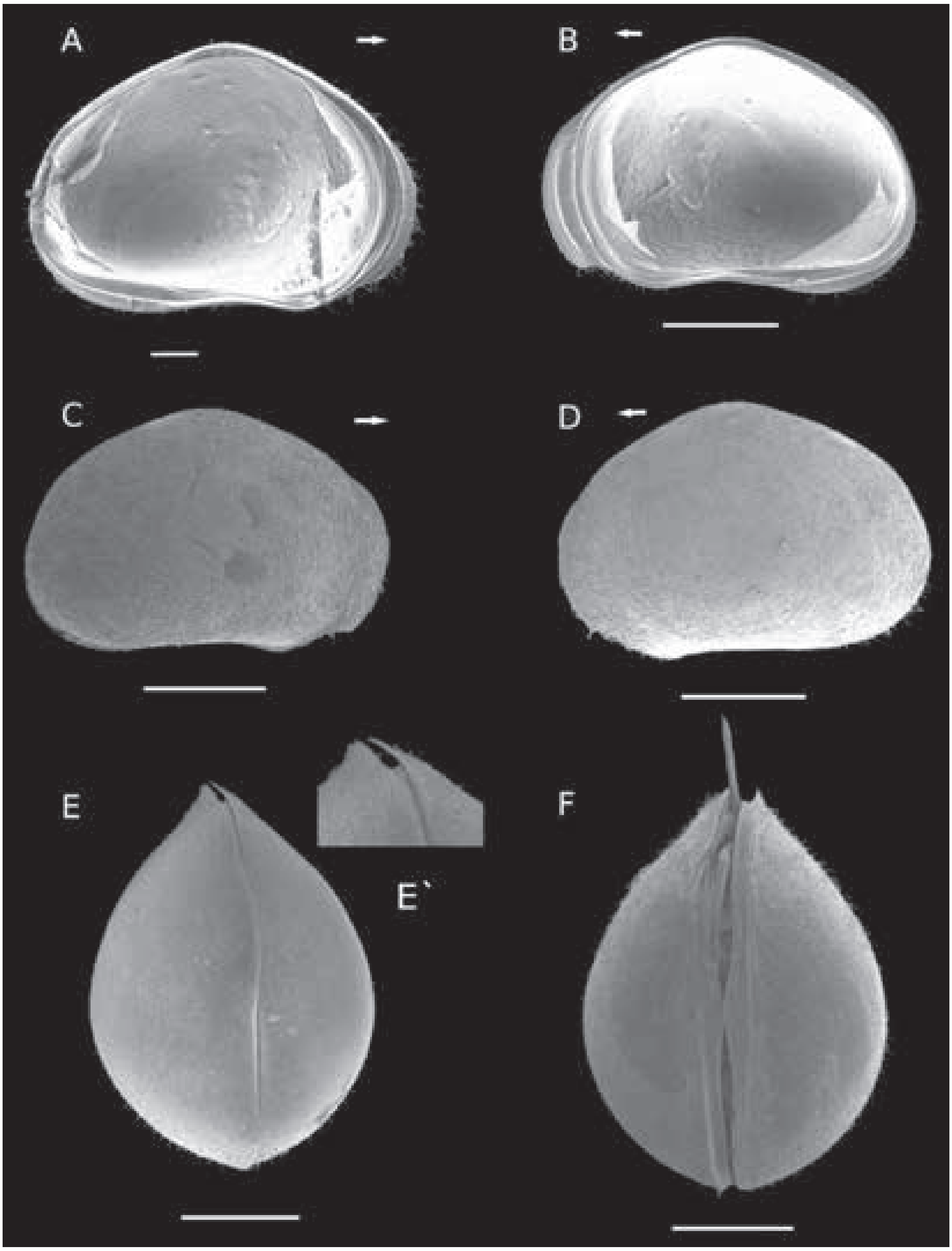

Image 3. SEM images of *Cypris decaryi* Gauthier 1933, female: A—LV internal view | B—RV, internal view | C—RV, external view | D—LV, external view | E—carapace, dorsal view | E`—carapace, anterior valve margin | F—carapace, ventral view. Scale bar: A—200 µm | B–F—500 µm. The arrow indicates the anterior region.

morphology by its characteristic shape and smooth surface. The species is relatively closer to *C. pretusi*, as both have anterior beak-like appearance but the width: length and height: length ratio of the two species make them different. It differs from type species *C. pubera* by the presence of large spines on the posterior margin of its carapace, and from *C. granulata* in valve ornamentation. In contrast to *C. protubera*, *C. decaryi* differs due to the granulated surface on the valve and its margins, which are hairy except for the dorsal margin, and by a prominent anteroventral protuberance. Both the claws are serrated along the dorsal margin in *C. protubera*, while claws in *C. decaryi* are serrated only upto half part.

Distribution

Cypris decaryi was first described from Androy, Madagascar by Gauthier in 1933. It was later reported by Brehm (1934) from Paramaribo, Suriname of northern South America, by Gauthier (1939) from Lake Fitri, by Klie (1944) from Lake Edward, Kiss (1960) from Burundi, Triebel (1961) from Caribbean Island, Rome (1962) from surrounding of the Lake Tanganyika, McKenzie (1971) from Aldabra islands. Broodbakker (1983) reported it from Bonaire, Curacao and Puerto Rico Island, from two localities from Sri Lanka by Neale (1984); from Namibia by Martens (1990), from Jamaica by Little & Hebert (1994), from Brazil by Martens et al. (1998) and Balearic Islands by Zamora et al. (2005). The first report from India was made by Victor & Fernando (1979), followed by Jain (1979) from Kachchh, Gujarat, and by Battish in 1986 (loc. cit.) from Patiala, Punjab. In the present study, *C. decaryi* is reported from the riverine potholes of Nighoj, Maharashtra.

DISCUSSION

South America, India, and Madagascar were connected during the late Cretaceous period (Krause et al. 2006). Zamora et al*.* 2005 reported *C. decaryi* from the Balearic Islands, Spain, and predicted the presence of the species due to the transportation of rice. Rice fields are considered ideal habitats for introducing and establishing alien species (Rossi et al*.* 2003). Species originally endemic to South America, Asia, and Africa might have been introduced into Italy through rice seeds (Smith et al. 2018). We assume that *C. decaryi* has originated from Madagascar, possibly the drifting of the continents led to establishment of the species in various areas of previously known Gondwana.

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ARTICLE

Tectonic turmoil: consequences of violent earthquake-2025 on biodiversity collapse in Myanmar

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Abstract: This study provides a preliminary rapid-response assessment of the immediate impacts of the 2025 violent earthquake in Myanmar on biodiversity. The photographic evidence and communication with the local communities reported mass mortality of freshwater gastropods in Inle Lake, with predictions of substantial losses among several bithyniid species, including endemic ones. Additionally, the unnatural deaths of freshwater fishes (e.g., carps and catfishes) in the Mahamuni Pagoda Pond, Mandalay, indicate that the earthquake also affected larger freshwater vertebrates. This first documentation highlights the need for further investigations into freshwater ecosystems, particularly within the Irrawaddy River basin, to comprehensively assess the earthquake's impact on native biodiversity. The study also recommends further scientific validation and long-term monitoring efforts in Inle Lake to support the restoration of lost biodiversity and to safeguard the livelihoods of the native Intha communities that depend on this freshwater ecosystem.

Keywords: Aquatic species, biodiversity loss, conservation, Gastropods, freshwater fishes, seismic impact, southeastern Asia.

Burmese: ဤလေ့လာမှုသည် ၂၀၂၅ ခုနှစ်တွင် မြန်မာနိုင်ငံ၌ ဖြစ်ပွားခဲ့သော ပြင်းထန်သည့် ငလျင်ကြောင့် ဇီဝမျိုးစုံမျိုးကွဲများအပေါ် ချက်ချင်းရိုက်ခတ်မှုများကို အခြေခံအဆင့် လျှင်မြန်စွာပြန်လည်ဆန်းစစ်ချက် တစ်ရပ်ကို ပံ့ပိုးဖော်ပြပေးထားသည်။ ဓာတ်ပုံမှတ်တမ်းများနှင့် ဒေသခံကျေးရွာများ၏ ဆက်သွယ်ပြောဆိုမှုများအရ အင်းလေးကန်အတွင်းရှိ ရေချိုခရုပက်ကျိများ အစုလိုက် သေဆုံးမှုကို တွေ့ရှိရပြီး ဒေသရင်း အပါအဝင် ဆက်စပ်မျိုးစိတ်များစွာတွင် သိသာထင်ရှားသော ဆုံးရှုံးမှုများ ရှိနိုင်ကြောင်း လေ့လာတွေ့ရှိရသည်။ ထို့အပြင် မန္တလေးမြို့ရှိ မဟာမုနိရေကန်တွင် ရေချိုငါးများ၏ သဘာဝအရ မဟုတ်သော သေဆုံးမှုများကိုကြည့်ခြင်းအားဖြင့် အဆိုပါ ငလျင်သည် ရေချိုကျောရိုးရှိသက်ရှိများ အပေါ်ပါ သက်ရောက်မှုရှိကြောင်း ညွှန်ပြနေသည်။ ဤလေ့လာမှုသည် မြန်မာနိုင်ငံအတွက် ပထမဆုံး မှတ်တမ်းတင်ချက်ဖြစ်ပြီး ဒေသရင်း ဇီဝမျိုးစုံမျိုးကွဲများအပေါ် ငလျင်၏သက်ရောက်မှုကို နက်ရှိုင်းစွာ အကဲဖြတ်နိုင်ရန်အတွက် အထူးသဖြင့် ဧရာဝတီမြစ်ဝှမ်းဒေသ အတွင်းရှိ ရေချိုဂေဟစနစ်များကို နောက်ထပ်လေ့လာမှုများ ပြုလုပ်ရန် လိုအပ်ကြောင်း ထင်ဟပ်ဖော်ပြလျက်ရှိနေသည်။ ယခုလေ့လာမှုတွင် ဆုံးရှုံးသွားသော ဇီဝမျိုးစုံမျိုးကွဲများ ပြန်လည်ထူထောင်ရေးနှင့် ဤရေချိုဂေဟစနစ်ကို မှီခိုနေရသော ဒေသခံအင်းသားကျေးရွာများ၏ ရှင်သန်ရပ်တည်ရေးကို ပံ့ပိုးရန်အတွက် အင်းလေးကန်အတွင်း နောက်ထပ်သိပ္ပံနည်းကျ စိစစ်အတည်ပြုမှုများနှင့် ရေရှည်စောင့်ကြည့်လေ့လာမှုများ ဆောင်ရွက်ရန် အကြံပြုထားပါသည်။

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BACKGROUND

Earthquakes occur when stress accumulates at plate boundaries due to friction and is suddenly released, causing fault movement, and generating seismic waves (Ide 2010). These natural phenomena significantly affect the environment through ground shaking, surface rupture, landslides, soil liquefaction, and tsunamis, leading to both immediate and long-term consequences (Ratnapradipa et al. 2012). Specifically, earthquakes trigger tsunamis that flood coastal areas, alter salinity, deposit harmful sediments, and damage critical marine habitats such as coral reefs, mangroves, and seagrass beds, disrupting aquatic biodiversity (Lebrato et al. 2019). In freshwater systems, earthquakes can shift river courses or create new reservoirs, hindering species migration, and water quality. Furthermore, the soil liquefaction can collapse habitats, particularly in reservoirs and lakes, causing further decline in many aquatic species. Moreover, the groundwater biodiversity is also significantly impacted by seismic activity, with loss of subterranean species (Galassi et al. 2014). It has been shown previously that the 2011 Tohoku earthquake and tsunami caused notable shifts in species diversity in rocky intertidal zones (Urabe et al. 2013). Additionally, earthquakes can trigger biogeochemical shifts in hydrothermal vents, disrupting aquatic ecosystems (Lebrato et al. 2019). A previous global study shows that earthquakes increase extinction risks for various species (Gonçalves et al. 2024).

In particular, the 2009 earthquake that affected the karstic Gran Sasso Aquifer in Italy is presumed to have induced significant biogeographical and ecological disturbances, altering habitats, disrupting ecosystem dynamics, and influencing species distribution patterns (Fattorini et al. 2017). Such seismic activity likely caused physical damage to critical ecosystems, including forests, wetlands, and agricultural lands, leading to habitat loss for numerous species, as observed across various biogeographic regions (Qiu et al. 2015; Sidle et al. 2018). The displacement of flora and fauna due to land shifts, landslides, and infrastructure damage has altered local biodiversity patterns, while disruption to natural habitats may impede species migration, reproduction, and access to food sources, potentially leading to long-term ecological imbalances (Li et al. 2022; Yuan et al. 2024). Additionally, earthquake impact on soil stability, and water systems has been reported to exacerbate threats to vegetation growth, and aquatic ecosystems, jeopardizing both terrestrial, and aquatic biodiversity (Galassi et al. 2014).

On 28 March 2025, Myanmar was struck by a series of earthquakes, beginning with a magnitude 7.7 tremor near Mandalay at 0620 h UTC (Coordinated Universal Time) (United States Geological Survey, https://earthquake.usgs.gov/earthquakes/eventpage/us7000pn9s/executive), followed by a 6.7-magnitude quake at 0632 h UTC in the western part of the country, and several subsequent aftershocks (Image 1). These included a magnitude 4.8 quake near Taungdwingyi at 06:39 UTC, a 4.9-magnitude tremor in Sagaing at 0642 h UTC, and a 4.9-magnitude earthquake near Taungngu at 0645 h UTC. Additional aftershocks continued throughout the morning, with several quakes of magnitudes 4.5–4.6, impacting areas such as Shwebo, Pyinmana, and Mandalay. The earthquake, caused by a strike-slip movement along the Sagaing Fault, underscores the ongoing tectonic strain between the Indian and Eurasian Plates (Shahzada et al. 2025). This event serves as a reminder of the region's high seismic risk, where the continuous pressure from the plate collision leads to the release of energy through fault ruptures. The earthquake sequence caused over 2,700 civilian deaths, 4,500 injuries, and 450 missing, with widespread destruction in Mandalay, Myanmar, and tremors spreading up to Thailand. Subsequently, countries like China, India, and the U.S. provided emergency aid, including supplies, medical help, and rescue teams, while the UN coordinated relief efforts. The immediate consequences of this natural disaster shift focus to human casualties, infrastructure damage, and emergency response, temporarily overlooking biodiversity loss. In the face of immediate humanitarian needs, attention is often distracted from ecological concerns, eventually relegating the habitat damage, ecosystem disruption, and species loss. Therefore, long-term recovery efforts must prioritize both human well-being, and biodiversity conservation by identifying, and restoring key ecological habitats to enhance resilience, and ensure sustainable future ecosystems.

The seismotectonics of this region are primarily driven by the ongoing collision between the Indian Plate and the Eurasian Plate, which began approximately 50 million years ago and continues to this day (Hurukawa et al. 2012). This collision has resulted in the formation of the Himalayan Mountain range and the Tibetan Plateau, generating significant seismic activity (Shahzada et al. 2025). The region is characterized by several fault systems, including the Main Himalayan Thrust (MHT), the Main Boundary Thrust (MBT), and the Sagaing Fault, each of which plays a crucial role in earthquake generation (Li et al. 2024). Myanmar, located at the eastern edge

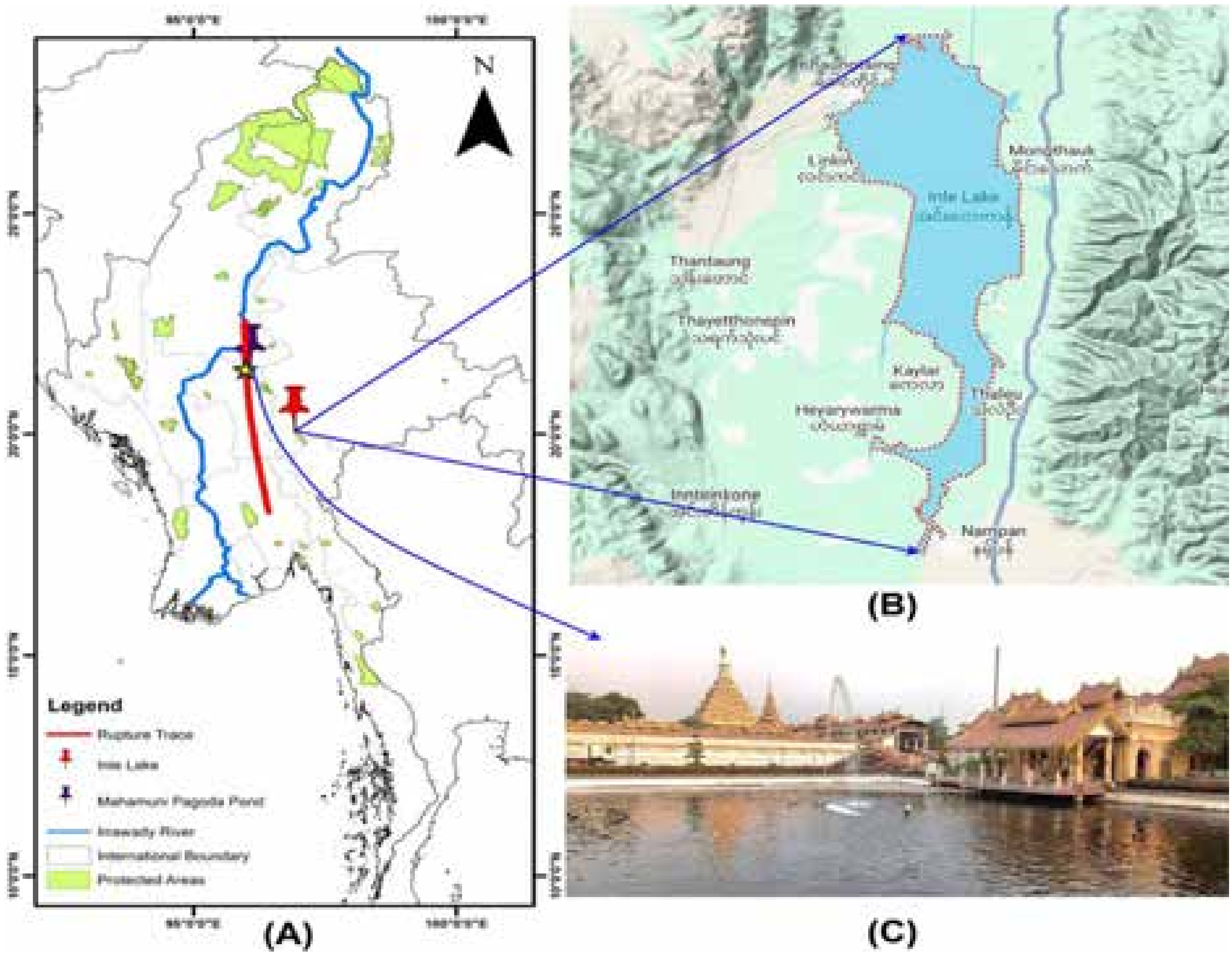

Image 1. A—map showing the rupture trace of the 28 March 2025, Myanmar earthquake in red. The underlying raster data was obtained from the United States Geological Survey. The yellow star marks the epicenter, the blue line represents the Irrawaddy River, and the green polygons indicate protected areas in Myanmar. The survey sites — Inle Lake and Mahamuni Pagoda Pond — are marked with color-coded pins. The map was manually edited using Adobe Photoshop CS 8.0 | B—location of Inle Lake | C—Mahamui Pagoda Pond in Myanmar.

of the Indian Plate's interaction with the Eurasian Plate, is influenced not only by Himalayan tectonics but also by the subduction zone off its coast, where the Indian Ocean Plate subducts beneath the Sunda Plate (Taylor & Yin 2009). The Sagaing Fault, a major strike-slip fault running through Myanmar, accommodates lateral motion between the Indian and Eurasian Plates, contributing to the region's seismic activity (Wang et al. 2014). Due to the relatively underdeveloped seismic monitoring and mitigation infrastructure in this region compared to other seismically active areas, there is a critical need for increased research into the region's seismotectonics for more effective risk assessment, and disaster preparedness in these earthquake-prone regions. Therefore, in light of the recent 2025 violent earthquake in Myanmar, the present study aims to undertake a rapid assessment of its immediate impacts on biodiversity in two ecologically and culturally significant sites: (i) Inle Lake, a naturally biodiversity-rich area located on the southern Shan Plateau and (ii) the Mahamuni Pagoda Pond in Mandalay, an artificial but conservation-relevant aquatic habitat. Given the critical role of both sites in regional biodiversity and conservation, this preliminary report offers an early overview of biodiversity loss resulting from the disaster. This study is intended to serve as a foundational baseline for more comprehensive post-disaster assessments of diverse biogeographic regions and native biota across Myanmar.

STUDY DESIGN

Following the earthquake on 28 March 2025, ecological alterations and biodiversity loss were assessed at Inle Lake (20.552° N, 96.916° E), located on the southern Shan Plateau, and at Mahamuni Pagoda Pond (21.951° N, 96.080° E) in Mandalay, Myanmar. Inle Lake is the second-largest lake in Myanmar and the only ancient lake on the Indochinese Peninsula. Despite its relatively small size (~116 km^2) and shallow depth (with an average of only two meters), this lake supports significant freshwater biodiversity and endemism, similar to other ancient lakes, such as Baikal in Russia, Tanganyika in Africa, and Biwa in Japan (Hampton et al. 2018). Furthermore, the Mahamuni Pagoda Pond harbours a diverse assemblage of aquatic fauna, including various species of carp (Cyprinidae), catfish (Siluriformes), and freshwater turtles. These animals are frequently released by pilgrims as part of long-standing religious and cultural rituals that symbolize the act of merit-making. The recent assessment was carried out at both study sites through a randomized questionnaire survey conducted among local inhabitants and community volunteers. The field documentation was supported by photographic evidence captured using a Canon EOS 7D Mark II camera equipped with an 18–135 mm lens.

The generation of the maps involved multiple stages of data retrieval and processing of vector files. Initially, global administrative boundary shapefiles were obtained from the DIVA-GIS platform (https://diva-gis.org/data.html), which provides high-resolution vector datasets suitable for spatial analysis. These shapefiles were imported into ArcMap (ArcGIS v10.6) for subsequent processing and overlay analysis. Furthermore, the rupture trace associated with the violent earthquake 2025 in Myanmar was obtained from the United States Geological Survey (USGS) Earth Explorer platform (https://www.usgs.gov/). Data on Myanmar's protected areas were acquired from the Protected Planet database (https://www.protectedplanet.net/en). This dataset includes officially designated protected regions and supports the assessment of environmental vulnerability. All spatial datasets were standardized by reprojecting them into the WGS 84 geographic coordinate system to ensure consistency and compatibility across layers. The processed data were compiled and exported for the generation of the final thematic maps.

OBSERVATION

Gastropod mortality in Inle Lake

This study documents the sudden mortality of millions of gastropods from multiple species in Inle Lake (Image 1). To date, 36 species of freshwater molluscs, including 18 endemic species, have been recorded from the Inle Lake basin (Annandale 1918a; Annandale & Rao 1925). The family Bithyniidae, one of the most common groups of freshwater snails within the basin, is widely distributed across Africa, Eurasia, and Australia, inhabiting rivers, wetlands, ponds, and lakes. Six species of bithyniid snails have been documented in the Inle Lake basin and surrounding regions, viz., *Hydrobioides turrita*, *H. nassa*, *H. physcus*, *H. avarix*, *Gabbia nana*, and *G. alticola*. Four of these species (*H. physcus*, *H. avarix*, *G. nana*, and *G. alticola*) are considered endemic to the Inle Lake basin (Zhang et al. 2025). In light of the recent earthquake in Myanmar, the widespread mortality of molluscs in Inle Lake suggests a dramatic loss of native biodiversity, including many endemic species (Image 2). The decaying carcasses of these snails have contributed to the rapid deterioration of water quality, potentially exacerbated by the release of unpleasant odours and the proliferation of harmful microbes. This microbial surge poses further risks to the remaining native freshwater species in the lake.

Fish mortality at Mahamuni Pagoda Pond

The study also documents the unnatural mortality of sacred freshwater fish in the Mahamuni Pagoda Pond following the recent earthquake (Images 1 & 2). This seismic disturbance appears to have triggered adverse ecological conditions in the confined aquatic environment, including potential shifts in water chemistry, hypoxia, and the suspension of sediment-bound pollutants, all of which could have contributed to the observed fish die-offs (Devane et al. 2014). This pond also supports breeding activities, where fish populations occasionally reach densities high enough to require transfer or release into nearby natural water bodies, most notably the Irrawaddy River (Global new light of Myanmar 2024). Such movement of fauna between managed and wild habitats presents both ecological opportunities and biosecurity risks, particularly following stress events like earthquakes. Furthermore, the presence of several freshwater turtle species within the pond is of particular conservation concern, including the Critically Endangered Burmese Roofed Turtle *Batagur trivittata*, and the Burmese Peacock Softshell *Nilssonia formosa* (Calle et al. 2021). Both species are endemic to

Image 2. Consequences of the 28 March 2025 violent earthquake on Myanmar's Biodiversity. A–D—mass mortality of millions of gastropods in Inle Lake | E—unnatural death of freshwater fish in the captivity at Mahamuni Pagoda, Mandalay. © July Hnin and Thadoe Wai.

Myanmar and are facing severe threats due to habitat loss, overexploitation, and illegal trade (Platt et al. 2019; Horne et al. 2021).

COMMENTARY

Earlier evidence suggests that earthquakes and their subsequent effects can influence the ecological dynamics, genetic composition, and structural changes within molluscan communities in Japan (Sato & Chiba 2016; Miura et al. 2017). Additionally, studies have documented that earthquakes impact molluscan species and their toxic metal accumulation, potentially posing significant risks to human health (Tapia et al. 2019). Thus, immediate intervention by local governments and conservation agencies is crucial to mitigate the ecological impacts of this event and protect the lake's unique biodiversity. In addition to its rich biodiversity, Inle Lake in Myanmar plays a pivotal role in supporting the livelihoods of the local Intha communities (Htwe et al. 2015). This aquatic ecosystem is also regarded as United Nations Educational, Scientific and Cultural Organization (UNESCO) — Man and the Biosphere Reserve (MAB) and is a wetland of International Importance designated under the Ramsar Convention (Oo et al. 2022). Furthermore, this ecosystem is also designated as a Wildlife Sanctuary and ASEAN Heritage Park in Myanmar. The lake serves as a critical source of several endemic freshwater fish and other aquatic species, providing essential sustenance and income through fishing activities (Annandale 1918b; Michalon 2015; Kano et al. 2016, 2022; Win 2018; Fuke et al. 2021, 2022; Musikasinthorn et al. 2023). A recent assessment of endemic fish species in Inle Lake revealed that Cypriniformes were the most dominant (70%), followed by Synbranchiformes (20%) and Anabantiformes (10%) in terms of relative abundance (Naing & Tun 2022). Aside from the discovery of new species of decapods and gastropods (Annandale 1918a; Kemp 1918; Annandale & Rao 1925; Ng et al. 2000; Sawada 2022; Zhang et al. 2025), the abundance, and diversity of other freshwater invertebrates in the lake have not yet been systematically assessed. Furthermore, the surrounding wetlands are home to distinctive floating gardens, where crops and vegetables are cultivated on platforms made from vegetation, enabling year-round agriculture in the nutrient-rich waters (Win 1996). Inle Lake also draws significant tourism, contributing to the local economy through hospitality services, guided tours, and the sale of regional crafts (Su & Jassby 2000). As an important transportation hub, the lake facilitates daily commutes for those residing in stilted houses along its shores, ensuring access to essential services and trade. Moreover, the lake is intricately linked to the cultural heritage of the area, with traditional crafts such as silk and lotus fiber weaving, alongside religious, and cultural practices centered around numerous pagodas, and monasteries. In addition, recent studies have documented significant alterations in land use and land cover change (LULCC) in the Inle Lake region, characterized by declining trends in forest, and perennial wetland areas primarily due to anthropogenic pressures (Karki et al. 2018; Michalon et al. 2019). The recent earthquake may have further intensified LULCC patterns in this ecosystem, underscoring the urgent need for comprehensive investigation to understand its dynamics, and ecological implications.

The artificial pond at Mahamuni Pagoda has been designated as a conservation priority site, where the resident turtles are afforded daily offerings and protection. This site serves as a semi-natural refuge that complements ex-situ conservation initiatives. The earthquake may have compromised water quality parameters such as dissolved oxygen levels, ammonia concentration, and temperature fluctuations, all of which are critical to the health of ectothermic reptiles (Qian et al. 2013). Given the ecological significance of the Mahamuni Pagoda reservoir, further interdisciplinary research is essential to evaluate the earthquake's impact on both aquatic biodiversity and water quality. This includes post-seismic monitoring and management of physicochemical parameters, histopathological assessments and treatments of affected fauna, and population surveys of key species. The results will be pivotal in formulating evidence-based conservation strategies to protect these culturally and biologically important aquatic organisms from future disturbances.

A key limitation of this study is its exclusive reliance on photographic evidence and information obtained through local communication following the March 2025 seismic event in Myanmar. Estimating the number of snails that died was based on visual documentation alone, which may have introduced significant biases in quantification. The lack of pre-event baseline data further complicates the assessment of how much of the population was impacted, making it difficult to determine whether the mortality event signifies a threat of extinction or a temporary fluctuation in population size. These constraints highlight the challenges of accurately assessing the biodiversity impacts of this natural calamity through remote observations. Additional scientific validation through water quality assessments, histopathological analyses of deceased species, and genetic studies aimed at evaluating ecosystem resilience is urgently needed to monitor the native biodiversity in this key ecosystem following the earthquake. Several protected areas in Myanmar are located in close proximity to active fault lines, including those possibly affected by the Violent March 2025 earthquake. In addition to Inle Lake, the region encompasses several protected areas located to the east of the fault line, including Panlaung & Padalin Cave Wildlife Sanctuary (WS), Pyin-O-Lwin Bird Sanctuary, Shwe-U-Daung WS, Minwuntaung WS, and Taunggyi Bird Sanctuary. On the western side of the fault line, key protected areas such as North Zamrari WS, Moeyungyi Wetland Ramsar Site, Minsontaung WS, Moeyungyi Wetland WS, and Popa Mountain Park harbour ecologically significant floral, and faunal assemblages. Given the ecological sensitivity of these areas, further investigation into the impacts of the March 2025 earthquake is essential to inform comprehensive post-disaster ecological assessments, and conservation strategies.

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COMMUNICATION

First record of the *Coeliccia svihleri* Asahina, 1970 (Odonata: Platycnemididae) in Arunachal Pradesh, India

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Abstract: This communication reports the first confirmed sighting of *Coeliccia svihleri* Asahina, 1970 in Arunachal Pradesh, India, based on photographic evidence collected in the presence of forest personnel at Deban in the Namdapha Tiger Reserve during October 2024. Environmental conditions in the region that may support the presence of this species are discussed, with an emphasis on the potential impact of climate change on species distribution and habitat stability. The discovery of *C. svihleri* adds a significant new record to the biodiversity of the region, outlining the further need for continuous monitoring and habitat conservation for sustaining in-situ biodiversity.

Keywords: Biodiversity, conservation, damselfly, discovery, environment, habitat, Namdapha National Park, in-situ, species.

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Competing interests: The authors declare no competing interests.

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Author contributions: Mahesh R: Sighting; Conceptualization; writing-original draft; formal analysis; methodology; draft preparation, review & editing; Rajesh Gopinath: visualization; writing, final review and editing Gaurav Joshi: formal analysis; investigation. Roshan Upadhaya: project administration; supervision.

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INTRODUCTION

Odonata, comprising both dragonflies and damselflies, are among the most ancient and ecologically significant insect orders (Corbet et al. 2006). Characterized by their large compound eyes, striking colours, and agile flight, these insects play a vital role as apex predators in freshwater and humid forest ecosystems, helping regulate insect populations and serving as indicators of environmental health (Gopinath et al. 2022). Worldwide diversity of odonates has been evaluated at 6,430 species classified in 823 genera (Paulson et al. 2025a) of these 493 species & 27 subspecies in 152 genera and 18 families are known to exist in India (Subramanian et al. 2020). Just like Lepidoptera, sadly many of the Odonata species are also under the threat of extinction due to emerging climate change induced modifications, and habitat loss owing to rampant development and inorganic urbanisation (Aadarsa et al. 2021).

Odonata inhabit a wide range of aquatic environments, including ponds, streams, rivers, and wetlands (Dijkstra et al. 2014). Damselflies, belonging to the suborder Zygoptera, are particularly known for their slender bodies, and delicate wings (Dijkstra et al. 2014). The Platycnemididae family of damselflies, also known as river damselflies, comprises over 400 species typically found in tropical, and subtropical freshwater habitats such as streams, rivers, and wetlands (Selys-Longchamps 1863; Allen et al. 1985; Dijkstra et al. 2014). These damselflies are characterized by distinctive wing morphology, which include flat or rounded tips. They are also known for their vibrant colour patterns, often featuring shades of blue, green, or yellow (Corbet et al. 2006). The genus *Coeliccia* is characterized by a slender, cylindrical abdomen, hyaline wings with rounded apices, and striking colour patterns, often with black bodies and blue, yellow, or chrome-yellow markings. The species in this genus are typically distinguished by the morphology of their wings and the structure of their anal appendages, which are used for species identification (Selys-Longchamps 1863; Kirby 1890).

This genus comprises 79 species globally (Paulson et al. 2025b), with 13 species recorded in India (Subramanian 2014). Among these, only four have so far been documented from the state of Arunachal Pradesh. These include *Coeliccia bimaculata* Laidlaw, *C. prakritik* Lahiri, *C. renifera* Selys, and *C. didyma didyma* Selys (Mitra et al. 2010).

Study Area

Namdapha National Park and Tiger Reserve, located in the Changlang District of Arunachal Pradesh, India, spans an area of approximately 1,985 km² and is one of the largest protected areas in the eastern Himalaya (Arunachal Online 2024). Situated at the convergence of the Patkai Range and the Dapha Bum Ridge of the Mishmi Hills, the park lies between 27.383°–27.650° N and 96.250°–96.967° E (Arunachal Online 2024). Figure 1 depicts the location of Namdapha Tiger Reserve in Arunachala Pradesh, India. The park's diverse topography includes tropical rainforests, subtropical forests, and alpine meadows, with elevations ranging from 200 m to over 4,571 m (Image 1). The region experiences a subtropical climate with significant variation in weather conditions at different elevations. Extending up to an area of 2,052.82 km², the species composition of Namdapha is also hence rich, thick, and diverse (www.arunachalonline.in). This diversity of habitats, along with its rich flora and fauna, makes Namdapha an important part of the Indo-Burma biodiversity hotspot. The park is also home to several endangered and endemic species, such as the Snow Leopard, Clouded Leopard, and Asian Elephant (Choudhury 2013). Deban, one of the key study locations within Namdapha National Park, is characterized by dense tropical rainforests with a variety of evergreen tree species such as *Dipterocarpus*, *Shorea*, and *Castanopsis*, along with bamboo groves, and diverse riverine ecosystems along the Noa-Dihing, and Namdapha Rivers (Sathyakumar et al. 2011).

METHOD

While Namdapha National Park has been a study area for periodic and regular lepidopteran surveys since 2018, attention is still sparse towards Odonata studies. A supervised-exploratory exercise was undertaken during October 2024 to document the Odonata species present in the region, with a particular focus on the identification and observation of species not previously recorded in the area.

The walks were carried out along trails and riverbanks within the park, with special attention paid to the rich wetland and stream habitats that are ideal for damselflies. The study to document the Odonata abundance and diversity was undertaken in the presence of authorised experts and forest personnel. The species identification was done by consulting experts (mentioned in the acknowledgement), and analysing the ID keys (Asahina 1970). Nikon D3300 DX-format DSLR Kit w/ 18–55mm DX

Figure 1. Location of Namdapha Tiger Reserve in Arunachala Pradesh, India. © Mahesh R.

Image 1. Representative image of Namdapha Tiger Reserve. © Nisha Gopinath.

VR II, Sony Cyber-shot DSC-RX10 IV Digital Camera RX10 Mark IV with 0.03s. AF/25X optical zoom, and Nikon Z50 compact mirrorless digital camera with 50–250 mm lens were utilised in this exercise.

RESULTS AND DISCUSSION

The present study has resulted in the sighting of 21 species, with confirmation of ID accomplished for about 16 species. The species observed during the exploration included *Trithemis aurora*, *Neurothemis fulvia*, *Orthetrum glaucum*, *Echo margarita*, *Cephalaeschna* sp., *Aristocypha spuria*, and *Neurobasis chinensis*. Species such as *Trithemis aurora* and *Neurothemis fulvia* were found in good numbers in the vegetation, while *Aristocypha, Echo*, and *Neurobasis* spp. were predominantly observed near streams, and riverine habitats. A mating couple of *C. didyma* (Selys, 1863) was also observed (Image 2). These observations highlight the diverse Odonata fauna present in the forest and the persistent need for further research to assess species distribution and ecological roles.

On 14 October 2024, at approximately 1100 h, a single 'male' individual of *Coeliccia svihleri* was observed resting in a shaded area along the trekking path on the Miao to Vijaynagar road. The species was identified from plates based on its distinct morphological features ably supported by the multiple-angled photographs taken (Image 3–9). The importance of this discovery highlights the first ever recorded verifiable sighting of *C. svihleri* in Namdapha National Park and Arunachal Pradesh. The identification was confirmed based on the morphological characteristics. The findings underscore the need for continued monitoring and documentation of Odonata biodiversity in this ecologically significant and sensitive zone.

Image 2. Mating individuals (male-top & female-bottom) of *Coeliccia didyma*. © Gaurav Joshi.

Systematic Position
Order: Odonata Fabricius, 1775
Suborder: Zygoptera Rambur, 1842
Family: Platycnemididae Selys, 1863
Genus: *Coeliccia* Selys, 1853
Coeliccia svihleri Asahina, 1970

Identification Features (Asahina 1970)

A slender species with paired round mesopleural spots and pointed superior caudal appendages. The labrum is black with a distinctly pale yellowish anterior border, the anteclypeus is zinc blue, and the postclypeus is shining black. The antefrons is black with a pale lower border, while paired pale spots are present near the lateral ocelli and one on the postfrons. The prothorax is black, and the pterothorax has broad black markings with paired elliptical yellow spots on the lower mesepisternum. Abdomen segments 1–8 are black dorsally, with small pale areas on segments 1, 3–5, while segments 9, and 10 are dark yellow with a minute black scar at the base of segment 9. The caudal appendages are dark yellow, with superiors pointed laterally, flattened dorsally, and bearing a median projection directed inward.

Image 3. Photograph of *Coeliccia svihleri* (male) individual from the Namdapha Tiger Reserve. © Mahesh R.

Scope of Discovery

While the primary objective was to enhance the

Image 4. Photograph of *Coeliccia svihleri* (male) individual from the Namdapha Tiger Reserve. © Mahesh R.

Image 5. Photograph of *Coeliccia svihleri* (male) individual from the Namdapha Tiger Reserve. © Mahesh R.

Image 6. Close-up feature of the photographed male individual from the Namdapha Tiger Reserve. © Gaurav Joshi.

known distribution of Odonata species in Namdapha Tiger Reserve, the current manuscript majorly highlights about the discovery of *C. svihleri*. This finding represents a significant contribution to the understanding of Odonata biodiversity in Arunachal Pradesh, an area that remains underexplored in terms of its damselfly fauna. This confirmed record of *C. svihleri* extends the known distribution of this species within India and adds a valuable data point for the region's Odonata inventory. The sighting in Namdapha, therefore, not only fills a gap in the geographical distribution of *C. svihleri* but also strives to highlight the rich and largely undocumented biodiversity of the park. Notably, this is not only the most recent verified observation from India since 2002, but also most probably the third (research/evidence-based) photographic verifiable record ever from India.

Habitat and Ecological Significance

The habitat in which *C. svihleri* was observed are shaded areas (Image 10), besides streams, riverbanks; thereby aligning with the typical ecological requirements of *Coeliccia* species, which are known to inhabit freshwater habitats such as streams, rivers, and wetlands (Selys-Longchamps 1863; Dijkstra et al. 2014). Namdapha's diverse topography, with its range of riverine and riparian ecosystems, provides an ideal habitat for such species. The presence of lush tropical and subtropical rainforests at lower elevations, transitioning into alpine meadows at higher elevations, offers a mosaic of microhabitats that support a wide variety of Odonata species. The observation of *C. svihleri* in this environment suggests that the park's water systems, particularly those along the Noa-Dihing and Namdapha rivers, may serve as important refugia for *Coeliccia* species. These riverine ecosystems, characterized by high humidity, stable temperatures, and rich aquatic vegetation, are conducive to the breeding and feeding behaviours of many damselfly species. As such, the sighting of *C. svihleri* further underscores the importance of conserving these fragile aquatic ecosystems within Namdapha National Park.

Image 7. Close-up feature of the photographed male individual from the Namdapha Tiger Reserve. © Roshan Upadhaya.

Image 8. Close-up feature of the photographed male individual from the Namdapha Tiger Reserve. © Rajesh Gopinath.

Biodiversity Implications and Conservation Concerns

C. svihleri Asahina is designated by the IUCN Red List assessment of 19 March 2018 as 'Least Concern' (Dow 2019). Yet information on its abundance and distribution is sparse. This could be either due to under-reporting or mis-identification.

This discovery hence highlights the need for further taxonomic and ecological studies of *C. svihleri* and other Odonata species present in the region. Despite their ecological importance as both predators and prey in freshwater habitats, Odonates remain relatively understudied in many parts of India, including the northeastern states. The region's diverse climatic conditions and topographic features make it an important hotspot for studying species distribution and ecological dynamics in response to climate change, and habitat loss. The presence of *C. svihleri* in Namdapha National Park may also be indicative of global environmental trends, particularly in relation to climate change (Olsen et al. 2022). Shifts in climate inducing extreme temperature, and erratic precipitation, could not only affect the habitat suitability, but its life cycle as well (John et al. 2023). Hydrological changes, including fluctuating river flow patterns, increased frequency and intensity of floods or droughts, may also alter the quality of the riverine, and wetland habitats that these Odonata species heavily rely on especially for their reproduction, and survival (Van et al. 2023).

Consequently, further monitoring is needed to track the species' population dynamics and range expansion, especially considering predicted climate-related disruptions. Additionally, while Namdapha is well-protected as a national park, continued conservation efforts are essential to ensure the preservation of its diverse habitats. Human-induced pressures such as deforestation, forest fragmentation, and encroachment on riparian zones pose ongoing threats to the park's biodiversity. Monitoring the health of its freshwater ecosystems will be critical in mitigating these threats and safeguarding species like *C. svihleri*. Any species which is sparsely documented, due to lack of credible knowledge of their life cycle, can invariably lead to extinction of the local populations (Chen et al. 2011). Hence, more focussed and habitat-specific explorations need to be indulged in towards the conservative approaches for these sensitive bio-indicator species (Fourcade et al. 2021).

Comparison with Previous Records

Worldwide, *C. svihleri* has been scientifically and systematically documented (to-date) from Bhutan, China (Yunnan), India (Assam), and Myanmar (mainland). This species was reported in 1991 and 2000 from Myanmar (Tsuda 1991; Tsuda 2000). The latest presence for it has been recorded in 2019 from Yunan, China (Zhang 2019).

The only records of *C. svihleri* in India are from regions located within the state of Assam, in Ledo and Kameng (Asahina 1970); in Abhoypur Forest and Naphuk (Asahina 1985). While Assam is a neighbouring state

Image 9. Close-up feature of the photographed male individual from the Namdapha Tiger Reserve. © Rajesh Gopinath.

Image 10. Typical habitat of discovery (Miao to Vijaynagar road). © Nisha Gopinath.

of Arunachal Pradesh, what is noteworthy to mention here are that the geographical regions that they have been spotted is at least aerially 161–285 km away from Namdapha National Park. The finding of *C. svihleri* in Arunachal Pradesh extends its known range beyond Assam, where it was first described by Asahina in 1970. The species' distribution in India, therefore, appears to be more extensive than previously thought, potentially indicating a wider ecological tolerance or the presence of under-explored habitats.

This new finding / sighting from the eastern Himalaya suggests a more complex biogeographical history for this species, potentially linking to the region's unique climatic conditions and its status as part of the Indo-Burma biodiversity hotspot. The sighting of *C. svihleri* in Namdapha National Park also emphasizes the potential for discovering additional, as-yet-undocumented Odonata species from this Tiger reserve. Given its diverse habitat types and the limited number of surveys conducted to date, it is highly likely that other rare or new species may yet be discovered, further enriching the biodiversity profile of this ecologically significant area.

CONCLUSION

This study presents the first record of *C. svihleri* from Arunachal Pradesh, significantly contributing to the known distribution of this species in India. This discovery serves as an addendum to existing inventory and hence is critical for deciphering the ecosystem dynamics, for regauging conservation strategies. Thereby the sighting underscores the need for continued surveys and research on Odonata in Namdapha National Park since the region remains relatively under-explored in terms of its dragonfly and damselfly fauna. Given the ongoing environmental changes in the region, including potential shifts in climate, further monitoring of species distribution is essential. This discovery adds valuable information to the biodiversity inventory of Namdapha and highlights the importance of conserving the park's rich ecological heritage. Further studies could delve upon the need for periodic explorations towards understanding the life cycle and time-based distribution map of this species.

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COMMUNICATION

Spider (Araneae) fauna in paddy ecosystem of Kangra Valley, Himachal Pradesh, India

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Abstract: Spiders are considered biological indicators of ecosystem health. The present study documents the diversity and abundance of predatory spiders in the paddy ecosystem of Kangra District, Himachal Pradesh, India, during the cropping period from July 2023 to October 2023. A total of 543 specimens were collected, representing 15 species across six families and nine genera. Oxyopidae was the most abundant family accounting for 44% of specimens, followed by Tetragnathidae (24%), Salticidae (10%), and Araneidae (10%); Lycosidae and Pisauridae were sparsely represented. The most abundant species was *Oxyopes javanus*, while *Peucetia viridana* was the least recorded. The abundance of spider populations exhibited temporal fluctuations throughout the study period, with the highest numbers recorded during the second fortnight of August. Among the three study localities, Shahpur exhibited the highest diversity, with a Shannon-Wiener Index (H) of 1.95 and a Simpson Index (D) of 0.84, indicating a well-balanced spider community, while Nagrota Bagwan had the highest evenness (J' = 0.93), suggesting a more uniform species distribution.

Keywords: Agroecosystem, biodiversity, biological control, community, conservation, insect-pest suppression, predatory spiders.

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Author contributions: MBS did extensive spider collections from the study locations, photography, data analysis, and manuscript preparation and writing. MSK conceptualization, methodology, and spider identification. AKS supervision and guidance.

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INTRODUCTION

Spiders are abundant invertebrate predators in many terrestrial, natural, and agricultural ecosystems (Reshma & Manju 2020). The updated checklist by Caleb & Sankaran (2025) documents 1,976 spider species in India from 511 genera comprising 63 families, representing approximately 3.7% of global spider diversity. Spiders play a pivotal role in agricultural pest control by regulating insect populations (Sudhikumar et al. 2005; Reshma & Manju 2020); and they are highly sensitive to habitat loss, climate change, and environmental disturbances (Thirukonda et al. 2022). Paddy *Oryza sativa* L. is a significant staple and cash crop in India, and spiders in paddy fields can play an important role in controlling populations of planthoppers, and leafhoppers (Samal & Misra 1975). Spider diversity documentation is a necessary aspect of conservation strategies involving integrated pest management, especially where paddy is an important crop as in Kangra Valley of Himachal Pradesh. A preliminary investigation of spider fauna by Chhavi et al. (2021) reported nine spider families, of which four: Araneidae, Oxyopidae, Salticidae, and Tetragnathidae were also recorded in the present study. Detailed information on species diversity and community composition remains limited, and the present investigation was undertaken to comprehensively assess spider communities in the paddy ecosystem of Kangra Valley.

MATERIAL AND METHODS

Study Area

The study was conducted across three localities in the Kangra District of Himachal Pradesh: Nagrota Bagwan, Palampur, and Shahpur. In Nagrota Bagwan, the surveyed locations were Jalbimbi (32.105° N, 76.369 °E), Tharu (32.105° N, 76.369° E), and Tarandi (32.103° N, 76.368° E). In Palampur locality, the locations included Banuri (32.082° N, 76.534° E), Holta (32.105° N, 76.545 °E), and Rajpura (32.105° N, 76.544° E). Whereas, in Shahpur, spider collections were carried from Chandaran (32.211° N, 76.118° E), Jhaghi (32.2086° N, 76.1803° E), and Manjhiar (32.202 °N, 76.189 °E) (Figure 1).

Field data were recorded during the cropping period from July to October 2023. Thirty days after transplantation fortnightly sampling was undertaken using quadrates. Spiders were collected from three quadrates (1 × 1 m) placed at each selected location using direct hand collection method. In addition to that, five sweeps were performed at the same location. Observations and collections were carried out during the morning (0700–0800 h) and evening (1700–1800 h). Each of the three quadrates were observed for a one-hour duration. The collected spider specimens were preserved in 70% ethyl alcohol. The adult spider specimens were identified based on taxonomic literature (Tikader 1970; Tikader & Malhotra 1980; Tikader & Biswas 1981; Gajbe 2008; Yoshida 2009; Jäger 2011; Caleb 2020; Sankaran & Caleb 2023; World Spider Catalog 2025).

Specimens have been deposited in the National Insect Museum (NIM) of Indian Council of Agricultural Research–National Bureau of Agricultural Insect Resources, Bengaluru for further studies. The diversity indices of spider communities were calculated using the following indices:

Margalef's Index of Richness (MI): Measures species richness using the formula:

$$MI = (S - 1) / \ln (N)$$

Where S is the number of species, and N is the total number of individuals. A higher MI value indicates greater richness.

Shannon-Wiener Diversity Index (H): Calculates species diversity based on abundance and evenness:

$$H = \Sigma \{Pi \times \ln (Pi)\}$$

Where Pi is the proportion of individuals of a species. Higher H values represent more diverse and evenly distributed communities.

Simpson's Index (D): Measures dominance of species:

$$D = \Sigma (Pi^2)$$

The complement (1-D) indicates diversity, values closer to 1 signifying greater diversity.

Pielou's Evenness Index (J): Analyse the evenness of species distribution: $J = H / H_{max}$

Where $H_{max} = \ln (S)$. The index ranges from 0–1, 1 indicating maximum evenness.

Statistical calculations were performed in Microsoft Excel program.

RESULTS

A total of 15 species belonging to nine genera under six families were recorded from the paddy ecosystem of Kangra Valley of Himachal Pradesh (Table 1). Oxyopidae was the dominant family, constituting six species under two genera, followed by Araneidae (3 species), Tetragnathidae, Pisauridae, Lycosidae, and Salticidae, recording one species each (Table 1, Figures 2 & 4). Analysis of spider population data from the three study sites—Nagrota Bagwan, Palampur, and Shahpur—

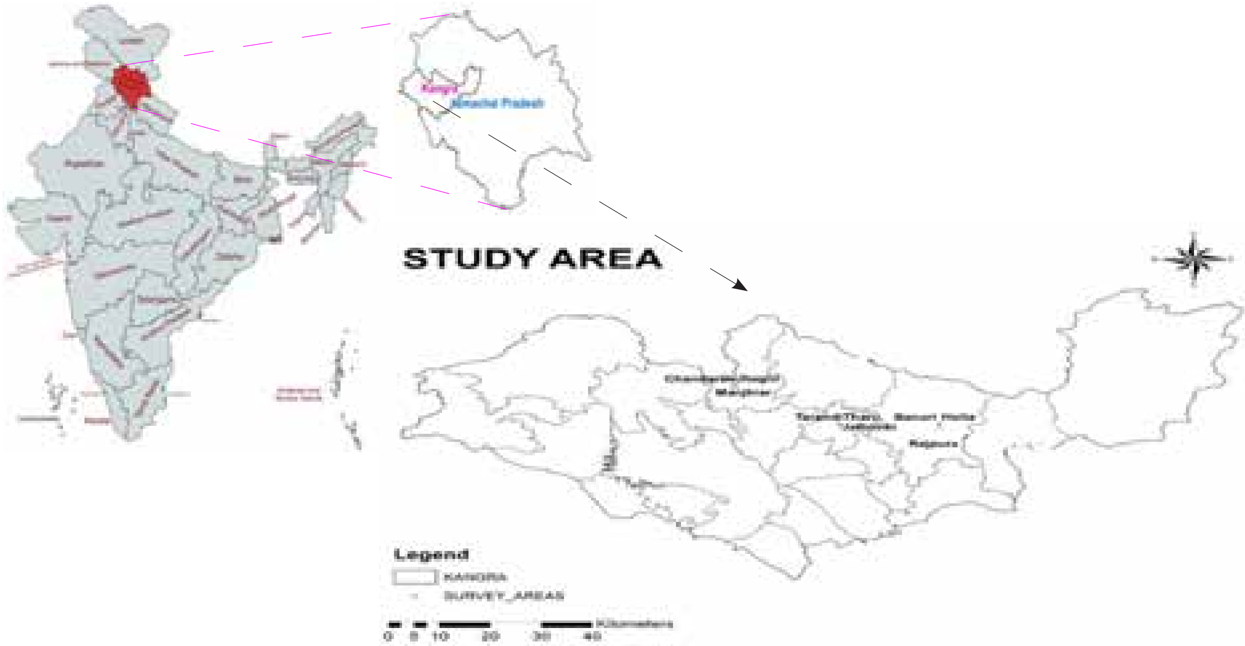

Figure 1. Different locations surveyed in Kangra District, Himachal Pradesh, India

Table 1. The relative abundance of spider species associated with paddy ecosystems of Kangra Valley, Himachal Pradesh.

Family/ Species	Collection based on quadrates and sweeps nets July–October 2023 (number of individuals)				Relative abundance (in %)
	Nagrota Bagwan	Palampur	Shahpur	Total	
Araneidae Clerck, 1757					
Argiope aemula (Walckenaer, 1841)	0	18	0	18	3.31
Neoscona theisi (Walckenaer, 1841)	0	11	0	11	2.03
Neoscona vigilans (Blackwall, 1865)	0	0	27	27	4.97
Lycosidae Sundevall, 1833					
Hippasa lycosina Pocock, 1900	21	0	0	21	3.87
Oxyopidae Thorell, 1869					
Oxyopes hindostanicus (Pocock, 1901)	12	14	0	26	4.79
Oxyopes javanus (Thorell, 1887)	55	61	47	163	30.02
Oxyopes shweta (Tikader, 1970)	0	18	0	18	3.31
Oxyopes sp.	0	0	11	11	2.03
Peucetia sp.	0	8	6	14	2.58
Peucetia viridana (Stoliczka, 1869)	0	4	1	5	0.92
Pisauridae Simon, 1890					
Nilus phipsoni (F.O. Pickard-Cambridge, 1898)	19	0	25	44	8.10
Salticidae Blackwall, 1841					
Plexippus paykulli (Audouin, 1826)	15	16	22	53	9.76
Tetragnathidae Menge, 1866					
Leucauge celebesiana (Walckenaer, 1841)	20	0	0	20	3.68
Leucauge fastigata (Simon, 1877)	31	22	34	87	16.02
Tetragnatha sp.	12	0	13	25	4.60
Total	185	172	186	543	100.00

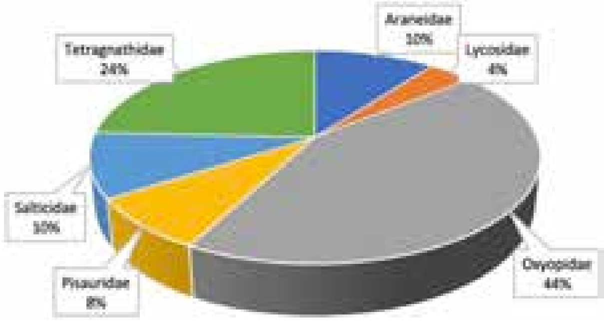

Figure 2. Family composition of spiders recorded from paddy ecosystems of Kangra Valley.

revealed notable variation in species composition and family-level abundance, indicating distinct assemblage structures across the locations. Perusal of the data contained in Figure 2 revealed that based on 543 collected individuals, Oxyopidae was the most abundant family, comprising 44% individuals, followed by Tetragnathidae (24%), Salticidae (10%), and Araneidae (10%). The remaining families, Pisauridae, and Lycosidae were sparsely represented. *Oxyopes javanus* was the most dominant species across all sites, contributing to 30.02% of the total species abundance, followed by *Leucauge fastigata* (16.02%), and *Plexippus paykulli* (9.76%). The spiders present in the paddy ecosystem were categorized into the four guilds based on their foraging behaviour. Specialist/Stalkers (Oxyopidae, Salticidae) were the most dominant guild in the selected localities, encompassing 53.4%, followed by orb web weavers (34.6%), ambushers (8.1%), and ground hunters (3.9%) (Table 2).

The spider diversity indices showed disparities across the localities of Nagrota Bagwan, Palampur, and Shahpur. Nagrota Bagwan had the Shannon-Wiener index of 1.94 and Pielou evenness index of 0.93, indicating a highly diverse, and evenly distributed spider community (Table 3). This indicates that distribution of spider species in Nagrota Bagwan was more uniform. In contrast, Palampur had the lowest Pielou's Evenness index (0.88), supporting a relatively more uneven distribution of spiders, although the Shannon-Wiener index (1.93) remained high, indicating relatively high diversity but less balanced. The Margalef index was the highest in Palampur (1.55), indicating a slightly greater variety of species with regard to the other two localities, while Nagrota Bagwan had the lowest MI (1.34), indicating moderate species richness. The Shannon-Wiener diversity index (H) was calculated for three localities namely Nagrota Bagwan, Palampur, and Shahpur. The obtained values were 1.94, 1.93, and 1.95,

Table 2. Different foraging guilds of spider groups recorded from Kangra Valley.

	Foraging guild	Family	Proportion (in %)
1	Ground hunters	Lycosidae	3.9
2	Orb web weavers	Araneidae Tetragnathidae	34.6
3	Ambushers	Pisauridae	8.1
4	Specialists/ stalkers	Oxyopidae Salticidae	53.4

Table 3. Diversity indices of spider fauna in different localities of Kangra Valley.

Parameters/ Diversity indices	Localities		
	Nagrota Bagwan	Palampur	Shahpur
Species richness (S)	8	9	9
Total individuals (N)	185	172	186
Margalef index (MI)	1.34	1.55	1.53
Shannon-Wiener index (H)	1.94	1.93	1.95
Simpson index (D)	0.83	0.81	0.84
Pielou evenness index (J')	0.93	0.88	0.89

respectively. These values indicate that species diversity is relatively consistent across the three localities, with minor variations suggesting a relatively stable ecological balance. Shahpur had the highest Simpson index (0.84), followed by Nagrota Bagwan (0.83), suggesting a more balanced spider community in these areas compared to Palampur (0.81), where the community was more dominated by spider species namely, *Oxyopes javanus*, *Oxyopes shweta*, and *Argiope aemula*.

DISCUSSION

In the present study, six spider families, namely, Araneidae, Lycosidae, Oxyopidae, Pisauridae, Salticidae, and Tetragnathidae, were recorded across three localities of paddy ecosystem of Kangra Valley. The majority of spider species belonged to the families Oxyopidae, Tetragnathidae, and Araneidae. Earlier studies have also identified Oxyopidae, Tetragnathidae and Araneidae as dominant spider families in paddy ecosystem from various parts of India (Sebastian et al. 2005; Premila 2003; Moses et al.2023).

Foraging guild classification was done by Uetz et al. (1999). The data on different foraging guilds of spiders are presented in Table 2. The dominance of specialists/ stalkers (53.4%) over web builders in the paddy

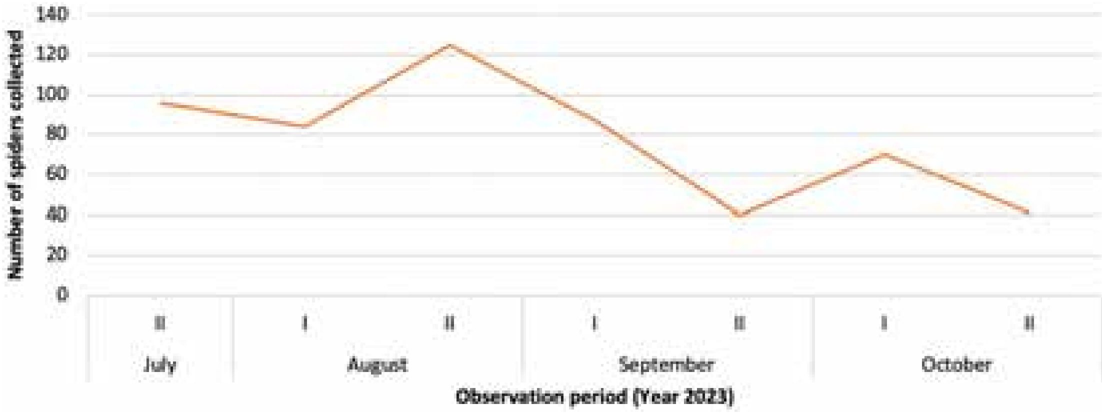

Figure 3. Seasonal abundance of spiders in paddy ecosystem of Kangra Valley.

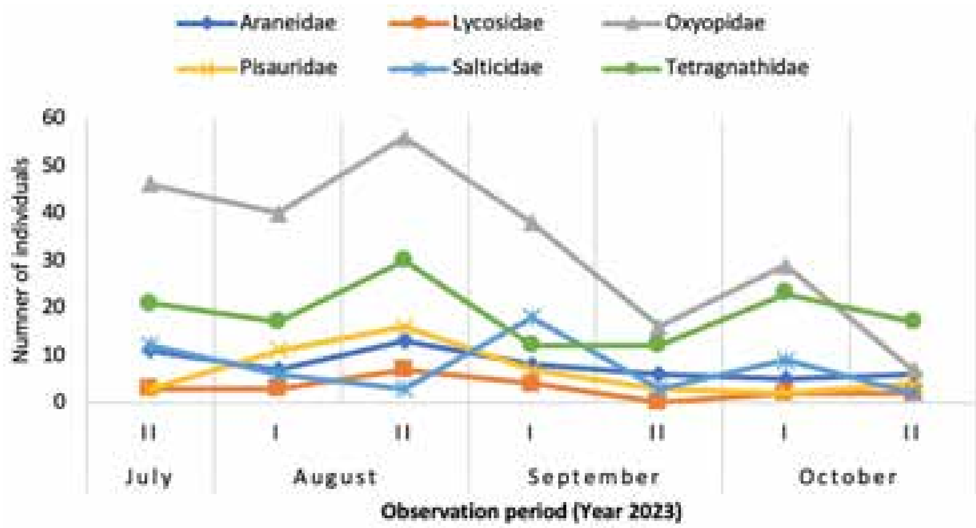

Figure 4. Month-wise population fluctuation of individuals of different spider families.

ecosystem may be attributed to frequent agricultural disturbances, such as worker movement during the cropping season, and heavy rains. These disturbances often damage webs, making it difficult for web-building spiders to thrive. Consequently, stalker spiders, which do not rely on webs, are more successful in such disturbed environments. Data on seasonal abundance of spider shows that spider populations fluctuated throughout paddy cropping period (July 2023 to October 2023), including peak of 125 individuals in the second fortnight of August (Figure 2). The population was higher from the second fortnight of July to the first fortnight of September. Our results demonstrated that spider diversity was significantly higher in locations exhibiting greater habitat complexity, characterized by intense pest (prey) buildup smothered with intensive coverage of weedy vegetation in the field bunds. These findings are in line with Uetz (1991), who documented that structurally complex habitats offer a broader range of ecological niches, and resources, thereby facilitating higher spider species richness. Spiders are sensitive to habitat structure and more complex habitats, such as complex vegetation, inclined to propel more diverse spider population. Adjoining habitats also play a role in determining spider composition by affecting prey and predator movements (Polis et al. 1998). These observations are supported by the findings of Sudhikumar et al. (2005), who emphasized the need for further studies on adjoining habitats and bunds to understand their impact on spider populations in paddy fields.

Although all collections were made in paddy fields, variation in spider species abundance across the locations may be attributed to differences in plant density, growth stages, water levels, pesticide use, surrounding

Image 1. Habitus Images: A—*Argiope aemula* (♂) | B—*Neoscona theisi* (♀) | C—*Neoscona vigilans* (♂) | D—*Nilus phipsoni* (♀) | E—*Oxyopes hindostanicus* (♀) | F—*Oxyopes javanus* (♂) | G—*Oxyopes shweta* (♂) | H—*Oxyopes* sp. | I—*Peucetia viridana* (♀) | J—*Hippasa lycosina* (♀) | K—*Plexippus paykulli* (♀) | L—*Leucauge celebesiana* (♀). © Manoj Salunkhe and M. Sampathkumar.

vegetation, prey availability, and microhabitat conditions. These local factors play a significant role in supporting spider communities. Overall, complexity of habitat, and availability of prey are determining factors in buildup of spider populations and their ecological role in pest regulation in paddy ecosystems.

Richness and abundance of spider recorded in the current investigation highlight the pivotal role of habitat structure, and vegetation complexity in impacting the prevalence of spider species. The physical structure and complexity of crop plants provide favourable conditions for spiders by facilitating web construction, prey availability, shelter, and favourable microclimatic factors, viz., temperature and humidity, which also support mating and predatory activities. These findings are in line with the observations of Young & Edwards (1990), who documented variations in the habitat structure, including plant density, and vegetation cover, significantly affect the diversity, distribution, and ecological distribution of spider species. In a nutshell, we encountered six spider families, with Oxyopidae as the most abundant family. *Oxyopes javanus* was the most numerically prominent, followed by *Leucauge fastigata*. Among the selected localities, species richness was highest in Shahpur (1.95) and Nagrota Bagwan (1.94) compared to Palampur (1.93). A higher dominance of foraging guild specialists/stalkers was observed across all localities. Considering all aspects, the spider community is influenced by various factors, like habitat complexity, prey species type, adjacent fields, and various abiotic factors (Padma & Sundararaj 2021; Dave & Trivedi 2024). The findings of this investigation provide information on the spider diversity recorded in the paddy ecosystem of Kangra District, thereby strategies can be worked out for conservation of these spiders in regulating insect pests, as farmers of this region are in favour of biocontrol-based approaches in pest management. Future research directions should prioritize on prey preference, habitat selection, adaptability of climatic factors, and predatory potential of dominant spider species.

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SHORT COMMUNICATION

A new variety of *Chara corallina* Willd. (Charophyta: Characeae) from Kamrup District, Assam, India

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Abstract: A new variety, *Chara corallina* var. *kamrupensis* P.P.Baruah, S.Bhattacharjee, N.Kalita & B.Boruah var. nov. is described from Kamrup District, Assam (India), based on the observations made under light and scanning electron microscope. This new variety differs from the other two taxonomically accepted varieties of the species viz., *C. corallina* var. *kyusyensis* K.Imahori and *C. corallina* var. *portonovensis* D.Subramanian in having bracts throughout the body, number of spirals in oogonia, and reduced size of antheridia & coronula cells.

Keywords: *Chara corallina* var. *kamrupensis,* Charophyta, freshwater habitats, green algae, light microscopy, scanning electron microscopy, stoneworts.

Charophyta, popularly known as stoneworts or brittleworts constitute one of the major groups of macrophytic green algae occurring in fresh to brackish water ecosystem (Mondal et al. 2021), which shows similarities with some aquatic angiosperms like, *Ceratophyllum*, and *Myriophyllum* (Casanova 2005; Baruah et al. 2024). A few unique morphological features such as, presence of nodes & internodes, branchlets, bracts, stipulodes, and attractive reproductive structures (Mann et al. 2022) like nucule (female reproductive structure), and globule (male reproductive structure) make the taxa different from the other algal groups (Mandal & Ray 2004).

As per algaebase (Guiry & Guiry 2023), a total of 360 taxonomically accepted taxa have been accounted under the genus *Chara*, which includes 221 species, three sub-species, 49 varieties, and 87 formae throughout the globe. The species *Chara corallina* Willdenow, 1805, is one of the most attractive species within the genus *Chara* that have unique characteristics like monoecious plant body, and gametangia at the base of the whorl. According to the recent literature, this species itself has been divided into two accepted varieties, viz., *Chara corallina* var. *kyusyensis* K. Imahori, 1954, and *Chara corallina* var. *portonovensis* Subramanian, 1981 (Guiry & Guiry 2023). The former was first reported from Japan by Imahori (1954) inhabiting freshwater habitat. Subsequently, the species was reported from Korea (Choi & Kim 1996), and India (Karande 1999). On the other hand, *C. corallina* var. *portonovensis* was reported for the first time by Subramanian (1981) from a freshwater habitat of Tamil Nadu (India) which was later on documented in a checklist by Gupta (2012)) from the same region.

The study of a few *Chara corallina* samples in different freshwater aquatic habitats from the Kamrup District of Assam during routine explorations revealed an interesting variety of the species. In this study, we introduce a new variety of *Chara corallina* Willdenow,

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1805 with photomicrographs & descriptions, and compare it with the other two aforementioned varieties. The present communication is aimed to highlight light microscope (LM) and scanning electron microscopic (SEM) observations, and descriptions of *Chara corallina* var. *kamrupensis,* a new additional variety, to science from Kamrup District of Assam (India).

Materials and Method

Collection and observation of samples

Samples were collected from the different freshwater habitats of Kamrup (S1 – 26.087^{o} N, 91.610^{o} E; S2 – 25.975^{o} N, 91.235^{o} E; S3 – 26.449^{o} N, 91.622^{o} E; S4 – 26.348^{o} N, 91.729^{o} E) and Aquaculture & Biodiversity Centre (S5-26.154^{o}N, 91.666^{o}E) of Gauhati University under Kamrup Metro District of Assam (India). Physicochemical properties of the habitats like pH, temperature, and conductivity were also measured to be pH 6.8–7.6, 18–22 ^{o}C, and 139–260 µS/cm, respectively. After collection, samples were washed vigorously with double distilled water, and brought to the Plant Ecology Laboratory, Gauhati University for observations. Leica S9i microscope was used for photography of the samples in fresh conditions. Herbarium was also prepared after drying and fixing the part of the collected samples in Formalin-Glacial Acetic Acid-Alcohol (FAA) solution following the standard protocol as given by Seshagirirao et al. (2016), and the remaining portion of the samples were preserved in 4% formalin solution following Mondal et al. (2021) for future use.

FeSEM study

A portion of the fresh samples was first washed in double distilled water followed by detachment of reproductive parts using scalpels and needles, air dried at room temperature by keeping them on a glass cover slip. Once dried, the samples were dipped in 3% glutaraldehyde solution for 24 h in 4^{o}C and then 0.1 M phosphate buffer was used to rewash the sample. The samples were dehydrated with 30%, 50%, 70%, 90%, 100% ethanol solution (Sadiq et al. 2017), and then coated with gold as per protocol prior to taking SEM photographs (John & Moore 1987; Urbaniak 2011) with SEM-Zeiss Sigma 300 at CIF, Gauhati University.

Identification of the sample

The samples were identified morphologically by comparing the characters with the standard monographs and literature, i.e., Sundaralingam (1959), Pal et al. (1962), Wood & Imahori (1964), Choi & Kim (1996), Subramanian (2002), and John et al. (2005).

Results

Taxonomic treatment

***Chara corallina* var. *kamrupensis* P.P.Baruah, S.Bhattacharjee, N.Kalita & B.Boruah, var. nov. (Figure 1–4)**

Plant monoecious, more than 40 cm in height (Image 1A); axis stout to fragile, 350–450 µm in diameter; ecorticated; Branchlet 2–3 times longer than internodes, six in a whorl (Image 1D), each with 3–4 segments, ultimate segment smaller and conical to oval in shape having only one dactyl (Image 1C); branchlets swollen at node/nodal region; both upper and lower nodes possess bracts, bracteoles absent throughout the body; stipulodes rudimentary; Gametangia produced at the base of the whorls as well as at the nodes, aggregated at the base (Images 1D,E), and solitary at node (Image 1I); antheridia mature earlier than oogonia; Antheridia smaller than the typical varieties, 367–407 µm in diameter (Image 4C) , greenish in colour (Images 1E,F,H,I) ; Oogonium small, 940–1,000 µm in length with coronula cell, 700–750 µm broad (Image 4A), greenish in colour but gradually turns into brick-red at maturity; Coronula five in number, 40–47 µm long, 25–30 µm broad (Image 1G; Image 4B); spiral cells five in number with eight convolutions.

Present specimen tallies with *C. corallina* var. *portonovensis* (Subramanian 2002) but differs in:

1. Presence of bract throughout the body.
2. Much smaller antheridia and oogonia.
3. Number of spirals in oogonia.
4. Much smaller coronula cells.

Present specimen tallies with *C. corallina* var. *kyusyensis* (Choi & Kim 1996) but differs in

1. Presence of bract throughout the body.
2. Lower node sterile.
3. Smaller antheridia and larger oogonia.
4. Much smaller coronula cells.

Type: India, Assam: Kamrup District, Aquaculture and Biodiversity Centre, 26.154O N & 91.666O E, 72 m, 5.xi.2023, S. Bhattacharjee GUBH20650 (holotype: GUBH) (Image 5)

Etymology: The variety 'kamrupensis' is named after its collection site Kamrup District.

Discussion

Chara corallina, a notable morphologically attractive as well as ecologically well-known freshwater species within the genus *Chara* that mainly has two taxonomically accepted varieties, viz., *C. corallina* var. *portonovensis* and *C. corallina* var. *kyusyensis*. The present endeavour provides the unique diagnostic

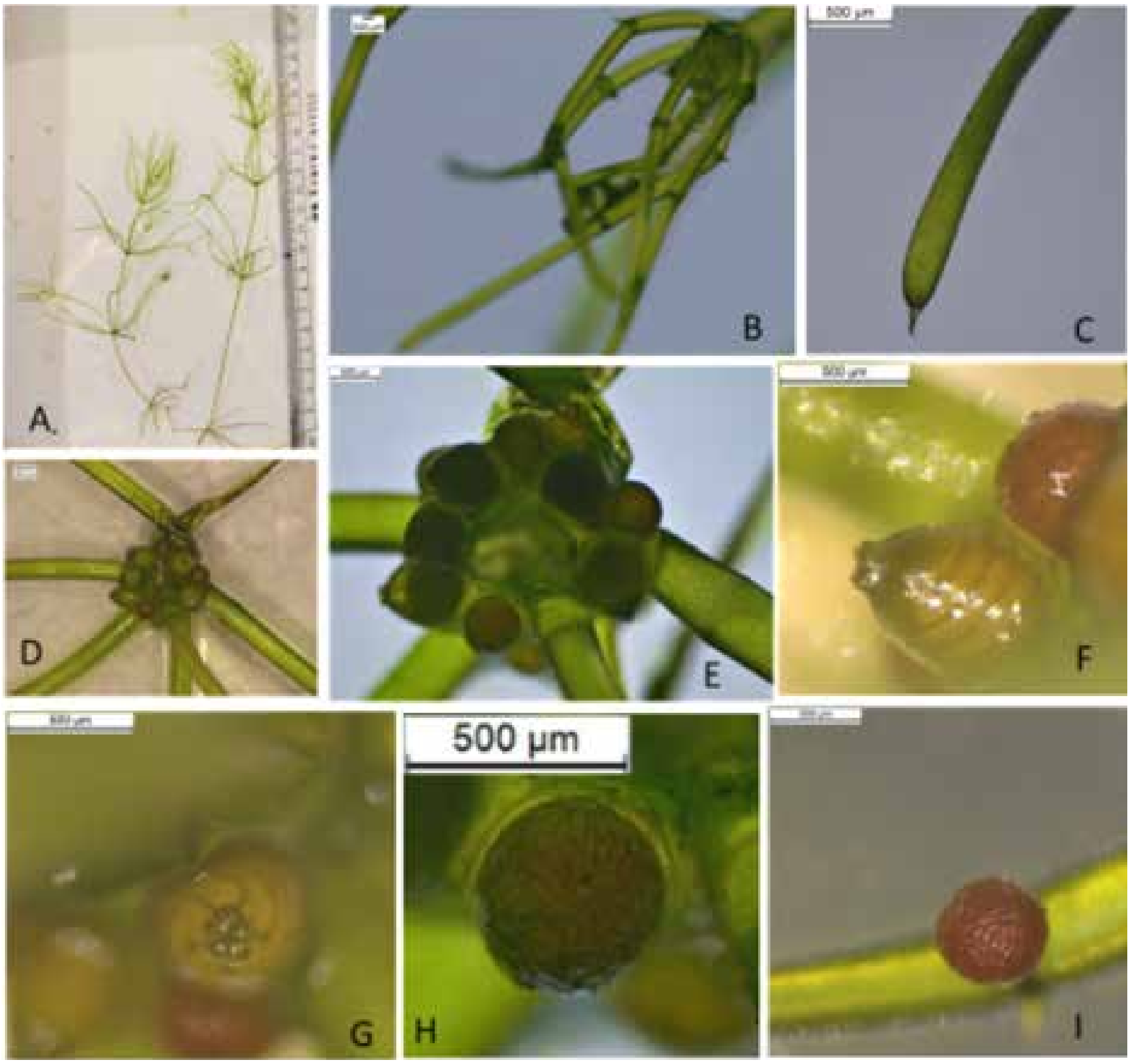

Image 1. Light microscopic photographs of *Chara corallina* var. *kamrupensis*: A–D—Morphology | A—Whole plant body | B—Apical end showing bracts and branchlet with segments | C—Single branchlet with dactyl | D—A whorl of branchlet | E–I—Reproductive structures | E—Aggregated gametangia | F—A pair of antheridium and oogonium | G—Oogonium showing coronula cells and spirals | H—A octascutate antheridium with triangular shield cells | I—A matured antheridium. © Bhattacharjee and Kalita.

differences (Table 1) of the studied species from these accepted varieties due to the presence of sterile lower nodes and bracts, a critical morphological distinguishing feature (Pal et al. 1962). The absence of bracts in *C. corallina* var. *portonovensis* (Subramanian, 2002) and rudimentary or sometimes absent (Choi & Kim 1996) in *C. corallina* var. *kyusyensis* could make us convinced to differentiate this variety form the other two. The studied species closely resembles *C. corallina* var. *portonovensis* in branchlet morphology but differs from *C. corallina* var. *kyusyensis* due to its lower sterile branchlets (Choi & Kim 1996; Subramanian 2002). The studied variety possesses a bunch of extremely smaller antheridia of having a size of less than 500 µm also established this study taxon as a new variety (Table 2). Though there have been insufficient SEM investigations to distinguish between the varieties of *C. corallina*, an effort was made to observe the gametangia sizes that underscore with facts and figures as an authenticated novel variety.

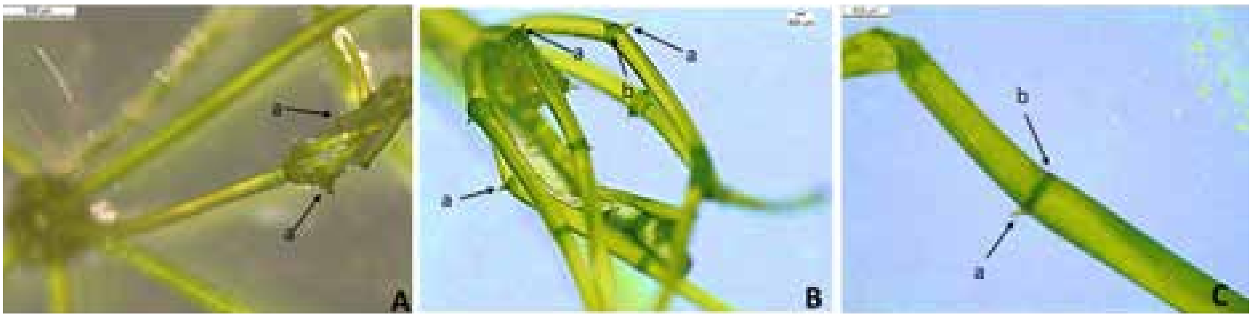

Image 2. Light microscopic photographic images of *Chara corallina* var. *kamrupensis*: A–C—Bracts on the nodes of the branchlets (a—Bracts | b—Nodes on branchlets). © Bhattacharjee and Kalita.

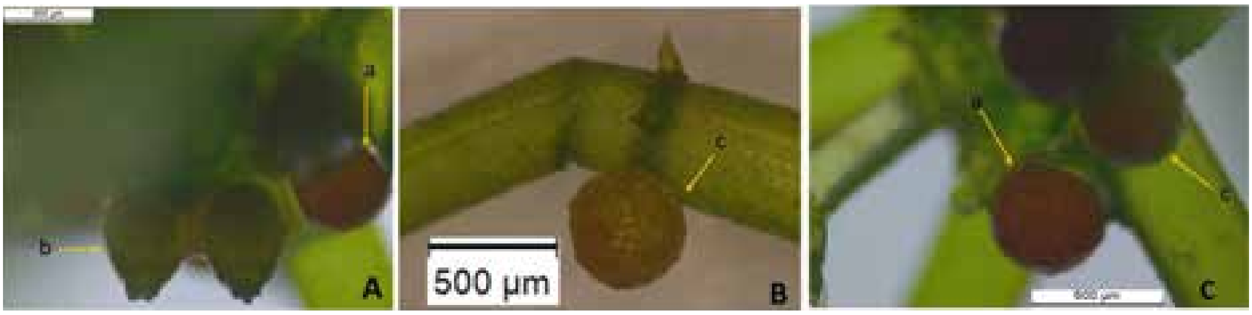

Image 3. Light microscopic photographic images of *C. corallina* var. *kamrupensis*: A–C—Antheridia and oogonia at different maturity stages (a—Mature, ripened, brick reddish antheridia | b—Young and premature oogonia | c—Yellowish-green premature antheridia). © Bhattacharjee and Kalita.

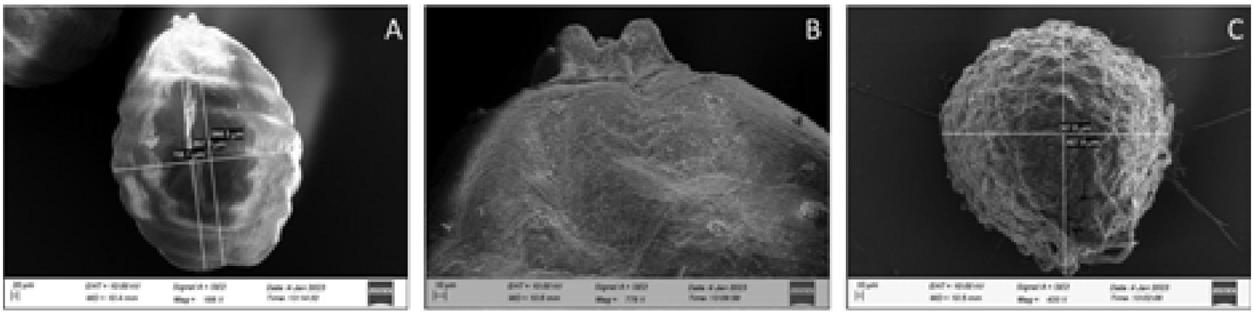

Image 4. Scanning electron microscopic photograph well developed reproductive structures of *Chara corallina* var. *kamrupensis*: A—Mature oval oogonium with eight convulations | B—Coronula cells of oogonium | C—Mature spherical to slightly oblong antheridium. © Rakesh Talukdar, CIF, Gauhati University.

Table 1. Comparison between the vegetative features of accepted varieties of Chara corallina with the new variety.

Features	***C. corallina*** **var.** ***portonovensis*** D. Subramanian (Subramanian 2002)	***C. corallina*** **var.** ***kyusyensis*** K.Imahori (Choi & Kim 1996)	***C. corallina*** var. ***kamrupensis*** var. nov.
Plant body	Monoecious, lower node sterile	Monoecious, lower node fertile	Monoecious, lower node sterile
Height	Up to 23 cm	Up to 30 cm	Up to 40 cm
Thickness	4,000 µ	1,000 µ	450–650 µ
Stipulodes	ND	Degenerated	Rudimentary
Bracts	Absent at the upper node	Rudimentary or absent or degenerated	Present (3 in a whorl), throughout the body (Images 1B, 2A,B,C)
Branchlets	Six branchlets in a whorl with 5–6 segments	Six branchlets in a whorl with five segments	Six branchlets in a whorl with 3–4 segments (Images 1A, 2A,B)

Table 2. Comparison of reproductive structure of accepted varieties of *Chara corallina* with the new variety.

Characteristics	***C. corallina*** var. ***portonovensis*** D.Subramanian (Subramanian 2002)	***C. corallina*** var. ***kyusyensis*** K. Imahori (Choi & Kim 1996)	***C. corallina*** var. ***kamrupensis*** (Studied Species)
Oogonia	Large, orange, 2,500–2,600 µm in length; 1,200–1,300 µm in breadth.	700 µm in length; 450 µm in breadth.	Moderate, Greenish, 940–1,000 µm in length; 700–750 µm in breadth. (Images 1E,F,G, 4A,B)
Antheridia	Very large, orange, 1,335 µm in diameter	480–640 µm in diameter	Very small, Brick reddish, 367–407 µm in diameter (Images 1E,F,H,I, 3A,B,C, 4C)
Coronula	235 µm long, 200 µm broad	120 µm long, 270 µm broad	40–47 µm long, 25–30 µm broad (Images 1G, 4B)

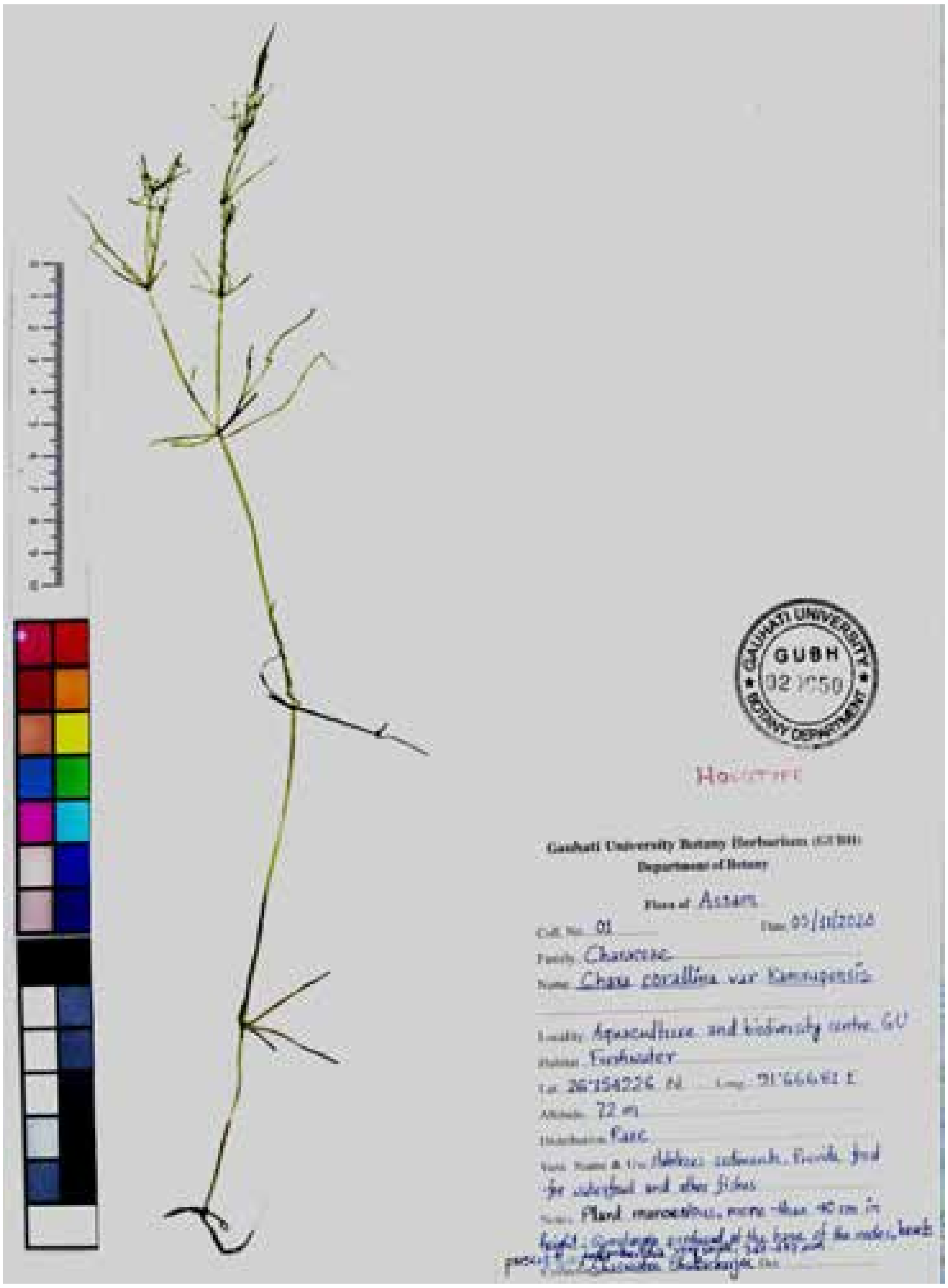

Image 5. Holotype of *C. corallina* var. *kamrupensis* (GUBH 20650) from Aquaculture and Biodiversity centre. © Bhattacharjee and Kalita.

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OPEN ACCESS

SHORT COMMUNICATION

Re-collection of two climbing asclepiads: *Cynanchum corymbosum* and *Oxystelma esculentum* (Apocynaceae: Asclepiadoideae) from Assam, India

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Abstract: Two lesser-known climbing asclepiads—*Cynanchum corymbosum* Wight and *Oxystelma esculentum* (L.f.) Sm.—of the family Apocynaceae, sensu lato, have been recollected from Assam, India after a gap of 67 and 87 years, respectively. A detailed taxonomic account, colour photo plates, and a map showing the collection sites in Assam has been provided. This recollection highlights the importance of continued botanical exploration and conservation efforts in the region.

Keywords: Climbers, conservation, Gentianales, pollinators, plant diversity.

Asclepiads are the fascinating group of plant kingdom belonging to the subfamily Asclepiadoideae under the family Apocynaceae, sensu lato (Endress 2016; Demarco 2017). They are characterised by having more complex and elaborate floral organization among the eudicots (Endress 2016). Via extreme floral synorganization, the asclepiads led to the evolution of floral organs (Demarco 2017). The presence of corona, gynostegium, and pollinaria bearing two pollinia distinguish the asclepiads from other Apocynaceous members of plant domain (Swarupanandan 1996; Endress & Bruyns 2000; Endress 2016). Furthermore, asclepiads exhibit a wide array of habits ranging from herbs, shrubs, climbers to epiphytes; commonly distributed in the tropical areas.

Cynanchum L. and *Oxystelma* R.Br. are two climbing genera of asclepiads native to the tropics and subtropics, belonging to the family Apocynaceae under the subfamily Asclepiadoideae, and the tribe Asclepiadeae (Endress & Bruyns 2000; Endress et al. 2014). *Cynanchum* L. is a widespread genus of the tropics consisting of 259 globally accepted species (POWO 2024). Members of the genus are usually twiners, bearing basally cordate leaves and prophylls with annulated gynostegial staminal corona often forming cup shaped interstaminal corona (Liede & Kunze 1993; Liede & Meve 2013; Shen et al. 2019; Xu et al. 2021). While, *Oxystelma* R.Br. is a little-known genus of the family habituated by climbing herbs bearing campanulate flowers with pointed coralline corona comprising only two globally accepted species (POWO 2024).

During a field survey to Bongaigaon and Kamrup districts of Assam during the month of October and November in 2024, the authors encountered two climbing asclepiad taxa bearing milky latex and flowers with distinct corona, and pollinarium. Further taxonomic

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investigation of the collected specimens, the climbers were identified as *Cynanchum corymbosum* Wight and *Oxystelma esculentum* (L.f.) Sm. Upon consultation of the available literature and herbarium specimens, it was revealed that both the species are the recollection from the state after a gap of 67 and 87 years, respectively.

Cynanchum corymbosum Wight was first described by Robert Wight in 'Contributions to the Botany India' in the year 1834. In Assam, the species was first collected by U.N. Kanjilal in 1915 from Darrang District of Assam. Subsequently, G. Panigrahi collected the same species from Kakoi Reserve Forest of North Lakhimpur District of Assam in 1957. Following this collection, no further records of the species has been reported from Assam. Therefore, the present collection is a re-collection of the species *Cynanchum corymbosum* Wight from the state after a gap of 67 years.

The genus *Oxystelma* R.Br. was first described by R. Brown in 'Prodromus Florae Novae Hollandiae et Insulae van-Diemen' in the year 1810. Later on, James Edward Smith in 1813 validly published the name *Oxystelma esculentum* (L.f.) Sm. based on the type species *Periploca esculenta* L.fill. (1781). The first collection of the species from Assam was made in 1868 from Goalpara District (K001129273!). After the collection, G.K. Deka again collected the species from the same locality in 1937, marking the last reported collection from the state. Hence, the present collection of the species *Oxystelma esculentum* by the authors reported the recollection of the lesser-known asclepiad taxon from Assam after a break of 87 years.

Materials and Methods

The plant specimens were collected during October and November, 2024. Morphological observations of the climbers were recorded and colour photographs showing the habit of the plant has been taken at their natural habitats. Floral parts were dissected and photographed under the Labomed stereo zoom microscope. Further specimens were identified by consulting relevant literatures (Hooker 1883; Kanjilal et al. 1939; Deb 1983; Singh et al. 2012) and accessing available herbarium specimens housed at CAL, ASSAM, ARUN, and other online databases (https://www.gbif.org/; https://plants.jstor.org/). Voucher specimens were prepared following the standard herbarium techniques of Jain & Rao (1976), and submitted at ASSAM, and Gauhati University Botanical Herbarium (GUBH). A detailed taxonomic description of the collected species with colour photoplates and a location map showing the collection sites of the species have been provided.

Taxonomic Treatment

Cynanchum corymbosum

Wight, Contr. Bot. India: 56.1834; Hook.f. Fl. Brit. India. 4:24.1883; Kanjilal et al. Fl. Assam 3:286.1939; Deb, Fl. Tripura State 2:31.1983

Description

Climbing shrub, stem terete; twinning; glabrous. Internodes 12–16 cm long. Latex milky. Leaves opposite, ovate, glabrous, abaxially pubescent along the veins; apex acuminate, base cordate, margin ciliate, lateral veins 4–6 pairs, lamina 10–11 × 7–7.8 cm; petiole terete, 5–5.5 × 2–3 mm. Prophylls deciduous, orbicular with cordate base, apex apiculate, 0.7–1 × 0.6–1.1 cm. Flowers many, arranged in corymbiform cymes, peduncle slender, 2.5–3 cm long; Pedicel 0.8–1cm long, Bract ovate triangular, apex acute, abaxial side pubescent, glabrous adaxially, 1−1.2 × 0.8 mm. Calyx 5-lobed, lobes 1.8−2 × 1.3−1.6 mm, ovate, apex acute, glabrous, green. Corolla campanulate, tube short, 1−1.2 mm long, lobes 5, linear, apex acute, glabrous, margin slightly recurved abaxially, 4.5−5.2 × 2−2.2 mm. Interstaminal corona cupular, shiny white, mouth with irregular incinerates, 3.8–4 × 2−2.4 mm, arises from the base of staminal corona; staminal corona five lobed, 1.2−1.5 mm, fused with anther cap. Gynostegium 2 × 1.3 mm, stigma pentagonal, creamy white, 1.2−1.3 mm long, laterally surrounded by five anther caps; anther cap rhomboid ovate, papery white, 0.6−0.8 × 0.4−0.6 mm; pollinarium five, inserted within anther caps, pollinia pendulous, elliptic, golden yellowish, glossy, 328−352 × 165−178 µm; caudicle short, corpusculum shiny red, 310–323 × 154–176 µm. Pistil 2.5−2.7 mm, stigma rhomboid, capitate, 1.2−1.3 mm long, style slender 1.5 mm long. Follicles lanceolate, 12−14 × 4−5.5 cm, covered with dense long fleshy spines. Seeds comose, 1−1.2 × 0.6−0.8 mm, ovate orbicular, margin dentate crenate, coma silky white.

Flowering and Fruiting: August–October (Flowering), October–December (Fruiting).

Habitat: Roadside forests and scrub jungles.

Distribution: Thailand, Vietnam, Cambodia, Bangladesh, Eastern Himalaya [China, Myanmar, northeastern India (Assam, Tripura)], Nicobar Island.

Specimen examined: BANGLADESH, Sylhet, coll. Wight., Wall. Asclep. no. 81(K), K000894620! (Isotype); INDIA, Assam, Darrang, 6.i.1915, coll. U.N. Kanjilal [ASSAM]; Lakhimpur, Kakoi RF, 22.xi.1957, *G. Panigrahi* [ASSAM]; Kamrup, Hajo, 26.245° N, 91.588° E, 2 October 2024, coll. G. Saikia GSL08 (ASSAM); Bongaigaon, Kakoijana RF, 26.471° N, 90.639° E, 5.xi.2024, coll. G.

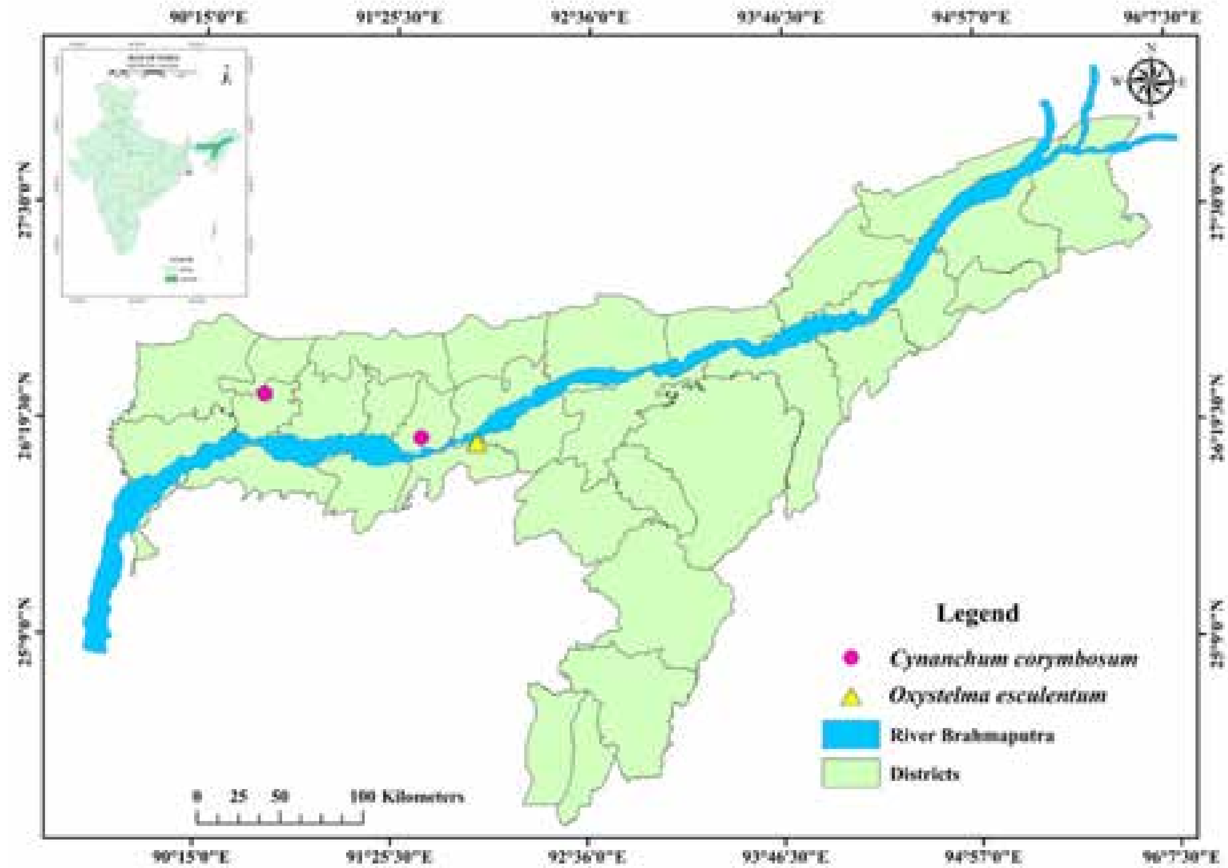

Figure 1. Map showing the collection sites of *Cynanchum corymbosum* and *Oxystelma esculentum* from Assam.

Saikia GSL09 (GUBH) [Present report].

Note: The specimen was collected from two locations, the roadside forest areas of Kakoijana RF, Bongaigaon, and Pakorkona region of Hajo, Kamrup District of Assam. The plant was found to climb on the bamboos, *Senna siamea*, *Ficus hispida*, *Tectona grandis*, and twinning with other climbers such as *Ichnocarpus frutescens*, *Mikania micrantha*, *Paederia foetida*, *Stephania japonica*, and *Tinospora cordifolia.* Remarkably, in both the collection sites the Common Leopard Butterfly *Phalanta phalantha* and Common Swift *Pelopidas agna* belonging to the order Lepidoptera were found as the common pollinators of the species. The common Black Garden Ant *Lasius niger* has been noticed as the pollinator in the Pakorkona area of Kamrup District (Image 3). Additionally, fruits of the genus *Cynanchum* are usually solitary (Khanum et al. 2016). In the present collection fruits bearing a pair of follicles have also been recorded (Image 4).

Oxystelma esculentum

(L.f.) Sm. A.Rees, Cycl. 1. 25: 1813; *Periploca esculenta* L.f., Suppl. Pl. 168 (1781); *O. esculentum* (L.f.) R.Br. Hook.f. Fl. Brit. Ind. 4:17:1883; Kanjilal et al. Fl. Assam 3: 281: 1939; Sinha et al. Fl. Mizoram 2: 108: 2012

Description

Climbing or twinning herb. Stem terete, glabrous, green; internodes 2−10 cm long. Latex milky. Leaves opposite; lamina linear lanceolate, oblong, apex acute, base cuneate, glabrous, midvein distinct, 10–15 × 0.8−1.2 cm, lateral nerves 9−10 pairs; petiole 5−8 mm long. Inflorescence drooping, lateral or axillary, 1−6 flowered raceme; peduncle glabrous, 2.5−5.2 cm long. Flowers campanulate, 2.8−3.2 × 2−2.2 cm, pedicel 1−1.4 cm long, reddish-green. Bract ovate elliptic, apex acute, pubescent abaxially, adaxial side glabrous, 4.5−5 × 1.2−1.5 mm. Calyx five lobed, divided up to base, lobes ovate lanceolate, glabrous within, glandular outside, apex acute, faintly reddish, 5.2−5.5 × 1.2−1.4 mm. Corolla campanulate, articulated with purple veins on inner side, outer side creamy white, without purplish veins; tube 6−8 mm long, five lobed; lobes triangular, apex acute, margin ciliate with white dense hairs, 1−1.3 × 0.5−0.7 cm. Corona two types; outer coroline, lobes five,

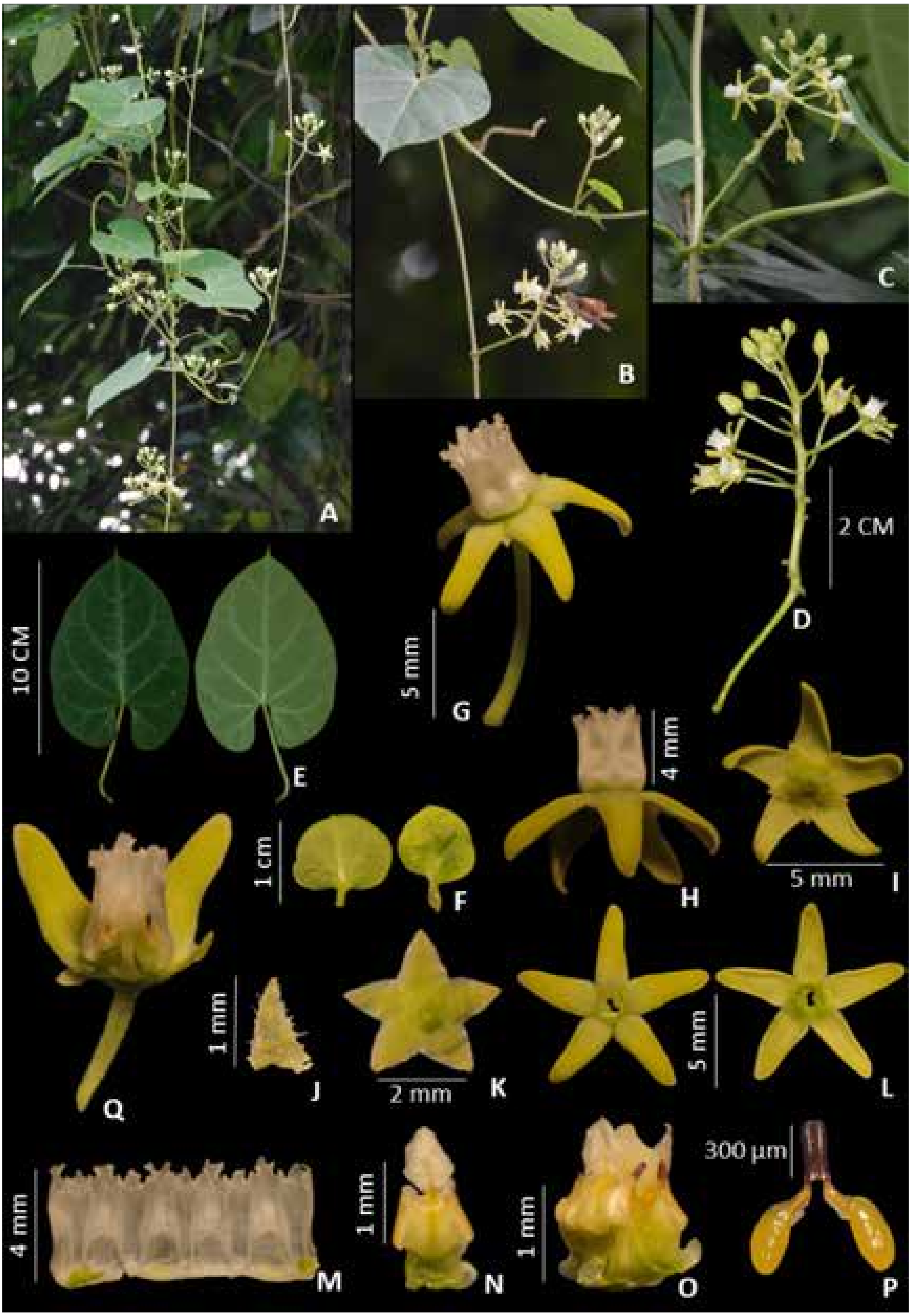

Image 1. ***Cynanchum corymbosum*** **Wight: A,B—Habit | C,D—Inflorescence | E—Leaves | F—Prophylls | G—Complete flower | H—Corolla with corona | I—Back view of flower | J—Bract | K—Calyx | L—Corolla | M—Interstaminal corona with incised apex | N—Staminal corona lobe with fused anther cap | O—Gynostegium | P—Pollinarium | Q—LS of flower. © Gitartha Saikia.**

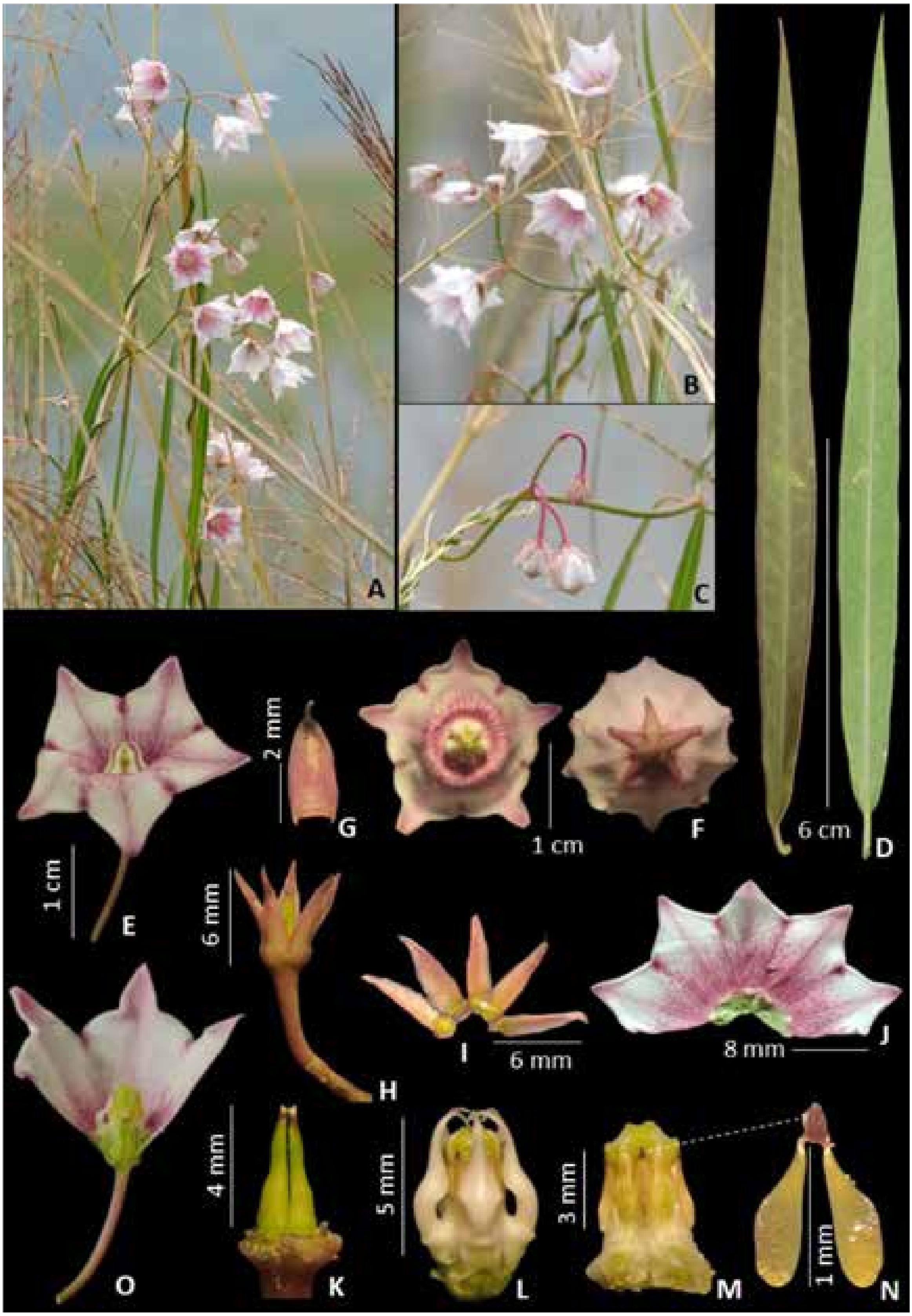

Image 2. *Oxystelma esculentum* (L.f.) Sm.: A—Habit | B,C—Inflorescence | D—Leaves | E—Complete flower | F—Top and back view flower | G—Bract | H—Calyx with gynoecium | I—Calyx | J—Corolla | K—Gynoecium | L—Gynostegium with coralline corona | M—Gynostegium with attatched staminal corona | N—Pollinarium | O—LS of flower. © Gitartha Saikia & Saurav Kumar Boruah.

Image 3. Documented pollinators of *Cynanchum corymbosum*. © Gitartha Saikia.

Image 4. Solitary and paired follicles of *Cynanchum corymbosum*. © Gitartha Saikia.

uniseriate, fleshy, creamy white, arises from the base of corolla tube, apex undulate, pointed, 5.2–6 × 1.2–1.5 mm; staminal corona scaly, 5-lobed, adnate to the staminal column, apex acute, tip keeled incurved, basaly inflated, fused with anther cap. Gynostegium 4.8–5.2 × 3.8–4 mm, stigma pentagonal, light green, surrounded laterally by five anther caps. Anther cap obovate elliptic, outerside membraneous, adaxially glabrous with two distinct ridges. Pollinarium five, inserted within anther caps with a pair of pollinia, caudicles short; corpusculum elliptic, dark brown, 284–287 × 108–113 µm; pollinia pendulous, glossy, oblanceolate, golden yellow, 1116–1130 × 358–366 µm. Fruits and seeds not seen.

Flowering and Fruiting: August–October (Flowering), September–December (Fruiting).

Habitat: Wet habitats near wetlands and ditches.

Distribution: India (Assam), Bangladesh, Myanmar, Nepal, China, Cambodia, Thailand, Vietnam, Sri Lanka, Pakistan, western Australia

Specimen examined: INDIA, Assam, Goalpara, 17.viii.1868, [Cat no. 8219], K001129273!; Goalpara, 8.ix.1937, coll. G.K. Deka [ASSAM]; Kamrup: Khamrenga beel, Chandrapur, 26.223° N, 91.923° E, coll. G. Saikia, 28.x.2024, coll no. GSL07 (ASSAM) [Present report].

Note: The specimen was collected from the Khamrenga wetland of Kamrup District of Assam, an extended portion of Amchang WS. At the collection site, only a few individuals were documented twinning on *Chrysopogon zizanioides* and *Phragmites karka* thriving near the wetland. The common Honey Bee *Apis melifera*, common Ant Mimicking Spider *Castianeira zetes*, and the common Black Garden Ant *Lasius niger* were observed as the pollinators of the species at the collection site.

Conclusion

Recollection of these two lesser known asclepiadoid taxa *Cynanchum corymbosum* and *Oxystelma esculentum* from Assam after a gap of more than 60 years affirms the continued distribution of the species within the state. Occurrence of very limited populations of the species *Oxystelma esculentum* at the collection site entails an immediate attention regarding the conservation of the species in the wild. Additionally, enquiry into the pollinators of these asclepiads for insights into the pollination biology will reveal better understandings regarding the pollination behaviour of this fascinating group of plants.

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SHORT COMMUNICATION

New distribution record of two jumping spider species of the genus *Pellenes* Simon, 1876 and *Thyene* Simon, 1885 (Araneae: Salticidae) from Gujarat, India

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Abstract: The discovery and records of two species, *Pellenes iva* Caleb, 2018 and *Thyene bivittata* Xie & Peng, 1995 are documented for the first time from Gujarat state.

Keywords: Arachnids, arid habitats, biodiversity, first record, Kachchh, morphology, plexippini, range extension, taxonomy, western India.

Indian Plexippini is represented by 24 genera and 63 species (Maddison 2015; Basumatary et al. 2021; Marathe et al. 2024; Caleb & Sankaran 2025). Of these, nine genera and 14 species are reported from Gujarat State: *Epeus* Peckham & Peckham, *Bianor* Peckham & Peckham, *Harmochirus* Simon, *Hyllus* C.L. Koch, *Modunda* Simon, *Plexippus* C.L. Koch, *Telamonia* Thorell, *Thyene* Simon, and *Vailimia* Kammerer (Yadav et al. 2017; Parmar & Prajapati 2023).

The genus *Pellenes* (Simon, 1876) is widespread, comprising 67 described species worldwide (WSC 2025). Among these, three species are found in India including, *P. allegrii* (Caporiacco, 1935) from Kashmir, *P. himalaya* (Caleb, Sajan & Kumar, 2018) from Uttarakhand, and *P. iva* (Caleb, 2018) from Tamil Nadu (Caleb & Sankaran 2025).

The genus *Thyene* (Simon, 1885) has a total of 59 described species around the world (WSC 2025). In India it is represented by three species, viz., *T. bivittata* (Xie & Peng, 1995) from Uttarakhand, *T. calebi* (Kanesharatnam & Benjamin, 2018) from Tamil Nadu, and *T. imperialis* (Rossi, 1846) from Gujarat, Haryana, Karnataka, Madhya Pradesh, Maharashtra, Odisha, Rajasthan, and Tamil Nadu (Caleb & Sankaran 2025).

During recent studies, we identified two more plexippine jumping spider species of the genus *Pellenes* (Simon, 1876) and *Thyene* (Simon, 1885), which are new to Gujarat State. The present paper thus deals with the discovery and records of two species *Pellenes iva* (Caleb, 2018) and *Thyene bivittata* (Xie & Peng, 1995) for the first time from Kachchh, Gujarat.

Materials and Methods

The specimens were hand-collected and studied under a Zeiss Stemi 508 stereomicroscope and

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microphotographic images were taken by a Axiocam Erc 5s digital camera attached to the stereomicroscope and enabled with the software Zeiss ZEN 2.6 lite, version 2.6.76.0. The Left palps were removed, studied, and photographed by placing them in a cavity block filled with 70% ethanol. All the measurements are in millimeters. The species were identified based on Caleb & Kumar (2018) and Logunov (2021). The examined specimens have been deposited in the reference collection of the Web of Nature (WON) Research Foundation, Gujarat, India (curator: Dhruv A. Prajapati).

Abbreviations used in the text: ALE—anterior lateral eye | AME—anterior median eye | PLE—posterior lateral eye | PME—posterior median eye | RTA—retrolateral tibial apophysis | CTA—compound terminal apophysis.

Family Salticidae Blackwall, 1841

Genus *Pellenes* Simon, 1876

Type species: *Attus cruciger* Walckenaer, 1805

***Pellenes iva* Caleb, 2018**

(Images 1–7)

Pellenes (Pelmultus) iva Caleb, in Caleb & Kumar, 2018: 6, figs 1–29

Material examined: WON104450A, 4.iv.2022, two males, India, Gujarat, Danta Village (24.1911° N, 72.770° E), 162 m, leg. S. Parmar; WON104450B, 4.x.2024, one male, India, Gujarat, R.R. Lalan, college Campus-Bhuj (23.236° N, 69.660° E), 155 m, from grassy patches, leg. S. Parmar; WON104450C, 21.vii.2024, one male, India, Gujarat, Aranya Park, Gandhinagar (23.195° N, 72.673° E), 77 m, leg. D. Prajapati.

Diagnosis: The species can be easily distinguished by the following characters: male pedipalp with thin embolus accompanied with a CTA (Image 6). RTA strong, straight, broad at base with a narrowed blunt tip, directed at 12 O'clock position, a faint ridge concealed behind the RTA (Image 7) (Caleb & Kumar 2018).

Description: Male (Images 1–7), total length 2.80; carapace length 1.47, width 1.15; abdomen length 1.40, width 0.93. Eye measurements: AME 0.27, ALE 0.13, AER 0.87, PME 0.03, PLE 0.13, PER 1.04. Leg measurements: I 3.20 (1.03, 0.66, 0.75, 0.45, 0.33); II 2.02 (0.65, 0.42, 0.35, 0.32, 0.27); III 2.95 (1.05, 0.51, 0.58, 0.45, 0.36); IV 2.36 (0.79, 0.39, 0.41, 0.42, 0.34). Carapace black with a hairy white spot behind middle of AMEs and two hairy white spots behind PLEs, a basal white stripe borders the outer edges laterally; eyes surrounded by white orbital setae; clypeus blackish with a basal transverse white stripe. Chelicerae dark brownish with vertical stripes of white scales, with two fused teeth on promargin, one tooth on retromargin. Sternum oval, brown. Abdomen ovoid, densely clothed with rusty brown hairs; anterior margin adorned with white scales. A distinct longitudinal mid-dorsal stripe present, accompanied by two pairs of lateral white patches that appear to converge. Spinnerets brownish in color. Palps brownish; embolus slender, accompanied with a CTA (Image 6). RTA strong, straight, broad at base with a narrowed blunt tip, directed at 12 O'clock position, a faint ridge concealed behind RTA (Image 7).

Variation: The studied specimen has the following variations when compared to the holotype male from Tamil Nadu: three hairy white spots on carapace (one behind AMEs and one each behind PLEs) (Image 1–4), while only two white spots on carapace behind PLEs are seen in the holotype male of *P. iva* (Figure 1 in Caleb & Kumar 2018). The two pairs of small lateral white stripes do not touch the medial stripe on abdomen (Images 1 & 5) whereas, lateral stripes almost touch the medial stripe on abdomen in holotype (anterior), and paratype (both anterior and posterior stripes) (Figure 5 in Caleb & Kumar 2018). Also, femur of leg I is light brown (Images 1–5) (Dark brown in holotype male, Figure 1–5 in Caleb & Kumar 2018).

Natural history**:** *P*. *iva* was found in the arid and semi-arid, open habitats with scattered grassy patches along with low shrubs nearby urban area and individuals were mostly found on ground surfaces in direct sunlight.

Distribution: India (WSC 2025).

Distribution in India: Tamil Nadu (Caleb & Kumar 2018) and Gujarat (new record) (Figure 1).

Genus *Thyene* Simon, 1885

Type species: *Attus imperialis* Rossi, 1846

***Thyene bivittata* Xie & Peng, 1995**

(Images 8, 9 & 10)

Thyene bivittata Xie & Peng, 1995: 105, f. 1A-E

Thyene bivittata Jastrzębski, 2006: 1, f. 1-5

Thyene bivittata Logunov, 2021d: 357, f. 27-39

For a complete list of taxonomic references refer WSC (2025).

Material examined: WON104622A, 21.v.2021, one male, India, Gujarat, Danta Village (24.191° N, 72.770° E), 143 m, leg. S. Parmar; WON104622B, 12.vii.2024, one male, India, Gujarat, Bhuj (23.238° N, 69.634° E), 209 m., leg. S. Parmar.

Diagnosis: The species can be easily distinguished by the following characters: male pedipalp with slender and long embolus encircling tegulum, bulbus rounded with small finger-shaped membranous outgrowth on anterolateral position (Image 9). RTA simple, long, broad at the base and narrowed blunt tip, curved dorsally,

Images 1–4. Live images of *Pellenes iva* Caleb, 2018: 1—male in natural habitat, dorso-lateral view l 2—same, lateral view l 3—same, dorsal view l 4—same, latero-frontal view. © Subhash Parmar.

directed at 2 O'clock position (Image 10) (Logunov 2021).

Description: Male (Image 8–10), total length 4.10; carapace length 2.02, width 1.46; abdomen length 2.08, width 1.15. Eye measurements: AME 0.50, ALE 0.27, AER 0.95, PME 0.07, PLE 0.25, PER 1.14. Leg measurements: I 3.72 (1.25, 0.58, 0.75, 0.56, 0.54); II 3.48 (1.18, 0.54, 0.72, 0.52, 0.51); III 3.92 (1.32, 0.51, 0.68, 0.77, 0.62); IV 4.07 (1.29, 0.63, 0.85, 0.64, 0.68). Carapace darkish brown with a posterior-median whitish-orange patch. Anterior eyes surrounded by white and reddish orange scales anterior, and posterior respectively. Clypeus brown. white patch extends posteriorly along lateral sides, from below ALEs to base of carapace. Chelicerae black with two teeth on promargin and one bifurcated tooth on retromargin. Abdomen elongated, with a median yellowish band running longitudinally from anterior to posterior end, lateral sides uniformly dark brown along entire length. Spinnerets dark brown. Embolus slender and long, encircling tegulum, bulbus flat, rounded with small finger-shaped membranous outgrowth on anterolateral position (Image 9). RTA simple, long, broad at base and narrowed blunt tip, curved dorsally, directed at 2 O'clock position (Image 10).

Natural history: *Thyene bivittata* was observed inhabiting dry, open scrubland with sparse vegetation, often found on low bushes, and leaf litter during daytime. Specimens collected by hand, indicating diurnal activity, and ground associated microhabitat preference.

Distribution: Pakistan, India, Nepal, China (WSC 2025)

Images 5–10. 5, 6 & 7: *Pellenes iva* Caleb, 2018: 5—male, dorsal view l 6—male left pedipalp, ventral view l 7—same, retrolateral view l 8, 9 & 10—*Thyene bivittata* Xie & Peng, 1995 | 8—male habitus, dorsal view l 9—male left pedipalp, ventral view l 10—same, retrolateral view. Scale bars: 1 mm (5 & 8) l 0.1 mm (6–7 & 9–10). © Subhash Parmar.

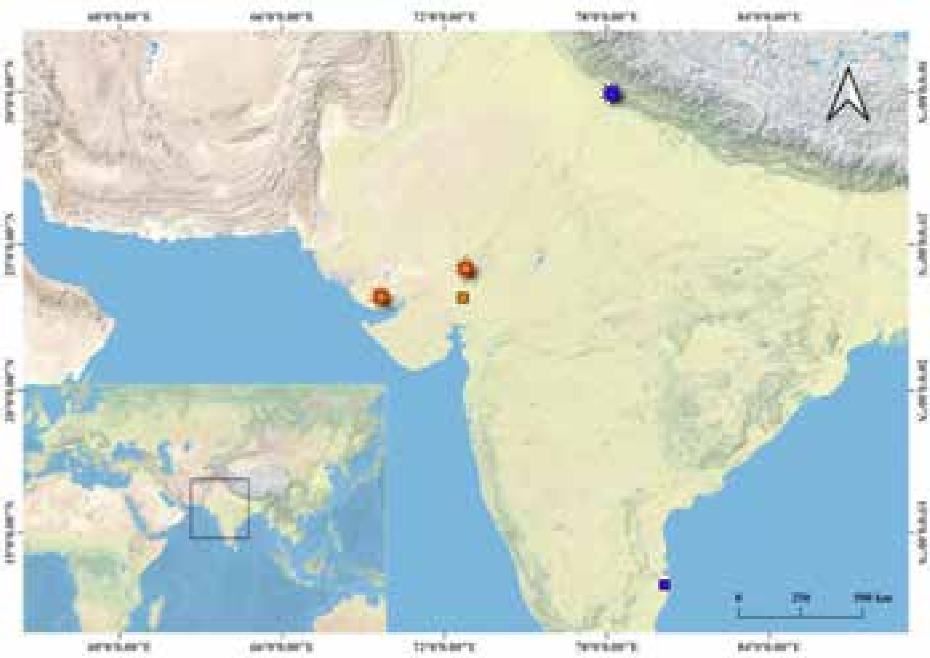

Figure 1. Distribution of *Pellenes iva* Caleb, 2018 (squares) & *Thyene bivittata* Xie & Peng, 1995 (stars) in India l Blue color represents previous literature records l Saffron color represents new records.

Distribution in India: Uttarakhand (Logunov 2021) and Gujarat (new record) (Figure 1).

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SHORT COMMUNICATION

Sympetrum orientale (Selys, 1883) (Odonata: Libellulidae): a new addition to the Odonata fauna of Kashmir Himalaya, India

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Abstract: Odonata, which includes dragonflies and damselflies, are a significant insect group in wetland ecosystems, with 6,410 species globally, including 498 in India and 257 in the Indian Himalaya. These insects serve as indicators of ecosystem health and their population declines are often considered an indication of pollution or environmental degradation. The present study focuses on *Sympetrum orientale* (Selys, 1883), a new addition to the Odonata fauna of Kashmir Himalaya, India. It has been recorded from the Boniyar and Uri Regions of Baramulla District.

Keywords: Bioindicator, Boniyar, damselflies, dragonflies, first record, pollution, population decline, Uri, wetland.

Odonata, which includes dragonflies and damselflies, is a significant insect group in wetland ecosystems, with 6,410 described species globally, including 498 in India and 257 in the Indian Himalaya (Subramanian & Babu 2020; Schorr & Paulson 2024). Odonates are characterised by a delicate body and are frequently employed as markers of the health of ecosystems. Their diversity, abundance, and presence can be used to gauge the availability and quality of aquatic habitats, particularly water. Calvert (1898) conducted the first study on Kashmiri Odonata identifying 15 species, later expanded to 21 by Fraser (1933, 1934, 1936). Singh & Baijal (1954), Chowdhary & Das (1975), and Asahina (1978) contributed more research on the Odonata fauna of Kashmir. Riyaz & Sivasankaran (2021) reported 10 species from the Hirpora Wildlife Sanctuary in Shopian, Kashmir; Qureshi et al. (2022) recorded 11 species from Pulwama District in Kashmir; Paray & Mir (2023) reported a total of 24 species of Odonata under 12 genera and five families from Kashmir; and Hussain et al. (2024) reported a total of 18 species of Odonata under 11 genera and four families in Hokersar wetland, a Ramsar site of Kashmir Himalaya, India. The genus *Sympetrum* Newman, 1833 under the family Libellulidae is a species-rich genus with 57 described species globally (Schorr & Paulson 2024). Species of this genus are mostly distributed in temperate areas of the Holarctic region (Pilgrim & von Dohlen 2012). Species like *Sympetrum arenicolor* Jödicke, 1994; *Sympetrum fonscolombii* (Selys, 1840); *Sympetrum haritonovi* Borisov, 1983; *Sympetrum hypomelas* (Selys, 1884); *Sympetrum meridionale* (Selys, 1841); *Sympetrum orientale* (Selys 1883); *Sympetrum speciosum* Oguma, 1915; and *Sympetrum striolatum* (Charpentier, 1840) are reported from the Indian Himalaya and other parts of India (Subramanian & Babu 2024).

The present survey was carried out during the months

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of July and September 2023 at eight selected sites in Kashmir Himalaya to study the odonate fauna of the region. During this study, *S. orientale* was documented from Boniyar (34.081 ^{0}N, 74.072 ^{0}E) and Uri (34.088 ^{0}N, 75.034 ^{0}E) regions of Baramullah District, the first report of this species from the region (Image 1); it was sighted and collected at slow-moving streams, rivers, ponds, and paddy fields (Figure 2). Photographs of specimens were taken using a Canon EOS 200D camera with 250 mm. The collected specimens are deposited in the museum with the accession number ZoolSo2223-Kash of the Department of Zoology, University of Kashmir.

Materials and Methods

Study area: Kashmir is the northernmost region of India, covering an area of 15,948 km^2 and situated between 33.227–34.083 ^{0}N and 73.341–75.797 ^{0}E. Its southern and southwestern borders are formed by the Pir Panjal Range, whereas its northern and northeastern borders are formed by the northern Kashmir Range, which divide it from the icy plateau of Ladakh (Hussain 1987). During the present study a total of eight sites were selected from Baramulla District of Kashmir Himalaya, which is the northern part of Kashmir based on their geographical parameters. *Sympetrum orientale* (Selys, 1883) was reported from two sites of the selected ones during the months of July and September 2023, viz., Boniyar and Uri (Image 1).

Identification of the specimens

The identification of species was completed using taxonomic literature (Fraser 1933, 1934, 1936) and field guides (Subramanian 2009). Kalkman et al. (2020) and Subramanian & Babu (2017) were followed for species nomenclature and classification.

Results

Systematic position
Order: Odonata
Suborder: Anisoptera
Superfamily: Libelluloidae
Family: Libellulidae
Genus: *Sympetrum*
Species: *S. orientale* (Selys, 1883).

Material examined: 4 females, 2 males, 34.081 ^{0}N, 74.072 ^{0}E, Boniyar, Baramulla, UT of Jammu & Kashmir, India, 1,577 m, 24.vii.2023, collected by Sahiba Khan. 2 females, 2 males, 34.088 ^{0}N, 75.034 ^{0}E, Uri, Baramulla, UT of Jammu & Kashmir, India, 1,721 m, 16.ix.2023, collected by Sahiba Khan and Beenish Bashir.

Diagnosis: Males are medium sized, head – labium reddish-brown, labrum dull red, occiput reddish-brown, eyes reddish-brown above paler below and laterally, thorax reddish-brown; dorsum bright red in colour and humeral and lateral sides light yellow with narrow black strips or lines; legs blackish; wings transparent palely enfumed with bright yellow colour amber marking at

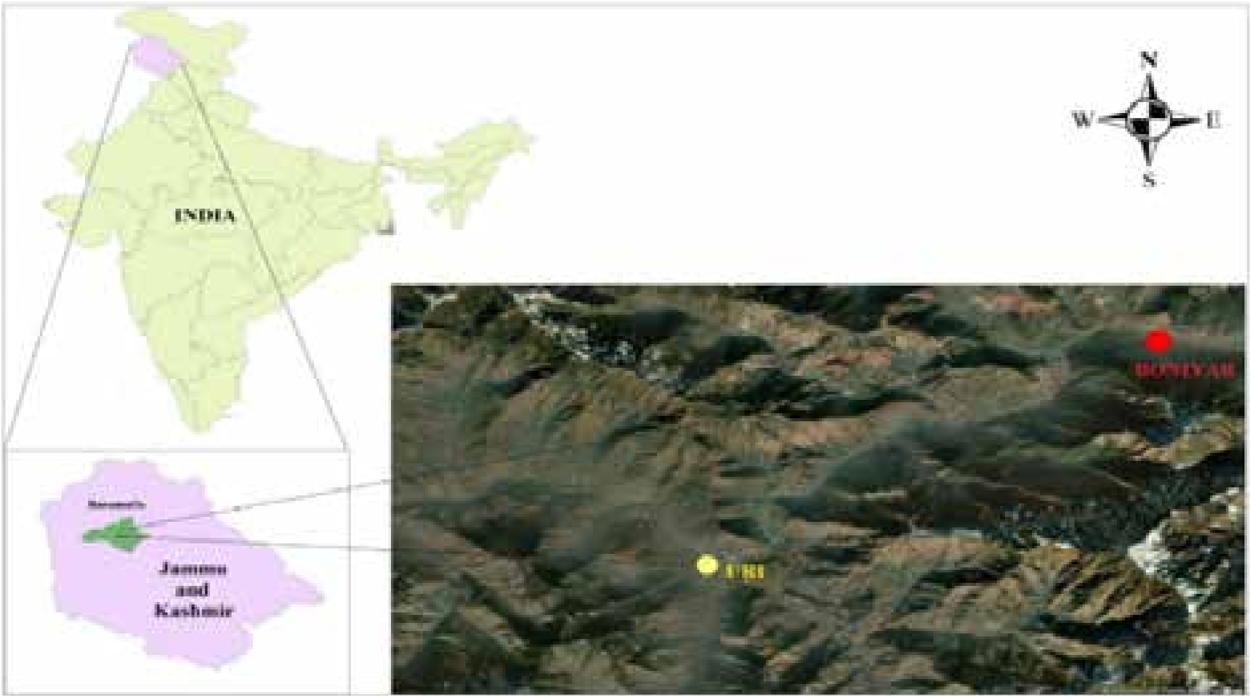

Image 1. Map of the study area where *Sympetrum orientale* was recorded.

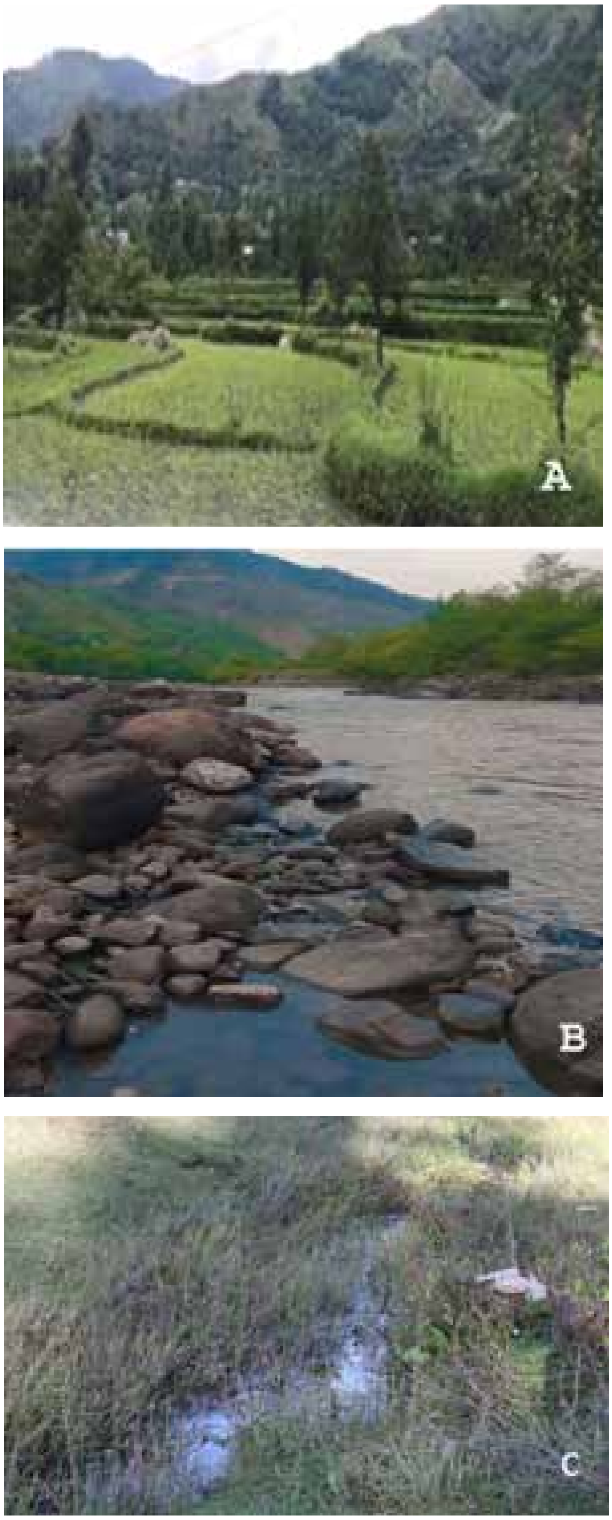

Image 2. Habitat of *Sympetrum orientale*: A—Paddy field| B—Stream| C—Pond. © Sahiba Khan.

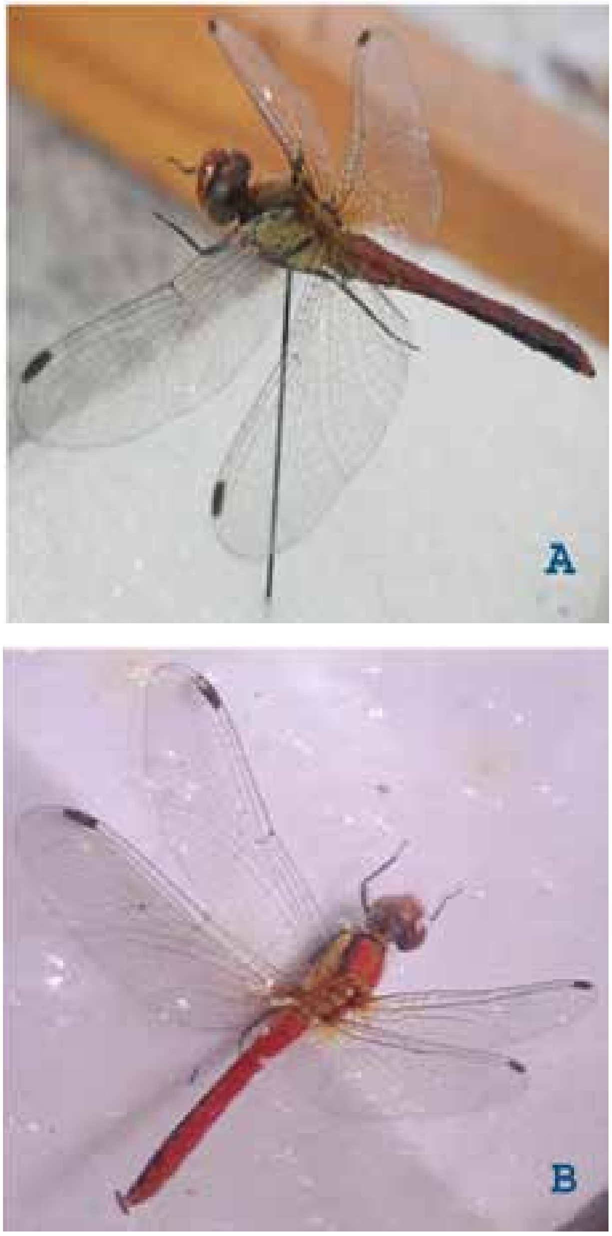

Image 3. *Sympetrum orientale* (male): A—Lateral habitus of the dry preserved specimen | B—Dorsal view. © Tanveer Ahmad Dar.

basis of wings, brighter red on dorsum and with humeral and lateral narrow black stripes or lines, the extent of which is variable – in forewing from base to half of the cubital vein and first antenodal crossvein, in hindwing reaching up to cubital nervure or up to the discoidal cell and arc, wing membrane reddish-brown, pterostigma dark reddish-brown, abdomen dorsum reddish, ventral side black, black ventral side overlapping onto the sides in most of the abdominal segments, anal appendages reddish, black beneath (Image 3); female resembles with male, greenish antehumeral stripe, humeral stripe bordered dark reddish-brown, abdomen with black interrupted subdorsal stripes (Image 4). *S. orientale* is not widely distributed and abundant like its closely

Image 4. *Sympetrum orientale* (female): A—Dorsal habitus of the dry preserved specimen | B—Lateral view. © Tanveer Ahmad Dar.

related species.

National and global distribution

It was previously recorded in Himachal Pradesh, Arunachal Pradesh, and Meghalaya (Mitra 2006; Babu & Nandy 2010). Recently the species has been reported from Mysore city of Karnataka (Suchitra & Chethan 2021) and in West Bengal (Dawn 2021). This study has reported this species for the first time from the Kashmir Himalaya region of India. Apart from India, the species is distributed in China and Nepal (Kalkman et al. 2020). The photographic proof of the species without its description was provided by Riyaz (2020) from the Shopian District of Kashmir Himalaya.

Habit and Habitat

The *Sympetrum orientale* ((Selys 1883) is found near fresh water, such as lakes, ponds, canals, ditches, and riverbanks as well as near forest habitats.

Remarks

According to IUCN Red List status, the species fall under the 'Data Deficient' category. Regional documentation of odonates is important for their long-term conservation and management.

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SHORT COMMUNICATION

First confirmed sighting of the elusive Eurasian Otter in Goa, India

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Abstract: Otters are semi-aquatic carnivores that play a vital role in maintaining the balance of freshwater ecosystems. India is home to three species of otters: the Smooth-coated Otter *Lutrogale perspicillata*, the Asian Small-clawed Otter *Aonyx cinereus*, and the Eurasian Otter *Lutra lutra*. In Goa, only the Smooth-coated Otter and the Asian Small-clawed Otter had been previously recorded. Our discovery has confirmed the presence of the Eurasian Otter in Goa, expanding its known distribution. This ground-breaking finding was made on 14 February 2025, when an injured otter was found near Dharbandoda, Goa. Upon examination, the presence of a distinctive W-shaped or zig-zag patterned rhinarium confirmed that the otter was indeed a Eurasian Otter. Unfortunately, the otter was later declared dead. This discovery highlights the rich biodiversity of Goa and emphasizes the need for further research and conservation efforts to protect these elusive creatures and their habitats.

Keywords: Dharbandoda, freshwater ecosystem, otter distribution, semi-aquatic carnivore, Western Ghats.

Otters are indicators of healthy aquatic ecosystems, playing a key role for maintaining land water continuum. The Eurasian Otter *Lutra lutra* has been recorded across northern, central, western, and eastern India, particularly in the Kashmir, Himalayan foothills, and parts of the Western Ghats (Joshi et al. 2016; Mudappa et al. 2018; Palei et al. 2021; Jamwal et al. 2023; Mohsin et al. 2024). Until now, there were no confirmed records of this species in Goa. Previous studies have only reported the presence of the *Smooth-coated Otter* L. *perspicillata* and the Asian Small-clawed Otter A. *cinereus* (Borker et al. 2014). The Otter population in Goa may face a range of anthropogenic threats, including unregulated mining, and riverbank modifications all of which degrade the riparian habitats. Increasing tourism pressure, night-time vehicular traffic, and encroachment on wetland habitats may also contribute to disturbance, and habitat fragmentation. This paper documents the first scientific record of *Lutra lutra* in Goa and discusses its significance.

Observation and Details

On 14 February 2025, an otter was discovered lying on the roadside near Dharbandoda, Goa (15.4001° N, 74.1307° E). Dharbandoda is a small settlement located near the western edge of Bhagwan Mahavir Wildlife Sanctuary. The surrounding habitat includes semi-evergreen forest patches, agricultural, and some closed stone quarries, with seasonal streams & rivulets connected with Ragada River eventually connecting to Zuari River basin.

The individual had sustained an injury near its mouth but was still breathing heavily. Wildlife rescuer Charan,

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Image 1. Eurasian Otter lying in the middle of the road. © Abhijeet Patil (Planet Life Foundation).

Image 3. Front paw of Eurasian Otter. © Arcane Conservancy Trust.

Image 2. The distinct W-shaped or zig-zag shaped rhinarium. © Dr. Charmaine Pinto - Pet Care Clinic.

along with Abhijeet Patil from Nature's Nest Goa, promptly transported the otter to a veterinary hospital for medical attention. On arrival at the veterinary facility, the otter was found to be semi-conscious, and unresponsive to stimuli. A visible laceration was observed at the lower jawline. The injury appeared to be consistent with trauma, possibly due to vehicular collision, as inferred from the roadside location, and absence of other wounds.

During treatment, a critical morphological characteristic—the W-shaped or zig-zag rhinarium (the furless skin surface surrounding the external openings of the nostrils)—was observed, confirming the species as *Lutra lutra* (Blanford 1888; Mudappa et al. 2018), a trait diagnostic of *Lutra lutra*. The confirmation was based on existing identification guides and previous morphological studies of otters in India. For external expert consultation, the photos were sent to the members of the International Otter Survival Fund (IOSF), who also confirmed the species to be Eurasian Otter. However, due to the emergency nature of the case and the otter's condition, molecular identification could not be carried out at the time. Later on 15 February 2025, early morning the Otter was declared dead. Apart from photographic documentation, no other biological samples were preserved post-mortem due to lack of

Image 4. Hind leg of Eurasian Otter (distinct webbing between the digits). © Arcane Conservancy Trust.

permission for collection, and sample storage.

This marks the first scientifically documented record of *Lutra lutra* in Goa. The record is significant because:

1. It confirms the presence of all three otter species found in Goa—a state known for its rich riparian and estuarine ecosystems.
2. It suggests the need for further otter surveys in the region, as the species might have been overlooked due to its elusive nature, and nocturnal habits.

Discussion

Although Goa does not currently have a formal otter-specific conservation program, otter habitats benefit indirectly from protection within areas like Bhagwan Mahavir Wildlife Sanctuary, and Mollem National Park. Large parts of riparian habitats remain unprotected and vulnerable to degradation, calling for targeted conservation interventions. These findings can help inform state wildlife authorities and local conservation agencies by highlighting the need to include otters in existing freshwater ecosystem protection plans. It also calls for immediate identification and protection of critical river stretches where Eurasian Otters may persist, through habitat mapping, community engagement, and stricter regulation of harmful activities like sand mining. As a direct follow-up, we propose initiating a seasonal otter monitoring program in eastern Goa through camera trapping and sign-based surveys, coupled with community interviews.

Conclusion

This report establishes the first record of *Lutra lutra* in Goa and confirms that the state home to all three otter species. This record underscores the conservation value of Goa's freshwater systems and suggests that even small, forest-adjacent rivers may harbour elusive species like *L. lutra.* Recognizing and protecting such microhabitats is essential for preventing local extinctions. The detection of Eurasian Otters in Goa not only expands the known distribution range of the species but also indicates the ecological integrity of Goa's riparian corridors and highlights the role of these landscapes in supporting keystone carnivore species.

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SHORT COMMUNICATION

First photographic record of Smooth-coated Otter *Lutra perspicillata* (Carnivora: Mustelidae) from Nandhaur Wildlife Sanctuary, Uttarakhand, India

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Abstract: Otters serve as apex predators and function as keystone species within aquatic ecosystems. Three species of otters are found in India, i.e., Eurasian Otter *Lutra lutra*, the Smooth-coated Otter *Lutra perspicillata,* and the Asian Small-clawed Otter *Aonyx cinereus*. However, little is known about otter distribution in Uttarakhand. Our study presents the first photographic evidence of Smooth-coated Otter from Nandhaur Wildlife Sanctuary, Uttarakhand. Smooth-coated Otter is listed on Schedule I of Wildlife (Protection) Act 1972, affording it highest level of protection in India. Further studies will be crucial for assessing their distribution pattern and threats faced by them in the Nandhaur landscape.

Keywords: Aquatic ecosystems, camera trap, Nandhaur landscape, otters, photographic evidence, riverine habitat, Schedule I, semi-aquatic species.

Otters belong to the family Mustelidae and are well adapted for semi-aquatic life with their webbed feet, fur, and tapering tail. They serve as indicator species within ecosystems and play a vital role in regulating invasive species in aquatic environments (Anoop & Hussain 2005). There are 14 extant species of otters found worldwide, with three species occurring in India (Mammal Diversity Database 2025).

India is home to the Eurasian otter *Lutra lutra*, the Smooth-coated Otter *Lutra perspicillata,* and the Small-clawed Otter *Aonyx cinereus* (Hussain 1999). Smooth-coated Otter is a large-sized otter, weighing 8–11 kg and found across much of southern and southeastern Asia (Pocock 1941; Medway 1969; Hussain 1993; Hussain 2013a). It is classified as 'Vulnerable' on the IUCN Red List and is protected under Schedule I of Wildlife (Protection) Act, 1972 (amended 2022). Among all three species of otters found in India, Smooth-coated Otter is perhaps most widely distributed (Hussain 2013b). They have been studied from different regions of India, for example Chambal region (Hussain & Choudhury 1995, 1997; Hussain 1996, 2013a), Kerala (Anoop & Hussain 2004, 2005; Raha & Hussain 2016; Sreehari & Nameer 2016), Goa (Krupa et al. 2017; Dias et al. 2022; Duke & Goldberg 2022; Dias 2023), Odisha (Mishra et al. 2018; Palei et al. 2020, 2023; Rath et al. 2023), and Rajasthan (Nawab 2013), among others.

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In Uttarakhand, otters are present in Bhagirathi basin (Pal et al. 2021), upper Ganga basin (Nawab & Hussain 2012a,b; Khan et al. 2014) Kosi, Ramganga, and Khoh (Gupta et al. 2020). In addition to that, otters are also found in Rajaji, Corbett Tiger Reserve, and Lansdowne Forest Division (Nawab & Hussain 2012a; Joshi 2014; Basak et al. 2021). However, there is limited information regarding presence of Smooth-coated Otters in Kumaon region of Uttarakhand, particularly beyond Corbett Tiger Reserve. This situation is also evident in the Nandhaur Wildlife Sanctuary (NWS), where suitable habitat for otters exists, yet no studies have reported their presence. We present the first photographic record of Smooth-coated Otter from Nandhaur Wildlife Sanctuary.

Methods

Nandhaur Wildlife Sanctuary was created in 2012 and lies in Uttarakhand state of India. Its geographical extent is 79.675 E, 29.184 N & 80.009 E, 29.138 N (Mehra 2015). It is bounded by Gola River in the west and Sharda River in the east, providing connectivity with Shuklaphanta National Park of Nepal. NWS is an integral part of the Terai Arc Landscape (TAL), which is spread across India (Uttarakhand, Uttar Pradesh, and Bihar) and Nepal. The major forest type is tropical moist-deciduous forest dominated by Sal *Shorea robusta* and associated species such as *Terminalia tomentosa* and *Adina cordifolia* (Champion & Seth 1968). Among the mammals, Bengal Tiger *Panthera tigris*, Indian Elephant *Elephas maximus*, Sambar *Rusa unicolor*, Chital *Axis axis*, and Barking Deer *Muntiacus vaginalis* are found. NWS comprises of four ranges, namely, Nandhaur, Jaulasal, Danda, and Sharda with an area of approximately 270 km^2 (Figure 1). Nandhaur and Kalaunia are the major rivers which are perennial in nature. Apart from that several seasonal streams crisscross the Nandhaur landscape.

On 6 March 2024, we saw an otter while we were deploying camera traps for the estimation of tiger density in NWS. However, there was some doubt regarding the identity of the species. To further confirm the identity of otter species found in NWS, we deployed five IR camera traps (OT1, OT2, OT3, OT4, and OT5) (Cuddeback Inc, USA) for a period of 10 days in the Nandhaur range of NWS. The placement of camera traps was based on

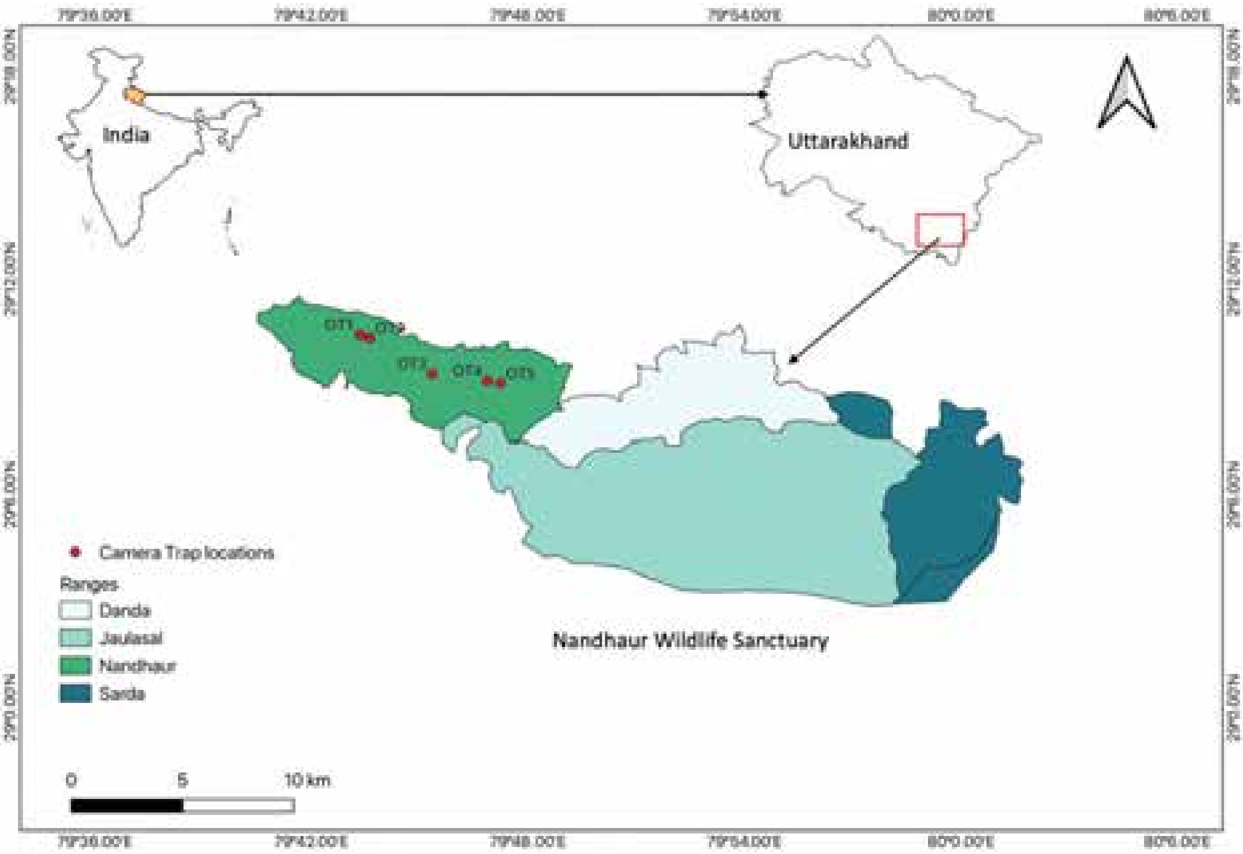

Figure 1. The geographical location and map outlining the ranges within Nandhaur Wildlife Sanctuary (NWS), Uttarakhand, India. The red dots show the location of camera traps deployed in Nandhaur range of NWS.

Image 1. Photographs of Smooth-coated Otters captured in Nandhaur range, Nandhaur Wildlife Sanctuary, Uttarakhand, India.

the presence of otter signs, such as tracks or scat. The geographical coordinates of the camera traps were recorded using a Garmin GPSMAP 64s device. The resultant data was then used to create a map using QGIS version 3.34.4 Prizren (QGIS Development Team 2024).

Results

Otter photographs were captured at two locations in the Nandhaur range, i.e., OT4 and OT5 on separate days (Image 1). They were identified as Smooth-coated Otter based on tail characteristics, smooth fur, and overall stature in consultation with members of IUCN Otter Specialist Group (Atul Borker & Nicole Duplaix, pers. comm. July 2024).

Discussion

This study establishes the presence of Smooth-coated Otter in Nandhaur Wildlife Sanctuary and future management plans must take it into consideration. Forest department should focus on minimising disturbance to riverine habitat, reducing soil erosion, and conserving fish population which will allow otters to thrive in NWS.

There are no reliable estimates of Smooth-coated Otter population, and it is suspected to decline by more than 30% over the next three decades (Khoo et al. 2021). Lack of information on population estimates and distribution of species could hinder our ability to make informed decisions, potentially undermining conservation efforts. Therefore, it is imperative to conduct systematic surveys for otters in Nandhaur landscape to determine their population and distribution patterns, thus ensuring their long-term survival.

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