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Cover: Life and death in one night - wolf hunting the hare. Mixed media—gouache, acrylics, pen & colour pencils. © Dupati Poojitha.

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ARTICLE

Negative interaction or coexistence? Livestock predation and conservation of wild carnivores in Kazinag National Park and adjacent region in the Kashmir Himalaya, India

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Abstract: Livestock predation by wild animals poses a significant challenge to communities residing in and around protected areas. This study aimed to assess the extent and patterns of livestock predation by Asiatic Black Bears and Leopards in villages around Kazinag National Park and adjoining areas: Limber Wildlife Sanctuary, Lachipora Wildlife Sanctuary, and Naganari Conservation Reserve, in Kashmir, India. Semi-structured questionnaire surveys and interviews conducted with residents and herders camping in the study area were used to collect data on livestock predation. A total of 72 livestock kills were documented for the years 2021 and 2022, involving Leopards and Black Bears. Statistical analysis revealed significant differences in predation patterns based on age class, livestock type, time & place of events, injury pattern, and body part affected. Sheep were most frequently targeted, with total economic loss estimated at >USD 15,000. Asiatic Black Bears primarily attacked at night and preferred cattle and sheep, while Leopards targeted goats and horses, peaking in summer and late autumn. The main factors influencing predation were grazing within the park and adjacent protected areas, and poorly constructed corrals. Mitigation strategies recommended include building robust corrals and designating specific grazing zones away from core wildlife habitats. The study emphasizes the need for comprehensive, context-specific approaches to ensure the long term human-wildlife coexistence in the region.

Keywords: Animal damage, Asiatic Black Bears, economic losses, leopards, livestock, management, predation, protected areas.

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Author contributions: UD—conducted fieldwork, collected data, performed formal analysis, curated data, and drafted the original manuscript. BAB—designed the study, supervised the research, provided resources, reviewed and edited the manuscript, and handled correspondence.

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INTRODUCTION

Human-wildlife negative interactions arise when the actions of wildlife have a negative impact on humans, or vice versa (Mekonen 2020). This conflict has serious consequences for both humans and wild animals, as well as the environment, by causing damage to crops, disturbance and destruction of habitats, predation on livestock, and killing of both wildlife and humans (Mekonen 2020; Merkebu & Yazezew 2021; Dwamena 2023). The perceived threats posed by wild animals to human economic assets like crops and livestock are considered a significant factor in the decline of many large mammalian species globally (Woodroffe et al. 2005; Pillai & Pillay 2016; Nyhus 2016). The establishment of protected areas (PAs) has played a crucial role in the conservation of wildlife (Ekka et al. 2022), yet these ecologically sensitive zones are facing increasing pressure from human-induced activities (Manral et al. 2016; Mengist 2020; Akrim et al. 2021).

The PAs are expected to achieve diverse conservation, social, and economic objectives (Job et al. 2020; Mengist 2020). However, increased livestock predation within these areas has a major negative impact on their perceived benefits (Parker et al. 2022; Lamichhane et al. 2023). Livestock predation is a significant issue in the PAs (Kuiper et al. 2021) due to shared resources between humans, livestock, and wild animals (Shrestha et al. 2022). Communities residing in and around PAs, often economically disadvantaged, depend on forests for sustenance (Mengist 2020; Gonçalves et al. 2022). Imposing restrictions without providing adequate benefits further strains their relationship with conservation efforts (Parker et al. 2022). Hence, ensuring viable alternatives for local communities is essential for effective conservation.

Big cats such as leopards and tigers in Asian countries are primarily responsible for the predation of livestock (Ramesh et al. 2020) but wolves, brown bears, and black bear also contribute substantially (Maheshwari & Sathyakumar 2020; Singh et al. 2024). The predation of livestock poses a substantial threat to the socio-economic fabric of agro-pastoral communities (Chinchilla et al. 2022). While large carnivores, humans, and livestock have coexisted for millennia, recent decades have witnessed an increase in human-wildlife conflicts (Woodroffe et al. 2005; Göttert & Starik 2022). This escalation is attributed to factors such as habitat fragmentation, human population expansion, diminished wild prey, and increased predator numbers due to the conservation laws (Alexander et al. 2016; Suryawanshi et al. 2017; Khanal et al. 2020).

Effective implementation of suitable mitigation measures is crucial for minimizing livestock predation and fostering coexistence between carnivores and agricultural communities. Mitigation approaches used globally, include eradicating or translocating the problem carnivore, zoning, aversive conditioning, shifting from small to large livestock, increasing wild prey availability, and employing livestock-guarding dogs and protective collars (Linnell et al. 2012; Chinchilla et al. 2022). Similarly, compensation for livestock losses due to predation is useful to increase public acceptance of predators (Ravenelle & Nyhus 2017), but may not always incentivize proactive conflict prevention (Braczkowski et al. 2020), and can be expensive and controversial. In contrast, incentive-based systems and insurance programs can encourage producers to adopt more effective mitigation strategies while being economically sustainable (Jacobs & Main 2015; Badola et al. 2021).

The Himalayan subtropical pine forest region falls within a high human-wildlife interaction zone (Sharma et al. 2020). The northwestern Himalaya is a prominent example of an area where diverse wildlife populations coexist with human communities, leading to frequent conflicts (Singh et al. 2024). Therefore, it is essential to shift from human-wildlife negative interactions to coexistence, which requires an extensive understanding of the reasons and spatial factors of the conflicts (Kuiper et al. 2021). We conducted this study to understand the livestock predation in and around Kazinag National Park (KNP) in the Kashmir Himalaya due to black bear and leopard. The main objective of the study was to provide a clear understanding of the pattern, and ways to mitigate livestock predation for long term conservation planning in the region.

Study Area

The current study was conducted in the KNP and adjacent areas: Limber Wildlife Sanctuary (LiWS), Lachipora Wildlife Sanctuary (LaWS), and Naganari Conservation Reserve (NCR). The KNP is situated within an altitude range of 2,100–4,305 m and falls between 34.178–34.2646 ^{0}N & 73.9971–74.2397 ^{0}E. The LiWLS lies between 34.2064–34.2129 ^{0}N & 74.1818–74.1990 ^{0}E. LaWLS lies between 34.1414–34.2043 ^{0}N & 74.0205–74.1238 ^{0}E, and NCR lies between 34.2064–34.2129 ^{0}N & 74.1818–74.1990 ^{0}E. Established in 2007, KNP was formed by integrating the core regions of LiWS, LaWS, and NCR. The survey was conducted in 10 villages, five from LiWS (Bodrali, Babagayl, Limber, Choolan, Kharaad, and Suchen), three from NCR (Naganari, Muqam, and

Zehanpoora), and two from LaWS (Lachipoora-A and Lachipoora-B).

Located approximately 70 km away from Srinagar near the Line of Control, the KNP is characterized by dense forests. It serves as a habitat for the 'Near Threatened' Markhor *Capra falconeri* and spans an area of 89 km^2. The park boasts a rich biodiversity, hosting a variety of wildlife, including 20 mammal species and 120 bird species (Farooq et al. 2021). Notably, it is also home to the Western Tragopan *Tragopan melanocephalus*, an avian species classified as 'Vulnerable' by the International Union for Conservation of Nature (IUCN) Red List. Asiatic Black Bears *Ursus thibetanus* and Leopards *Panthera pardus* are often involved in conflict with humans in the adjacent landscape of the KNP.

METHODS

Data on livestock populations were obtained from the Animal/Sheep Husbandry Department of Jammu & Kashmir and village heads (Table 1). Data on livestock predation by the Asiatic Black Bear and the Leopard were collected from KNP, LiWLS, LaWLS, and NCR using semi-structured questionnaires, following the approach outlined by Dhungana et al. (2019). The chain-referral sampling method (Noy 2008; Akrim et al. 2023) was employed, wherein village heads initially provided information about predation incidents in their communities. Afterward, the owners of the affected livestock were interviewed using purposive non-probability sampling to gather detailed information. This included the species of livestock killed, the sex and age of the animal, the feeding pattern, the time and date of the incident, the predator responsible, and the geocoordinates of the predation site. The questionnaire was originally prepared in English, which was translated into the local languages, i.e., Kashmiri and Urdu, for understanding of the local population in the study area.

Where possible, information on livestock predation incidents was further cross-verified by other residents. Monthly visits to the village heads were carried out over a two-year period (January 2021 to December 2022) to document any new predation incidents. A total of 62 individuals were contacted during the study, out of which 42 provided complete responses. This targeted approach ensured that data were drawn from direct conflict incidents rather than general perceptions, which could introduce unrelated variables. Limiting the sample to directly impacted households mitigates potential study bias by focusing on genuine conflict cases.

We categorized livestock into specific age classes as follows: neonates (newborn to a few months old), juveniles (beyond the neonate stage but not yet fully grown), sub-adults (close to maturity), adults (fully mature), and pregnant females. Seasons were also categorized: winter (December, January, February), spring (March, April, May), summer (June, July, August), and autumn (September, October, November). In order to analyse the temporal patterns of livestock predation, each incident was categorized based on the time of occurrence. The timing categories were defined as follows: morning (0500–1000 h), day (1000–1600 h), evening (1600–2100 h), and night (2100–0500 h).

The economic valuation of livestock losses was conducted using current local market prices from key markets in the Kazinag region, including Baramulla and various village-level markets (Supplementary Table 1). This valuation took into account the type of animal, along with its age and gender, to provide an accurate estimate of the financial impact on affected households. Notably, no substantial pricing variations were observed between the larger urban markets and the local village markets.

Data analysis

We conducted all the statistical analyses using the R software 4.2.2 (R Core Team 2022). Since the data was categorical, we used Pearson's chi-square test of independence to investigate statistical differences between the incidents of Asiatic Black Bears and Leopards with respect to (i) age classes; (ii) livestock type; (iii) months; (iv) place of event; (v) time of event; (vi) village; (vii) gender; (viii) injury pattern; (ix) feeding pattern; and (x) body part affected.

In addition to assessing statistical significance with the chi-square test, we examined over-represented and under-represented categories to gain deeper insights into the patterns of predation incidents. By comparing observed counts within each category combination (e.g., age class, livestock type, and time of event) to

Table 1. Total livestock holding across the study areas. (Source: Animal/Sheep Husbandry & Fisheries Department of Jammu & Kashmir and village heads).

Study area	Villages (n)	Sheep	Goat	Cattle	Horse
Limber Wildlife Sanctuary	6	2486	720	389	56
Lachipora Wildlife Sanctuary	2	1498	365	63	30
Naganari Conservation Reserve	3	997	381	377	16

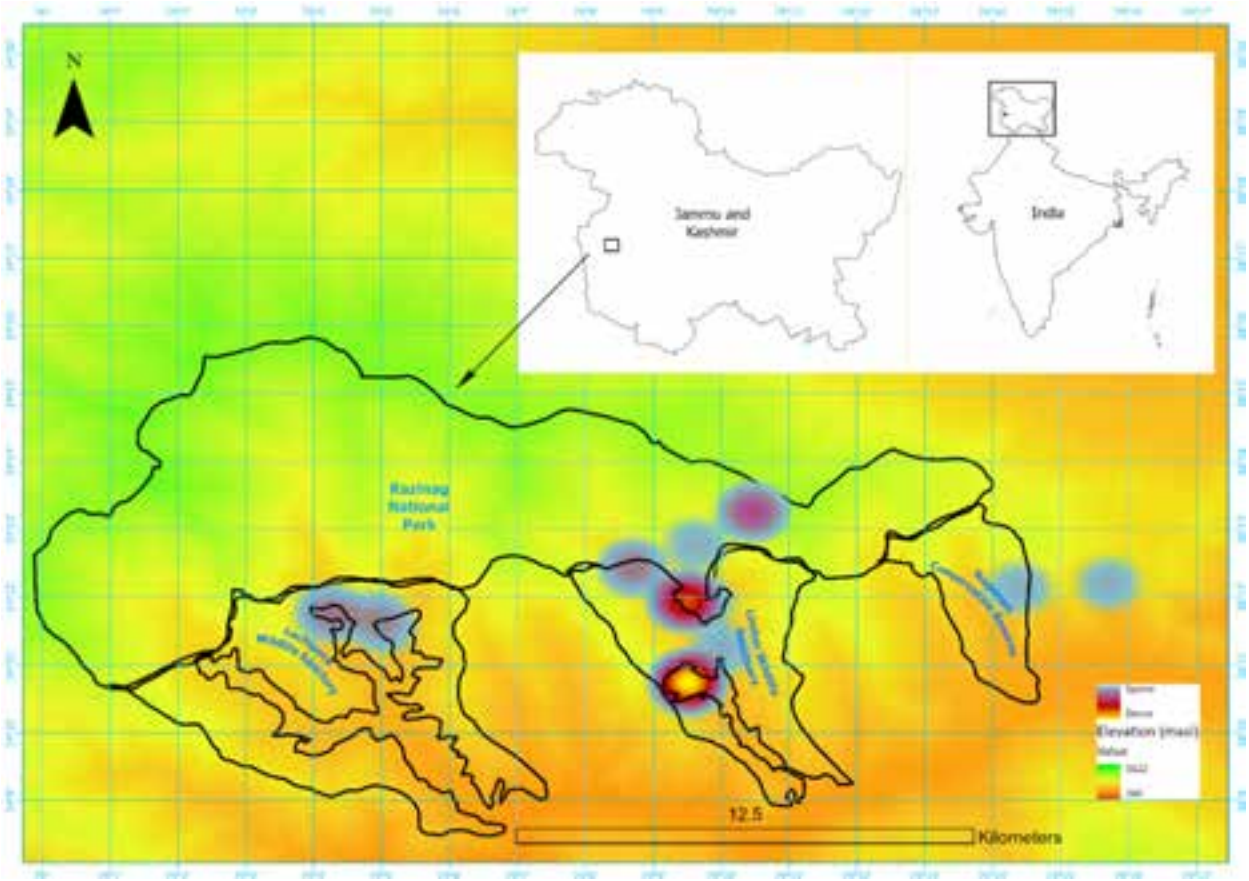

Figure 1. Study area showing livestock predation sites.

the expected counts, we identified specific scenarios where predation was higher or lower than anticipated. We expressed Pearson's residual scores as the degree of deviation between observed and expected counts using the "vcd 1.4-8" package (Meyer et al. 2020). This analysis is relevant as it highlights specific factors or conditions (such as certain livestock types or times of day) that may influence predator behaviour, aiding in identifying risk factors for livestock predation.

We conducted a regression analysis to examine the relationship between the number of animals predated as a dependent or response variable and several factors as independent or predictor variables, including the distance from human habitation, distance from the forest, the gender and age class of the predated animal, the season of the predation incident, and the time of the incident. For the regression models, we calculated the variance explained (i.e., $R_{adj.}^2$) and the associated statistical significance at P ≤0.05 level (i.e., 5% level of significance).

RESULTS

Livestock Types and Losses

Across the study area, four main types of livestock were reared: sheep, goat, cattle, and horse. During the study period, a total of 72 livestock kills in 42 incidents were documented in the villages surrounding KNP, with an equal number of cases attributed to Leopards (n = 36) and Asiatic Black Bears (n = 36). Notably, eight of these incidents involved mass killings, with each event resulting in the predation of 2–10 livestock in a single attack. The total economic loss due to these predation events was estimated at USD 15,887 over the two years.

Analysis of Predation Patterns

Significant differences (χ^2 = 31.89, df = 3, p <0.001) were observed in the types of livestock preyed upon by each predator species. Incidents involving Asiatic Black Bears were predominantly higher for cattle and sheep, whereas Leopard-related attacks were more frequent on goat and horse (Figure 2). Among different livestock types, sheep were the most frequently preyed upon,

accounting for 45.83% of total kills by both predator species.

Further analysis showed that the age of livestock significantly influenced predation patterns (χ^2 = 13.16, df = 4, p = 0.015). Asiatic Black Bear attacks were disproportionately high among neonates, and pregnant females, while Leopard attacks were more common among juveniles, and sub-adults. Additionally, significant differences were observed in predation patterns across age classes within each livestock species killed by both predators (χ^2 = 31.8, df = 12, p = 0.012). For Cattle, both predators primarily targeted younger age groups, as well as pregnant females; sub-adults and adults were less frequently attacked. Predation on goat was mainly concentrated among sub-adults. Horses were more commonly targeted in sub-adult age group. In contrast, sheep experienced a higher incidence of predation among adults and pregnant females.

Seasonal and Temporal Patterns

The study found distinct seasonal trends in predation. Asiatic Black Bear attacks were more common in spring (97%), while Leopard attacks showed bimodal peaks during spring (44%) and summer (33%) (Figure 3). These seasonal differences were statistically significant (χ^2 = 24.38, df = 3, p <0.001).

Temporal variations were also observed, with most predation incidents (56.6%) occurring at night. Asiatic

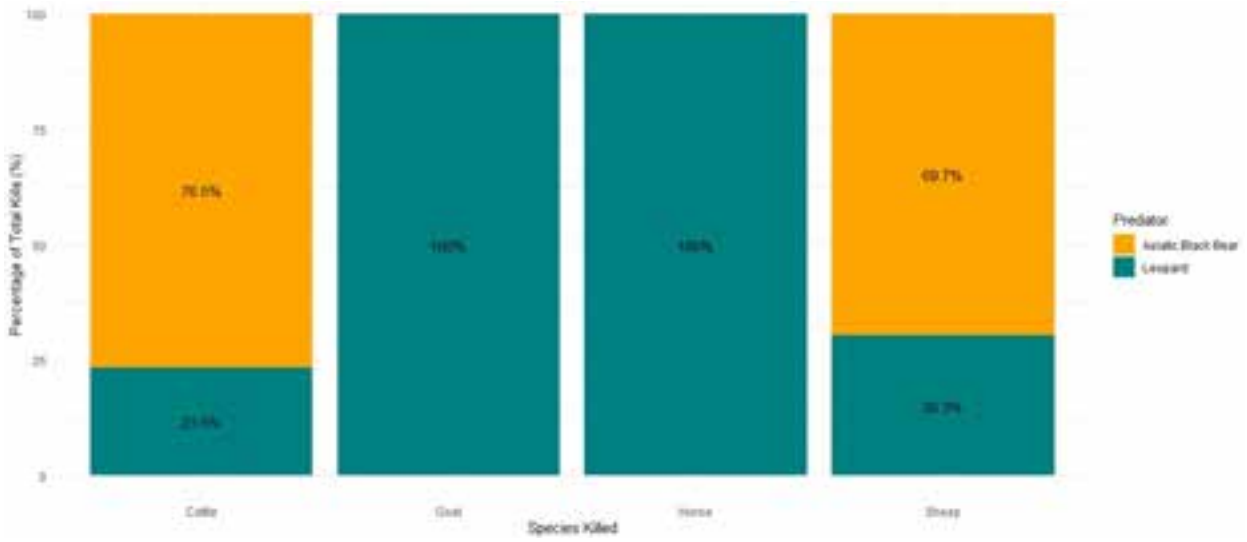

Figure 2. Livestock type killed by predators.

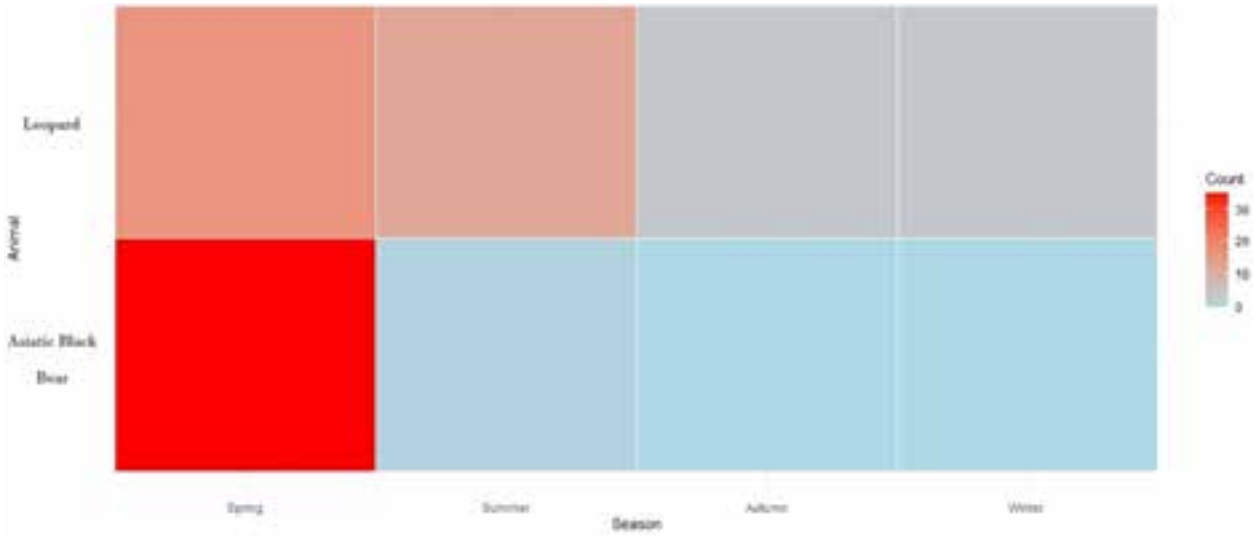

Figure 3. Livestock predation by the two large carnivores across different seasons in the study area.

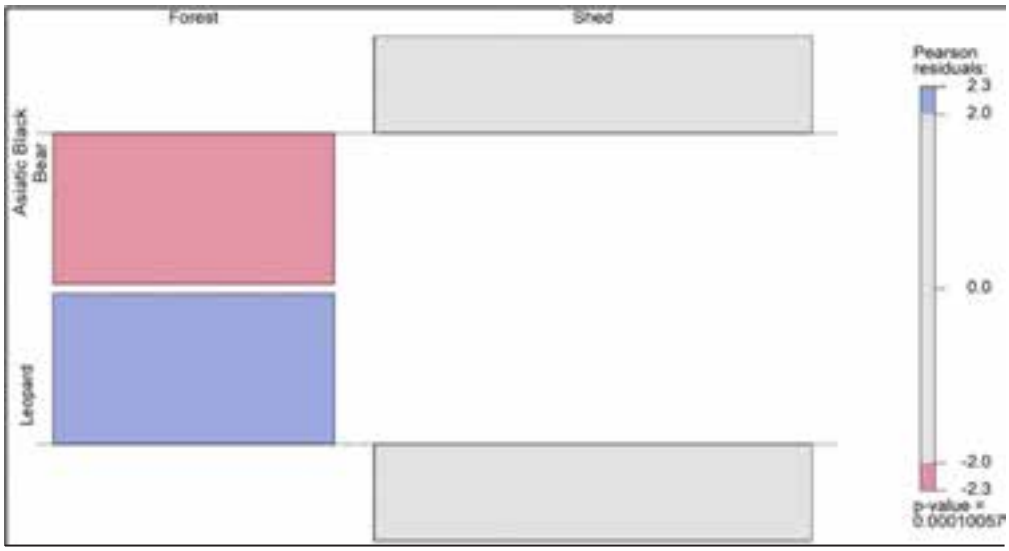

Figure 4. Pearson's residuals for the number of animals killed by the two predators against place of event.

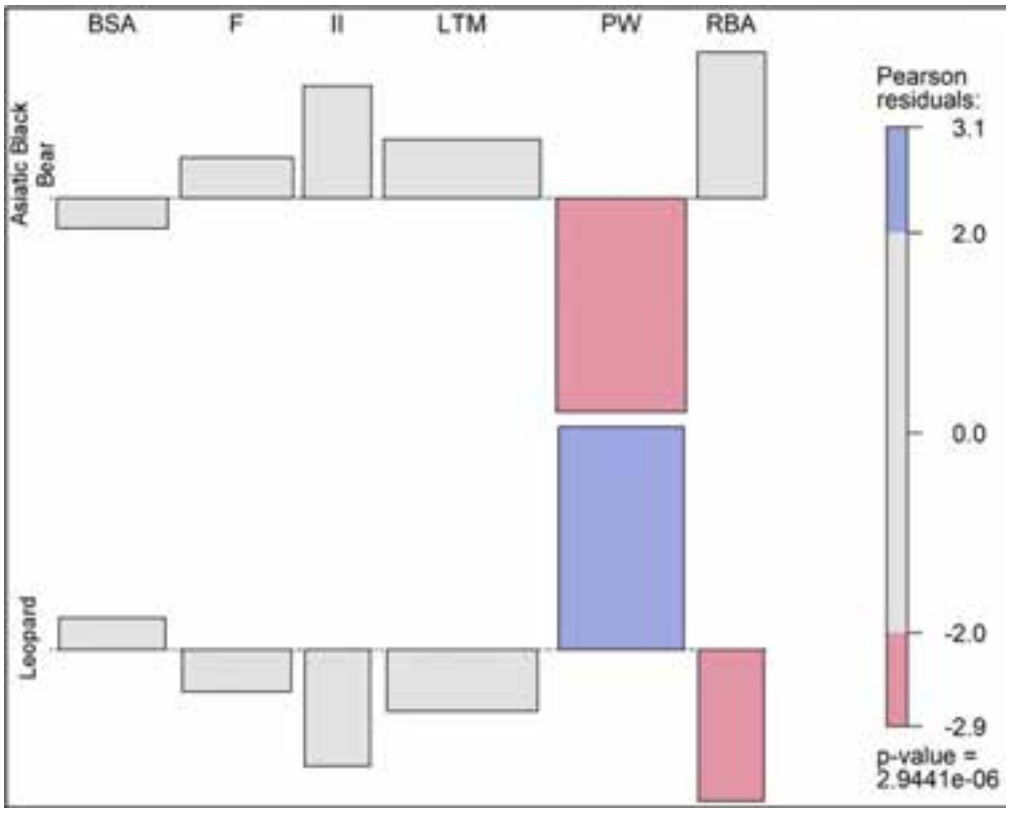

Figure 5. Pearson's residuals for the number of animals killed or injured by animal type against injury pattern. BSA—Bruises/Scratches/Abrasions | F—Fractures | II—Internal injuries | LTM—Lacerations/Torn Muscles | PW—Puncture wounds | RBA—Ripped Belly/Abdomen.

Black Bear attacks were predominantly nocturnal, while Leopard attacks occurred more often during the day (χ^2 = 16.7, df = 2, p <0.001).

Influence of Spatial Factors

The location of predation incidents also differed significantly (χ^2 = 13.18, df = 1, p <0.001) between the two predators: Asiatic Black Bear attacks were more

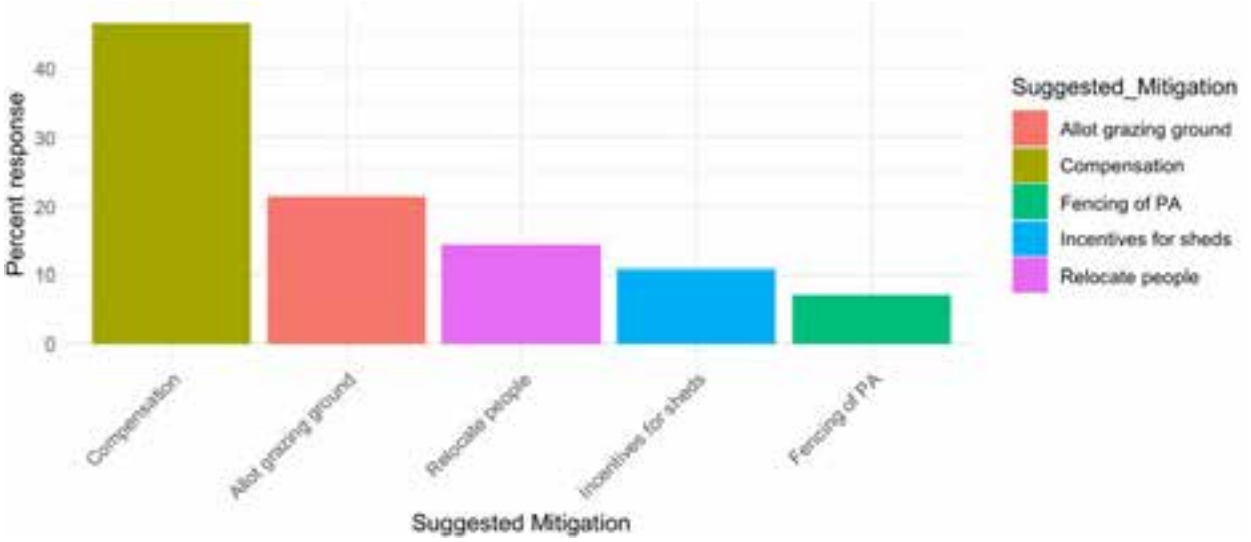

Figure 6. Suggested mitigation methods by respondents to alleviate livestock damage.

common in corrals or sheds during night-time, whereas Leopards were more likely to attack in forested areas during the day (Figure 4).

Determinants of Livestock Predation

The results of the Poisson regression model indicated several significant predictors influencing the number of livestock predated. The intercept (β = −2.270, p = 0.079) suggests a baseline level of predation when all predictors are at their reference levels. Among the categorical variables, the age class of livestock significantly affected predation rates. Juveniles (β = 2.108, p = 0.007), sub-adults (β = 1.678, p = 0.029), and adults (β = 1.71, p = 0.026) were more likely to be predated. Similarly, the month of incidence showed a significant effect, with predation events being higher during spring (β = 1.66, p = 0.004). Other variables, such as gender, time of incidence, and distance from habitation or forest, did not show statistically significant effects on predation. We also found a strong positive correlation between the total number of livestock held and the number of animals lost to predation (r^2 = 0.72, p = 0.019).

Patterns of Injury

The types of injuries inflicted by the two predator species showed significant difference (χ^2 = 33.54, df = 5, p <0.001). Asiatic Black Bear attacks were more likely to cause fractures, internal injuries, lacerations, and ripped abdomens, while Leopard attacks commonly resulted in bruises, scratches, abrasions, and puncture wounds (Figure 5). Further analysis of the body parts affected by these attacks showed that Asiatic Black Bears inflicted injuries mainly on the abdomen, flank, head, limbs, and underbelly, whereas Leopards targeted the face, groin, nape, neck, and spine (χ^2 = 52.83, df = 13, p <0.001).

Community-Recommended Mitigation Strategies

The majority of respondents (46.42%) advocated for the provision of ex-gratia as a primary measure to compensate livestock losses caused by wild animals (Figure 6). Other suggestions included allocating government-designated grazing grounds (21.42%), providing financial assistance for building better livestock sheds (10.71%), relocating communities from high-interaction zones (14.28%), and implementing fencing around protected areas (7.14%).

DISCUSSION

Our study highlighted substantial predation on livestock by Leopard and Asiatic Black Bear in villages around Kazinag National Park, with seasonal and spatial variations in attack patterns. These findings align with previous research on livestock predation by carnivores (Akrim et al. 2023; Singh et al. 2024), suggesting that carnivore preference for certain livestock types and predation timings are likely influenced by ecological and behavioral factors. Although, the overall incidence of livestock predation was relatively low, and randomly distributed in our study area. A few herders bore the brunt of the losses, leading to a domino effect that exacerbated the impact on their livelihoods. The reported economic loss of USD 15,887, in the two-year

study period is substantial for the communities around KNP, who are primarily dependent on the livestock and/or agriculture. This substantial loss has driven many people in the study area to abandon livestock rearing, which has profound implications for local economies and traditional ways of life.

Our study found that sheep were primarily predated by both predators, similar with findings of Khan et al. (2018) in Pakistan from similar landscape. This high rate of predation is likely due to the large sheep population in the study villages, making them more readily available as prey. Leopards showed a clear preference for goats, hunting them more often than expected based on their availability. This behaviour is similar to findings by Dhungana et al. (2019) in Nepal, where Leopards were found to prefer prey within a weight range of 10–40 kg. Conversely, Asiatic Black Bears preyed upon all types of livestock, with no specific livestock preference, illustrating the opportunistic nature (Bowersock et al. 2021) of Asiatic Black Bear predation.

In ecosystems with diverse resources and pronounced seasonal changes, large carnivores frequently adopt opportunistic foraging strategies, adjusting their prey preferences and hunting behaviors with the seasons (Davidson et al. 2013). Consistent with this, our study observed significant seasonal variations in predation patterns, with Leopard attacks showing bimodal peaks in summer and spring. The seasonal variation of Leopard predation can be related to the grazing cycle in the study area which involves moving livestock to higher altitudes (behaks) from May to June, followed by partly attended or unattended livestock grazing in summer pastures (July to August), and free grazing in and around village forests from September to April. During summer, livestock grazing pushes natural prey of Leopards away (Khan et al. 2018), resulting in increased predation on livestock during these months.

The increased livestock killings by Asiatic Black Bear in spring can be attributed to lesser availability of natural food. Asiatic Black Bears rely on high-quality food throughout the year, consuming soft mast such as berries in summer and hard mast like nuts and acorns in autumn (Bowersock et al. 2021). In spring, the scarcity of these food sources may drive Asiatic Black Bears to seek alternative foods, such as livestock, to fill their nutritional gap (Malcolm et al. 2014). This dietary shift underscores the bears' adaptability to changing food availability and points to a heightened risk of human-wildlife conflicts during periods of food scarcity. These findings underscore the seasonal dynamics in livestock predation incidents, emphasizing the necessity of considering temporal trends when devising and implementing effective management and mitigation strategies for human-wildlife conflict.

Statistical analysis of spatial factors influencing livestock predation revealed distinct patterns between Asiatic Black Bears and Leopards. Asiatic Black Bears frequently attacked livestock housed in corrals during night-time, where confined spaces offer them a concentrated and easily accessible food source. As opportunistic feeders (Kozakai et al. 2020), Asiatic Black Bears readily exploit these enclosures, and insufficient night-time protection further increases the risk of predation. Night-time attacks in corrals often led to mass killings, severely impacting herders' livelihoods. Similar trends were observed by Samelius et al. (2021) in the Tost Mountains, South Gobi, Mongolia, where such incidents fostered negative attitudes towards conservation and sometimes led to retaliatory actions against wildlife. The prevalence of Asiatic Black Bear attacks at night underscores the importance of enhancing protective measures in corrals to mitigate economic losses and improve coexistence.

In contrast, Leopards showed a preference for forested environments, where they rely on stealth and camouflage to hunt. As solitary predators (Roex et al. 2022), Leopards use dense vegetation for concealment, allowing them to approach and ambush prey effectively, which aligns with their natural hunting strategies (Beattie et al. 2020). Leopard attacks were more frequent during the day, highlighting the importance of attended livestock grazing and regulated grazing in the forested areas to reduce predation risks.

The distinct injury patterns inflicted by Asiatic Black Bears and Leopards provide insight into each predator's hunting strategy and physical characteristics (Stirling & Derocher 1990; Pawar et al. 2018; Lin et al. 2020). Asiatic Black Bears caused more severe injuries, such as fractures and internal injuries, due to their larger size and powerful attacks. Leopards, in contrast, inflicted bruises, abrasions, and puncture wounds consistent with quick, immobilizing attacks aimed at disabling prey with minimal exertion, aligning with their ambush style (Pawar et al. 2018; Lin et al. 2020). These findings not only aid in identifying the predator responsible for attacks but also underscore the need for targeted veterinary interventions post-attack to improve livestock survival rates.

Ex-gratia compensation, suggested by nearly half of the respondents, has shown to mitigate negative attitudes by providing financial relief to affected communities (Braczkowski et al. 2020; Mekonen 2020).

However, compensation alone may not address the root causes of conflict; it is essential to couple financial support with preventive measures, such as secure corrals and designated grazing zones, to minimize predation. We identified two main factors responsible for livestock predation in the region: grazing within designated protected area boundaries and inadequately constructed corrals. Additionally, villages with larger livestock holdings were found to experience higher rates of predation, likely due to the increased availability of prey. Livestock rearing and agriculture are essential economic activities for local communities in the study area. Consequently, losses in these sectors affect not only the economic stability but also the mental and emotional well-being of these communities.

This study advocates for an integrated approach to mitigate livestock predation in the villages around KNP. Beyond financial compensation, effective conflict management requires preventive strategies tailored to the seasonal and spatial patterns identified in this study. Robust livestock enclosures, night-time monitoring, rotational grazing, and alternative grazing areas are recommended to reduce predation risks. Additionally, fostering community awareness on coexisting with wildlife and the ecological role of predators can contribute to long-term conservation goals.

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Supplementary Table 1. Market prices of livestock by species, age, and sex.

Species killed	Gender	Age (in years)	Market value
Cattle	F	1	18000
Cattle	F	1.5	20000
Cattle	F	2	25000
Cattle	F	3	70000
Cattle	F	4	70000
Cattle	F	5	65000
Cattle	F	6	60000
Cattle	F	7	50000
Cattle	F	8	45000
Cattle	M	0.4	5000
Cattle	M	0.5	5000
Cattle	M	1	15000
Cattle	M	2	25000
Cattle	M	3	35000
Cattle	M	4	45000
Cattle	M	5	45000
Cattle	M	6	40000
Cattle	M	7	40000
Cattle	M	8	30000
Goat	F	1	7500
Goat	F	2	8000
Goat	F	3	10000
Goat	F	4	8000
Goat	F	5	8000
Goat	F	6	7000
Goat	M	1`	7000
Goat	M	2	9000
Goat	M	3	12000
Goat	M	4	14000
Goat	M	5	11000
Goat	M	6	10000
Horse	M	1	20000
Horse	M	2	30000
Horse	M	3	45000
Horse	M	4	50000
Horse	M	5	55000
Horse	M	6	55000
Horse	M	7	55000
Horse	M	8	55000
Horse	M	9	55000
Horse	M	10	55000
Sheep	F	1	6000
Sheep	F	2	10000
Sheep	F	3	10000
Sheep	F	4	8000
Sheep	F	5	8000
Sheep	F	6	7000
Sheep	M	1	8000
Sheep	M	1.5	8000
Sheep	M	2	10000
Sheep	M	2.5	12000
Sheep	M	3	15000
Sheep	M	4	17000
Sheep	M	5	20000
Sheep	M	6	20000

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ARTICLE

Avifaunal diversity and conservation significance of coastal ecosystems on Rameswaram Island, Tamil Nadu, India

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Abstract: Biodiversity-rich areas tied to heritage, religious tourism, and ecotourism, often face changes to their landscapes due to infrastructure development. Such activities may threaten the species survival and disrupt the delicate ecosystems in these regions. Hence it becomes imperative to build up baseline species data from such areas for biodiversity conservation and management interventions. Towards achieving this objective, avifaunal inventories were documented from Kothandaramar Lagoon, Dhanushkodi Lagoon, and the Arichalmunai beach in Rameswaram Island, Ramanathapuram District, Tamil Nadu, which is an important site for winter migrants. A total of 147 avian species belonging to 17 orders and 45 families from August 2021 to July 2023 were recorded. Order-wise, Charadriiformes (52 species) dominated the area, followed by Passeriformes (27 species) and Pelecaniformes (21 species). According to the IUCN Red List of Threatened Species, 11 'Near Threatened', three 'Vulnerable', two 'Endangered' (Great Knot *Calidris tenuirostris* and Siberian Sandplover *Anarhynchus mongolus*), and one unassessed species (Hanuman Plover *Charadrius seebohmi*) were recorded. The relative abundance based on the frequency of observations indicated that 61% (90 species) were common, 22% (32 species) were uncommon, and 17% (25 species) were rare. Winter visitors constituted 42% (62 species) and one was a passage migrant (Rosy Starling *Pastor roseus*). Coastal lagoons of this region comprise diverse habitats that play a vital role for birds, which provide places for nesting, roosting, and foraging. This baseline data emphasizes the importance of Dhanushkodi Lagoon along with adjacent areas as an important wintering site on the southeastern coast of India for migratory shorebirds as well as highlights the importance of adjoining small forested patches thus required to be declared as a protected area.

Keywords: Bird migration, Central Asian Flyway, Gulf of Mannar, Hanuman Plover breeding, over-summering, shorebirds, waterbirds, winter visitors.

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Author details: Byju, H., has worked on the shorebirds and waterbirds in the Gulf of Mannar region for a decade and at present a member of the biodiversity panel of five bird sanctuaries including two Ramsar sites and the Gulf of Mannar Biosphere Reserve. Maitreyi, H., is a research scholar working on seabirds in the region. Raveendran, N., is a naturalist with a decade of experience in birds and awareness education and serves as a biodiversity member in the bird sanctuaries and Gulf of Mannar Biosphere Reserve. Ravichandran, S., is a professor with three decades of experience in marine ecology and oceanography.

Author contributions: BH—conceptualization, writing, editing and supervision, MH—writing, editing, data management and maps, RN—data curation; SR—editing and overall supervision.

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INTRODUCTION

India is home to numerous biodiversity hotspots including those designated as Ramsar sites (Sandilyan 2017). Wetlands including coastal lagoons, characterized by shallow water bodies separated by natural barriers like sandbars or coral reefs support diverse avifauna, both migratory and resident (Chandana et al. 2012; Silva et al. 2013). Coastal lagoons are critical habitats for migratory shorebirds such as mudflats, beaches, or mangroves (Alfaro & Clara 2007). Migratory shorebirds are a global indicator species for habitat changes (Piersma & Lindstrom 2004). As India experiences a massive economic boom, many unprotected areas are under severe strain on landscape changes and biodiversity loss, and many of these areas lack biodiversity documentation to understand the actual loss. Documentation of avifaunal diversity and distribution in India (Ali & Ripley 1987) has played a pivotal role in assessing long-term landscape changes (Rika & Santosa 2007). Bird surveys represent a valuable tool in gathering pertinent information and aid in identifying priority conservation sites (Peterson et al. 2000) as the structural composition of bird communities within an area provides invaluable insights into landscape changes over time (Kattan & Franco 2004). This comprehensive understanding has facilitated ecological assessments and conservation planning efforts (Kati & Sekercioglu 2006), leading to the development of management strategies and interventions (Paul & Cooper 2005).

The Ramanathapuram District in Tamil Nadu harbours five bird sanctuaries, including two Ramsar sites and the Gulf of Mannar (GoM) Biosphere Reserve, an Important Bird and Biodiversity Area (IBA). Recent records of an Arctic Skua *Stercorarius parasiticus* (Byju & Raveendran 2022a) and an uncommon sighting of a Light-mantled Albatross *Phoebetria palpebrate* (Byju & Raveendran 2022b) underscore the importance of bird monitoring efforts in the island. It also highlights the necessity of conducting field surveys to establish bird population data in new or adjoining areas of well-established bird congregation sites (Llanos et al. 2011). Extensive research and conservation interventions will help manage threats like pollution, habitat loss, hunting, disturbance, or impact of climate change. Several reports emphasized that habitat destruction is one of the vital reasons for the decline of waterbirds (Brooks et al. 2002; Sandilyan et al. 2010). Coastal wetlands of tropical countries including India, face impounding anthropogenic pressures, leading to the rapid loss of these ecosystems. Most of such pressures are related to the conversion of the coastal wetlands for agriculture, aquaculture, tourism, transport, construction, and disposal of industrial wastes and untreated sewage (Prasad et al. 2002; Bassi et al. 2014). Avifaunal updates from the district include documentation from the 21 islands within the GoM (Byju et al. 2023a) and identification of a new wintering sites within the Karangadu Mangroves (Byju et al. 2023b) and Valinokkam Lagoon (Byju et al. 2023c). Through intensive monitoring, three breeding sites of the new taxon, i.e., Hanuman Plover *Charadrius seebohmi* from the Kentish Plover subspecies *Charadrius alexandrinus seebohmi* have been discovered in the district (Byju et al. 2023d), which encompasses the current study area.

The mentioned findings from the region underscore the importance of gathering baseline data from previously unexplored regions to designate areas of conservation significance. Consequently, the present study on the Kothandaramar Lagoon, Dhanushkodi Lagoon, and Arichalmunai Beach in Rameswaram Island was devised to compile an avifaunal checklist since this is an important bird congregation place for long distant migrant shorebirds on the GoM region in the Central Asian Flyway (CAF) (Rashiba et al. 2022) and the findings will contribute to declare it as a protected area. Additionally, our additional objectives of the study include the impact of tourism on the coastal areas by vehicles and plastic waste disposal by the visitors (religious, heritage, and ecotourism initiatives).

MATERIALS AND METHODS

Study Area

The study area extended from the Rameswaram Reserve Forest up to Arichalmunai Beach encompassing the 15 km long Dhanushkodi Lagoon (Image 1). It consists of the Kothandaramar Lagoon, Dhanushkodi Lagoon, and Arichalmunai Beach, which hereafter is referred to as Dhanushkodi Lagoon (9.15–9.27 N & 79.32–79.44 E). This area includes zones that are muddy and flooded with rain water during winter months like Kothandaramar Lagoon which is surrounded by the Bay of Bengal and GoM, having saline water which leads to plenty of phytoplankton including diatoms, dinoflagellates, and blue green algae. It provides a foraging ground for flamingos. The Arichalmunai part is exclusively marine earlier with sandy beaches but some muddy substratum of late becoming sandier; the central part near Mukundarayar Chatram and Dhanushkodi is a mixture of sandy clay and thus intermediate between the other two zones.

Field Surveys

In Dhanushkodi Lagoon, field surveys were conducted monthly from August 2021 to July 2023. The surveys focused on observing bird activity during the peak hours, at 0600–1000 h and 1600–1800 h. The methodology employed a combination of block count and direct visual count methods (Howes & Bakewell 1989; Bibby et al. 2000). Eleven vantage points (Image 1) were identified along the entire stretch of the lagoon considering the consistent water availability and congregation patterns, with distances ranging 600–1,500 m starting from the forested patch. Observations were conducted using Nikon binoculars (10 x 50) and photographs were taken with a Canon camera with 100–400 mm lens and later identified with the help of field guides (Grimmett et al. 2011; Hayman et al. 2011). Since this is a 15-km long stretch with different tidal variations, survey were conducted during low tides when the maximum bird activity was there, mainly for waterbirds. A 5-min setting period was observed at each vantage point to allow the waterbirds to settle down to the human presence. Land birds were recorded as and when it was observed at each vantage point for 15 min. The observations recorded while moving from one vantage point to another were entered as incidental records. The residential status of the birds was grouped as resident (R), resident/ non-breeding (R/NB), passage migrant (PM), and winter visitor (WV) depending on their timing and duration of occurrence (Grimmett et al. 2011). The common name, scientific name, and IUCN Red List status are followed (IUCN 2024). The relative abundance of species was based on the frequency of observation as common (C): frequently observed in the study area (encountered on most visits 6–8/10 visits); uncommon (UC): spotted on multiple occasions but not as frequently as in the case of common (encountered less than 3–5/10 visits); rare (R): less frequently encountered in the entire study period (encountered 1–2/10 visits) (Mackinnon & Philips 1993).

To understand the impact on the number of tourists visiting the Arichalmunai region of the island, the number of tourist vehicles and the local vehicles plying on the road were counted, with the help of the forest department from the forest check post exclusively for plastic usage deterrence in the area. An average of 300 tourist vehicles plies were found along with 200 local vehicles to Kothandaramar Temple (religious tourism) and beyond to Arichalmunai (beach drive) every weekday (Image 12). This increased up to 700

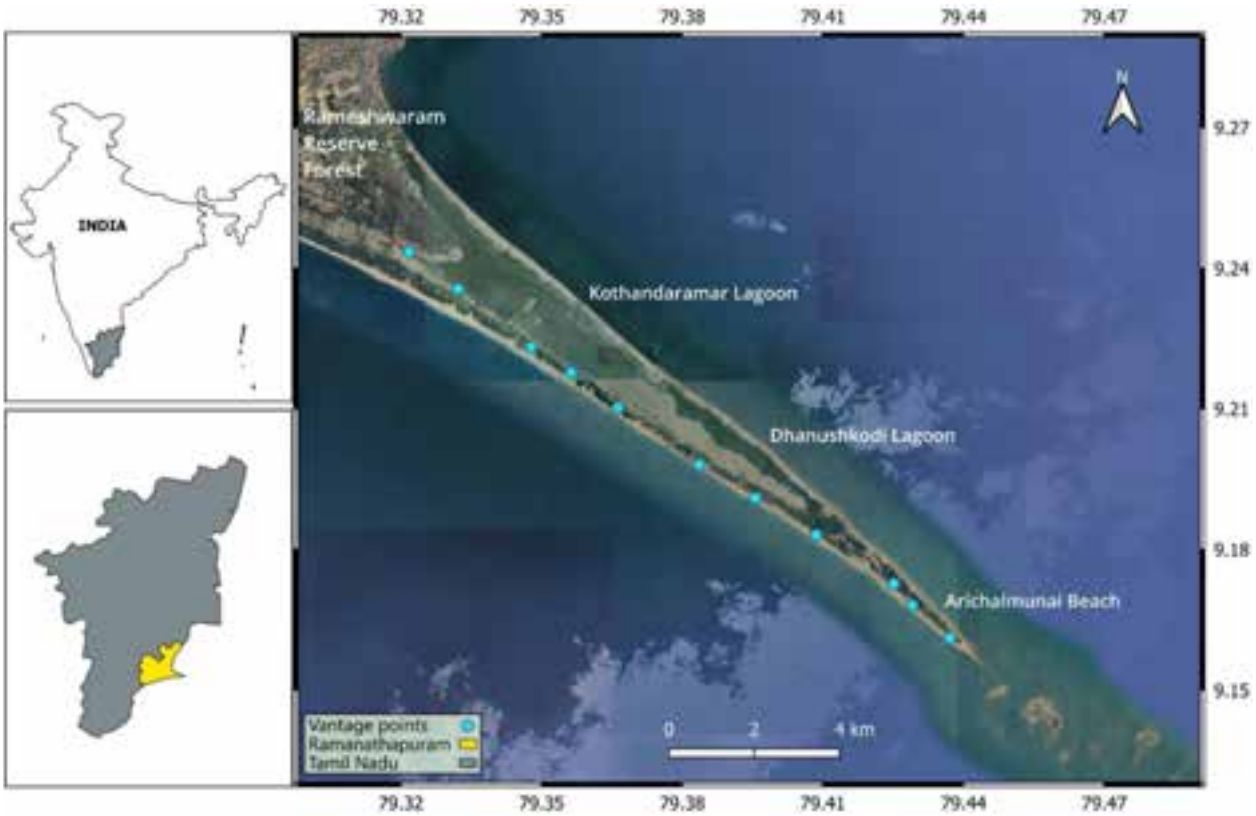

Image 1. Study area showing the vantage points in Dhanushkodi Lagoon.

during weekends with 300 local vehicles (total 1,000). Assuming a vehicle can accommodate an average of four people (a tourist van can hold up to 15), the number of tourists could be 2,000–4,000 individuals per day/week and up to 800,000/year. The area is restricted for tourists after 1800h and a few fishermen community stay there overnight, for fishing purposes.

RESULTS AND DISCUSSION

A total of 147 avian species across 17 orders and 45 families from the study area (Table 1) (Images 2–8) were recorded. Order Charadriiformes was the most dominant (52 species), represented by families of Scolopacidae (25 species), Laridae (17 species), and Charadriidae (10 species). The other major representation of orders was Passeriformes (27 species), Pelecaniformes (21 species), and Accipitriformes (10 species) (Figure 1). The residential status of the birds revealed that winter visitors (WV) constituted 42% (62 species) and one (i.e., Rosy Starling *Pastor roseus*) was passage migrant (PM). Three species of local migrants (LM) recorded, were Western Reef Egret *Egretta gularis*, White-bellied Sea Eagle *Icthyophaga leucogaster,* and Oriental Honey Buzzard *Pernis ptilorhynchus*. Among the avifauna recorded, 54 species constituted 36.7% of residents (R), and 26 species (17.6%) were residents but non-breeding (R/NB). The relative abundance based on the frequency of observation indicated that 90 species (61.2%) were common, 32 species (21.7%) were uncommon, and 25 species (17%) were rare.

The arrival of migrants usually begins in the first week of August and departure of migrants extend till the last week of April to the first week of May. Family Stercorariidae with two exclusive seabirds, Arctic Skua *Sterocorarius parasiticus* and Pomarine Skua *Sterocorarius pomarinus*; rare seabirds like Flesh-footed Shearwater *Ardenna carneipes*; and rare shorebirds like Red-necked Phalarope *Phalaropus lobatus* were recorded during the migratory period. Among the Laridae family, Bridled Tern *Onychoprion anaethetus*, Sooty Tern *Onychocommonprion fuscatus,* and White-winged Tern *Chilidonias leucopterus* are the highlighted (rare) species from the study area. Eleven 'Near Threatened' (NT) species were documented during the study period, all of which are waterbirds or shorebirds: Bar-tailed Godwit *Limosa lapponica,* Black-tailed Godwit *Limosa limosa*, Ruddy Turnstone *Arenaria interpres*, Dunlin *Calidris alpina*, Eurasian Curlew *Numenius arquata,* Great Stone-curlew *Esacus recurvirostris*, Red-necked Stint *Calidris ruficollis,* Red Knot *Calidris canutus,* Spot-billed

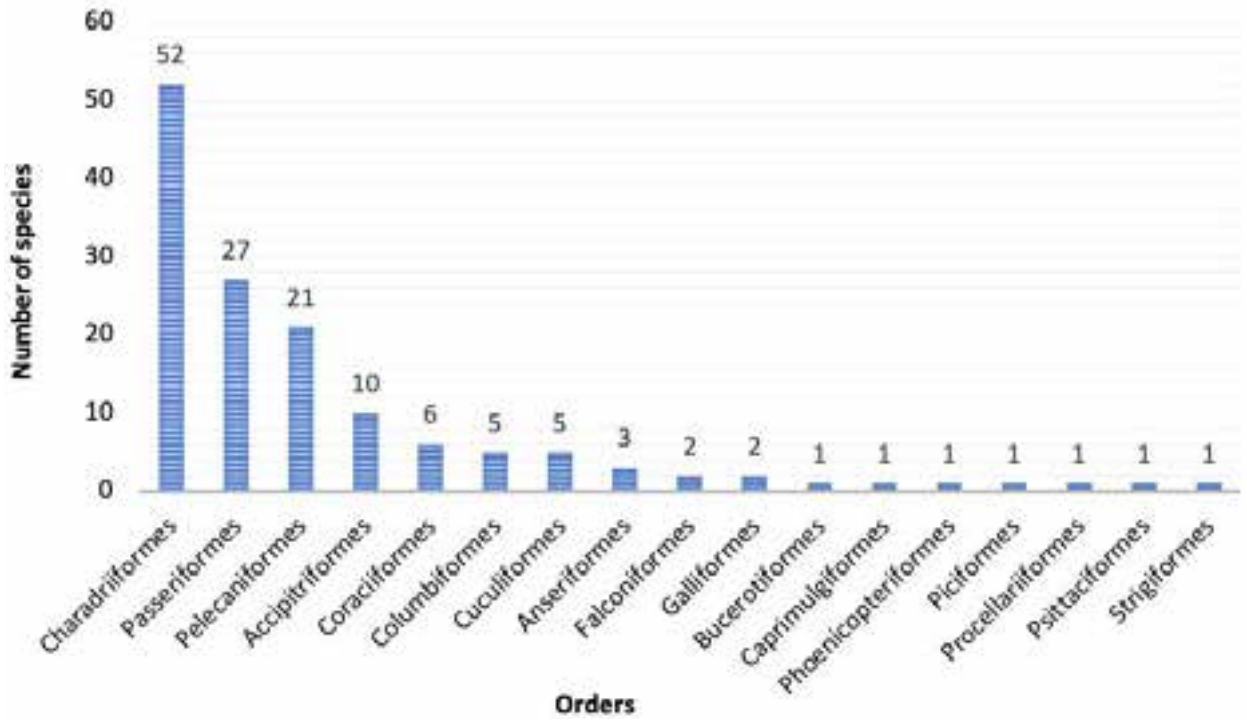

Figure 1. Order-wise representation of bird species at Dhanushkodi Lagoon.

Table 1. Avifaunal checklist of Dhanushkodi Lagoon of Ramanathapuram, Tamil Nadu, India

	Order/Family/Common name	Scientific name	Global IUCN Red List status	Resident status	Relative abundance
	Anseriformes: Anatidae				
1	Knob-billed Duck	*Sarkidiornis melanotos*	LC	R/NB	Ra
2	Indian Spot-billed Duck	*Anas poecilorhyncha*	LC	R/NB	Ra
3	Northern Pintail	*Anas acuta*	LC	WV	Ra
	Phoenicopteriformes: Phoenicopteridae				
4	Greater Flamingo	*Phoenicopterus roseus*	LC	R/NB	C
	Columbiformes: Columbidae				
5	Rock Pigeon	*Columba livia*	LC	R	C
6	Spotted Dove	*Spilopelia chinensis*	LC	R	C
7	Eurasian collared Dove	*Streptopelia decaocto*	LC	R	C
8	Laughing Dove	*Spilopelia senegalensis*	LC	R	C
9	Red Collared Dove	*Streptopella tranquebarica*	LC	R	UC
	Caprimulgiformes: Apodidae				
10	Asian Palm Swift	*Cypsiurus balasiensis*	LC	R	C
	Cuculiformes: Cuculidae				
11	Asian Koel	*Eudynamys scolopaceus*	LC	R	C
12	Grey-bellied Cuckoo	*Cacomantis passerinus*	LC	R	Ra
13	Greater Coucal	*Centropus sinensis*	LC	R	C
14	Blue-faced Malkoha	*Phaenicophaeus viridirostris*	LC	R	C
15	Pied Crested Cuckoo	*Clamator jacobinus*	LC	R/NB	C
	Galliformes: Phasianidae				
16	Grey Francolin	*Ortygornis pondicerianus*	LC	R	C
17	Indian Peafowl	*Pavo cristatus*	LC	R	C
	Pelecaniformes: Ciconiidae				
18	Asian Openbill	*Anastomus oscitans*	LC	R/NB	C
19	Painted Stork	*Mycteria leucocephala*	LC	R/NB	C
	Pelecanidae				
20	Spot-billed Pelican	*Pelecanus philippensis*	NT	R/NB	C
	Ardeidae				
21	Black-crowned Night Heron	*Nycticorax nycticorax*	LC	R/NB	C
22	Eastern Cattle Egret	*Bubulcus coromandus*	LC	R/NB	C
23	Purple Heron	*Ardea purpurea*	LC	R/NB	UC
24	Grey Heron	*Ardea cinerea*	LC	R/NB	C
25	Indian Pond Heron	*Ardeola grayii*	LC	R/NB	C
26	Intermediate Egret	*Ardea intermedia*	LC	R/NB	C
27	Great Egret	*Ardea alba*	LC	R/NB	C
28	Little Egret	*Egretta garzetta*	LC	R/NB	C
29	Striated Heron	*Butorides striata*	LC	R/NB	C
30	Western Reef Egret	*Egretta gularis*	LC	LM	UC
	Threskiornithidae				
31	Black-headed Ibis	*Threskiornis melanocephalus*	LC	R/NB	UC
32	Red-naped Ibis	*Pseudibis papillosa*	LC	R/NB	UC
33	Eurasian Spoonbill	*Platalea leucorodia*	LC	R/NB	C
34	Glossy Ibis	*Plegadis falcinellus*	LC	R/NB	C

	Order/Family/Common name	Scientific name	Global IUCN Red List status	Resident status	Relative abundance
	Phalacrocoracidae				
35	Great Cormorant	*Phalacrocorax carbo*	LC	R/NB	UC
36	Indian Cormorant	*Phalacrocorax fuscicollis*	LC	R/NB	C
37	Little Cormorant	*Microcarbo niger*	LC	R/NB	C
	Anhingidae				
38	Oriental Darter	*Anhinga melanogaster*	LC	R/NB	UC
	Charadriiformes: Recurvirostridae				
39	Black-winged Stilt	*Himantopus himantopus*	LC	R	C
	Burhinidae				
40	Indian Stone-curlew	*Burhinus indicus*	LC	R	C
41	Great Stone-curlew	*Esacus recurvirostris*	NT	R	C
42	Beach Stone-curlew	*Esacus magnirostris*	NT	R	Ra
	Charadriidae				
43	Black-bellied Plover	*Pluvialis squatarola*	VU	WV	C
44	Pacific Golden Plover	*Pluvialis fulva*	LC	WV	UC
45	Siberian Sandplover	*Anarhynchus mongolus*	EN	WV	C
46	Greater Sandplover	*Anarhynchus leschenaultii*	LC	WV	C
47	Kentish Plover	*Anarhyncus alexandrinus*	LC	WV	C
48	Common Ringed Plover	*Charadrius hiaticula*	LC	WV	UC
49	Hanuman Plover	*Charadrius seebohmi*	NA	R	C
50	Little-ringed Plover	*Charadrius dubius*	LC	WV	C
51	Red-wattled Lapwing	*Vanellus indicus*	LC	R	C
52	Yellow-wattled Lapwing	*Vanellus malabaricus*	LC	R	UC
	Scolopacidae				
53	Black-tailed Godwit	*Limosa limosa*	NT	WV	UC
54	Bar-tailed Godwit	*Limosa lapponica*	NT	WV	UC
55	Whimbrel	*Numenius phaeopus*	LC	WV	C
56	Red-necked Phalarope	*Phalaropus lobatus*	LC	WV	Ra
57	Eurasian Curlew	*Numenius arquata*	NT	WV	C
58	Temminck's Stint	*Calidris temminckii*	LC	WV	UC
59	Little Stint	*Calidris minuta*	LC	WV	C
60	Ruff	*Calidris pugnax*	LC	WV	UC
61	Curlew Sandpiper	*Calidris ferruginea*	VU	WV	C
62	Dunlin	*Calidris alpina*	NT	WV	Ra
63	Red-necked Stint	*Calidris ruficollis*	NT	WV	Ra
64	Common Sandpiper	*Actitis hypoleucos*	LC	WV	UC
65	Ruddy Turnstone	*Arenaria interpres*	NT	WV	C
66	Green Sandpiper	*Tringa ochropus*	LC	WV	C
67	Marsh Sandpiper	*Tringa stagnatilis*	LC	WV	UC
68	Wood Sandpiper	*Tringa glareola*	LC	WV	UC
69	Common Greenshank	*Tringa nebularia*	LC	WV	C
70	Common Redshank	*Tringa totanus*	LC	WV	C
71	Terek Sandpiper	*Xenus cinereus*	LC	WV	C
72	Broad-billed Sandpiper	*Calidris falcinellus*	VU	WV	C
73	Sanderling	*Calidris alba*	LC	WV	C

	Order/Family/Common name	Scientific name	Global IUCN Red List status	Resident status	Relative abundance
74	Great Knot	*Calidris tenuirostris*	EN	WV	UC
75	Red Knot	*Calidris canutus*	NT	WV	UC
76	Common Snipe	*Gallinago gallinago*	LC	WV	UC
77	Pin-tailed Snipe	*Gallinago stenura*	LC	WV	Ra
	Rostratulidae				
78	Greater Painted Snipe	*Rostratula benghalensis*	LC	R/NB	Ra
	Laridae				
79	Slender-billed Gull	*Chroicocephalus genei*	LC	WV	C
80	Black-headed Gull	*Chroicocephalus ridibundus*	LC	WV	C
81	Brown-headed Gull	*Chroicocephalus brunnicephalus*	LC	WV	C
82	Pallas's Gull	*Ichthyaetus ichthyaetus*	LC	WV	C
83	Lesser Black-backed Gull	*Larus fuscus*	LC	WV	C
84	Steppe Gull	*Larus fuscus barabensis*	LC	WV	Ra
85	Common Tern	*Sterna hirundo*	LC	WV	UC
86	Little Tern	*Sternula albifrons*	LC	WV	UC
87	Caspian Tern	*Hydroprogne caspia*	LC	WV	C
88	Great Crested Tern	*Thalasseus bergii*	LC	R/B	C
89	Lesser Crested Tern	*Thalasseus bengalensis*	LC	WV	C
90	Sandwich Tern	*Thalasseus sandvicensis*	LC	WV	Ra
91	Gull-billed Tern	*Gelochelidon nilotica*	LC	WV	C
92	Whiskered Tern	*Chlidonias hybrida*	LC	WV	UC
93	White-winged Tern	*Chilidonias leucopterus*	LC	WV	Ra
94	Bridled Tern	*Onychoprion anaethetus*	LC	WV	Ra
95	Sooty Tern	*Onychoprion fuscatus*	LC	WV	Ra
	Stercorariidae				
96	Arctic Skua	*Stercorarius parasiticus*	LC	WV	Ra
97	Pomarine Skua	*Stercorarius pomarinus*	LC	WV	Ra
	Procellariiformes: Procellariidae				
98	Flesh-footed Shearwater	*Ardenna carneipes*	NT	WV	Ra
	Accipitriformes: Pandionidae				
99	Osprey	*Pandion haliaetus*	LC	WV	Ra
	Accipitridae				
100	Booted Eagle	*Hieraaetus pennatus*	LC	WV	UC
101	Black Kite	*Milvus migrans*	LC	R	C
102	Black-winged Kite	*Elanus caeruleus*	LC	R	C
103	Brahminy Kite	*Haliastur indus*	LC	R	C
104	Shikra	*Accipiter badius*	LC	R	C
105	Eurasian Marsh Harrier	*Circus aeruginosus*	LC	WV	Ra
106	Monatgu's Harrier	*Circus pygargus*	LC	WV	Ra
107	Oriental Honey-buzzard	*Pernis ptilorhynchus*	LC	LM	UC
108	White-bellied Sea Eagle	*Icthyophaga leucogaster*	LC	LM	C
	Strigiformes: Strigidae				
109	Spotted Owlet	*Athene brama*	LC	R	C
	Bucerotiformes: Upupidae				
110	Common Hoopoe	*Upupa epops*	LC	R	C

	Order/Family/Common name	Scientific name	Global IUCN Red List status	Resident status	Relative abundance
	Piciformes: Picidae				
111	Black-rumped Flameback	*Dinopium benghalense*	LC	R	C
	Coraciiformes: Meropidae				
112	Blue-tailed Bee-eater	*Merops philippinus*	LC	R	C
113	Green Bee-eater	*Merops orientalis*	LC	R	C
	Coraciidae				
114	Indian Roller	*Coracias benghalensis*	LC	R	C
	Alcedinidae				
116	Pied Kingfisher	*Ceryle rudis*	LC	R	C
117	Common Kingfisher	*Alcedo atthis*	LC	R	C
118	White-throated Kingfisher	*Halcyon smymensis*	LC	R	C
	Falconiformes: Falconidae				
118	Peregrine Falcon	*Falco peregrinus*	LC	WV	Ra
119	Eurasian Kestrel	*Falco tinnunculus*	LC	R	C
	Psittaciformes: Psittacidae				
120	Rose-ringed Parakeet	*Psittacula krameri*	LC	R	C
	Passeriformes: Dicruridae				
121	Black Drongo	*Dicrurus macrocercus*	LC	R	C
	Laniidae				
122	Brown Shrike	*Lanius cristatus*	LC	WV	UC
	Corvidae				
123	House Crow	*Corvus splendens*	LC	R	C
124	Rufous Treepie	*Dendrocitta vagabunda*	LC	R	UC
125	Large-billed Crow	*Corvus macrorhynchos*	LC	R	C
	Nectariniidae				
26	Purple-rumped Sunbird	*Leptocoma zeylonica*	LC	R	C
127	Purple Sunbird	*Cinnyris asiaticus*	LC	R	C
	Estrildidae				
128	Indian Silverbill	*Euodice malabarica*	LC	R	UC
	Passeridae				
129	House Sparrow	*Passer domesticus*	LC	R	C
	Motacillidae				
130	Paddy Field Pipit	*Anthus rufulus*	LC	R	C
31	White-browed Wagtail	*Motacilla maderaspatensis*	LC	R	C
132	Western Yellow Wagtail	*Motacilla flava*	LC	WV	Ra
	Alaudidae				
133	Jerdons Bushlark	*Mirafra affinis*	LC	R	C
134	Oriental Skylark	*Alauda gulgula*	LC	R	C
135	Skyes's Short-toed Lark	*Calandrella dukhunensis*	LC	WV	UC
	Cisticolidae				
136	Common Tailorbird	*Orthotomus sutorius*	LC	R	C
137	Plain Prinia	*Prinia inornata*	LC	R	C
138	Ashy Prinia	*Prinia socialis*	LC	R	C
	Leiotrichidae				
139	Yellow-billed Babbler	*Argya affinis*	LC	R	C

	Order/Family/Common name	Scientific name	Global IUCN Red List status	Resident status	Relative abundance
	Acrocephalidae				
140	Blyth's Reed Warbler	*Acrocephalus dumetorum*	LC	WV	UC
141	Booted Warbler	*Iduna caligata*	LC	R/NB	Ra
	Hirundinidae				
142	Barn Swallow	*Hirundo rustica*	LC	WV	Ra
	Pycnonotidae				
143	Red-vented Bulbul	*Pycnonotus cafer*	LC	R	C
	Sturnidae				
144	Brahminy Starling	*Sturnus pagodarum*	LC	R	UC
145	Common Myna	*Acridotheres tristis*	LC	R	C
146	Rosy Starling	*Pastor roseus*	LC	PM	UC
	Muscicapidae				
147	Indian Robin	*Copsychus fulicatus*	LC	R	C

IUCN Red list status: LC—Least Concern | NT—Near Threatened | VU—Vulnerable | EN—Endangered | NA—Not assessed | Resident status: WV—Winter Visitor | LM—Local Migrant | R—Resident | R/NB—Resident/Non-Breeding | Relative abundance: C—Common | UC—Uncommon | Ra—Rare.

Pelican *Pelecanus philippensis,* Flesh-footed Shearwater *Ardenna carneipes,* and Beach Stone- Curlew *Esacus* magnirostri; three 'Vulnerable' species Curlew Sandpiper *Calidris ferruginea,* Broad-billed Sandpiper *Calidris falcinellus*, and Black-bellied Plover *Pluvialis squatarola*; two 'Endangered' (EN) Great Knot *Calidris tenuirostris* and Siberian Sandplover *Anarhynchus mongolus*; one unassessed Hanuman Plover; and the rest of 130 species were in the 'Least Concern' (LC) category according to the IUCN Red List of Threatened Species.

It is evident from the study that 62 species of winter migrants visited or occupied the area during the migratory period. This is one of the best waterbird congregation sites during the migratory season in the Gulf of Mannar region (Rashiba et al. 2022). Similar studies on the eastern coast of India were recorded in Valinokkam Lagoon (Byju et al. 2023c) with 154 species of birds, of which 35 were shorebirds and 58 species were winter visitors, and, Karangadu mangroves (Byju et al. 2023b) with 107 species of birds, of which 18 were shorebirds and 15 species were winter visitors. Findings from Pulicat Lagoon by Alam et al. (2023), the second-largest brackish water lagoon on the east coast of India, also complement these findings with the record of 52 species of winter visitors. The maximum counts as one-time peak counts of a few species of shorebirds, gulls, and terns were recorded during the study period (Table 2), along with the global population size and population trend of each species for a better understanding.

From the observations, the following are the shorebird species that were dominant in the region: Siberian Sandplover *Anarhynchus mongolus*, Curlew Sandpiper *Calidris ferruginea*, Greater Sandplover *Anarhyncus leschenaultii,* and Kentish Plover *Anarhynchus alexandrinus*. This is in line with previous studies carried out on the eastern coast of India at Point Calimere (Balachandran 2006), Chilika (Balachandran et al. 2020), and Valinokkam (Byju et al. 2023c). A study by Balachandran (1998) showed that Greater Sandplover is found in abundance only in GoM on the eastern coast compared to the western coast of India. Byju et al (2023e) observed Siberian Sandplover, Curlew Sandpiper, and Little Stint as the most abundant shorebirds on the Manoli Island of GoM.

Family Laridae was represented by six species of gulls and 11 species of terns. The gull species recorded are Slender-billed Gull *Chroicocephalus genei*, Black-headed Gull *Chroicocephalus ridibundus*, Brown-headed Gull *Chroicocephalus brunnicephalus*, Pallas's Gull *Ichthyaetus ichthyaetus*, Steppe Gull *Larus barabensis*, and Lesser Black-backed Gull *Larus fuscus*. Of these, the most dominant ones were Brown-headed and Black-headed gulls. The tern species include, Little Tern *Sternula albifrons*, Gull-billed Tern *Gelochelidon nilotca*, Caspian Tern *Hydroprogne caspia*, Whiskered Tern *Chlidonias hybrida*, Common Tern *Sterna hirundo*, Greater Crested Tern *Thalasseus bergii*, Lesser Crested Tern *Thalasseus bengalensis*, Sandwich Tern *Thalasseus sandvicensis,* White-winged Tern *Chilidonias leucopterus*, Bridled Tern *Onychoprion anaethetus*, and Sooty Tern *Onychocommonprion fuscatus*. Lesser Crested Tern and Greater Crested Tern, the breeding residents of

Table 2. One-time peak count of a few important waterbirds with global population trends.

Species	One-time peak count	Month and Year of observation	Global population trend (BirdLife International 2024)	Global population size (number of mature individuals) (BirdLife International 2024)
Numenius phaeopus	34	February 2023	Decreasing	Unknown
Limosa lapponica	6	August 2022	Decreasing	Unknown
Limosa limosa	9	August 2022	Decreasing	Unknown
Pluvialis squatarola	206	April 2023	Decreasing	490,000–630,000
Charadrius hiaticula	2	October 2023	Decreasing	Unknown
Pluvialis fulva	7	April 2022	Decreasing	Unknown
Anarhynchus leschenaultii	2,998	April 2023	Decreasing	100,000–225,000
Charadrius dubius	50	March 2022	Stable	Unknown
Anarhynchus mongolus	4,006	March 2022	Decreasing	18,000–50,000
Charadrius seebohmi	25	October 2023	Not assessed	Unknown
Anarhyncus alexandrinus	1,402	March 2022	Decreasing	100,000–499,999
Esacus magnirostris	8	June 2022	Decreasing	4,000
Numenius arquata	47	February 2022	Decreasing	Unknown
Esacus recurvirostris	3	January 2023	Decreasing	Unknown
Actitis hypoleucos	21	August 2022	Decreasing	Unknown
Tringa stagnatilis	304	February 2022	Decreasing	Unknown
Tringa ochropus	151	October 2023	Increasing	Unknown
Xenus cinereus	95	August 2022	Decreasing	Unknown
Calidris ferruginea	3,498	September 2023	Decreasing	Unknown
Tringa glareola	27	February 2023	Stable	Unknown
Calidris falcinellus	40	February 2023	Decreasing	Unknown
Tringa nebularia	86	August 2022	Stable	Unknown
Tringa totanus	352	September 2022	Unknown	Unknown
Calidris alpina	10	February 2022	Decreasing	Unknown
Calidris ruficollis	2	September 2023	Decreasing	Unknown
Calidris temminckii	50	February 2022	Unknown	110,000– 850,000
Calidris minuta	710	February 2022	Increasing	1,000,000– 1,100,000
Calidris tenuirostris	102	March 2022	Decreasing	Unknown
Arenaria interpres	520	April 2023	Decreasing	300,000–500,000
Calidris alba	80	February 2022	Unknown	Unknown
Calidris pugnax	2	March 2023	Decreasing	Unknown
Phalaropus lobatus	2	January 2023	Decreasing	Unknown
Himantopus himantopus	45	December 2021	Increasing	Unknown
Sterna hirundo	202	March 2021	Unknown	Unknown
Gelochelidon nilotica	80	February 2021	Decreasing	Unknown
Hydroprogne caspia	301	November 2020	Increasing	Unknown
Thalasseus bergii	2007	March 2021	Stable	Unknown
Thalasseus bengalensis	2996	March 2021	Stable	Unknown
Sternula albifrons	509	March 2021	Decreasing	Unknown
Chlidonias hybrida	4	July 2022	Stable	Unknown
Ichthyaetus ichthyaetus	15	March 2021	Increasing	Unknown
Chroicocephalus brunnicephalus	814	March 2022	Stable	Unknown
Chroicocephalus ridibundus	308	January 2021	Unknown	Unknown
Chroicocephalus genei	260	December 2022	Unknown	180,000–230,000
Larus barabensis	55	February 2021	Data not available	Data not available
Larus fuscus	170	November 2022	Increasing	Unknown
Phoenicopterus roseus	1409	February 2021	Increasing	Unknown

this area, were the most prevalent tern species during the study period, followed by Little Tern and Common Tern. Among other large waterbirds, Greater Flamingo *Phoenicopterus roseus* was seen mostly restricted to the Kothandaramar Lagoon compared to other study areas but rarely in the Dhanushkodi region only few in numbers. Although 50% of the species for which one-time peak count was mentioned are 'Least Concern' on the IUCN Red List, global population analysis shows a decreasing trend (BirdLife International 2024). Notably, the global population size of 76% of these listed species is unknown (Table 2).

Most land birds are recorded from the lagoon peripheries or the Rameswaram Reserve Forest areas. Some ground-nesting land birds such as Oriental Skylark *Alauda gulgula* used the grassy patches in Dhanushkodi areas as breeding ground emphasizing the need for avifaunal diversity assessments in lagoon regions, besides waterbirds. The new breeding records of Hanuman Plover from the study areas in Dhanushkodi emphasize the need to conserve these unprotected habitats as a significant part of the CAF (Byju et al. 2023d).

For long-distance migratory shorebirds, stop-over sites are essential along with breeding and wintering locations (Boere et al. 2006). Waterbirds, particularly shorebirds, mudflats, and shallow lagoons provide pivotal habitat (Sandilyan et al. 2010) which is evident in the study where shorebirds constituted 35.3% (52 species) of the total avifauna. Therefore, it is important to perform extensive investigations to identify all crucial stopover sites, seasons, and ecosystems along the Indian east coast (Rao et al. 2022) that are not hitherto done. The present study area along with Valinokkam Lagoon (Byju et al. 2023c), Karangadu Mangrove ecosystem (Byju et al. 2023b) will fill up the gap in bird studies on the east coast in the Ramanathapuram region.

Potential Threats and Conservation Suggestions

The newly proposed railway line work (Image 9) for Dhanushkodi from Rameswaram and concretization in the region by building roads that have been extended up to Arichalmunai from Dhanushkodi will impact the habitat in the future as new soil will be brought to the area for construction activities impacting the feeding activity of the shorebirds. Seepage of hard soil from these structures may result in the hardening of the substrate in the long run. This may lead to the disappearance of the natural habitat for invertebrates, like molluscs, nereis worms, and crustaceans like crabs, the food for these migratory birds (Byju et al. 2023a). Many studies have proven that shorebird diversity, abundance, and dispersion are influenced by food availability, substrate type, water quality, and other factors (Skagen & Knopf 1993; Manikannan et al. 2012).

Other threats include invasive plant species like *Neltuma juliflora* which is profusely taking over the mudflats and lagoon edges in Dhanushkodi region (Image 10). According to Murugan et al. (2020), invasive species modify ecosystems by impacting the dynamics of soil organic carbon and nutrients. Disturbance may also be a major issue during the breeding season, as the presence of humans may scare away adults and allow predators to take eggs and young ones (Martínez-Abraín et al. 2010; Tobajas et al. 2022). It was also observed that domestic dogs are becoming a source of disturbance to migratory birds (Mundkur & Langendoen 2019) and breeding birds (Byju et al. 2023d), and disturbance can have severe consequences for migratory shorebirds that forage and roost in the coastal mudflats (Das et al. 2022).

Tourism is a major industry based on coastal wetlands of India (Jayappa & Deepika 2018) including Rameswaram Island due to the importance of religious belief and beach drives. Tourists may unintentionally disturb shorebirds by walking too close to their nesting sites, driving vehicles on beaches, or engaging in activities such as kite flying or dog walking, all of which can disrupt the birds' normal activities and lead to negative consequences (Mundkar et al. 2023). One of the major impacts is the religious (heritage) tourism in Rameswaram, Kothandaramar temple area, and the Dhanushkodi region. The amount of waste like used clothes which is a religious custom to throw the used ones after taking a holy dip on the beaches and plastics (mostly from packed foods and water bottles) is having a long-term impact on the habitat utilization of the shorebirds in the area (Images 11 & 12). Microplastics were found in the corals of GoM and tourism was found to be the source of these (Krishnakumar et al. 2021). Several species are vulnerable to the effects of plastic pollution including the consumption of microplastics even by juveniles (Athira et al. 2024).

The impact of the tourist vehicles and visitors includes the leftovers of food, plastics, and used clothes. This has increased the dog population which is again a major threat to shorebirds and the nesting of Olive Ridley Turtle *Lepidochelys olivacea* (Image 13). Restricting the number of vehicles to 200–250 per day or restricting private vehicles after a certain point in Rameswaram and introducing public transport facilities through local vehicles involving local communities in the fragile area could be some of the steps towards a management solution to the threats. This would also help in boosting

Image 2. Arctic Skua.

Image 3. Beach Stone-curlew.

Image 4. Hanuman Plover.

Image 5. Lesser Noddy.

Image 6. Bridled Tern.

Image 7. Sooty Tern.

Image 8. Red-necked Phalarope.

Image 9. Red Pillar stone laid for proposed railway line acquisition on the beach.

Image 10. *Neltuma juliflora* overgrowing to the edge of mudflats.

Image 11. Remnants on religious practices as garbage on the edge of the foraging area.

Image 12. Overcrowding of tourist carrying vehicles and vendors in Arichalmunai.

Image 13. Feral dog feeding on dead Olive Ridley Turtle in Dhanushkodi.

the local economy. The plastic check post started by the forest department with the assistance of the local community towards the entry to these regions had collected around one tonne of plastic bottles, five tonnes of plastic covers, and small throw-away items in one year during our study period. The estimations are that uncollected plastic items are around four tonnes in the area during the same period. The interactions with the local administration exposed the lack of garbage collection staff and improper disposal methods. Hence the resolution of this issue needs the collaborative efforts of all local stakeholders.

Coastal wetlands are in a critical state and essential to maintain them for shorebird migration routes worldwide. Although GoM is a protected area and an IBA, the adjacent sites often suffer from management issues like the invading exotic species (Gan et al. 2009). In a nutshell, both the designation of new reserves and the improved management of existing reserves are essential in this case.

CONCLUSION

In conclusion, prioritizing the creation of new protected areas is crucial to preserving locations of global significance for waterbirds including migratory shorebirds and breeding studies of unassessed Hanuman Plovers on the selected sites in Arichalmunai and Dhanushkodi of the Rameswaram Island. Unchecked tourism remains a major threat to the Dhanushkodi region, which can have adverse impact on shorebirds, including habitat loss, disturbance, and pollution. These impacts can lead to reduced reproductive success, decreased survival rates, and overall population decline. Some steps can be taken to mitigate these impacts, such as implementing strict regulations on coastal development, establishing protected areas for shorebirds, educating tourists about the importance of minimizing their impact on wildlife, and investing in sustainable tourism practices as suggested. By adopting some of the suggestions, it can be ensured that shorebirds will continue to thrive in coastal environments, while also benefiting tourism.

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ARTICLE

Conservation of sea turtles on the beach areas from Sonadia Island to Saint Martin's Island in the Bay of Bengal in Bangladesh

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Abstract: Five species of sea turtle are known to nest on the coastal beaches of Bangladesh: Loggerhead Sea Turtle *Caretta caretta*, Green Sea Turtle *Chelonia mydas*, Hawksbill Sea Turtle *Eretmochelys imbricata,* Olive Ridley Turtle *Lepidochelys olivacea*, and Leatherback Sea Turtle *Dermochelys coriacea*. Olive Ridleys are more common than Green Turtles, and the others are very rare. Sea turtle hatcheries were visited on the Bay of Bengal beaches running from Sonadia Island to the Saint Martin's Island Beaches of Cox's Bazar in Bangladesh, from January to March 2022. During this period 22 hatcheries were found operating in the field, of which 11 were maintained by Marine Life Alliance, eight by NACOM (Nature Conservation Management) and two by CODEC (Community Development Centre); one was anonymous. Only Olive Ridley Turtles nesting was recorded during 2021–22. CODEC recorded 26 nests and collected 2,943 eggs for hatcheries, which released 1,612 healthy hatchings into the Bay of Bengal. The clutch size was 21–165 (average 103, n = 26), and the incubation period was 45–75 days (average 53 days, n = 1,612). The higher air temperature from March to May hastened the hatching process. NGOs are working on conservation aspects of the sea turtles, mostly by collecting eggs and releasing hatchlings into the Bay of Bengal. They have also prepared booklets and posters, hoisted banners, published papers, and organised seminars, rallies and workshops for education and awareness of the local people. These initiatives are encouraging, but it may be better if the efforts of NGOs to support sea turtle conservation were more integrated.

Keywords: Awareness, coastal beaches, distribution, education workshop, hatcheries, marine turtles, Olive Ridley Turtle, releasing hatchlings, status.

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INTRODUCTION

Sea turtles are an important part of the planetary food web, and they have played a vital role in maintaining the health of the world's oceans for more than 100 million years (Wilson et al. 2010). Bangladesh's coastal waters and beaches support turtles and provide suitable habitats for egg laying and hatchlings. Five of the world's seven species of sea turtles lay their eggs on the coastal beaches of the Bay of Bengal in Bangladesh, extending from the Sundarbans to Saint Martin's Island, and including some old and newly-emerged coastal islands.

Literature review suggests that works on sea turtles in Bangladesh are inadequate, but records on egg laying, maintaining hatcheries and releasing hatchings are quite extensive and go back more than four decades. The listing of five species known to occur in Bangladesh territory of the Bay of Bengal was reported by Khan (1982a,b, 1987, 2010, 2015), Khan (2008, 2018), Shafi & Quddus (1976, 1982), and Sarker & Sarker (1988).

Ahmed et al. (1986) first reported the egg-laying activities of Olive Ridley Sea Turtle from Saint Martin's Island. Later, the Ministry of Environment and Forests (now called Ministry of Environment, Forest and Climate Change) made hatcheries on Saint Martin's Island and reported nesting records of sea turtles from 1996–2002, and hatchery success from 2000–01 to 2001–02 (CWBMP 2008). The Centre for Advanced Research in Natural Resources & Management (CARINAM) NGO started working on sea turtles in 1996 and then in 2000–2005, maintained hatcheries and released hatchings in the Bay of Bengal. The Center for Natural Resource Studies (CNRS) did the same work as CARINAM possibly for a few years from 1997.

The CWBMP (Coastal and Wetland Biodiversity Management Project) under the DoE (Department of Environment) of the Ministry of Environment and Forests started monitoring, conservation programmes and networking in the three Cox's Bazar ECAs (Ecologically Critical Area), viz., the Saint Martin's Island (now it is a Marine Protected Area), the Sonadia Island ECA and Cox's Bazar-Teknaf Peninsula ECA during November 2005 to January 2008; it maintained sea turtle hatcheries (in Sonadia East, Sonadia West, Pechardwip, Khurermukh, Bodormokam, and the St. Martin's Island beaches) and released hatchlings in the Bay of Bengal (CWBMP 2008). It also created public awareness, information, education, and training of stakeholders for conserving sea turtles.

NACOM has been managing sea turtle hatcheries since 2007, and Isabela Foundation did it during 2017–18 (Isabela Foundation 2018). Recently (2021–2022) CODEC (Community Development Centre) is working on the hatcheries as a pilot project on an experimental basis. Unlike other NGOs, the Marine Life Alliance has been mostly working on sea turtles, maintaining hatcheries, and releasing hatchlings in the Bay of Bengal since 1997. It also did a radio-tracking experiment on the Olive Ridley Turtles. The prime goal of all NGOs is the same to maintain hatcheries, hatch the eggs of sea turtles and release the hatchlings in the Bay of Bengal, and create conservation awareness.

According to local elders, about 30 years ago turtle nesting was quite common on most of the beach areas of the Saint Martin's Island. Nests remained unexploited in-situ due to high nesting frequency, and sightings of hatchling emergence were common (Islam 2002).

Status and distribution of Sea Turtles in Bangladesh

Globally, the IUCN lists Hawksbill Turtle as Critically Endangered, and Loggerhead, Green, Leatherback and Olive Ridley Turtles as Endangered (IUCN Bangladesh 2000). The Red list categories were assessed for these five species by IUCN Bangladesh (2015) as Critically Endangered (Green, Leatherback and Hawksbill Turtles), Vulnerable (Olive Ridley Turtle) and Data Deficient (Loggerhead Turtle).

1. Loggerhead Turtle (*Caretta caretta*): There are two records of the occurrence of this species in Bangladesh. One female laid eggs at Saint Martin's Island (Bhuiyan et al. 1985) and another was a stranded dead specimen found at Kassopia Island under Hatiya Upazila of Noakhali District in January 1995 (Khan 1996). The nearest egg-laying site of this species is the islands of Myanmar (Thorbjarnarson et al. 2000) east of the Saint Martin's Island. It should be noted that Olive Ridleys and Loggerheads are commonly misidentified (Frazier 1985).

2. Green Turtle (*Chelonia mydas*): Green Turtles are less widespread than Olive Ridleys and their nesting records are reported from Inani to Teknaf mainland beaches, Shahporir Dip, Saint Martin's, Sonadia, Kutubdia, Hatiya, and Swandip Islands between 1984 and 1994 are either rare or absent in the Sundarbans coastal beaches (cf. Rashid & Islam 2006). On several occasions, young individuals were seen from the research vessel of the Marine Fisheries Research Institute in the shallow continental shelf in south-central Bangladesh (F. Alam pers. comm. 1995 in Rashid & Islam 2006). Adult sea turtles are also trapped in fishing nets mostly during winter (December–January) which is the peak nesting period.

3. Leatherback Turtle (*Dermochelys coriacea*): Literature search indicates that there is no evidence of Leatherback nesting in Bangladesh (Mitra 1914). However,

one adult stranded dead individual was washed up after a storm on the Saint Martin's Island's beach on 11 April 1997 (Rashid & Islam 1999). Live individuals were caught in fishing gears in and around Sonadia Island and the emergence of one turtle on Saint Martin's Island was recorded in April 2001 (Islam 2002). One Leatherback Turtle (carapace length 152.4 cm, height 91.44 cm and weight 95 kg) was caught in the fishing net of local fishers in the Bakkhali River (Moheshkhali channel) on 14 July 2005 (Haroon & Rahman 2006).

4. Hawksbill Turtle (*Eretmochelys imbricata*): This is a rare visitor on the beaches of Bangladesh and was a regular visitor on the beaches of Saint Martin's Island (A. Kasem pers. comm. in Rashid & Islam 2006). One female nested and laid 56 eggs in January 1992 (Rashid 1997; Rashid & Islam 2006). An immature turtle was trapped in a fishing net in the northwestern waters of the Saint Martin's Island on 13 November 1996 (Rashid & Islam 2006). Three turtles nested on the beach of the Saint Martin's Island during 1998–99 (Islam 2002). In December 1997, January 2000 and January–March 2001, stuffed subadult specimens of Hawksbill Turtle were on sale at curio shops in Cox's Bazar and at least six specimens of sea turtles were sold in 2001 (Islam 2001).

5. Olive Ridley Turtle (*Lepidochelys olivacea*): Olive Ridley Turtles are the common nesters on the sandy beaches along the mainland coasts of Bangladesh from the Sundarbans to the Saint Martin's Island and also to the newly emerged coastal islands' beaches where human interference is low or absent. Besides those, other nesting beaches are Mandarbaria, Dubla, Egg, and Putney Islands in the Sundarbans; Swandip, Hatiya, Nijhumdip, Kutubdia, and Moheshkhali Islands, and Bhola Islands. Of all the nesting grounds of Olive Ridley Turtles in Bangladesh, the Sonadia and Saint Martin's Islands are the best known to all.

The major objectives of this work were to:

(1) identify the available turtle species that come to lay eggs on the beach areas from the Sonadia Island to the Saint Martin's Island;

(2) figure out the total number of turtle hatcheries (Government, INGO, NGO, Private Research Organization) are found in the beach areas from the Sonadia Island to the Saint Martin's Island;

(3) quantify the total species-wise hatchlings found in the last 5 years;

(4) identify the existing problems/obstacles for the turtle nesting/hatching and conservation in the beach area; and

(5) provide possible suggestions for ex-situ and in-situ conservation.

METHODS

We (MFA), consultant; SKN, project director, Nature and Life Project; and the research assistant, Mr. Omar Shahdat) visited the beach areas from Inani to the Saint Martin's Island via the Sonadia Island to find out any signs and symptoms of laying eggs by the sea turtles during January to March 2022. We mostly worked during the day and we did not see any recent turtle crawling signs for egg-laying. We visited all turtle hatcheries in the study area and took their photographs. The result of one hatchery that was maintained by CODEC from January to May 2021 has also been incorporated into this study.

We tried to make personal contact with different NGOs to have recent (last decade) data on the sea turtle hatcheries, but it was not available to us. Problems and obstacles faced in running turtle hatcheries were pin pointed. All available published and unpublished reports on the sea turtles in Bangladesh found online were consulted and relevant information incorporated in this report. Based on field visits and my (MFA) long experience (42 years) working on wildlife in this country, threats to sea turtles on the nesting beaches and coastal waters were identified and suggested possible recommendations for in-situ and ex-situ conservation measures.

Incubation days have been compiled on monthly basis to show the relationship with monthly weather data and then correlation analysis has been done and regression lines have been prepared.

RESULTS

During our pilot survey period (January–March 2022), we found 22 hatcheries on the Saint Martin's Island to Inani Beach via the Sonadia Island, of which eight hatcheries belonged to NACOM (including one in-situ nest), 11 owned by Marine Life Alliance, two managed by CODEC (of which one was also maintained during January–May 2021) and owner of one was unknown (Image 1, Table 1, Figure 1).

Bamboo lattice fences have been used to build hatcheries in seven cases, nylon thread (medium or thin) nets used in five, four each hatcheries have aluminum and plastic wire nets, and in two cases both plastic wire nets and nylon thread net have been used. All these hatcheries used bamboo poles for supporting the fences. In one case, it is an in-situ nest nearly circular in shape (1.5 m radius with 1 m height), where a thin nylon net is used as a fence supported by poles of tree branches. The size of the hatchery ranges (length x width x height) from 4 x

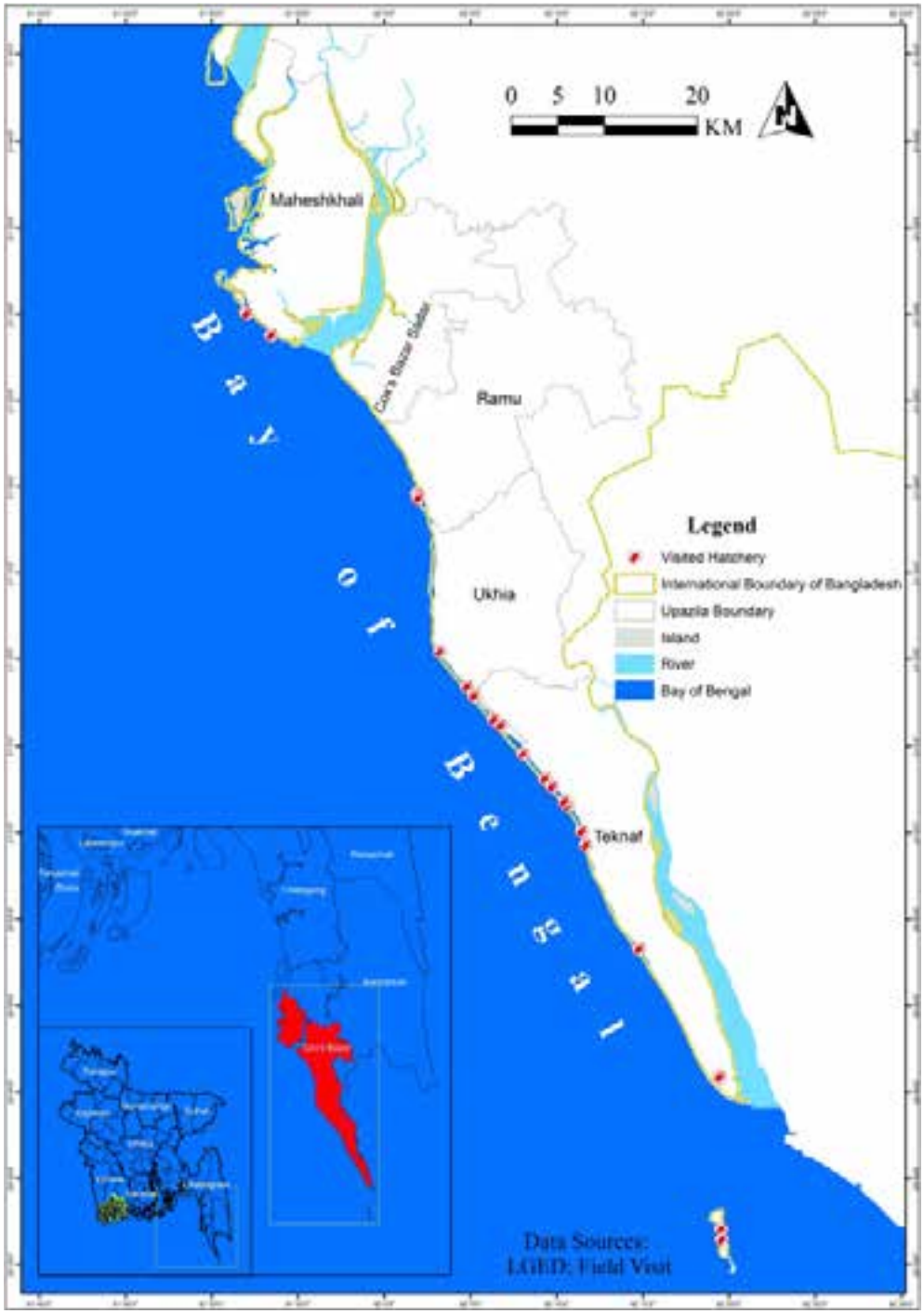


Image 1. Study area located on the Bangladesh map.

3 x 1 to 28 x 21 x 1.5 m^3 (average 7.4 x 5.4 x1.5 m^3). The hatcheries are placed at 10–300 m far from the high tide water mark depending on the beach condition, except for the Shahporir Dip hatchery. This is because in Shahporir Dip, the sandy beach area is restricted by Border Guard Bangladesh. The suitable habitat is not found near the sea beach. Hence, they have selected a safe place for turtle hatchery about 900 m far from the beach.

During the study period, eggs from 26 nests of Olive Ridley Turtles were transferred into the CODEC hatcheries and the collected eggs of each nest were put into egg pits made artificially, similar to natural nests (Table 2). The clutch size of eggs laid by each female Olive Ridley Turtle was 21–165 (average 103, n = 26). The incubation period

Table 1. List of hatcheries found from Saint Martin's to Inani during March–May 2022.

Hatchery operating Org.	Address of the Hatcheries and Hatcheries belong to	GPS (N, E)	Total
Marine Life Alliance	4. Hafiz Chara, 1 no. Ward, Teknaf UP, Teknaf*	20.887, 92.245	11
	5. Matha Bhanga Beach, Baharchara, Teknaf	20.988, 92.194	
	7. Halbunia, Shilkhali, Baharchara, Teknaf	21.025, 92.177	
	9. Choukidar Para, Shilkhali, Baharchara, Teknaf	21.043, 92.162	
	11. Shamlapur Beach, Shilkhali, Teknaf	21.075, 92.134	
	12. Supportkhali, Ukhiya	21.103, 92.112	
	14. Soyankhali, Ukhiya	21.131, 92.086	
	15. Imamer Dail, Ukhiya	21.140, 92.079	
	16. Patuatek, Inani, Ukhiya	21.174, 92.053	
	18. Pencherdip, Himchari, Cox's Bazar	21.324, 92.032	
	22. Sonadia Poshchimpara, Moheshkhali	21.501, 91.865	
Nature Conservation Management (NACOM)	1. Marine Park, Golachipa, Saint Martin's, Teknaf	20.617, 92.325	8
	2. Shilboniar Ghula Beach, Uttarpara, Saint Martin's, Teknaf	20.607, 92.326	
	3. Majerpara Primary School, Sha-porir Dip, Teknaf	20.764, 92.324	
	8. Bainnapara, Shilkhali, Baharchara, Teknaf	21.030, 92.173	
	17. Pencherdip, Himchari, Cox's Bazar (In-situ)	21.326, 92.031	
	19. Pencherd-p, Himchari, Cox's Bazar	21.322, 92.032	
	20. Sonadia Purbopara, Moheshkhali	21.479, 91.890	
	21. Sonadia Poshchimpara, Moheshkhali	21.500, 91.867	
CODEC	6. Hazom Para, Shilkhali, Baharchara, Teknaf	21.001, 92.190	2
	10. Uttar Skhilkhali, Baharchara, Teknaf	21.051, 92.154	
Unknown	13. Motherbunia, Baharchara, Teknaf	21.108, 92.105	1

*** Serial number of hatcheries was made from Saint Martin's Island to Inani.**

was 45–75 days (average 53 days, n = 1,612 eggs). The eggs hatched in January took a higher incubation period and subsequently the period went down and it was the lowest in May. This is because of air temperature that means in higher temperatures the incubation period was less than the lower temperature (Table 3, Figures 2–7). The correlation and regression of incubation period (in days) data with the weather data (monthly mean air temperature, relative humidity and total rainfall) have been calculated. The results show high significance between monthly incubation days and monthly total rainfall in 2022 ($r = 0.999$, $df = 1$, $P < 0.001$) and the others have moderate degrees of significance ($r = 0.560$ to 0.957, $df = 1$, $P > 0.05$) because of meagre data (three months). It should be mentioned here that at least five sets of data are required for showing good correlation and regression statistics.

In total 2,943 eggs of 26 gravid females Olive Ridley Sea Turtles were conserved in the hatcheries of CODEC, of which 1,346 eggs were from 12 females at Hazom Para Hatchery and 1,597 eggs from 14 females at Shilkhali

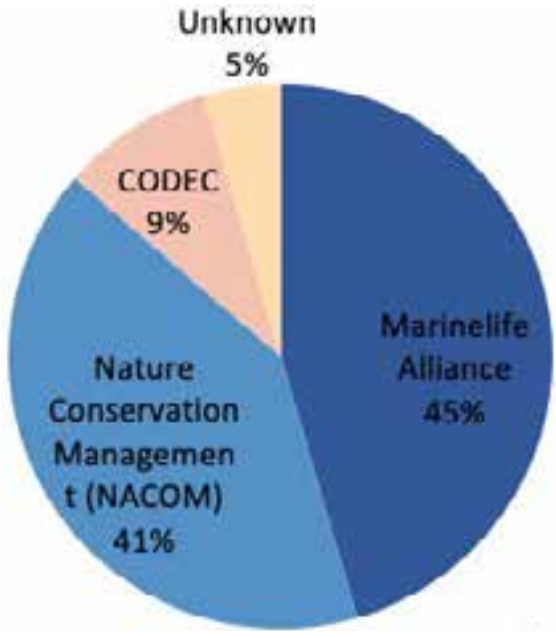


Figure 1. Hatcheries operating in Cox's Bazar, Sonadia ECA and Teknaf Peninsula.

Hatchery (Table 2). Overall, 1,612 (i.e., 54.77%) healthy hatchlings were released into the Bay of Bengal, of which 839 (i.e., 52.05%) were from Hazom Para Hatchery and 773 (i.e., 47.95%) from the Shilkhali Hatchery (Table 2).

Threats to Nesting Beaches

The following inland threats to marine turtles in Bangladesh were identified through interviewing local people, hatchery caretakers, and from our own experiences:

(1) disorientation caused by flashing lights on the beachside and man-made obstructions on the nesting beaches, particularly on the Saint Martin's Island and also other beaches along the Marine Drive Road, and some beach areas where hotels, motels, and rest houses have been established, and have crowded visitors;

(2) nest and hatchling predation by feral dogs and natural predators such as jackals, mongooses, monitor lizards, and predatory birds;

(3) physical alteration of beach infrastructure, e.g., Marine Drive Road has engulfed some areas of the long beach and created connectivity roads, making access to people that creates crowed and disturbed the ideal situation of the beach;

(4) an unusual increase in number of vehicles on Marine Drive Road, flashing lights and blowing of horns that disturb nesting facilities of the sea turtles in the beach areas;

(5) turtles getting entangled in fishing net; fishermen kill turtles when entangled in their nets, and use of beaches for drying fish and mending fishing nets;

(6) encloser nets ('gher-jal') prevent gravid females from reaching the beach, and/or they get entangled in the net;

(7) increased mechanized boats disturbing gravid females from reaching the beaches;

(8) boats anchored on the inter-tidal zone as well as in the water use flashlights which create barriers for nesting of the sea turtles as well as prevent gravid females to come onto the beach;

(9) beach seine fishing either kills or obstructs the movement of turtles;

(10) disturbances during shrimp-fry collection;

(11) alteration of the nesting beaches by the Jhao (*Casuarina equisitifolia*) plantation and new plantations have destroyed some nesting ground of the turtles. Bangladesh Forest Department plants Jhao trees there because newly emerged beach areas will be occupied by the people for their own purpose;

(12) egg poaching, earlier 90–95% of nests were exploited by humans- but now it is at a minimum;

(13) flooding nests by the high tide; tidal waves and cyclones flood the egg laying areas and consequently eggs are damaged;

(14) nest losses due to beach erosion is not so significant;

(15) flashing light on the beach and human (tourists) presence, especially on the Saint Martin's Island and other areas; and

(16) often poaching of eggs by the miscreants.

Conservation measures taken

The following initiatives have been taken by the Government of Bangladesh, and NGOs and international organisations for the conservation and management of sea turtles (Table 6).

So far, data could be collected from different sources on the conservation of eggs of turtles and hatching them into the hatcheries and releasing the hatchlings into the Bay of Bengal have jotted in Table 7.

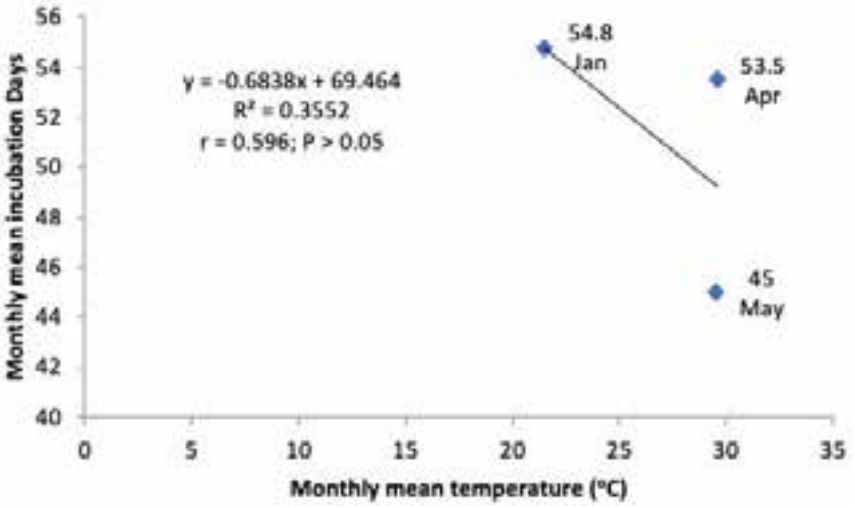
DISCUSSION

The reasons for the lower rate of healthy hatchlings were due to: (i) 138 eggs were rescued from the miscreants and conserved at Hazom Para Hatchery did not hatch; (ii) the egg-laying date of these 138 eggs was unknown and was not preserved properly, that is why, not a single egg hatched; (iii) on the other hand, miscreants destroyed many eggs of seven clutches at Shilkhali Hatchery; and (iv) consequently and in addition, some dead and deformed hatchlings emerged in both hatcheries.

During 1996–98, 29 sea turtles (both sexes and subadults) were found dead on the beach of Saint Martin's Island, of which 19 individuals died due to fishing as suspected (Islam 2002). In 2000–01, more than 51 dead Olive Ridley Turtles were washed ashore (Islam 2002). The south and south-west offshore zones from the Saint Martin's Island are in deep sea, and these are mainly foraging zone of sea turtles and are also used by large mechanized fishing boats. So, dead turtles float for some days and are finally washed ashore on the beaches of the Saint Martin's and other coasts of Bangladesh (Islam et al. 1999).

According to local elders, nesting was common on most of the beaches 10–15 years ago. Rashid (1986) recorded 35 Green Turtles in one-night nesting on one beach. A maximum of seven Olive Ridley females were observed nesting in a single night in this study.

Although there are no records of Loggerheads nesting on the Saint Martin's Island, it is possible that they nested



* Source: Rashid & Islam 2006

Figure 2. Relationship between monthly mean incubation days of eggs of Olive Ridley Turtle and monthly mean temperature during 2022.

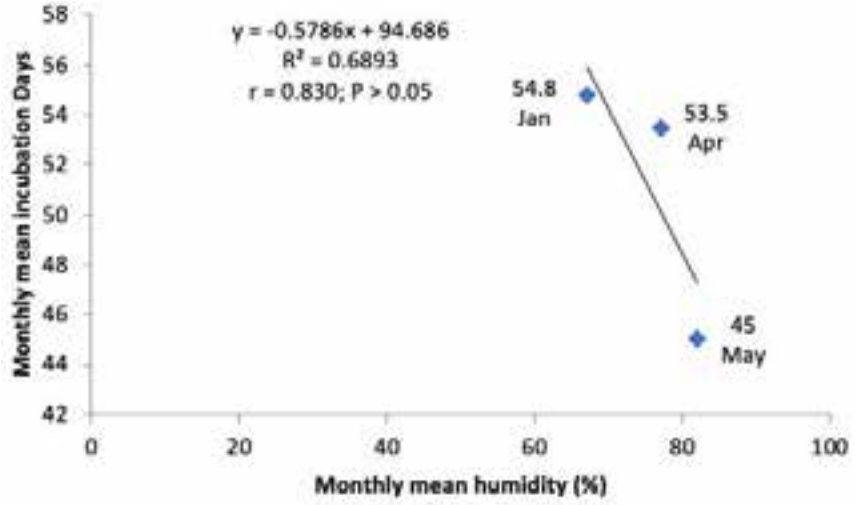


Figure 3. Relationship between monthly mean incubation days of eggs of Olive Ridley Turtle and monthly mean relative humidity during 2022.

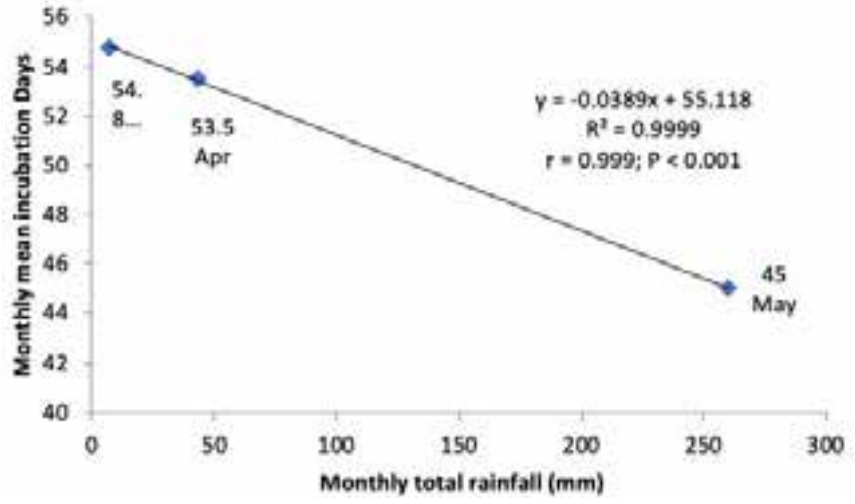


Figure 4. Relationship between monthly mean incubation days of eggs of Olive Ridley Turtle and monthly total rainfall during 2022.

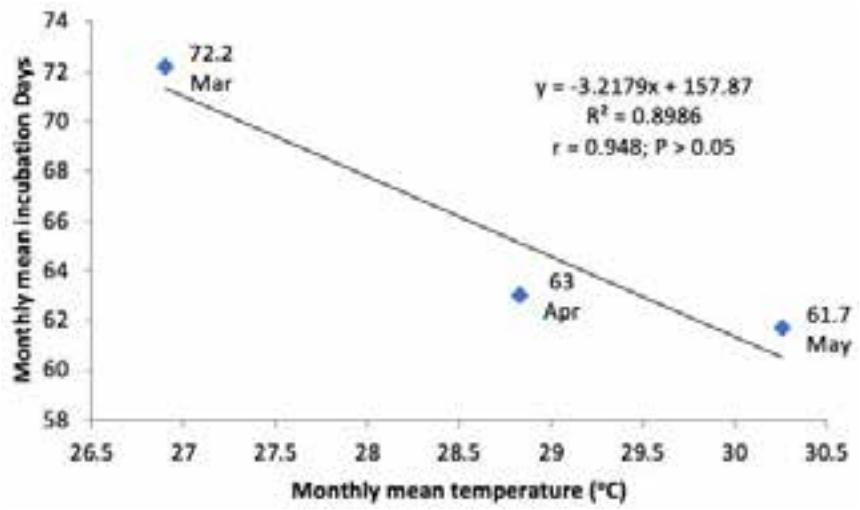


Figure 5. Relationship between monthly mean incubation days of eggs of Olive Ridley Turtle and monthly mean temperature during 2021.

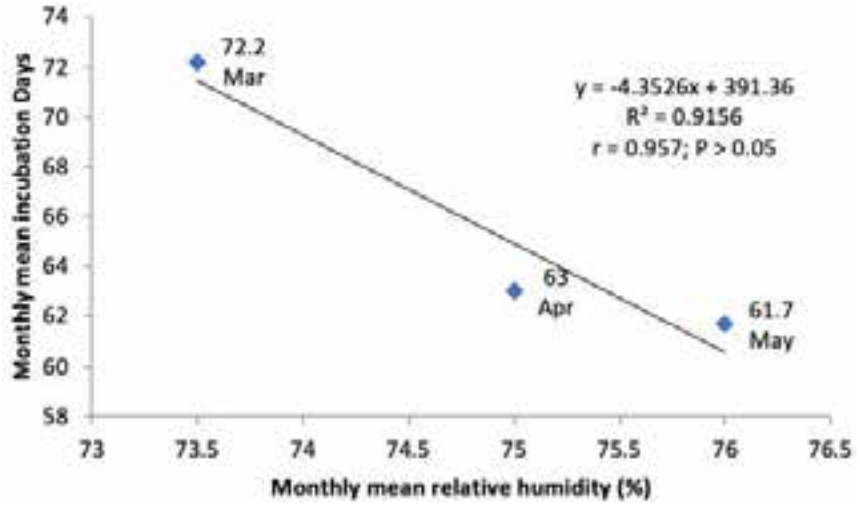


Figure 6. Relationship between monthly mean incubation days of eggs of Olive Ridley Turtle and monthly mean relative humidity during 2021.

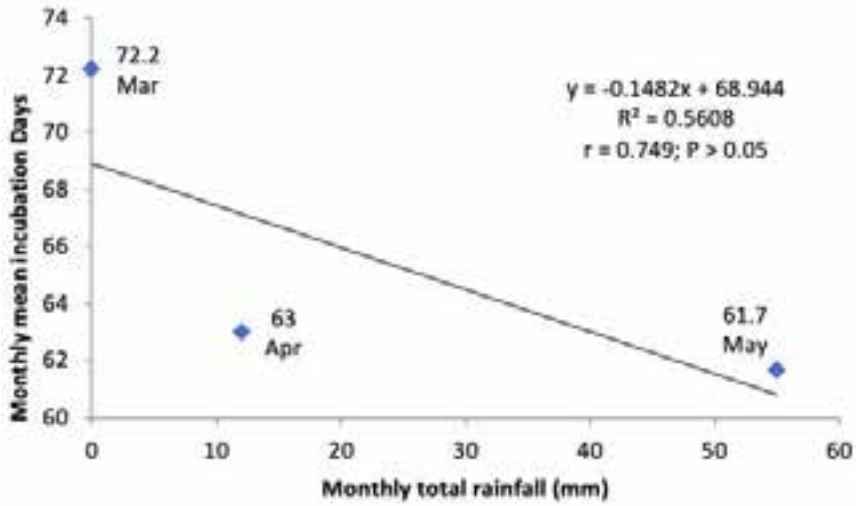


Figure 7. Relationship between monthly mean incubation days of eggs of Olive Ridley Turtle and the monthly total rainfall during 2021.

Table 2. Hatchery of CODEC pilot project in Cox's Bazar of Bangladesh during 2021–2022.

A. Hazom Para, Baharchara, Teknaf

Egg collection date	Egg collection time	No. of eggs	No. of nests	No. of egg pits in the hatchery	Hatching date	Incubation days (no. of hatchlings)	No. of healthy hatchlings	No. of dead/ deformed hatchlings	Healthy hatchling rate (%)	Remarks
13.01.21	2.20 am	142	1	7	23.03.21–29.03.21	69 (09), 70 (10), 71 (05), 73 (14), 74 (08), 75 (11)	57	85	40.14	Cold tempera-ture
28.01.21	8.00 pm	21	1	1	01.04.21	63 (03)	03	18	14.29	-do-
11.03.21	3.30 am	105	1	6	12.05.21	62 (77)	77	28	73.33	
11.03.21	9.00 pm	90	1	4	12.05.21	62 (68)	68	22	75.56	
13.03.21	3.40 am	149	1	6	12.05.21-15.05.21	60 (86), 63 (28)	114	35	76.51	
13.03.21	9.00 pm	32	1	1	16.05.21	64 (25)	25	07	78	
Sub-total		**539**	**6**	**25**			**344**	**195**	**43.31**	
14.11.21	11.20 pm	132	1	5	05.01.22–08.01.22	52 (01), 52 (02), 55 (34)	37	95	28.03	Cold tempera-ture
20.02.22	02.00 am	149	1	6	13.04.22–22.04.22	54 (05), 54 (09), 55 (78), 58 (01), 63 (26)	119	30	79.86	
25.02.22	02.00 am	138	1	5	-	00	00	138	00	Escaped eggs from the miscreants. How many days ago the eggs were collected was not known.
03.03.22	04.00 pm	143	1	6	22.04.22 –24.04.22	49 (11), 50 (80) 51 (28)	119	24	83.21	
04.03.22	3.40 am	111	1	4	24.04.22–27.04.22	50 (62), 51 (16), 53 (20)	98	13	88.28	
09.03.22	02.30 am	134	1	6	27.04.22	48 (122)	122	12	91.04	
Sub-total		**807**	**6**	**32**	**-**	**-**	**495**	**312**	**-**	
Total		**1346**	**12**	**57**	**-**	**-**	**839**	**507**	**62.33**	
Average						**56.55 ± 6.99**				

B. Uttar Shilkhali, Baharchara, Teknaf

Egg collection date	Egg collection time	No. of eggs	No. of nests	No. of egg pits in the hatchery	Hatching date	Incubation days (no. of hatchlings)	Total no. of healthy hatchlings	No. of dead/ deformed hatchlings	Healthy hatchling rate (%)	Remarks
29.01.22	08:00 pm	124	1	5	07.04.22–13.04.22	68 (24), 71 (14), 73 (07), 74 (28)	73	51	58.87	Miscreants destroyed eggs in the hatchery.
18.02.22	02.30 am	121	1	5	13.04.22	56 (50)	50	71	41.32	-do-
21.02.22	01.00 am	107	1	4	15.04.22	54 (39),	39	68	36.44	-do-
21.02.22	08:00 pm	102	1	4	15.04.22–20.04.22	54 (22), 59 (11)	33	69	32.35	-do-
04.03.22	11.00 pm	141	1	6	21.04.22–23.04.22	47 (18), 48 (14), 49 (17)	49	92	34.75	-do-
05.03.22	9:30 pm	105	1	4	24.04.22–25.04.22	49 (31), 50 (16),	47	58	44.76	-do-
05.03.22	11:40 pm	131	1	5	26.04.22–27.04.22	51 (20), 52 (25)	45	86	34.35	-do-
26.03.22	03.00 am	107	1	4	11.05.22	45 (60)	60	47	56.07	
26.03.22	03.20 am	85	1	3	11.05.22	45 (48)	48	37	56.47	
26.03.22	04.00 am	92	1	4	11.05.22	45 (52)	52	40	56.52	
26.03.22	05.15 am	81	1	4	11.05.22	45 (46)	46	35	56.79	
26.03.22	06:00 am	165	1	6	11.05.22	45 (94)	94	71	56.96	
27.03.22	04:30 am	108	1	4	11.05.22	45 (50)	50	58	46.29	
27.03.22	04:30 am	128	1	5	12.05.22	45 (87)	87	41	67.96	
Total		**1597**	**14**	**64**			**773**	**824**	**48.40**	
Grand Total		**2943**	**26**	**96**			**1612**	**1331**	**54.77**	

Table 3. Weather Data from Teknaf Weather Station, Cox' Bazar and incubation days of eggs (- = No data)

Incubation data plus weather data of 2022.

Month	Mini Temp	Maxi Temp	Average Temp	Mini RH	Maxi RH	Average RH	Total Rainfall	Incubation Days
Jan '22	14.77	28.22	21.50	43	91	67.0	07	54.8
Feb	16.14	29.89	23.02	56	87	71.5	12	-
Mar	21.26	33.27	27.27	44	85	64.5	00	-
Apr	25.60	33.53	29.57	61	93	77.0	43	53.5
May	25.70	33.30	29.50	69	95	82.0	260	45.0

Incubation data plus weather data of 2021

Month	Mini Temp	Maxi Temp	Average Temp	Mini RH	Maxi RH	Average RH	Total Rainfall	Incubation Days
Mar	21.47	32.33	26.90	58	89	73.5	00	72.2
Apr	24.00	33.65	28.83	61	89	75.0	12	63.0
May	26.34	34.18	30.26	62	90	76	55	61.7

Table 4. Number of sea turtles that laid eggs during 1996–2003 and 2005–2010 on Bangladesh beaches*.

Year	Olive Ridley Turtle	Green Turtle	Hawksbill Turtle	Leatherback Turtle
1984–94[1]	287**	31	1	0
1996–97	83	4	0	0
1997–98	124	5	0	0
1998–99[1]	47	9	3	0
1999–2000	86	6	0	0
2000–01	137	4	0	1 (?)
2001–02	73	22	0	0
2002–03	85	3	0	0
Subtotal	**635**	**53**	**3**	**1 (?)**
2005–06	155	0	-	-
2006–07	142	1	-	-
2007–08	162	3	-	-
2008–09	151	3	-	-
2009–10	158	2	-	-
Subtotal	**768**	**10**	**-**	**-**
Total	**1,403**	**63**	**3**	**1 (?)**

* Sources: Islam 2002, MoEF No date, CWBMP 2008, Islam et al. 2011, NACOM 2010. [1] Rashid & Islam 2006, ** including 204 from Saint Martin's Island in 1996-97, excluded from the total.

Table 5. Number of marine turtles affected by various human activities at the Saint Martin's Island from October 1996 to February 2003*.

Nature of Threats/Disturbances	Number of turtles
1. Predation by dogs	20
2. Nests destroyed by dogs	7
3. Unsuccessful nesting due to rocks	18
4. Females with flippers cut	9
5. Unsuccessful due to tourist disturbances	13
6. Females with injury on the carapace	8
7. Females with tumours on flippers	2
Total	**77**

on the island in years past (Rashid & Islam 2006).

A total of 27 adult and sub-adult turtles of both sexes were found dead on the beaches during 1996-98, more than half of which were believed to be caused by fishing activities. More than 54 dead adult and sub-adult turtles washed ashore during the 2000–01 season. In 1996 the Marine Fisheries Research Institute (MFRI) conducted fishing-related sea turtle mortality and reported that turtle deaths were not significant (Rashid 1997). However, that report probably underestimated the potential impact of fishing, as turtles continue to be found dead along the shoreline.

Since 1996, success has been gained through several awareness programmes, which have helped some of the traditional fishermen view sea turtles as friendly animals instead of being harmful to their fishing activity. Nevertheless, more work is needed, as most entangled turtles are still found dead. In addition, in Bangladesh TEDs (Turtle excluder devices) are not used on shrimping boats and the government is taking no initiative to impose any regulations regarding TED use. Another important factor is the submersion time and the depth at which other types of nets are set, which can affect turtle mortality.

Observations of 10 persons including one local from

Table 6. Initiatives taken for the conservation and management of sea turtles*.

Organization	Major activities
Government of Bangladesh	1. Declaration of Ecologically Critical Areas
	2. Sustainable resource management
	3. Establishment of ecotourism in that area
Non-Government Organizations (NGOs) and International Organization	1. School education programme
	2. Community awareness programme
	3. Hatchery management
	4. Establishment of education and research center
	5. Establishment of hatcheries
	6. Supporting ecotourism activity
	7. Ex-situ conservation through hatcheries
	8. Encouraging fishermen to use TEDs in gear

* Source: Hossain et al. 2013.

Table 7. Eggs conserved, and hatchlings released between 2000–2022.

Year	Egg conserved	Hatchling released	Sources
2000–01	3,850	2,700	MoEF (No date)
2001–02	7,600	5,680	MoEF (No date)
Total	**11,450**	**8,380**	
2007–2010	**28,642**	**26,408**	NACOM et al. (2010)
2021–22	**2,943**	**1,612**	CODEC (This study)
Grand Total	**43,035**	**36,400**	

1984 to 2003 on sea turtle nesting places were reported by Rashid & Islam (2006) from 14 different spots of Bangladesh, of which Olive Ridleys nested in 13 spots, Green Turtles in seven spots and Hawksbills in one spot (the Saint Martin's Island). They recorded 287 Olive Ridley Turtle nests (including 204 at the St. Martin's Island in 1996–97), 31 Green Turtles and one Hawksbill Turtle were reported by locals from the St. Martin's Island plus egg-shells were seen in Egg Island and Mandarbaria of the Sundarbans (Table 4).

From October 1996 to February 2003 (Rashid & Islam 2006), 77 turtles were affected by various human activities on the Saint Martin's Island, of which dogs (as first brought by the human on the Island) were the highest disturbing animals (predated eggs and destroyed nests), the second highest was unsuccessful nesting due to rocks and the third highest was unsuccessful nesting due to tourist disturbances (Table 5).

Furthermore, with the increase of local and international tourists in recent years especially on the Saint Martin's Island, the Bangladesh Parjaton Corporation (National Tourism Authority) started building hotels, motels, and other recreation centres in many areas along the coast, Inani and Cox's Bazar in particular. Some private enterprises including locals have constructed motels in the areas, which are identified as sea turtles' nesting beaches (Inani and the Saint Martin's Island), which is a clear violation of the country's law.

Increased fishing boats have increased oil spills, pollution and disposal of solid domestic and machinery wastes. The beaches are being used for drying fish and mending fishing nets during sea turtles' nesting period.

Increased human activities and beach lighting (especially on the Saint Martin's Island) have also increased that disturb nesting females and disorienting hatchlings. The Bangladesh Forest Department under the Ministry of Environment, Forest and Climate Change is the sole authority for the protection, conservation, and management of all wildlife in the country.

Different NGOs are working on conservation aspects of the sea turtles and mostly collecting eggs and hatching them into their hatcheries and releasing them into the Bay of Bengal. They have also printed booklets and posters; hoisted festoons and banners; published a few papers; organised seminars, rallies and workshops for education and awareness of local people. These actions are encouraging, but it would be better if all these works on sea turtles in the country were integrated.

Very recently (in 2024), one threat has come for the mother turtles of our beaches, which was injuries caused by the propellor of the cruise ship ferrying tourists from Inani to Saint Martin Island during the winter season.

CONCLUSION

Marine turtles face population decline in many places of the world and its population is severely depleted in Bangladesh due to various anthropogenic threats. Reports of all organizations working on sea turtles are submitting reports to the respective donors are not accessible and open access. Community-based conservation would be the best idea for conserving these unique creatures of the oceanic planet. It would be better if all works on the sea turtles were integrated.

RECOMMENDATIONS

The following recommendations have been suggested for the conservation of sea turtles in Bangladesh:

1. Take meaningful steps to save sea turtle nesting beaches from human interference.
2. Awareness building, education, research on population biology, conservation of nests and nest-building beach areas.
3. Ecological Critical Area Rules 2016 and Protected Area Management Rules 2017, and regulations should properly be implemented.
4. Community-based conservation would be the best way to save these unique creatures of the oceanic planet.
5. As fishermen are responsible for the death of sea turtles, so using TED in fishing boats can be an effective tool for reducing the mortality of turtles.
6. The number of hatcheries should be established like 1-Hatchery/2 km of the sandy beach.
7. Hatchery management should be improved scientifically; and if all works on sea turtles were integrated this could bring better outcomes.

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ARTICLE

Noteworthy records of vascular plants from the West Bank, occupied Palestinian territories

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Abstract: This study reports noteworthy data records on 23 species belonging to 19 families of vascular plants from the West Bank (occupied state of Palestine). For 15 uncommon/rare species, the newly collected data meaningfully extend their range: *Saccharum spontaneum*, *Cyrtomium falcatum, Eleocharis palustris, Crypsis factorovskyi, Coincya tournefortii, Medicago ciliaris, Abutilon theophrasti, Anabasis oropediorum, Allium rothii, Fallopia convolvulus, Glycyrrhiza echinata, Plantago major, Pseuderucaria clavata, Lupinus palaestinus*, and *Cistanche violacea.* Eight other species are recorded for the first time in the West Bank: *Tordylium cordatum, Bergia ammannioides*, *Sambucus ebulus*, *Araujia sericifera, Euphorbia graminea, Potamogeton nodosus, Cyrtomium falcatum,* and *Ulmus minor.* Three of those eight species (*Araujia sericifera, Euphorbia graminea,* and *Cyrtomium falcatum*) are not local in the studied region (introduced species). The fact that three of the eight new records were introduced indicates that human disturbance is becoming dominant here as elsewhere in the world. Such data are useful as Palestine is currently implementing a new National Biodiversity Strategy and Action Plan and one of its actions is focused on the conservation of rare species of plants and combatting introduced/invasive species.

Keywords: Biodiversity, conservation, flora, geographic distribution, range extension, rare species, State of Palestine.

تقدم هذه الدراسة سجلات بيانات جديرة بالملاحظة عن 23 نوعًا تنتمي إلى 19 عائلة من النباتات الوعائية من الضفة الغربية (دولة فلسطين المحتلة). بالنسبة لـ 15 نوعًا غير شائع/نادر ، تعمل البيانات المجمعة حديثًا على توسيع نطاقها بشكل مفيد: Saccharum spontaneum ،Cyrtomium falcatum ،Eleocharis palustris ، Crypsis Factorovskyi ،Coincya Tournefortii ،Medicago ciliaris ،Abutilon theophrasti ،Anabasis oropediorum ،Allium rothii ، Fallopia convolvulus ،Glycyrrhiza echinata ،Plantago الكبرى، Pseuderucaria clavata. و Cistanche violacea ،تم الترمس الفلسطيني، . تسجيل ثمانية أنواع أخرى لأول مرة في الضفة الغربية وهي: Tordylium cordatum ،Bergia ammannioides،Sambucus ebulus ،Araujia sericifera ،Euphorbia graminea ،Potamogeton nodosus ،Cyrtomium falcatum ،Ulmus minor في ثلاثة من هذه الأنواع الثمانية ليست محلية . المنطقة المدروسة (أنواع مُستوردة). تشير حقيقة إدخال ثلاثة من السجلات الثمانية الجديدة إلى أن الاضطراب البشري أصبح مهيمنًا هنا كما هو الحال في أماكن أخرى من العالم. مثل هذه البيانات مفيدة حيث أن فلسطين حاليًا تنفيذ استراتيجية وخطة عمل وطنية جديدة للتنوع الحيوي، وأحد أنشطتها يركز على الحفاظ على الأنواع النادرة من النباتات

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INTRODUCTION

The small geographic area of Palestine boasts diverse habitats because of the geologic history of the African and Arabian tectonic plates' movements that resulted in high mountains but also the lowest point on earth at the Dead Sea. This geologic history and Palestine's geographic location at the nexus of the Eurasian and African continents allowed this area to have diverse habitats and to include floristic elements covering five assemblages: Mediterranean, Irano-Turanian, Saharo-Sindian, Coastal, and Ethiopian-Sudanese. The local flora was studied showing significant floral biodiversity (e.g., Zohary 1966, 1972; Feinburn-Dothan 1978, 1986; Danin 2004; Al-Sheikh 2019), but much remains to be explored, including updating the presence, ecology, and conservation status of many families and groups. New distributional records from the West Bank (occupied Palestinian Territories) are being published now (Al-Sheikh & Mahasneh 2016; Pahl & Qumsiyeh 2021; Al-Sheikh & Qumsiyeh 2021, 2022; Gideon & Qumsiyeh 2023; Qumsiyeh & Al-Sheikh 2023).

The flora is threatened by human activities including climate change, pollution, habitat destruction, overexploitation, invasive species, and Israeli settlement activities (Qumsiyeh & Abusarhan 2021; Qumsiyeh 2024). Nearly a third of the known species of plants in the West Bank are rare or threatened (Al-Sheikh & Qumsiyeh 2022). Recently, a new protected area network for the state of Palestine Gaza Strip, and the West Bank was created and approved at the highest level of government (see Qumsiyeh et al. 2023).

Together with the new National Biodiversity Strategy and Action Plan (NBSAP), the plans to manage the protected areas highlighted understanding plant distributions and the presence of invasive species to facilitate habitat conservation and to face the human-induced threats to the environment. These gaps in knowledge are important to address to bridge the science-policy-practice gap for plant conservation. Hence, a program was developed to collect field data and herbarium specimens, especially from protected areas to fill that gap. The knowledge of the flora of the West Bank is expanded with 23 noteworthy records.

MATERIALS AND METHODS

The survey covered areas of the West Bank (occupied Palestinian Territories) over five years 2019–2024). Some data was collected before (2015–2019) but starting in 2019, field efforts were intensified while taking into account some pauses during the COVID-19 pandemic and the 2023/2024 conflict that resulted in Israeli restrictions on the Palestinian movement. Plants were observed, photographed, and specimens were collected by the team of the Palestine Institute for Biodiversity and Sustainability (PMNH) at Bethlehem University. Data collected include locality coordinates, elevation, dates collected, and notes on habitats. Species morphological descriptions given below as well as identification are from published sources (Zohary 1966, 1972; Davis 1972; Feinbrun-Dothan 1978, 1986). Voucher herbarium specimens were prepared and deposited in the herbarium collection of the Palestine Museum of Natural History and catalogued and numbered in the collection for future reference (numbers given below as PMNH-H). For each species, we give (in order) the Latin name, location collected, coordinates, elevation, date, and herbarium number. Comparison with literature records and especially data posted at https://biogis.huji.ac.il/ (henceforth BIOGIS) was done for geographic distribution to assess the extension of ranges and whether they are native or introduced. Accepted Latin names were verified on the World Flora Online (WFO) plant list database to ensure that the names are up-to-date and not synonyms.

RESULTS

Family Amaryllidaceae

***Allium rothii* Zucc.**

Bethlehem Governorate, Kisan, 31.589 N & 35.256 E, altitude 582 m, 11.iii.2021, PMNH H0269; and 31.584 N & 35.258E, altitude 573 m, 24.ii.2024; Khalil Governorate, Bani Naim, 31.528 N & 35.214 E, altitude 573 m, 01.iv.2019, PMNH H 1223.

A bulbous plant, bulb ovoid, 3–4 cm in diameter. Stem 6–15 cm. Leaves many, lanceolate, 0.6–3 cm, smooth margin, spread on the ground, longer than stem. Spathe persistent, shorter than the hemispherical umbel with dense flowers. Perianth stellate, white with a purple or greenish midvein. Filaments and anthers are dark purple as long as perianth. Ovary dark purple. Style short. Flowering February–April. This species was noted rarely in areas north of the Naqab and seems to exist in disjointed batches in the transition zone of the Irano-Turanian to the Mediterranean zone in the southern part of the West Bank (BIOGIS and our data).

Family Asclepiadaceae

***Araujia sericifera* Brot.** (Image 1)

Qalqilia Governorate, Sanneria, 32.168 N & 35.025 E, altitude 131 m, 11.xi.2020, PMNH H0694.

Description from Santa Cruz & Cordero (2018): Sub-shrub climbing or vine, up to 5 m long, evergreen, lactiferous. Stem pubescent, unbranched or branched, circular. Taproot, with a main axis and smaller secondary branches. Leaves simple, entire, opposite, with petiole of 10–20 mm long, ovate-oblong, ovate-lanceolate, 40–95 × 15–60 mm, apex acuminate, base truncate, upper surface green and glabrous, and under surface canescent and densely pubescent. Inflorescences are axillary of 2–5 flowers, sometimes solitary, pedicels 10–16 mm long. Calyx with 5 sepals, ovate or lanceolate. Corolla lobes 5 patent, oblong or ovate-acuminate, apex obtuse, white or greenish dorsally. Androecium with 5 stamens. Seeds ca. 400 per fruit, 6.3–7.8 × 2.8–3.5 mm, compressed, oval-lanceolate, rough, with pappus sericeous, 25 × 40 mm long, white, deciduous. Flowering July–September. This species, originally from South America (Federici et al. 1988), was introduced to Europe and more recently to historical Palestine, primarily in coastal areas. This is the first record from the West Bank, but we expect to find this species in other parts of the West Bank with similar habitats.

Family Cyperaceae

***Eleocharis palustris* (L.) Roem. & Schult.**

Jinsafut, Qalqilia Governorate, 32.053 N & 35.134 E, altitude 412 m, 14.iii.2021, PMNH-H 0372.

A perennial plant with creeping rhizomes. Stem leafless, erect, glaucous, ended with a solitary terminal spikelet of inconspicuous greenish-brown flowers. Leaves bladeless, brown sheaths clustered at the base of the stem. Flowering March–July. According to BIOGIS , it is common in the coastal areas of Palestine and was supposedly observed in two areas in the West Bank: West of Qusin near Nablus (2022 & 2023) and in the Dheisheh area of Bethlehem (1985). The latter is now a highly urbanized area, and despite the visit, it was not located. It was found in humid habitats in the periphery of a vernal pool near Jinsafut (see Qumsiyeh et al. 2022) and this seems to be also its habitat in other parts of the Mediterranean.

Family Dryopteridaceae

***Cyrtomium falcatum* (L.f.) C.Pres.**

Ramallah Governorate, Southwest of Deir Ibzei, 31.093 N & 35.124 E, altitude 575 m, 10.ix.2021, PMNH H 0286.

A perennial fern with a large rhizome. Leaves are made up of 6–10 pairs of shiny bright green leaflets. Each leaflet has a flat to wavy to slightly toothed margin and a netlike pattern of veins. Sori is held by brown or black indusial on the underside of each leaflet. It is native to eastern Asia. Nevertheless, as stated by POWO (2024), this plant was introduced in various regions around the world. *Cyrtomium falcatum* is a popular ornamental plant and was brought into the country but finding it in the wild in crevices in soft rock (first record in the West Bank in the wild) indicates its potential spread, an issue discussed by Van Valkenburg et al. (2014).

Family Caprifolaceae

***Sambucus ebulus* L.** (Image 1A)

Ramallah Governorate, Ain Sinia, 31.972 N & 35.229 E, altitude 644 m, 14.viii.2020, PMNH-H0322; Bethlehem Governorate, Battir, Ain Battir, 31.727 N & 35.138 E, altitude 650 m, 23.vi.2009, PMNH-H 0414; Hebron Governorate, Ain Hasaka, 31.564 N & 35.090 E, altitude 904 m, 02.v.2018, PMNH-H 0415.

Glabrous, perennial herb, 0.5–2 m with creeping rhizome. Leaves have 3-6 paired leaflets; leaflets lanceolate to elliptic, serrate, 7–15 x 2–6 cm. Stipules ovate. Inflorescence with three primary flat-topped rays, 7–10 cm in diameter. Flowers white; anthers purple. Fruits drupe globose, black. Flowering July-August in wet areas. This species is known in the wild from Europe, Turkey, Syria, Lebanon, northern Iraq, and northern Iran (Ebadi & Hisoriev 2011). The species was not reported from Jordan (Al-Eisawi 2013; Taifour & El-Oqlah 2017). As per BIOGIS it is around Jish in the upper Galilee, in Ein Shalaf just south of lake Tiberias, and in Sataf west of Jerusalem. This record is the first in the West Bank. The plant has numerous medicinal uses (Jabbari et al. 2017).

Family Chenopodiaceae

***Anabasis oropediorum* Maire** (Image 1)

Bethlehem Governorate, Al Rashaydeh area, Wad Hasasah, 31,575 N & 35.383 E, altitude 168 m, 07.iii.2015, PMNH H 1631; Bethlehem Governorate, Al Rashaydeh area, entrance of Wadi Darajeh, 31,572 N & 35.383 E, altitude 157 m, 24.ii.2024, PMNH H 1632.

Small shrub 25–60 cm. Stems divergent at the base, woody to nearly half of their length; branches opposite with nearly equal internodes. Leaves reduced to 2-lobed short cupule; pointed at the young stems' apices. Flowers opposite with perianth having five membranous wings 5–7 mm long; ovate-orbicular; white or pink. Ovary papillose; stigma thick; papillose. Embryo spiral

coiled. Flowering October–November. There are four undated and undocumented mentions of this species in the West Bank (BIOGIS). Our two documented records (with herbarium specimens) for this rare species are noteworthy.

Family Cruciferae

***Coincya tournefortii* (Gouan) Alcaraz, T.E.Díaz, Rivas Mart. & Sánchez-Gómez**

Jenin Governorate, National Agricultural Research Center, Arraba meadow, 32.77 3 N & 35.261 E, altitude 267 m, 14.ii.2017, PMNH-H0887.

It is annual, 20–70 cm, hispid below, glabrous above. Radical leaves rosulate, petiolate, lyrate-pinnatisect. Lateral lobes 4–12, oblong, dentate-crenate. Inflorescences 10–20 flowers pale yellow, corymbose. Calyx 3–4 mm, Petals 6–8 mm, linear or oblong. Fruiting pedicels 1–4 cm, fruit 3–6 cm, erect, glabrous. Seeds brown. Flowering January–April. Habitat in sandy soil. This plant was found growing in deep rich terra rosa fields of the Arraba meadow. The species is widespread in coastal areas of historic Palestine. In the West Bank, this is the third record after Ain Yabrud and Lubban Al-Sharqiya noted on BIOGIS.

Family Cruciferae (Brassicaceae)

***Pseuderucaria clavata* (Boiss. & Reut.) O.E.Schulz** (Image 1)

Bethlehem Governorate, AlRashaydeh desert, 31.479 N & 35.364 E, altitude 257 m, 07.iii.2015, PMNH-H1624.

Annual, glabrous, 10–35 cm. Stem ascending, branching from the base. Leaves fleshy; 3–9 cm; petiolate; pinnatisect into linear terete lobes; radical leaves broader and longer petioles. Calyx violet; 6–10 mm. Petals 13–22 mm; pale violet; long-clawed. Fruit erect; 35–75 × 2 mm; linear; terminating style with a minute stigma. Flowering February–April. This species was observed by Danin in the southeastern part of the West Bank, near Ain Gedi (BIOGIS) near our locality. These are the northernmost records of the species which is found mostly in the Naqab in our region and is a very rare species.

Family Elatinaceae

***Bergia ammannioides* Heyne ex Roth**

Sanour, Jenin Governorate, 32.370 N & 35.255 E, altitude 347 m, 30.vi.2024, PMNH-H2199.

Annual, 10–25 cm, stems pinkish, hairy, erect, branched from the base. Leaves 10–30 x 5–10mm, opposite elliptic- oblong to oblanceolate, acute, serrate with pointed tips except in the basal part. Flowers in subsessile axillary clusters. Sepals 5, pinkish, 1.2–1.5 mm, lanceolate, acuminate, membranous margins, ciliolate. Petals 5, lanceolate, acute, white, shorter than sepals. Stamens 5, as long as petals, anthers pale yellow. Ovary 5-celled, subglobose; stigmas 5, reddish. Seeds numerous, 0.2–0.3 mm, ovoid, brown. Flowering August–September. The species is known from Africa to Asia and into Australia (https://powo.science.kew.org/). In the studied region, it is reported from very few localities in Jordan and the coastal and Galilee regions of historic Palestine. This is the first record of this species and this family in the West Bank.

Euphorbiaceae

***Euphorbia graminea* Jacq.** (Image 1)

Nablus Governorate, Nablus, 32.220 N & 35.266 E, altitude 540 m, 05.i.2023, PMNH-H 1611; 32.214 N & 35.280 E, altitude 550 m, 10.i.2024, PMNH-H1610.

A perennial herb 30–80 cm high with milky juice. Stem erect, pentagonal, glabrous. Leaves alternate, petiolate, ovate-rounded, 17–40 mm long, 10–20 mm wide, entire, acuminate. Cyathia together with a peduncle cyme, and leaf-bracts opposite, linear or lanceolate, involucres turbinate; petaloid appendage 2–4 (5), white, obcordate at apex. Stamen 13–20, basifixed, inner filament ca. 1 mm, outer ones ca. 0.5 mm; anther yellow; female flower pedicel pubescent; ovary, 3 carpels, styles 3. Capsules 2 mm long, 3 mm diameter, exserted out of involucre, pedicel ca. 4 mm long, each carpel with 1 seed; seed 3 (Webster & Burch 1967). This perennial herb, originally from South America, is commonly found growing along roadsides (https://www.worldfloraonline.org/taxon/wfo-0000962344). This is the first record of this introduced species (native to Mexico), in the West Bank.

Family Malvaceae

***Abutilon theophrasti* Medik.**

Qalqilia Governorate, Falamia, 32.224 N & 35.015 E, altitude 106 m, 27.vi.2022, PMNHH-H1135.

Annual, 40–60–(80) cm, tomentose. Stem single, branched above. Leaves alternate, 7–15 x 6–8 cm, long petioles, ovate-cordate, long acuminate, entire. Flowers grow on stalks, either individually or in clusters. Calyx 0.8–1 cm, campanulate. Corolla yellow, one and a half times longer than calyx; five obovate petals attached at the base, notched at the apex. Fruit 1.5–2 cm in diameter; mericarps 10–16 with awns up to 3 mm, 1–2 seeded each. Blooming: May–September. It was noted on BIOGIS from Wadi Joz in east Jerusalem but ours is the first verified West Bank record.

Image 1. Phenology of selected plants: A—*Sambucus ebulus* | B—*Euphorbia graminea* | C—*Pseuderucaria clavata* | D—*Anabasis oropediorum* | E—*Araujia sericifera* | F—*Potamogeton nodosus* | G—*Cistanche violacea*. © Palestine Institute for Biodiversity and Sustainability, Bethlehem University.

Family Orobanchaceae

***Cistanche violacea* (Desf.) Hoffmanns & Link** (Image 1G)

Bethlehem Governorate, Al Rashaydeh area, 31.488 N & 35.345 E, altitude 257 m, 07.iii.2015, PMNH H 1617.

A parasitic desert plant, up to 30 cm. Bracts longer than calyx. Calyx campanulate, glabrous, divided into lobes to its middle. Corolla 2.5–3.5 cm longer than calyx by 2.5 times, glabrous, white corolla tube, deep purple lobes, slightly curved outwards dark lilac limbs. It is characterized by a prominent yellow semi-circular fold on the lower corolla lip. This is the first record of this species in the West Bank. Reported in a few localities in the Naqab and south Jordan (El-Eisawi 2013). Medicinal and herbal uses, and worldwide distribution may make this an important global economic plant, though reproducing it ex situ might be difficult (Thorogood et al. 2021; Azab 2021).

Family Papilionaceae (Leguminosae)

***Glycyrrhiza echinata* L.**

Jenin Governorate, Sanour, 32.360 N & 35.247 E, altitude 366 m, 31.vii.2022, PMNH-H0746.

Perennial herb, 20–50 cm. Stem erect. Leaves 4–16 cm composed of 5–6 pairs of oblongs to elliptical, obtuse, or acute leaflets. Peduncles up to 7 cm. Flowers 2–4 mm, in dense 1–4 cm spherical heads. Calyx teeth are triangular. Corolla bluish. Ovary glandular. Fruiting heads 3–7 cm. spherical. Pod 1–1.5 × 0.5 cm, with prickles. 2–3 seeds. Flowering May–October. According to BIOGIS, there is only one visual but undated record from the Qabatiya area in the West Bank.

***Medicago ciliaris* (L.) All.**

Jenin Governorate, Arraba meadow, National Agricultural Research Station, 32.773 N & 35.262 E, altitude 267 m, 27.iv.2016, PMNH-H0420.

Annual, 30–50 cm. Stems procumbent or ascending. Stipules ovate, dentate with 2-fid distal tooth. Leaflets are sometimes blotched, 6–20 × 5–15 mm, obovate, and shortly apiculate. Peduncles 1–4 (rarely up to 10) flowered. Flowers 5–9 mm. Calyx hairy, teeth equal to tube or shorter. Corolla is about twice as long as calyx, yellow. Fruit large, spherical to ovoid, 10–20 mm high, spiny, covered with many-celled hairs, coils 6–10, the broadest 9–15 mm diameter, surface covered with a distinct net of veins, with about seven anastomosing veins, spines 2–4 mm long. Seeds 1–2 in each coil. Flowering March–May. Prefers damp, deep soils. This is the third locality record for this rare species in the West Bank after Ein Yabrud and Wadi Al-Joz (near Jerusalem) (BIOGIS).

***Lupinus palaestinus* Bioss.**

Qalqilia Governorate, Sanneria, 32.127 N & 35.045 E, altitude 236 m, 30.iii.2022, PMNH-H0888.

Annual, hairy. Stems 15–30 cm, erect, branched from the base. Leaves 5–177 cm, stipules 1–1.5 cm, adnate at base to petiole, petioles hairy, much longer than the blade, leaflets 6–10, subsessile, lanceolate to obovate, obtuse. Racemes many-flowered, erect, exceeding foliage. Pedicels are shorter than calyx. Flowers about 1.5–2.3 cm, erect. Calyx persistent, hirsute-villose, lower lip longer than the upper lip. Corolla is twice as long as calyx; standards white lilac; wings connate at apex, keel violet at apex. Pod hirsute-villose, 4–7 × 2 cm long, 2-4-seeded, erect, flattened, oblong-linear with a short beak. Flowering February–April. Habitat in loamy soils in coastal areas. This species was reported mostly along the coastal areas of historic Palestine, and BIOGIS has two records in the West Bank but in atypical habitats (Kafr Qaddum & Kisan). It may have arrived through soil translocation from the coast for gardens since it is not its habitat. Our specimen from the Qalqilya area is within the kind of coastal habitats where we expect to see this species.

Family Plantaginaceae

***Plantago major* L.**

Ramallah Governorate, Aboud, 32.034 N & 35.071 E, altitude 250 m, 28.iv.2012, PMNH-H 0880.

Perennial herb, glabrous. Leaves rosulate, broadly ovate or elliptic, obtuse, 3–7-veined, narrowed to a long petiole. Scapes erect as long as leaves or longer. Spikes narrow cylindrical, 5–35 cm. Bracts ovate, white margined. Calyx lobes are equal, with a green midrib. Corolla lobes are short and acute. Seeds minute, angular. Flowering March–October. It is found near streams. BOIOGIS showed unconfirmed locations in three other West Bank areas: Qusin, Jalazon, and Wadi Joz.

Family Poaceae (Graminae)

***Saccharum spontaneum* L. Wild**

Nablus Governorate, Usarin, 31.118 N & 35.303 E, altitude 687 m, 10.xii.2020, PMNH-H 0403.

Perennial grass with stiff leaves that are 0.5–1.0 cm wide, canaliculate, long attenuate, serrulate at margins, keeled with white midrib, ligule short brown ciliate. Panicle 50–60 x 6–10 cm. Silky-villose with spikelets 4–6 mm, awnless, enveloped in long white silky hairs of callus, which are twice as long as spikelets. Lemma and palea are shorter than glumes which are ciliate. Flowering September–January. A presumed record from the Ain Fashkha area was noted which was identify as "Israel", but it is in the occupied Palestinian Territories (Olsvig-Whittaker et al. 2009). That paper was not taxonomic (not associated with herbarium specimens), their identification is uncertain. In any case, the established record is of significant as this plant is rare in the region. Wild sugarcane is noted in northern Africa and Asia, with one record in Lebanon (https://www.worldfloraonline.org/taxon/wfo-0000896738).

***Crypsis factorovskyi* L.**

Qalqilia Governorate, Qarawet Bani Zaid., 32.053 N & 35.134 E, altitude 412 m, 26.viii.201(, PMNH-H 0886.

This annual plant has internodes enveloped by leaf sheaths up to half their length. Leaf blades are densely-haired, especially on the upper surface. Panicles are head-like, compressed, terminal, and axillary. Terminal heads have numerous spikelets, 4–6 mm, with short pedicels, enveloped by an involucre of two opposite coriaceous distal leaves. Glumes are shorter than spikelets, hyaline, and lanceolate; lower glumes shorter and narrower than the upper. Palea two-veined, shorter than lemma. Stamens 3. Flowering June–August. Habitat includes inundated soils in winter and dry in summer. This species is mainly in the mountains and coastal areas within 1948 areas of Palestine and is noted as "very rare" in the Galilee (BIOGIS; Danin 2004). The species prefers moist habitats and as per BIOGIS it is around a small pond in Qusin, while while it was recorded it in the vernal pool near Jinsafut after drying (see Qumsiyeh et al. 2022). Two other species of *Crypsis* were recently reported from the West Bank: *C. acuminata* Trin. and *C. alopecuroides* (Piller et Mitterpol) and Schrader (Qumsiyeh & Al-Sheikh 2021).

Family Polygonaceae

***Fallopia convolvulus* (L.) Á.Löve**

Bethlehem Governorate, Husan, 31.715 N & 32.129 E, altitude 690 m, 16.vi.2021, PMNH-H 0715.

Herbaceous vine growing to 1.5 m. Stem twine clockwise around other plant stems. Leaves alternate, petiolate, triangular 1.5–6 cm long, 0.7–3 cm wide. Flower small in short racemes, 5 green, white tepals, 5 stamens. Pistil with fused stigmas forming a head. Fruit achene with one seed. This northern European species was introduced and is now spreading in the temperate Mediterranean climate in our region. In the West Bank, there are three other localities as per BIOGIS, but two of them are arid locations and unlikely. If this interpretation is correct, then this is the second record from the West Bank.

Family Potamogetonaceae

***Potamogeton nodosus* Poir.** (Image 1)

Jenin Governorate, Sanour, 32.368 N & 35.267 E, altitude 356 m, 14.viii.2022, PMNH-H1620.

A rhizome creeping perennial herb. Leaves floating and submerged borne on petiole; floating leaves, elliptic, entire 6–15 × 2.5–4 cm in length and width; submerged leaves translucent, lanceolate up to 15 × 4 cm; entire, stipules up to 8 cm. Spike 3–6 cm with a long peduncle. Inflorescence is a spike of many small flowers arising from the water on a peduncle. Fruitlets are tiny with a short beak. Flowering May–August. This species, found in the Galilee and coastal areas, and this is the first record in the West Bank.

Family Umbelliferae (Apiaceae)

***Tordylium cordatum* (Jacq.) Poir.**

Jenin Governorate, Siri's nature reserve, 32.309N & 35.316 E, altitude 484 m, 26.ii.2016, PMNH-H1612; Jenin Governorate, Jaba`, Hraish mountain, 32.336 N & 35.256 E, altitude 738 m, 06.iv.2022, PMNH-H 1613.

Annual, 40–80 cm. Stem erect; branched; angular; hispidulous. Lower leaves long - petiolate, cordate, blade 4–8 cm, doubly crenate; upper leaves ovate-oblong or three sects into ovate segments. Umbels are mostly terminal long peduncles. Bracts and bracteoles many, deflexed, bracteoles long or longer than the umbellets. Petals 2–3 mm unequally 2-parted. Fruits are discoid; dimorphic; 5–7 mm; orbicular; tuberculate with a smooth margin; outer part of the margin white. Flowering April–June. The species was noted in the northern areas of historic Palestine, BIOGIS reports two localities near the border (Green Line) and inside the West Bank one from 1977 observation in the northwest of the West Bank and one in the northeast near Jalbuon. Our documented records are deeper inside the West Bank.

Family Ulmaceae

***Ulmus minor* Mill.**

Ramallah Governorate, Ain Sinia, 32.971N & 35.230E, altitude 644 m, 14.viii.2020, PMNH-H 1635.

The tree typically grows to 20–30 m with a rounded crown. The bark of the trunk is rough and furrowed in older trees to form a block pattern. The shoots are slender. The leaves are smaller than those of the related European species, hence the specific epithet minor. Leaves on juvenile growth (Suckers, seedlings) are coarse and pubescent, whereas those on mature growth are generally smooth, though remaining highly variable in form; there are generally fewer than 12 pairs of side veins. A common characteristic is the presence of minute black glands along the leaf veins, detectable with the aid of a magnifying glass. The samara is oval or obovate, glabrous, 12–15 mm long, notched at the top, with the seed close to the notch. The species is noted in northern areas of historic Palestine, and this is the first record in the West Bank and is also the most southern record of its distribution in our region.

DISCUSSION

The data presented above adds noteworthy records of 23 species strengthening knowledge of the flora of the West Bank, an area (together with the Gaza Strip) projected to be the new state of Palestine (now recognized by 160+ countries). For 15 uncommon/rare species, our data meaningfully extend their range: *Saccharum spontaneum*, *Cyrtomium falcatum, Eleocharis palustris*, *Crypsis factorovskyi, Coincya tournefortii*, *Medicago ciliaris, Abutilon theophrasti*, *Anabasis oropediorum, Allium rothii, Fallopia convolvulus, Glycyrrhiza echinata, Plantago major, Pseuderucaria clavata, Lupinus palaestinus*, and *Cistanche violacea.* Eight other species are recorded for the first time in the West Bank: *Tordylium cordatum, Bergia ammannioides*, *Sambucus ebulus*, *Araujia sericifera, Euphorbia graminea, Potamogeton nodosus, Cyrtomium falcatum,* and *Ulmus minor.* Three of those eight species *(Araujia sericifera, Euphorbia graminea,* and *Cyrtomium falcatum*) are not local in our region (introduced species). Of course, not all introduced species are invasive. This indicates that human disturbance is becoming dominant here as elsewhere in the world with a concomitant need for monitoring and

eradication programs for invasive plants. The other five are noteworthy and rare (likely threatened) species and this helps us define key areas for conservation in line with the new National Biodiversity Strategy and Action Plan.

In planning the sustainable development of any country, a better understanding of its fauna and flora is essential. Indeed, this is emphasized in the new National Biodiversity Strategy and Action Plan and the new protected areas network (Qumsiyeh et al. 2023). It was found that uploaded data on BIOGIS may not always be reliable because it can include observations by non-professionals. Alternatively, terra rosa soil brought from coastal Mediterranean areas may bring some species into the West Bank (especially around Israeli settlements), giving unusual distributional data (e.g., *Lupinus palaestinus).*

Such botanical studies usually face difficulties globally due to a lack of resources and capacity of local people. This is exacerbated in developing countries like Palestine, where doing fieldwork is extremely hazardous due to restrictions on movement by the Israeli occupation authorities. Yet, work like this is essential for conservation efforts even in difficult circumstances.

Due to habitat changes, overexploitation, climate change, pollution, invasive species, and Israeli occupation practices, a significant portion of Palestine's biodiversity is vulnerable or threatened (Al-Sheikh & Qumsiyeh 2021, 2022; Pahl & Qumsiyeh 2021; Husein & Qumsiyeh 2022; Qumsiyeh & Albardeiya 2022). Understanding distributions and aligning them with the newly designated protected area network for the nascent state of Palestine (Qumsiyeh et al. 2023) could help conservation efforts for threatened taxa.

In conclusion, such detailed floristic data is important to collect to add to the baseline for understanding flora and will eventually help in better informing and devising conservation efforts.

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COMMUNICATION

Citizen science conservation: a case study using two threatened large aquatic American salamanders (Amphibia: Urodela), the Common Mudpuppy *Necturus maculosus* (Proteidae) and the Eastern Hellbender *Cryptobranchus alleganiensis* (Cryptobranchidae) observations on iNaturalist

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Abstract: Amphibians are facing threats globally which can present challenges to managers seeking to document declines. Citizen science platforms are emerging as an effective tool to document presence of species worldwide. However, little is known regarding the ability to characterize trends of large, fully aquatic easily identifiable salamander presence on these platforms within North American freshwater habitats, as a proxy for monitoring threatened species. This manuscript provides a baseline for the use of iNaturalist observations to characterize life history and anthropogenic factors associated with two amphibian species in decline, the Eastern Hellbender *Cryptobranchus alleganiensis* and Common mudpuppy *Necturus maculosus* salamanders. I report on predatory behavior, percent alive versus dead, and potential impacts of fishing on these salamanders. Conservation approaches such as those presented in this communication can provide a method for monitoring species using the power of citizen science in areas where researchers are managing threatened populations of amphibians.

Keywords: Amphibian declines, aquatic conservation, biodiversity, community science, herpetology.

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INTRODUCTION

Threats to freshwater biodiversity can include decreased water quality, habitat degradation, and microplastic pollution (Ahmed et al. 2022). Moreover, worldwide amphibians are facing numerous threats, including habitat destruction, fragmentation, emerging infectious diseases, and synergistic impacts (Green et al. 2020). Salamanders found in streams may be especially susceptible to environmental changes brought on by climate change (Lowe 2012). Two large fully aquatic salamanders which have a wide geographic range and are readily identified, are the Eastern Hellbender, *Cryptobranchus alleganiensis* (Daudin, 1803), and the Common Mudpuppy *Necturus maculosus* (Rafinesque, 1818). While information is lacking, mudpuppies may be experiencing declines (Lannoo et al. 1994; Hoffman et al. 2014), as they are often found in similar habitats with hellbenders (Nickerson et al. 2002). Purported reasons for mudpuppy declines include chemical pollution from lampricide and siltation alongside degraded habitat (Bonin et al. 1995; Matson 2005) and exploitation by biological supply companies (Holman 2012). Mudpuppies are regularly captured as bycatch during ice fishing, as they are active during the winter (Lennox et al. 2018). Eastern Hellbender declines are characterized by a lack of recruitment, with populations primarily comprised of older adults across their historical geographic range (Wheeler et al. 2003, Keitzer et al. 2013). Therefore, methods are needed which allow for temporal monitoring of these populations using effective, low costs non-invasive solutions. One potential solution to this issue is citizen science monitoring.

Citizen science monitoring via natural history databases has allowed for rare, threatened species to be documented and shared with the scientific community (Wilson et al. 2020). Among the many citizen science platforms, iNaturalist (www.inaturalist.org) is rapidly emerging as a powerful tool to document species presence, as a popular smartphone application where users upload images which are later identified by experts (Nugent 2018). Data obtained from citizen science participants on this platform can provide valuable freely accessible data, in many cases accurate to the species level (Wittmann et al. 2019). While this application has been used to assess injury rates of turtles (Seburn et al. 2023) and document invasive reptiles (Mo & Mo 2022), further work needs to consider how this citizen science data can contribute to monitoring rare species, their interactions with recreationalists, and potentially document mortality and even ecological connections with other species.

In order to test the potential for iNaturalist as a monitoring tool for threatened amphibian taxa, I quantified observations for two readily identifiable aquatic salamanders, the Eastern Hellbender and the Common Mudpuppy in the United States across their geographic range. The aim of this study is to determine: i) the overall presence of observations for each species, ii) any trends for annual increased use of the application using yearly observations as a proxy alongside seasonal observation trends, and iii) discuss how this approach can be incorporated into other conservation studies of threatened taxa by examining life history, ecological traits, and anthropogenic impacts in observations on this citizen science platform.

MATERIALS AND METHODS

Obtaining observation data

To compile data, observations were searched within iNaturalist, using the "explore" tab for both "Hellbender *Cryptobranchus alleganiensis*" and "Common Mudpuppy *Necturus maculosus*" in the United States, then further constrained to only those for wild, verified, research grade quality (confirmed by at least two agreeing naturalist). Research grade observations entail finer taxonomic resolution and reliable identification (Campbell et al. 2023). I also constrained search to only include observations up to 31 December 2023 so as not to bias annual observations. Observations were then exported for collection of state data, annual increase, monthly observations, and notes on individual specimens. All observations were downloaded on 20 January 2024. Moreover, each observation image was visually examined by author between 20 January 2024 and 31 January 2024, and manually processed for number of live versus dead, documentation of any behaviors, and life history stage (adult versus juvenile). Observation images were further assessed for species accuracy, as these two species are readily identifiable with adult hellbenders possessing dorsally flattened bodies, overall large size and reduced eyes, while adult mudpuppies possessing large feathery external gills, small limbs, and flattened tail (Petranka 1998). Moreover, larval hellbenders are robust with similar morphologies, while mudpuppy larvae often possess distinct dorsal dark lines bordered by yellow stripes (Conant & Collins 1998). Observations that included information on fishing were also noted. For quantification of juvenile, overall body size was assessed in image and if larvae or eggs

were present, the observation was counted as 'juvenile'. Data from downloaded observation was sorted in excel and primarily descriptive statistics are reported.

RESULTS

In total I documented 260 total observations for Eastern Hellbenders and 457 for Common Mudpuppy which met search requirements on the iNaturalist platform. All post included images that were readily identifiable to species level for both hellbenders and mudpuppies. Observations for hellbenders were from ten total states, while observations for mudpuppies were across 20 states, all within their historical geographic range. The top three states with observations for mudpuppies were Pennsylvania, New York, and Michigan, whereas for hellbenders was North Carolina, Pennsylvania, and Tennessee. The percentage of alive and dead individuals was similar for both species, 87.7% & 12.3% and 97.7% & 2.3%, respectively for mudpuppies and hellbenders (Table 1). All mortalities ('dead') observations for hellbenders were of adults, whereas for mudpuppies only one juvenile was characterized as 'dead' with all remaining mortalities comprised of adults. Moreover, the percentage of adult versus juvenile was 79.4% & 20.6% and 90.4% & 9.6%, for mudpuppies and hellbenders, respectively. All observations of hellbenders included only one individual in image, whereas for common mudpuppy, there were 444 observations with one individual, 10 observations with two individuals, and one each for three, four, and nine individuals in an observation image.

Several instances of observations including text mention of individuals being captured by fisherman were included with representative examples as "*Hooked this hellbender in the tail while fly fishing*", "*hooked by fisherman*", and "*caught on rod and reel*" "*caught on hook*" ,"*angler caught on nightcrawler*", "*a fisherman had caught and killed this poor mudpuppy while powerlining*", and "*killed by fisherman*". In at least one observation for mudpuppies, there was mention of "*found while netting for minnows, released unharmed*" and for one with hellbender as "*it was caught in a fishing line, it survived*" which implied release of individual following observer encounter. Instances of predation on mudpuppy included several observations of mink predations (4), seagulls (2), and a water snake (1) predating on live adults (Image 1). In addition, there was one incidence of an observation of a dead mudpuppy regurgitated from a water snake. There were no observations for predation on hellbenders. The number of images including eggs was six for both mudpuppies and hellbenders. Four observations of mudpuppies and three for hellbenders included only the skeletal remains (Image 2), yet was readily identifiable as species based on unique morphology.

Table 1. Observation data from iNaturalist for the Common Mudpuppy, *Necturus maculosus* and the Eastern Hellbender, *Cryptobranchus alleganiensis*. Ad—adult | Juv—Juvenile | A—alive | D—dead.

	Common Mudpuppy	Eastern Hellbender
% Life Stage	Ad:79.4%, Juv: 20.6%	Ad: 90.4%, Juv: 9.6%
% Alive/Dead	A: 87.7%, D:12.3%	A: 97.%, D: 2.3%
Representative textual observations	*"angler caught on nightcrawler", " a fisherman had caught and killed this poor mudpuppy while powerlining", "regurgitated from a water snake", "being eaten by a water snake", "killed by fisherman", "caught on hook", "caught on rod and reel".*	*"it was caught in a fishing line, it survived", "nest with male guarding", "hooked by fisherman", "hooked this hellbender in the tail while fly fishing", "specimen was deceased. A rock crushed his shoulder and front leg. It was given to the NC Wildlife Resources Biologist".*

The number of annual observations for both mudpuppies and hellbenders generally increased over time (Figure 1). As the iNaturalist platform came into existence in 2008, there were still retrospective posts from 2000 till 2008, which include previous observations prior to the posting date for several observations. In addition, there was a distinct decrease in the number of annual observations for both species from 2020 to 2022, likely due to the Covid-19 lockdown. The months in which the greatest number of observations were documented was April (70), July (54), and March (53) for mudpuppies, and July (54), August (47), and September (45) for hellbenders. For hellbenders these three observation months account for 56.1% of all observations. Therefore, when these observations are combined, iNaturalist provided a successful tool to investigate natural history, presence, predation, mortality, and anthropogenic issues associated both species of large fully aquatic amphibians.

DISCUSSION

This communication provides evidence of utilizing the citizen scientists platform iNaturalist to document presence of declining salamanders species across their home range alongside observations which are of interest to conservation managers, including fishing

Image 1. Representative observations of the Common Mudpuppy showing adult caught on fishing line, predation by mink, predation by seagull, predation by water snake, and juvenile, and egg life stages. Image obtained from iNaturalist under Creative Commons, from the following users: tuckerc, teuclide, baker053, suepk, jcmon, and jayinmadtown.

and documentation of predation events involving these large fully aquatic salamanders. Interestingly, the use of iNaturalist observations to obtain data reveals that this platform may provide similar results for other declining herpetofauna, and other taxa (e.g., mammals, birds, fish) to detect potential exploitation or human-wildlife interactions. Historically, the Eastern Hellbender has been harvested and exploited in some cases large numbers killed (Nickerson & Briggler 2007), largely due to the false beliefs that it is either venomous or consumes all the fish. However, engaging trout anglers via outreach education programming has been found to increase reporting of observations to state agencies responsible for managing eastern hellbenders (Williams et al. 2019). While several observations included images which show either mudpuppy or hellbender in a fishing net, it is unclear for many observations which were mortalities what the exact cause of death was for a specific individual.

The months in which observations were highest for both species could be explained by times in which natural aquatic areas are frequented by recreationalists or anglers frequenting natural areas. Interestingly, the months with the greatest number of observations for hellbenders includes a portion of their breeding season, when individuals are known to be active (Nickerson & Mays 1973) and are likely readily visible in shallow clear streams. Interestingly, the number of observations increased annually over time for both species, indicating the potential for this method of monitoring to provide managers with data on locations as a complement to more traditional surveys or even more recent non-invasive techniques in aquatic environments, i.e., eDNA and underwater camera surveys. However, it is important to note that this increase in annual observations likely does not reflect an actual on ground population increase for these salamanders, but just a change in likely frequency of posts or usage of the iNaturalist application. Subsequently, further research in population estimation which incorporates mark-recapture studies should be more reflective of actual status and population trends of these two enigmatic aquatic salamanders.

Future biodiversity studies should investigate threatened taxa across conservation status and taxonomic groupings in other geographic regions using this citizen science platform. This study demonstrates the potential of iNaturalist to provide a monitoring tool for threatened species and should be applied to other threatened taxa. Species which are readily identifiable based on morphology should be further studied for their presence on this citizen science platform, as it is vital for citizen science collected data to be accurately

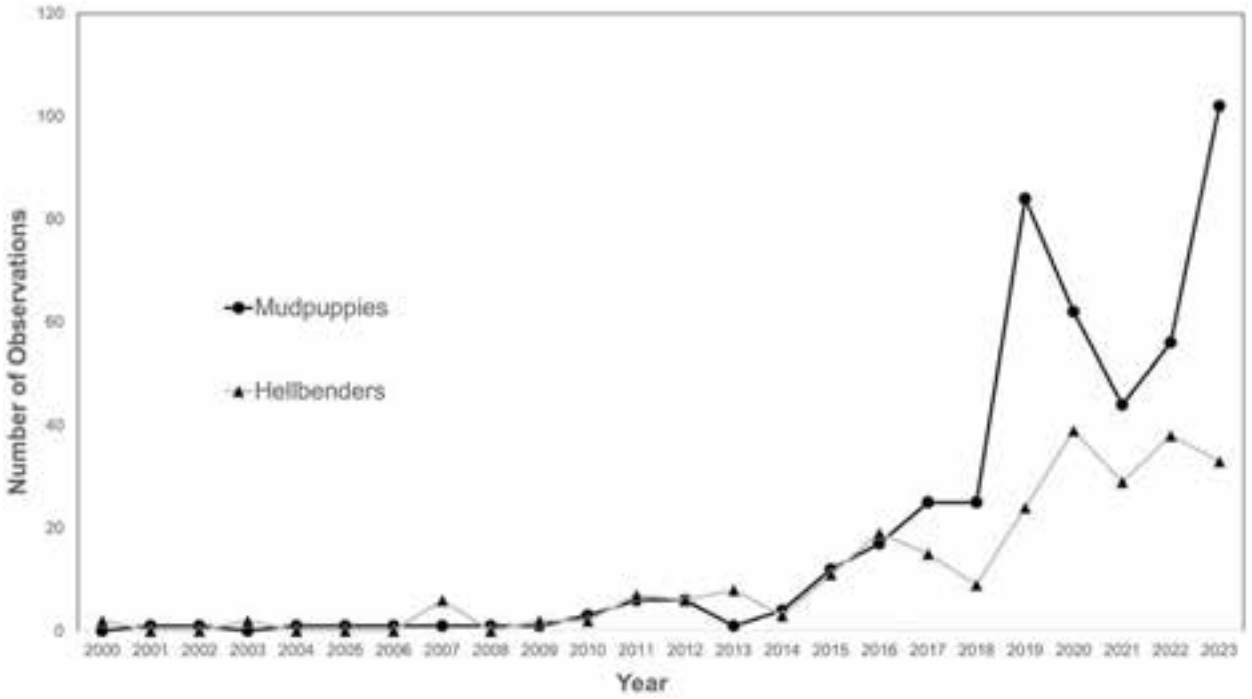

Figure 1. Annual number of observations for mudpuppies and hellbenders on iNaturalist.

Image 2. Representative observations of the Eastern Hellbender showing adult caught on fishing line, mortality, skeletal remains, larvae in hand, juvenile, and eggs. Image obtained from iNaturalist under Creative Commons, from the following users: sjhnny, acmills, hikeleader, hydrophilus, jsexton22, and mcw162.

verified if it to be used for research. Subsequently, it is important for researchers to only include species that are research grade or species for which morphology can be utilized for reliable identification. It is also important to only use images where animals are clearly visible and identification is further validated by researchers or

taxonomic experts. Given the large number of threats facing freshwater fauna, obtaining data using this method can provide a metric for threatened species presence while identifying conservation priorities. For example, while some rare species found in other areas of the world present challenges for surveying, researchers should consider scanning iNaturalist observations for their species and geographic region of choice. As I noted both species being captured by anglers, future outreach should incorporate the impact of fishing on these large fully aquatic salamanders in decline. Moreover, iNaturalist observations are concentrated in North America, with fewer observations in Africa, central America, and southeastern Asia (Di Cecco et al. 2021). Subsequently, it is possible that in some geographic areas, this application may not have as many observations as others, outreach science programs where researchers encourage local communities to record observations on their phones can add value to rare species surveys. I anticipate the use of this smartphone application will continue to increase in its use, it may indeed provide a tool for future monitoring of threatened taxa.

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COMMUNICATION

A preliminary study of odonate fauna in the high ranges of Munnar, southern Western Ghats, India

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Abstract: A study was conducted at Munnar Forest Division Idukki District, Kerala, the southern Western Ghats, to assess the diversity of odonates. Around 44 species of odonates, which include 29 species of Anisoptera (dragonflies) and 15 species of Zygoptera (damselflies). The odonate diversity of Munnar Forest Division accounted for 24.72 % of the odonates in Kerala and 22.45 % of the odonates of the Western Ghats. The study highlights the importance of biodiversity documentation at high altitudes in the Western Ghats.

Keywords: Anisoptera, biodiversity, ecosystem, endemic, Idukki District, Kerala, Odonata, pre-monsoon, Zygoptera.

Malayalam: പശ്ചിമഘട്ടമലനിരകളുടെ ഭാഗമായ ഇടുക്കി ജില്ലയിലെ മൂന്നാർ ഫോറസ്റ്റ് ഡിവിഷനിൽ തുമ്പികളുടെ വൈവിധ്യം വിലയിരുത്തുന്നതിനായി ഒരു പഠനം നടത്തുകയുണ്ടായി. 44 വിവിധയിനം തുമ്പികളെ ഈ പഠനത്തിന്റെ ഭാഗമായി കണ്ടെത്തുകയുണ്ടായി. അതിൽ 29 ഇനം കല്ലൻതുമ്പികളുടെ (അനിസോപ്റ്റെറ) വിഭാഗത്തിലും 15 ഇനം സൂചിത്തുമ്പികളുടെ (സൈഗോപ്റ്റെറ) വിഭാഗത്തിലും ഉൾപ്പെടുന്നു. മൂന്നാർ വനം ഡിവിഷനിൽ കേരളത്തിലെ മൊത്തം തുമ്പിവൈവിധ്യത്തിന്റെ 24.72%, പശ്ചിമഘട്ടത്തിലെ മൊത്തം തുമ്പിവൈവിധ്യത്തിന്റെ 22.45% കാണപ്പെടുന്നു. കേരളത്തിലെ തുമ്പികളുടെ സംരക്ഷണവുമായി ബന്ധപ്പെട്ടു പ്രാധാന്യമർഹിക്കുന്ന ഒരു മേഖലയാണ് മൂന്നാർ എന്ന് ഈ പഠനം സൂചിപ്പിക്കുന്നത്.

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Author contributions: TSK—fieldwork, analysis and manuscript preparation. NN—fieldwork and analysis. AR—fieldwork and analysis. PON—principal supervisor throughout the project work and guidance during manuscript preparation.

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INTRODUCTION

The order Odonata is one of the fascinating groups of winged insects which comprises both dragonflies and damselflies (Grimaldi & Engel 2005). They act as an important top predator at both larval and adult stages and hence form an important tool for various types of assessments and monitoring, such as measures of biodiversity, wetland health, integrity, and the biological impact of climate change. There are over 6,376 odonate species known worldwide (Paulson et al. 2022), 493 in India, 196 in the Western Ghats (Subramanian & Babu 2020), and 178 in Kerala (Chandran et al. 2022; Society for Odonate Studies 2022). The 178 species of odonates of Kerala belong to 87 genera in two suborders and 14 families (Chandran et al. 2022; Society for Odonate Studies 2022), and 68 species are endemic to the Western Ghats.

Studies on odonates of the Western Ghats are far and in between. These include the studies by Mathavan & Miller (1989) who reported 36 species of odonates from Periyar Tiger Reserve, Idukki District, Kerala; 29 species of odonates were recorded from Silent Valley and New Amarambalam Reserved Forests in Kerala by Rao & Lahiri (1982), Emiliyamma & Radhakrishnan (2000), recorded 25 species of odonates from Parambikulam Wildlife Sanctuary, Palakkad dt. Kerala, Adarsh et al. (2015) recorded 48 species of odonates from Chinnar Wildlife Sanctuary, Idukki District, Kerala and Sadasivan et al. (2022) recorded 116 species of odonates from Shendurney Wildlife Sanctuary, Kollam District, Kerala. The present paper summarises the findings of odonates from Munnar Forest Division conducted during the pre-monsoon months: February to May 2022.

Study Area

The Munnar Forest Division is located in the high ranges of the southern Western Ghats. It consists of four ranges, namely Munnar Range, Devikulam Range, Adimaly Range, and Neriamangalam Range with a total area of 892.707 km². The study focused on the hilly regions (>1100 m) of the Munnar Forest Division, which majorly included the Munnar and Devikulam Ranges. The study area is located between 10.067–10.167 ^{0}N & 77.083–77.167 ^{0}E (Figure 1). The details of the study localities are given in Table 1.

The topography of the study area is hilly with undulating terrain. The altitude varies from 33 m near Palamattom on the bank of the river Periyar in the Neriamangalam Range to Anamudi (2,695 m) in the Munnar Range. The average annual rainfall of the region is about 3,000 mm, and it receives both southwestern and northeastern monsoons. Temperatures range 6–35 °C, and the climate is more or less temperate in high-altitude areas. The air is highly humid throughout the year, and the relative humidity is about 80 % and above (Kerala Forest and Wildlife Department 2011).

The Munnar Forest Division consists of different habitat types, which include, west coast tropical evergreen forest, west coast semi-evergreen forest, southern moist mixed deciduous forest, southern montane wet grasslands, the southern montane wet temperate forest along with tea plantations, eucalyptus plantations, cardamom hill reserves, and wattle plantations (Kerala Forest and Wildlife Department 2011).

METHODS

The study was carried out in the pre-monsoon months from February 2022 to May 2022 at selected high-altitude sites (above 1,100 m) in the Munnar Forest Division. The field was categorized into seven habitats, and three sites were randomly selected from each habitat for surveying (21 sites in total). The habitats include grassland, eucalyptus plantation, shola forest (southern montane wet temperate forest), wattle plantations, pond and riverine ecosystem, Cardamom Hill Reserve (evergreen), and tea plantation. A single field visit was made to each of the three sites in each of the seven habitats between 0900 and 1300 h when odonate activity was at its peak. The belt transect method (Kulkarni et al. 2013) was done to document odonates and a 500 m transect line having a width of 10 m was taken on each site. The transect and the coordinates were taken using a mobile application called 'Geotracker' (https://geo-tracker.org/).

Collection and killing were avoided for species identification. Observed odonates were photo-documented using a Nikon COOLPIX P900 and a Nikon D5600 DSLR camera with a 70–300 mm lens. Most of the species were identified on the spot by close observation and later confirmed using taxonomic monographs of Fraser (1933, 1934, 1936) and field guides (Subramanian 2009; Kiran & Raju 2013). The taxonomy and nomenclature that have been used are as per Kalkman et al. (2020). The odonates observed during the study period were categorized into five groups based on their relative abundance. Accordingly, those species which were sighted 80–100 % of the survey days were categorized as very common (VC), 60–79 % as common (C), 40–59 % as occasional (O), 20–39 % as rare (R), and

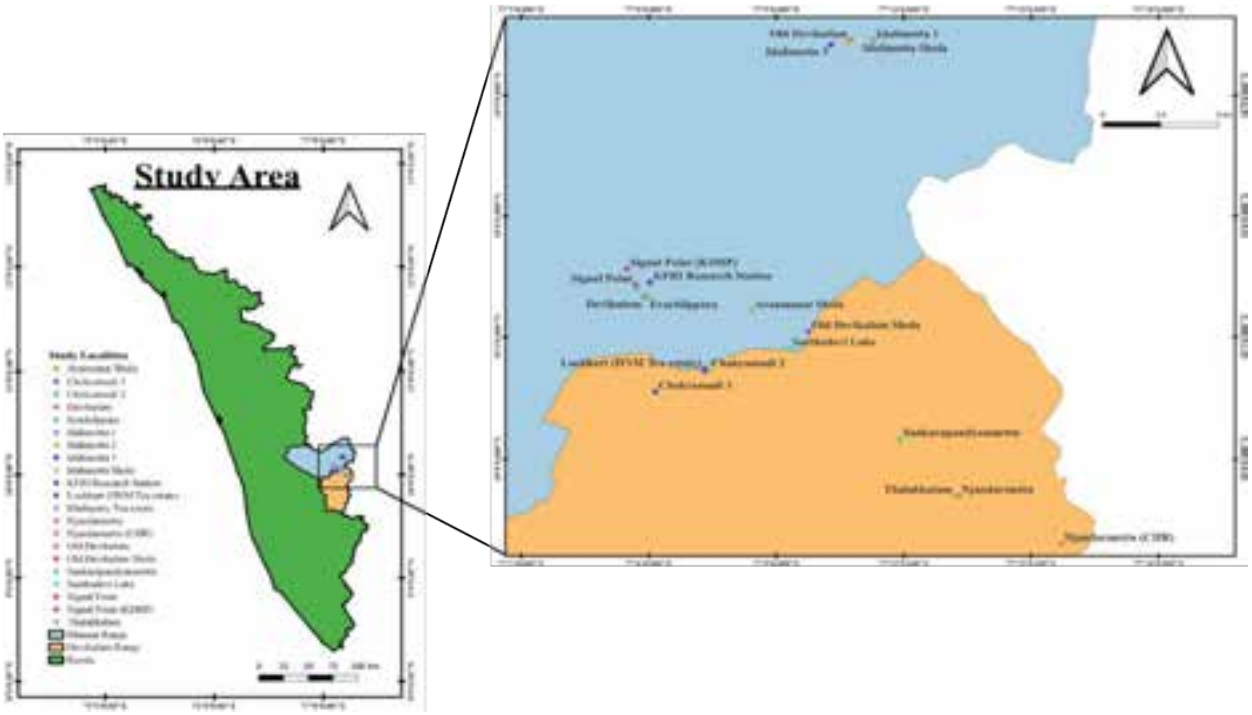

Figure 1. Study locations from the present survey.
HNM Tea estate—Harrisons Malayalam Tea estate | CHR—Cardamom Hill Reserve | KDHP—Kannan Devan Hills Plantation.

very rare (VR) for those that were sighted less than 20% of the field days. The species richness and abundance were recorded and Simpson & Shannon diversity indices and evenness values were also calculated using PAST software.

RESULTS AND DISCUSSION

The study has encompassed 44 species of odonates, which include 29 species of Anisoptera (Dragonflies) and 15 species of Zygoptera (Damselflies) spread across eight families (Table 2). The family Libellulidae was the most dominant in Anisoptera with 24 species, followed by Aeshnidae (3), Macromiidae (1), and Gomphidae (1). Among Zygoptera, Coenagrionidae (9) was the dominant family, followed by Lestidae (3), Platycnemididae (2), and Chlorocyphidae (1). Family-wise species richness of odonates (both Anisoptera and Zygoptera) along with their relative abundance is given in Figure 2.

The distribution of odonates in the study area was classified into seven different habitat types. Habitat-wise distribution and species diversity of odonates in the Munnar Forest Division are given in Table 3. Maximum species richness was observed in the pond and riverine ecosystem (26 species), followed by eucalyptus plantation (17 species), Cardamom Hill Reserve (11 species), wattle infested areas (8), grassland (6 species), shola forest (6 species), and tea plantation (5). The species abundance was maximum in the pond and riverine ecosystem and minimum in the shola forest.

The Simpson & Shannon diversity indices and evenness values of the seven habitats were calculated (Table 4). In this study, the value of the Gini Simpson's index ranged 0.794–0.932 in different habitats. The Simpson index showed the maximum value for the pond and riverine ecosystem (0.932) and the minimum value for grassland (0.794). Hence, species diversity is high in pond and riverine ecosystem habitats. The value of the Shannon Weiner index for different habitats range 1.47–2.87, with the maximum value shown by pond and riverine ecosystem and the minimum by tea plantation. As a result, pond and riverine ecosystems have the highest species richness and evenness.

Out of the 44 species recorded, four of the odonate species are endemic, two to the Western Ghats, one to peninsular India, and one to India. *Esme cyaneovittata* and *Esme mudiensis* are endemic to the Western Ghats, *Heliocypha bisignata* is endemic to peninsular India and *Hylaeothemis apicalis* is endemic to India. There are 196 species of odonates in the Western Ghats and 178 species of odonates in Kerala. Considering the total

Table 1. Details of the study localities at Munnar Forest Division.

	Habitat	Coordinates	Altitude (m)	Weather	Temperature (°C)	Humidity (%)
1	**Grassland**					
	a) Chokramudi 1	10.028 °N & 77.102 °E	1,736	Sunny	25	48
	b) Old Devikulam 2	10.173 °N & 77.179 °E	1,788	Sunny	23	47
	c) Chokramudi 2	10.036 °N & 77.123 °E	1,736	Sunny	25	48
2	**Eucalyptus plantation**					
	a) Devikulam	10.067 °N & 77.098 °E	1,615	Cloudy	24	68
	b) KFRI Research Station	10.072 °N & 77.100 °E	1,594	Partly Cloudy	22	63
	c) Signal Point	10.071 °N & 77.095 °E	1,522	Sunny	24	47
3	**Shola forest**					
	a) Aranmanai Shola	10.061 °N & 77.140 °E	1,676	Sunny	22	51
	b) Old Devikulam Shola	10.052 °N & 77.163 °E	1,801	Sunny	23	47
	c) Idalimotta Shola	10.172 °N & 77.183 °E	2,239	Cloudy	19	68
4	**Wattle infested area**					
	a) Idalimotta 1	10.173 °N & 77.188 °E	2,190	Cloudy	17	95
	b) Idalimotta 2	10.171 °N & 77.177 °E	2,372	Cloudy	17	95
	c) Idalimotta 3	10.171 °N & 77.171 °E	2,387	Cloudy	17	95
5	**Pond and riverine ecosystem**					
	a) Erachilppara	10.066 °N & 77.099 °E	1,615	Partly cloudy	21	72
	b) Seethadevi Lake	10.045 °N & 77.155 °E	1,762	Sunny	24	42
	c) Njandarmettu (CHR)	9.965 °N & 77.261 °E	1,143	Cloudy	22	81
6	**Cardamom Hill Reserve**					
	a)Thalakkulam	9.985 °N & 77.220 °E	1,254	Cloudy	22	81
	b)Njandarmettu	9.985 °N & 77.221 °E	1,143	Cloudy	24	75
	c)Sankarapandyanmettu	10.008 °N & 77.199 °E	1,249	Cloudy	23	75
7	**Tea plantation**					
	a) Signal Point (KDHP)	10.078 °N & 77.091 °E	1,537	Partly Cloudy	23	63
	b) Lockhart (HNM Tea estate)	10.036 °N & 77.122 °E	1,518	Sunny	22	66
	c) Madupatty Tea estate	10.069 °N & 77.096 °E	1,630	Cloudy	24	68

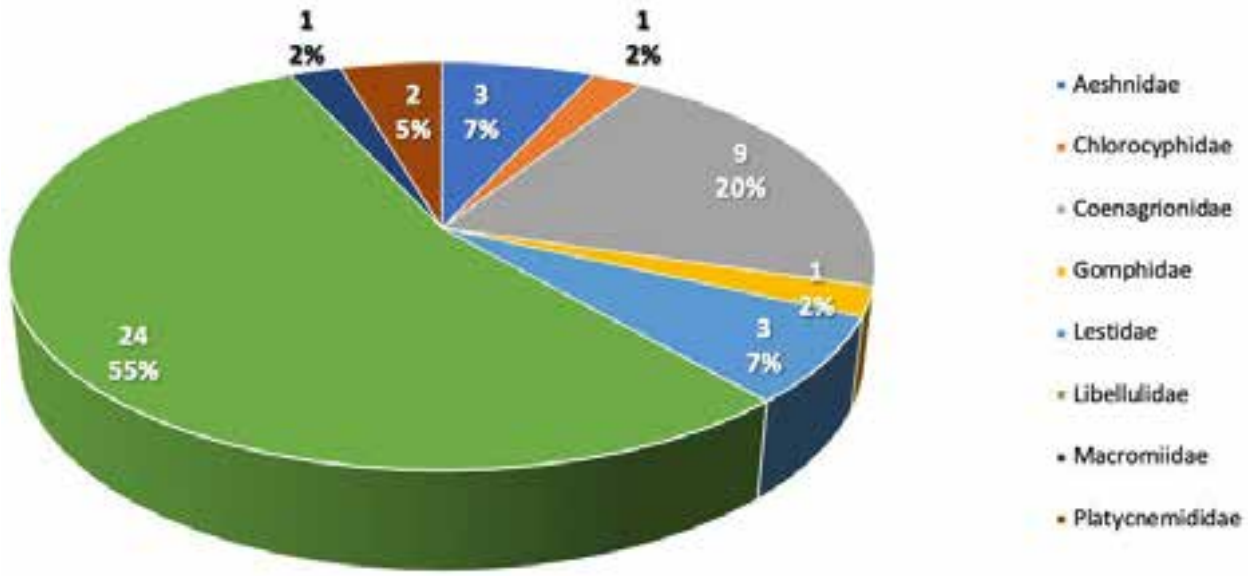

Figure 2. Family-wise species richness and relative abundance of odonates in Munnar Forest Division.

number of species of Odonates in Kerala, the present study accounted for 24.72 % of the odonates in Kerala and 22.45 % of the odonates of the Western Ghats. None of the odonate species from the region is protected under the Indian Wildlife Protection Act (WPA) of 1972. According to the IUCN Red List 2022, one species is staged under the 'Not Evaluated' category, four species under the 'Data Deficient' category, and the remaining 39 species are staged under the 'Least Concern' category, which implies that none of the species from the present study is listed as a threatened species.

Due to their amphibious life history, relatively short generation time, high trophic position, and diversity, the order Odonata is considered an important component

Table 2. Checklist of odonates recorded from the study habitats of Munnar Forest Division, Idukki, Kerala, southern Western Ghats.

	Family/Scientific name	Endemicity	IUCN status	Abundance	Study habitats
A.	**Zygoptera (Damselflies)**				
	Coenagrionidae				
1	*Aciagrion approximans krishna* Fraser, 1921		LC	R	P, C
2	*Aciagrion occidentale* Laidlaw, 1919		LC	O	E, P, C
3	*Agriocnemis pieris* Laidlaw, 1919		LC	R	E, W
4	*Agriocnemis pygmaea* (Rambur, 1842)		LC	VR	P
5	*Ceriagrion coromandelianum* (Fabricius, 1798)		LC	VR	P
6	*Ischnura rubilio* Selys, 1876		NE	VR	P
7	*Ischnura senegalensis* (Rambur, 1842)		LC	R	G, P
8	*Pseudagrion microcephalum* (Rambur, 1842)		LC	VR	P
9	*Pseudagrion rubriceps* Selys, 1876		LC	VR	P
	Platycnemididae				
10	*Esme cyaneovittata* Fraser, 1922	EN WG	DD	VR	S
11	*Esme mudiensis* Fraser, 1931	EN WG	DD	VR	S
	Chlorocyphidae				
12	*Heliocypha bisignata* (Hagen in Selys, 1853)	EN P	LC	VR	S
	Lestidae				
13	*Indolestes gracilis davenporti* (Fraser, 1930)		LC	VC	G, E, W, P, C, T
14	*Lestes dorothea* Fraser, 1924		LC	VR	P
15	*Lestes elatus* Hagen in Selys, 1862		LC	VR	P
B.	**Anisoptera (Dragonflies)**				
	Aeshnidae				
16	*Anaciaeschna martini* (Selys, 1897)		LC	VR	P
17	*Anax immaculifrons* Rambur, 1842		LC	VR	P
18	*Gynacantha dravida* Lieftinck, 1960		DD	VR	E
	Libellulidae				
19	*Acisoma panorpoides* Rambur, 1842		LC	R	E, T
20	*Brachydiplax chalybea* Brauer, 1868		LC	VR	P
21	*Brachydiplax sobrina* (Rambur, 1842)		LC	O	E, S, W, P
22	*Brachythemis contaminata* (Fabricius, 1793)		LC	R	E, P
23	*Bradinopyga geminata* (Rambur, 1842)		LC	O	G, E, T
24	*Crocothemis servilia* (Drury, 1770)		LC	O	G, E, W, C
25	*Diplacodes trivialis* (Rambur, 1842)		LC	O	E, W, T
26	*Hylaeothemis apicalis* Fraser, 1924	EN I	DD	R	P, C
27	*Orthetrum chrysis* (Selys, 1892)		LC	O	E, W, P, C
28	*Orthetrum glaucum (Brauer, 1865)*		LC	VR	C
29	*Orthetrum luzonicum* (Brauer,1868)		LC	R	G, C
30	*Orthetrum pruinosum* (Burmeister, 1839)		LC	O	E, P, T
31	*Orthetrum sabina* (Drury, 1770)		LC	VR	P
32	*Orthetrum triangulare* (Selys, 1878)		LC	R	W, C
33	*Palpopleura sexmaculata* (Fabricius, 1787)		LC	VR	E
34	*Pantala flavescens* (Fabricius, 1798)		LC	R	G, W
35	*Rhodothemis rufa* (Rambur, 1842)		LC	VR	P
36	*Sympetrum fonscolombii* (Selys, 1840)		LC	VR	S

	Family/Scientific name	Endemicity	IUCN status	Abundance	Study habitats
37	*Tetrathemis platyptera* Selys, 1878		LC	O	E, P, C
38	*Tramea limbata* (Rambur, 1842)		LC	VR	P
39	*Trithemis aurora* (Burmeister, 1839)		LC	VR	E
40	*Trithemis festiva* (Rambur, 1842)		LC	VR	E
41	*Urothemis signata* (Rambur, 1842)		LC	VR	P
42	*Zyxomma petiolatum* Rambur, 184		LC	R	E, P
	Macromiidae				
43	*Epophthalmia vittata* Burmeister, 1839		LC	VR	C
	Gomphidae				
44	*Ictinogomphus rapax* (Rambur,1842)		LC	R	S, P

Legend: EN W—Endemic to Western Ghats | EN P—Endemic to Peninsular India | EN I—Endemic to India.
LC—Least Concern | DD—Data Deficient | NE—Not Evaluated.
G—Grassland | E—Eucalyptus Plantation | S—Shola Forest | W—Wattle Plantation | P—Pond and Riverine Ecosystem | C—Cardamom Hill Reserve | T—Tea Plantation.

Table 3. Habitat-wise distribution of odonates at Munnar Forest Division.

Habitat	Aeshnidae	Chlorocyphidae	Coenagrionidae	Gomphidae	Lestidae	Libellulidae	Macromiidae	Platycnemididae
Grassland	0	0	2	0	7	8	0	0
Eucalyptus Plantation	1	0	6	0	7	23	0	0
Shola Forest	0	2	0	1	0	2	0	3
Wattle Plantation	0	0	2	0	5	9	0	0
Pond and Riverine Ecosystem	2	0	25	1	17	25	0	0
Cardamom Hill Reserve	0	0	7	0	4	15	1	0
Tea Plantation	0	0	0	0	4	7	0	0

Table 4. Species richness and diversity of odonates in high ranges of Munnar Forest division.

Habitats	Grassland	Eucalyptus plantation	Shola forest	Wattle plantation	Pond and riverine Ecosystem	Cardamom Hill Reserve	Tea plantation
Species richness	6	17	6	8	26	11	5
Abundance	17	37	8	16	70	27	11
Species relative abundance	0.14	0.39	0.14	0.18	0.59	0.25	0.11
Shannon's diversity index (H')	1.56	2.53	1.73	1.89	2.87	2.07	1.47
Simpson's diversity index (D)	0.21	0.08	0.07	0.12	0.07	0.131	0.182
Inverse Simpson's diversity index (1/D)	4.86	12.81	14.00	8.00	14.64	7.63	5.50
Gini Simpson's index (1-D)	0.79	0.92	0.93	0.88	0.93	0.87	0.82

of freshwater ecosystems as well as a good indicator of ecosystem health (Corbet 1993). This reiterates the fact that more systematic exploration of biodiversity should be carried out in unexplored regions of the Western Ghats, especially in light of increasing anthropogenic influences and habitat transformations. The present study highlights the existing diversity of unexplored odonate fauna in the high ranges of the Munnar Territorial Division. Major changes in the degradation quality of available habitats could also result in a loss of regional odonate diversity, especially for endemic species. These changes could also have a cascading effect on terrestrial biodiversity.

A previous study on odonates from Chinnar Wildlife Sanctuary (Adarsh et al. 2015), a component of Munnar Wildlife Division, has recorded a total of 48 species of

Image 1–7. Habitat photos: 1—Aranmanai Shola (Shola forest) | 2—Idalimotta (Wattle infested area) | 3—KFRI Research Station (Eucalyptus plantation) | 4—Sankarapandyanmettu (Cardamom hill reserve) | 5—Signal Point (Tea plantation) | 6—Chokramudi (Grassland) | 7—Seethadevi Lake (Pond and riverine ecosystem).

Image 8–15. Odonates photos: 8—*Agriocnemis pygmae* | 9—*Pseudagrion microcephalum* | 10—*Brachidiplax chalybea* | 11—*Orthetrum triangulare* | 12—*Hylaeothemis apicalis* | 13—*Orthetrum glaucum* | 14—*Epophthalmia vittata* | 15—*Diplacodes trivialis*.

Image 16–23. Odonates photos: 16—*Trithemis festiva* | 17—*Sympetrum fonscolombii* | 18—*Orthetrum sabina* | 19—*Palpopleura sexmaculata* | 20—*Anaciaeschna martini* | 21—*Gynacantha dravida* | 22—*Acisoma panorpoides* | 23—*Anax immaculifrons*.

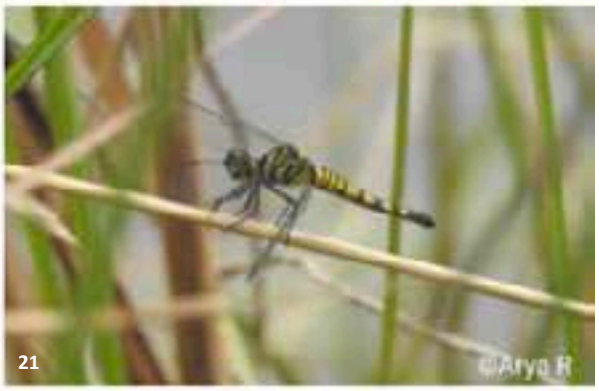

Image 24–31. Odonates photos: 24—*Orthetrum luzonicum* | 25—*Crocothemis servilia* | 26—*Orthetrum chrysis* | 27—*Orthetrum pruinosum* | 28—*Pantala flavescens* | 29—*Brachydiplax sobrina* | 30—*Urothemis signata* | 31—*Rhodothemis rufa*.

odonates, which includes 31 species of dragonflies and 17 species of damselflies. The present study has recorded 14 new records of odonates, which include nine species of dragonflies and five species of damselflies.

The study also highlights the sighting of Martin's Duskhawker *Anaciaeschna martini* (Selys 1897) from wattle-infested areas of Idalimotta (above 2000m), which was previously recorded as a rediscovery from Nilgiris in September 2014 and later from the Munnar region in the Anamalais landscape of the Western Ghats in June 2019 (Sadasivan et al. 2021). The observed individual was a female ovipositing on emergent vegetation and no males were observed guarding or nearby the female. The species was identified by the typical female morphological characteristics of a brownish body with yellowish-green markings on the thorax and a brownish-yellow abdomen, as well as a dark band along the leading edge of the wings. Disturbed habitats such as wattle-infested areas may provide suitable breeding sites and hunting grounds for species like Martin's Duskhawker, which may explain the presence of this locally 'not common' species.

Even though there have been frequent surveys and few published papers (Adarsh et al. 2015; Sadasivan et al. 2021) in the wildlife division of Munnar, currently there are no published papers in Munnar territorial division as far as odonates are concerned. Under the circumstance that no previous research papers have been published under the Munnar territorial division, the present study comes into the light, providing far-reaching information regarding the diversity, distribution, and habitat preference of the recorded odonate species during the pre-monsoon period. The short-term study also acts as a preliminary report on odonates and forms a trail for further studies during the monsoon and post-monsoon months, where a peak in species richness can be expected due to the southwest monsoon.

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OPEN ACCESS

COMMUNICATION

A new species of *Arctodiaptomus* Kiefer, 1932 (Copepoda: Diaptomidae) from the Kumaun Himalaya of India

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Abstract: A new species of the freshwater copepod genus *Arctodiaptomus* is described from a high-altitude lake of Kumaun Himalaya. The undescribed species differs from their congeners by the presence of a strong comb-shape denticulated spine at the antepenultimate segment of male right antennule. Basis of the male fifth right leg possess a butterfly shape hyaline membrane on the inner lateral side; 2-segmented endopod with board distinct proximal segment. Endopodite of the female fifth leg is elongated round apex without any septum. The identified diaptomid tends to be restricted in the Himalayan region; it seems apparently isolated from the purported main area of the origin.

Keywords: *Arctodiaptomus kumaunensis* sp. nov., Calanoida, carotenoids, diaptomids, Maheshwar Kund, morphology, photoprotectant, plankton, western Himalaya.

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Competing interests: The authors declare no competing interests.

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Author contributions: Shaikhom Inaotombi: Conceptualization, methodology, data collection (field sampling, laboratory analysis), writing—original draft. Debajit Sarma: Funding acquisition, supervision, project administration, data collection (field sampling), writing—review & editing.

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INTRODUCTION

So far, 441 species of diaptomids have been described from 60 genera (Boxshall & Defaye 2008). In the Palaearctic region, *Heliodiaptomus* Kiefer, 1932 is one of the most described genera while *Arctodiaptomus* is represented by 76 species. Knowledge on distribution status of the genera is currently hindered by underestimation due to the lack of taxonomic expertise. Some *Arctodiaptomus* are highly invasive and tolerant to extreme environments (Rizo et al. 2015). They show limited distribution ranges that linked primarily with ancient biogeographical events (Leibold et al. 2010). Indian diaptomids are represented by Diaptomin and Paradiaptominae subfamilies. Diaptominae are dominant and represented by over 50 species from 12 genera; while Paradiaptominae has a single genus and species in India (Rayner 2000; Dussart & Defaye 2002). Most Indian Diaptomidae were recorded from the Gondwana Indian Peninsular region (Reddy 2013), and the existing information from the Himalayan region is limited. Many species may confine to different elevations which were originally isolated and further acclimatized or adapted to the recurrent extreme environment. Here, we describe a new pigmented species of *Arctodiaptomus* from a high-altitude lake of Kumaun Himalaya.

MATERIAL AND METHODS

Plankton sample was collected from Lake Maheshwar Kund of Uttarakhand, India (Figure 1) using 0.22 mm plankton net. The diaptomids were sorted out and fixed with 70% ethanol; vials were stored for further identification. Materials were dissected in water + glycerin drop and scan under a high magnification microscope. Descriptions were made based on the observation and photographs of each section are illustrated below. The type specimens were further deposited at Central Entomological Laboratory, Zoological Survey of India, Kolkata, India.

RESULT

Order Calanoida
Family Diaptomidae Baird, 1850
Subfamily Diaptominae Kiefer, 1932
Genus *Arctodiaptomus* Kiefer, 1932

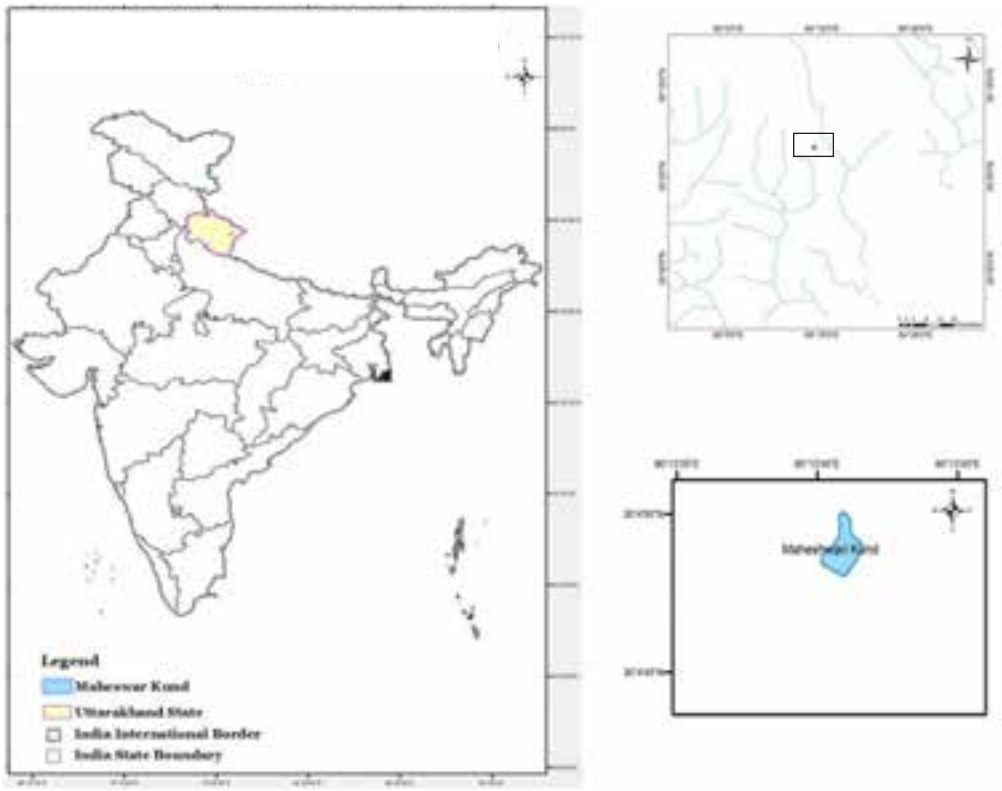

Figure 1. The location map showing type locality (Maheshwar Kund) of *Arctodiaptomus kumaunensis* sp. nov.

***Arctodiaptomus kumaunensis* sp. nov.**

(Image 1–6; Figures 2–3).

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Material examined

Holotype: C7099/2, 13 May 2016, female, Maheshwar Kund (5,219 m), a high-altitude lake of Kumaun Himalaya, Uttarakhand, India (30.080 ^{0}N, 80.504 ^{0}E). Specimens were preserved in 70% ethanol with a drop of glycerin. Vials containing 4 un-dissected specimens were deposited in Central Entomological Laboratory, Zoological Survey of India, Kolkata.

Allotype: C7100/2, 13 May 2016, male, preserved in 70% ethanol was deposited at Central Entomological Laboratory, Zoological Survey of India, Kolkata.

Paratypes: C7101/2 & C7102/2, 13 May 2016, two males & two females, vails containing two males (separately) and two females collected from the same site were deposited at Central Entomological Laboratory, Zoological Survey of India, Kolkata.

For analysis of physicochemical parameters, water samples were collected from the littoral zone of the lake in prewashed polyethylene bottles and transported to the laboratory under ideal condition (Wetzel & Likens 1979). Temperature, pH, conductivity, and dissolved oxygen (DO) were measured on the site itself using Hanna multi-parameter probe (Model 9828). Turbidity was measured using a turbidity meter (HACH 2100Q). Nitrite-nitrogen, nitrate-nitrogen, ammoniacal-nitrogen and phosphorous were estimated by Spectroquant Multy (Merck, Germany; SN072414). Alkalinity and hardness were estimated by titration methods. The method of analysis and formulation of the reagents used are based on American Public Health Association (1992).

Habit and Habitats

The new species is apparently a relict population in the high-altitude aquatic environment of the Kumaun Himalaya (2,446.6 m). The Maheshwar Kund is a shallow (7.3 m) oligotrophic small water body (average PO_4 P 0.04 mg/l). The water quality parameters (mean, n = 6) of the lake habitats were as follows: water temperature 15.1 ºC, pH 8.20, alkalinity 21 ppm, nitrate 0.90 ppm, oxidation-reduction potential 195 mV, total dissolved solids 17 ppm, conductivity 20 µScm^{-1}. The annual average rainfall in the region is 1308.6 mm as per (Purohit & Kaur 2016). The lake receives moderate hydroperiods and mainly fed by spring discharges, subsurface inflow streams, and direct rainfall. The catchment area covered by forest vegetation is mainly composed of *Quercus leucotricophora* A.Camus and *Rhododendron arboretum* Sm. The new species is predominantly found in the littoral zone where the accumulation of terrestrial plant debris was high. The turbidity of the water column was very low (0.97 NTU). The substratum has a low submerged macrophyte and sediment contains a moderate amount of organic matter (4.60 %) covered by a superficial mud layer.

Etymology: The specific name "*kumaunensis*" is named after the place "Kumaun Himalaya" of India where the new species is found.

Diagnosis: Female: Total length excluding caudal setae ranges from 1.42 mm to 1.64 mm (average 1.55 mm ± 0.08, n = 10); prosome length = 1.23 mm; prosome width = 0.41 mm (Image 1a, Figure 2A). Prosome is an oval shape with 5 pedigers cephalosome. The 5th pediger is slightly asymmetrical in the posterior wings reaching the proximal part of the genital somite.

Urosome (Image 1b, Figure 2B) 30 percent of the total length, divided into 3-segmented; Genital somite widened distally having slight lateral protrusions with sensillum. Long anal somite with two symmetrical caudal rami 2.2:1 length to width and haired along the distal half of both inner and outer margin; one dorsal, one small lateral and four-terminal setae (Image 1c, Figure 2C).

Antennules symmetrical, 25-segmented, reaching up to caudal ramus (Image 1d, Figure 2D). A long and stout seta on segment 1 reaching upto segment 5 (Image 1e). From segment 3–8 has either aesthetasc or one seta (Image 1f). The distribution of appendages per segment as 1(1+ae); 2(3+ae); 3(1+ae); 4(1); 5(1+ae); 6(1); 7(1+ae); 8(1); 9(2+sp); 10(1); 11(2); 12(1+ae); 13(2); 14(1+ae); 15(1); 16(1+ae); 17(1); 18(1); 19(1+ae); 20(1); 21(1); 22(2); 23(2); 24(2); 25(4+ae). Where, segments are representing by Arabic numerals, while number of setae = Arabic numeral in parenthesis; ae = aesthetasc; sp = spine. The right antennule has similar appendages distribution with left antennule.

Mandible (Image 2a, Figure 2F) with eight pointed teeth on gnathobase and one seta near tooth margin (Image 2b); basis with two setae; endopod 2-segmented, possesses two setae at the proximal while seven setae at the distal segment. Exopod 4-segmented; one seta each on the first three segments and three setae on the distant segment (Image 2c, Figure 2E).

First leg with one seta on the internal margin of coxa, reaching up to the proximal part of the first endopodal segment. Cluster plumose at the external margin in the joining of coxa and basis. Basis with 3-segmented exopod and 2-segmented endopod (Image 2d, Figure 2H).

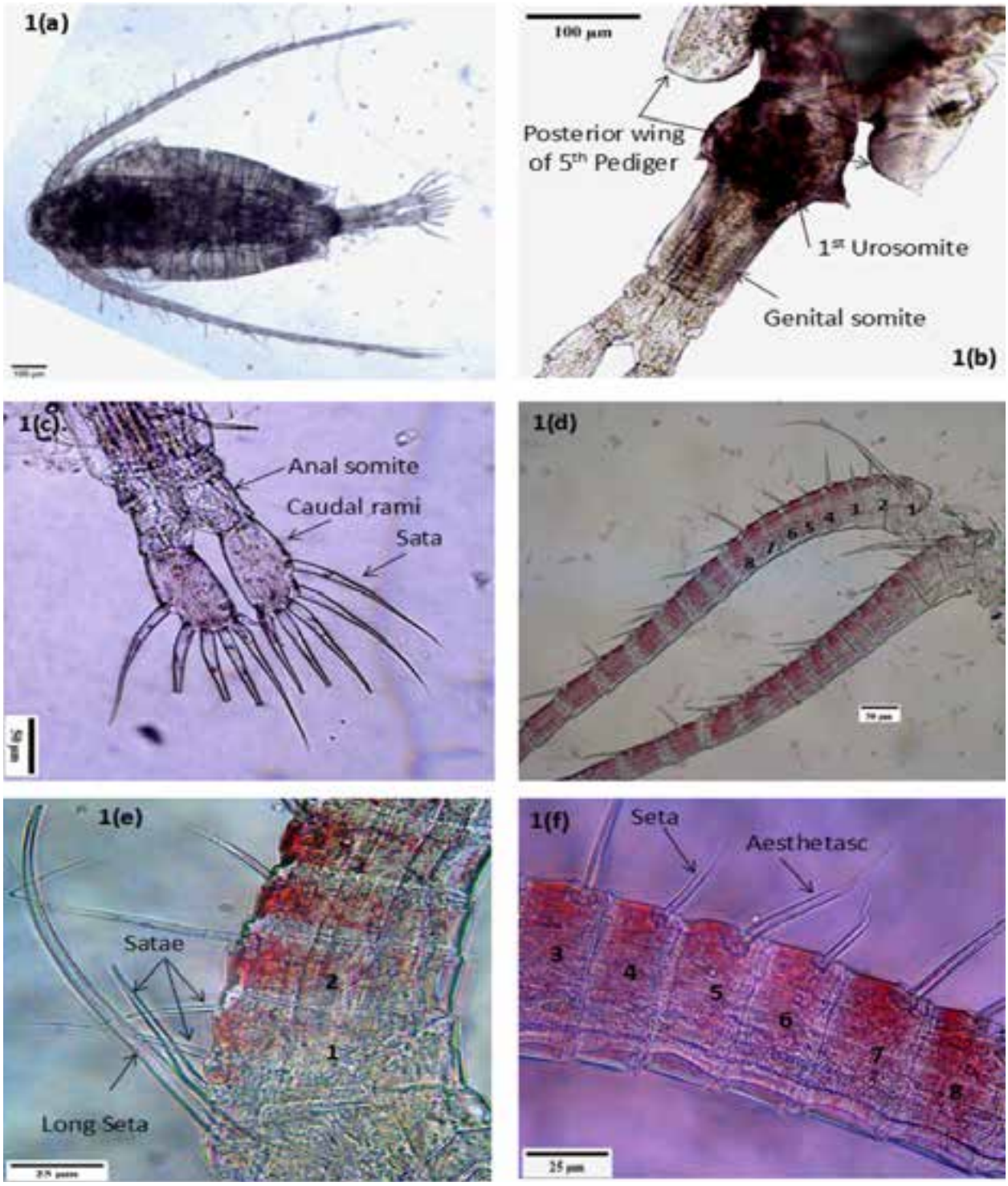

Image 1. a—*Arctodiaptomus kumaunensis* sp. nov. (female) | b—5th Prediger with 1st urosome and genital somite | c—Anal somites and caudal ramus of urosome | d—Antennules | e—Segment 1–4 of antennule | f—Segment 3–8 of antennules. © Inaotombi Shaikhom.

Maxilliped distinct and strong; coxa with three distinct lobes; one seta in first, two seta in second and three setae in third lobe of the coxa. Endopod 5-segmented; two setae each in second, third and fourth segments. Terminal fifth segment has four setae (Image 2e, Figure 2G).

Second, third and fourth swimming legs are biramous with 3-segmented rami (Image 2f, Figures 2I, 2J). Fifth

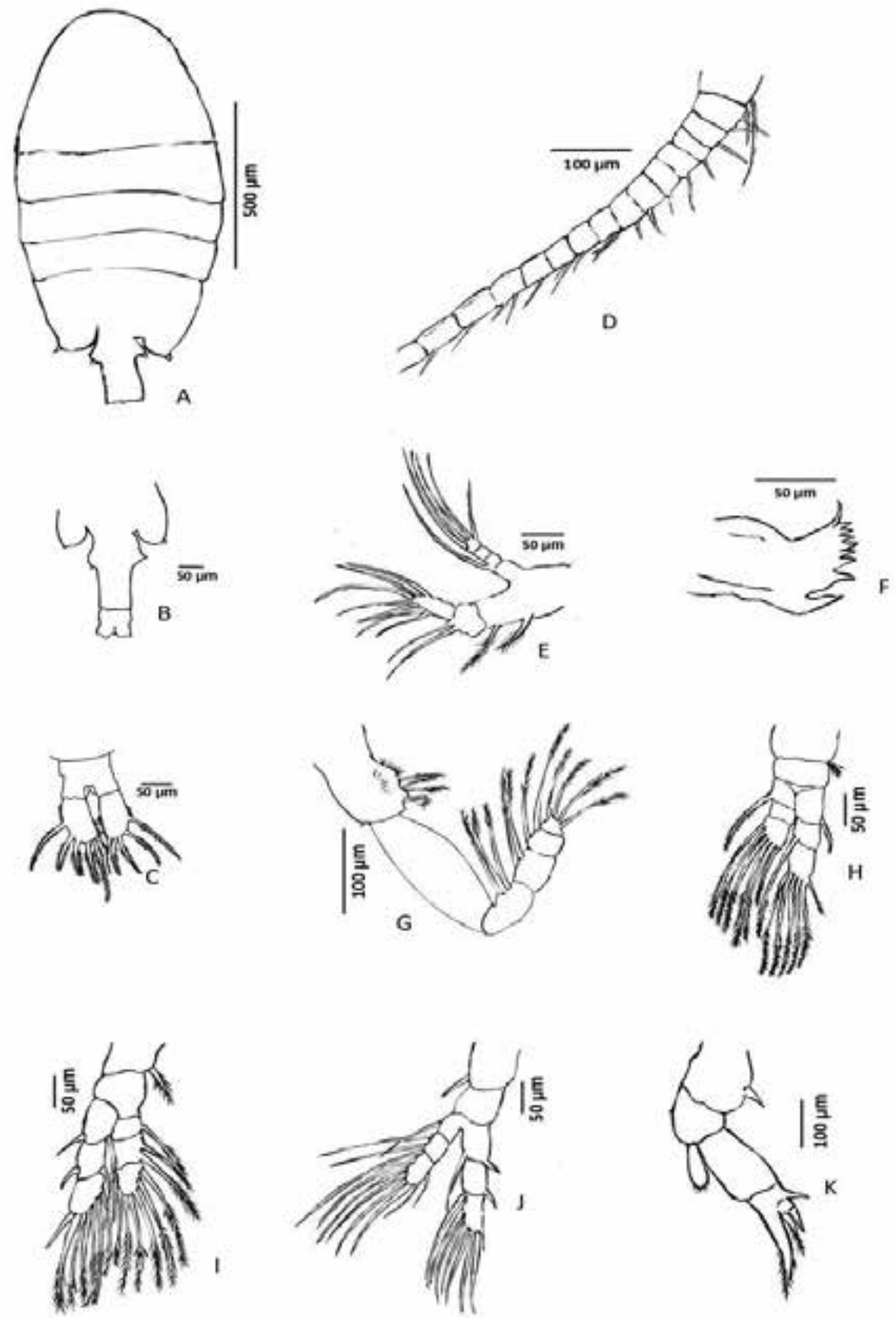

Figure 2. ***Arctodiaptomus kumaunensis*** **sp. nov., female (holotype): A—dorsal view | B—5th Prediger with 1st urosome and genital somite | C—anal somites and caudal ramus of urosome | D—antennules | E—mandible basis with mandibular palp | F—mandibular teeth with gnathobase | G—maxilliped | H—first leg | I—third swimming leg 3 | J—fourth swimming leg | K—symmetrical fifth leg. © Inaotombi Shaikhom.**

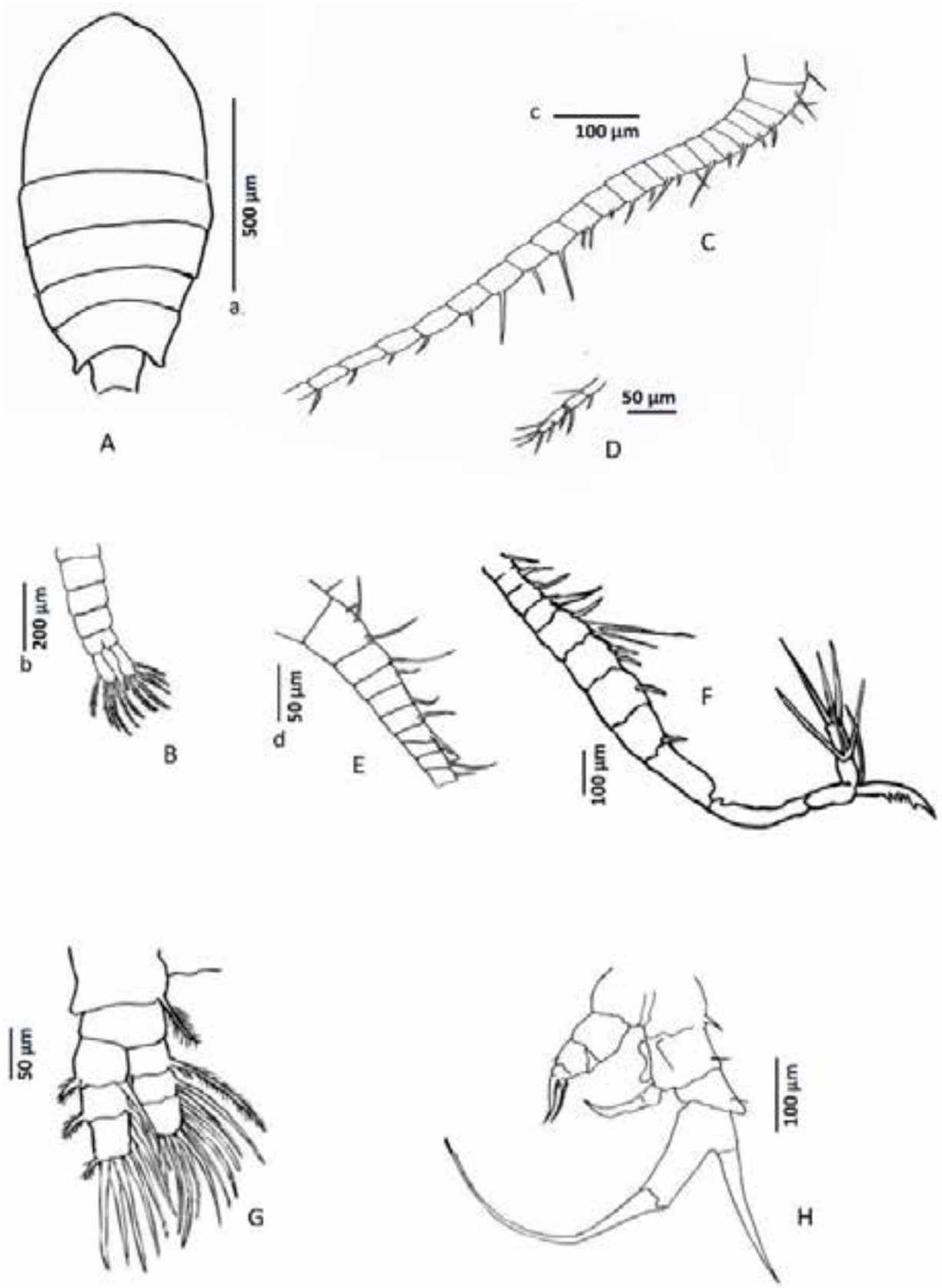

Figure 3. ***Arctodiaptomus kumaunensis*****, sp. nov., male (isotype): A—dorsal view | B—urosome | C—left antennule (1–21 segment) | D—left antennule (22–25) | E—right antennule (1–10 segment | F—right antennule (10–22 segment) | G—symmetrical third leg | H—asymmetrical fifth leg. © Inaotombi Shaikhom.**

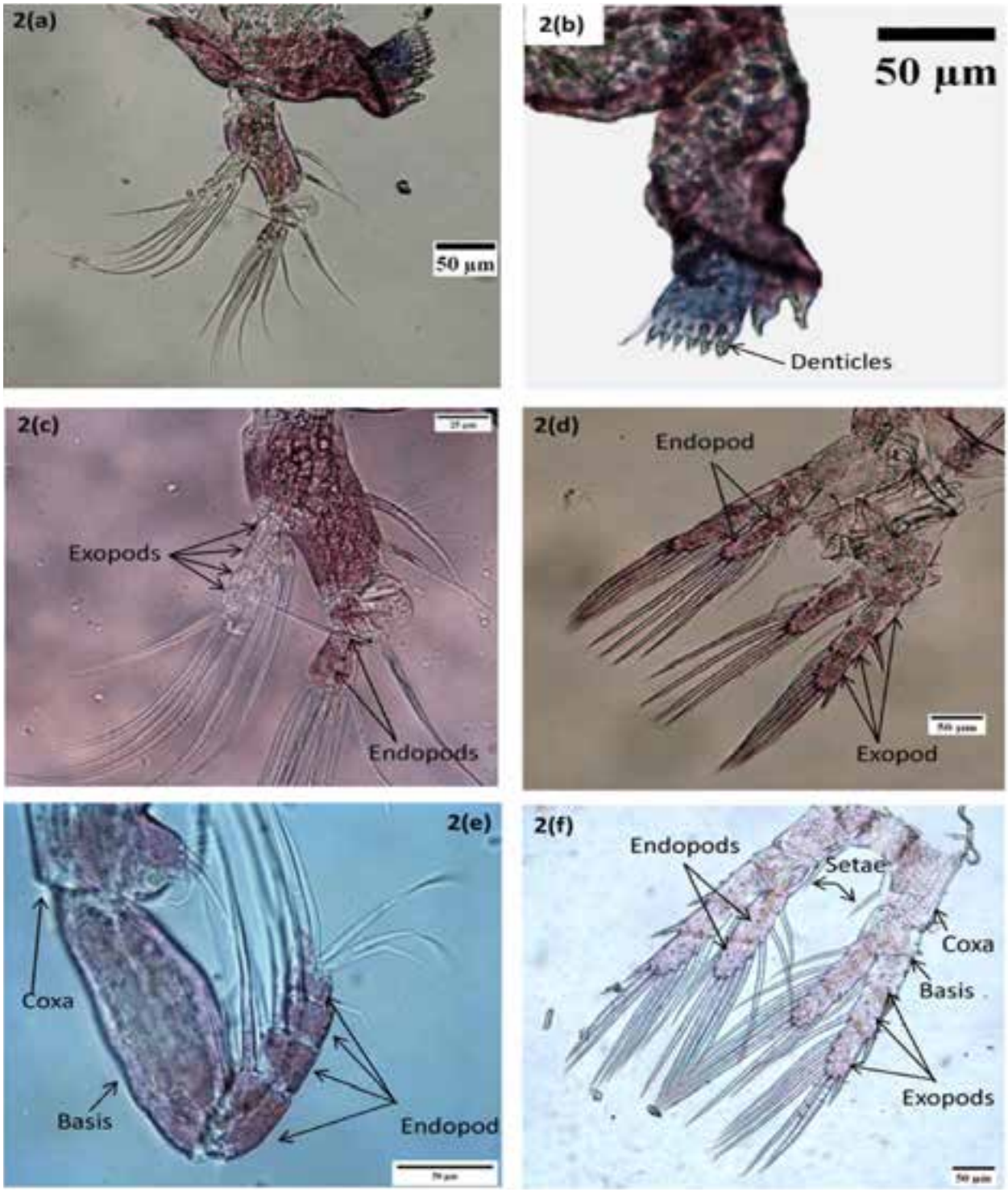

Image 2. *Arctodiaptomus kumaunensis* sp. nov. (female): a—Mandible | b—Mandibular teeth with gnathobase | c—Mandible basis with mandibular palp | d—Swimming leg 1 | e—Maxilliped | f—Swimming leg 3. © Inaotombi Shaikhom.

legs biramous, symmetrical (Image 3a); coxa roughly rectangular shape armed with reduced lateral process (Image 3b). Basis with short inner margin and possesses small delicate lateral seta. Endopod unsegmented and blunt end, nearly two times longer than wide. Exopod 3-segmented, exopod-1 about 1.7 times as long as wide; second exopod segment with long end claw at inner margin and a spine near the base of the third segment.

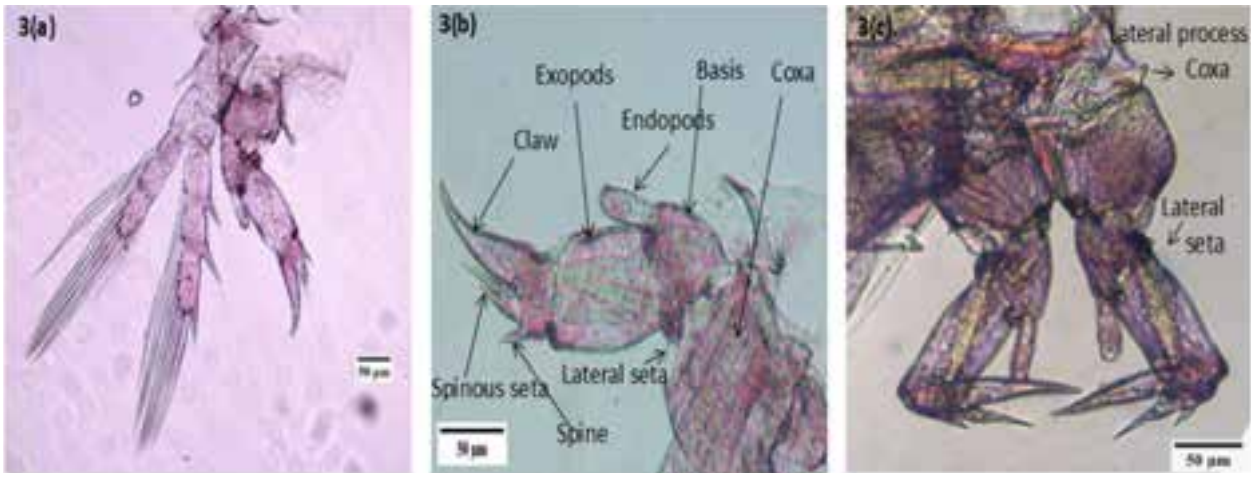

Image 3. *Arctodiaptomus kumaunensis* sp. nov.: a—Fourth and fifth Leg (Female) | b—Symmetrical biramous fifth leg (Female) | c—Fifth right leg (Female). © Inaotombi Shaikhom.

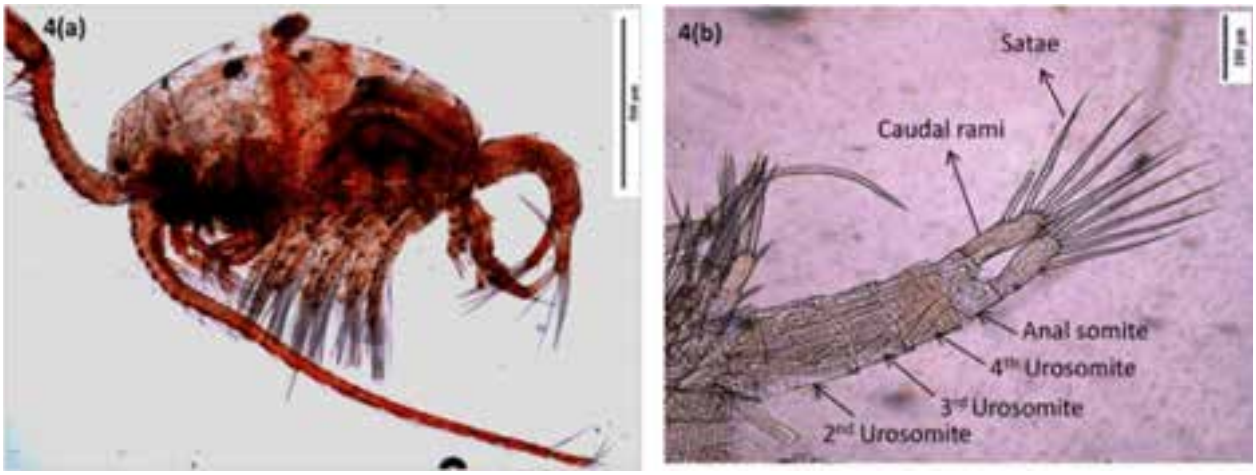

Image 4: a—*Arctodiaptomus kumaunensis* sp. nov. (male) | b—Urosome. © Inaotombi Shaikhom.

The third exopod segment extremely reduced with two spinous setae – one long and another short (Image 3c, Figure 2K).

Male

Total length excluding excluding caudal seta ranges from 1.45 mm to 1.56 mm with average length of 1.50 mm (± 0.05, n = 10); prosome length = 1.07 mm; prosome width = 0.45 mm; rostrum strong, no bifid. Fifth pedigerous somite tapering posteriorly with reduced lateral wings (Image 4a, Figure 3A).

Urosome 5-segmented, 30 percent of total body length. First urosomite without lateral spine; second to fourth urosomites equal size with slightly tapering posteriorly; fourth urosomite with slight protruding at the inner lateral margin. Anal somite reduces with 'v' shape infringe at the posterior middle margin; naked caudal rami symmetrical, about 2.7 times as long as wide and similar setae distribution with female ramus (Image 4b, Figure 3B).

Antennule asymmetrical; left antennule 25-segmented; longer seta at segment 3, 7, 9, 14, 16, 18, 21 and 23 (Image 5a, Figures 3C,D). Three setae in segment 2 (Image 5b) and one seta each on segment 3–8 (Image 5c). Right antennule with 22 segments; one seta each on segment 1, 3–8, 10, 11, 15, and 18–20. Seta of segment 3, 12, and 14 are exceptionally long (Image 5d, Figure 3E). One strong stout spine on segment 13; one short and one long seta on segment 14; longer seta reaching up to segment 17. Segment 15 with one seta and one spine; geniculated between segment 18 and 19 (Image 5e, Figure 3F). Two long setae at the distal margin

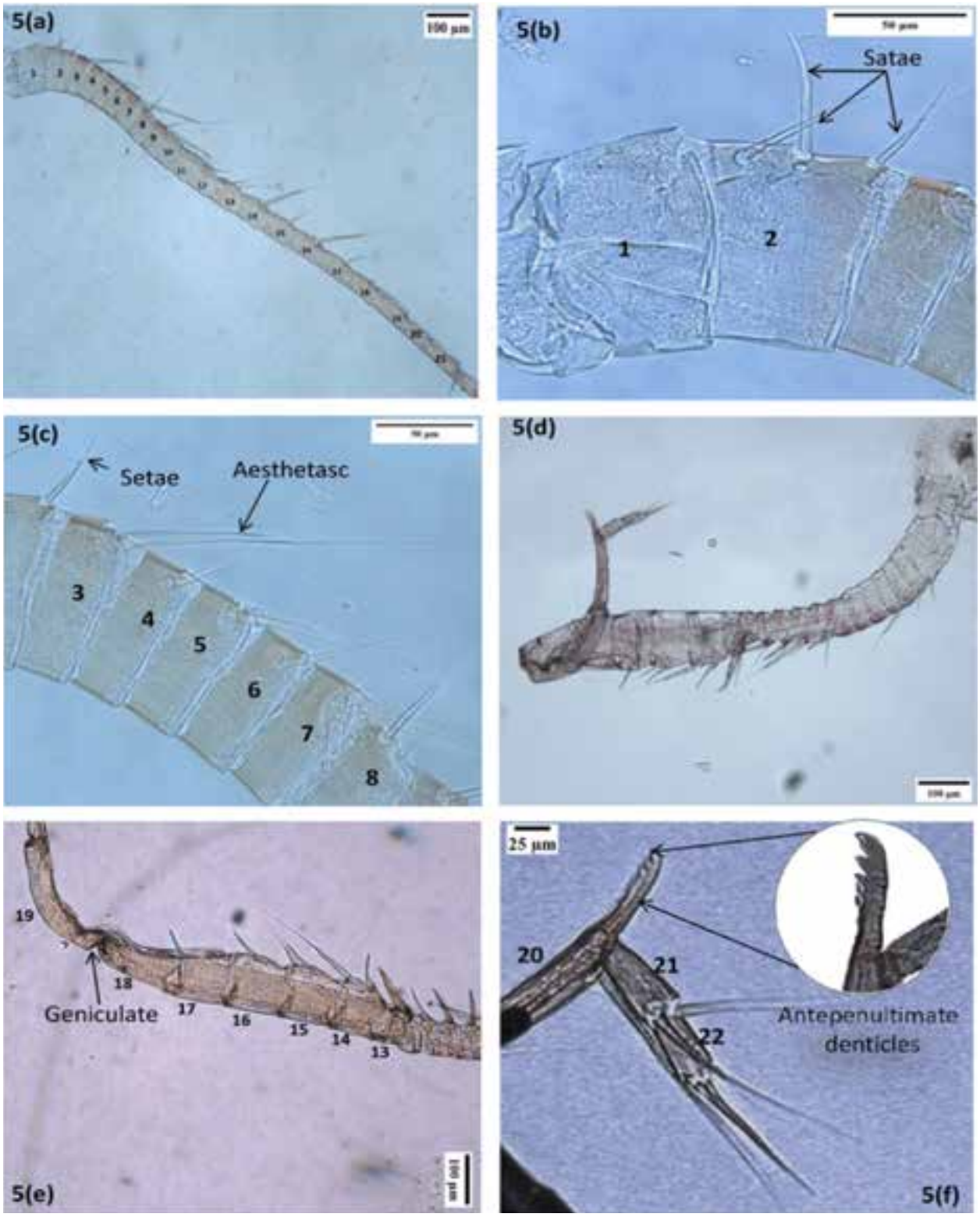

Image 5. *Arctodiaptomus kumaunensis* sp. nov. (male): a—Left antennule | b—Segments 1–2 left antennules | c—Segments 3–8 left antennules | d—Right antennules | e—Segments 13–19 right antennules | f—Segments 20–22 right antennules with antepenultimate. © Inaotombi Shaikhom.

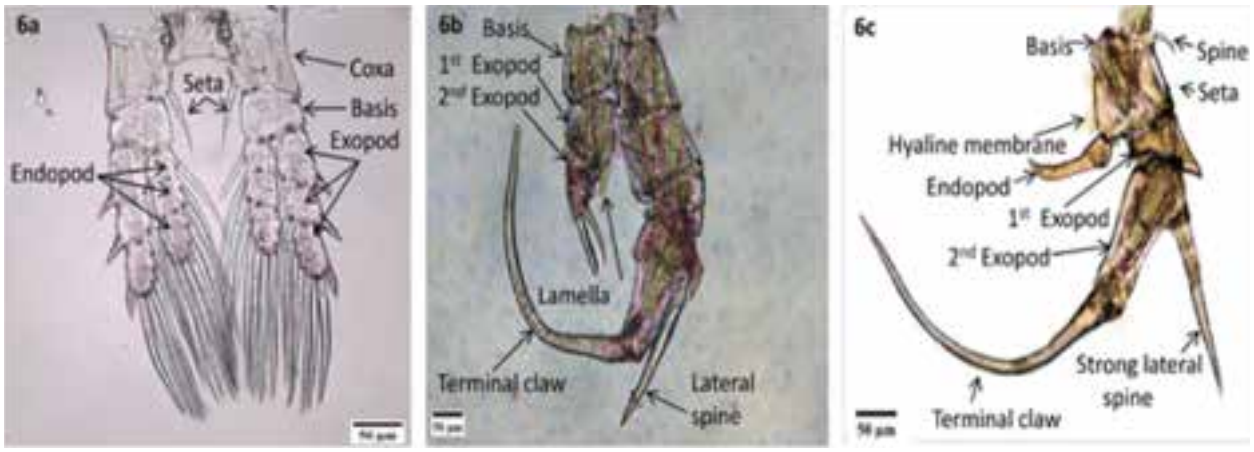

Image 6. *Arctodiaptomus kumaunensis* sp. nov. (male): a—Symmetrical 3rd Leg | b—Asymmetrical fifth leg | c—Fifth right leg. © Inaotombi Shaikhom.

of both segment 19 and 20. A strong and long comb-like process with five denticles on antepenultimate distal outer margin of segment 20 reaching well beyond the distal margin of succeeding segment (Image 5f). Segment 21 with two long setae and terminal segment with two long and two short setae.

Swimming legs similar with the female leg; 4 biramous. Leg 1 having one seta on coxa and basis with 3 segmented exopod and 2-segmented endopod. 2–4 leg symmetrical with one seta on coxa, basis with 3-segmented exopod and endopod (Image 6a, Figure 3G). Leg 4 biramous with 3-segmented rami similar with female leg 4. Fifth leg asymmetrical, left fifth leg short, reach up to the middle of first exopod segment of the proximal right fifth leg. Basis rectangular shape with one narrow hyaline lamella along inner margin and one triangular hyaline lamella along bottom margin. Exopod 2-segmented, first exopod segment slightly wider than second. Second exopod broad at proximal and tapering at the distal armed with two dactylus like spines (Image 6b, Figure 3H). Endopod is extremely reduced. Right fifth leg longer than left; coxa short and bear a slender spinous process on the distal portion of external margin. Basis roughly rectangular shape; possesses a very thin delicate seta at outer margin. A butterfly shaped hyaline membrane attached on the inner lateral side. Exopod 2-segmented, first exopod very short and triangulation expansion at the outer distant margin; second exopod four times longer than the first segment. Strong straight lateral spine at distal first quarter; longer than spine bearing segment. Terminal claw is relatively slender, curved, tapering gradually from the enlarged base and 1.5 times longer than combine length of exopod 1 and expod 2. Endopod 2-segmented, roughly curved tapering at the end reaching midlength of second exopodite segment. Proximal segment board and 0.3 times as long as the distant segment (Image 6c, Figure 3H).

Table 1. Armature formula of the female swimming legs.

Legs	Coxa	Basis	Exopod	Endopod
1st Leg	0–1	0-0	I-1; 0-1; I,3,2	0–1; 2, 3,1
2nd Leg	0–1	0-0	I-1; I-1; I,3,3	0–1; 0–2; 2,2,3
3rd Leg	0–1	0-0	I-1; I-1; I,3,3	0–1; 0–2; 2,2,3
4th Leg	0–1	0-0	I-1; I-1; I,3,3	0–1; 0–2; 2,2,3

DISCUSSION

The *Arctodiaptomus* genus is widely distributed in the Palaearctic region (Reid 2007). They are generally found in small clear water bodies having well developed littoral vegetation (Woltereck 1941; Segers et al. 1995). Among the *Arctodiaptomus*, the species of *A. dorsalis* are considered as neotropical and occurs in perennial ponds, lakes, phreatic and groundwater (Suárez-Morales & Reid 2003). They are also present in temporary water bodies including seasonal floodplain and able to survive in overwinter (Havel et al. 2000; Williams-Howze 1997). *Arctodiaptomus alpinus* and *Arctodiaptomus parvispineus* are cold stenothermal species that usually occurs in oligotrophic high altitude mountain water bodies (Raina & Vass 1993; dos Santos Silva et al. 1994; Reddy 1994; Jersabek et al. 2001; Shu et al. 2013b).

The new species described herein corresponds with *A. parvispineus* reported by Kiefer in 1935 from

Table 2. Morphological features of the genus Arctodiaptomus recorded from the Indian Himalaya.

		***Arctodiaptomus* (*Haplodiaptomus*) *parvispineus* Kiefer 1935**	***Arctodiaptomus* (*Rhabdodiaptomus*) *michaeli* Reddy et al. 1990**	***Arctodiaptomus kumaunensis* sp. nov.**
MALES (♂)				
Body length excluding caudal setae (mm)		1.83 mm	1.31 mm	1.50 mm
Caudal ramus length:width		1:3	1:4	1:2.7
Right Antennule (♂)				
	Segment 13	No stout spine.	Very short spine.	Long stout spine.
	Segment 18–19	No geniculated	No geniculated	Geniculated
	Segment 20–21	No spine or hyaline membrane on antepenultimate segment.	Spinous process nearly straight and round apex on antepenultimate segment.	A comb-shaped process with 5 denticles on antepenultimate segment.
Right fifth leg (♂)				
	Right fifth leg basis	Hyaline lobe each on posterior face and distal inner margin;	A large hyaline lobe on the inner margin.	A butterfly shape hyaline lobe on inner margin.
	Right fifth leg exopod-2	1.6 times as long as median wide; lunate chitinous lobe on posterior surface.	2 times as long as median wide; crescentic hyaline lobe near disto-inner corner.	3 times as long as median wide; no hyaline lobe.
	Right fifth leg endopod	1-segmented, apex oblique, with short coarse hairs.	1-segmented, apex oblique, with transverse row of short, coarse hairs.	2-segmented, proximal segment boarder; 0.3 times as long as distant segment; roughly curved tapering at the end.
Left fifth leg (♂)				
	Left fifth leg basis	Almost trapezoid; 3 hyaline lamella outgrowths on posterior surface: one lobe on upper, second narrow lamella along inner margin, third triangular lamella along bottom margin.	Almost rectangular; one narrow hyaline lamella along inner margin;	Rectangular; one narrow hyaline lamella along posterior inner margin and one triangular hyaline lamella along on proximal margin.
	Left fifth leg exopods	2-segmented; proximal conical shape and distal small almost rounded.	2-segmented; proximal conical shape and distal almost oval.	2-segmented; proximal conical shape and broader at proximal and gradual tapering upto the distal segment.
	Left fifth leg apical process	2 terminal processes; outer finger-like spinose process and inner out curved setiform process longer than spine.	2 terminal processes; outer finger-like spinose process and inner out curved setiform process slightly longer than spine.	2 terminal processes; outer finger-like spinose process and inner out curved setiform process slightly shorter than spine.
	Left fifth leg endopod	1-segmented; small and reaching up to mid length of second exopod; apex rounded with minute spines	Slightly cylindrical non segmented reaching mid length of second exopod; apex rounded with transverse row of coarse hairs, and minute spine on inner side.	Extremely reduces.
FEMALES (♀)				
Mean body length excluding caudal sate (mm)		1.83	1.56	1.55
Caudal ramus length:width		1:2.3	1:2.7	1:2.2
Fifth leg (♀)				
	Fifth leg (♀) coxa	Roughly conical, armed with sensillum at proximal outer margin and triangular spine at disto-outer corner on posterior surface.	Roughly rectangular armed with small broad-based hyaline spine at disto-outer corner on posterior surface.	Roughly rectangular armed with lateral processes at proximal outer margin.
	Fifth (♀) exopod1	1.5 times as long as wide; 2 lateral sensilla on outer margin.	Right leg stouter than left leg; 1.5 times as long as wide; 2 sensilla on outer margin.	1.7 times as long as wide; no sensilla on outer margin.
	Fifth (♀) endopod	A vague cross septum at mid length; an apex rounded with row of short hairs.	Weakly divided 2 unequal segments; an apex rounded with transverse row of short coarse hairs, and small spine on each side.	Endopodite no cross septum, apex rounded with a row of short hairs.

a pond in Chushol, Ladakh of western Himalaya, India. As the species was not described completely, a new re-description was made by Shu et al. (2013a) with its collected from Potatso National Park of Yunnan, China. Some similar morphological features in female *A. parvispineus* and *A. kumaunensis* sp. nov. are 25-segmented antennules; second exopod segment (end claw) slender, both margins with fine spinules, a thick spine near the base of third segment, lateral margins nearly straight but curved at the end. The male *A. parvispineus* and *A. kumaunensis* sp. nov. have almost similar sizes. Right antennule armed with relatively long spines on segment 8, 10, and 11. Basis of right fifth leg in male is a trapezoid shape, 1.5 times longer than wide. *A. kumaunensis* sp. nov. has also a close affinity to *Arctodiaptomus michaeli* (Reddy et al. 1990), particularly the hyaline membrane in the fifth right leg of the male and second exopod on fifth leg of the female. *A. kumaunensis* sp. nov. shared some diagnostic characters with sub-genus *Hesperodiaptomus* such as formation of long process in the ante-penultimate segment of the male geniculate antennule and presence of slender terminal curved claw in the male fifth leg which is gradually tapering to the tip.

As compared with congeners of the genus *Arctodiaptomus*, the newly described taxon showed many distinguished features. The second exopod segment of the male right leg in *Arctodiaptomus kumaunensis* sp. nov. is relatively long (3 times as long as median wide) and no hyaline lobe possesses. The geniculate between segment 18 and 19 of the right antennule was not found in other Himalayan nominal species. Segment 13 of the male right antennule of *Arctodiaptomus kumaunensis* sp. nov. has a relatively stout spine. A strong comb-like process with 5 denticles on segment 20–21 antepenultimate segment of male right antennules is useful in separating the close relative species. The endopodite of the male 5th leg is extremely reduced and the endopodite of the female 5th leg is elongated but has no septum. The three corresponding species of Himalayan *Arctodiaptomus* can be separated from each other based on the characters in Table 2.

The most specialized character of male *A. kumaunensis* sp. nov. is the presence of a strong comb-shaped denticulate spine on the antepenultimate segment of right antennule. The spine reaches well beyond the distal margin of the succeeding segment. The endopod of the right fifth leg in male *A. kumaunensis* is two segmented and observed typical ornamentation. Basis of which processes a butterfly shape hyaline membrane on the inner lateral side. Expod-2 of male right fifth leg thrice as long as median wide. The peculiar character of *A. kumaunensis* sp. nov. is reddish body colour. The concentration of pigment carotenoids, astaxanthin, in the newly described species is 1.9 µg/mg. The identified diaptomid tends to adapt well in the Himalayan Mountain system with this photoprotectant.

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COMMUNICATION

Morpho-anatomical characterization and conservation status of the Whisk Fern *Psilotum nudum* (L.) P.Beauv. (Polypodiopsida: Psilotaceae) from Cooch Behar District of West Bengal, India

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Abstract: The district Cooch Behar of West Bengal, India is considered a unique zone for pteridophytes. The Whisk Fern *Psilotum nudum* (Family Psilotaceae), one of the primitive members of living vascular plants considering its age of evolution during the Devonian, is reported to occur in the Cooch Behar District. The present study has been designed to investigate the current conservation status as well as to describe the morphological and anatomical features of the epiphytic species. The present study revealed that the natural falling of old aged host trees and cleaning and white painting of host tree trunks lead to habitat destruction which may lead to extinction of the species from the studied areas. During the field visits, a new site of the occurrence (Madan Mohan Temple of Cooch Behar City) of the species has also been recorded. Plants are perennial and pendent in nature. The rhizome is achlorophyllous, freely branched, and covered with rhizoids. The aerial stem is up to 36 cm long, repeatedly dichotomously branched and chlorophyllous. Leaves are scalelike, without any midrib, lanceolate to ovate, and without ligules. Synangiums are composed of three connected sporangia, bearing numerous bean-shaped spores. Stele in rhizome is haplostelic type; while, it is actinostele in the aerial stem. Morpho-anatomical description of the species has been documented for the first time from West Bengal and has enriched the botanical information of the species. Proper conservation of the taxa is utmost necessary in order to maintain their population in natural habitat.

Keywords: Anatomy, eastern indo-himalaya, ecology, epiphyte, habitat loss, living fossil, morphology, pteridophytes.

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INTRODUCTION

The genus *Psilotum* (belonging to the primitive family Psilotaceae), with its two Indian species, i.e., *P. nudum* (L.) P.Beauv. and *P. complantum* Sw. (Pande 2002; Chauhan et al. 2003; Muthukumar et al. 2009), is often grouped with the extinct psilophytes, the Rhyniales, and Zosterophyllales dating from the Devonian some 400 million years ago (Roux 2003). Many paleobotanists and plant morphologists considered the members under *Psilotum* as 'living fossils' or 'living rhyniophytes' (Kidston & Lang 1917; Banks 1975; Kaplan 1977; Wagner 1977; Rothwell 1999); but unfortunately, no fossils of psilophytes are known to exist. Recent morpho-anatomical studies (Bell & Hemsley 1992; Stewart & Rothwell 1993) suggest that the genus is not closely related to rhyniophytes; rather, the primitive characters present in living psilophytes represent a reduction from a more typical modern fern plant. Similarly, according to molecular data, it is evident that *Psilotum* is a fern and that psilophytes are sister to ophioglossoid ferns (Qiu & Palmer 1999; Pryer et al. 2001; Smith et al. 2006; Schneider et al. 2009).

Psilotum nudum (Greek—'psilos' means smooth or naked and Latin—'nudus' means naked, and both referring to the smooth and naked character of the stems; commonly known as whisk fern - Qiu & Palmer 1999), one of the two species in the genus *Psilotum*, is widely distributed across tropical and sub-tropical areas of both hemispheres (Zhang & Yatskievych 2013). In India, the species is reported to be found in Andaman Islands, Nicobar Islands, Western Ghats, Eastern Ghats, central India, eastern India, northwestern India (Thothathri et al. 1970; Pande 2002; Chauhan et al. 2003; Valavan et al. 2016; Kanivalan & Rajendran 2017) with its first report in Barren Island, an isolated one in the Andaman group of islands (Prain 1893). In West Bengal, the species is reported to occur in Darjeeling (Pande 2002), Cooch Behar (Biswas 1956; Bandyopadhyay et al. 2006; Mandal 2023) and Jhargram (Sen & Bhakat 2021) districts. *P. nudum* has most recently been assessed for The IUCN Red List of Threatened Species in 2020 and is listed as 'Least Concern' (Bárrios & Copeland 2021).

The whisk fern became a popular pot plant in Japan during the Edo Period (1603–1867), leading to the selection of slightly over 100 ornamental garden varieties, most of which are illustrated in the 'Matsubaran fu' (Hoshizaki & Moran 2001; Chernova et al. 2020). The plant is also reported to be used for different medicinal purposes in India and Hawaii (Foster & Gifford 1974; Benjamin & Manickam 2007; Mannan et al. 2008; Karthik et al 2011; Kumari et al. 2011; Revathi et al. 2013; Valavan et al. 2016, Mandal 2023).

Until now, several morpho-anatomical studies of *P. nudum* have been published from the different parts of the world (Ford 1904; Sporne 1962; Schulte et al. 1987; Nazarian et al. 2010; Vahdati et al. 2014; Rahman et al. 2015; Valavan et al. 2016); as per literature survey, detailed morpho-anatomical studies of the species from India especially from the state of West Bengal is lacking. Keeping all these in mind, the present study has been designed to investigate the present conservation status and to describe the morpho-anatomical characters of the species from the Cooch Behar District of West Bengal, India for the first time which will enrich the botanical information of the species. The current study will also report a new site of the occurrence of the species.

MATERIALS AND METHODS

The Cooch Behar District (Image 1), situated in the foothills of the eastern Indo-Himalaya, is known for its rich floristic composition. Field visits have been conducted across different seasons during January 2021 to September 2022 to observe the habitat and population growth pattern. The plant, *P. nudum* has been collected from the previously reported study area (Biswas 1956; Bandyopadhyay et al. 2006), i.e., Narendra Narayan Park (26.325 ^{0}N, 89.450 ^{0}E; elevation 14.5 m; Image 1), Cooch Behar for morphological and anatomical studies. Morphological description has also been done from the new site of occurrence of the species, i.e., Madan Mohan Temple (26.320 ^{0}N, 89.444 ^{0}E; elevation 14.5 m; Image 1), Cooch Behar based on the available plant specimens. Geographical locations of the study areas were recorded using the device GARMIN® eTrex® 22x. Anatomical studies have been performed through hand–sectioning of rhizome, aerial shoot of different orders and synangium. Slides were prepared after double staining and photographs were taken for photographic documentation. Spore morphology was examined under a light microscope (10X × 40X) and described as per Erdtman (1945, 1971). Identification of the plant specimen was made using relevant floras (Chinnock 1998; Diggs et al. 2006) and proper nomenclature was maintained following POWO (2022). Voucher specimens were deposited in the Department of Botany, A.B.N. Seal College, Cooch Behar.

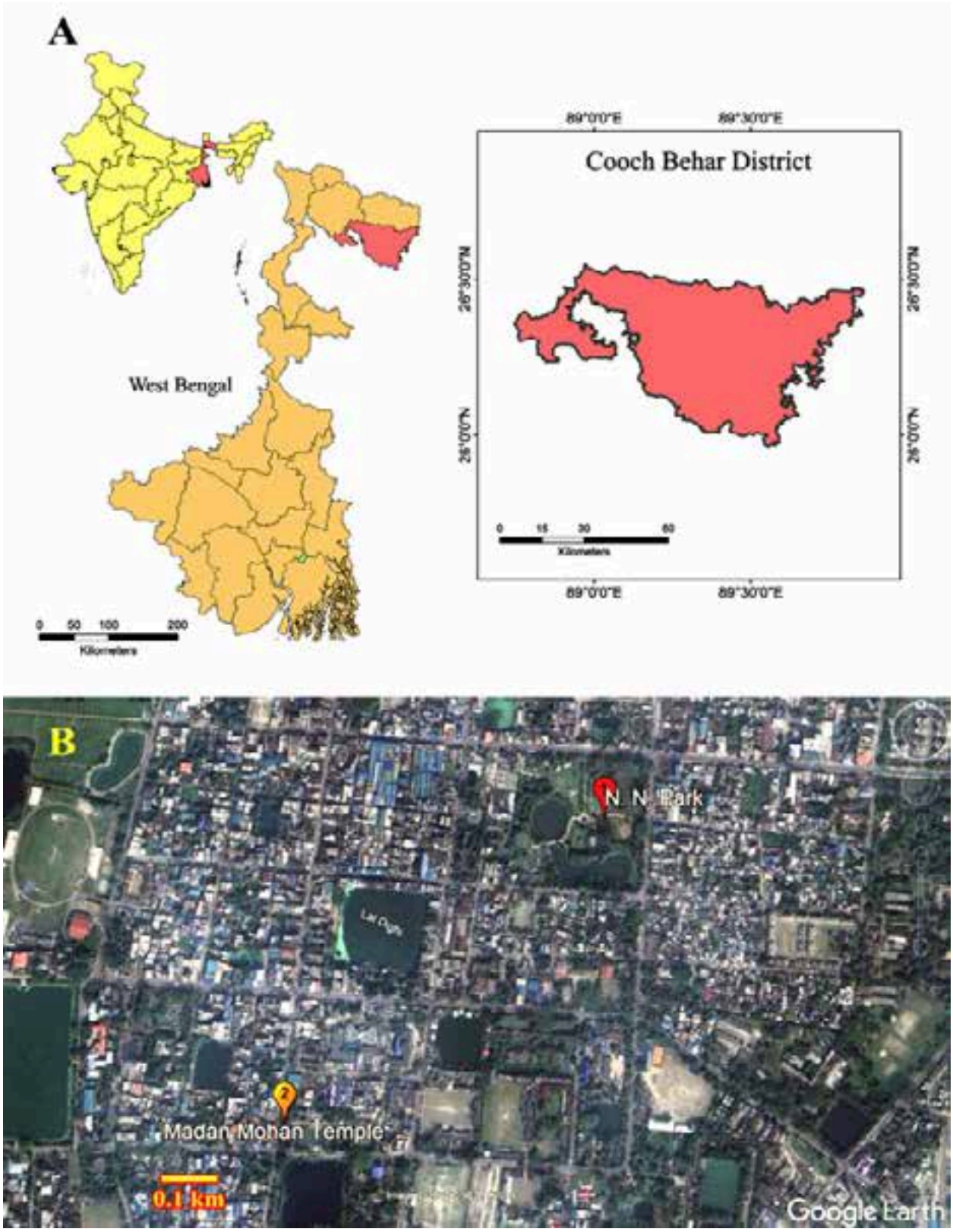

Image 1. A—Map of India and West Bengal highlighting the district Cooch Behar (red- orange color) | B—Study areas; Narendra Narayan Park (marked in red pin 1) & Madan Mohan Temple (marked in orange pin 2). Map prepared using an open source QGIS Desktop 3.22.

RESULTS AND DISCUSSION

Habitat, ecology and conservation status

The plant population of *Psilotum nudum* recorded from the new site of occurrence (Madan Mohan Temple) was found to grow on the tree trunk base (up to 1.5 m) of an old katgolap tree (*Plumeria* sp.) in association with *Drynaria quercifolia* (L.) J.Sm., *Pyrrosia lanceolata* (L.) Farw. and some species of orchids and mosses (Image 2). Approximately, 35 *Psilotum* plants were found to be grown in the tree trunk of which only a few with sporangium. The host tree is very old and eventually dying day by day as per the information provided by the gardener of the temple. Cleaning and white painting of the tree trunks of the temple before the ancient and traditional Rash Utsav is a very common practice for the beautification of the garden and may harm the concerned species and lead to loss from the site. Hence, in situ and ex situ conservation strategies should be taken to protect the species. The author made the gardener aware of the importance of the species and suggested barricading the tree and not to paint the tree trunk so that the species can grow in its natural habitat.

Biswas (1956) only reported a few plants of the species growing on *Polyalthia longifolia* along with an orchid (*Dendrobium* sp.) in the main park (now named Narendra Narayan Park) and predicted the species has been introduced from south India along with the orchid collection. Later on, a team from ENVIS, Botanical Survey of India, Kolkata visited the same park and reported that the species on the trunk of five very old trees (out of six trees) of *P. longifolia* in association with *D. quercifolia* and some orchid species (Bandyopadhyay et al. 2006). The present study revealed that approximately 15 plant species are found to be grown in the first tree; the second tree becomes dead and only the remnants of trunk remains without having *Psilotum* plant; the third tree also contains no *Psilotum* species as reported earlier; more than 50 plant species are found to be grown in the fourth tree (Image 2); there is no trace of the fifth tree and no plants are found to be grown on the tree number six, though the previous authors reported that many plants were found to be grown in fifth and sixth trees. From the current study it is clear that the plant population decreased day by day which may be due to the natural falling of host plants and or cleaning and painting of the tree trunks. The park authority made aware by the present author regarding the present status of this significant plant species in the park with a suggestion for taking necessary measures to protect this declining species.

Morphological description

Plants are perennial medium-sized herbs, that grow as an epiphyte and pendent in nature (Image 3). Rhizome is brown (achlorophyllous), cylindrical, slender, freely branched, 2.0–3.0 cm long, 1.5 mm in diameter, and covered with hair-like structures, called rhizoids. The rhizome merges above the surface with the aerial part of the plant. The aerial stem is 16–36 cm in long and 0.5–2.0 mm in diameter, repeatedly dichotomously branched above with 30–42 branches, often pentagonal towards the main stem, first and second dichotomy, quadrangular towards the third and fourth dichotomy and triangular in the most distal portions (fifth dichotomy), glabrous and green in color (chlorophyllous), with longitudinal parallel lines twisted slowly around the stem. Leaves are scale-like (Image 3), lacking a midrib, 1.5–2.0 mm long, spirally arranged on the stem, lanceolate to ovate in outline, pointed, and without any ligules. Synangia (Image 3) is 2.5–3.0 mm in diameter, orbicular, smooth, light green during young stages, become yellowish when mature and composed of three fused sporangia (Image 3) separated by three longitudinal and arched depressions, bearing numerous kidney or bean-shaped spores, a dichotomous bract is present around the synangium. Spores are homosporous, monad, bilaterally symmetrical, monolete, prolate to per–prolate in shape, large sized (polar axis: 76.68–88.52 µm, equatorial diameter: 36.42–45.92 µm), exine thick (3.26–4.98 µm), exine ornamentation verrucate-tuberculate (Image 3).

Anatomical description

A model plant drawing of *P. nudum* has been displayed in the image (Image 3) to show the scheme of sampling sites for transverse sections (T.S.) of rhizome and aerial stem of different dichotomies.

Rhizome

The T.S. of the rhizome is more or less circular in shape (Image 3). Epidermis is thin, inconspicuous and single layered. Most of the epidermal cells extend into two celled absorptive rhizoids. Below the epidermal layer, there is a broad cortex of thin-walled cells. Stele is protostele (haplostele) in nature. Pith is absent and the xylem mass is usually chain- like / rod- like in outline and without any protoxylem. The xylem is surrounded by uniform layers of phloem which in turn is surrounded by the pericycle. Outside the pericycle, a distinguishable endodermal layer is present with conspicuous Casparian strips on radial walls. Vahdati et al. (2014) have also reported the presence of haplostele in the rhizome;

Image 2. Photographs of host plants bearing *Psilotum nudum*: A—Painted tree trunk of *Plumeria* sp. at Madan Mohan Temple | B—Tree trunk of *Polyalthia longifolia* at N.N. Park. © Aninda Mandal.

Nazarian et al. (2010) have reported the stellar type as actinostele.

Aerial stem

In T.S., the aerial stem appeared pentagonal towards the main stem (Image 3), first (Image 3) and second (Image 3) dichotomy, quadrangular towards the third (Image 3) and fourth (Image 3) dichotomy and triangular in the most distal portions (fifth dichotomy; Image 3). The aerial stem shows a well-marked single-layered cuticularized epidermis, and large numbers of stomata are found to be present in the grooves of the stem. The cortex is broad and is differentiated into three zones. The outermost zone is 3-layered, cells are thin- walled, vertically elongated with intercellular spaces, parenchymatous, nucleated, and contain chlorophyll. The middle cortex is 3–4 layered, and cells are thick-walled and sclerenchymatous. The inner cortex is 5–7 layered, cells are thin-walled, parenchymatous, and without any intercellular spaces. The stele is surrounded by well-marked endodermis. Pericycle is not distinguishable. The stele in the aerial stem is of actinostele type. Xylem is star-shaped and the protoxylem lies at the tip of each ray. Presence of actinostele has also been reported earlier by different authors (Schulte et al. 1987; Khoshravesh et al. 2009; Vahdati et al. 2014); however, Gifford & Foster (1989) and Nazarian et al. (2010) interpreted the stele as siphonostele.

CONCLUSION

Psilotum nudum is one of the primitive vascular plants still living and often considered as 'living fossil'. In the present study, the species is found to grow as an epiphyte in the tree trunks of very old aged plants in the studied areas. The host trees are gradually falling down due to their very old age. Cleaning and sometimes white painting of host tree trunk for beautification of park and garden lead to habitat destruction. Continuous habitat loss may lead to extinction of the species from

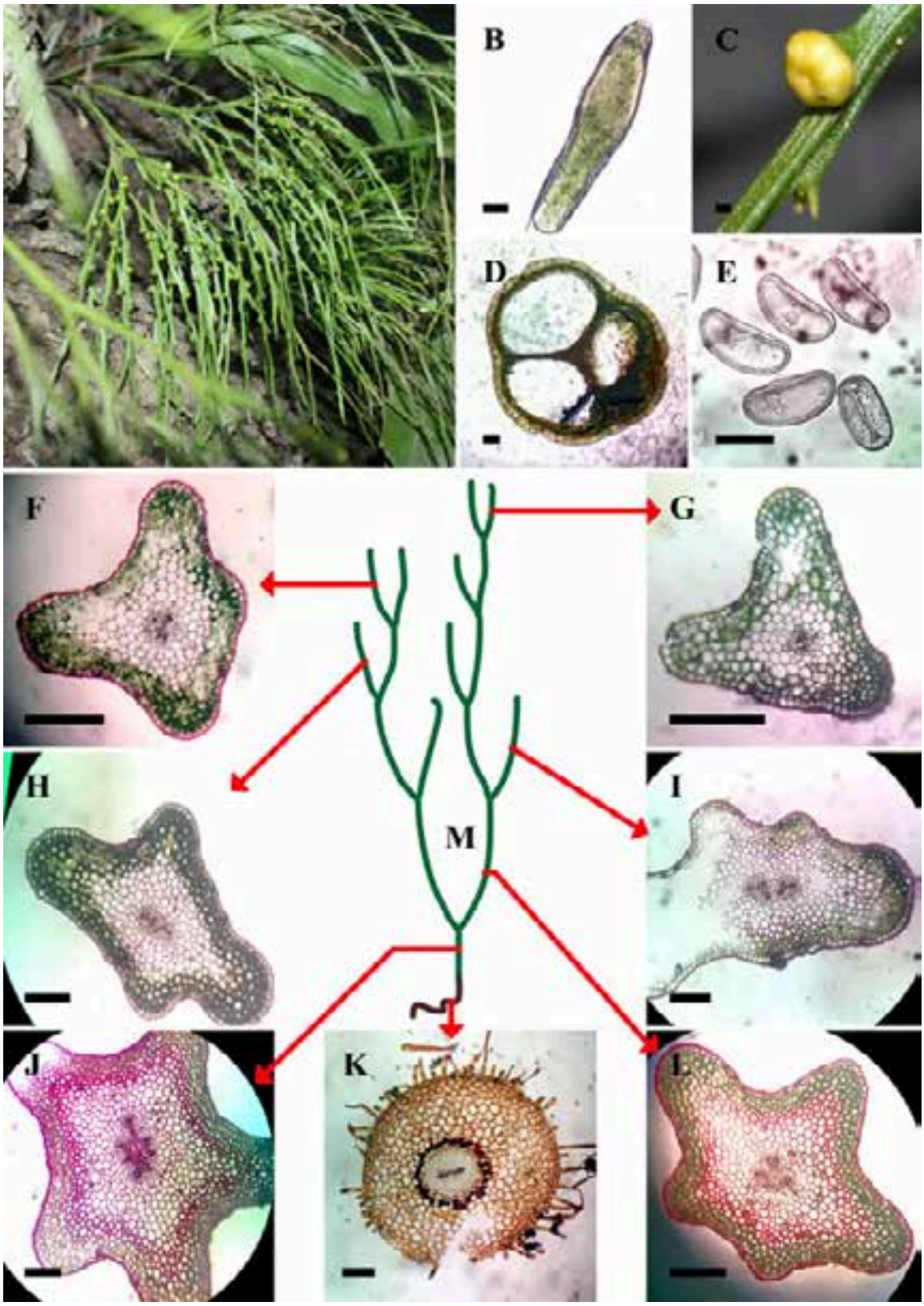

Image 3. Morpho-anatomy of *Psilotum nudum*: A—Sporophytic plant body growing on tree trunk | B—Scale leaf | C—Matured synangium | D—Transverse section of synangium with trilobed structure | E—Monolete spores | F—Fourth dichotomy | G—Fifth dichotomy | H—Third dichotomy | I—Second dichotomy | J—Transverse section of main stem | K—Transverse section of rhizome showing two-celled rhizoids | L—First dichotomy | M—Scheme of sampling sites on a typical model plant for transverse-sections of different dichotomies (Scale bar: B, D, F, G, H, I, J, K, L—0.25 mm, C—0.5 mm, E—50 µm). © Aninda Mandal.

the studied areas. So, necessary measures should be taken immediately for in situ and ex situ conservation of the botanically interesting species. Detailed morpho–anatomical description of the species is also carried out for the first time from the district Cooch Behar of West Bengal, India which will enrich the botanical information of the species.

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COMMUNICATION

Six new reports of corticioid fungi from India

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Abstract: The objective of the present paper is to describe and illustrate six species of corticioid fungi collected from four tehsils of the Chamba District of Himachal Pradesh (India). The described species, *Brevicellicium exile* (H.S.Jacks.) K.H.Larss. & Hjortstam, *Kurtia magnargillacea* (Boidin & Gilles) Karasiński, *Physodontia lundellii* Ryvarden & H.Solheim, *Rhizochaete violascens* (Fr.) K.H.Larss., *Sistotrema coroniferum* (Höhn. & Litsch.) D.P.Rogers & H.S.Jacks, and *Tubulicrinis cinctus* G.Cunn. are new additions to corticioid fungi reported from India.

Keywords: Agaricomycetes, Basidiomycota, diversity, northwestern Himalaya, taxonomy.

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Competing interests: The authors declare no competing interests.

Author details: Dr. Poonam is currently working as assistant professor, Department of Botany, Government Post Graduate College, Chamba (Himachal Pradesh). She has worked on the taxonomy of corticioid fungi from district Chamba for hes PhD research work. He has thoroughly surveyed district Kullu and collected 486 specimens of the corticioid fungi. She has described and illustrated 191 taxa including 20 new records for India and 43 first reports for Himachal Pradesh. Dr. Avneet Pal Singh, assistant professor, Department of Botany, Punjabi University, Patiala is a mycologist and works on the taxonomy, histo-pathology and evaluation of corticioid and polyporoid fungi (Agaricomycetes, Basidiomycota). He actively engaged in the research work for more than two decades and has published about eighty research papers describing nearly three hundred and ten taxa based on morphological and DNA sequence based molecular phylogenetic studies. He has to his credit two new genera and twenty two new species of corticioid and poroid fungi. Dr. Gurpaul Singh Dhingra retired as professor from Department of Botany, Punjabi University, Patiala (Punjab) and has more than three decades of teaching and research experience. His area of specialization is mycology and plant pathology with special interest in corticioid and poroid fungi. He and has described large number of new genera and species of these fungi form different parts of India. He has worked on the antidiabetic, CNS and anticancer activity of medicinally important poroid fungi.

Author contributions: Poonam has thoroughly surveyed the study area and collected the corticioid specimens. She has worked out the morphological details of the collected specimens and prepared the standard descriptions along with illustrations. Avneet Pal Singh has explored the taxonomic literature for identity of the worked out specimens and identified the worked out specimens. He has also contributed to the draft of manuscript and photography of the specimens described presently. Dr. Gurpaul Singh Dhingra is an expert in the field of taxonomy of corticioid fungi and confirmed the identification. He critically analyzed the draft and made valuable suggestions.

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INTRODUCTION

Corticioid fungi are a group of higher fungi (Basidiomycota, Agaricomycetes) that mostly grow in association with different forms of wood substrate. These are also referred to as crust fungi because of the formation of macroscopic sporophores with unilateral hymenium that are mostly resupinate or sheet-like. The hymenial surface is usually smooth, occasionally varies from tuberculate, ridged, warted, toothed, to merulioid. The colour of the hymenophore mostly ranges from whitish to shades of grey, yellow, orange, red, or brown. The sporophores are quite diverse with reference to hyphal type, ancillary structures, shape and size of basidia and basiodiospores. On the basis of morphological features most of corticioid fungi were earlier placed in the family Corticiaceae (Aphyllophorales). The molecular phylogenetic studies indicated the family to be an unnatural group. Hence, these fungi have been currently distributed into twelve orders of the class Agaricomycetes (Agaricomycotina, Basidiomycota).

Corticioids are ecologically significant because of their role in the recycling of wood and agricultural residues. These fungi breakdown different kinds of organic matter, decompose soil components and regulate the balance of carbon and other nutrients for maintaining soil health (Tong et al. 2022). The members of corticioid fungi have ability to produce extracellular enzymes and actively transform carbon and other nutrients, water, and oxygen along a highly branching hyphal network (Boddy 1991; Cragg et al. 2015). The secretion of lignin or cellulose decaying enzymes makes this group capable of colonizing different types of wood in a forest ecosystem and are responsible for white or brown rot, respectively.

Four tehsils of the Chamba District (Himachal Pradesh, India) were thoroughly surveyed for the collection of sporophore specimens of corticioid fungi. These were identified as *Brevicellicium exile* (H.S. Jacks.) K.H.Larss. & Hjortstam, *Kurtia magnargillacea* (Boidin & Gilles) Karasiński, *Physodontia lundellii* Ryvarden & H.Solheim, *Rhizochaete violascens* (Fr.) K.H.Larss., *Sistotrema coroniferum* (Höhn. & Litsch.) D.P.Rogers & H.S.Jacks, and *Tubulicrinis cinctus* G.Cunn. on the basis of macroscopic and microscopic features and their comparison with the published literature (Eriksson & Ryvarden 1973; Eriksson et al. 1981, 1984; Hjortstam et al. 1988; Boidin et al. 1991; Bernicchia & Gorjón 2010; Hakimi et al. 2013; Manoharachary et al. 2022; fungifromindia.com 2024; Mycobank 2024). The species documented presently are new records for India.

MATERIAL AND METHODS

During the years 2013–2018, extensive fungal excursions were carried out in four tehsils of the Chamba District of Himachal Pradesh (India) for the purpose of gathering sporpohore specimens of corticioid fungi. The sporophores were gently separated from the substrate using a chisel and hammer. All the collected specimens were thoroughly cleaned and dried either in sun or on an electric drier. The macroscopic characteristics of the sporophores were observed and noted with the help of a hand lens. Kornerup & Wanscher (1978) was referred for the colour citation. The microscopic features were examined by preparing crush mounts and free-hand cut sections in 3%, 5%, and 10% potassium hydroxide (KOH) solution. The microscopic preparations were stained in cotton blue (1% in lactophenol), congo red (1% in distilled water), phloxine (1% in distilled water), and Melzer's reagent (0.5 g iodine, 1.5 g potassium iodide, 20 g chloral hydrate and 20 ml distilled water). Details of the microscopic structures were outlined as line diagrams using a camera lucida at different magnifications (100x, 400x, and 1,000x) of the compound microscope. Taxonomic descriptions comprising the macro and microscopic features were prepared and subsequently compared with the literature for identification. The specimens of these corticioid species were deposited in the Herbarium, Department of Botany at Punjabi University, Patiala (PUN).

RESULTS

Brevicellicium exile (H.S.Jacks.) K.H.Larss. & Hjortstam, Mycotaxon 7(1): 118 (1978). (Image 1)

Corticium exile H.S.Jacks., Canadian Journal of Research 28(6): 721 (1950).

Sporophore resupinate, effused, adnate, ≤160 µm thick in section; hymenial surface smooth both in fresh and dry state; yellowish white to pale yellow both in fresh and dry state; margins fibrillose, paler concolorous when determinate.

Hyphal system monomitic. Generative hyphae subhyaline, septate, clamped, smooth, thin-walled; subicular hyphae horizontal, ≤2.5 µm wide, less branched; subhymenial hyphae vertical, ≤4.5 µm wide, richly branched, almost isodiametric. Sphaerocysts spherical, 10– 12 × 6– 7 µm, thin-walled, with basal

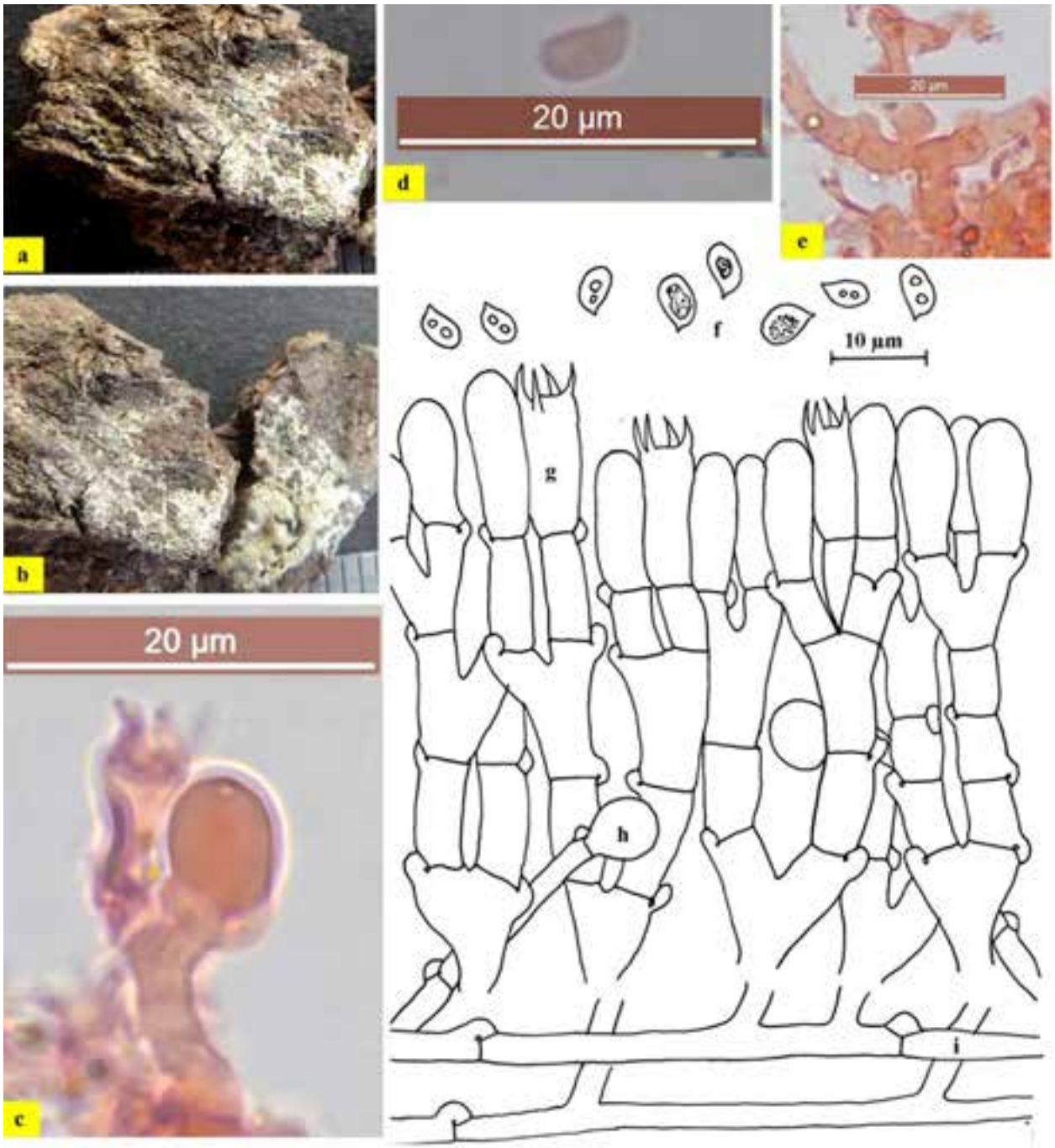

Image 1. ***Brevicellicium exile*****: a–b—Sporophore showing hymenial surface Fresh (a) and Dry (b) | c–e—Photomicrographs showing sphaerocyst (c), basidiospore (d), and generative hyphae (e) | f–i—Line diagrams depicting the outline of basidiospores (f), basidium (g), sphaerocyst (h), and generative hyphae (i). © Poonam.**

clamp. Basidia cylindrical, 11– 13 × 5.5– 6.7 µm, basally clamped, four sterigmate; sterigma ≤ 5 µm long. Basidiospores ellipsoid to broadly ellipsoid, distinctly apiculate, 4.5–5.5 × 2.8–3.5 µm, thin-walled, smooth, acyanophilous, inamyloid, with oily contents.

Collection examined: India, Himachal Pradesh: Chamba, Dalhousie, Jandrighat, on stump of *Cedrus deodara*, Poonam 9198 (PUN), 05 November 2013.

Remarks: *Brevicellicium exile* is peculiar in having smooth hymenial surface, basally clamped sphaerocysts and ellipsoid to broadly ellipsoid basidiospores. *Brevicellicium olivascens* (Bres.) K.H.Larss. & Hjortstam differs in having grandinioid to slightly hydnoid hymenophore and subglobose to somewhat angular

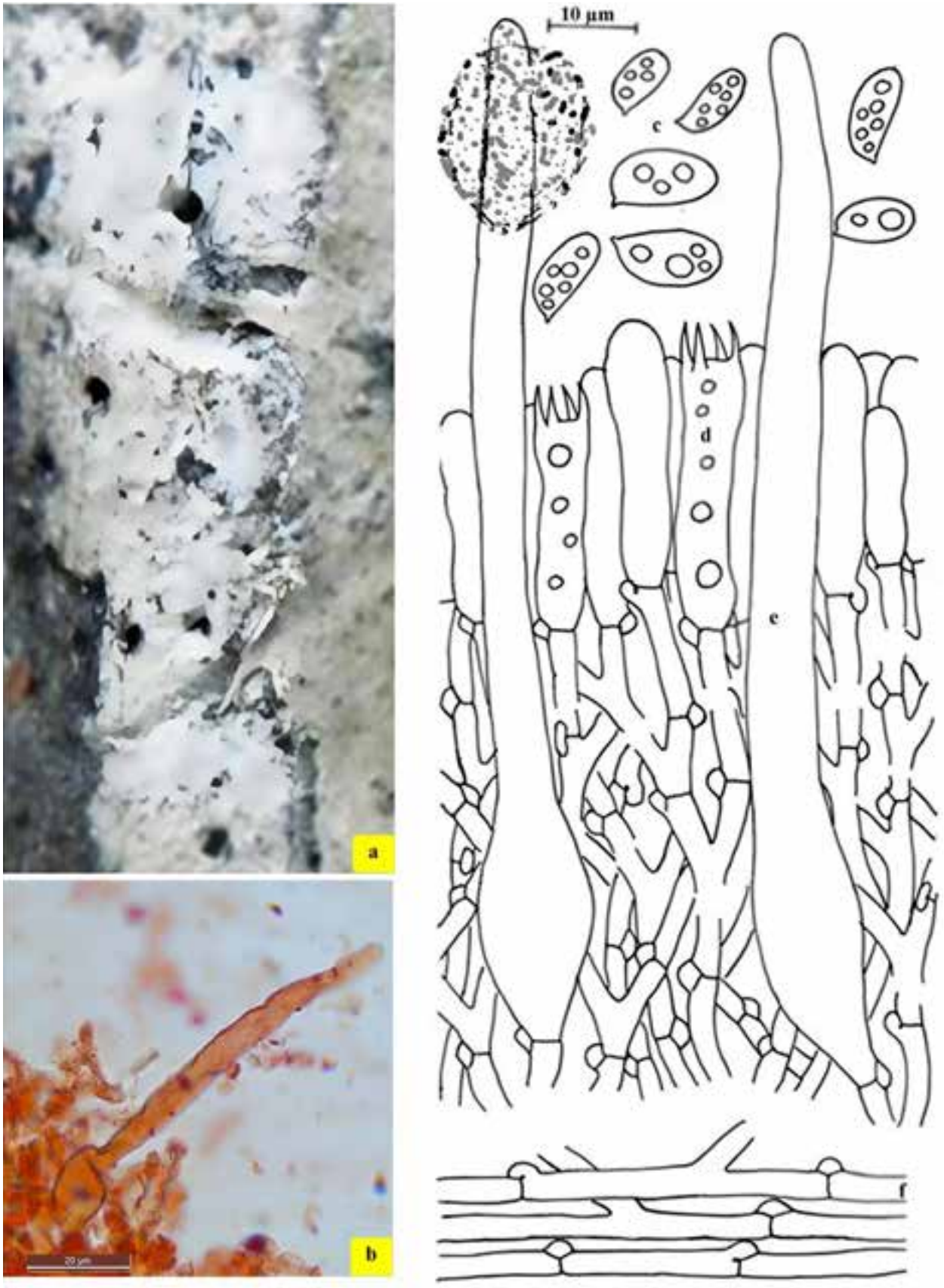

Image 2. ***Kurtia magnargillacea***: a—Sporophore showing hymenial | b—Photomicrograph showing a cystidium | c–f—Line diagrams depicting the outline of basidiospores (c), basidium (d), cystidium (e), and generative hyphae (f). © Poonam.

basidiospores (Bernicchia & Gorjón, 2010). Earlier it has been reported from Belgium, France, United Kingdom, Sweden, Italy, Denmark, Norway, Finland and Spain (Mycobank 2024).

Kurtia magnargillacea (Boidin & Gilles) Karasiński, Index Fungorum 141: 1 (2014). (Image 2)

Hyphoderma magnargillaceum Boidin & Gilles, Cryptogamie Mycologie 12(2): 113 (1991).

Sporophore resupinate, effused, adnate, ≤200 µm thick in section; hymenial surface smooth both in fresh and dry state; yellowish white to greyish-yellow both in fresh and dry state; margins fibrillose, paler concolorous when determinate.

Hyphal system monomitic. Generative hyphae ≤3 µm wide, subhyaline, septate, clamped, thin-walled, smooth; subicular hyphae horizontal, less branched; subhymenial hyphae vertical, richly branched. Cystidia subfusiform, basally widened, narrowing towards apex, 122–135 × 12–14 µm, thin-walled, with basal clamp, with resinous deposits at the tip; projecting ≤40 µm out of the hymenium. Basidia clavate to subclavate, with suburniform constriction to sinuous, 23–31 × 6–7.2 µm, basally clamped, with oily contents, four sterigmate; sterigma ≤5 µm long. Basidiospores subcylindrical to ellipsoid to broadly ellipsoid, distinctly apiculate, 7.2–12 × 3.8–6.2 µm, thin-walled, smooth, acyanophilous, inamyloid, with oily contents.

Collection examined: India, Himachal Pradesh: Chamba, Bharmour, Holi, on a dried branch of *Picea smithiana*, Poonam 10101 (PUN), 23 August 2015.

Remarks: *Kurtia magnargillacea* is characteristic of having subfusiform cystidia with resinous deposits at the tip and subcylindrical to ellipsoid to broadly ellipsoid basidiospores. *Hyphoderma argillaceum* (Bres.) Donk differs from *K. magnargillacea* in having comparatively smaller basidiospores. Earlier, it had been described only from France (Boidin & Gilles 1991; Mycobank 2024).

Physodontia lundellii Ryvarden & H.Solheim, Mycotaxon 6(2): 375 (1977). (Image 3)

Sporophore resupinate, effused, adnate, soft, ceraceous, ≤280 µm thick in section; hymenial surface grandinioid to hydnoid both in fresh and dry state; yellowish-white to greyish-yellow when fresh, yellowish-white to light yellow on drying; margins fimbriate, paler concolorous when determinate.

Hyphal system monomitic. Generative hyphae subhyaline, septate, clamped, smooth; subicular hyphae horizontal, ≤4.5 µm wide, less branched, thin- to thick-walled, sometimes with ampullate septa; subhymenial hyphae vertical, ≤2.8 µm wide, richly branched, thin-walled. Ancillary elements of two kinds. Gloeocystidia shape variable, usually oblong to clavate to sometimes with a narrow, terminal protuberance, 16–36 × 8–10 µm, frequent in the hymenium, subhymenium, and trama of the aculei, with basal clamp, thin-walled, oily contents not stained in sulphovanillin. Cystidia subulate to subfusiform, 38–52 × 6.3–7.5µm, thin-walled, basally clamped, without oily contents; projecting ≤10 µm out of the hymenium. Basidia clavate to subclavate, 12–15 × 4.5–6 µm, basally clamped, four sterigmate; sterigma ≤3 µm long. Basidiospores ellipsoid to broadly ellipsoid, distinctly apiculate, 3.6–5 × 2.7–3.6 µm, thin-walled, smooth, acyanophilous, inamyloid.

Collections examined: India, Himachal Pradesh: Chamba, Udaipur, Chihma, on sticks of *Pinus roxburghii*, Poonam 10100 (PUN), 6 September 2018.

Remarks: The genus *Physodontia* is described only on the basis of *P. lundellii* which is peculiar in having grandinioid to hydnoid hymenial surface, two types of cystidial elements and ellipsoid to broadly ellipsoid basidiospores. Earlier it has been reported from Sweden, Finland, and Norway (Mycobank 2024).

Rhizochaete violascens (Fr.) K.H.Larss., Nova Hedwigia 103(3–4): 562 (2016). (Image 4)

Himantia violascens Fr., Observationes mycologicae 1: 211 (1815)

Sporophore resupinate, effused, loosely adnate, pellicular, ≤500 µm thick in section; hymenial surface smooth to cracked, turns reddish violet on putting 3% KOH solution; orange white to greyish orange when fresh, pale orange to greyish-orange to brownish-orange on drying; margins fibrillose due to presence of rhizomorphs, paler concolorous.

Hyphal system monomitic. Generative hyphae subhyaline, septate, clamped, thin-walled; subicular hyphae horizontal, ≤5 µm wide, less branched, encrusted with crystalline encrustation, subiculum light brown but turns reddish-violet in 3% KOH solution; subhymenial hyphae vertical, ≤3 µm wide, richly branched, smooth in the subhymenial zone. Rhizomorphs usually unbranched, ≤22 µm wide. Individual hyphae ≤3.3 µm wide, septate, clamped. Basidia clavate, 20–24 × 4.5–6.5 µm, basally clamped, four sterigmate; sterigma ≤4.2 µm long. Basidiospores ellipsoid, distinctly apiculate, 5.5–7.5 × 2.4–3.4 µm, thin-walled, smooth, acyanophilous, inamyloid.

Collection examined: India, Himachal Pradesh, Chamba, Churah, Bhandal, on the stump of *Picea smithiana*, 10103 (PUN), 15 August 2014.

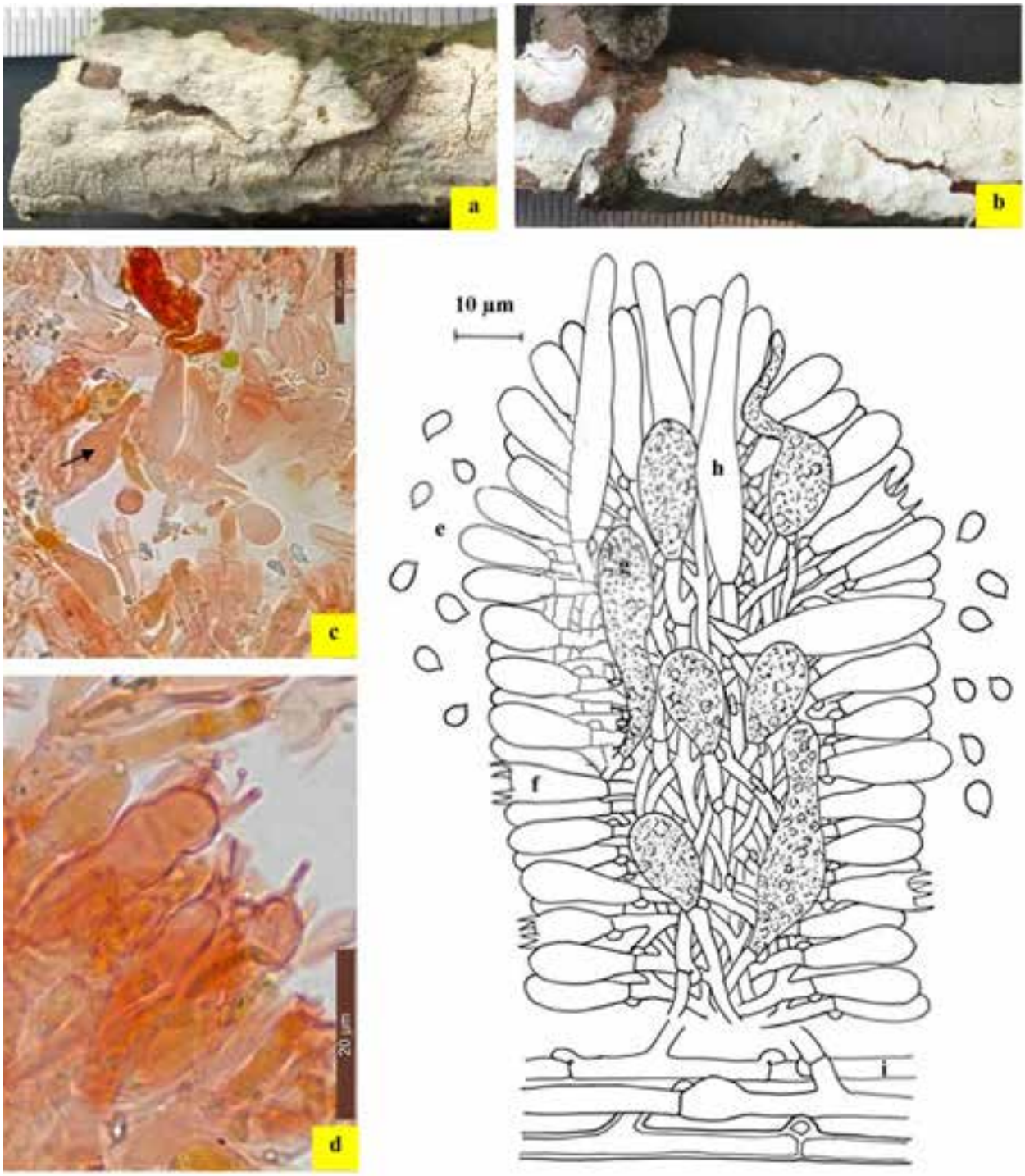

Image 3. ***Physodontia lundellii*****: a–b—Sporophore showing hymenial surface Fresh (a) and Dry (b) | c–d—Photomicrographs showing cystidia (c) and basidia (d) | e–i—Line diagrams depicting outline of basidiospores (e), basidium (f), gloeocystidium (g), cystidium (h), and generative hyphae (i). © Poonam.**

Remarks: *Rhizochaete violascens* is characteristic in having smooth to cracked hymenial surface, unbranched rhizomorphs, and ellipsoid basidiospores. It differs from the rest of the species of the genus *Rhizochaete* in lacking cystidial elements. The previous reports of *R. violascens* are from Belarus, Denmark, Estonia, Finland, France, Germany, Italy, Norway, Netherland, Russia, Spain, and Switzerland (Mycobank 2024).

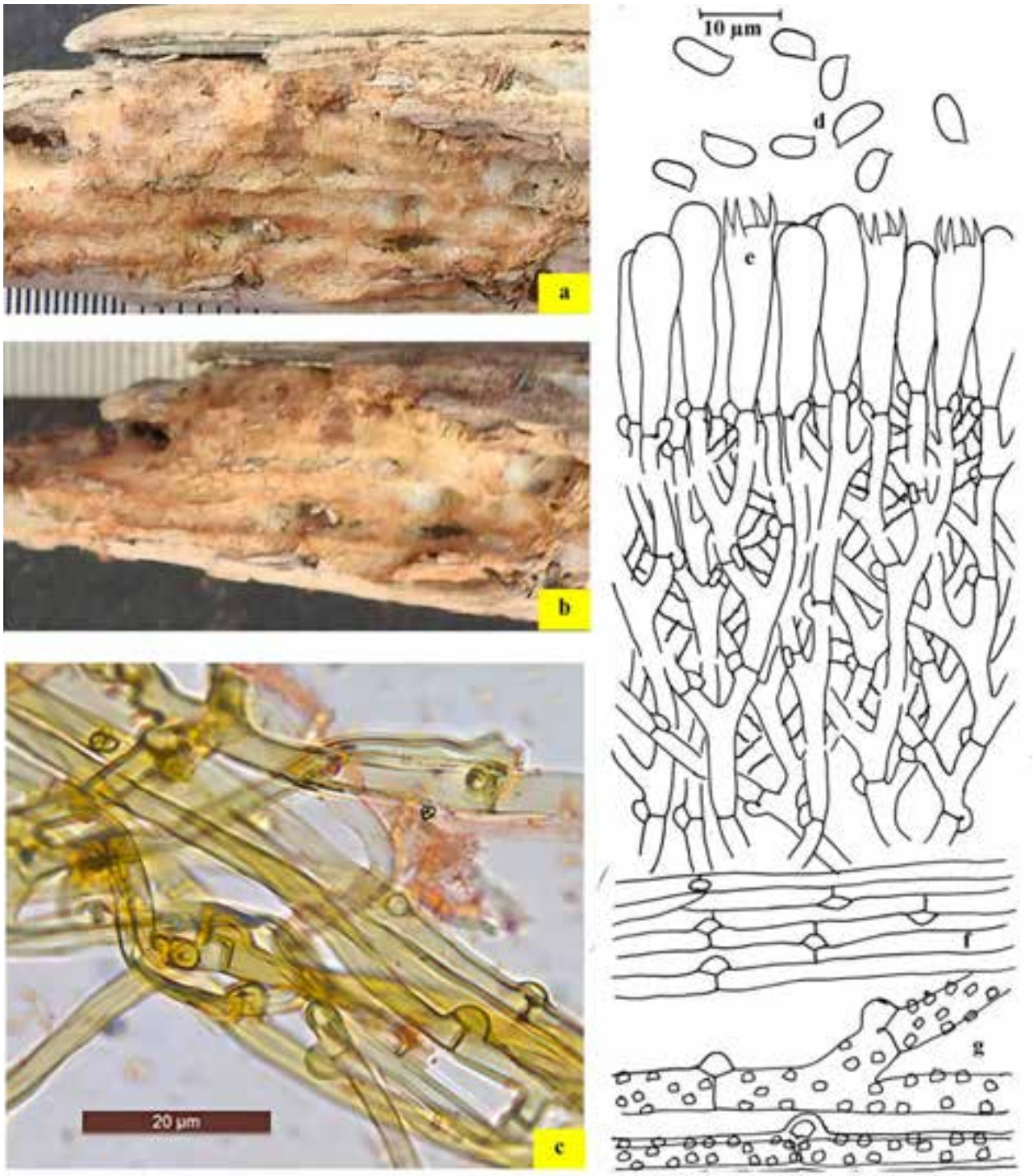

Image 4. ***Rhizochaete violascens*****: a– b. Sporophore showing hymenial surface Fresh (a) and Dry (b) | c—Photomicrograph showing hyphal strands | d–g—Line diagrams depicting outline of basidiospores (d), basidium (e), hyphal strands (f), and generative hyphae (g). © Poonam.**

Sistotrema coroniferum (Höhn. & Litsch.) D.P.Rogers & H.S.Jacks., Farlowia 1(2): 282 (1943). (Image 5)

Gloeocystidium coroniferum Höhn. & Litsch., Sitzungsberichte der Kaiserlichen Akademie der Wissenschaften Math.-naturw. Klasse Abt. I 116: 825 (1907).

Sporophore resupinate, effused, loosely adnate, pellicular, ≤200 µm thick in section; hymenial surface smooth to tuberculate both in fresh and dry state; greyish-white to yellowish-white when fresh, yellowish-

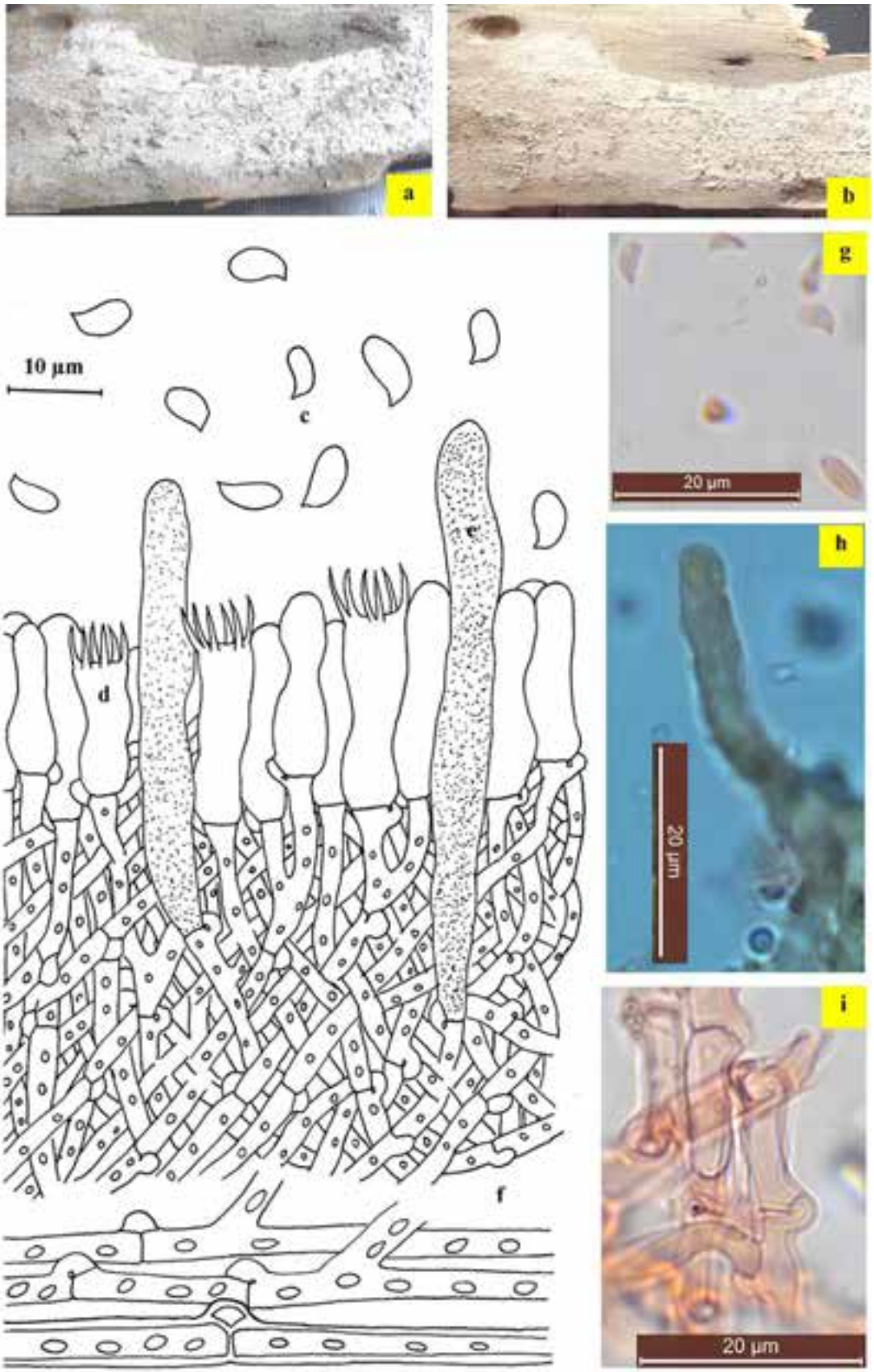

Image 5. ***Sistotrema coroniferum***: a–b. Sporophore showing hymenial surface Fresh (a) and Dry (b) | c–f—Line diagrams showing the outline of basidiospores (c), basidium (d), cystidium (e), and generative hyphae (f) | g–i—Photomicrographs showing basidiospores (g), cystidium (h), and generative hyphae (i). © Poonam.

white to greyish-yellow on drying; margins pruinose, paler concolorous when determinate.

Hyphal system monomitic. Generative hyphae subhyaline, septate, clamped, smooth, with oily contents; subicular hyphae horizontal, ≤5 µm wide, less branched, thick-walled; subhymenial hyphae vertical, ≤4 µm wide, occasionally with ampullate septa, richly branched, thin-walled. Gloeocystidia subcylindrical, flexuose, 48–66 × 5.5–6.6 µm, with basal clamp, smooth, thin-walled, oily contents not stained in sulfovanillin; projecting ≤20 µm out of the hymenium. Basidia suburniform to urniform, 14–22 × 5.5–6.1 µm, basally clamped, six sterigmate; sterigma ≤4 µm long. Basidiospores suballantoid to allantoid, distinctly apiculate, 5.5–7.8 × 2.2–3.4 µm, thin-walled, smooth, acyanophilous, inamyloid.

Collections examined: India, Himachal Pradesh: Chamba; Hardaspura colony, on stump of *Populus ciliata*, Poonam 9203 (PUN), 4 November 2015; Hardaspura colony, on stump of *Populus ciliata*, Poonam 10107 (PUN), 4 November 2015.

Remarks: *Sistotrema coroniferum* is peculiar in having six sterigmate basidia, suballantoid to allantoid basidiospores along with subcylindrical flexuose gloeocystidia. *Sistotrema sernanderi* (Litsch.) Donk differs in having four sterigmate basidia and subcylindrical to suballantoid basidiospores. It has been earlier reported from Austria, Caucasus, Germany, Estonia, France, Slovakia, United Kingdom, Belgium, Sweden, Italy, Denmark, Norway, Switzerland, Finland, and Spain (Mycobank 2024).

Tubulicrinis cinctus G.Cunn., Bulletin of the New Zealand Department of Industrial Research 145: 332 (1963) (Image 6)

Sporophore resupinate, effused, adnate, ≤200 µm thick in section; hymenial surface smooth both in fresh and dry state; yellowish-grey to grey when fresh, pale yellow to greyish-yellow on drying; margins fibrillose, paler concolorous when determinate.

Hyphal system monomitic. Generative hyphae subhyaline, septate, clamped, smooth; subicular hyphae horizontal, ≤3.2 µm wide, thin- to thick-walled, less branched; subhymenial hyphae vertical, ≤ 2.4 µm wide, richly branched, thin-walled. Lyocystidia cylindrical, 61–89 × 8–10 µm, with rooting base, lumen narrow, capillary ending abruptly into a widened thin-walled apex, with basal clamp, encrusted with crystalline deposits at the apex that dissolve in 3% KOH solution, slightly amyloid. Basidia clavate, 12–22 × 5.6–7.2 µm, somewhat stalked, constricted, basally clamped, four sterigmate; sterigma ≤4 µm long. Basidiospores 4.8–6.4 × 3.2–4.8 µm, subglobose, distinctly apiculate, thin-walled, smooth, acyanophilous, inamyloid.

Collections examined: India, Himachal Pradesh: Chamba, Churah, Bhandal, on stump of *Pinus wallichiana*, Poonam 10106 (PUN), 15 August 2014; Churah, Bhandal, on stump of *Pinus wallichiana*, Poonam 10752 (PUN), 15 August 2014.

Remarks: *Tubulicrinis cinctus*, a new report of corticioid fungi from India, is peculiar in having cylindrical, rooted, lyocystidia with crystalline encrustation at the apex and subglobose basidiospores. *Tubulicrinis globisporus* K.H. Larss. & Hjortstam is different in having comparatively larger and strongly amyloid cystidia (Hjortstam et al. 1988). The previous reports are from Russia, Caucasus, Sweden, Norway, and Turkey (Mycobank 2024).

CONCLUSIONS

During the course of present studies, six corticioid species have been added to the account of corticioid fungi from India. Of these, the genus *Physodontia* has been recorded for the first time from India. These six species have been described on the basis of morphological features. In the future attempt will be made to supplement the comprehensive morphological observations with DNA sequence based molecular phylogenetic analysis. The polyphasic approach would definitely authenticate the morphology based identification and may also form the basis for the proposal of some novel taxa.

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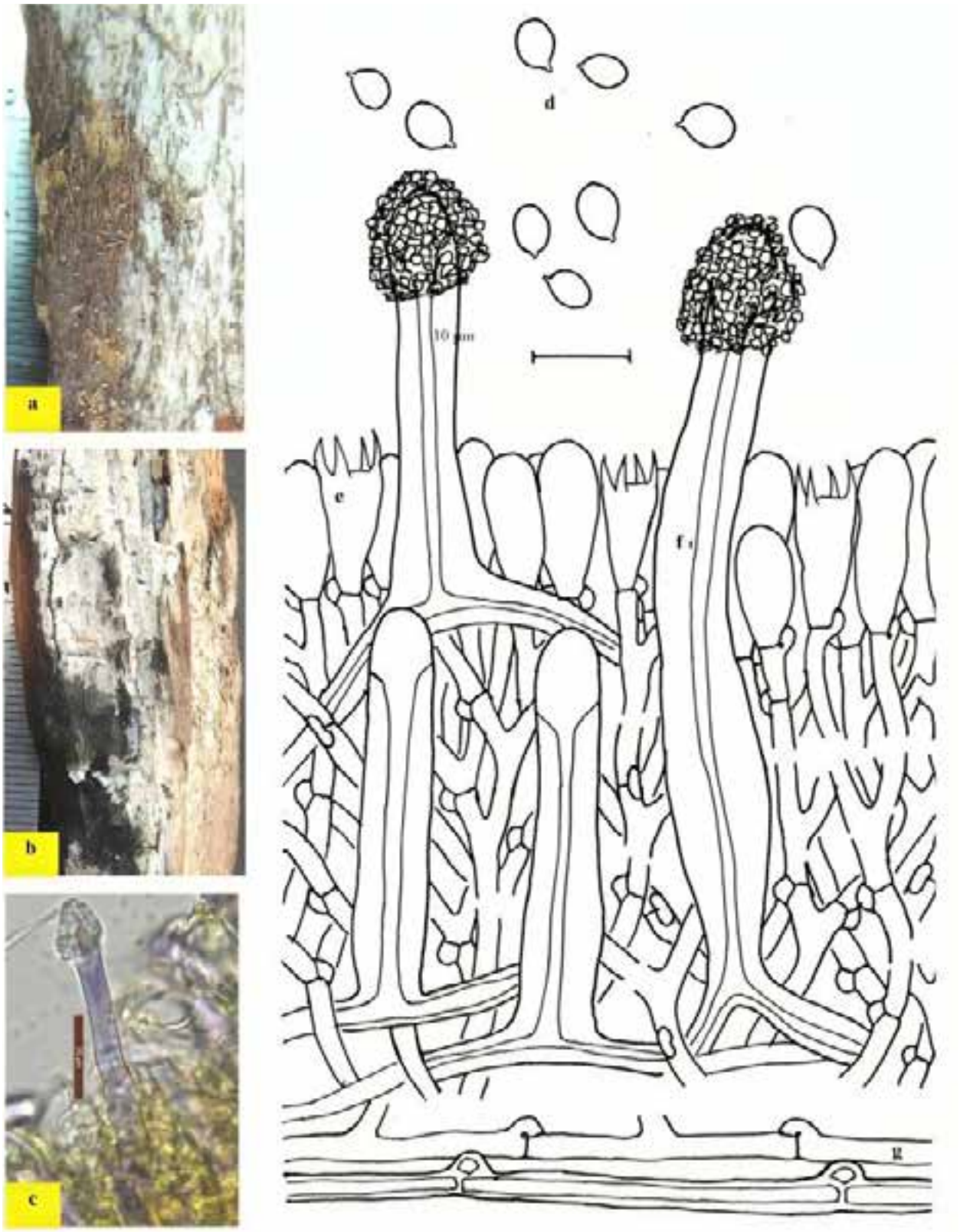

Image 6. ***Tubulicrinis cinctus***: a–b—Sporophore showing hymenial surface Fresh (a) and Dry (b) | c—Photomicrograph showing lyocystidium | d–g—Line diagrams depicting outline of basidiospores (d), basidium (e), lyocystidum (f), and generative hyphae (g). © Poonam.

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OPEN ACCESS

COMMUNICATION

On the *Maravalia echinulata* (Niessl ex Rabenh.) Ono (Pucciniales: Chaconiaceae) with reference to its host range and distribution

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Abstract: *Maravalia echinulata* (Niessl ex Rabenh.) Ono has been rediscovered from West Bengal, India, after its last report in 1931. Sections of infected host leaves were cut, stained in cotton blue, and mounted in lactophenol. All five spore forms of this macrocyclic autoecious rust fungus are described in detail, with notes on its world distribution, distribution in India, and host range. Pycnia were found to be amphigenous, whereas aecia, uredinia, and telia were hypophyllous. Pycnia subcuticular, globose with flexuous hyphae belonging to type 4 of Hiratsuka & Sato (1982) containing chains of spermatia. Aeciospores are spiny, and catenulate, forming long chains connected by hyaline disjunctor cells. Urediniospores pedicellate, spiny, hyaline, and thin-walled when young, but brown and thick-walled when mature, intermingled with paraphyses. Basidium cylindric with a pedicel, 4-celled, tetrasterigmatic; basidiospores globose. Discrepancies in descriptions of microscopic characters by different authors with regard to the present observations have also been discussed.

Keywords: India, macrocyclic, rediscovery, rust fungus, *Scopella echinulata*, spore forms, West Bengal.

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Author details: During this study, Mr. Sayantan Jash was a postgraduate student of Botany with keen interest in the field of mycology and plant pathology. Now he is working on the systematics of fungi as a junior research fellow at Botanical Survey of India. Dr. Asit Baran De is a retired associate professor of Botany with a great contribution to fungal research, especially fungal taxonomy. He has described eight taxa new to science. Dr. De is one of the authors of the very popular book 'Polyporaceae of India'.

Author contributions: All authors have contributed equally throughout the study.

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INTRODUCTION

Uromyces echinulatus Niessl ex Rabenhorst was first described in 1881 (Rabenhorst 1881), which parasitized *Bassia latifolia* Roxb. (= *Madhuca latifolia* Macbr.). It was described based on the collection made by Dr. S. Kruz from the Royal Botanic Garden, Calcutta (now Acharya Jagadish Chandra Bose Indian Botanic Garden, Shibpur, Howrah, West Bengal, India). In 1939, it was transferred to the genus *Scopella* Mains (Mains 1939) and then in 1984 to the genus *Maravalia* Arth. (Ono 1984). Therefore, the valid name of the species is *Maravalia echinulata* (Niessl ex Rabenh.) Ono.

From literature and also from available herbarium specimens, it is evident that the world distribution of *Maravalia echinulata* is restricted to only five Asian countries, namely India (Ono 1984), Myanmar (Thaung 2005), Nepal (IMI 189185), Pakistan (Ahmad 1956), and Sri Lanka (Spaulding 1961). Its global distribution has been presented in an outline map of the world (Figure 1).

Butler & Bisby (1931) mentioned that Mitra collected this fungus from West Bengal, India. But this report was not substantiated by any reference or herbarium specimen. It has been rediscovered from West Bengal in 2019 by the present authors, and was found to grow on the leaves of *Madhuca latifolia*. This is the report of this fungus from the state of West Bengal about 90 years after its last report (Butler & Bisby 1931). From the literature (Mains 1939; Cummins 1950; Thirumalachar 1950; Verma 2015), it is evident that there is much controversy regarding its characters.

In the present study, the characteristics of *M. echinulata* originating from West Bengal is described, with special emphasis on its spore types and microscopic features. The host range and distribution of this fungus have also been discussed.

MATERIAL AND METHODS

During a survey conducted in West Bengal (October 2019–February 2020) to record naturally occurring host plants of different rust fungi, some infected leaves of *Madhuca latifolia* were found in some localities of Bardhaman town in Purba Bardhaman District. The infected leaves of different plants were collected separately on 20 November 2019. Thin sections of infected leaves were cut by using sharp blades. Staining of the sections was done with cotton blue and mounted in lactophenol. After staining, some sections were teased apart with sharp needles and then mounted in lactophenol. Microscopic observations were made under ×600 and ×1,500 magnifications of a Nikon Ti-U inverted microscope. To determine the range of spore sizes, 20 spores of each type were measured. Voucher specimens were properly processed and then deposited in the herbarium of the Department of Microbiology, The University of Burdwan (BURD), Bardhaman, West Bengal, India. Identification of the fungus was done based on the descriptions provided by different literatures, including Mains (1939), Cummins (1950), and Ono (1984). The holdings of *Maravalia echinulata* were also studied from different internationally recognized herbaria, including Royal Botanic Garden, Kew (K), The New York Botanical Garden (NY), Meise Botanic Garden (BR), New Zealand Fungal Herbarium (PDD), University of Michigan (MICH), and University of Minnesota (MIN), to record its host range and distribution.

RESULTS

Field observation

The fungus was regularly seen in the field infecting leaves of *Madhuca latifolia* as very small dark brown somewhat elevated pustules. Dark pustules were surrounded by irregular pale-green to yellowish halo zones (Image 1). The infection started in October and remained up to February. The survey showed that all the trees in the study area were infected.

Taxonomy

Each infected leaf collected from different trees showed all of the five spore forms, confirming the species as macrocyclic and autoecious. The species is described based on the present collection, which is as follows:

***Maravalia echinulata* (Raben.) Ono, Mycologia 76(5): 924. 1984.** (Image 2 & 3)

Uromyces echinulatus Niessl ex Raben., Hedwigia 20: 149. 1881.

Scopella echinulata (Raben.) Mains [as (Niessl) Mains], Ann. Mycol. 37: 58. 1939.

Pycnia (Image 2a) amphigenous, sub-cuticular, lenticular to hemispheric, 40.0–50.0 × 80.0–120.0 µm; spermatiophores producing chains of spermatia, spermatia (Image 2b) globose to elliptical, hyaline, thin- walled, 1.5–2.0 × 1.5–1.8 µm; flexuous hyphae long and hyaline. Aecia hypophyllous, sub-epidermal, more or less concentrically and densely grouped with

Figure 1. World distribution of *Maravalia echinulata*.

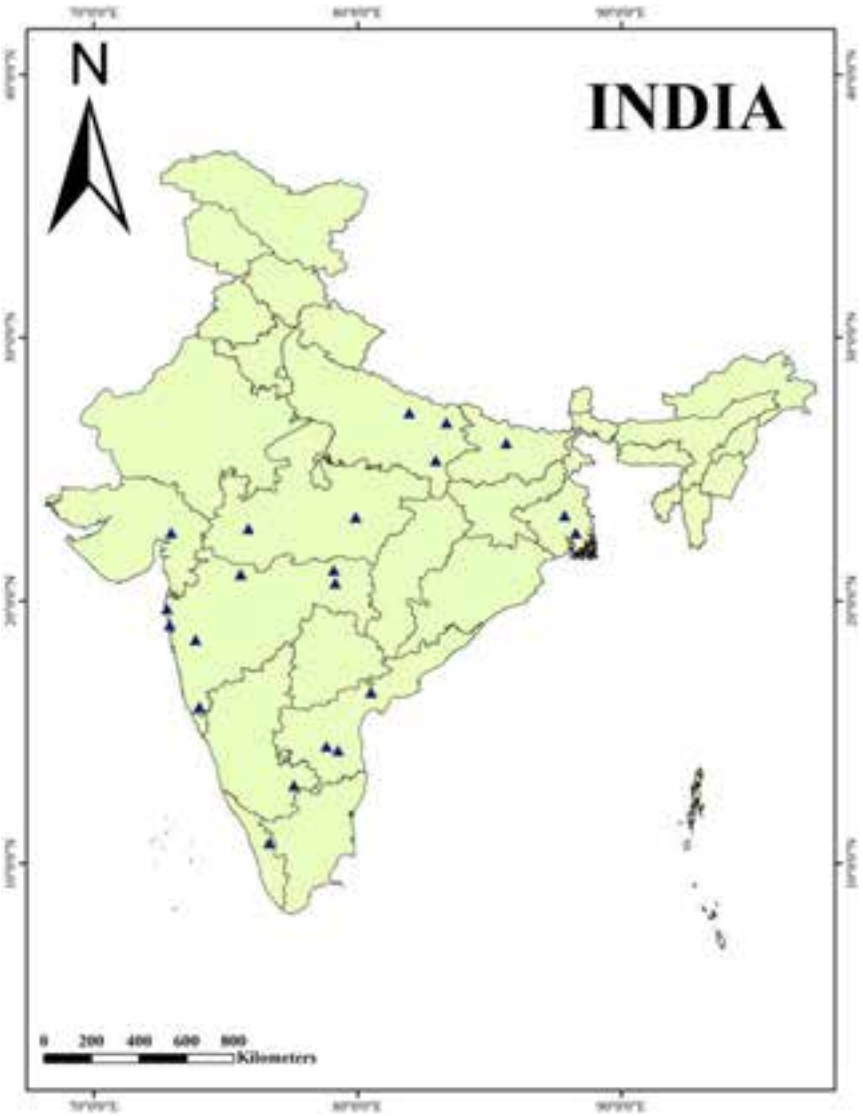

Figure 2. Map showing distribution of *Maravalia echinulata* in India (blue triangles indicate the localities).

pycnia, becoming confluent, causing reddish brown spots epiphyllously, about 0.2–1.0 mm in diameter, individual sori of about 0.1–0.2 mm diameter, chocolate-brown, pulverulent; aeciospores forming chains (Image 2c,d) connected by hyaline disjunctors, asymmetrical, triangular in face view, obovate or oblong-elliptic in lateral view, 26.0–32.0 × 31.0–42.0 µm, hyaline and thin-walled when young but when mature dark cinnamon to chestnut-brown, coarsely echinulate above (Image 2e), spore wall 2.0–3.0 µm thick. Uredinia hypophyllous, sub-epidermal, very similar to aecia but more scattered and chestnut-brown; urediniospores (Image 2f,g) similar to aeciospores in shape and size, sometimes containing oil droplets; spore wall densely covered by spines but with smooth area on one side near the base; the urediniospores borne on long pedicels, pedicels hyaline, up to 28.0 µm long. Telia hypophyllous sub-epidermal, more or less rounded or ovoid, 0.2–0.5 mm in diameter, crowded in irregular groups or often scattered singly, yellowish or pale brownish; teliospores (Image 2h,i,j) obovoid or sub-angular, apex broadly rounded to sub-truncate, pedicellate, 22.0–27.0 × 34.0–50.0 µm; outer spore wall hyaline, very thin, about 0.5 µm, covered with spines, whereas inner spore wall brownish, up to 1.5 µm thick; pedicels hyaline, up to 30.0 µm long. Teliospores intermingled with numerous paraphyses, teliospores and paraphyses arising from highly developed hyaline to yellowish thin- to slightly thick-walled cylindrical basal cells (Image 2k). Paraphyses (Image 2l) cyllindric to clavate, hyaline, aseptate, longer than pedicellate teliospores. Basidia cyllindric with a hyaline pedicel, 4-celled, tetrasterigmatic, tetrasporous (Image 2m,n); sterigmata short, hyaline bearing single basidiospore on each; basidiospores globose, hyaline, thin-walled.

Mycelia hyaline, thin-walled to slightly thick-walled, simple-septate, up to 5.0 µm wide, intercellular (Image

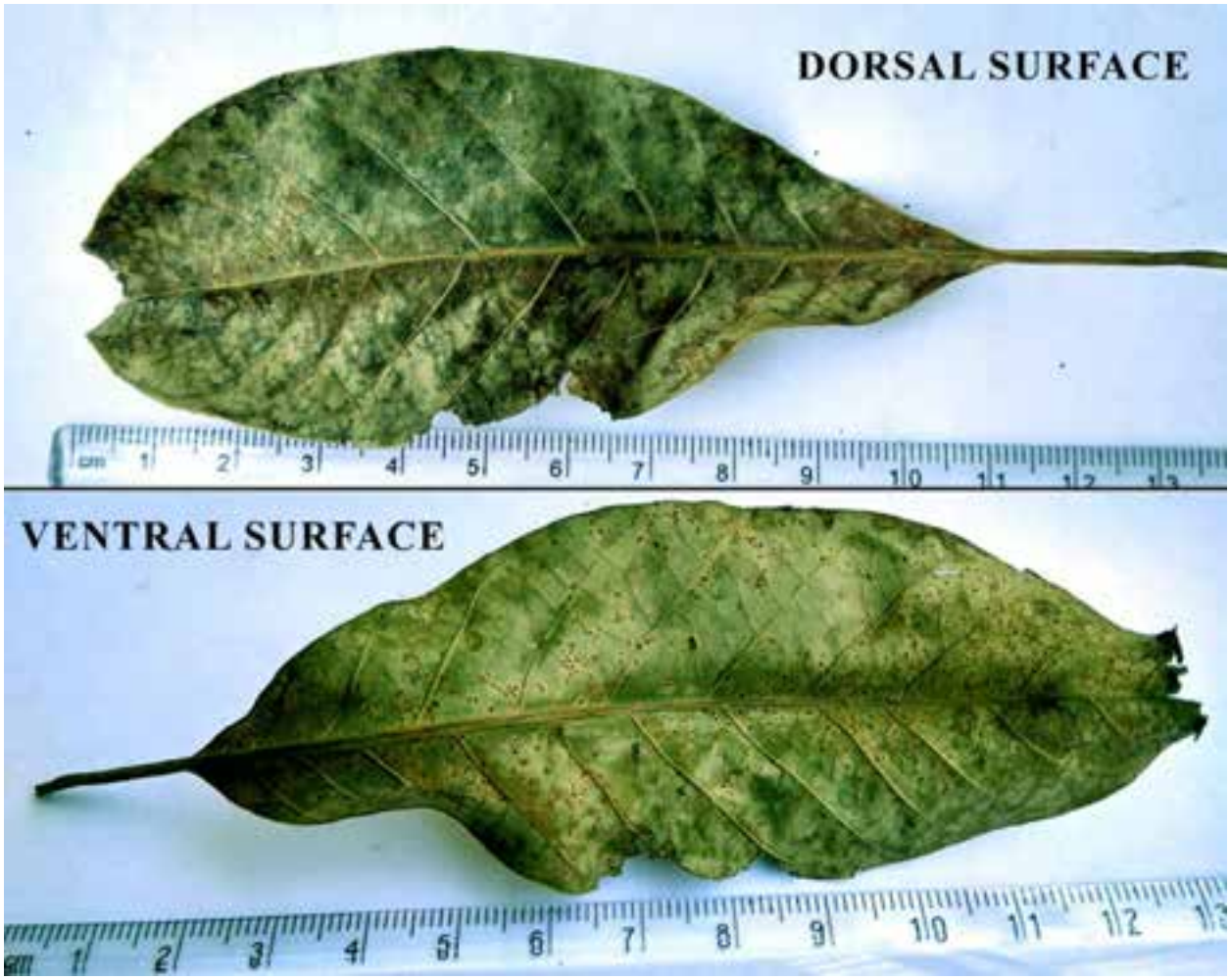

Image 1. Infected leaf of *Madhuca latifolia* with dark brownish pustules surrounded by irregular pale-green to yellowish halo zones. Scale as per photograph. © Sayantan Jash & Asit Baran De

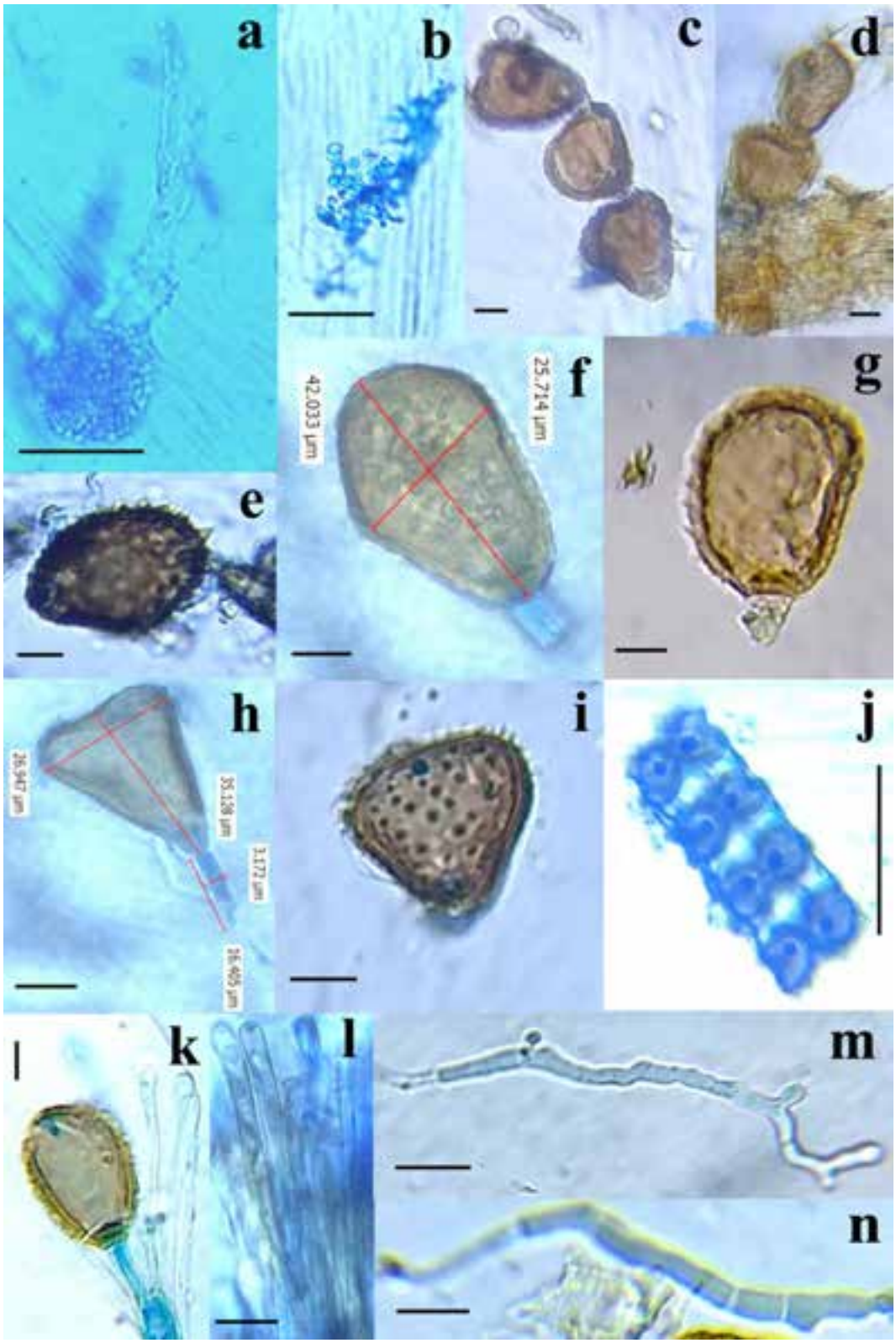

Image 2. Different spore forms: a—pycnium with a spermatium attached on flexuous hypha | b—spermatia | c—chain of three aeciospores connected by disjunctor cells | d—chain of two aeciospores connected with host tissue | e—aeciospore with spiny outer wall | f & g—urediniospore | h—pedicellate teliospore | i—'reticulate-spinulose' teliospore | j—spines of teliospore arising from the lumina surrounded by muri | k—pedicellate teliospore and paraphyses arising from a large cylindrical basal cell | l—paraphyses | m—successive basipetal development of basidiospore on 4-celled tetrasterigmatic basidium | n—4-celled basidium with the initiation of basidiospore on sterigma of its terminal cell. Bar: a = 50 µm; b–n = 10 µm. © Sayantan Jash & Asit Baran De.

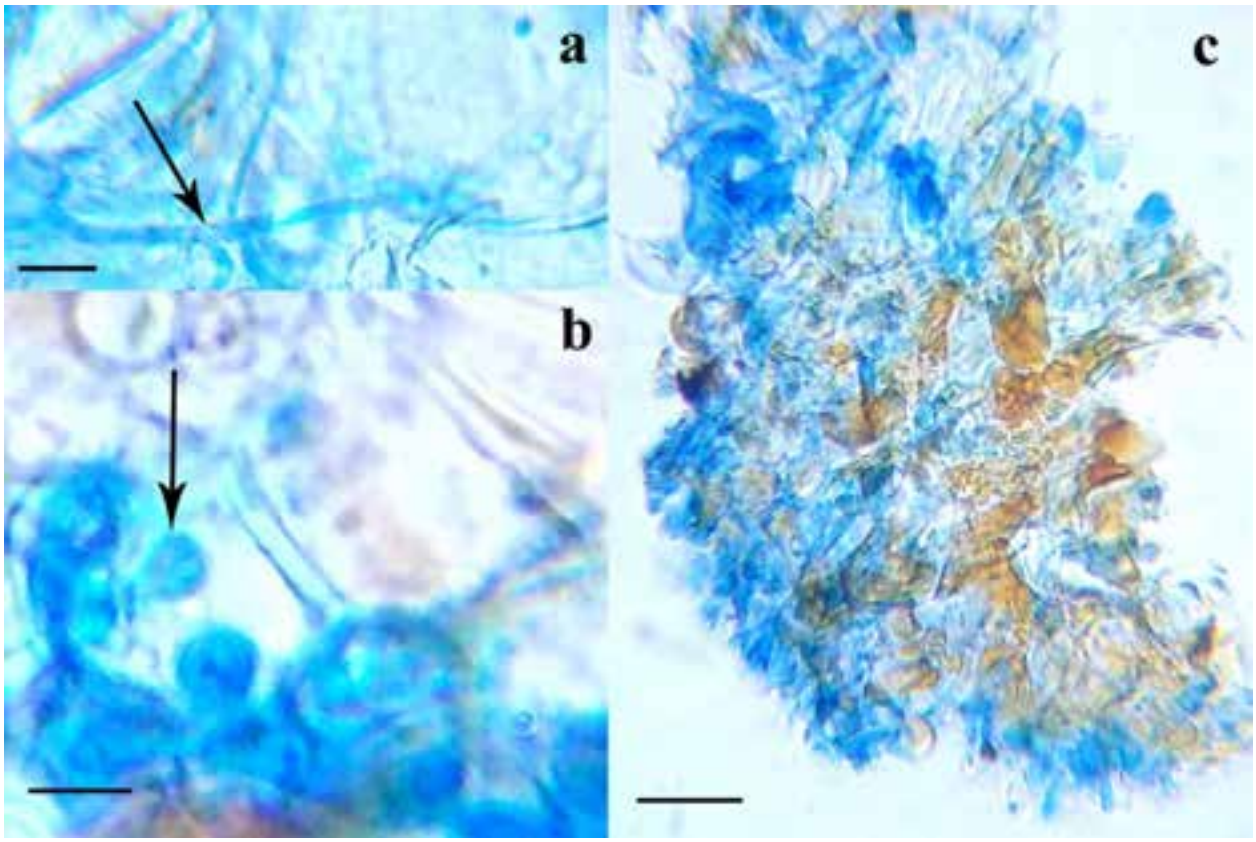

Image 3. Tissues of the infected leaf showing: a—intercellular hyphae of the pathogen | b—intracellular bulbous haustorium | c—post-inflectional gummy secretion by the host. Bar = 10 µm. © Sayantan Jash & Asit Baran De.

3a), but some are intracellular, forming hyaline, thin-walled and bulbous haustoria (Image 3b). Abundant gummy substances (Image 3c) were secreted by the host plant at the post infection stage to defend itself from further invasion by this pathogen.

Specimens examined

On leaves of *Madhuca latifolia* (Roxb.) Macbr., Leg. A.B. De & S. Jash; 20 November 2019; Bardhaman (23.233 ^{0}N, 87.863 ^{0}E, 30 m altitude), Purba Bardhaman, West Bengal, India—BURD MCBH1939, BURD MCBH1940, BURD MCBH1941.

Collections: INDIA: Bihar – Pusa, 21 December 1914, leg. P.C. Kar (PDD 14053); locality not mentioned, 05 February 1986, leg. J.N. Sinha (IMI 314115). Gujarat – locality not mentioned, March 1984, leg. not mentioned (IMI 284368). Karnataka – Bangalore, 1 March 1946, leg. M.J. Thirumalachar (WIS-f-0080583); 3 August 1946, leg. M.J. Thirumalachar (MICH 295078). Madhya Pradesh – locality not mentioned, 23 April 1980, leg. V.R. Neelay (IMI 248182); 21 October 1986, leg. K.S. Khan (IMI 311371). Maharashtra – Palghar, 22 February 1912, leg. H.M. Chebber (MICH 295080); Poona, Maharashtra Assoc. for Cult. Sci., 19 March 1965, leg. M.N. Kamat (IMI 112556); Sirsi, September 1912, leg. G.S. Kulkarni (PDD 9797). Uttar Pradesh – Gorakhpur, 23 February 1984, leg. P. Narayan (IMI 283997); 22 October 1984, leg. not mentioned (IMI 290974); locality not mentioned, 05 March 1980, leg. R.P. Verma (IMI 246910). West Bengal – Bardhaman, 20 November 2019, leg. A.B. De & S. Jash (BUR MCBH1939, BUR MCBH1940, BUR MCBH1941); Calcutta, H. Botanico, – s.d., leg. Dr. S. Kruz 3551 (K-M000187873, K-M000187874, NY 00046133, NY 00046134, UC 1886570); s.d., leg. G. Rabenhorst s.n. (BR5020078034467).

MYANMAR: Mandalay, 28 November 1974, leg. M.M. Thaung (LAM 220082, UC 1886570); s.d., leg. M.M. Thaung (IMI 161589).

NEPAL: locality not mentioned, 18th October 1974, leg. K.L. Manandhar (IMI 189185, IMI 189192).

SRI LANKA: Peradeniya, 16 June 1908, leg. T. Petch (K-M000187875); August 1912, leg. T. Petch (BR5020078035471, K-M000187876, MICH 295079, MICH 296112, MIN 1228326, MIN 1228327, MIN 1267657, NY 03432410, WIS-f-0085023); locality not mentioned, s.d., leg. T. Ptech (IMI 67265).

DISCUSSION

Although *Maravalia echinulata* (Niessl ex Rabenh.) Ono has been found to cause rust disease in five Asian countries (India, Myanmar, Nepal, Pakistan and Sri Lanka), it mostly affects its hosts growing in India except its northern and northeastern parts (Figure 2). Different localities of its occurrence in India are presented in Table 1 along with its hosts recorded by different workers.

From Table 1 it is evident that *Maravalia echinulata* (Niessl ex Rabenh.) Ono mostly grows on two species of *Madhuca* Ham. ex Gmel., namely *Madhuca latifolia* (Roxb.) Macbr. and *Madhuca longifolia* (Koenig ex L.) Macbr. Rabenhorst (1881) described the species based on a specimen infecting the leaves of *Bassia latifolia* Roxb. Several authors, including Spaulding (1961), Sathe (1969), Narayan & Kamal (1985), and Bilgrami et al. (1991) reported *Madhuca indica* Gmel. as its host. But *Bassia latifolia* and *Madhuca indica* are just synonymous with *Madhuca latifolia*. Mains (1939) and Sathe (1969) mentioned the occurrence of this rust fungus on *Bassia longifolia*, which is currently accepted as *Madhuca longifolia*. Thirumalachar (1950) mentioned *Bassia bourdilli* [correct name is *Madhuca bourdillonii* (Gamble) H.J.Lam] as a new host collected from Mysore (now Karnataka, India). In 1986, Dr. C.R. Patil collected the rust fungi on leaves of *Sideroxylon tomentosum* Roxb. from Amboli (Maharashtra) and M.S. Patil reported it as a new host of *Maravalia echinulata* (Patil 1991). So, this fungus has, so far, been found to parasitize only four host species, namely, *M. bourdillonii*, *M. latifolia*, *M. longifolia*, and *S. tomentosum*. From all these reports, it can be stated that the host range of this fungus is strictly restricted to the angiospermic family Sapotaceae to date.

As regards characters of its different spore forms, there are great controversies. According to Thirumalachar (1950), its pycnium is conoid without conspicuous ostiolar paraphyses. But from the present observation, it is evident that the pycnium of *M. echinulata* is globose with flexuous hyphae and, therefore, belongs to type 4 of Hiratsuka & Sato (1982), not type 5 or 7.

Aeciospores were stated to be pedicellate and uredinoid type (Thirumalachar 1950), but in our observation they are catenulate, forming long chains connected by hyaline disjunctor cells.

Teliospores have been stated to be hyaline and smooth (Mains 1939; Cummins 1950), but very thin-walled according to Mains (1939) and slightly thick-walled according to Cummins (1950). Mains (1939) and Cummins (1940) also found that teliospores of this species arise from highly developed cylindric basal cells. Similar observations were made by the authors, who also observed spiny teliospores as hyaline and thin-walled when young, but brown and thick-walled when mature. Similar types of brown, thick-walled teliospores with a spiny outer wall have been observed by Rabenhorst (1881) and Pathak et al. (2015).

Teliospores are intermingled with numerous paraphyses, which are cylindrical to clavate, hyaline, thin-walled and much longer than pedicillate teliospores. Although Thaung (2005) has mentioned numerous fine

Table 1. Different localities and hosts of *Maravalia echinulata* growing in India.

State	Locality	Host	References
Andhra Pradesh	Amaravati	*Madhuca longifolia*	Hosagoudar 2013
	Cuddapah	*Madhuca latifolia*	Cummins 1950
	Penagaluru	*Madhuca latifolia*	Cummins 1950
Bihar	Pusa	*Madhuca latifolia*	Butler & Bisby 1931
Gujarat	Anand	*Madhuca latifolia*	Jamaluddin et al. 2004
Karnataka	Bangalore	*Madhuca latifolia* and *Madhuca bourdillonii*	Thirumalachar 1950
Kerala	Palghat	*Madhuca latifolia*	Bilgrami et al. 1991
Madhya Pradesh	Indore	*Madhuca latifolia*	Pathak et al. 2015
	Jabalpur	*Madhuca latifolia*	Verma 2015
Maharashtra	Amboli	*Sideroxylon tomentosum*	Patil 1991
	Jalgaon	*Madhuca latifolia*	Firdousi 2020
	Mumbai	*Madhuca longifolia*	Sathe 1969
	Nagpur	*Madhuca latifolia*	Parandekar 1964
	Palghar	*Madhuca latifolia*	MICH 295080
	Poona	*Madhuca latifolia* and *Madhuca longifolia*	IMI 112556, Sathe 1969
	Sirsi	*Madhuca latifolia*	PDD 9797
Uttar Pradesh	Benaras	*Madhuca latifolia*	Payak 1949
	Gonda	*Madhuca latifolia*	Narayan & Kamal 1985
	Gorakhpur	*Madhuca latifolia*	IMI 283997, IMI 290974
West Bengal	Bardhaman	*Madhuca latifolia*	Present study
	Howrah	*Madhuca latifolia*	Rabenhorst 1881, Mains 1939, Ono 1984

paraphyses in *Maravalia echinulata*, most of the authors had probably ignored this character in their description.

A gap in the secondary wall above the hilum of urediniospores and teliospores has been observed, which indicates the existence of continuous cytoplasmic communication of these spores with their pedicels through the passage in the secondary wall.

Spines of aeciospores, urediniospores and teliospores are formed in the centre of lumina bordered by muri. These spores of *Maravalia echinulata*, therefore, may be better described as reticulate-spinulose rather than just reticulate or just spinulose.

Ono (1984) reported that each metabasidium forms one short, apical sterigma, and from this sterigma, globose to subglobose basidiospores are formed successively. Thus, the basidiospores occur in clumps at the apex of the metabasidium. Thirumalachar (1950) had reported another type of metabasidium divided into four cells and arranged in a linear fashion. No sterigmata was reported. Moreover, the spore formation was described by directly rounding off of basidial cells. In the present observation, basidium was found with a linear row of four cells. Typical short hyaline sterigmata were found to develop from each cell bearing basidiospore on each. According to Ono (1984), the basidiospore of the terminal cell of basidium is the largest one and becomes successively smaller towards the basal cell.

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SHORT COMMUNICATION

A rare low elevation photographic record of Himalayan Serow *Capricornis sumatraensis* ssp. *thar* (Hodgson, 1831) from Nameri National Park, Assam, India

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Abstract: The Himalayan Serow *Capricornis sumatraensis* ssp. *thar* is predominantly found in middle regions of the Himalaya. During the Phase IV camera trapping protocol for 2023–24, a single sighting of this species was recorded at an unprecedented low elevation of 110 m in Nameri National Park, Assam, India. This sighting marks the first recorded presence of the Himalayan Serow in Nameri National Park. The discovery suggests potential habitat flexibility and raises questions about the species' ecological adaptability, with important implications for its conservation.

Keywords: Deo Sagoli, disturbance-induced displacement, ecological adaptability, phase IV camera trapping, semi-evergreen forest.

The Himalayan Serow *Capricornis sumatraensis* ssp. *thar* is a medium-sized, goat-like ungulate species belonging to the Bovidae family and Caprinae subfamily. Typically, it inhabits the moderately sloped terrains of the Himalaya, known for its elusive nature and adaptability to mountainous environments. The Serow plays a significant role in its ecosystem, serving as a prey base for carnivores such as the Indian Leopard *Panthera pardus fusca* and the Bengal Tiger *Panthera tigris tigris* (Phan et al. 2012; Deka et al. 2021).

Although the Mainland Serow *Capricornis sumatraensis* has a wide geographic range across Bangladesh, Bhutan, Cambodia, China, India, Indonesia, Laos, Malaysia, Myanmar, Nepal, Thailand, and Vietnam (Phan et al. 2020), the subspecies *Capricornis sumatraensis* ssp. *thar* is restricted to the Himalayan region (Mori et al. 2019). In India, it is found from Jammu and Kashmir to eastern Arunachal Pradesh, including Himachal Pradesh, Uttarakhand, Bihar, Sikkim, and Assam (Choudhury 2003; Sathyakumar et al. 2013; Pawar et al. 2018; Targe et al. 2023; Safi & Maurya 2024).

Historically, in Assam, the species has been recorded in the hilly regions on the northern bank of the Brahmaputra River, in districts such as Kokrajhar, Chirang, Baksa, Sonitpur, Lakhimpur, and Dhemaji. It is locally known as "Deo Sagoli" in Assamese. Typically, the serow inhabits mountain slopes, gorges and valleys, temperate coniferous forests, and broadleaved forests at altitudes ranging 100–4,000 m, generally preferring 2,500–3,500 m (Jnawali et al. 2011; Paudel et al. 2015).

Increased deforestation, habitat fragmentation, subsistence hunting, incompatible land use changes, and increased livestock grazing pose significant threats to the species (Phan et al. 2020). The Himalayan Serow is listed in "Schedule I" of the Wildlife (Protection) Act,

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1972 (amended), in Appendix I of CITES, and classified as 'Vulnerable' by the IUCN Red List (Phan et al. 2020). Reliable data on its distribution and population status, however, are scarce, making it challenging to develop effective conservation action plans. Recent shifts in habitat use and sightings at lower elevations are noteworthy and warrant further investigation.

Materials and Method

Nameri National Park (NNP) is located in the foothills of the eastern Himalayas and is contiguous with Pakke Tiger Reserve to the north and north-east. It is bounded by the Jia Bhorali River to the west and the Bor Dikorai River to the east. The NNP spans across 200 km² with altitudes ranging 36–321 m. It comprises tropical evergreen, semi-evergreen, and moist deciduous forests, with patches of bamboo and cane. Grasslands constitute less than 10% of the area, whereas semi-evergreen and moist deciduous forests dominate (Das & Deori 2011). The region is rich in faunal diversity, harbouring over 40 mammalian species, more than 400 species of bird, and over 40 species of herpetofauna. It is also designated as an Important Bird Area (IBA) under A1 and A2 categories.

As part of the Phase IV Protocol of the National Tiger Conservation Authority for 2023-24, 196 camera traps were deployed in 98 trap stations within Nameri National Park with a sampling effort (n = 30) from 2 February to 2 March, 2024. Each trail camera (Cuddeback X-Change Color Model 1279) was positioned in a fabricated camera trap holder at a height of approximately 30–45 cm above the ground. The cameras were placed to face each other in 2 km² grids (Figure 1).

Results

The Himalayan Serow was recorded in Tiger grid no. 37 with one adult individual's photo-capture instance on 19 February 2024 at 0715 h (Table 1). It is likely that the individual was grazing or searching for water in the vicinity. The area comprised of moist deciduous, semi- evergreen patches mostly comprising of *Magnolia hodgsonii*, *Dillenia indica*, *Premna bengalensis*, *Bridelia retusa*, *Litsea monopetala*, *Dysoxylum binectariferum*, *Amoora wallichi*, *Magnolia oblonga*, *Stereospermum chelonoides*, *Mallotus nudiflorus*, *Castanopsis*

Figure 1. LULC map of NNP showing CT locations and Himalayan Serow.

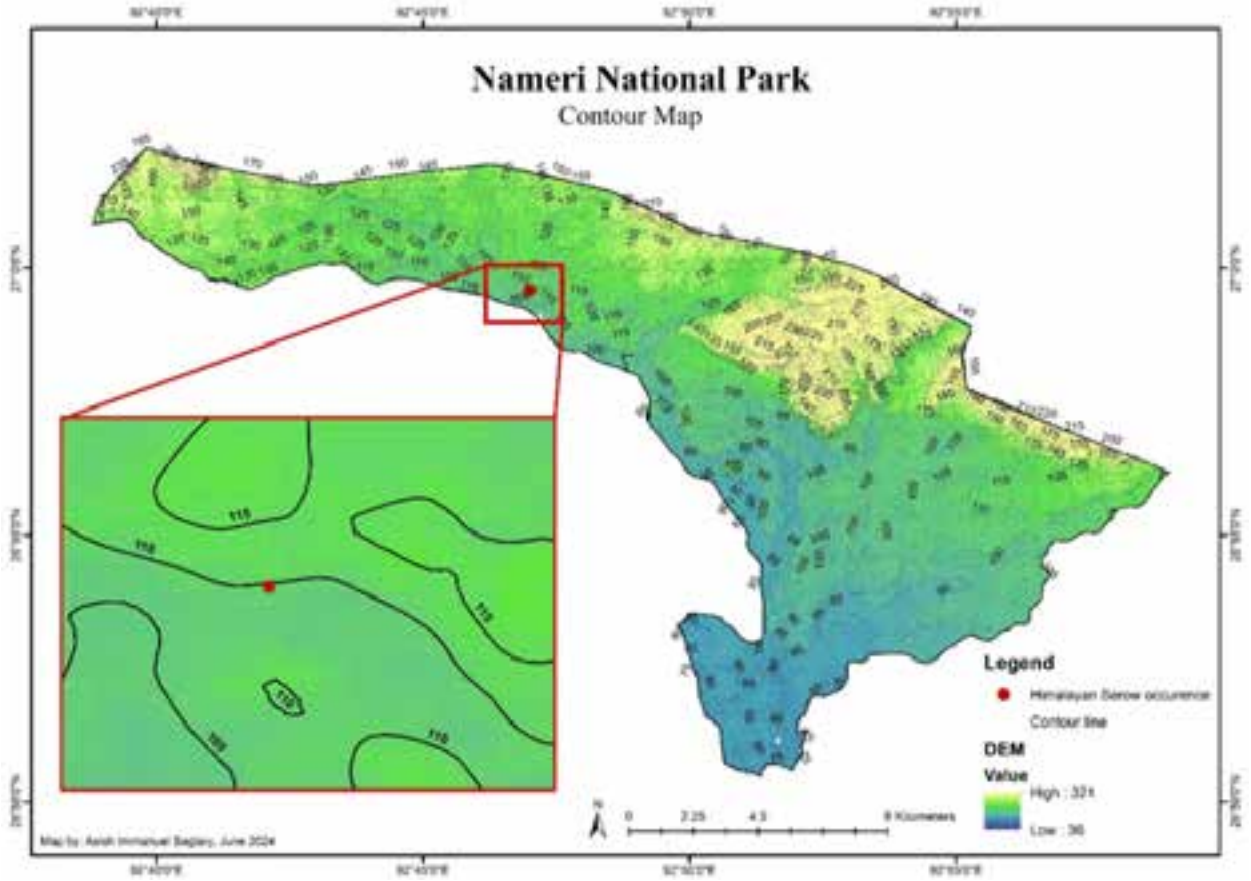

Figure 2. Contour map of NNP showing elevation and Himalayan Serow occurrence.

indica, *Pterospermum acerifolium*, *Morus laevigata*, *Cinnamomum glanduliferum*, *Tetrameles nudiflora*, and *Duabanga grandiflora* (Image 1). The location is proximity to a branch of river Jia Bhorali with an alluvial grassland patch comprising of *Saccharum spontaneum*, *Tamarix dioica*, and *Alpinia nigra*. Vegetation analysis revealed a diverse composition supporting the presence of multiple ungulate species. Predatory species such as the Indian Leopard and the Royal Bengal tiger were also photo-captured at the same trap location, along with other ungulate species such as Barking Deer *Muntiacus muntjac* and Sambar *Rusa unicolor*, demonstrating sympatric habitat usage (Image 2). This is the first recorded sighting of the Himalayan Serow in Nameri National Park at 110 m (Figure 2).

Table 1. Details of Himalayan Serow photo captured in Nameri National Park.

	Particulars	Description
1.	Tiger grid number	37
2.	Camera ID	C037B
3.	Location	26.993333°N, 92.783408°E
4.	Elevation	110 m
5.	Habitat type	Woodland
6.	Distance to river	250 m
7.	Distance to nearest human settlement	490 m
8.	Date & time of capture	19 February 2024 at 0715 h
9.	Predatory species captured in the same camera trap	*Panthera pardus fusca*, *Panthera tigris tigris*
10	Sympatric species captured in the same camera trap	*Muntiacus muntjac*, *Rusa unicolor*

Discussion

The presence of the Himalayan Serow at such a low elevation, with recent records from Manas (Deka et al. 2021), Valmiki (Safi & Maurya 2024), and now Nameri, is unusual and may be attributed to several factors:

1. Habitat adaptability: the Serow may exhibit greater habitat flexibility than previously understood, allowing it to exploit lower elevation environments.

2. Seasonal migration: the sighting could be part of a seasonal migration pattern, possibly in response to

Image 1. Photographic record of Himalayan Serow in Nameri National Park. © Research Cell, Nameri Tiger Reserve.

climatic variations or resource availability.

3. Disturbance-induced displacement: increased human activities and habitat disturbances at higher elevations might have driven the Serow to seek refuge in lower, less disturbed areas.

Similar shifts in habitat use have been documented in other ungulate species, indicating a potential adaptive response to environmental changes. These findings suggest that the Serow's ecological niche may be broader than traditionally perceived. Given the limited literature available, it is crucial to study its behaviour, ecology, population, and distribution status in relation to global climate change threats before the risk of regional extinction arises.

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Image 2. Other sympatric ungulate and predatory species recorded from the same location. © Research Cell, Nameri Tiger Reserve.

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SHORT COMMUNICATION

Sightings of Red Goral *Nemorhaedus baileyi* in the community forest of the Upper Siang region, Arunachal Pradesh: an insight into its conservation challenges and implications within a tribal-managed landscape

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Abstract: A recent Sclater's Monal survey conducted in the Upper Siang region of Arunachal Pradesh (India) resulted in the sighting of two Red Goral individuals - a young adult and a juvenile. These observations were made within the Mount Eko Dumbing area, which is owned and managed by the indigenous Simong tribal community. The report includes photographic documentation of the observed Red Gorals and provides detailed illustrations of their habitat characteristics, as well as the deep traditional relationships that the Simong people maintain with these species and the surrounding natural environment. Additionally, the study highlights the critical conservation challenges and opportunities relevant to the Red Goral in this ecologically and culturally significant region.

Keywords: Adi, Bovidae, highlands, hunting, Mount Eko Dumbing, ritual, Simong, taboo, traditional belief system, traditional knowledge.

Red Goral *Nemorhaedus baileyi* (Pocock, 1914) is an enigmatic small goat-antelope species in the Bovidae family. It is classified as 'Vulnerable' on the IUCN Red List, included in CITES Appendix I (Nijhawan 2020), and receives the highest level of protection in China (Xiong et al. 2013) & under India's Wild Life (Protection) Act of 1972 as a Schedule I species. Red Gorals are one of the geographically restricted species within the *Nemorhaedus* genus, being geographically confined to the temperate mountain ranges of southeastern China, northern Myanmar, and the eastern region of Arunachal Pradesh, India (Nijhawan 2020).

In Arunachal Pradesh, India, the Red Goral is known to commonly occur in the Mishmi Hills region east of the Siang River (Anjaw, Dibang Valley, Lower Dibang Valley, East Siang, Lohit, and Changlang districts), with the Dibang Wildlife Sanctuary serving as a stronghold for the species. To the west of the Siang River, the species is relatively rare, occurring only sporadically, with its range extending as far west as the Tawang District (Choudhury 2013).

The presence of the species has been confirmed from various locations across the state, including Namdapha National Park (Datta et al. 2008) and community forests beyond Vijaynagar near the border with Myanmar in Changlang (Nijhawan 2020), Kamlang Tiger Reserve in Lohit (Singh & Gupta 2021), Walong in Anjaw (Choudhury 2009; Patgiri et al. 2023), Mehao WS in Lower Dibang Valley (Ahmad & Gopi 2024),

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Dibang Valley and Upper Siang District (Aiyadurai 2014; Nijhawan 2020). Additionally, according to Nijhawan (2020), the Red Goral may also likely to be found in the higher catchments of the Kameng (previously reported by Mishra et al. 2005 and Mishra et al. 2006 from West Kameng District), Kurung, Kumey, and Subansiri rivers within the state.

Here, we report the recent sightings of the Red Goral within the Simong community forest in the Upper Siang District located adjacent to the Dihang-Dibang Biosphere Reserve. While the presence of the species has been reported from this region, these accounts have been based solely on verbal confirmations (Nijhawan 2020), as there are currently no known published records documenting its occurrence from this specific location.

The information on the Simong community's traditional knowledge and their local environment outlined here was obtained through extensive discussions with Simong guides and subsequently validated through informal interviews with the village's elders, hunters, and shaman.

The Observations

A field survey was undertaken from 29 October 2023 to 04 November 2023 to study the Sclater's Monal *Lophophorus sclateri* within the highland regions of the Simong community's forest land, covering an elevation range of 2,500–4,200 m (Image 1). During this survey on 03 November 2023, a young adult Red Goral (Image 2) was observed grazing in the open, undergrowth shrub-and-grass covered habitat within the 'Hadang Edpang' locality of the Mount Eko Dumbing region, situated in the north-eastern part of the community forest. The individual was recorded at an elevation of 3,145 m (28.434°N, 95.084°E) and a slope of ~30–40° angle. Subsequently, within 200 m of the first sighted location, a young fawn (Images 3 & 4) was spotted on a steep, rugged crag with a drop and sparse vegetation, at an elevation of 3,120 m (28.4°N, 95.084°E). Both sightings occurred within the span of an hour, between 1430 h

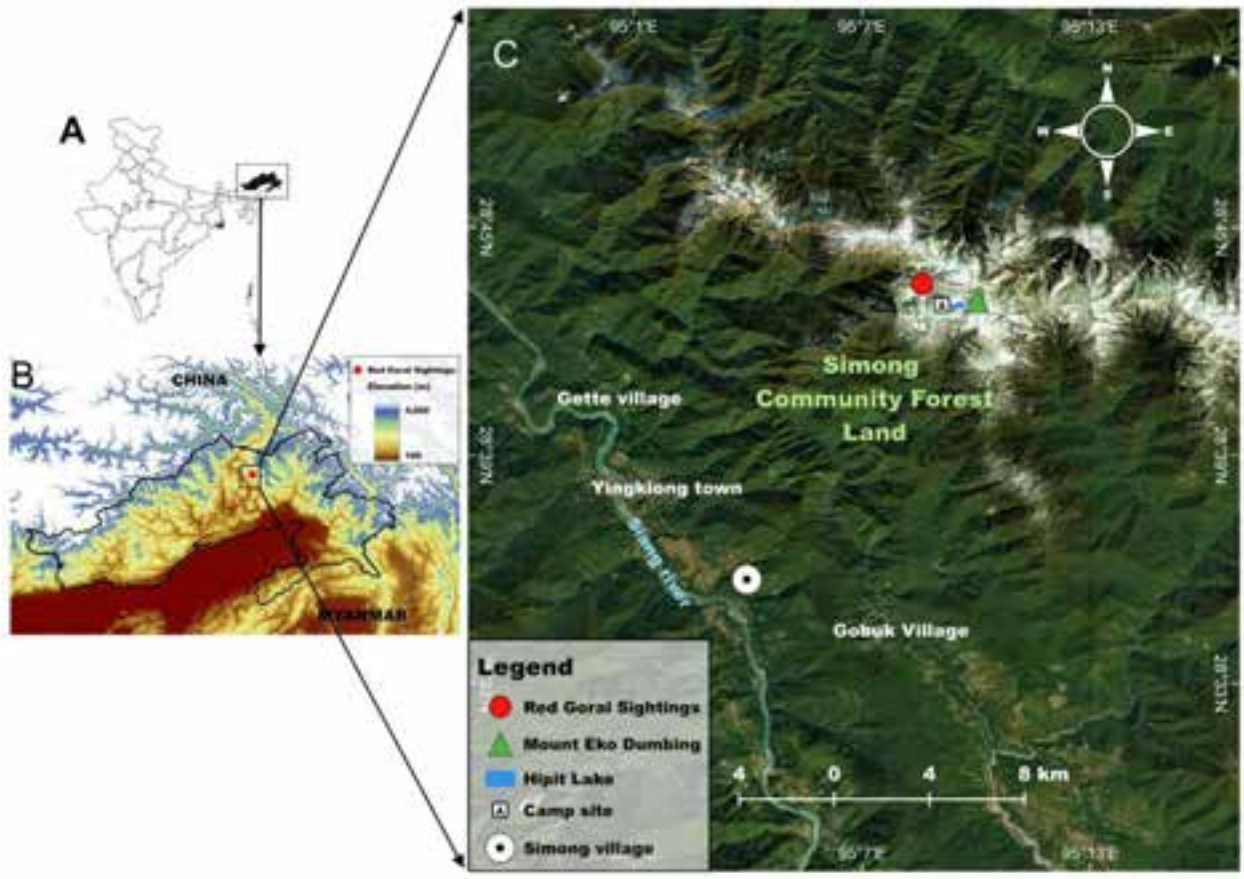

Image 1. A—Map of India highlighting Arunachal Pradesh | B—An elevation map of Arunachal Pradesh showing the study site in the Upper Siang region and Dihang-Dibang Biosphere Reserve (Green) | C—a location map of the Red Goral sightings within the Simong Community Forest (undefined boundary).

and 1530 h, under overcast skies with light drizzle.

The Simong community, their landscape and its wildlife

The Simong (or Himong) community is a small subgroup within the larger Adi ethnic group, residing in the Upper Siang District of Arunachal Pradesh. According to the 2011 census data, the Simong village consists of 179 households and a total population of 672 individuals. The community maintains ownership of a substantial forested area spanning a wide range of elevations, from approximately 700–4,200 m.

The Mount Eko Dumbing (Image 5), the highest point within their land, is situated at the heart of this territory and is revered as a sacred site, along with the surrounding highland region. Like many other tribal communities in the state, the Simong have their own distinct traditions and belief systems that are deeply integrated with the natural landscape. They are traditional hunters, and their utilization of the forest's resources is directly linked to their traditional practices. While they predominantly extract resources from the nearby forests and fallow lands, they generally avoid the highlands due to taboos associated with these regions.

According to the Simong people's belief system, the high-altitude mountains within their forested lands are believed to be the domain of a spiritual entity known as 'Jimu Tayang', who is regarded as the guardian and owner of the highlands and its wildlife. During certain ceremonial occasions such as 'Unying-Aran' and 'Jihang' when the Simong require access to resources from these highlands, they perform a ritual involving the sacrifice of domestic animals. This sacrificial ritual is intended to appease 'Jimu Tayang' and facilitate the exchange of resources. They believe that failing to uphold proper sacrificial rituals would result in personal misfortunes, as well as the imposition of unfavourable weather conditions throughout their ceremonial journeys.

The Simong people claims that their intricate relationship with their forest land helps safeguard the highland region and its species, including the 'Hiyar' (Simong: Red Goral).

Conservation challenges and prospects for the Red Goral in the region

As per locals, the once wildlife-abundant highlands that harboured substantial populations of Red Gorals and other wildlife species have been severely degraded due to hunting pressure, particularly from illegal hunting activities targeting Musk Deer *Moschus* sp. They believe that neighbouring tribal clans (probably other than Adi tribe) from the surrounding area illegally trespass into

Image 2. Photograph of the young adult Red Goral observed at the 'Hadang Edpang' area of the Mount Eko Dumbing region. © Kishon Tekseng.

Image 3. Photograph captures a curious Red Goral juvenile, with a distinctive white spot clearly visible on its forehead. © Kishon Tekseng.

Image 4. The Red Goral juvenile swiftly navigating the steep, rocky slope. © Kishon Tekseng.

Image 5. Camp site with a panoramic view of the Mount Eko Dumbing and the nearby Hipit Lake. © Takhe Bamin.

their community's forest territory to engage in such hunting activities. A study by Datta-Roy (2022) indicates that the inhabitants of the Bomdo village, which is situated around 25 km from the Simong Village and belongs to the same Adi tribal group, also engage in the hunting of Musk Deer and Takin from their surrounding highlands.

During our investigation, we discovered two recently utilized encampments of the potential illegal hunters in the Mount Eko Dumbing region (both of which were later dismantled by our local guides, a resident of the Simong community). The illegal hunters are also known to exploit the Red Goral as well as other wildlife species like Mishmi Takin *Budorcas taxicolor*, Himalayan Black Bear *Ursus thibetanus*, and various pheasant species. These animals are targeted for their meat, organs, and to sustain themselves during their expeditions. As a result, our Simong guides reported, these wildlife populations have become rare, and their sightings have declined significantly within the local area. While the Simong people have implemented a hunting ban within their own community, some individuals are still likely to be engaged in the practice.

Such instances of the exploitation of Red Goral in conjunction with the hunting of Musk Deer are already a significant issue in Arunachal Pradesh as well as in Myanmar, where hunters have been noted to rely on the meat of the Red Goral to sustain themselves during their extended expeditions targeting Musk Deer (Nijhawan 2020; Rabinowitz & Khaing 1998).

Red Goral is a poorly known species, with limited knowledge regarding its population dynamics, geographic distribution, behaviour, and habitat ecology. Given its restricted range and declining population, unsustainable illegal hunting and habitat loss due to infrastructure development and expansion of monoculture forestry pose serious threats to the species (Nijhawan 2020).

Undertaking comprehensive research on the Red Goral is necessary to address the existing knowledge gaps and conservation challenges associated with this species. Also, it is critical to recognize that although

the Red Goral and its habitat may benefit from the protections provided by the state's designated protected areas, a major portion of the species' geographic range exists outside these delineated zones, on lands owned and managed by local tribal communities. Subsequently, conservation efforts within these tribal-owned and managed landscapes are crucial. To achieve this, it is essential to understand and acknowledge the cultural traditions and belief systems of these indigenous communities, which often play a pivotal role in preserving the species and its surrounding environment, as exemplified by the Simong people. Furthermore, actively engaging the local tribal stakeholders in the planning of future conservation strategies is imperative to ensure the long-term viability of the Red Goral population and its habitat.

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SHORT COMMUNICATION

New record of *Sapria himalayana* Griff. (Rafflesiaceae) from Eaglenest Wildlife Sanctuary, Arunachal Pradesh, India

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Abstract: The eastern Himalayan region is renowned for its exceptional and abundant floral and faunal biodiversity, harbouring numerous endemic plant species. Among them, *Sapria himalayana* Griffith, an endoparasitic, rare, and endangered plant, was first discovered in the Mishmi Hills of Arunachal Pradesh in 1836. Despite its discovery nearly two centuries ago, the species remains poorly understood. While some recent studies have begun to explore the genetics and demography of this species, there is still a significant knowledge gap in the understanding of the life history patterns of this parasitic plant. Here, a new record has been added to the distribution of *Sapria himalayana* from Eaglenest Wildlife Sanctuary, West Kameng District, Arunachal Pradesh. Around 21 flowers were scattered on the forest floor, spanning various developmental stages from buds to flower maturation, including desiccated flowers. The bud emerges from the roots of *Tetrastigma* sp. (host plant). One of the primary challenges in conducting extensive research on the intriguing Himalayan Sapria is its infrequent and unpredictable flowering patterns. Therefore, understanding these aspects (flowering phenology and enigmatic traits) is crucial for further research and preserving this rare species and its hosts in the face of ongoing habitat loss. Conducting an annual plant survey in the Eaglenest Wildlife Sanctuary can help identify patterns to unravel these mysteries.

Keywords: Distribution, endangered, endoparasitic, flowering phenology, host plant, Himalayan region, *Tetrastigma* sp.

Sapria himalayana Griffith., (Rafflesiaceae) is a rare and endangered flowering plant (Nayar & Sastry 1987). All three genera of the Rafflesiaceae family are endoparasites, thriving within their grapevine (Vitaceae) hosts (Nikolov et al. 2014). *Sapria* and its two sister clades, *Rhizanthes* and *Rafflesia*, have lost the genes required for photosynthesis and rely entirely on obligate host species for sustenance (Osathanunkul 2019). Unusually, these parasitic angiosperms do not have an external vegetative body, only the solitary flower bud, which emerges from the host's roots and matures to a unisexual flower for brief periods to complete the life cycle. The hosts of *S. himalayana* include various *Tetrastigma* vines (*T. obovatum, T. cruciatum, T. laoticum, T. bracteolatum,* and *T. serrulatum*) recorded from Thailand and northeastern India (Elliott 1990; Arunachalam et al. 2004).

The genus *Sapria* has four species (Dorji et al. 2022). Among them, only *S. himlayana* has a wide distribution, and the other three species, *S. poilanei* Gagnep., *S. ram* Bänziger & B. Hansen., and *S. myanmarensis* (Tanaka et al. 2019) are endemic and have small ranges. *S. poilanei* is endemic to Cambodia, *S. ram* is endemic to

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Thailand, and the recently discovered *S. myanmarensis* is endemic to Myanmar (Bänziger et al. 2000; Holden 2010; Tanaka et al. 2019). The Himalayan Sapria was first described by the British botanist William Griffith in 1844, which was discovered by him in 1836 from the Mishmi Hills of Arunachal Pradesh, India (Griffith 1844; Dorji et al. 2022). After its discovery, it has been reported only a few times from other regions of northeastern India (Borah & Ghosh 2018; Ahmad et al. 2020; Devi et al. 2022; Singh et al. 2022; Syiemiong et al. 2022). Its distribution range includes Bhutan, northeastern India, Tibet, south-central China, Myanmar, Thailand, and Vietnam (Dorji et al. 2022). The flower of *S. himalayana* is unique and exceptionally beautiful. It is velvety and has 10 distinct perigone lobes. The flower emits a putrid odour. Previous studies have reported that the release of the foul odour attracts insect pollinators that pollinate the dioecious flower (Bänziger 2004; Davis et al. 2008). Very few studies have documented fruiting; fruits are black, 3.1–5 cm long, with a low fruiting rate (Bänziger 2004). The seeds are blackish-brown and 0.6–0.65 mm long, and rodents perform seed dispersal (Bänziger 2004; Borah & Ghosh 2018).

Even though it was discovered almost two centuries ago, the comprehensive knowledge of Himalayan Sapria is still lacking. Here, a new record of *Sapria himalayana* from Eaglenest Wildlife Sanctuary, West Kameng District, Arunachal Pradesh is documented (Image 1). A previous study from 1938 documents the flower's presence from the same district in Aka Hills, near Rupa (Bor 1938; Dorji et al. 2022). That was the second-ever recorded instance of this wildflower. Following an 85-year interval, another record is now documented in this region. Eaglenest Wildlife Sanctuary (WS) is located in the West Kameng District of Arunachal Pradesh, India. Being a part of the Eastern Himalaya Global Biodiversity Hotspot, Eaglenest WS harbours diverse plant species. The WS covers an area of 217 km^2 with an elevation gradient ranging 500–3,300 m. Annual precipitation ranges from roughly 1,500 mm to over 3,000 mm (Mohan & Athreya 2011). The elevation gradient shapes diverse forest ecosystems, transitioning from tropical wet evergreen forest at lower elevations (below 1,000 m) to broadleaved subtropical (between 800–2,000 m), temperate forest at higher elevations (between 1,800–2,800 m), and above 2,800 m, temperate coniferous forest. The elevation gradient hosts various plant species, contributing significantly to the region's rich floral biodiversity. The critically

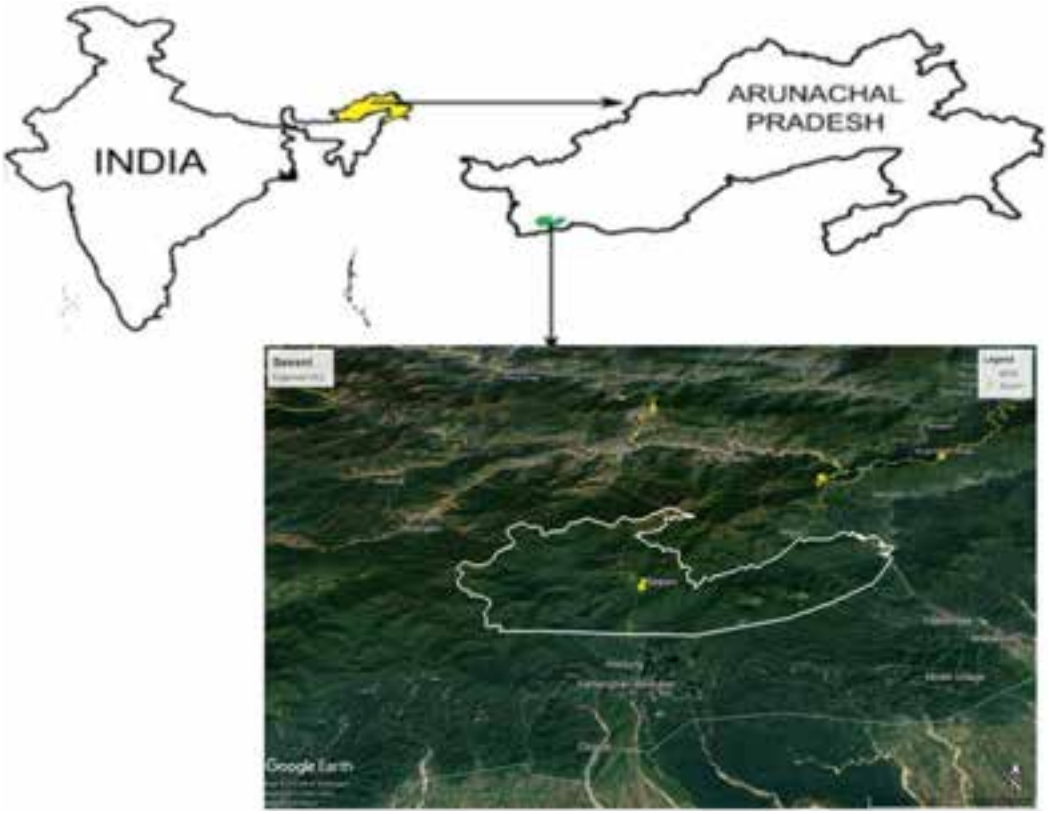

Image 1. The map shows the location of Sessni inside Eaglenest Wildlife Sanctuary, Arunachal Pradesh, India.

Image 2. A bud of *Sapria himalayana* on the forest floor emerging from the host's root.

Image 3. An individual flower of *Sapria himalayana* Griff. in its natural habitat.

Image 4. A naturally aborted *Sapria himalayana* bud beside a healthy bud.

Image 5. A decaying flower of *Sapria himalayana*.

Image 6. A *Sapria himalayana* flower with 12 perigone lobes.

Image 7. Measurements of the *Sapria himlayana* flower's diameter.

Image 8. Measurements of a *Sapria himlayana* mature bud.

Image 9. The host plant of *Sapria himlayana*, i.e., *Tetrastigma* sp. of Vitaceae.

endangered *Gymnocladus assamicus and valuable medicinal plants like Paris polyphyla are found at higher altitudes.* The dominant woody trees at lower elevations include *Magnolia hodgsonii*, *Ficus* spp., *Canarium resiniferum*, *Pinus roxburghi*, *Castanopis hystrix, Gynocardia odorata,* etc. Additionally, the understorey is dominated by *Elatostema platyphyllum*, *Strobilanthes hamiltoniana*, *Trivalvaria* sp., and *Achyrospermum wallichianum*.

In December 2023, five globose buds were encountered on the forest floor while walking along a trail in the primary forest. Following this initial observation, a systematic investigation was undertaken at the exact site on the next day. Each individual blooming flower was counted and the dimensions were measured (diameter and height) of flowers and buds. Each floral development stage was documented, including fresh buds, aborted flower buds, mature fresh flowers, and decaying flowers.

Accurate geographical coordinates and elevation data were captured using a GPS tracking device for precise locational mapping. Given that the species is IUNC Endangered, the exact coordinates of this record are not shared. Host plants associated with the parasitic flowers were photographed for later taxonomic identification. Subsequent identification of both the parasitic flower and its host plants was carried out using scientific literature and botanical resources.

The *S. himalayana* individuals were discovered near the Sessni camp of Eaglenest WS. Around 21 individuals spanning various developmental stages were observed, from bud emergence to flower maturation, including naturally decaying buds and decaying flowers (Image 2–5). The buds cluster in groups of three or five, scattered across the forest floor. Most flowers grew on gentle slopes, but some were found on level ground. A nearby water stream may fulfil the specific habitat requirements of this species. The flowers of *S. himalayana* are vibrant red, with sulphur-yellow dots on their perigone lobes. Most of the flowers have 10 perigone lobes in count. An individual *S. himalayana* flower with 12 perigone lobes (Image 6) is also recorded, contrasting with past published literature indicating the flower typically exhibits 10 perigone lobes. The flower was roughly 20 cm (Image 7) in diameter and about 12 cm tall. A mature bud was 12 cm wide (Image 8). The flower emits putrid smells that can be detectable from a few meters away. The vegetative parts of *S. himalayana* grow inside the host's lianas of *Tetrastigma* spp. (Image 9) of Vitaceae. During the reproductive phase, the protocorm emerges from the hosts' roots and then matures into a flower—the flower blooms in the winter, from November to February.

Eaglenest WS faces significant environmental challenges, including climate change and the spread of invasive plants at lower elevations. In this context, *Sapria himlayana* is a poorly understood taxon and highly sensitive to environmental factors. The plant has a naturally high bud mortality rate (Osathanunkul 2019). Extensive research on the fascinating Himalayan Sapria has been challenging because of its infrequent, unpredictable, and secretive flowering patterns. The study underscores the urgent need for comprehensive research into the elusive flowering phenology and enigmatic traits of *S. himalayana* to inform practical conservation efforts. In order to establish patterns and solve these mysteries, an annual plant survey is proposed in the Eaglenest WS. Apart from the West Kameng of Arunachal Pradesh, Namdapha National Park

of Changlang District is this plant's most extensively documented habitat (Arunachalam et al. 2004; Borah & Ghosh, 2018). Recent observations also indicate its presence in other parts of Arunachal Pradesh, including the evergreen forests of the East Siang District and the Mehao Wildlife Sanctuary in the Lower Dibang Valley District (Ahmad et al. 2020; Taram et al. 2020).

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Pinnatella limbata (Bryophyta: Neckeraceae): reassessment of conservation status based on recent findings

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Abstract: *Pinnatella limbata* Dixon (Neckeraceae), a rheophytic moss species with a bistratose leaf margin unique in the genus was reported from Sampkhand in Kanara district of Karnataka State in India. The species was subsequently collected from two additional localities of Kodagu (Coorg) District in Karnataka State and that *P. limbata* should be removed from the threatened category of the IUCN World Red List of bryophytes due to the new information of its distribution range. The present collection from Aralam Wildlife Sanctuary, in the Kannur District of Kerala is a range extension of this species in the Western Ghats and the first report from Kerala. An attempt is made to reassess the IUCN Red List status of *P. limbata*.

Keywords: Aralam Wildlife Sanctuary, IUCN Red List, Kannur District, Karnataka, Kerala, mosses, new record, taxonomy, Vulnerable, Western Ghats.

A world monograph of *Pinnatella* by Enroth (1994) gives a thorough and insightful re-examination, clarifying all the taxonomic complexities that existed in the genus and recognized 15 species. Recently, Manju et al. (2023) added a new species *P. enrothiana* Manju, J.Muñoz, Sruthi, Mufeed & K.P.Rajesh, from the Western Ghats of India to the list. Among the *Pinnatella* species *P. minuta* (Mitt.) Broth. is the only representative in the Neotropics and continental Africa. The greater diversity for *Pinnatella* lies in southern and southeastern Asia (Enroth 1994).

During a field survey in the deep forest of the Aralam Wildlife Sanctuary in the Kannur District of the Peninsular Indian state of Kerala, an intriguing moss species was discovered. It was found attached to a large rock surface in a streamside and hanging down like a loose green curtain covering the entire rock surface. Through careful examination and detailed study, the species was identified as *P. limbata* of the family Neckeraceae. *P. limbata* can be distinguished from other *Pinnatella* species by its bistratose leaf margin which is a unique feature of the species. It was first described by Dixon (1921) from the Kanara district of Karnataka State based

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on the collection by Mr. L.J. Sedgwick during 1919. Later, Raghavan in 1960 collected the species from Agumbe of Karnataka and observed that it is a fairly common species on moist rocks in association with *Papillaria fuscescens* (Hook.) A.Jaeger (Raghavan & Wadhwa 1968). Subsequently, Schwarz (2013) based on the collections of Frahm, Schwarz, & Schumm in 2012 reported it from other two localities of Karnataka. The present collection proved to be the first report of the species from the state of Kerala and it implies a range extension of the species in the Western Ghats. The present collection showed variability in the stem length and texture of the plant as compared to previous reports. Usually, it has a shorter stem, maximum up to 15 cm. Here relatively larger species were found, reaching twice the length of those reported earlier.

Pinnatella limbata was assessed as a 'Critically Endangered' species in the IUCN World Red List of bryophytes (id 39178; Bryophyte Specialist Group, 2000; https://www.iucnredlist.org/species/39178/10167017). Schwarz (2013) based on the new information gathered on its distribution suggested that *P. limbata* should be removed from the threat category of the IUCN Red List of bryophytes. The present collection from Kerala is a record of its further range extension in the Western Ghats. The IUCN Red List status of *P. limbata* Dixon is further reassessed here (Images 1,2).

Materials and Methods

The present collection was made from the Aralam

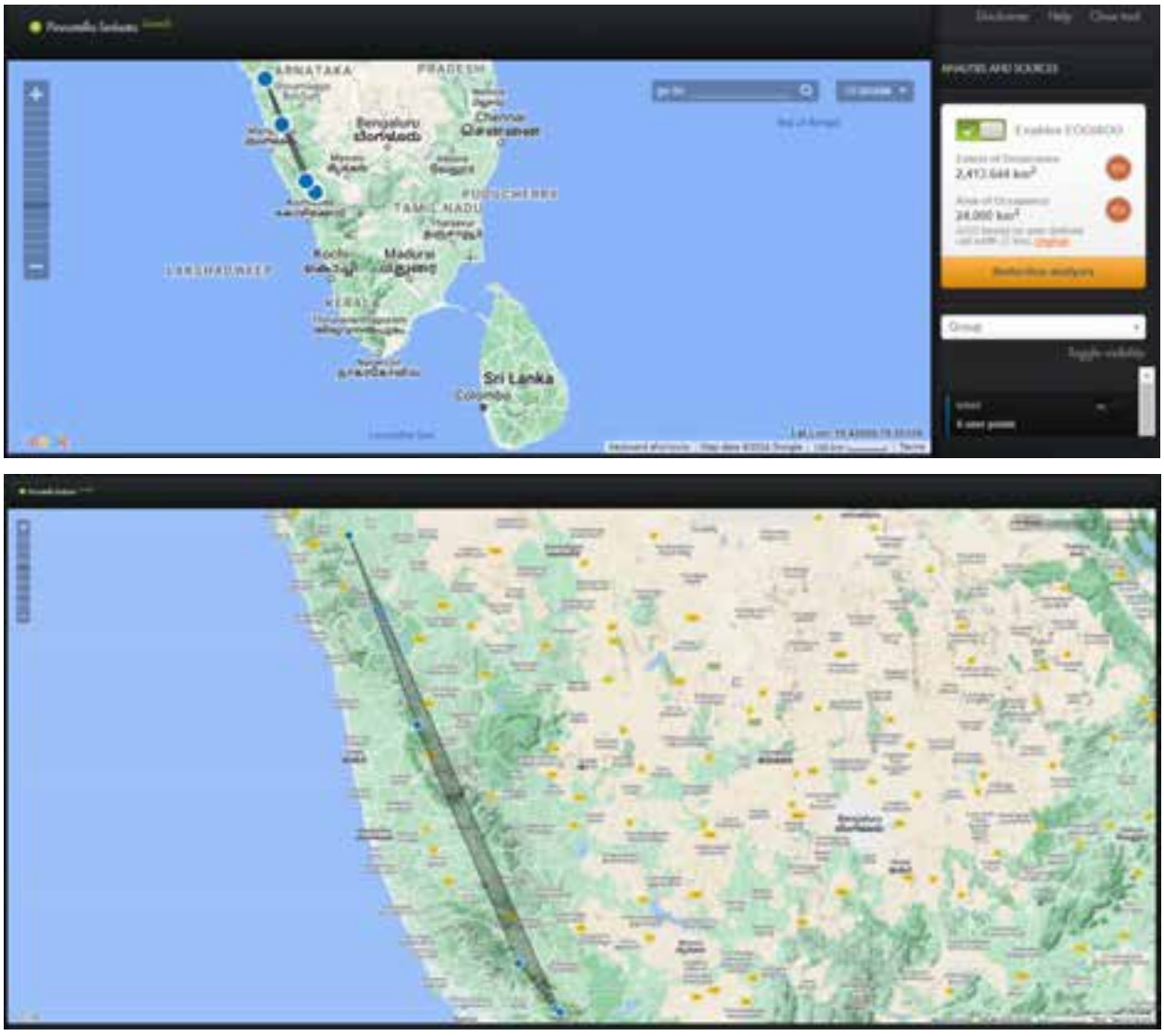

Image 1. Distribution and assessment of extent of occurrence and area of occupancy of *Pinnatella limbata* Dixon. (https://geocat.iucnredlist.org/editor).

Wildlife Sanctuary, a protected evergreen forest in the Western Ghats of Kannur District in Kerala in peninsular India. The collections were made in two different seasons from different localities. A combination of microscopes was used to study the characteristics of the specimen, a Leica Sapo Stereo Microscope was used for morphological observations, and an Olympus CX21liLED microscope for anatomical examinations. Magnus Analytics MagVision software (version: x64, 4.8.15674.20191008) was used to measure the plant parts and cells. An updated description of the species was prepared based on the present collections. The collected specimens were processed and the herbarium packets of standard size are deposited in the Calicut University Herbarium (CALI) and Central National Herbarium (CAL).

The distribution data of this species has been tabulated based on previous records as well as the present observations. The area of occupancy (AOO) and extent of occurrence (EOO) were assessed using GeoCat (Bachman et al. 2011; https://geocat.iucnredlist.org/editor). The threat status was assessed according to the IUCN Red List criteria (Version 3.1).

Results

Taxonomic treatment

Pinnatella limbata Dixon, J. Indian Bot. 2: 184. 1921. – Type: India, Karnataka, Leonard John Sedgwick, #6437 1919 (BM).

Plants gregarious, pendent, up to 30 cm long, irregularly pinnately branched, older parts dark green to brownish green, younger parts and branches pale green, flagelliform branches present; stolons in cross-section oval-round, cortical cells small, in 2–3 layers, thick-walled, inner medullary cells in several layers, comparatively larger, thin-walled. Stolon leaves small, closely appressed, loosely imbricate, 0.7–0.9 x 0.4–0.5 mm, triangular in shape, gradually ending to an acute tip, margin serrulate except at extreme base; costa reaching above half of the leaf. Stipe short, 1–2 cm long, 0.4 mm diameter in cross-section, with 6–9 layers of cortical cells surrounding several layers of rounded to hexagonal medullary cells, central strand absent; stem pale yellow, up to 27 cm long, with 6–7 layers of small, thick-walled cortical cells in cross-section, medullary cells thin-walled, larger than cortical cells, rounded to hexagonal, central strand absent. Stem leaves comparatively larger than stolon leaf, ovate-lanceolate, 1.7–2.3 x 0.9–1.2 mm, loosely imbricate, twisted when dry, nearly symmetrical, leaf apex sub-acute–obtuse, sometimes mucronate, margin entire below, serrulate at apex, leaf cross-section adaxially flat, abaxially convex, bistratose margin ends near extreme tip, leaf tip cells rhomboidal, 8–14 x 3–7 µm, median laminal cells slightly elongated than tip cells, 11–27 x 3–5 µm, basal cells elongated vermicular, 19–50 x 3–6 µm, extreme basal juxta costal cells porose; costa ending below apex. Stem leaf base wider than branch leaf, 1.7–2.1 x 0.8–0.9 µm, leaf apex obtuse, sometimes mucronate, margin entire below, serrulate apex, bistratose margin vanishing near tip. Cells at leaf tip rhomboidal, 8–13 x 3–8 µm, median laminal cells slightly elongated than apex cells, 13–27 x 2–4 µm, basal cells elongated vermicular, 25–46 x 3–4 µm, extreme basal cells porose near the costa. Sporophyte not observed (Image 3).

Specimens examined: India, Kerala, Kannur District, Aralam Wildlife Sanctuary, Meenmutty waterfalls (400 m), 11.947N, 75.882E, on a large rock near stream, 28 September 2022, Sruthi O.M. 14898 (CALI); Chavachi waterfalls (280 m), 11.929N, 75.901E, on a large rock surface near stream, 11 January 2023, Sruthi O.M. 14262 (CALI); Meenmutty thodu (664 m), 11.950N, 75.890E, on a rock near streamside, 12 January 2023, Sruthi O.M. 14303 (CALI).

Distribution: Karnataka, Kanara District, Sampkhand (Dixon 1921; Enroth 1994), Shimoga District, Agumbe (Raghavan & Wadhwa 1968); Kodagu (Coorg) District, Kabbinakad, the area around Kabbe Holiday Homestay and the area around Honey Valley Homestay (Schwarz 2013); Kerala (present study).

Habitat: This species grows as a mat or curtain on moist large rocks near stream sides which is not inundated by overflowing waterfalls but is always wet due to the flow of water. The type specimen was also reported from a similar habitat.

IUCN Red List reassessment: *Pinnatella limbata* is known only from a small area in the Brahmagiri region of the Western Ghats, with an EOO of 2,413.644 km^2 and an AOO of about 24 km^2. As per the major criteria (B1 and B2) of the IUCN Red List (ver. 3.1) it thus qualifies for consideration as Endangered (EN). It also meets sub-criteria B1a and B2a, as it is known from less than 10 locations. Since the area is protected and located in interior forest there are no other direct threats to the species. Observations on other sub-criteria such as trends of population decline are not available at present. Although restricted in EOO and AOO, it does not qualify for Endangered (EN) due to more than five locations that are not severely fragmented. However, it does not qualify for Vulnerable (VU) either due to no known threats which are impacting the area, extent, quality, locations, or mature individuals. The species is categorized as Near Threatened as it misses the criteria

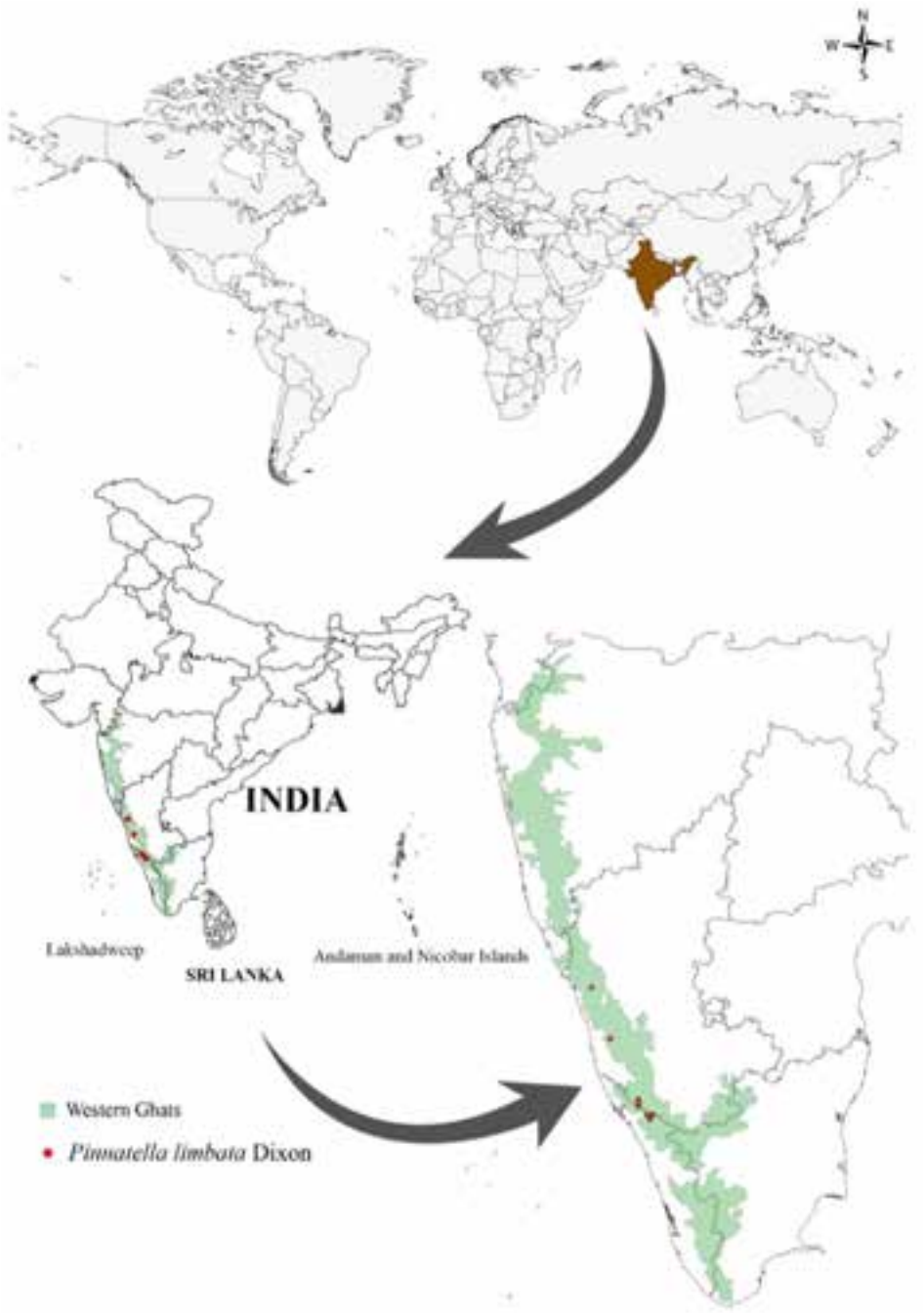

Image 2. Locations of *Pinnatella limbata* Dixon in the Western Ghats of India.

for VU narrowly.

Discussion

In the genus *Pinnatella, P. limbata* is unique in having the bistratose leaf margin. The species is known to grow on moist rocks in the streams and streamlets of evergreen forests in a small area in the Brahmagiri region of the Western Ghats of Karnataka and Kerala. The bistratose margins may be an adaptation for the rheophytic habitat, as it makes the leaves stronger (Enroth 1999). Thulasi *et al*. (2024) based on Ecological Niche Modelling (ENM) analysis of *Elaphoglossum beddomei*, a Southern Indian endemic fern, predicted sharp decline of evergreen habitats in the Western Ghats of India. This trend of loss of quality of habitats will also affect other Southern Indian endemics, especially those adapted to the moist habitats. *P. limbata* was assessed as Critically Endangered (Bryophyte Specialist Group 2000), as it was

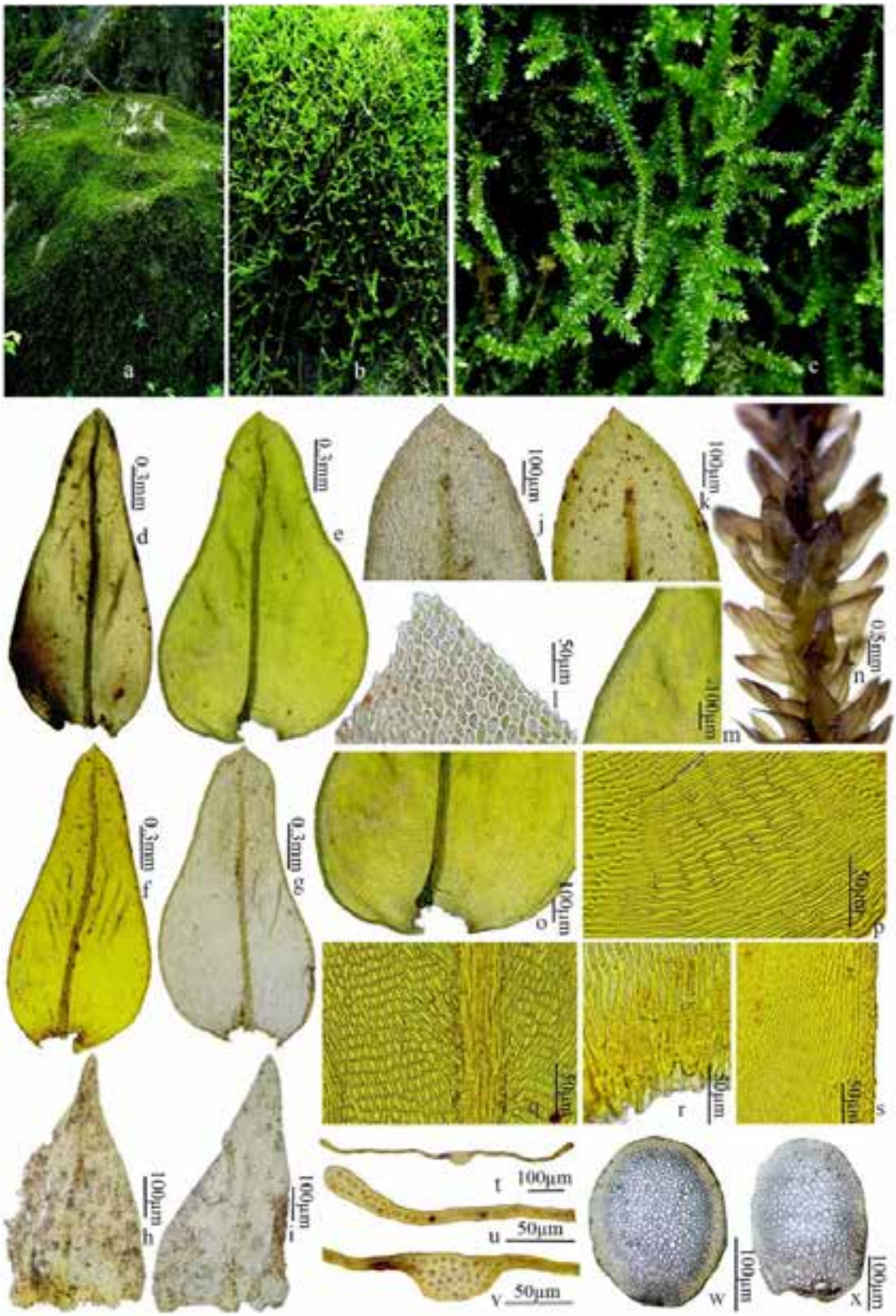

Image 3. ***Pinnatella limbata*** **Dixon: a–c—habit | d,e—stem leaves | f,g—branch leaves | h—stolon leaf | i—stipe leaf | j—leaf tip of stem leaf | k—leaf tip of branch leaf | l—leaf tip cells | m—margin of stem leaf | n—a portion of primary stem showing leaf arrangement | o—stem leaf base | p—laminal cells of stem leaves | q—cells near costa | r—basal porose cells | s—bistratose leaf margin | t–v—cross section of leaf | w—cross-section of primary stem | x—cross-section of stolon. © O.M. Sruthi.**

known only from the type collection from the Western Ghats of Karnataka. In the present re-assessment, based on updated distribution data from Karnataka (Dixon 1921; Raghavan & Wadhwa 1968; Schwarz 2013) and Kerala (present observations) the current status of the species has been categorized as Near Threatened due to its no known threats which are impacting the area, extent, quality, locations, or mature individuals.

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SHORT COMMUNICATION

Additions of two genera of liverworts (Marchantiophyta) to the bryoflora of Nagaland, India

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Abstract: *Pseudolepicolea trollii* (Herzog) Grolle & Ando and *Schiffneriolejeunea tumida* (Nees) Gradst. were recorded for the first time in the bryoflora of Nagaland. This also constitutes the first report of the two genera from the state. Photomicrographic details of the plants have been provided for easy identification.

Keywords: Bryophytes, extended distribution, Marchantiophyta, Nagaland, new record, Photomicrographic, *Pseudolepicolea*, *Schiffneriolejeunea*.

The state of Nagaland is situated in the extreme northeastern part of India having a geographical area of about 16,578 km^2. The state lies between the geographical coordinates of 25.324–27.020 ^{0}N and 93.193–95.113 ^{0}E. The state shares an international border with Myanmar (Burma) in the eastern side, while the Indian states of Assam, Arunachal Pradesh, and Manipur are situated to its western, northern, and southern sides, respectively. Nagaland's diverse topography, ranging from hills and valleys to forests and grasslands, coupled with its humid subtropical and temperate climate, creates a rich mosaic of microhabitats. These conditions are ideal for bryophytes like liverworts, mosses, and hornworts, which thrive in moist and shaded environments. The interplay of high rainfall, varying temperatures, and rich organic matter supports the lush growth of these plants. The rich biodiversity of Nagaland supports a wide range of bryophytic species, contributing to a vibrant and ecologically significant flora.

Few bryologists have worked on the bryoflora of Nagaland. Contributions to the moss flora of Nagaland were made by Bansal et al. (2010, 2011), Chaturvedi et al. (2011a,b), Sale (2012), Sale & Yanthan (2020, 2021a,b), and Sahu et al. 2022. Whereas, Udar & Asthana (1985), Chaturvedi & Chaturvedi (2008), Nath et al. (2010), Chaturvedi et al. (2011c), Chaturvedi & Eshuo (2012), Eshuo (2013, 2014), Eshuo & Chaturvedi (2011a,b,c, 2014), Eshuo et al. (2013a,b), and Ali et al. (2024) contributed towards the knowledge of liverworts and hornworts of the state.

During the bryological exploration in Nagaland, some interesting liverwort specimens were collected from the Kohima and Mokokchung districts. On critical examination of the collected specimens, two specimens were identified as *Pseudolepicolea trollii* (Herzog) Grolle & Ando (Pseudolepicoleaceae) and *Schiffneriolejeunea tumida* (Nees) Gradst. (Lejeuneaceae), which are hitherto unknown to the bryoflora of Nagaland.

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Materials and Methods

The collected specimens were air-dried and preserved in a standard packet (size 4 × 6 in) of a brown paper sheet. The dried specimens were soaked in water for 2–5 min to stretch out the plant body fully and morphological characters were observed under a stereo zoom Leica S6D microscope and macro-photographs were taken by using a Leica DFC420 camera attached to the microscope. The cut sections of the specimens were mounted in 30% glycerine and observed under the Leica microscope and photomicrographs were taken using the Leica DFC40 camera mounted on the Leica DM1000 microscope. The preserved specimens have been deposited at the Herbarium, Department of Botany, D.M. College of Science, Manipur (DMH) for future reference.

Taxonomic treatment

Psuedolepicolea trollii (Herzog)

Grolle & Ando, Hikobia 3: 177. 1963. *Blepharostoma trollii* Herzog, Ann. Bryol. 12: 80. 1939. *Lophochaete trollii* (Herzog) R.M.Schust., J. Hattori Bot. Lab. 23: 199. 1960. (Image 1)

Plant small, light green to brownish green, branched, branching *Frullania*-type, intercalary, rarely terminal, 10–17 mm long, 0.9–1.2 mm wide including leaves. Rhizoids are scarce and mostly present at the basal part of the stem. Stem orbicular in outline in transverse section, 9–11 cells across, 126–133.5 × 97.5–99.5 µm in diameter, differentiated; cortical cells 2-layered, sub-quadrate to polygonal, 9.8–15.4 × 5.1–11.9 µm; medullary cells quadrate to sub-quadrate or polygonal, 9.3–17.6 × 8.9–14.3 µm, thin-walled. Leaves imbricate, obliquely spreading, 0.58–0.75 mm long, 0.15–0.2 mm wide, bis bifid, lobes lanceolate, 4-lobed, lobes erect, linear, median lobes subparallel, lateral lobes spreading, lobes 12–17 cells long, 3–5 cells wide at the base, 3–4 cells uniseriate towards the apex, sinus narrow; leaf lamina 4–7 cells long, 11–15 cells wide at middle, margin crenulated; apical cells elongate, 39.2–59.8 × 9.6–12 µm, thick-walled; sub-apical cells rectangular to sub-quadrate, 47–66 × 7.5–13.0 µm, thick-walled; median cells quadrate to sub-quadrate, 19–43 × 8–20 µm, thick-walled; basal cells quadrate to polygonal, 22.5–45 × 8.5–19 µm; oil-bodies not seen. Under leaves imbricate, similar to leaves, bis bifid, 4-lobed, lobes 8–13 cells long, 3–4 cells wide at the base, 2–4 cells uniseriate at apex, sinus narrow. Androecium not seen. Perianth cylindrical, apex toothed, bracts larger than normal leaf, 1.19–1.4 mm long, 0.4–0.52 mm wide, 4-lobed, lobe ¼ of the bract length. Spores brownish green, globose, 12.8–14.4 µm in diameter. Elaters 75–105.6 µm long, 9–11.5 µm wide with bi-spiral thickening bands.

Ecology: The plants grow on moist soil and rocks in association with mosses, and the species of *Jungermannia*, *Scapania*, *Cephalozia*, and *Bazzania*.

Range: India, Bhutan, China, Indonesia, Japan, Malaysia, Nepal, and Taiwan.

Distribution in India: Arunachal Pradesh, Nagaland (present study), Sikkim, and West Bengal.

Specimen Examined: India: Nagaland, Kohima District, Khonoma, 25.371°N 94.114°E, 1700–2300 m, KE10424.

Notes: In India, the genus *Pseudolepicolea* is represented by two species, viz., *Pseudolepicolea fryei* (Perss.) Grolle & Ando and *P. trollii*. *P. fryei* has been reported from Uttarakhand in western Himalaya, whereas *P. trollii* was so far known from Arunachal Pradesh, Sikkim, Uttarakhand, and West Bengal (Singh et al. 2014; Singh & Singh 2023). Therefore, the occurrence of this taxon in Nagaland bryoflora is a new generic addition to the state with an extended distributional range.

Schiffneriolejeunea tumida (Nees)

Gradst., J. Hattori Bot. Lab. 38: 335. 1974. *Ptychanthus tumidus* Nees, Naturgesch. Eur. Leberm. 3: 213. 1838. (Image 2)

Plant light green to brownish-green, 30–60 mm long, 2.0–3.5 mm wide including leaves, irregularly branched. Stem orbicular in outline in transverse section, 0.2 × 0.25 mm in diameter, 9–11 cells across, differentiated; cortical cells 1–2-layered, quadrate to sub-quadrate, 14.5–25.0 × 7.2–21.0 µm, thick-walled; medullary cells quadrate, polygonal, 20–31 × 12–20 µm. Leaves closely imbricate, incurved, margin entire, ovate-oblong, 0.9–1.5 x 1.0–1.6 mm, apex rounded, cells quadrate to penta-hexagonal, apical cells 16–25 × 13–20 µm, median cells 23–30 × 17–22 µm, basal cells 25–44 × 15–22 µm, with nodular trigones; oil-bodies 2–5(6) per cell, 8.6–12.5 µm long, 2.1–4.0 µm wide, elongate-elliptical, or circular, roughly segmented; leaf lobule rectangular, 1/3 of the leaf length, with 2 teeth, first tooth 2 cells long, 1–2 cells wide, second tooth 5 cells long, 3 cells wide at base, 2 cells uniseriate at apex. Under leaves imbricate to contiguous, 0.3–0.5 mm long, 0.5–0.7 mm wide, wider than long, margin entire, apex oblong to obtuse. Autoicous. Androecia on short lateral branches toward the apical region, male bracts in 5–13 pairs, strongly inflated, smaller than vegetative leaves, antheridia not seen. Gynoecium with bracts in 3 pairs, bracteoles lanceolate, 1.5–2.0 mm long, 0.9–1.5 mm wide, bifid

Image 1. ***Pseudolepicolea trollii*** **(Herzog) Grolle & Ando: a—A portion of the female plant in ventral view | b–d—Leaves | e–g—Underleaves | h–l—Female bracts | j—Perianth | k—T.S. of the perianth | l—T.S. of Stem | m–n—Leaf Median cells | o—Leaf apical cells | p—Apical cells of female bract | q–r—Leaf basal cells | s—Spores | t—Elater. © Kazhuhrii Eshuo.**

Image 2. ***Schiffneriolejuenea tumida*** **(Nees) Gradst.: a—A portion of a plant in ventral view | b—A portion of Male plant| c–d—Leaves | e–g—Underleaves | h–k—Male bracts and bracteoles | l—Female bract | m—Female bracteole | n–o—Perianths | p—Capsule and seta | q—T.S. of perianth | r—T.S. of the stem | s—Leaf lobule | t—Leaf median cells | u—Leaf marginal cells | v—leaf basal cells | w—oil-bodies | x—Elater | y—Spores. © Kazhuhrii Eshuo.**

with acute apex; perianth obovate-obpyriform, with 3–5 inflated keel in the distal half and a short beak. Spores oblong to globose – sub-globose, whitish-green, 31–41 x 46–74 µm in diameter, spinose. Elaters 292.5–535 µm long, 14.5–20 µm wide with bi-spiral thickening bands.

Ecology: Epiphytic, growing in association with *Frullania*, *Acrolejeunea,* and mosses.

Range: India, Africa, Australia, China, Fiji, Indonesia, Malaysia, New Caledonia, Papua New Guinea, Philippines, Singapore, Sri Lanka, Taiwan, and Thailand.

Distribution in India: Andaman & Nicobar Islands, Nagaland (present study), and Tripura.

Specimen Examined: India: Nagaland, Mokokchung district, Mopunchuket, 26.235°N 94.313°E, 1,000–1,200 m, KE10517.

Notes: The genus *Schiffneriolejeunea* is represented by four species in India, viz., *S. cumingiana*, *S. polycarpa, S. pulopenangensis,* and *S. tumida* (Udar & Awasthi 1982; Dandotiya et al. 2011). The taxa are mainly distributed in southern India and Andaman & Nicobar Islands with only *S. tumida* recently reported from Tripura in northeastern India (Singh & Kumar 2016). Therefore, the occurrence of this taxon in Nagaland bryoflora is a new generic addition to the state with an extended distributional range.

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SHORT COMMUNICATION

Phycolepidozia indica (Marchantiophyta: Jungermanniales) an endemic leafless liverwort from Kerala part of Western Ghats, India

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Abstract: The genus *Phycolepidozia* R.M.Schust. of the family Cephaloziellaceae is globally known by only two species, viz. *P. exigua* R.M.Schust., a neotropical species and *P. indica* Gradst., J.-P. Frahm & U. Schwarz, a southern Indian endemic species. The leafless liverwort *P. indica*, so far known by its type collection from Karnataka only, is being presently recorded from the Kerala part of the Western Ghats. In the present paper an illustrative account of the species is being provided.

Keywords: Cephaloziellaceae, Karnataka, leafless stems, leafy liverwort, new record, Phycolepidoziaceae, taxonomy, threatened, Wayanad.

Phycolepidozia R.M.Schust. is a fascinating leafy liverwort with many unique features. Unlike most liverworts, it lacks leafy lobes and underleaves on its stems and branches giving it a somewhat algal appearance. However, it's reproductive structures, both the male and female gametoecia are adorned with leaves. The genus *Phycolepidozia* belonging to the family Cephaloziellaceae was described by R.M. Schuster (1966) with a single species, *P. exigua* R.M.Schust. based on its type collection from Dominica (Caribbean Island). Later it was also collected from Venezuela (GBIF 2024). It is known to occur on tree trunks in humid rainforest in the tropical American region. This species was assessed as Critically Endangered (CR) due to its rare occurrence (Bryophyte Specialist Group 2000; Hallingbäck & Hodgetts 2000; Schäfer-Verwimp 2010). A second species was added to this genus after 37 years from India by Gradstein et al. (2014), as *P. indica* Gradst., J.-P. Frahm & U.Schwarz from the forests of the Western Ghats of Karnataka state in Peninsular India.

During our recent survey in the Wayanad District of Kerala state (Figure 1), we came across an unusual interesting plant specimen, and even mistook it for an alga due to its leafless stem. However, on closer observation, we could confirm it as *P. indica*.

Materials and Methods

The bryophyte collection was made during December 2023 near the Tentgram, a popular tourist destination,

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Competing interests: The authors declare no competing interests.

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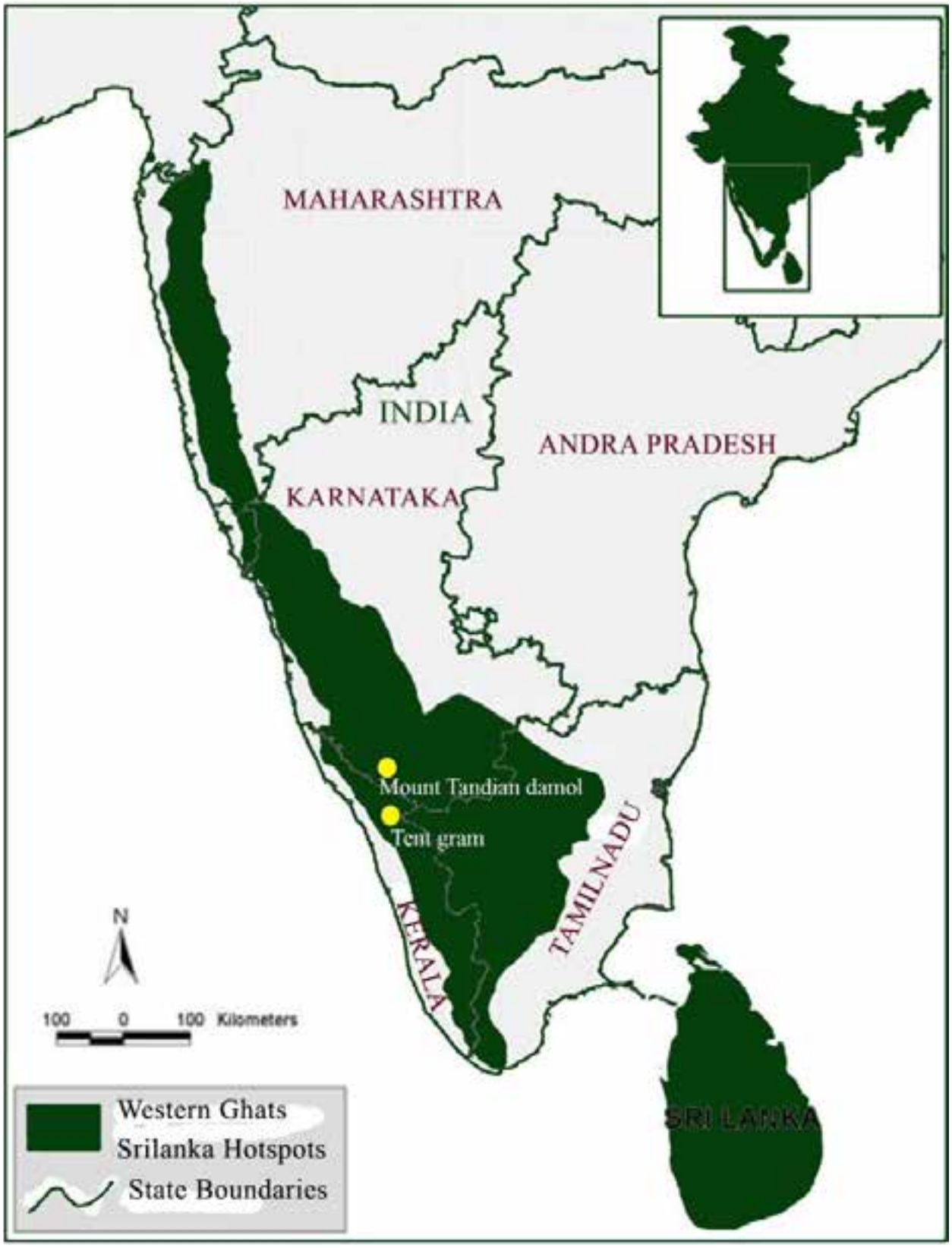

Figure 1. Location map of collection site of *Phycolepidozia indica* Gradst., J.-P.Frahm & U.Schwarz in the Western Ghats.

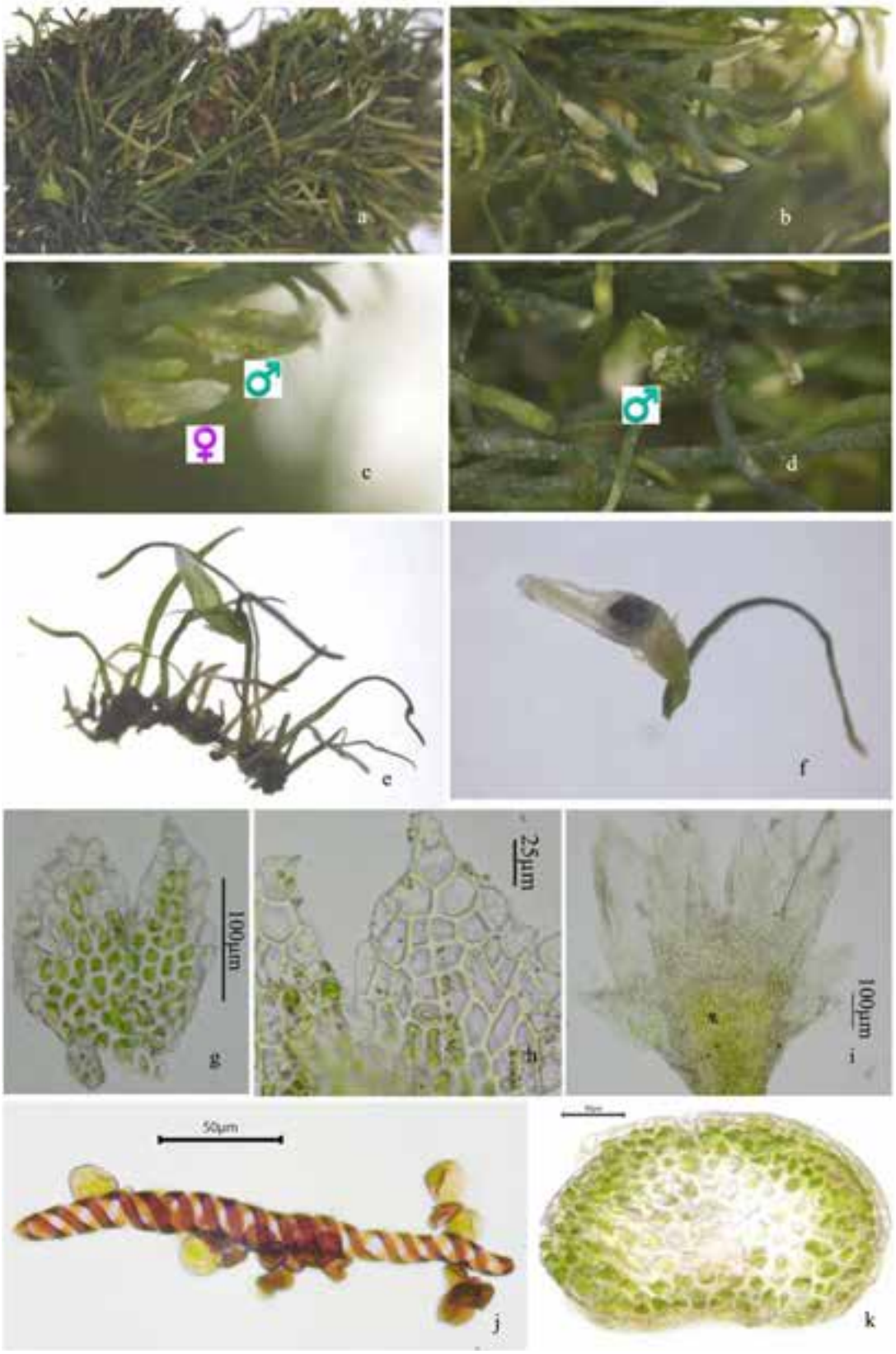

Image 1. ***Phycolepidozia indica*** **Gradst., J.-P.Frahm & U.Schwarz. a—habit showing leafless branches | b—female branch | c—branch showing female and male structure | d—male branch with small bracts | e–f—enlarged view of female branch with sporogonium enclosed within perianth | g—male branch with bract | h—bract cells | i—connate bract and bracteoles | j—spores and elater | k—cross section of stem. © Manju & Krishnendhu.**

amidst thick forest in the Wayanad district of Kerala. The leafless liverwort was found growing on a large, rocky patch. The morphological features were studied under a Leica SApo stereo microscope, and internal features using an Olympus CX21liLED compound microscope. The photomicrographs were recorded using Magcam DC5 5.1MP camera and Magnus Analytics MagVision software (version x64.4.8.15674.2-01991008). The voucher specimens are housed in the Calicut University Herbarium (CALI).

Taxonomic Treatment

Phycolepidozia indica Gradst., J.-P. Frahm & U. Schwarz, Taxon 63(3): 499. 2014. – Type: INDIA, Western Ghats, Karnataka State, Coorg District, trail to the summit of mount Tandiandamol, 25.9 km south-west of Madikeri, 1,610 m, on a shaded rock in remnant forest along the trail, 12.2208 ^{0}N, 75.6095 ^{0}E, 11 November 2012, U.Schwarz, J.-P.Frahm & F.Schumm s.n. (PC). (Image 1).

Plant monoecious, pale green to dark green, green to blackish when dried, caespitose, bristles like mats on rocks, shoots leafless, arising from rhizomes, 2.30–5.29 mm long, 0.12–0.17 mm thick. Stem straight to remotely angled, irregularly branched, branches 0.51–2.63 mm long, 0.11–0.15 mm thick with pointed tip, devoid of leaves, but with alternatingly protruding few-celled hyaline projections on lateral sides representing vestigial leaves; in surface view the dorsal epidermal cells oblong, thick walled, green; ventral epidermal cells short, rectangular and pale green. Stem cross section shows 18–21 cells across, 280–300 × 170–180 µm in diameter; the outer cortical cells green, chlorophyllous, thick walled, small sized, 8–15 × 5–13 µm, arranged in 4–5 layers of cells; the inner medullary cells hyaline, non chlorophyllous, thin walled, larger, 18–23 × 13–19 µm, arranged in 4–5 layers of cells; branches greenish, arising from ventral sides in straight angles, erect, small hyaline projections on either side of stem representing the leaf position. Rhizoids hyaline and smooth, arising from the rhizomes, also present on shoot tip. Gametoecia leafy, colourless, arising from short branches. Androecia terminal or intercalary in position, mostly adjacent to the perianth, comprising 6–7 leaf-like bifid appendages or bracts, 0.9–1.2 mm, cells chlorophyllous, 19–30 × 11–15 µm. Gynoecia terminal on short branches, bracts and bracteoles connate, female bract in 2–3 series, innermost bract 0.3–0.4 mm long; perianth 0.8–1.2 × 0.30–0.37 mm, 6-keeled with green base and hyaline tip, orange to brown cover on its tip, cells hyaline, 46–81 × 11–24 µm. Cells of perianth and male and female bracts contain 5–8 globular oil bodies. Seta very thin, 3 mm long; capsule cylindrical; spores immature, spherical, 17–19 µm in diameter, brownish yellow; elaters 213–239 × 15–18 µm, brownish, with strong bi-spiral bands.

Habitat: The species was collected near to semi evergreen forest from a shady large rocky patch where water drips regularly.

Distribution: India, southern Western Ghats, Karnataka (Coorg District), and Kerala (Wayanad district – present study), endemic.

Specimen examined: India: Kerala, Wayanad District, Thollayiram kandi, Tentgram (1,180 m), 02.12.2023, 11.4903 ^{0}N, 76.0995 ^{0}E, coll. K.P. Rajesh, #202511 (CALI).

Discussion

Schuster (1966) considered *Phycolepidozia* under a separate family Phycolepidoziaceae R.M.Schust. when he first described *P. exigua.* However, based on the molecular analysis Gradstein et al. (2014) concluded that the genus is closely related to Cephaloziellaceae and included it under Cephaloziellaceae. The Wayanad region is known with a rich Bryoflora comprising more than 170 species, including endemics such as *Trichostomum wayanadense* Nair et al., *Amphidium gangulii* Nair et al., *Pinnatella enrothiana* Manju et al., *Acidodontium indicum* Vineesha et al., etc (Nair et al. 2005; Manju et al. 2023; Vineesha et al. 2023). The present finding of a curious genus, *Phycolepidozia,* also signifies the quality of the habitats in the Wayanad region in supporting a rich biodiversity. However, due to the small size of the plant, the chance to ignore or miss many species is high. The continued intensive surveys in the habitats of the Western Ghats are proved worthy in documenting many more taxa. The present location of the species, Wayanad, is about 82 km (aerial distance) from the earlier known localities in Karnataka State. Like *P. exigua*, the present species is also very rare as it is known only from two locations with very small extent of occurrence and area of occupancy and hence may be threatened.

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NOTE

First photographic documentation of avian egg predation by Common Palm Civet *Paradoxurus hermaphroditus* (Pallas, 1777) (Mammalia: Carnivora: Viverridae)

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An avifaunal survey was conducted in August 2024 as part of a biodiversity monitoring program inside Pondicherry University campus. This campus is located at the Coromandel coast of southern India and covers an area of 3.15 km^2 (Parthasarathy et al. 2010). On 1 August 2024 at 17.20 h, we found a nest with two eggs in the hollow of a fallen dead tree about 1 m off the ground next to a drainage pond located at 12.024536°N, 79.848332°E (Image 1). Nesting materials included dead twigs and leaves, leaf litter, *Acacia* seed pods and snake skin shed.

We installed a Cuddeback Blue Series camera trap model 1279 equipped with an IR flash on 2 August 2024 around 18.00 h to monitor the nest. The camera trap was set to time-lapse mode to take an image every five minutes, five burst images and a video of 30 seconds duration whenever the motion sensor was triggered.

When retrieving the camera trap on 4 August 2024, we found the nest destroyed without any sign of the eggs nearby. The camera trap images showed that the nest belonged to an Indian Robin *Copsychus fulicatus*. The camera trap recorded a Common Palm Civet *Paradoxurus hermaphroditus* predating the nest on 3 August 2024 at 23.23 h. When it found the nest, it climbed onto the tree (Image 2), took out the eggs and destroyed the nest in the process. Then it climbed down the tree log and consumed the eggs (Image 3) including egg shells within 2–3 minutes. The Indian Robin was recorded close by the destroyed nest on 4 August 2024 (Image 4).

Our records present the first photographic evidence in India of Indian Robin egg consumption by a Common Palm Civet. To date, documented predation events of the Common Palm Civet on bird nests include two reports from Thailand; in Khao Yai National Park, it preyed on nestlings in one of 87 recorded predation events (Pierce & Pobprasert 2013). In Phuluang Non-hunting Area, it also preyed on nestlings in three of 179 total predation events (Khamcha et al. 2018). In India, it was documented preying on Indian Pitta *Pitta brachyura*

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Image 1. Geo-tagged image of the Indian Robin nest with the eggs. © AVANI – PU Nature Club.

Image 2. Common Palm Civet *Paradoxurus hermaphroditus* climbing on to the fallen tree to inspect the nest on 3 August 2024. © AVANI – PU Nature Club.

Image 3. Common Palm Civet *Paradoxurus hermaphroditus* in the process of consuming the eggs. © AVANI – PU Nature Club.

nestlings in Gujarat (Solanki et al. 2018) and with a Red-billed Blue Magpie *Urocissa erythroryncha* kill in Valmiki Tiger Reserve, Bihar (Maurya et al. 2017). Interview respondents in Malaysia claimed that the Common Palm Civet frequently attacks poultry chicks and consumes poultry eggs (Hasan & Csányi 2023).

The Common Palm Civet's diet has been described as predominantly frugivorous including but not limited to fruits and seeds of *Gnetum scadens*, Sacred Fig *Ficus religiosa*, Papaya *Carica papaya*, Common Jack *Artocarpus heterophyllus*, Wild Jack *A. hirsutus*, Fishtail Palm *Caryota urens*, Sugar-apple *Annona squamosa*, and Wild Himalayan Pear *Pyrus pashia* (Su & Sale 2007; Jothish 2011; Khan et al. 2019; Akrim et al. 2023). Vertebrate remains identified in scat samples indicate that it occasionally also consumes rodents, Indian Hare

Image 4. Indian Robin *Copsychus fulicatus* looking at the predated nest on 4 August. © AVANI – PU Nature Club.

Lepus nigricollis, and invertebrates like snails and insects (Khan et al. 2019; Akrim et al. 2023). In Similipal Tiger Reserve, it was observed feeding on termite alates (Rathore et al. 2024).

Our camera trap images provide further insights into the diet of the Common Palm Civet and exemplify the benefit of using camera traps in avifaunal surveys.

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NOTE

First record of Eurasian Crag Martin *Ptyonoprogne rupestris* (Scopoli, 1769) (Aves: Passeriformes: Hirundinidae) from Tamil Nadu, India

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Eurasian Crag Martin *Ptyonoprogne rupestris* is a small-sized aerial insectivorous bird from the family Hirundinidae, commonly grouped under swallows and martins. Eurasian Crag Martin breeds in India and Pakistan Himalayan region; winters mainly in Western Ghats of Karnataka, Maharashtra, Goa, and Gujarat states (Grimmett et. al. 2011). Eurasian Crag Martin has brown-grey crown and upper parts, dark brown wings and tail, tail square, white spots on inner webs of feathers (except inner and outermost pairs, occasionally spots also on outer pair), chin and throat pale with dark speckling, pale buff breast grading into brown-grey belly and brown undertail-coverts, underwing-coverts blackish (Turner 2020). Forages close to cliff faces, over the gorges, woodland and villages; outside breeding season they tend to forage over farmland, meadows, rocky coasts, swamps, and lakes (Turner 2020). Eurasian Crag Martin differs from widely resident Dusky Crag Martin *Ptyonoprogne concolor* by larger size, paler brown upperparts and underparts with throat and breast noticeably paler than belly and vent, further underwing appears strong two-toned compared with that of Dusky Crag Martin. Its habitat includes rocky cliffs and gorges (Grimmett et al. 2011), mountains, crags, and coastal cliffs; and around human habitations (Turner 2020).

The Eurasian Crag Martin was recorded from Tamil Nadu State with photographic evidence (Image 1–4). On 18 August 2024 at 0810 hr while birding at Sithakiri Malai (10.732 ^{0}N, 77.694 ^{0}E), Kuppanavalasu of Dindigul District of Tamil Nadu, two individuals were recorded actively foraging near cliff faces and occasionally perching on a crag. It is a rocky hill at 350 m surrounded by grasslands and agricultural lands.

The Eurasian Crag Martin is assessed as 'Least Concern' on the IUCN Red List (BirdLife International 2024) and listed under Schedule-II of Wildlife (Protection) Act 1972. It is listed as species with a high priority with long-term (the proportional change in frequency of reporting in 2022 when compared with the frequency before the year 2000) trend with a rapid decline (79%) and a current annual (the average annual change in frequency of reporting during the year 2015–2022) trend with the decline (5.51%) in the population (SoIB 2023) with limitations of the study (Maitreyi 2024), even though it's stable globally (BirdLife International 2024).

This is the first sighting of Eurasian Crag Martin in Tamil Nadu. Birders overlook these birds due to their small size, speed, and altitude at which they fly (Shendokar & Kukade 2016). Sighting reports of these species are important to predict their migration routes, and range extension and to protect them.

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Image 1–2. Eurasian Crag Martin *Ptyonoprogne rupestris* perching in a crag. © Naveen Kumar S.

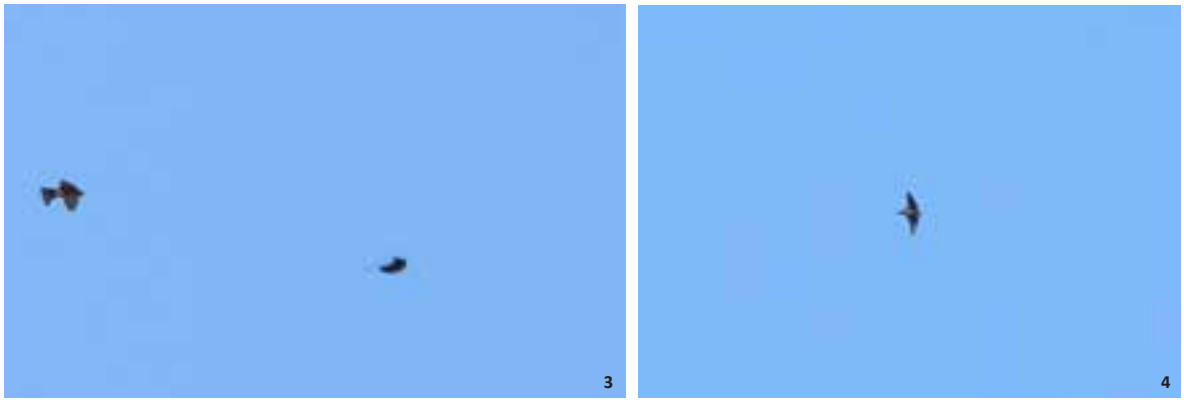

Image 3–4. Eurasian Crag Martin *Ptyonoprogne rupestris* in flight. © Naveen Kumar S.

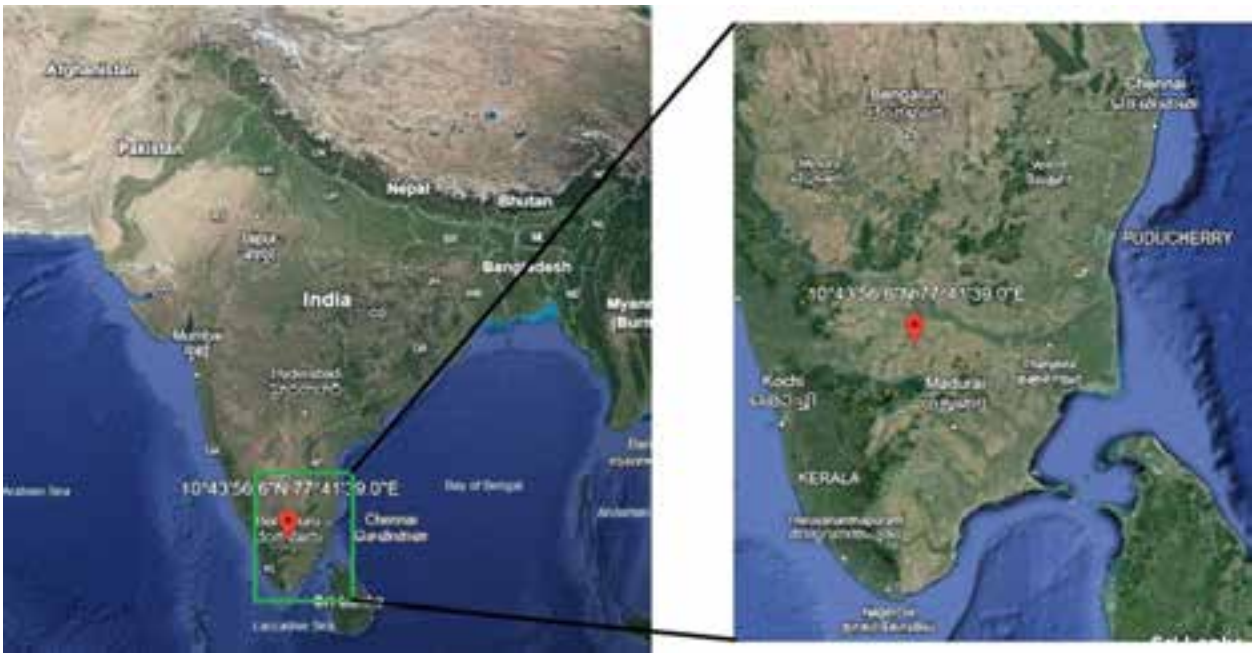

Image 5. Map showing sighting locations of Eurasian Crag Martin in Tamil Nadu, India.

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NOTE

Megachile vera Nurse, 1901 (Insecta: Hymenoptera: Megachilidae): a new record of leaf cutter bee from Kerala, India

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Family Megachilidae is the third largest bee family in the world with 4,169 species and with 239 species records from India (Ascher & Pickering 2024). They are a family of bees with long-tongue just like the bees of family Apidae but the fore wing of Megachilidae has only two submarginal cells, except in Fideliini (Michener 2007). Genus *Megachile* Latreille, 1802 comprises of Leaf-cutter bees, resin bees and mason bees (Sardar et al. 2021). They are robust, non-metallic bees with tergal fasciae, and females of this genus bear abdominal scopa (Gupta 1993). Bees of this genus are excellent pollinators of many crops. Prakash & Bijoy (2022) recorded two new reports of *Megachile* bees from Kole wetlands of Kerala. In the present study, a specimen of *Megachile vera* Nurse, 1901 was collected from Palakkal which is a part of the Thrissur North Kole. A single female specimen of *M. vera* was caught in white pan trap that was kept in the study site during field day. This species has been reported from various states of India (Figure 1) including Rajasthan (Alwar, Deeg, Sikar, Kota, Udaipur) Haryana (Hisar, Sonipat), Gujarat (Deesa, Veeraval, Dantiwada), Punjab, Maharashtra, Himachal Pradesh, Dadra & Nagar Haveli, Odisha, Tamil Nadu, and West Bengal (Gupta 1993; Kumari et al. 2019; Sardar et al. 2021; Ascher & Pickering 2024). According to Gupta (1993) the species, *M. vera,* belongs to subgenus *Eutricharaea* Thomson. But based on the latest update of world bee species guide and checklist the subgenus of the species is uncertain (Ascher & Pickering 2024). So, here we are not categorizing the species into subgenus level.

Detailed redescription of *M. vera* is provided here along with images. Species identification was done using original description by Nurse (1901) and subsequent detailed description by Gupta (1993). Labomed Luxeo 6z microscope was used for identification and Leica DMC4500 digital camera mounted on a Leica M205 C stereo microscope was used to take images of the specimen. This species is a new addition to the bee fauna of Kerala.

***Megachile vera* Nurse, 1901 (P.150)**

Major diagnostic features of *M. vera* includes dull orange colouration beneath fore femora, apex of trochanter and femur of meso and metathoracic legs and terminally tapered, slightly upturned apex of abdomen.

Female: Total length: 11.09 mm

Head: Black with white pubescence; strongly punctate: white pubescence absent on middle region of

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clypeus, supra clypeus and vertex; clypeus with medio-longitudinal smooth line; supra clypeus impunctate; apical margin of clypeus with emarginations; scape, pedicel black, flagellomeres light brown; pedicel and F1 almost equal in length; F1 slightly shorter than F2; mandible 4 dentate, base covered with white pubescence, incomplete cutting edge in 2nd and complete cutting edge in 3rd interspace; gena with slightly yellowish-white pubescence; genal area close to mandible with long white branched hairs; vertex strongly punctate with incurved margin.

Mesosoma: Closely and coarsely punctate; scutum slightly convex, anterior and lateral margins with yellowish-white pubescence; disc of scutum and scutellum bare or with few yellowish-white hairs; scutellum slightly convex with rounded posterior margin; wings hyaline with brown veins; tegulae brown, finely punctate; propodeum finely and closely punctate, covered with long yellowish-white hairs; legs with white hairs except on the underside of tarsi; fulvous hairs on the underside of tarsi; fore femora underneath, apex of trochanter and femur of mid legs, trochanter and femur of hind legs dull orange; base of claws with setae.

Image 1. Habitat of the collected specimen. © Anju Sara Prakash.

Metasoma: Tapering towards posterior end and slightly upturned; black with fine, close punctures at base of tergal segments and coarse punctures towards

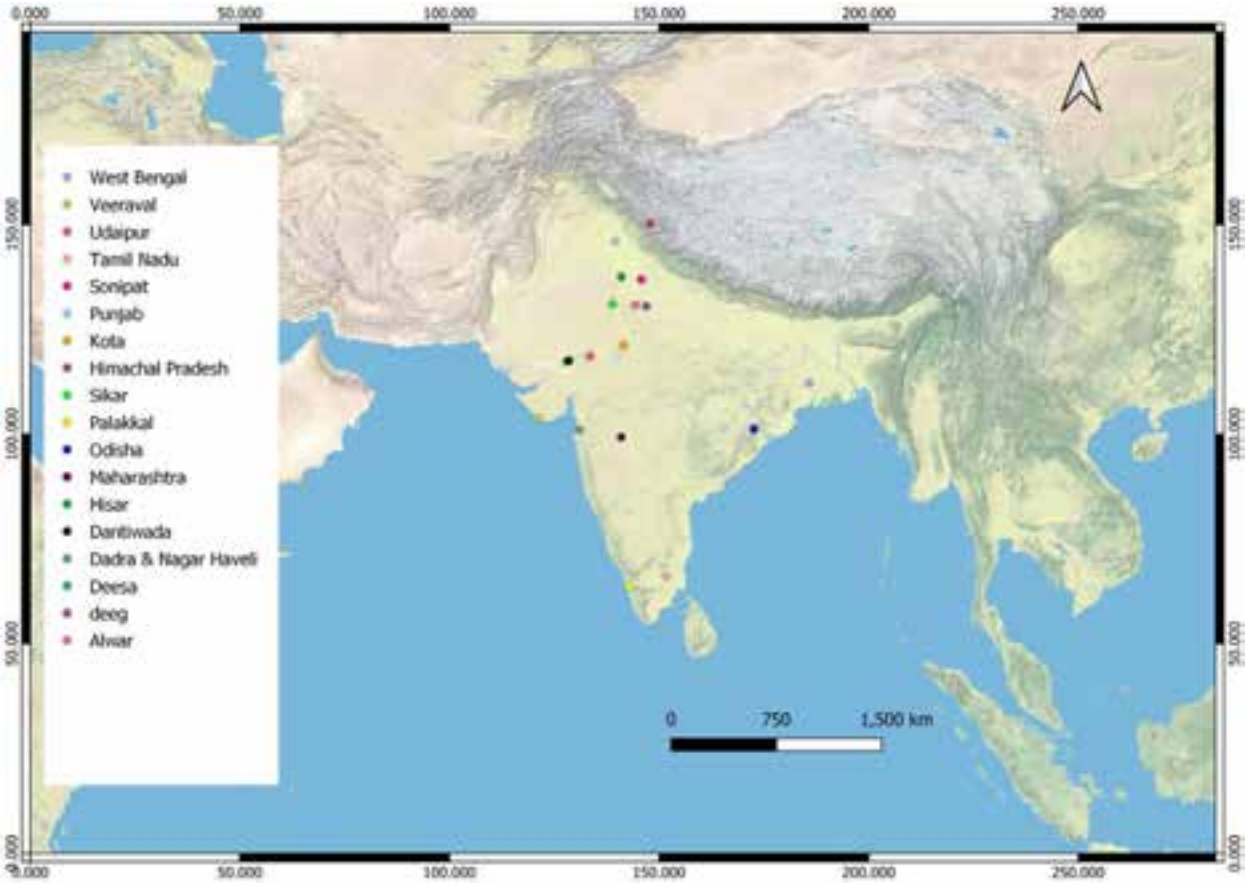

Figure 1. Distribution map of *Megachile vera* from India.

Image 2. *Megachile vera* Nurse, 1901: A—Habitus dorsal view | B—Habitus lateral view | C—Habitus ventral view showing parts of legs with dull orange colour | D—Abdomen showing slightly upturned apex. © Anju Sara Prakash.

apex; T1 covered with long yellowish white hairs; T2–T5 with yellowish-white fasciae; T6 with black hairs; T1–T5 laterally with long white hairs; T6 laterally with long black hairs; Sternum black except slightly brownish on the apical margins of S2–S5; scopal hairs on S2–S5 pale white; scopal hairs on S6 black; S6 finely punctate at base, coarsely towards apex; apical region with fringe of short black hairs.

Material examined: 1 female, 16.ii.2021, Palakkal, Thrissur (10.478735 °N, 76.21322 °E), White pan trap collection.

Remarks: This species resembles *Megachile femoratella* Cockerell, 1918 in having dull orange-coloured femora of legs. Unlike *M. vera*, *M. femoratella* doesn't have terminally tapering abdomen.

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