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Cover: Digital illustration of Smooth-coated Otter *Lutrogale perspicillata* by Dupati Poojitha. Reference from the picture taken by Rana & Sugandhi.

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COMMUNICATION

Distribution of rheophytes in Kopili River Basin, Assam and Meghalaya, India

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Abstract: Rheophytes are plant species that are confined to the beds of swift-running streams and rivers and grow there up to flood level, but not beyond the reach of regularly occurring flash floods. Little is known about this group of plants in Assam. Between 2018 and 2022, the Kopili River Basin in Assam emerged as a hotspot for rheophytic flora with the description of three new species and range extensions of another two species from the Koka–Panimur region of West Karbi Anglong. Subsequent downstream impact assessment (2024–2025) for the Lower Kopili Hydro Electric Project and Kopili basin survey including the tributeries revealed the presence of 16 rheophyte species distributed across upstream reaches of the Kopili River and its tributaries, including Amring / Mynrinag, Borpani, Diyung, Karkar, Mynteng, Umium, Digaru, and Umrong Nala. These species exhibit remarkable ecological adaptations, thriving on riverbanks and rocky substrates under extreme acidic conditions (pH as low as 2.9 in the Karkar River). The Kopili River Basin represents a unique ecological niche for rheophytes in northeastern India as no other river system supports diverse species of this kind. Immediate Immediate conservation interventions and policy integration are essential to safeguard these species and their unique habitats from anthropogenic pressures.

Keywords: Conservation importance, flora, Koka–Panimur region, northeastern India, range expansion, unique habitat.

Assamese: 'ৰিওফাইছ' (Rheophytes) বুলি জনা উদ্ভিদবোৰ হল এনে উদ্ভিদ প্ৰজাতি যিবোৰ খৰস্ৰোতা, ঝৰ্ণা আৰু নদীৰ পাৰৰ পানীৰ শিলৰ স্তৰৰ মাজত সাধাৰণতে উপলব্ধ হয় ইয়াৰ উপৰিও বানপানীত হোৱা পানীৰ উচ্ছতাৰে ইয়াৰ বৃদ্ধি সম্প্ৰসাৰিত হয়। এই উদ্ভিদবোৰৰ বিষয়ে অসমৰ পৰিপ্ৰেক্ষিতত অতি কমেই তথ্য উপলব্ধ। ২০১৮ ৰ পৰা ২০২২ চনৰ ভিতৰত, পশ্চিম কাৰ্বি আংলং জিলাৰ কোকা - পানিমুৰ অঞ্চলত তিনিটা নতুন প্ৰজাতিৰ বিৱৰণৰ লগতে আৰু আন দুটা প্ৰজাতিৰ বিস্তাৰৰ সৈতে কপিলী নদী উপত্যকাৰ ৰিওফাইট উদ্ভিদৰ এটা গুৰুত্বপূৰ্ণ 'হটস্পট' ৰূপে পৰিগণিত হৈছে। পৰৱৰ্তী ২০২৪ - ২০২৫ চনৰ নিম্ন কপিলী জলবিদ্যুৎ প্ৰকল্পৰ বাবে উদ্ভৱ হোৱা নিম্নপ্ৰবাহীয় জলৰাশিৰ প্ৰভাৱ মূল্যায়ন আৰু ওচৰৰ উপনদী সমূহৰ সমগ্ৰ কপিলী উপত্যকাৰ সমীক্ষাত কপিলী নদীৰ শীৰ্ষ অঞ্চলসমূহত আৰু ইয়াৰ উপনদীসমূহত—যেনে, আমৰিং/মাইনৰিনাগ, বৰপানী, দিওং, কাৰ্কাৰ, মইণ্টেঙ, উমিয়াম, ডিগাৰু আৰু উষং নালা—মুঠ ১৬টা ৰিওফাইট উদ্ভিদ প্ৰজাতিৰ উপস্থিতি চিনাক্ত কৰা হয়। এই উদ্ভিদসমূহ অত্যন্ত কঠিন পৰিৱেশত খাপ খোৱাকৈ বিকশিত হৈছে - নদীকূল আৰু শিলৰ দ্বাৰা গঠিত স্থলত, অতি অম্লীয় পানীতো (যেনে কাৰ্কাৰ নদীত pH মাত্ৰ ২.৯ পৰ্যন্ত হোৱাৰ দৃষ্টান্ত আছে) ইয়াৰ উপস্থিতি দেখা গৈছে । উত্তৰ - পূৰ ভাৰতত ৰিওফাইটবোৰৰ বাবে কপিলী নদী উপত্যকা এটা অনন্য পৰিবেশগত স্থান, কাৰণ আন কোনো নদী অৱবাহিকাত এনে ধৰণৰ বৈচিত্ৰ্যময় প্ৰজাতিসমূহ উপলব্ধ নহয়।এই বিশেষ প্ৰজাতিসমূহ আৰু সেইবোৰৰ অন্য বাসস্থল সমূহ মানৱসৃষ্ট কুপ্ৰবাহৰ পৰা ৰক্ষা কৰিবলৈ তৎক্ষাণিক সংৰক্ষণমূলক পদক্ষেপ আৰু নীতি-নিৰ্ধাৰণ অতি প্ৰয়োজনীয়।

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Competing interests: The authors declare no competing interests.

Author details: Dr. Jayanta Das is working as an environment specialist for AFRY India Pvt. Ltd. since 2021. The current assignment is to see the implementation of environmental stipulations and statutory compliances for the construction of Lower Kopili Hydro Electric Project (LKHEP) under APGCL in Assam. Updating the EIA for the LKHEP including downstream and back water assessment. Dr. Deepak Kumar Baruah is an environment expert of Assam Power Generation Corporation Limited (APGCL) since 2017. Currently he supports APGCL in monitoring the compliance of the environmental and statutory requirements of all the power generating units (hydro, gas based) under APGCL. He also reviews the environmental reports prepared by the consultants before submission to the respective organizations.

Author contributions: JD and DKB designed the study for the diverse and unique habitat of rheophytes while updating the EIA of the Lower Kopili Hydro Electric Project. Field study were carried out by JD and DKB with the logistic support from Assam Power Generation Corporation Limited. Data interpretation and distribution maps were prepared by JD. Both the authors reviewed and approved the final manuscript.

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INTRODUCTION

The term 'Rheophyte', coined by van Steenis (1932) and elaborated in later works (1978, 1981), refers to flood-tolerant plants restricted to swift-running rivers and streams. Rheophytes are plants that grow along the margins of swift water currents or sometimes on the streambed or on its rocks (van Steenis 1981, 1987). Rheophytes are morphologically characterized by having narrow, oblanceolate leaves – leaflets (stenophylls) and other features that are adapted to the unique habitat that decreases resistance to the swift-running water (Kato & Imaichi 1992). Due to short petioles, narrow leaves, and tough but flexible stems, the rheophytes can stand firm against swift-running free flowing streams. Survival in or at the edge of a river system can exert extreme and diverse stressors on the plants growing there. At times of high flooding, plants must be able to remain anchored and withstand the power of flowing water. During the long dry period, plants are exposed to hot, rocky, gravelly or sandy areas (Puff & Chayamarit 2011). Rheophytes occur worldwide but are found particularly in evergreen rainforests, where they are the dominant aquatic macrophytes in tropical river systems (van Steenis 1978; Quiroz et al. 1997; Ameka 2000; Hoyos-Gomez & Bernal 2018). The high richness of rheophytic taxa was mostly found in southern Mexico, southern China, Borneo, and northern & eastern Australia. In contrast, the geographical distribution of rheophytes in gymnosperms is restricted to New Caledonia and Tasmania (Costa et al. 2020). Members of this biological group of plants are not necessarily taxonomically related, but they show a common adaptation to a restricted ecological habitat or environmental factors (van Steenis 1981; Ameka 2000; Ameka et al. 2002; Hoyos-Gomez & Bernal 2018).

Rheophytes can be roughly divided into three main groups or life-forms. Hydrophytic rheophytes are permanently submerged herbs. Torrenticolous rheophytes are submerged in a vegetative state, flowering periodically when waters are low. The rheophytic land plants are shrubs or herbs, some mat-rooted on rocks. Two categories of rheophytes are recognized obligate and facultative rheophytes (Ameka et al. 2002). Obligate rheophytes are confined to waterfalls, streams and river-beds and banks, and below the flood level. Facultative types are found not only in river-beds but also occur in wet places where they are not subjected to fast-flowing water. In the Kopili River Basin, rheophytic plants or rheophytes refer to obligate rheophytes with torrenticolous and rheophytic land plants.

This unique group of plants came to the limelight in Assam during 2018–2022 with the description of three new species (*Carissa kopilii*, *Syzygium nivae*, & *Pavetta puffii)* and range expansion of two species (*Syzygium cyanophyllum* & *Ixora yunnanensis)* from Koka, Panimur area of West Karbi Anglong along the Kopili River. The Kopili River is a southern-bank tributary of the Brahmaputra River, originating in the southwestern slope of the Shillong Peak in Meghalaya. About 76% of the river lies in Assam. The total catchment area is approximately 20,560.5 km^2. The basin area sees an annual rainfall of 980–1,700 mm with an average annual run-off of the basin at 600 mm, generating an average yearly flow volume of 9,023 million m^3 (MCM). Kopili is often noted as 'mighty' for its volume of water flow and intensity during peak monsoons causing flash floods, landslides, widespread displacement of people in the downstream.

Pavetta puffii was first described by Sarma et al. (2018) from Koka, Panimur, West Karbi Anglong District, Assam, on the edges of Kopili riverbed, 25.718° N, 92.822° E, alt. 102 m. *Syzygium nivae* was first reported by Sarma et al. (2019a) from the same locality 25.732° N, 92.822° E, alt. 90 m. Again Sarma et al. (2020) described *Carissa kopilii* from 25.736° N & 92.821° E, alt. 85 m. Associated rheophytic species recorded are *Syzygium cyanophyllum* (recorded after 103 years) by Sarma et al. (2019b)*, Ixora yunnanensis* (New to India and range expansion of the species)*, Tarenna pumila*, *Eriobotrya angustissima*, and *Syzygium polypetalum*. Moreover, recently *Heptapleuram assamicum* and *Munronia assamica* were described by Dey et.al. 2025 from the same area of the Kopili Basin. These seven species were not recorded from any other localities other than Koka, Panimur area under West Karbi Anglong and Dima Hasao districts of Assam on the banks of the river Kopili (Image 1).

A survey to document and study the rheophytes of Kopili River Basin is important for a number of reasons: (i) rheophytes are poorly known in Assam and Meghalaya, (ii) they are the dominant aquatic macrophytes in rivers; and are useful biological indicators of river health, and (iii) the diversity of rheophytes is threatened and some species are in danger of disappearing by the increased land-use practices adjoining the rivers and in the river courses for mining (e.g., sand & boulder), and also damming of rivers for hydropower (Kuetegue et al. 2019).

METHODS

A survey of rheophytes was carried out along the river and streams, in the Kopili River Basin to document the occurrence of rheophytes during April 2023–April 2025. After identifying an initial set of species based on the available literature, the authors conducted detailed field surveys timed with flowering seasons to ensure accurate documentation of the basin's rheophyte diversity covering Assam and Meghalaya.

The rheophytes were explored by combining rafting, transect walks, and plot-based recording from water level to the upper flood level, which is a standard ecological approach to survey these unique communities. This option was deemed better than establishing fixed-area plots, as the reach of flooding is different at each point, depending on the physiography.

The rheophytic species were spotted from the boat, and every species found in the area, even those growing on rocks in the middle of the river were collected. Species were collected, photographed, and identifications were made. Distribution maps of rheophytes of Kopili Basin were prepared using georeferenced specimen data from collected specimen labels, available literature, and from this field survey. Literature consulted were of Flora of Jowai and vicinity, Meghalaya. Vol. 1–2 (Balakrishnan 1981–1983); Forest Flora of Meghalaya. Vol. 1–2 (Haridasan & Rao 1985–1987); The Flora of British India. Vol. 1–7 (Hooker 1872–1897); Flora of Nongpoh and its vicinity. Vol. 1–3 (Joseph 1982); Flora of Assam. Vol. 1 (Kanjilal et al. 1934), Vol. 2 (Kanjilal et al. 1936), Vol. 3 (Kanjilal et al. 1938), and Vol. 4 (Kanjilal et al. 1940). Recent species descriptions of rheophytes from the West Karbi Anglong and Dima Hasao were also consulted, viz., Sarma et al. (2020) for identification of *Carissa kopilii*, Sarma et al. (2019a) for *Syzygium nivae,* Sarma et al. (2018) for *Pavetta puffii,* Sarma et al. (2019b) for *Syzygium cyanophyllum,* Sarma et al.

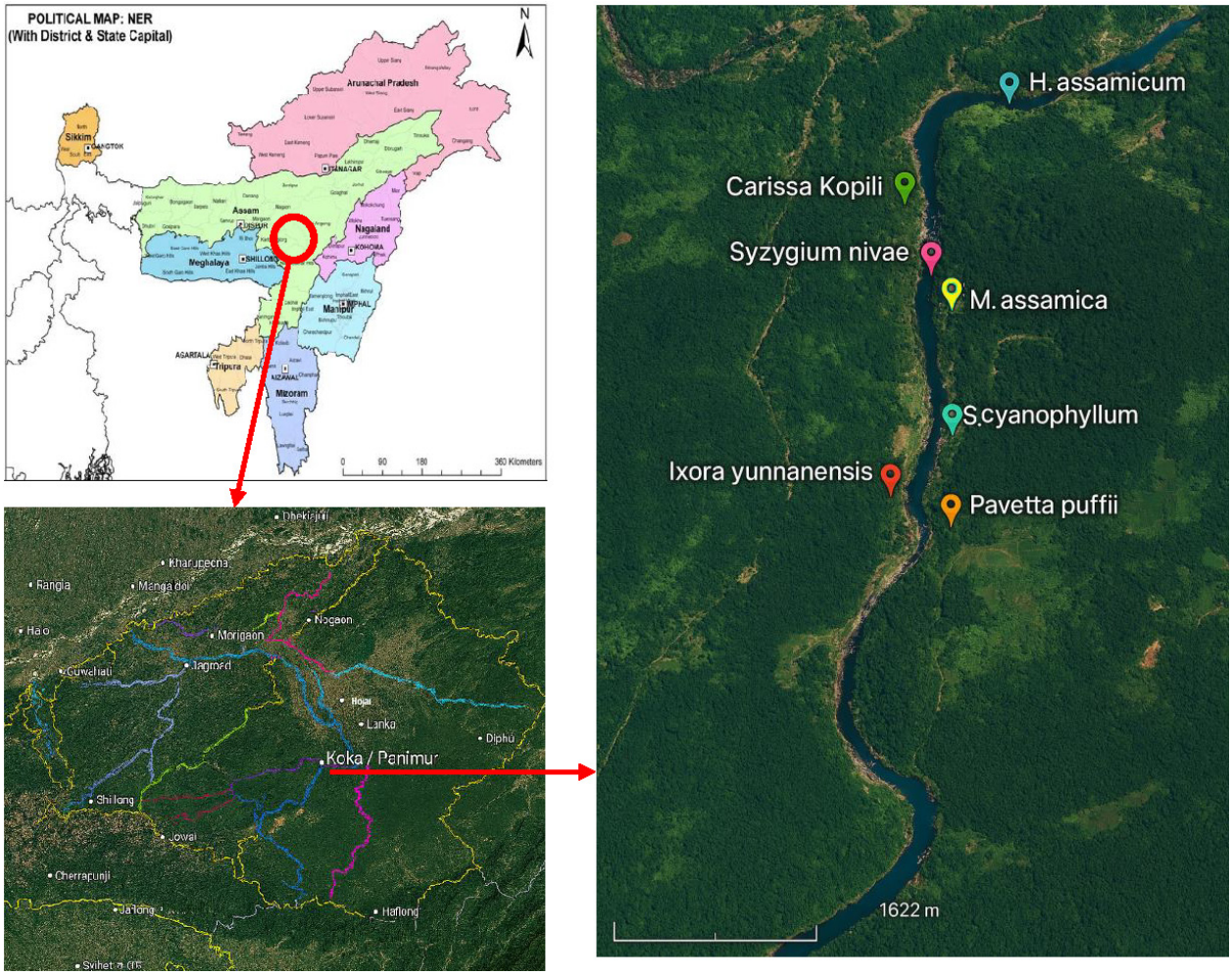

Image 1. Known localities of rheophytes in Kopili Basin in Koka Panimur area till November 2025.

(2019c) for *Ixora yunnanensis,* Dey et al. (2025a) for *Heptapleuram assamicum*, and Dey et al. (2025b) for *Munronia assamica.* Major databases like Kew's Plants of the World Online (POWO) and the Global Biodiversity Information Facility (GBIF) were also consulted.

Based on their distribution along the river, as documented from our survey and observations, the estimated area of occupancy (EAO) of the rheophytes were calculated as per International Union for Conservation of Nature parameters (IUCN 2017).

RESULTS

All the rivers in the Kopili Basin were surveyed and based on the identification of vegetative and phenological stages, rheophytes were identified by consulting the existing literature. Based on the identified plants so far, distribution pattern of the rheophytes in the Kopili River Basin is described.

There are 13 tributaries of the Kopili River (Image 2). Rheophytes are present in eight tributaries in the Kopili Basin, which are Kharkor, Amring, Borpani, Digaru, Mynteng, Diyung, Umium, and Umrong rivers (Image 3). Rheophytes are also found in the main channel of the basin Kopili in the upstream of the confluence of the Amring River.

The extent of occurrence (EOO) of the rheophytes in the Kopili River basin is 460,700 ha (4,607 km^2), and area of occupancy (AOO) of the rheophytes is 155.75 ha (1.5575 km^2) (Image 4, Table 1).

Table 1. Area of occupancy of rheophytes in Kopili Basin.

	River	Hectare (ha)
1	Amring	21.76
2	Kopili	22.41
3	Barpani	49.07
4	Mynteng	18.96
5	Karkar	6.51
6	Diyung	35.32
7	Umium	0.78
8	Digaru	0.55
9	Umrong	0.38
	Total	155.75

After identification, 16 species of rheophytes were confirmed from the Kopili River Basin (Table 2 &3).

Carissa kopilii, *Syzygium nivae, Pavetta puffii*, and *Munronia assamica* are distributed in the Koka – Panimur area of West Karbi Anglong and Dima Hasao districts only.

Syzygium cyanophyllum was first recorded by Kanjilal et al. (1937) as *Eugenia cyanophylla* in the Dehangi area of Dima Hasao and later in 2019, it was described as *Syzygium cyanophyllum* by Sarma et al. (2019a). This species was recorded from Kopili, Amring, Diyung, Mynteng, and Barpani in Assam and Meghalaya.

Ixora yunnanensis was recorded in Koka - Panimur

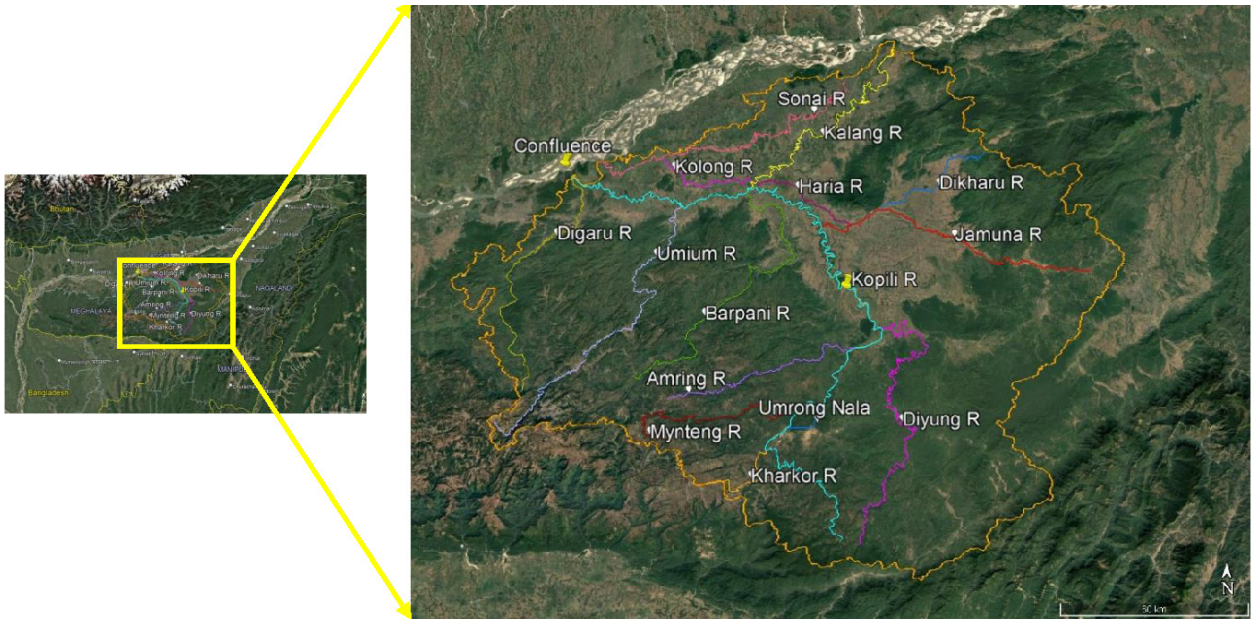

Image 2. Showing Kopili River Basin with its tributaries.

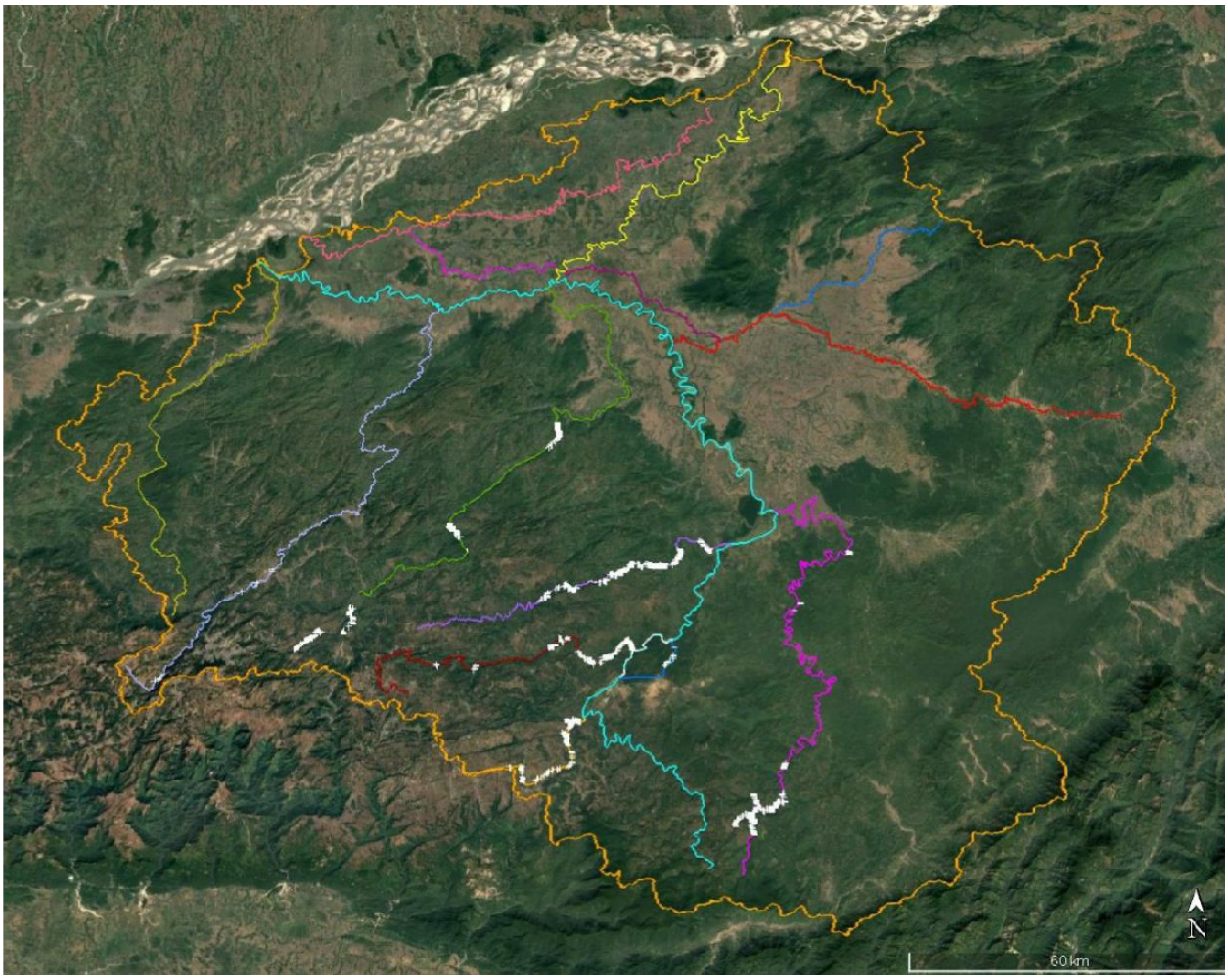

Image 3. Showing the distribution of rheophytes in Kopili Basin (white patches).

area for the first time in India by Sarma et al. (2019 c) as range expansion of the species 760 km westward from Yunnan province.

Heptapleuram assamicum, after its first description by Dey et al. (2025) from main stream of Kopili were also recorded from Borpani and Diyung rivers also.

Syzygium polypetalum is native to a region encompassing the eastern Himalaya and extending through southeastern Asia. Its primary distribution includes Assam, Arunachal Pradesh the states of India, Bangladesh and Myanmar. This species was recorded from the Kopili, Amring, Diyung, Mynteng, and Barpani rivers.

Ficus ischnopoda is widely distributed across tropical and subtropical Asia, native from northeastern India (Assam, Meghalaya) and Bangladesh through southeastern Asia (Myanmar, Thailand, Laos, Vietnam, Malaysia) into southern China (Yunnan, Guizhou). *Ficus ischnopoda* is also widely distributed in the Kopili Basin, including Kopili, Amring, Barpani, Mynteng, Kharkor, Diyung, Umium, and Umrong rivers.

Eriobotrya angustissima is native to tropical Asia, specifically found in Assam, Meghalaya (Khasi Hills) (India) and southern Vietnam, growing in wet tropical environments. This species was recorded from Kopili, Amring, Barpani, Mynteng, Kharkor, Diyung, Umium, and Umrong rivers in the Kopili Basin.

Phoebe angustifolia is native to southern and southeastern Asia, specifically the Assam region of India, extending into China (southeastern Yunnan) and Indo-China (Vietnam, Myanmar, Cambodia, Laos), thriving in evergreen forests. Kopili, Amring, Barpani, Mynteng, Diyung, Umium, and Umrong rivers in the basin support the distribution of this species.

Ficus squamosa is found across southern and southeastern Asia, naturally distributed from the Himalaya (Nepal, Bhutan, northeastern India) through Myanmar, Thailand, Laos, China (Yunnan), and into parts

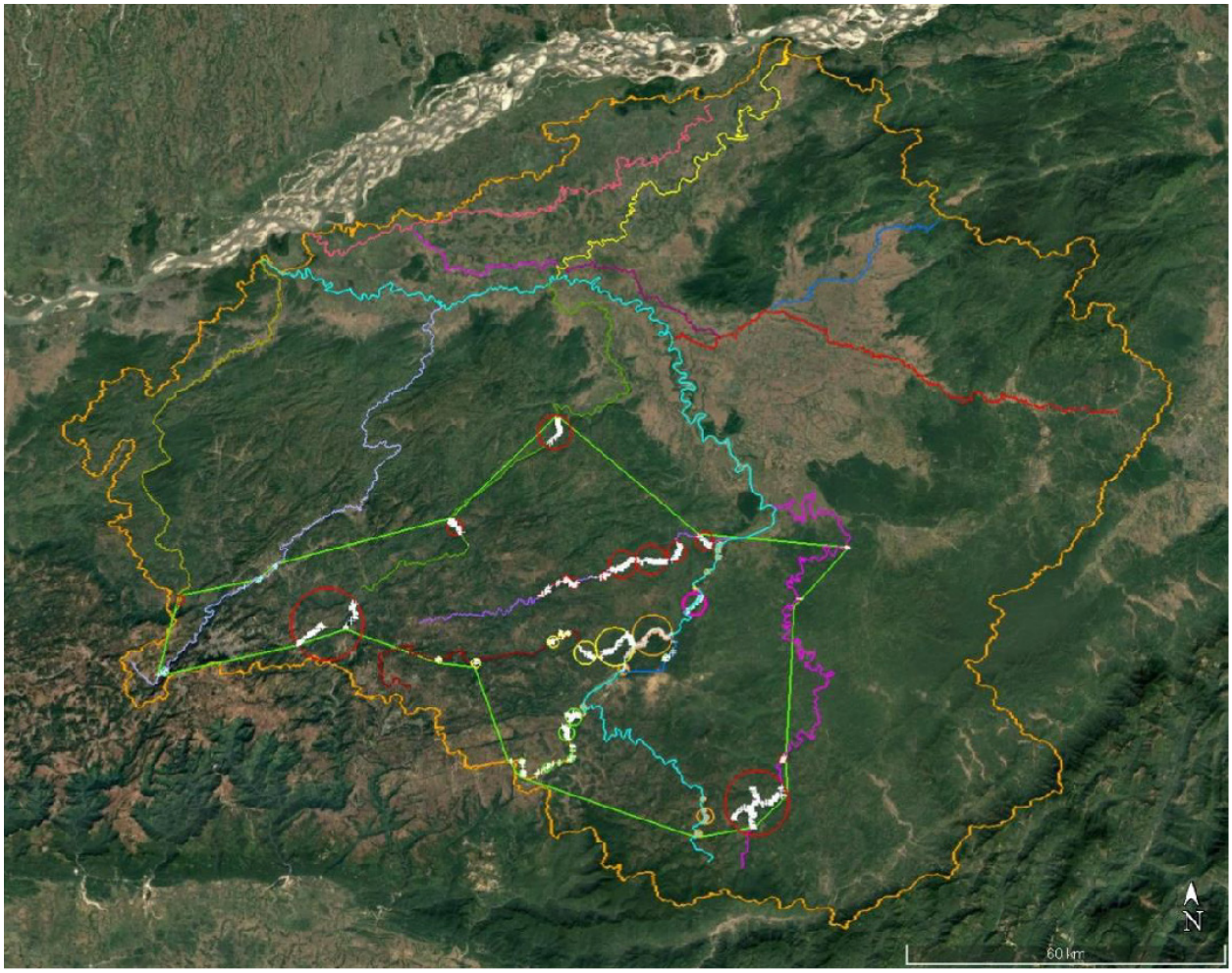

Image 4. Showing extent of occurrence and area of occupancy of rheophytes.

of Vietnam. *F. squamosa* is recorded from Kopili, Amring, Digaru, Barpani, Mynteng, and Diyung rivers.

Homonoia riparia is widespread across Indo-Malesia and southern China, thriving along riverbanks and flooded plains from India, Sri Lanka, and southeastern Asian nations (of Thailand, Vietnam, Philippines, Indonesia) through to New Guinea and Taiwan. This species was recorded from Kopili and Amring rivers only.

Tarenna pumila is a shrub native to the wet tropical biome, specifically found in Assam and Meghalaya in India. The species was recorded from the Kopili and Diyung rivers only.

Huchimingia piscidia is native to southern and southeastern Asia, found in India (Assam, Meghalaya, Mizoram), Myanmar, Thailand, Bangladesh, China (Yunnan, Xizang), Laos, and Vietnam. This species was distributed in the Kopili mainstream only.

Rotala rotundifolia is native to southern, southeastern, and eastern Asia. It's a common weed in its native range, found across India (Assam, Andhra Pradesh, Kerala, Sikkim), Nepal, China, Japan, Thailand, and Vietnam. This species is distributed in the Kopili and Amring rivers.

The upstream reaches of the Kopili River Basin, specifically in areas like Umrangso in Assam and the Jaintia Hills of Meghalaya, have historically been and are still known for the practice of illegal rat-hole mining (Nomani et al. 2021). Acidic nature (pH range 2.9–6.0) of river water of Kharkor, Mynteng and Kopili River (up to confluence of Diyung River) makes the river not suitable for the growth of planktons and fishes. But interestingly, these rheophytes flourish in that acidic water also.

DISCUSSION

The study confirms that the Kopili River basin provides a unique habitat for the rheophytes in Assam

Table 2. Recorded rheophytes from the Kopili River Basin.

	Species	Family	Distribution in the rivers
1	*Carissa kopilii*	Apocynaceae	Kopili, Diyung, Borpani, Amring, Mynteng
2	*Syzygium nivae*	Myrtaceae	Kopili
3	*Pavetta puffii*	Rubiaceae	Kopili
4	*Syzygium cyanophyllum*	Myrtaceae	Kopili, Amring, Diyung, Mynteng, Barpani
5	*Ixora yunnanensis*	Rubiaceae	Kopili, Diyung
6	*Syzygium polypetalum*	Myrtaceae	Kopili, Amring, Barpani, Mynteng, Kharkor, Diyung, Umium, Umrong
7	*Ficus ischnopoda*	Moraceae	Kopili, Amring, Barpani, Mynteng, Kharkor, Diyung, Umium, Umrong
8	*Eriobotrya angustissima*	Rosaceae	Kopili, Amring, Barpani, Mynteng, Kharkor, Diyung, Umium, Umrong
9	*Phoebe angustifolia*	Lauraceae	Kopili, Amring, Barpani, Mynteng, Diyung, Umium, Umrong
10	*Ficus squamosa*	Moraceae	Kopili, Amring, Digaru, Barpani, Mynteng, Diyung,
11	*Homonoia riparia*	Euphorbiaceae	Kopili, Amring,
12	*Tarenna pumila*	Rubiaceae	Kopili, Diyung,
13	*Heptapleuram assamicum*	Araliaceae	Kopili, Barpani, Diyung,
14	*Munronia assamica*	Meliaceae	Kopili
15	*Huchimingia piscidia*	Fabaceae	Kopili
16	*Rotala rotundifolia*	Lythraceae	Kopili, Amring

and Meghalaya. Sixteen species were recorded from the Kopili River Basin. Range expansion of *Carissa kopilii*, *Syzygium cyanophyllum*, *Ixora yunnanensis*, and *Heptapleuram assamicum* was established. But species like *Syzygium nivae*, *Munronia assamica,* and *Pavetta puffii* were recorded from the type locality only. The remaining nine species of rheophytes were also recorded from different river tributaries in the Kopili Basin (Table 2).

Many rheophytic species are endemic to small areas, sometimes even to a single river (van Steenis 1981, 1987), and they are useful indicators of river health (Ameka et al. 1996). Several studies have documented that rheophyte taxa are often endemic with narrow distributions and fragmented populations, making them range restricted and often threatened (Philbrick et al. 2010; Yoshimura et al. 2019; Costa et al. 2020). Furthermore, due to their particular habitat, they are the first species to become locally extinct when a river is dammed or its flow regime is altered. Rheophytes are often disregarded in the environmental impact studies made for planning dams (Integral 2012). Relocation of individuals of narrowly endemic species is a difficult alternative, which often proves unsuccessful (Zimmermann 2011). This may be particularly true for those species growing on rock crevices, or that are firmly attached to submerged rocks.

This work urges botanists, conservationists, and policy makers to do more to protect the stretches and habitats in the Kopili River Basin of rheophytes and put in place strategies and action plans for the conservation of this important biological group.

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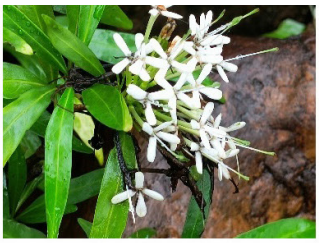
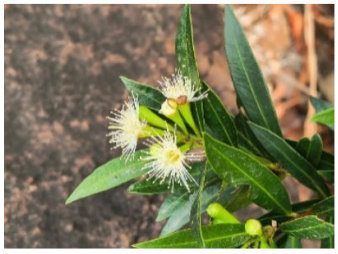
Carissa kopilii

Syzygium nivae



Pavetta puffii



Syzygium cyanophyllum

Ixora yunnanensis

Syzygium polypetalum

Ficus ischnopoda

Eriobotyra angustissima

Phoebe angustifolia

Ficus squamosa

Tarenna pumila

Homonoia riparia

Heptapleuram assamicum

Munronia assamic

Huchimingia piscidia

Rotala rotundifolia

Image 5. Rheophytes of the Kopili River Basin. © Jayanta Das.

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