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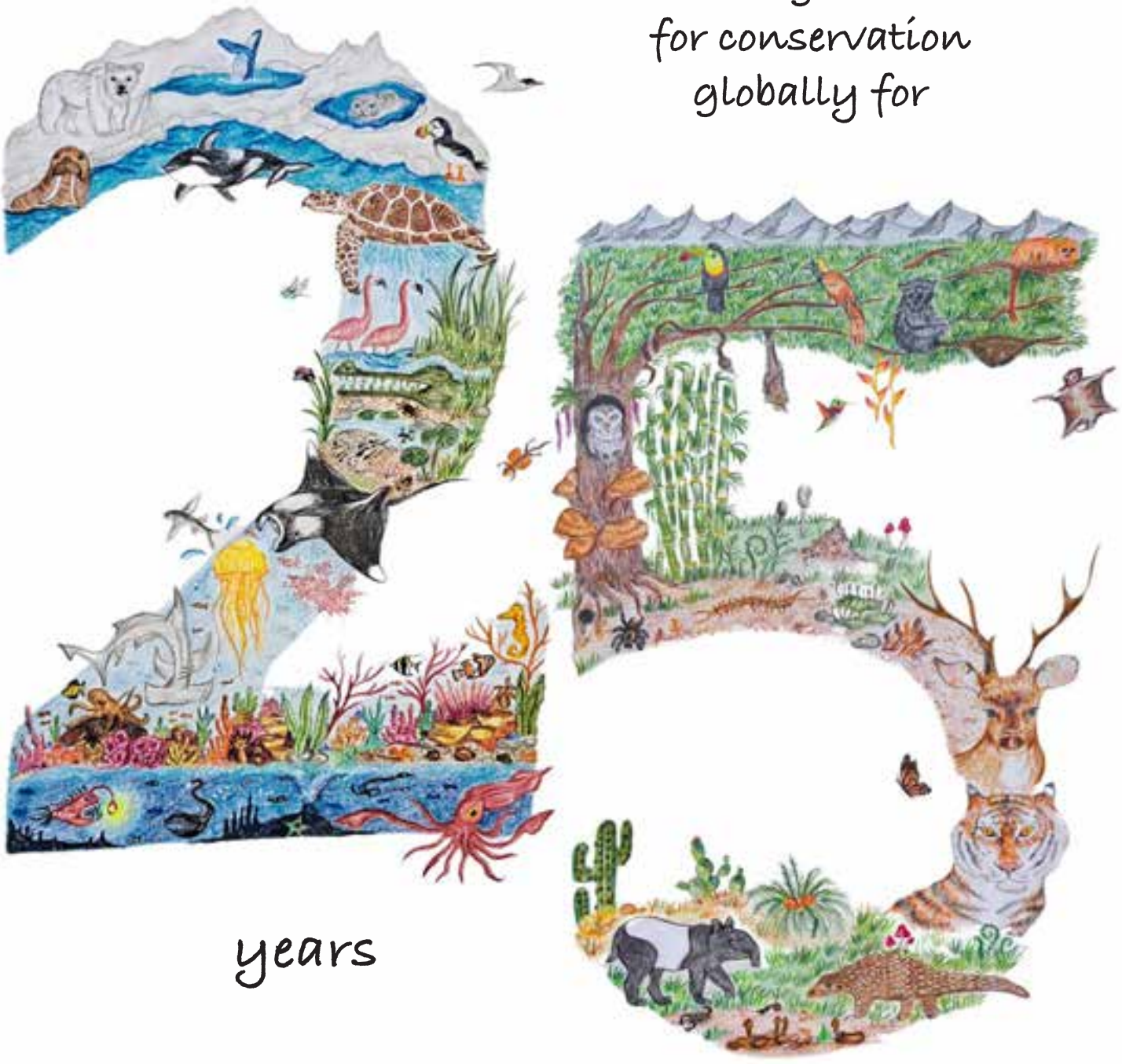
Building evidence for conservation globally for



years

Silver Jubilee Issue

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continued on the back inside cover

Cover: The breathtakingly beautiful SIlver Jubilee cover of JoTT is done in color pencils and ink by the 13-year old darling, Elakshi Mahika Molur.

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EDITORIAL

Celebrating 25 years of building evidence for conservation

For a quarter of a century, the *Journal of Threatened Taxa* has been serving a critical role in conservation. Every month, without fail, the pages of this open access online publication fill up steadily with words that describe the wonders of the natural world — as observations, scientific experiments, or opinions — serving over 120,000 readers across the world.

A product made in India without the hype or hoopla, serving scientists, organizations, conservationists, wildlifers, educators, veterinarians, pathologists, environmentalists, communities, independent researchers, and institutions among others. *JoTT* — as it is popularly known — has grown from a 12-page peer-reviewed section of *Zoos' Print* in April 1999 to this issue of March 2024 with 200 pages. A journey, as the founder, I never thought of in my wildest imagination to achieve this.

I would like to imagine, given its popularity, *JoTT* is a cornerstone for conservationists, scientists, and enthusiasts worldwide; and I have been told repeatedly that it is a beacon of excellence serving the community at large.

The legendary Sally Walker and I realized the need for a peer-reviewed journal in the late 1990s during our various Conservation Assessment and Management Plan (CAMP) workshops to assess the Red List status of species from various groups (Mammals, Plants, Reptiles, Amphibians, Invertebrates, Fish) across India. A common thread of complaint from all scientists and biologists in the various workshops was the lack of a timely and affordable peer-reviewed journal that would help publish articles relevant for conservation quickly and be freely available. The costs of purchasing articles in those days were prohibitive for most Indians as well as other southern Asians, and we had heard the same to be true of other biodiversity-rich countries around the world that were poor. So, the seed of our next adventure was sown in those different workshops in 1997–98. As the number of technical articles submitted to *Zoos' Print* increased, we decided to submit some of those to experts to review. The encouragement from the scientific world spurred us to start a peer-reviewed section called *Zoos' Print Journal*. And, we have come a long way since.

Zoos' Print Journal lasted until December of 2007 when we decided that it had reached a stage where a standalone journal with a name more inclusive than what was at that point in time would have a better impact. Based on the experience of *ZPJ*, we renamed it as the *Journal of Threatened Taxa* in January 2009. *Zoo's Print* continues to be published as a disseminator of information for conservation science on the 21st of every month while *JoTT* is published on the 26th of every month.

With the combination of *ZPJ* and *JoTT*, this 25th-anniversary edition is the 318th issue (Totally, there have been 105 issues of *ZPJ*, 183 regular issues of *JoTT*, and 30 Monographs in *JoTT*). Other milestones include almost 28,000 pages combined and this issue crossing the 25,000 pages in the new avatar (25,018 pages); the total number of articles published is 3,873 (965 in *ZPJ* and 2,908 in *JoTT*).

Many people have contributed significantly to the evolution of JoTT, starting from Binu Priya who helped manage *ZPJ* initially for a couple of years, followed by B. Ravichandran who took over as the managing editor of *JoTT*. Ravi's contribution has been invaluable. The periodicity, solidity, and frequency of *JoTT* are purely due to his dedication, patience, and perseverance. Another person who has shaped *JoTT* is Latha Ravikumar, whose dogged application, determination, tireless contribution to building, maintaining, updating, backing-up, archiving, and constantly fixing the website has ensured its near smooth performance. Without these two people, I would have been hard-pressed to keep *JoTT* going. Other people in the office who have helped out include Priyanka Iyer, and more recently Usha Ravindra and Trisa Bhattacherjee for the copious amounts of copyediting they volunteer. Thanks are also due to the remote staff, Melito Pinto and Paloma Naronha, for helping with copyediting. A special shout-out to our enthusiastic volunteers, Fred Pluthero, Mira Bhojwani, and P. Ilango who have given many an article better shape in their presentation style and language.

I am indebted to more than 150 subject/section editors for their constant support and tireless efforts, but would like to mention a few names who have stood by and delivered consistently — Drs. Mewa Singh, Priya

Davidar, L.A.K. Singh, Mandar Paingankar, Hemant Ghate, Pankaj Kumar, Solomon Raju, John Caleb, Angie Appel, H.N. Kumara, & S.R. Ganesh among others; Raju Vyas & H. Byju; and several others whom I apologize for not mentioning by name due to space. I wish to thank each and every one of the thousands of reviewers, who have shaped the publications. I am indebted to two friends who have stood by us with monetary support—Drs. Neelesh Dahanukar and Mandar Paingankar—without whose help digitizing and archiving would have been very difficult.

I was unhappy (and still am) to introduce the article processing contribution in 2021 when COVID 19 almost closed *JoTT*. It helped us stay afloat mainly thanks to the staff of WILD and Zooreach who volunteered their time uncomplainingly and still do. I am indebted to the authors who range from novices to top scientists from more than 80 countries who continue to publish in *JoTT* despite the modest APC. They shattered my perception of losing out on authors and submissions when *JoTT* model changed from platinum open access to gold open access. And, I'm thankful to all the readers who use and distribute the publications all over the world making *JoTT* a success.

Ending this celebratory editorial, I wish to thank my office colleagues, who have stood by Sally and me all these years and have braved all the challenges of working in this field. But for them, this journey of *JoTT* would not have been possible. And, of course, the support I get from home from my wife Payal and from our daughter Elakshi Mahika who are rock solid pillars of support and to whom I'm forever indebted. The absolutely amazing cover of this celebratory issue is made by Elakshi. Her varied artistic abilities are a delight to discover every day. I discussed the cover and gave her a free hand at applying herself and she did it with doing her own research, developed the context, and visualized the theme. I had nothing to add to the 13-years old's interpretation of what *JoTT* does and its philosophy. I'm sure she'll make Stephen Nash, the creator and illustrator of the *JoTT* logo, proud.

Sanjay Molur
Founder & Chief Editor, JoTT
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ARTICLE

Identifying plants for priority conservation in Samar Island Natural Park forests (the Philippines) over limestone using a localized conservation priority index

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Abstract: The escalating degradation of ecosystems and the consequent reduction in critical services essential for human communities are global concerns. This study aimed to identify top-priority plants for conservation using a localized conservation priority index (LCPI), customized for the locality. The LCPI, a point scoring method, ranked 50 evaluated species based on criteria such as harvesting risk, economic and cultural use, species distribution, and frequency value. Thirteen species were classified as high priority, requiring stringent harvesting regulations, while the remaining 37 were designated at a medium priority level, allowing specific quotas for harvesting. Notably, all 13 high-priority species exhibited higher harvesting risks. These include *Caryota rumphiana* Mart., *Aquilaria cumingiana* (Decne.) Ridl., *Cycas riuminiana* Regel, *Dracaena angustifolia* (Medik.) Roxb., *Oncosperma tigillarium* (Jack) Ridl., *Oreocnide rubescens* (Blume) Miq., *Kleinhovia hospita* L., *Diospyros blancoi* A.DC., *Codiaeum sp*., *Gymnostoma rumphianum* (Miq.) L.A.S.Johnson, *Caryota cumingii* Lodd. ex Mart., *Artocarpus rubrovenius* Warb., and *Palaquium* sp. Local communities engage in harvesting all parts of certain plant species. Following the identification of priority plants, geotagging was employed to enhance targeted in situ conservation efforts, providing valuable guidance for local leaders in initiating localized conservation of threatened biodiversity.

Keywords: Biodiversity, conservation approaches, endemics, forest ecosystem services, geotagging, habitat protection, karst landscape, priority levels, species distribution, threatened plants.

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INTRODUCTION

Destruction of natural landscapes has been rampant all over the world. This has been one of the triggering bases for the proposed new conservation science by Kareiva & Marvier (2012). Both observed that conservation has been failing and it is until now. A huge track of forests of all types (lowland, lower montane, upper montane, mangroves) dominated by economically and ecologically important tree species (Brown 1921; Ohsawa 1984; Fernando et al. 2008; Buot 2020; Buot et al. 2022; Martinez & Buot 2022) had been destroyed all through these years (Santiago & Buot 2018; Cadiz & Buot 2009, 2010; Caringal et al. 2019; Obeña et al. 2021; Villanueva & Buot 2018; Villanueva et al. 2021a,b; Buot & Osumi 2011; Magcale-Macandog et al. 2022). This massive forest degradation was very prominent during the anthropocene when human activities tended to prevail, aggravating the serious impacts of the global climate change problem (Kamiohkawa et al. 2021; Malhi et al. 2014; Pulhin et al. 2010; Steffen et al. 2007, 2011). The result had been far from what has been expected by humanity: biodiversity loss (FAO 2015), food insecurity (National Research Council 2006; Frongillo 2023), water insecurity (Young et al. 2021; Frongillo 2023), air pollution (National Institute of Environmental Science 2020), eutrophication of water bodies (Yang et al. 2008; Yang 2022), diseases and the subsequent reduction of critical ecosystem services (Anyanwu et al. 2016; Buot et al. 2022) direly needed by the human communities. If this trend is sustained, a remarkable decrease in the community well-being index will be imminent (Buot 2017; Buot et al. 2017; Buot & Cardenas 2018; Buot & Dulce 2019; Buot et al. 2020; Buot & Buot 2022, 2023).

Ecosystem degradation has also been observed in Samar Island Natural Park (SINP) forests over limestone located in central Philippines triggered by both natural and anthropogenic causes. Being located along the Pacific, Samar Island is visited yearly by destructive and fatal typhoons. SINP has one of the most extensive forests over limestone not only in the Philippines but in the southeast Asian region as well. Forests over the limestone of Samar (locally known as 'kaigangan') are characterized by the abundance of calcium due to limestone dissolution, contributing to irregular geomorphology. It has high mineral and aquifer resources, aesthetic, cultural, and tourism value (Fernando et al. 2008; Patindol 2016; Tolentino et al. 2020). Kaigangan is a critical ecosystem serving as a habitats of unique flora and fauna (Obeña et al. 2021; Villanueva et al. 2021a,b; Tolentino et al. 2020) and microorganisms as well. Phase 1 of CONserve-Kaigangan, a research program led by the University of the Philippines Los Baños (UPLB) in collaboration with Samar State University (SSU) and Eastern Samar State University (ESSU), discovered and described new species of science inhabiting the canopy of the forests over limestone. These new species are *Decaisnina tomentosa* MD Angeles, Tandang, Carab.-Ort., & Buot (Tandang et al. 2022), *Corybas kaiganganianus* Tandang, A.S.Rob. & MD Angeles (delos Angeles et al. 2022a), *Begonia normaaguilariae* MD Angeles, Rubite, & Tandang (delos Angeles et al. 2022b), and *Schismatoglottis minuta* Tandang and MD Angeles (delos Angeles et al. 2023). Several new records have been documented too (Fernandez et al. 2020; Obeña et al. 2021; Villanueva et al. 2021a,b). Owing to these unique endemics and indigenous plant and animal diversity, coupled with the beautiful limestone hills and rocks, SINP has been nominated as a UNESCO World Natural Heritage Site.

The nomination of SINP for UNESCO listing should not be the end of conservation action. Rather, it should be the start of a well-meant conservation practice planning. There is a need to localize and prioritize conservation in Samar's kaigangan forests. This is essential in biodiversity conservation since not all plant species have been assessed yet by the IUCN and by the National Committee on Threatened Species in the Philippines. Prioritizing plants helps identify the taxa that need to be targeted for conservation with local communities taking active participation.

The paper aims to generate a list of top-priority plants for conservation at Samar Island Natural Park (SINP) using a localized conservation priority index (LCPI) (Villanueva & Buot 2020; Chanthavong & Buot 2019). Specifically, it determines the identity of plants and their levels of priority, discusses the uses of these plants by the locality, and geotags the occurrences of these priority plants in the plots to enhance in situ conservation.

The paper addresses UN Sustainable Development Goals 5 (Gender equality), 6 (Clean water), 11 (Sustainable cities and communities), 12 (Responsible consumption and production), 13 (Climate Action), 15 (Life on land), and 17 (Partnership to achieve goals).

METHODOLOGY

The Localized Conservation Priority Index (LCPI)

The *Localized Conservation Priority Index* is a point-scoring method used to rank species by the level of priority considering harvesting risk, economic

use, cultural use, species distribution, and frequency value. These criteria make up the environmental and socio-cultural aspects of each species. The sources of information were sourced from surveys, websites to literature sources.

The score ranges from 1 (lowest) to 5 (highest) for each criterion, where a higher score indicates a higher conservation priority. For harvesting risk, economic use, and cultural use, each plant part and use is equivalent to 1 point. Two plant parts and uses are equivalent to two points and so on. In the case of more than five plant parts (roots, leaves, stems, flowers, and fruits) and uses, the score is still 5. Data were gathered from the field plots, literature reviews, and local key informants. For the species distribution, we gathered data from the floras (Merrill 1923–1926; Pelser et al. 2011-onwards; Rojo 1999) and online databases like the International Plant Name Index (IPNI 2020) and World Flora Online. The more restricted the distribution of a species, the higher the score owing to rarity and the likelihood of the species becoming extinct in the future. If the species is only found in Samar, it receives a score of 5. Four (4) if found in Visayas, three (3) if found in Visayas and Mindanao, two (2) if found in the Philippines, and one (1) if found in Asia and the world (Cosmopolitan). The frequency value has been based on the plot data, referring to the occurrence value of each plant in the study site. A score of 5 for frequency values ranging 0–20, indicates vulnerability to risk. Frequency values of 21–40, 41–60, 61–80, and 81–100 will have scores of 4, 3, 2 and 1, respectively.

The formula that is used in this study is a modification from Villanueva & Buot (2020):

Localized Conservation Priority Index (LCPI) = *Harvesting Risk (HR) + Economic Use (EU) + Cultural Use (CU) + Species Distribution (SD) + Frequency Value*

A guide in categorizing the conservation priority levels for each plant and the appropriate action to take has been prepared as adopted by Villanueva & Buot (2020).

Geotagging of the priority plants

After identifying the priority plants at SINP, the top 20 priority plants with the highest conservation priority scores were geotagged to enhance in situ conservation. Geotagging was done manually within the 18 sampling plots in SINP using the Google Earth application to determine the latitude and longitude coordinates of each of the top 20 priority plants.

RESULTS AND DISCUSSION

Determining the localized conservation priority scores of plants at Samar Island Natural Park

Samar Island forests over limestone are one of the largest limestone formations in the Philippines, serving as a habitat for unique flora and fauna (Tolentino et al. 2019, 2020). Existing data available from the floral assessment of CONserve-KAIGANGAN in Paranas, Samar, and Taft, Eastern Samar support a high level of floral diversity and endemism of Samar kaigangan.

The evaluation of 50 plant species across 24 families in our study plots (see Table 2) utilized the LCPI, modified from Villanueva and Buot (2020), to identify the top 20 plants for priority conservation. The LCPI results categorized 13 plant species with high priority levels, scoring between 17 and 20, while the remaining 37 were classified with medium-priority levels (refer to Table 2). Notably, all 13 high-priority species scored 5 points for the harvesting risk criterion, indicating that all plant parts—roots, stems, leaves, flowers, and fruits—are susceptible to harvesting at any time. These high-priority species, such as *A. cumingiana, C. rumphiana, G. rumphianum, O. rubescens, Codiaeum* sp., and *K. hospita*, are primarily used for medicinal purposes by residents of Samar (see Table 3). Ornamental and landscaping uses are also common, with cultural applications noted for species like *C. rumphiana, C. cumingii*, and *A. cumingiana* employed in religious and festival activities, including church ornaments and decorations in Samar. Geographically, these high-priority species exhibit a mostly cosmopolitan distribution in SINP (Table 3), indicating their presence beyond the Philippines. Additionally, most priority species scored 5 points and exhibited frequency values ranging 1–20, signifying a sparse occurrence in the study plots. Given the extensive uses of these 13 high-priority species, with scores ranging 17–20, there is a critical need for strict regulation to prevent overexploitation.

Table 1. Priority scores and priority levels for each plant and the corresponding recommended action to take.

Score	Priority level	Decision
1–8	Low	Suitable for high-impact harvesting
9–16	Medium	Can be harvested with specific quotas
17–25	High	Require strict regulation in harvesting

Image 1. Top 5 priority plants in SINP: a—*Caryota rumphiana* | b—*Aquilaria cumingiana* | c—*Cycas riuminiana* | d—*Dracaena angustifolia* | e—*Oncosperma tigillarium*. © CONserve-KAIGANGAN project.

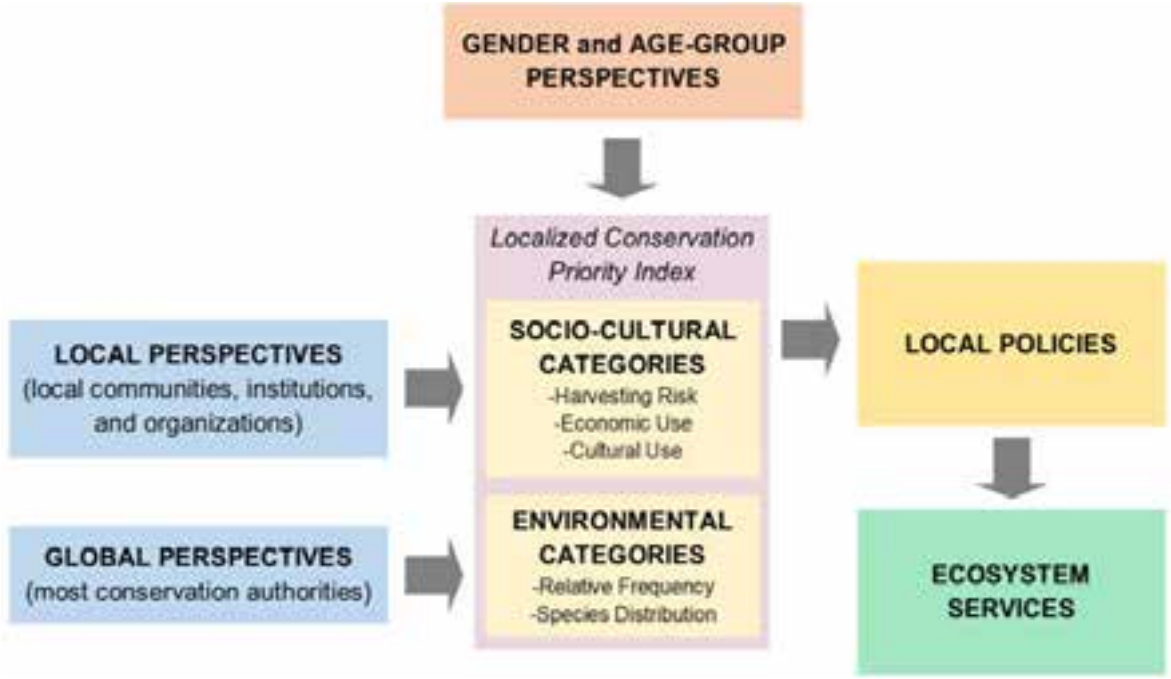

Figure 1. Framework for localized conservation for sustained ecosystem services.

Some Notes on the top 20 plants for priority conservation

Overall, the top 20 priority plants in SINP are composed of 17 species from Paranas, Samar, and eight species from Taft, Eastern Samar.

As seen in Table 3, there are a few high-priority level species that are considered threatened on a national and global scale. At the national level, among the top 20 priority plants in SINP, six are vulnerable species (*A. cumingiana, C. riuminiana, O. tigillarium, D. blancoi, S. negrosensis,* and *S. contorta*), and three belonging to other threatened species (*G. rumphianum, A. rubrovenius* and *A. rimosa*) (DAO 2017–11). On the other hand, at the global scale, IUCN (2022) identified one critically endangered species (*H. wenzeliana*), one endangered species (*C. riuminiana*), one vulnerable species (*A. cumingiana*), seven least concern species (*C. rumphiana, O. rubescens, K. hospita, C. hirsutum, P. nodosa, S. negrosensis,* and *S. contorta*), one near threatened species (*A. rimosa*), and one data deficient species (*C. cumingi*). It's noteworthy that the majority of priority plants in SINP lack recorded conservation status on both national and global scales. Surprisingly, many of these crucial plants, extensively utilized at the local level for various purposes, remain largely unexplored. The application of LCPI becomes crucial in documenting locally threatened biodiversity. These priority plants, under threat, hold immense economic significance, serving purposes such as food, medicine, timber, handicrafts, building materials, and ornamental use, as highlighted by Medecilo-Guiang et al. (2021).

***Caryota rumphiana* Mart.**

Caryota rumphiana is the top-ranking species, with an LCPI score of 20 points (Table 2). It is edible and can be used to make a variety of dishes, as well as raw material for furniture (Tropical Plants Database 2022). The fiber of this species is used for fish traps, for sewing, for kindling fires, and as wadding (Tropical Plants Database 2022). It is also used as an ornamental plant. In Samar Island, the leaves are used for church and for fiesta as decoration. The locals also reported that the roots are utilized for herbal medicine. *C. rumphiana* is distributed in the areas of Bismarck Arch, Moluccas, New Guinea, Solomon Island, and Sulawesi. In the Philippines, it was recorded in the province of Samar (Pelser et al. 2011 onwards).

***Aquilaria cumingiana* (Decne.) Ridl.**

Rank 2 is *A. cumingiana* obtaining a score of 19-points in SINP. This species is commonly known as agarwood and is valued for its highly priced resins extracted from the bark. The expensive resins are used to make perfume and aromatics, which are commonly used for ceremonial incense of rituals and other religious activities. Additionally, this species is used for furniture and traditional medicine (Tawan 2003; Persoon 2008). The locals in Samar Island also utilized the leaves and roots as an ingredient to make a coffee. It is distributed in Borneo, Moluccas, and the Philippines (Pelser et al. 2011 onwards).

***Cycas riuminiana* Regel**

The third in rank is an endemic species used by the locals in Samar as herbal medicine and as ornaments for churches and fiestas. It is distributed in the provinces of Bataan, Batangas, Cagayan, Cavite, Ilocos Norte, Isabela, Laguna, Pampanga, and Mindoro (Pelser et al. 2011 onwards).

***Dracaena angustifolia* (Medik.) Roxb.**

This species is occupying the fourth rank. It is found all throughout the Philippines and in countries such as Andaman Islands, Australia, Bangladesh, Bismarck Arch, Borneo, Cambodia, China, India, Java, Laos, Lesser Sunda Islands, Malay Peninsula, Moluccas, Myanmar, New Guinea, Nicobar Islands, Solomon Islands, Thailand, and Vietnam (Pelser et al. 2011 onwards). The plant is used as ornamental and fodder. The roots and leaves of this species can be used for medicine and the sap is used as a dye (POWO 2022; Tropical Plants Database 2022).

***Oncosperma tigillarium* (Jack) Ridl.**

The species is primarily used for housing and construction material particularly by Samar residents. Its leaves of can be a source of fiber and used as a raw material for making baskets and other weaving products (Tropical Plants Database 2022). Additionally, the buds and flowers of this plant are edible, while the roots are used as traditional medicine (Tropical Plants Database 2022). The other parts of this plant, such as sap and spines on stems are used as hunting instruments (Tropical Plants Database 2022). The whole plant is also ideal for landscaping (Fernandez et al. 1995). This species, the fifth in rank, is distributed in Borneo, Cambodia, Java, Malay Peninsula, Sumatra, Thailand, and the Philippines (Pelser et al. 2011 onwards).

***Oreocnide rubescens* (Blume) Miq.**

The leaves and shoots of this species are edible (Brink et al. 2003). The bast can produce fiber and the bark can be a source of dye (Brink et al. 2003). In Samar, the locals used the roots as herbal medicine. In other countries, it is utilized as a living fence (Brink et al. 2003). In the Philippines, this species occupying the 6th rank, is

Table 2. Conservation priority classification of plant species in Samar Island Natural Park.

Family/ Scientific name	Common name	HR	EU	CU	SD	FV	Total score	Priority level
Araliaceae								
Polyscias nodosa (Blume) Seem.	Bongliw	4	3	2	1	5	15	Medium
Arecaceae								
Caryota cumingii Lodd. ex Mart.	Karyota	5	3	2	2	5	17	High
Caryota rumphiana Mart.	Pugahan/ Tagabunga	5	5	4	1	5	20	High
Heterospathe intermedia (Becc.) Fernando	Banga	5	3	2	2	1	13	Medium
Oncosperma tigillarium (Jack) Ridl.	Anibong	5	5	2	1	5	18	High
Asparagaceae								
Dracaena angustifolia (Medik.) Roxb.	Tulang	5	5	2	1	5	18	High
Burseraceae								
Canarium hirsutum Willd.	Milipili	3	5	2	1	5	16	Medium
Casuarinaceae								
Gymnostoma rumphianum (Miq.) L.A.S.Johnson	Agoho del Monte	5	4	2	1	5	17	High
Clusiaceae								
Calophyllum soulattri Burm.f.	Pamintaogon	5	5	2	1	1	14	Medium
Garcinia rubra Merr.	Diis	2	1	2	2	5	12	Medium
Garcinia sp.	Madbad	2	1	2	2	5	12	Medium
Cornaceae								
Mastixia sp.	Tul-anan	4	2	2	2	4	14	Medium
Cycadaceae								
Cycas riuminiana Regel	Pitogo	5	2	4	2	5	18	High
Dipterocarpaceae								
Hopea philippinensis Dyer	Gisok	4	3	2	2	3	14	Medium
Shorea astylosa Foxw.	Yakal	4	4	2	2	1	13	Medium
Shorea contorta S.Vidal	White lauan	4	2	2	2	5	15	Medium
Shorea negrosensis Foxw.	Red lauan	5	5	2	2	1	15	Medium
Vatica mangachapoi Blanco	Bunguran Yakal	4	3	2	1	5	15	Medium
Ebenaceae								
Diospyros blancoi A.DC. syn.: *D. discolor* Willd.	Kamagong	5	5	2	1	5	18	High
Euphorbiaceae								
Codiaeum macgregorii Merr.	Marumanga	1	1	2	2	5	11	Medium
Codiaeum sp.	Dug-an	5	4	2	2	5	18	High
Hancea wenzeliana (Slik) S.E.C.Sierra, Kulju & Welzen	Apanang	4	3	2	2	5	16	Medium
Macaranga bicolor Müll.Arg.	Pailig	3	2	2	2	5	14	Medium
Tritaxis ixoroides (C.B.Rob.) R.Y.Yu & Welzen				2	2	5	9	Medium
Fabaceae								
Wallaceodendron celebicum Koord.	Banuyo/ Salukigi	5	2	2	2	4	15	Medium
Gnetaceae								
Gnetum gnemon L.	Bago	4	3	2	1	5	15	Medium
Lamiaceae								
Teijsmanniodendron ahernianum (Merr.) Bakh.	Kulipapa	3	3	2	1	5	14	Medium

Family/ Scientific name	Common name	HR	EU	CU	SD	FV	Total score	Priority level
Malvaceae								
Kleinhovia hospita L.	Tan-ag	5	5	2	1	5	18	High
Meliaceae								
Aglaia rimosa (Blanco) Merr.	Balubar / Bayanti	4	4	2	1	5	16	Medium
Vavaea amicorum	Nangka-nangka	3	3	3	1	5	15	Medium
Moraceae								
Artocarpus rubrovenius Warb.	Tugop	5	5	2	2	3	17	High
Ficus glandulifera var. camiguinensis	Katol	3	4	2	1	5	15	Medium
Ficus ampelas Burm.f.	Upling-gubat	2	3	2	1	5	13	Medium
Pandanaceae								
Benstonea copelandii (Merr.) Callm. & Buerki	Bariw	5	2	2	2	3	14	Medium
Phyllanthaceae								
Bridelia glauca Blume	Anislag	4	3	2	1	5	15	Medium
Rubiaceae								
Lasianthus trichophlebus Hemsl. ex F.B.Forbes & Hemsl.	Malabunot	5	3	2	1	5	16	Medium
Psychotria sp.		4	2	2	2	5	15	Medium
Neonauclea formicaria (Elmer) Merr.	Hambabalud	4	2	2	2	3	13	Medium
Salicaceae								
Flacourtia sp.	Hagupit	3	2	2	2	5	14	Medium
Sapotaceae								
Manilkara fasciculata (Warb) H.J.Lam & Maas Geest.	Patsaragon	4	5	2	1	1	13	Medium
Palaquium cf. *elongatum*	Long-leaved Nato	3	2	2	1	5	13	Medium
Palaquium sp.	Bagotambis	5	4	2	2	4	17	High
Pouteria velutina Elmer	Wakatan	3	1	2	2	4	12	Medium
Thymelaeaceae								
Aquilaria cumingiana (Decne.) Ridl.	Lapnisan/ Agar	5	5	3	1	5	19	High
Gonystylus reticulatus (Elmer) Merr.	Batuan			2	3	5	10	Medium
Urticaceae								
Oreocnide rubescens (Blume) Miq.	Lingatong	5	5	2	1	5	18	High
unidentified (Barit)	Barit	4	1	2	2	5	14	Medium
unidentified (Sumol)	Sumol	4	1	2	2	5	14	Medium
unidentified (Buskayan)	Buskayan			2	2	5	9	Medium
unidentified (Urukay)	Urukay			2	2	5	9	Medium

distributed in Laguna, Quezon, and Mindanao. It is also found in other neighboring islands of Java, Moluccas, and Sulawesi (Pelser et al. 2011 onwards).

***Kleinhovia hospita* L.**

The timber of this species is used for furniture and fuelwood, while the fiber is a raw material for rope (NRMC 1986). It has been used as an ornamental and the leaves are edible and have medicinal properties (NRMC 1986). Actually, the locals in Samar use this species which is in the 7th rank as herbal medicine. It is distributed in other countries such as Bangladesh, Caroline Island, Fiji, Hainan, Lesser Sunda Island, Malaya, Nansei-shoto, Samoa, Society Island, Solomon Island, Taiwan, Tonga, Vanuata, and Vietnam (POWO 2022).

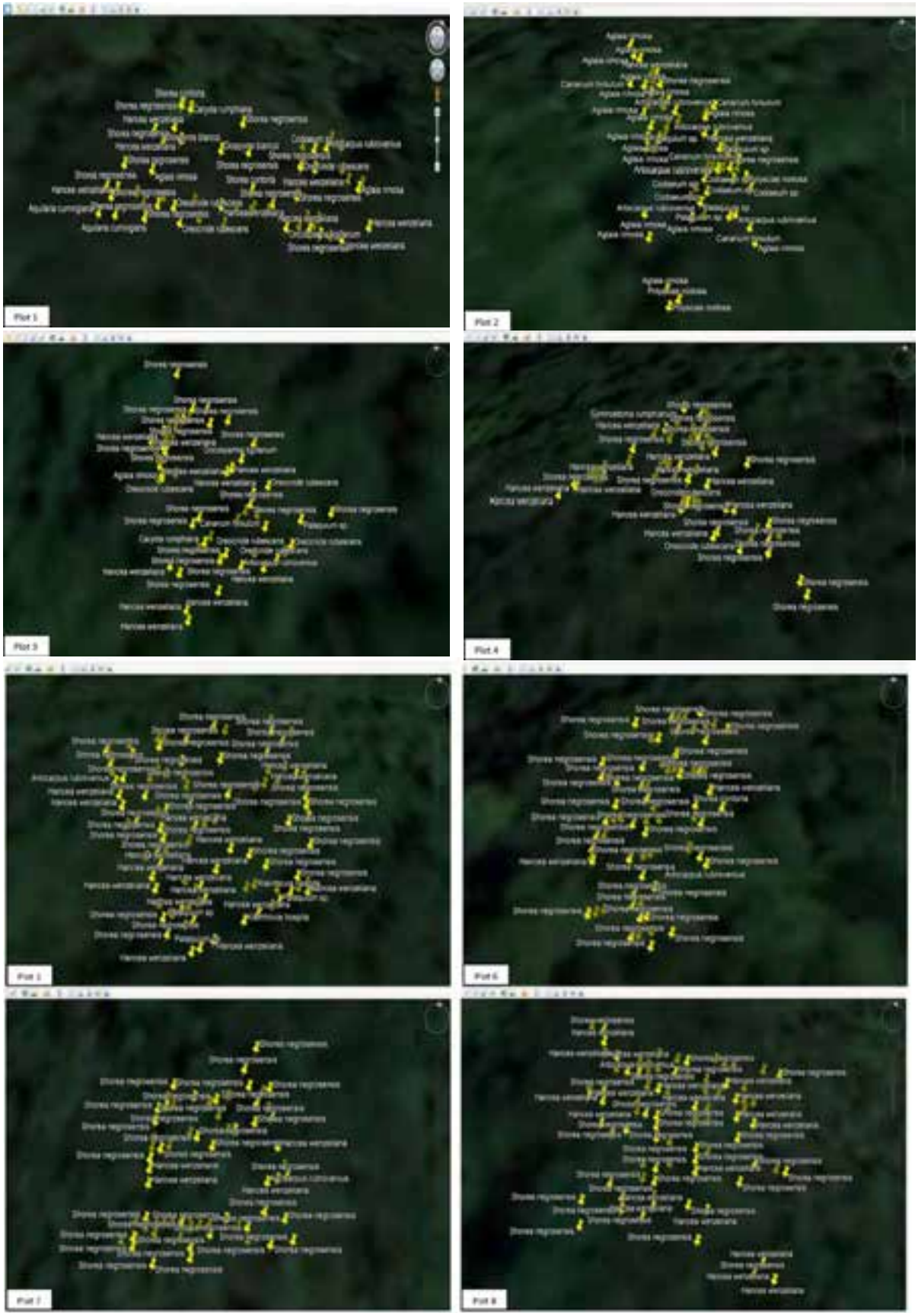

Image 2. Geotagging of priority plants in the municipality of Paranas, Samar in SINP.

Image 2. Geotagging of priority plants in the municipality of Paranas, Samar in SINP. (cont.)

***Diospyros blancoi* A. DC.**

Like other species, it is used as a material for handicraft, furniture, and construction purposes (Tomas-Carig 2020). This species is ranked 8th and the fruit of this species is edible, and the bark, leaves, and seeds are also used as medicine (Coronel 1991; Tomas-Carig 2020). This species is native to the Philippines and is also distributed in Taiwan and Borneo (POWO 2022).

***Codiaeum* sp.**

This species ranked ninth in the LCPI and has not yet been identified at the species level. Samar residents used this species for medicine, building materials, firewood, and animal forage.

***Gymnostoma rumphianum* (Miq.) L.A.S.Johnson**

This species is used for housing material, fuelwood, and as an ornamental. It is ranked 10th and can also be utilized for pulp making (Sosef & van der Maesen 1997). It is native to the Philippines and is distributed in other countries such as Moluccas, New Guinea, and Sulawesi (Pelser et al. 2011 onwards).

***Caryota cumingii* Lodd. ex Mart.**

Ranked 11th, *Caryota cumingii*, is used as a raw material for weaving products. This species is edible and can be cooked as vegetables as well as ingredient to make sago starch, sugar, and alcoholic beverages (Tropical Plants Based 2022). The plant is also used as ornamental. It is endemic in the Philippines and is distributed in the Philippine provinces of Guimaras, Apayao, Ilocos Norte, La Union, Laguna, Nueva Ecija, Nueva Viscaya, Pangasinan, Quezon, Rizal, Mindoro, Palawan, Panay, Samar, and Tawi-Tawi (Pelser et al. 2011 onwards).

***Artocarpus rubrovenius* Warb.**

This species can be used for construction and as a material for wood carving (NRMC 1986). Its bark also has medicinal properties (NRMC 1986). This Philippine endemic is ranked 12th and is distributed in the provinces of Batan, Albay, Aurora, Bataan, Batangas, Camarines, Isabela, Laguna, Pampanga, Quezon, Rizal, Sorsogon, and Mindoro (Pelser et al. 2011 onwards).

***Palaquium* sp.**

In Samar, locals use this plant for construction material. It is in the 13th rank and the fruits are edible and observed to be eaten by birds, monkeys, wild pigs, and deer.

***Hancea wenzeliana* (Slik) S.E.C.Sierra, Kulju & Welzen**

The locals in Samar used the timber of this species for housing and construction material, as well as fuelwood or charcoal. It ranked 14th using the LCPI. In the Philippines, this endemic species is distributed in the province of Surigao del Norte in Mindanao (Pelser et al. 2011 onwards).

***Aglaia rimosa* (Blanco) Merr.**

Aglaia rimosa is used as a housing or building material (Widodo 2003). Additionally, it serves as a traditional medicine to treat swollen stomach and has the potential to have anti-cancer properties (Widodo 2003). It is classified as other threatened species (OTS) in the Philippines' DAO 2017–11. It is ranked 15th and is distributed in the provinces of Alabat, Babuyan Island, Batan, Cebu, Guimaras, Albay, Aurora, Bataan, Batangas, Benguet, Cagayan, Camarines, Cavite, Ilocos Norte, Isabela, Laguna, Nueva Ecija, Nueva Viscaya, Pangasinan, Quezon, Rizal, Sorsogon, Agusan, Davao, Mindoro, Negors, Palawan, Panay, Romblon, Sibutu, Sibuyan, Ticao, and Y'ami (Pelser et al. 2011 onwards).

***Canarium hirsutum* Willd.**

Canarium hirsutum is edible and is used as traditional medicine to treat stomach ailments (Tropical Plants Database 2022). It is ranked 16th and is harvested for its resin (Kochummen 1995). It has also traditionally been used to produce light and as adhesive (Tropical Plants Database 2022). The locals of Samar Island have also reported that they used the resin for lighting, the leaves and roots for herbal purposes, and the timber as firewood and charcoal. The species is widely distributed in the Philippines. It is also distributed in other areas including Bismarck Arch, Borneo, Java, Lesser, Sunda Island, Malay Peninsula, Moluccas, New Guinea, Pacific Ocean, Solomon Island, Sulawesi, and Sumatra (Pelser et al. 2011 onwards).

***Lasianthus trichophlebus* Hemsl. ex F.B. Forbes & Hemsl.**

Lasianthus trichophlebus has a medicinal property potential (Tan et al. 2020). This species is distributed in China, Java, Malay Peninsula, Sulawesi, Sumatra, Taiwan, Thailand, and Vietnam. In the Philippines, it is recorded in the provinces of Mindoro and Palawan (Pelser et al. 2011 onwards). It ranked 17th using the LCPI.

***Polyscias nodosa* (Blume) Seem.**

Polyscias nodosa is used as a housing and construction material. It is ranked 18th and has been reported as good raw material for handicrafts, weaving, and woodworking products (Gapido & Batoon 2009). This species is distributed in Australia, Java, Lesser Sundra Islands, Moluccas, New Guinea, Solomon Islands, and Sulawesi. In Philippines, it is distributed in the provinces of Basilan, Leyte, Bataan, Batangas. Benguet, Ilocos Norte, Laguna, Pangasinan, Quezon, Rizal, Sorsogon, Zambales, and Palawan (Pelser et al. 2011 onwards).

***Shorea negrosensis* Foxw.**

This species is primarily used for housing, construction, and furniture material (Garcia et al. 2013; Ghazoul 2016). The locals in Samar use it as fuelwood. They also observed that the fruits are eaten by birds and wild pigs. The species ranking 19th using LCPI is also known to have tumor-inhibiting properties (NRCM 1986). This endemic is distributed in the Philippine provinces of Basilan, Biliran, Cebu, Leyte, Albay, Aurora, Cagayan, Camarines, Isabela, Laguna, Nueva Ecija, Quezon, Polillo, and Samar (Pelser et al. 2011 onwards).

***Shorea contorta* S.Vidal**

The species is used in housing, construction, furniture, veneer, hardboard, and plywood making (NRMC 1986). It is endemic to the Philippines and distributed in the provinces of Babuyan Islands, Basilan, Leyte, Marinduque, Masbate, Agusan, Lanao, Zamboanga, Mindoro, Negors, Polillo, Samar, and Sibuyan (Pelser et al. 2011 onwards). It ranked 20th in terms of conservation priority.

Geotagging priority plants at Samar Island Natural Park

From the identified top 20 priority plants, we meticulously documented a total of 2,000 individual priority species within SINP. The municipality of Paranas, Samar, revealed 17 priority species and 834 individuals, while Taft, Eastern Samar, exhibited eight priority species with 1,169 individuals. Every one of these plants underwent geotagging to enhance in situ conservation efforts, as illustrated in Image 2 and 3. Geotagging, in this context, refers to the process of attaching geographical metadata to media, such as images and videos, to precisely record the location where the specific data point was captured (Luo et al. 2011). Typically executed using smartphones or GPS-enabled devices, this method involves assigning the media or data points with coordinates, including latitude, longitude, altitude, compass bearing, place names, and other optional fields (Amaral 2014). Demonstrated as cost-effective and secure, geotagging enables teams or

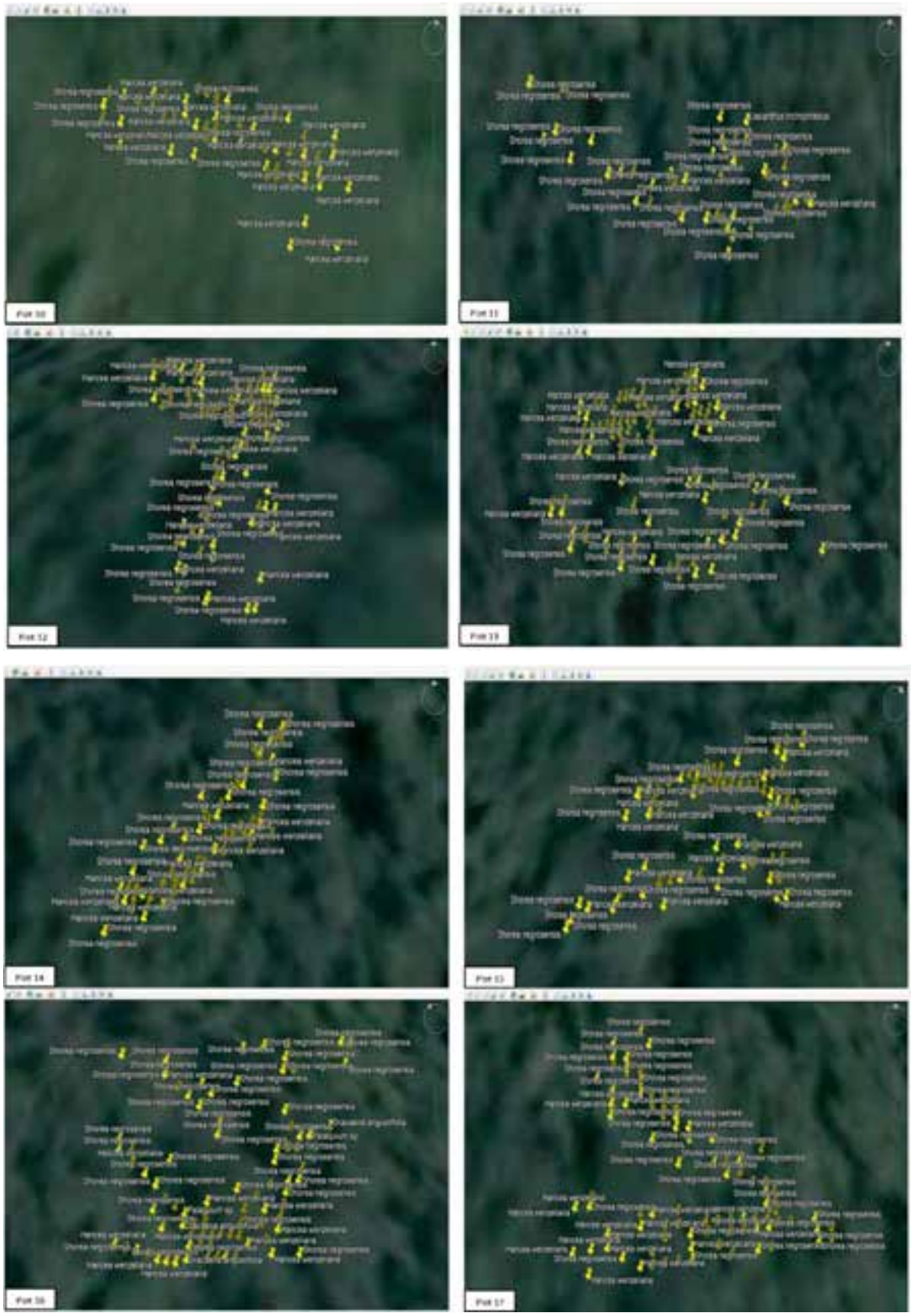

Image 3. Geotagging of priority plants in the municipality of Taft, Eastern Samar in SINP.

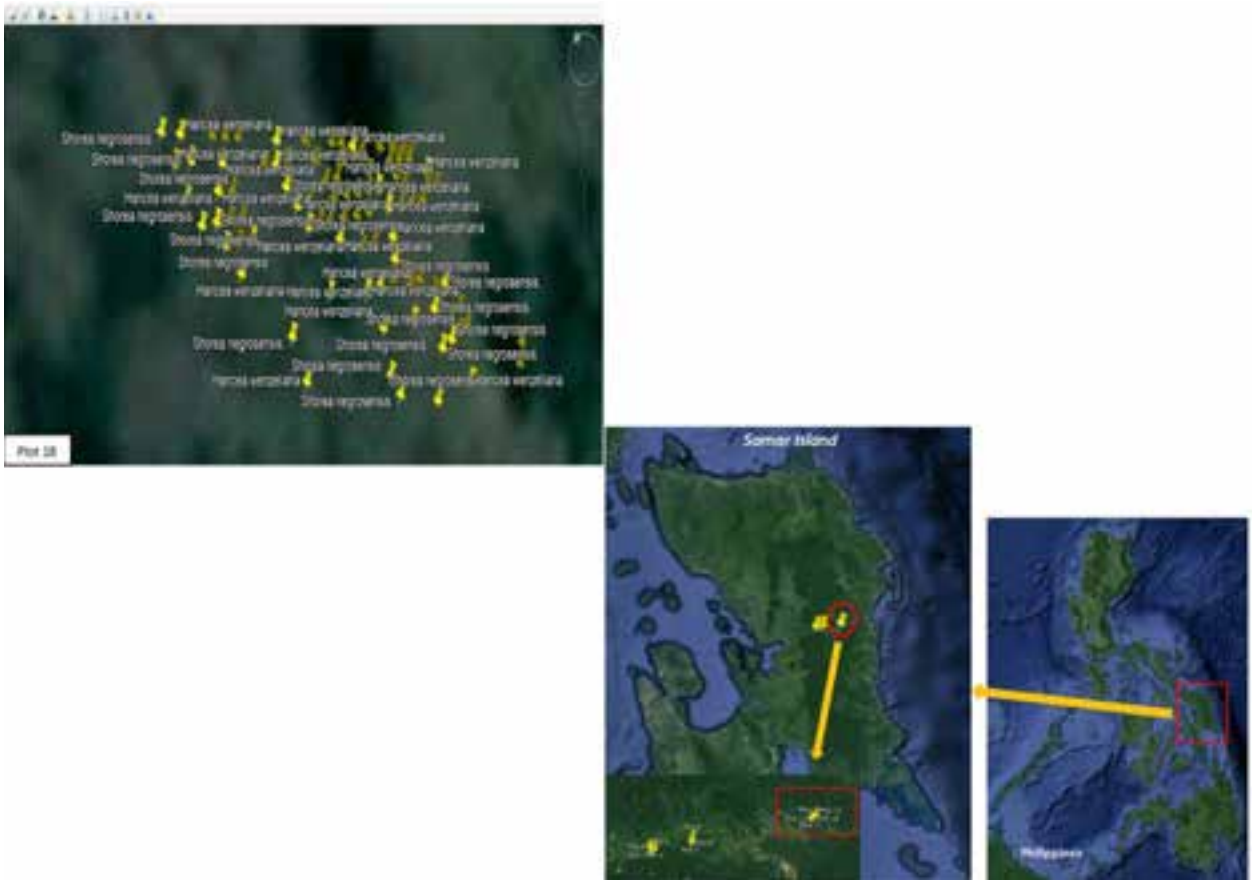

Image 3. Geotagging of priority plants in the municipality of Taft, Eastern Samar in SINP (cont.).

individuals to validate, monitor, and evaluate progress on the ground, thereby streamlining efforts and resources (World Bank 2013). The prevalent species within SINP, identified from the top 20 priority plants, *include S. negrosensis* and *H. wenzelinana*, as highlighted in Figures 2 and 3. Moreover, 89 individuals were meticulously documented from the top 13 species, categorized as high-priority, with 11 species predominantly found in Paranas plots and five in Taft plots. These high-priority species were observed across 10 plots within SINP (plots 1, 2, 3, 4, 5, 7, 8, 10, 13, and 16) (see Image 2 and 3). Noteworthy high-priority species common to both Paranas and Taft plots include *D. blancoi, A. rubrovenius*, and *Palaqium* species. Additionally, among the other high-priority plants, *A. rubrovenius* was exclusively identified in nine sampling plots within SINP, and this species remained the sole observation in plots 6, 7, 8, and 10, based on geotagged data. This underscores the resilience of *A. rubrovenius* in withstanding environmental and anthropogenic disturbances within SINP. Furthermore, two high-priority species, *G. rumphianum* and *C. riuminiana*, each accounted for a singular individual plant, with the former located in plot 4 and the latter in plot 16. Therefore, the essential tracking and monitoring in situ are imperative to safeguard and ensure the survival of these rare plants and their propagules within the protected area. The diminished number of species occurrences is attributed to human disturbances exacerbating agroclimatic anomalies on Samar Island, as outlined in Villanueva et al.'s recent study (2022). These factors significantly influence the physiological performance, encompassing survival, growth, and reproduction, as well as the resource distributions of these species (Bellard et al. 2012; Urban 2015; Howard et al. 2019; Kaspari et al. 2019).

A localized conservation priority framework for sustained ecosystem services

The LCPI serves as a straightforward point-scoring guide designed for local decision-making at the village level, particularly in prioritizing the conservation of locally threatened species. Its framework, depicted in Figure 1, is rooted in a multi-perspective approach to ensure inclusivity. This approach acknowledges the insights originating from local communities, institutions, and

Table 3. Uses, distribution, and conservation status of the species in Samar Island Natural Park.

Family/ Scientific name	Uses	Distribution	Conservation status	
			DAO 2017–11	IUCN
Araliaceae				
Polyscias nodosa (Blume) Seem.	Housing/ construction materials, handicrafts, fodder	Cosmopolitan	-	Least Concern
Arecaceae				
Caryota cumingii Lodd. ex Mart.	Food, handicrafts, plant selling (landscaping, ornamentals, seedling)	Within the Philippines	-	Data Deficient
Caryota rumphiana Mart.	Food, fiber, furniture, medicine, plant selling (landscaping, ornamentals, seedling), religious, festival	Cosmopolitan	-	Least Concern
Heterospathe intermedia (Becc.) Fernando	Fodder, housing materials, plant selling (landscaping, ornamentals, seedling)	Within the Philippines	-	Vulnerable
Oncosperma tigillarium (Jack) Ridl.	Food, medicine, furniture, housing and construction materials, handicrafts, accessories for tapping and hunting animals, plant selling (landscaping, ornamentals, seedling)	Cosmopolitan	Vulnerable	-
Asparagaceae				
Dracaena angustifolia (Medik.) Roxb.	Food, medicine, industrial material, fodder, plant selling (landscaping, ornamentals, seedling)	Cosmopolitan	-	-
Burseraceae				
Canarium hirsutum Willd.	Food, medicine, handicrafts, industrial materials, firewood	Cosmopolitan	-	Least Concern
Casuarinaceae				
Gymnostoma rumphianum (Miq.) L.A.S.Johnson	Firewood, charcoal, housing and construction materials, medicine, plant selling (landscaping, ornamentals, seedling)	Cosmopolitan	Other threatened species	-
Clusiaceae				
Calophyllum soulattri Burm.f.	Food, medicine, furniture, housing and construction materials, handicrafts, accessories for tapping and hunting animals, plant selling (landscaping, ornamentals, seedling)	Cosmopolitan	-	Least Concern
Garcinia rubra Merr.	Food	Within the Philippines	-	Near Threatened
Garcinia sp.	-	-	-	-
Cornaceae				
Mastixia sp.	Housing/ construction materials, furniture	-	-	-
Cycadaceae				
Cycas riuminiana Regel	Medicine, plant selling (landscaping, ornamentals, seedling), festival, religious	Within the Philippines	Vulnerable	Endangered
Dipterocarpaceae				
Hopea philippinensis Dyer	Housing/ construction materials, firewood, fodder	Within the Philippines	Critically endangered	Endangered
Shorea astylosa Foxw.	Medicine, furniture, housing/ construction materials, fodder	Within the Philippines	Critically endangered	Endangered
Shorea contorta S.Vidal	Furniture, housing/ construction materials	Within the Philippines	Vulnerable	Least Concern
Shorea negrosensis Foxw.	Medicine, furniture, housing/ construction materials, firewood, fodder	Within the Philippines	Vulnerable	Least Concern
Vatica mangachapoi Blanco	Housing/ construction materials, furniture, fodder	Cosmopolitan	Endangered	Vulnerable
Ebenaceae				
Diospyros blancoi A.DC. syn.: *D. discolor* Willd.	Food, medicine, furniture, handicrafts, housing/ construction materials, fodder, plant selling (landscaping, ornamentals, seedling)	Cosmopolitan	Vulnerable	-
Euphorbiaceae				
Codiaeum macgregorii Merr.	Medicine	Within the Philippines	-	-
Codiaeum sp.	Medicine, housing/ construction materials, firewood, fodder	-	-	-
Hancea wenzeliana (Slik) S.E.C.Sierra, Kulju & Welzen	Housing/construction materials, fodder, firewood	Within the Philippines	-	Critically Endangered
Macaranga bicolor Müll.Arg.	Medicine, firewood	Within the Philippines	-	Least Concern
Tritaxis ixoroides (C.B.Rob.) R.Y.Yu & Welzen	-	Within the Philippines	-	Vulnerable
Fabaceae				

Family/ Scientific name	Uses	Distribution	Conservation status	
			DAO 2017–11	IUCN
Wallaceodendron celebicum Koord.	Furniture, plant selling (landscaping, ornamentals, seedling)	Within the Philippines	Vulnerable	-
Gnetaceae				
Gnetum gnemon L.	Food, industrial materials, firewood and charcoal	Cosmopolitan:	-	Least Concern
Lamiaceae				
Teijsmanniodendron ahernianum (Merr.) Bakh.,	Housing/ construction materials, furniture, firewood, implements, plant selling (landscaping, ornamentals, seedling)	Cosmopolitan	-	Least Concern
Malvaceae				
Kleinhovia hospita L.	Food, medicine, furniture, housing/ construction materials, fiber, firewood, plant selling (landscaping, ornamentals, seedling)	Cosmopolitan	-	Least Concern
Meliaceae				
Aglaia rimosa (Blanco) Merr.	Medicine, housing/ construction materials, fodder, firewood	Cosmopolitan	Other threatened species	Near Threatened
Vavaea amicorum Benth.				Least Concern
Moraceae				
Artocarpus rubrovenius Warb.	Food, medicine, housing/construction materials, handicrafts, fodder, firewood, accessories for tapping and hunting wildlife	Within the Philippines	Other threatened species	-
Ficus glandulifera var. camiguinensis	Food, medicine, furniture, industrial, handicrafts, for implements, housing materials, fodder	Cosmopolitan	-	-
Ficus ampelas Burm.f.	Food, medicine, industrial use	Cosmopolitan	-	Least Concern
Pandanaceae				
Benstonea copelandii (Merr.) Callm. & Buerki	Fabric and fiber, plant selling (landscaping, ornamentals, seedling)	Within the Philippines	-	Least Concern
Phyllanthaceae				
Bridelia glauca Blume	Food, housing/construction materials, firewood	Cosmopolitan	-	Least Concern
Rubiaceae				
Lasianthus trichophlebus Hemsl. ex F.B.Forbes & Hemsl.	Medicine, housing/ construction materials, plant selling (landscaping, ornamentals, seedling)	Cosmopolitan	-	-
Psychotria sp.	Fodder, housing/ construction materials			
Neonauclea formicaria (Elmer) Merr.	Medicine, housing/ construction materials	Within the Philippines	-	Least Concern
Salicaceae				
Flacourtia sp.	Medicine, handicrafts			
Sapotaceae				
Manilkara fasciculata (Warb.) H.J.Lam & Maas Geest.	Food, fodder, furniture, housing/ construction materials, implements	Cosmopolitan	-	Vulnerable
Palaquium cf. *elongatum*		Cosmopolitan	-	Endangered
Palaquium sp.	Food, fodder, housing/ construction materials, plant selling (landscaping, ornamentals, seedling)			
Pouteria velutina Elmer			-	Near Threatened
Thymelaeaceae				
Aquilaria cumingiana (Decne.) Ridl.	Food, medicine, industrial, fodder, plant selling (landscaping, ornamentals, seedling)	Cosmopolitan	Vulnerable	Vulnerable
Gonystylus reticulatus (Elmer) Merr.		Within the Philippines	-	-
Urticaceae				
Oreocnide rubescens (Blume) Miq.	Food, medicine, industrial, fiber, housing/construction materials	Cosmopolitan	-	Least Concern
unidentified (Barit)	Housing/ construction materials	-	-	-
unidentified (Sumol)	Housing/ construction materials	-	-	-
unidentified (Buskayan)	-	-	-	-
unidentified (Urukay)	-	-	-	-

organizations in Samar Island, specifically in Paranas and Taft, where the Samar Island Natural Park is situated. Additionally, the LCPI integrates global perspectives by incorporating conservation concepts and principles from various conservation authorities. Gender and age group perspectives further enrich the framework by incorporating views from diverse age groups and genders, crucial in the decision-making process. The pluralistic lens employed aims to scrutinize both sociocultural and environmental (ecological) aspects of the LCPI, striving for a balance between anthropocentric and ecocentric viewpoints. While this remains an ongoing quest for the development of better tools in the future, the current iteration stands as a valuable interim resource. We remain optimistic that the insights garnered from LCPI can contribute to the refinement of local policies, ultimately leading to the sustained ecosystem services of the limestone forests in Samar Island Natural Park, benefiting both humans and nature.

CONCLUSION AND RECOMMENDATION

A total of 50 plant species had been screened for priority conservation at Samar Island Natural Park using the localized conservation priority index (LCPI). Thirteen have high-priority levels and 37 have either medium or low-priority levels, respectively. The top 20 plants have been prioritized as the focus of conservation action in the next 5–10 years. These are *Caryota rumphiana* Mart., *Aquilaria cumingiana* (Decne.) Ridl., *Cycas riuminiana* Regel, *Dracaena angustifolia* (Medik.) Roxb., *Oncosperma tigillarium* (Jack) Ridl., *Oreocnide rubescens* (Blume) Miq., *Kleinhovia hospita* L., *Diospyros blancoi* A.DC., *Codiaeum* sp., *Gymnostoma rumphianum* (Miq.) L.A.S. Johnson, *Caryota cumingii* Lodd. ex Mart., *Artocarpus rubrovenius* Warb., *Palaquium* sp., *Hancea wenzeliana* (Slik) S.E.C.Sierra, Kulju & Welzen, *Aglaia rimosa* (Blanco) Merr., *Canarium hirsutum* Willd., *Lasianthus trichophlebus* Hemsl. ex F.B.Forbes & Hemsl., *Polyscias nodosa* (Blume) Seem., *Shorea negrosensis* Foxw. and *Shorea contorta* S.Vidal. Furthermore, these top 20 plants had been geotagged in situ to enhance protection through intensive monitoring by park management. We are recommending village-level conservation policies to enhance both habitat and plant protection. Minimizing unnecessary roads or footpaths within the park can contribute to habitat protection. Plant protection can be done through ex situ conservation. Locals can collect scattered propagules under the canopy for backyard and home gardening. Conservationists are encouraged to undertake additional research aimed at refining the LCPI employed in this study. Furthermore, there is a need to explore more practical conservation options that align with sustainable development goals. This endeavor holds the potential to bring about tangible benefits for multiple stakeholders in the locality.

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ARTICLE

Status of floristic diversity and impact of development on two sacred groves from Maval Tehsil (Maharashtra, India) after a century

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Abstract: Global urbanisation and anthropogenic activities are leading to a decline in religious beliefs and adversely affecting the biodiversity, ecology, and environmental sustainability of sacred groves, particularly in Lonavala (Rye Wood Park) and Karla Grove in Maval Tehsil, Pune district, Maharashtra, India. The Lonavala Grove, situated at 18.749° N, 73.403° E, and 622 m, and the Karla Grove, located at 18.760° N, 73.478° E, with an elevation of 621 m, both within the Western Ghats, are undergoing transformations due to landscape gardens and urban developments despite their historical significance. Gammie Alexander's 1903 floristic research identified 84 species across both groves, but our present study reveals a significant decline. Lonavala and Karla groves now host 46 genera and 42 species and 25 genera and 29 species, respectively, totaling 120 species from 49 families and 110 genera. This decline is attributed to the introduction of alien and invasive species, resulting in the disappearance of six indigenous species over the past century. The research aims to explore and document changes in floristic diversity, utilising remote sensing methods like NDVI for growth and deterioration assessment, measuring tree and liana girth, and analysing the impact on native flora due to the spread of alien species.

Keywords: Biodiversity heritage site, garden development, girth measurement, global urbanization, impact on biodiversity and native flora, introduction of alien and invasive species, normalized difference vegetation index, remote sensing, sacred forest, urban sacred natural sites.

Abbreviations: C—Common | CIT—Common in thickets | CL—Climber | EC—Enormous climber | EH—Epiphytic Herb | E—Exotic | F—Few | G—Girth | HB—Herb | H—Height | I—Invasive | K—Karla | L—Lonavala | LAK—Lonavala and Karla | OOCAL—Only one climber at Lonavala | OOT—Only one tree | OOTIL—Only one tree in Lonavala | OSAK—Only seen at Karla | OTIAL—Only Two individuals at Lonavala | R—Rare | SIBG | SOTT—Seen only two trees | SSOMST—Small shrub or moderately size tree | T—Tree | TOTP—Two or three plants | TT—Tall tree | TTILW—Tall tree in Lonavala wood | VCC—Very common climber | VCIT—Very common in thickets | VLC—Very large climber.

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INTRODUCTION

Sacred groves are forest patches protected and managed by various indigenous communities on religious beliefs. In the modern era religious beliefs, cultural values, and socio-economic aspects have undergone significant changes. These changes have led to a decline in the motivation to protect and conserve sacred groves, resulting in their degradation (Khan et al. 2008; Palmeirim et al. 2023). The issues of degradation of sacred groves have been discussed by different researchers from Maharashtra, India, and worldwide (Gadgil & Chandran 1992; Chandran 1997; Bhagwat & Rutte 2006)

In Ethiopia, due to changes in land use patterns, there is a 36.6% decrease in sacred forest areas after a time change period of 15 years (Daye & Healey 2015). Mahabaleshwarkar et al. (2023) reported that there is a high risk of losing an important taxa *Canarium strictum* Roxb. due to degradation of the surrounding grove from Bhor, Thesil due to the developmental activities**.** The degradation of sacred groves in the Western Ghats is mainly caused by conflicts such as forest fires, encroachment for coffee plantations, deforestation for charcoal production, and the use of swamp groves for areca nut and paddy cultivation (Gadgil & Chandran 1992; Chandran 1997).

Land use for tourism, roads, mines, dams, and neo-urbanization has also resulted in the degradation of sacred groves (Pandey 1999; Bhagwat & Rutte 2006). According to Unnikrishnan (1995) and Patwardhan (2021), the newly constructed temple is a major threat to the deterioration of sacred groves. Tatay & Merino (2023) reviewed numerous sacred natural sites and showed how different cultures and religions have contributed to their preservation across the globe. Developmental activities within and surrounding groves, deforestation, land conversion, forest fragmentation, encroachment, and planned or accidental changes in the species composition are the most common anthropogenic disturbances in groves (Ray 2014).

Rutte (2011) highlighted various conflicts, policies, and potential solutions to maintain ecological reliability to avoid degradation of sacred groves. Management of protected areas like sacred groves is often unsuccessful in preventing human encroachment (Bhagwat & Rutte 2006). So, important sacred groves should be included in the ‚Protected Area Network' to ensure adequate conservation (Khan et al. 2008). Kulkarni et al. (2013) worked on the diversity of two monotypic sacred groves from the Pune district to evaluate the impact of development for 15 years interval and its comparative floristic account, which showed the reduction in the number of endemic herbs, shrubs, and climbers. The studies on floristic uniqueness and the effect of degradation on plant diversity of 15 sacred groves have been reported from the northern Western Ghats of Pune district, Maharashtra (Kulkarni et al. 2018). Godbole (1980) studied eight sacred groves from Maval Tehsil and documented the dominant species to understand the impact of development on the area and floristic diversity.

Historical and floristic importance of two sacred groves

Lonavala grove has been extensively explored by various British botanists, contributing valuable insights into its botanical richness. Notable reports include Graham (1839), Voigt (1845), Gammie (1903), Cooke (1908), and Santapau (1967), showcasing a range of genera and species (Table 1). Despite its historical fame, Santapau (1967) noted the challenge of fully documenting the grove's diversity.

Originally referred to as 'Lanowlee Woods' (Graham 1839) or 'Lanoli' (Mahan 1878), Lonavala grove featured broad belts of tall trees and massive climbers (Gammie 1903). The Lonavala Municipal Corporation has transformed it into 'Rye Wood Park' or 'Udyan,' a name reflective of the remaining large trees (Image 2F). The grove hosts the 'Mahashivratri' celebration, attracting a crowd (Images 2H & I).

Stuart (2019) and Hegewald (2022) suggest it as a Buddhist garden due to a water tank, while Hindus consider it a 'Mahadev grove' with a temple dedicated to Lord Shiva. Encroachments have impacted the temple of the god 'Waghoba' (Image 1A). Lonavala, a former British hill station, served as a rest and recreation area, altering the grove's face and disrupting biodiversity.

Voigt (1845) mentions saplings raised from grove seeds planted at the Calcutta Botanical Garden. Noteworthy trees include *Semecarpus anacardium* L.f., a source of creosote (Balfour 1870), and *Ficus drupacea* Thunb., creating natural topiary (Robert 1896) work (Image 1E). John Graham cited Lonavala Grove in the protologue of Alpinia neesiana Graham (Patil et al. 2021).

During the Mahashivaratri festival, thousands of pilgrims visit the 40-acre grove, which once extended to the Lonavala railway station. Development activities altered its appearance, underscoring the urgent need for conservation efforts and a thorough examination of

its floristic diversity.

The Karla grove, known for 'Karlyachi Rai' and housing the deity Mahalaxmi (Image 1B), was historically associated with a mango tree-filled Karla village (as of 1825). Situated in the Western Ghats biodiversity hotspot, both groves are rapidly deteriorating due to road widening, garden development, and encroachment. Remote sensing techniques, including NDVI, were employed to assess the grove degradation. This study emphasises a comparative analysis of floristic diversity, current status, the impact of degradation, changes in tree girth, and outlines measures for future conservation.

Study Area

The sacred groves under study are situated in Maval Tehsil of the Pune district in Maharashtra, India. Lonavala Grove also recognized as Ryewood Park, is positioned at 18.749°N, 73.402°E, with an elevation of 622 m. It is situated 1 km south of the city. Karla Sacred Grove is located at 18.760°N, 73.478°E, with an elevation of 621 m, and is positioned near the renowned 'Ekvira temple,' 5 km from Khandala. Lonavala and Karla sacred groves cover an approximate area of 19.06 and 7.63 acres, respectively.

MATERIAL AND METHODS

This study aimed to achieve the following objectives:

Floristic Survey: Conducted thorough field investigations from 1 January 2022, to 24 December 2022, to comprehend the floristic composition and current status of the area. Collected, pressed, and identified specimens using standard procedures and regional flora. Utilised documented data for comparative analysis with Gammie's (1903) floristic work, establishing an inventory of species for assessing the impact of development on the floristic diversity of Lonavala and Karla Groves.

Conducted a comparative analysis of old and new statistical data.

Photo documentation of diversity: Captured photographs of each flowering plant species, accompanied by essential field data.

Measurement of the girth of trees and lianas: Measured the girth of trees and lianas using a measuring tape to assess their growth and development. Compared the obtained data with previously reported measurements.

Table 1. Floristic diversity of Lonavala grove by different researchers.

Works on sacred groves	Genus	Species
Graham, 1839	12	14
Voigt, 1845	6	6
Gammie, 1903	68	74
Cooke, 1908	7	8
Santapau, 1967	1	1
Present study	42	46

Impact assessment studies and interpretation: Assessed the impact of development on Lonavala and Karla groves using remote sensing techniques and NDVI analysis. Examined geographical changes over 40 years (1980–2020) at 20-year intervals. Utilised Landsat 8 satellite imagery data to observe the degradation of the sacred grove. Calculated NDVI using QGIS software for a comprehensive analysis.

RESULT AND DISCUSSION

As a result of development activities, the floristic diversity and size of many sacred groves have declined (Mishra et al. 2004; Khan et al. 2008; Ray 2014; Kulkarni et al. 2018).

The sacred grove of Lonavala has been transformed into a garden by the Lonavala Municipal Corporation. To enhance aesthetics, various amenities have been introduced, including a rockery (Image 3C), a water tank adorned with water lilies, and renovations to the lawn (Image 2C–E). The incorporation of boulder construction and tree boulders further contributes to the visual appeal. The addition of more attractive plants compared to the previous composition has implications for the ephemeral and epiphytic flora within the sacred grove.

Despite the developmental activities such as lawn grass installation, weeding, ecotourism initiatives, and tile paving, there is still a presence of ephemeral flora on the tree trunks within the grove, as depicted in Image 2E.

Gammie (1903) mentioned *Alpinia neesiana* Graham (= *Zingiber neesanum* (J.Graham) Ramamoorthy), which was found on the grove's periphery, but now has been invaded by garden ornamental plants, and very few plants remain there. Additionally, the Western Ghats endemic taxon *Curcuma pseudomontana* J.Graham was discovered in the current investigation. The endemic species are on the verge of extinction from the grove

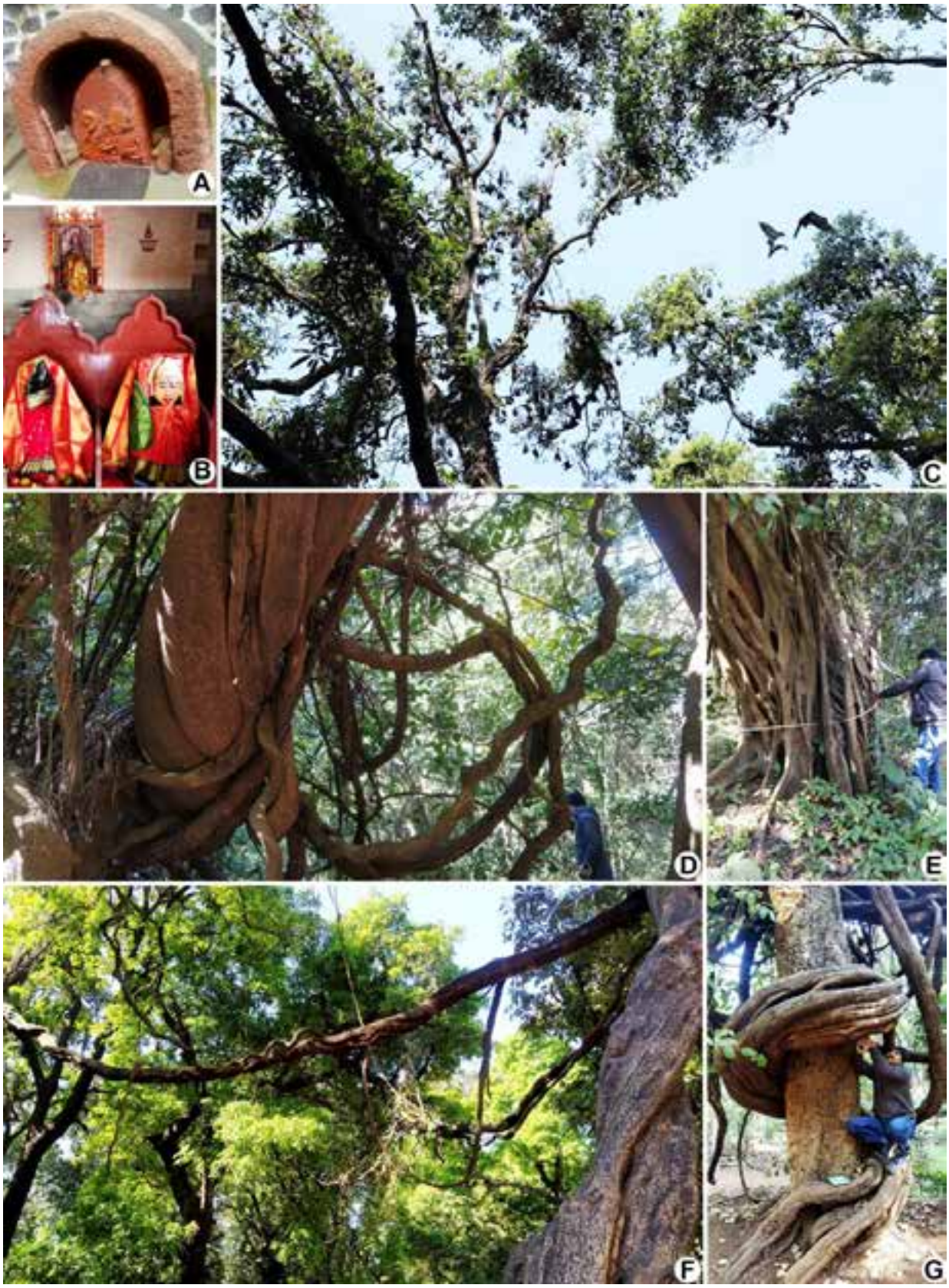

Image 1. A—Shrine of deity Waghoba in Lonavala grove | B—Mahalaxmi deity of Karla grove | C—Colony of Bats on Mango tree in Karla grove| D—Giant Lianas of *Combretum albidum* G. Don | E—Measuring girth of *Ficus drupacea* Thunb. | F—Giant liana of *Entada phaseoloides* (L.) Merr. | G—Topiary work of parasitic *Ficus drupacea* Thunb. © © Kishor Saste.

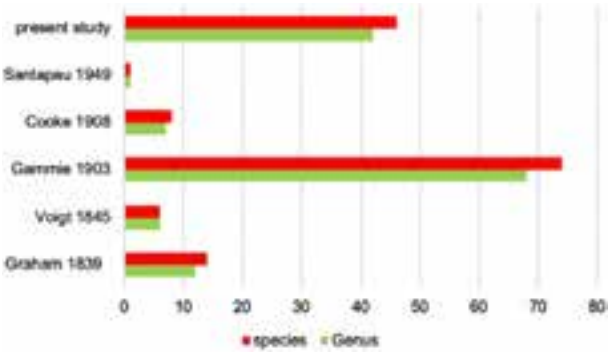

Figure 1. Floristic diversity of Lonavala grove by different researchers.

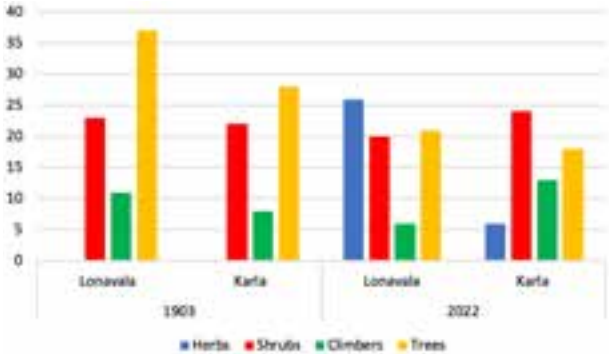

Figure 2. Bar diagram showing the number of herbs, shrubs, trees, and climbers.

as a result of construction, weeding, and the planting of ornamental plants like *Duranta* L. and *Bougainvillea*. comm. ex Juss. (Figure 3E–G)

Some groves are better suited for the occurrence of more sensitive, hygrophilous endemic species due to the water retention capacity of groves (Ray 2014). The abundance of the endemic taxon *Hedychium scaposum* Nimmo (= *Curcuma scaposa* (Nimmo) Skornick. & M.Sabu) on the west side of the lake boulders of the grove was noted in the Bombay Catalogue (Graham 1839). Unfortunately, because of waste-filled and polluted marshy habitat, this endemic taxon has now completely vanished. In addition to an embankment of the invasive ornamental weed *Sphagneticola calendulacea* (L.) Pruski, swampy waste areas are said to be home to a large population of the exotic taxon *Alocasia macrorrhizos* (L.) G. Don. (Image 3A & B). Most sacred groves are experiencing an ecological problem caused by the invasion of exotic weeds (Ramsankar 2010).

Due to the Britishers' lack of knowledge about traditional sacred grove practices and conservation, they planted ornamental plants in Lonavala Grove, which disrupted the grove's ecology. Instead, they believed that the sacred grove was a scheme by the Indian people to prevent the British government from claiming the land (Gadgil & Chandran 1992).

The tree trunks that were previously covered with climbers like *Piper nigrum* L., and epiphytes such as *Dendrophthoe longiflora* (Desr.) Ettingsh, are now entirely replaced with exotics like *Philodendron* and decorative climbers (Image 3D). The invasion of such decorative climbers has had a negative impact on populations of endemic flora such as grasses, orchids, and *Begonias*, leading them to grow on the boulders and damp walls of the grove.

Capparis moonii Wight was previously found in dense thickets at Lonavala grove. However, due to the clearing of the ground, only two individuals have been located. Unfortunately, several previously reported evergreen plant species by Gammie (1903) from the Lonavala grove have completely vanished. These species include *Dysoxylum binectariferum* (Roxb.) Hook.f. ex Bedd., *Zanthoxylum rhetsa* (Roxb.) DC., *Catunaregam spinosa* (Thunb.) Tirveng, and *Xantolis tomentosa* (Roxb.) Raf. The reduction in evergreen tree cover in sacred groves adversely affects the ecology (Gadgil & Chandran 1992; Unnikrishnan 1995; Ray 2014). It has also been revealed that certain taxa, which were reported one in number, are now extinct. However, *Machilus glaucescens* (Nees) Wight and *Mangifera indica* L. currently dominate the area. Unfortunately, due to garden expansion, the sacred groves of Lonavala are now home to more exotic weeds, escaped flora, and attractive species.

Critical note on girth measurement of giant lianas and other trees

A unique characteristic of both groves is the presence of the enormous lianas *Entada phaseoloides* (L.) Merr., *Combretum latifolium* Blume, and *Premna coriacea* C.B.Clarke. In a study conducted in the Pune district, the circumference of *Entada phaseoloides* (L.) Merr. from various sacred groves was reported. Bhise et al. (2013) found that the largest liana, measuring 1.22 m in circumference, was from Kalbhairavnath sacred grove. However, our current work shows that the same plant, previously measured at Lonavala grove with a circumference of 0.48 m, actually has a circumference of 1.83 m. This makes *Entada phaseoloides* (L.) Merr. not only the largest liana plant in Lonavala but possibly even in Maharashtra.

Most of the ancient trees that Gammie had mentioned and measured have disappeared from groves. The absence of plant girth measurements

Table 2. List of taxa reported in 1903 and present study.

Scientific name	Family	Habit	Status in 1903		Present Status	
			Lonavala	Karla	Lonavala	Karla
Clematis hedysarifolia DC.	Ranunculaceae	CL	–	CIT	–	R
Capparis moonii Wight	Capparaceae	CL	C	C	'2 nos.'	–
Sterculia guttata Roxb.	Malvaceae	T	+	+	–	+
Hiptage benghalensis (L.) Kurz	Malpighiaceae	CL	+	–	–	–
Grewia tiliifolia Vahl	Malvaceae	T	–	SSOMST	–	+
Firmiana colorata (Roxb.) R.Br.	Malvaceae	T	+	–	–	–
Zanthoxylum rhetsa (Roxb.) DC.	Rutaceae	T	+	–	–	–
Glycosmis pentaphylla (Retz.) DC.	Rutaceae	S	+	–	–	–
Atalantia racemosa Wight ex Hook.	Rutaceae	S	+	+	–	–
Dysoxylum binectariferum (Roxb.) Hook.f. ex Bedd.	Meliaceae	T	+	–	–	–
Celastrus paniculatus Willd.	Celastraceae	CL	VCC	VCC	–	+
Gymnosporia emarginata (Willd.) Thwaites	Celastraceae	S	+	+	–	+
Ventilago madraspatana Gaertn.	Rhamnaceae	S	C	C	–	–
Ziziphus rugosa Lam.	Rhamnaceae	S	+	+	+	+
Allophylus cobbe (L.) Forsyth f.	Sapindaceae	S	–	+	–	–
Schleichera oleosa (Lour.) Oken	Sapindaceae	T	+	–	–	–
Mangifera indica L.	Anacardiaceae	T	H: 15.24–21.34 m) (G: 3.05–3.97 m)	+	(G: 3.96 m)	+
Holigarna grahamii (Wight) Kurz	Anacardiaceae	T	C, (H :15.24 m) (G: 0.91–8.13 m)	–	2 nos (G: 2.35 m)	–
Semecarpus anacardium L.f.	Anacardiaceae	T	2 or 3 nos	2 or 3 nos	–	–
Butea monosperma (Lam.) Kuntze	Fabaceae	T	VC	VC	–	(G: 1.83 m)
Crotalaria retusa L.	Fabaceae	S	+	+	–	+
Dalbergia horrida var. horrida	Fabaceae	CL	–	+	–	(G: 1.07 m)
Mezoneuron cucullatum (Roxb.) Wight & Arn.	Fabaceae	CL	EC, (G: 0.46 m)	–	–	(G: 0.17–0.34 m)
Saraca asoca (Roxb.) W.J.de Wilde	Fabaceae	T	+	–	(G: 0.91 m)	–
Tamarindus indica L.	Fabaceae	T	–	+	–	–
Entada phaseoloides (L.) Merr.	Fabaceae	CL	+	(G: 0.91 m)	(G: 1.83 m)	+
Senegalia rugata (Lam.) Britton & Rose	Fabaceae	S	+	+	–	–
Albizia chinensis (Osbeck) Merr.	Fabaceae	T	(H: 21.37 m) (G: 3.05 m)	+	–	–
Terminalia bellirica (Gaertn.) Roxb.	Combretaceae	T	(H:15.24–21.37 m) (G: 1.52–4.57 m)	–	(G: 2.44 m)	–
Terminalia chebula Retz.	Combretaceae	T	+	–	–	–
Getonia floribunda Roxb.	Combretaceae	CL	+	+	–	(G: 0.91 m)
Combretum albidum G.Don	Combretaceae	CL	+	+	(G: 1.49–4.90 m)	–
Syzygium cumini (L.) Skeels	Myrtaceae	T	(G: 1.52–3.05 m)	+	+	(G: 2.44–3.17 m)
Memecylon edule Roxb.	Melastomataceae	T	VCIT (G: 0.31–0.61 m)	–	–	–
Memecylon umbellatum Burm.f.	Melastomataceae	T	+	+	+	+
Opuntia elatior Mill.	Cactaceae	S	–	+	–	–
Neolamarckia cadamba (Roxb.) Bosser	Rubiaceae	T	R	–	–	–
Catunaregam spinosa (Thunb.) Tirveng.	Rubiaceae	T	C	C	+	+
Psydrax umbellatus (Wight) Bridson	Rubiaceae	T	+	+	–	+
Ixora brachiata Roxb.	Rubiaceae	S	+	+	–	+
Ixora nigricans R.Br. ex Wight & Arn.	Rubiaceae	S	+	–	–	–

Scientific name	Family	Habit	Status in 1903		Present Status	
			Lonavala	Karla	Lonavala	Karla
Meyna spinosa Roxb. ex Link	Rubiaceae	S	(H: 6.10 m, G: 1.52 m)	+	–	(G: 4.5 m)
Pavetta indica L.	Rubiaceae	S	+	+	–	+
Acilepis dendigulensis (DC.) H.Rob.	Asteraceae	S	+	+	+	–
Xantolis tomentosa (Roxb.) Raf.	Spatotaceae	T	Vc	vc	–	+
Mimusops elengi L.	Spatotaceae	T	TTILW	+	–	–
Diospyros montana Roxb.	Ebenaceae	T	+	–	–	–
Jasminum malabaricum Wight	Oleaceae	CL	+	–	–	–
Chionanthus ramiflorus Roxb.	Oleaceae	T	C	C	R	R
Tetrapilus dioicus (Roxb.) L.A.S.Johnson	Oleaceae	T	+	(G: 0.76 m)	(G: 2.68–4.27 m)	+
Carissa carandas L.	Apocynaceae	S	+	+	–	+
Carissa spinarum L.	Apocynaceae	S	+	+	–	–
Anodendron parviflorum (Roxb.) I.M.Turner	Apocynaceae	CL	C	–	'1 nos.'	–
Cordia myxa L.	Boraginaceae	T	F	–	–	–
Heterophragma quadriloculare (Roxb.) K.Schum.	Bignoniaceae	T	–	'1 nos.'	–	+
Stereospermum chelonoides (L.f.) DC.	Bignoniaceae	T	TT	–	–	–
Strobilanthes ixiocephala Benth.	Acanthaceae	S	C	C	–	–
Lantana camara L.	Verbenaceae	S	+	+	+	+
Callicarpa tomentosa (L.) L.	Lamiaceae	S	+	(H: 7.62 m)	–	–
Premna coriacea C.B.Clarke	Lamiaceae	CL	+	–	+	–
Vitex negundo L.	Lamiaceae	S	C	–	R	R
Colebrookea oppositifolia Sm.	Lamiaceae	S	C	C		
Machilus glaucescens (Nees) Wight	Lauraceae	T	(G: 3.81 m)	+	(G: 1.83–2.74 m)	+
Lasiosiphon glaucus Fresen.	Thymelaeaceae	S	+	+	–	–
Elaeagnus latifolia Lour.	Elaeagnaceae	S	+	+	–	+
Dendrophthoe longiflora (Desr.) Ettingsh.	Loranthaceae	S	VCC	VCC	R	R
Macrosolen parasiticus (L.) Danser	Loranthaceae	S	C	C	–	–
Viscum capitellatum Sm.	Santalaceae	S	+	+	–	–
Osyris lanceolata Hochst. & Steud.	Santalaceae	T	+	+	–	–
Euphorbia neriifolia L.	Euphorbiaceae	S	+	+	–	–
Bridelia retusa (L.) A.Juss.	Phyllanthaceae	T	+	+	+	+
Holoptelea integrifolia (Roxb.) Planch.	Ulmaceae	T	–	+	–	–
Celtis tetrandra Roxb.	Cannabaceae	T	F	F	'1 nos.'	–
Ficus tinctoria ssp. *gibbosa* (Blume) Corner	Moraceae	T	–	+	+	+
Ficus drupacea Thunb.	Moraceae	T	+	–	(G: 5.27)	–
Ficus religiosa L.	Moraceae	T	+	+	–	–
Ficus amplissima Sm.	Moraceae	T	+	+	+	–
Ficus exasperata Vahl	Moraceae	T	+	+	+	–
Ficus racemosa L.	Moraceae	T	C	C	–	–
Artocarpus integrifolia L.f	Moraceae	T	+	+	–	(G: 0.76 - 2.50 m)
Gnetum edule (Willd.) Blume	Gnetaceae	CL	VLC, (G: 0.91 m)	+	–	–
Caryota urens L.	Arecaceae	T	+	+	+	+
Bambusa arundinacea Willd.	Poaceae	S	+	+	–	+
Pseudoxytenanthera ritchiei (Munro) H.B.Naithani	Poaceae	S	–	+	–	–

reported in 1903 suggests that old trees are no longer alive, or new ones are growing. However, the increase in girth measurements previously recorded indicates that the former trees and lianas are growing and recovering (as shown in Table 2). For instance, *Entada phaseoloides* (L.) Merr. grows 3 feet (0.914 m) in girth every 120 years.

In the Karla and Lonavala groves, the tallest trees, *Albizia chinensis* (Osbeck) Merr. (21.37 m) and *Mangifera* (21.34 m), have completely vanished. The two tallest trees in Lonavala grove, *Terminalia bellirica* (*Gaertn*.) Roxb. and *Holigarna grahamii* (Wight) Kurz, measuring 15.24 m and 21.37 m high, have also disappeared entirely.

In Karla Grove, the *Meyna spinosa* Roxb. ex Link has the largest girth, measuring 4.2 m, while the *Mezoneuron cucullatum* (Roxb.) Wight & Arn has the smallest girth, measuring only 0.17 m. On the other hand, in Lonavala grove, the *Ficus drupacea* Thunb and *Saraca asoca* (Roxb.) W.J.deWilde have the largest and smallest girths, measuring 5.27 m and 0.91 m, respectively.

In Karla Grove, the species with the thickest lianas is *Getonia floribunda* Roxb. It measures 0.91 m. On the other hand, *Mezoneuron cucullatum* (Roxb.) Wight & Arn has the thinnest lianas with a measurement of 0.17 m. In Lonavala Grove, the species with the thickest and thinnest lianas are *Combretum albidum* G.Don and *Entada phaseoloides* (L.) Merr. respectively. *Combretum albidum* G.Don has a measurement of 4.90 m while *Entada phaseoloides* (L.) Merr. measures 1.83 m.

Impact of development activities on the floristic of Karla Grove

Acacia auriculiformis A.Cunn. ex Benth. planted in social forestry and forest fire programs disturb the grove biota and hurt the area's ecological function (Gokhale 2005; Ray 2014). The floristic diversity of the sacred grove was degraded by the social forestry plantation program and invasive weeds (Burman 1996; Bhagwat & Rutte 2006). In 1903, *Clematis hedysarifolia* DC. was the most abundant species in both groves, but it has since disappeared from the Lonavala grove, with only a few individuals remaining in the Karla grove. The dominant species throughout the entire grove is *Trichosanthes tricuspidata* Lour climber, which covers every tree. Cucurbitaceae climbers like *Trichosanthes tricuspidata* Lour have invaded and dominated sacred groves due to various reasons, including climate changes, forest disturbances, and the formation of tree gaps caused by grove deforestation (Rai et al. 2016).

The Karla sacred grove is facing a major issue as *Asystasia gangetica* (L.) T.Anderson and *Trichosanthes tricuspidata* Lour are invading and spreading rapidly over the area as shown in Image (Image 2A & B). This has made it difficult for the locals and forest rangers to move around the grove. Moreover, social forestry and forest fires have severely damaged the floristic diversity of the grove (See Image 2B).

Big old trees play a vital ecological role in sacred groves. They provide nesting or sheltering cavities for 30% of vertebrate species (Lindenmayer et al. 2012; Lindenmayer & Laurance 2016) and also store large quantities of carbon. Loss of such species has considerable consequences on both biodiversity and

Figure 3. A—Map of India showing Maharashtra state and Pune district | B—Marked asterisk indicates Maval Tehsil.

Image 2. A—Invasion of Trichosanthes tricuspidata Lour in Karla grove | B—Social forestry and forest fire in Karla Grove | C—Development of garden | D— Introduction of water garden for water Lily | E—Paving of floor tiles | F—Sacred grove used as park | G—Use of sacred grove for enjoyment | H—Mahashivratri celebration in grove | I—Use of park as amusement for children during Mahashivratri festival | J—Use of grove for municipal worker housing. © Kishor Saste.

Table 3. List of newly reported taxa from Lonavala and Karla groves.

Botanical name	Family	Habit	Status (Wild/ exotic)	Lonavala	Karla
Achyranthes coynei Santapau	Amaranthaceae	HB	W	–	+
Aerides maculosa Lindl.	Orchidaceae	EH	W	+	–
Allamanda cathartica L.	Apocynaceae	CL	E	+	–
Alocasia macrorrhizos (L.) G.Don	Araceae	HB	E	+	–
Alternanthera sessilis (L.) DC.	Amaranthaceae	HB	I	–	+
Argyreia elliptica (Roth) Choisy	Convolvulaceae	CL	W	–	+
Aspidopterys cordata (B.Heyne ex Wall.) A.Juss.	Malpighiaceae	CL	W	–	+
Begonia crenata Dryand.	Begoniaceae	HB	W	+	–
Bougainvillea spectabilis Willd.	Nyctaginaceae	S	E	+	–
Caladium bicolor (Aiton) Vent.	Araceae	HB	E	+	–
Calliandra haematocephala Hassk.	Mimosaceae	S	E	+	
Carica papaya L.	Caricaceae	S	E	–	+
Chromolaena corymbosa (Aubl.) R.M.King & H.Rob.	Asteraceae	S	E	+	+
Clerodendrum infortunatum L.	Verbenaceae	S	E	+	–
Clerodendrum thomsoniae Balf.f.	Verbenaceae	S	E	+	–
Coccinia grandis (L.) Voigt	Cucurbitaceae	CL	W	–	+
Codiaeum variegatum (L.) Rumph. ex A.Juss.	Euphorbiaceae	S	E	+	–
Coleus scutellarioides (L.) Benth.	Lamiaceae	HB	E	+	–
Curcuma pseudomontana J.Graham	Zingiberaceae	HB	W	+	–
Cynarospermum asperrimum (Nees) Vollesen	Acanthaceae	HB	W	–	+
Cyrtococcum oxyphyllum (Hochst. ex Steud.) Stapf	Poaceae	HB	W	+	–
Cyrtococcum oxyphyllum (Hochst. ex Steud.) Stapf	Poaceae	HB	W		+
Dendrobium barbatulum Lindl.	Orchidaceae	EH	W	+	–
Dendrobium microbulbon A.Rich.	Orchidaceae	EH	W	+	–
Dracaena fragrans (L.) Ker Gawl.	Asparagaceae	S	E	+	–
Duranta erecta L.	Verbenaceae	S	E	+	–
Embelia ribes Burm.f.	Primulaceae	S	W		+
Eranthemum roseum (Vahl) R.Br. ex Roem. & Schult.	Acanthaceae	HB	W	+	–
Ficus hispida L.f.	Moraceae	T	W	+	–
Ficus retusa L.	Moraceae	T	W	–	+
Flemingia bracteata (Roxb.) Wight	Fabaceae	S	W	–	+
Garnotia arborum Stapf ex Woodrow	Poaceae	EH	W	+	–
Garnotia courtallensis (Arn. & Nees) Thwaites	Poaceae	EH	W	+	–
Gymnosporia rothiana (Walp.) M.A.Lawson	Celastraceae	S	W	–	+
Heliconia rostrata Ruiz & Pav.	Heliconiaceae	HB	E	+	–
Hydrangea macrophylla (Thunb.) Ser.	Hydrangeaceae	S	E	+	–
Ipomoea hederifolia L.	Convolvulaceae	CL	W	–	+
Justicia adhatoda L.	Acanthaceae	S	W	+	–
Kopsia fruticosa (Roxb.) A.DC.	Apocynaceae	T	E	+	–
Lantana *camara L.*	Verbenaceae	S	I	+	+
Lepidagathis fasciculata (Retz.) Nees	Acanthaceae	HB	W	+	–
Litsea ghatica Saldanha	Lauraceae	S	W	+	–
Livistona chinensis (Jacq.) R.Br. ex Mart.	Arecaceae	T	E	+	–
Macaranga peltata (Roxb.) Müll.Arg.	Euphorbiaceae	T	W	+	–
Nymphaea nouchali Burm.f.	Nymphaeaceae	HB	E	+	–
Oplismenus burmanni (Retz.) P.Beauv.	Poaceae	HB	W	–	+
Paspalum vaginatum Sw.	Poaceae	HB	E	+	–

Botanical name	Family	Habit	Status (Wild/ exotic)	Lonavala	Karla
Pavetta indica L.	Rubiaceae	S	W	–	+
Philodendron erubescens K.Koch & Augustin	Araceae	HB	E	+	–
Phoenix sylvestris (L.) Roxb.	Arecaceae	T	W	–	+
Phyllanthus reticulatus Poir.	Euphorbiaceae	S	W	–	+
Pogostemon parviflorus Benth.	Lamiaceae	S	W	–	+
Porpax filiformis (Wight) Schuit., Y.P.Ng & H.A.Pedersen	Orchidaceae	EH	W	+	–
Porpax reticulata Lindl.	Orchidaceae	EH	W	+	–
Rhaphidophora tetrasperma Hook.f.	Araceae	HB	E	+	–
Rhynchoglossum obliquum Blume	Gesneriaceae	HB	W	+	–
Smilax zeylanica L.	Smilacaceae	CL	W	–	+
Solanum diphyllum L.	Solanaceae	S	E	+	+
Solanum indicum Roxb.	Solanaceae	S	W	–	+
Solanum nigrum L.	Solanaceae	HB	W	–	+
Solanum torvum Sw.	Solanaceae	S	E	+	+
Sphagneticola calendulacea (L.) Pruski	Asteraceae	HB	I	+	–
Synedrella nodiflora (L.) Gaertn.	Asteraceae	HB	I	–	+
Teramnus labialis (L.f.) Spreng.	Fabaceae	HB	W	+	
Trichosanthes tricuspidata Lour.	Cucurbitaceae	CL	W	–	+
Turnera ulmifolia L.	Turneraceae	HB	W	+	
Urena lobata L.	Malvaceae	S	I		+
Vigna vexillata (L.) A.Rich.	Fabaceae	CL	W	+	–
Vincetoxicum indicum (Burm.f.) Mabb.	Apocynaceae	CL	W	–	+
Woodfordia fruticosa (L.) Kurz	Lythraceae	S	W	–	+
Zingiber neesanum (J.Graham) Ramamoorthy	Zingiberaceae	HB	W	+	–

ecosystems worldwide (Lindenmayer et al. 2012; Lindenmayer & Laurance 2016). Several *Ficus* species were reported in 1903 but are now completely extinct. The presence of *Ficus tinctoria* ssp. *gibbosa* (Blume) Corner and *F. microcarpa* L.f. surroundings of the forest near the temple indicates the former extent of the grove. According to Gammie (1903), Karla Grove once had a colony of bats that fed on the fruits of various *Ficus* species. However, due to development activities, only one taxon - *F. tinctoria* ssp. *gibbosa* (Blume) remains. Other species such as *Ficus tinctoria* ssp. *gibbosa* (Blume) Corner and *F. retusa* L. can be found about 200 m away from the main grove, indicating the original size and extent of the previous grove around the temple. The *Ficus* species has completely disappeared from the grove, and as a result, these bats have been discovered to be feeding on mango trees (Image 1C) and the leaves of other plants. *Ficus* is therefore a crucial keystone species for bat conservation in such sacred forests. Therefore, it is crucial to stress the significance of sacred groves for both the preservation of other animals as well as the protection of plants. Bats play a significant role in seed dispersal, which is crucial for overall forest regeneration (Blicharska et al. 2013).

Impact of development activities on endemic plants

The number of endemic species and all species in the sacred woods in the Pune district of the Western Ghats declines as disturbance levels rise (Kulkarni et al. 2013).

The endemic plant species from the grove, which were once reported as being common, are now becoming rare, and some have even completely disappeared from the grove, as a result of the impact of development. These endemic species include *Gnetum edule* (Willd.) Blume, *Clematis hedysarifolia* DC, *Curcuma scaposa* (Nimmo) Skolnick & M.Sabu, *Holigarna grahamii* (Wight) Kurz, *Jasminum malabaricum* Wight, and *Pseudoxytenanthera ritchiei* (Munro) H.B.Naithani. Out of the total species documented from the groves, 19 are found to be endemic to the Western Ghats (Table 4).

Degradation of sacred groves

Over the last four decades, the vegetation landscape in both Lonavala grove and Karla grove has undergone

Image 3. A—Invasion of water tank by exotic weeds | B—Waste place in the grove occupied by weeds | C—Rockery in grove | D—Ornamental climbers on tree trunk | E – *Amorphophallus* along with ornamental plant | F—Endemic plant with ornamental *Duranta erecta* L. | G—Removal of *Zingiber neesanum* (J.Graham) Ramamoorthy, an endemic species as weed.

Table 4. List of endemic plant species reported from both groves.

Family	Botanical Name	Location
Ranunculaceae	*Clematis hedysarifolia* DC	K
Anacardiaceae	*Holigarna grahamii* (Wight) Kurz	L
Begoniaceae	*Begonia crenata* Dryand.	L
Rubiaceae	*Ixora brachiata* Roxb.	L and K
Amaranthaceae	*Achyranthes coynei Santapau*	K
Oleaceae	*Jasminum malabaricum* Wight	L
Lauraceae	*Litsea ghatica* Saldanha	L
Gnetaceae	*Gnetum edule* (Willd.) Blume	L and k
Orchidaceae	*Dendrobium microbulbon* A.Rich.	L
Orchidaceae	*Porpax filiformis* (Wight) Schuit., Y.P.Ng & H.A.Pedersen	L
Orchidaceae	*Dendrobium barbatulum* Lindl.	L
Orchidaceae	*Aerides maculosa* Lindl.	L
Orchidaceae	*Curcuma pseudomontana* J.Graham	L
Orchidaceae	*Zingiber neesanum* (J.Graham) Ramamoorthy	L
Zingiberaceae	*Curcuma scaposa* (Nimmo) Skornick. & M.Sabu	L
Poaceae	*Pseudoxytenanthera ritchiei* (Munro) H.B.Naithani	L
Poaceae	*Garnotia arborum* Stapf ex Woodrow	L
Malpighiaceae	*Aspidopterys cordata* (B.Heyne ex Wall.) A.Juss.	K
Celastraceae	*Gymnosporia rothiana* (Walp.) M.A.Lawson	K

notable changes, as indicated by the NDVI calculated at 20-year intervals from 1980 to 2020.

In 1980, Lonavala grove exhibited dense vegetation surrounded by limited greenery. However, by 2000, the grove had experienced degradation, attributed to activities such as garden construction. By 2020, Lonavala grove would have displayed a moderate level of vegetation compared to its previously reported dense state.

In contrast, Karla grove remained largely unaffected in 1980 and 2000, surrounded by moderate vegetation. In 2020, there was evidence of degradation with a change in NDVI values, likely due to encroachment and building construction. Nevertheless, a notable increase in dense vegetation in Karla grove in 2020 suggests the initiation of a social forestry initiative (Image 4G).

Vegetation analysis

The natural sacred groves at Lonavala and Karla underwent extensive transformation into gardens and urban areas, respectively. Gammie (1903) listed 84 species and 74 genera in 1903. However, during the current investigation, only 45 genera and 48 species could be listed, resulting in a loss of 35 genera and

Table 5. The total number of genera and species reported from both groves.

Location	Genera	Species
L and K (1903)	74	84
L and K (2022)	45	48
L (2022)	42	46
K (2022)	23	26
Total	**110**	**120**

Table 6. Total number of herbs, shrubs, climbers, and trees reported from both the groves in 1903 and 2022.

Habit	1903		2022	
	Lonavala	Karla	Lonavala	Karla
Herbs	0	0	26	6
Shrubs	26	26	20	27
Climbers	11	8	6	13
Trees	37	28	21	18

36 species (Table 2). there is an addition of 42 genera and 46 species from Lonavala alone due to garden development and new additions of herbaceous plant species, 57% of species have been lost from both groves. There is an addition of 25 genera and 29 species to Karla Grove. Invasive plant species such as *Solanum diphyllum* L., *Chromolaena corymbosa* (Aubl.) R.M.King & H.Rob., and *Solanum torvum* Sw. were found in both groves during the current study. In total, both groves now contain 120 species belonging to 110 genera (Table 5).

Out of the 46 species reported from the Lonavala grove, 22 species (47.86%) of the flora, are reported to be ornamental. In 1903 there were 42 trees, 12 climbers, and 30 shrubs from both groves. As per a recent study, it includes 26 herbs, 15 shrubs, one climber, and four tree species respectively (Table 3). However, this grove has lost several tree species such as *Cordia myxa* L., *Diospyros montana* Roxb., *Dysoxylum binectariferum* (Roxb.) Hook.f. ex Bedd., *Ficus racemosa* L., *Ficus religiosa* L., *Firmiana colorata* (Roxb.) R.Br., *Schleichera oleosa* (Lour.) Oken., *Terminalia chebula* Retz., *Memecylon edule* Roxb., *Neolamarckia cadamba* (Roxb.) Bosser., *Mimusops elengi* L., *Stereospermum chelonoides* (L.f.) DC., *Semecarpus anacardium* L.f., and *Zanthoxylum rhetsa* (Roxb.) DC. Whereas in Karla Grove there is the inclusion of six herbs, 14 shrubs, seven climbers, and two trees respectively (Table 3). There were 42 trees, 12 climbers, and 30 shrubs reported in

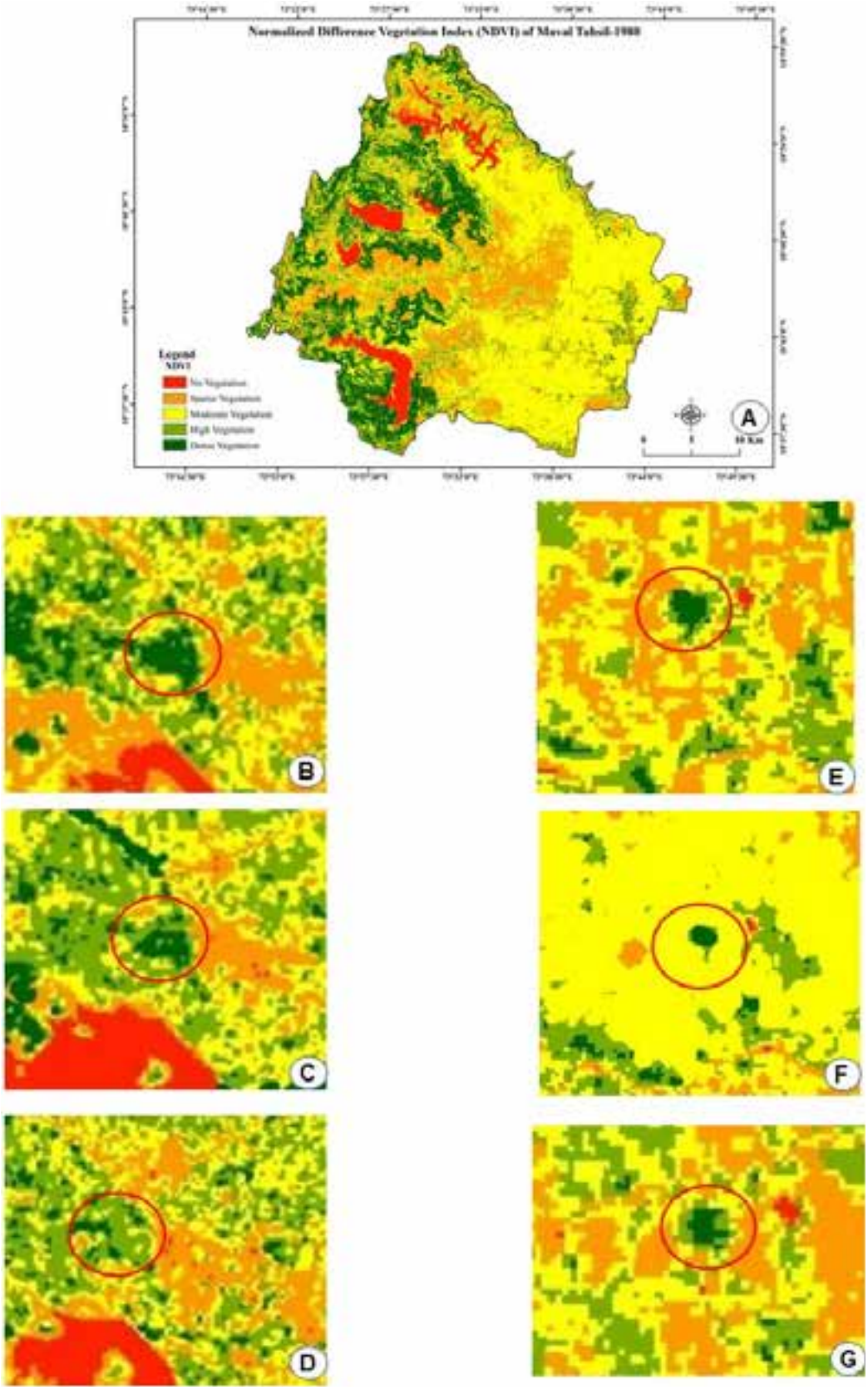

Image 4. A—NDVI of Maval Tehsil | B—NDVI of LG 1980 | C—NDVI of LG 2000, showing the decline of dense vegetation | D—NDVI of LG 2020, showing the decline of dense vegetation | E—NDVI of KG 1980 | F—NDVI of KG 2000, showing the decline of dense vegetation | G—NDVI of KG 2020 showing a rise in dense vegetation due to social forestry.

1903. After a century, there are 24 trees, 10 climbers, and 14 shrubs in both groves (Table 6).

CONCLUSION

The conversion of the sacred forest into gardens and urban areas has a paramount impact on biodiversity in the Western Ghats hill stations. Therefore, these sacred groves need protection under the Biological Diversity Act of 2002.

Traditional practices were used to preserve these groves in the past, but now there is a change in the management of these groves and a consequent loss of protective sentiments towards the sacred groves. To initiate conservation efforts, it is essential to first record the diversity of flora and closely observe the effects of development as well as the overall health of vegetation, utilising remote sensing techniques (Mahabaleshwarkar et al. 2023). Subsequently, the next phase involves lessening the impact of urban expansion on these wooded areas by adopting contemporary strategies, organising community awareness initiatives, and maintaining thorough documentation. Lastly, it is crucial to designate urban sacred natural sites as Biodiversity Heritage Sites under the regulations outlined in this Act, ensuring their sustained protection and welfare (Ormsby 2021).

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ARTICLE

Faunal inventory and illustrated taxonomic keys to aquatic Coleoptera (Arthropoda: Insecta) of the northern Western Ghats of Maharashtra, India

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Abstract: Following several surveys of aquatic Coleoptera during 2013–2018 in northern Western Ghats, India, we hereby provide an illustrated checklist with modified keys to the species of families Dytiscidae, Gyrinidae, Noteridae, and Hydrophilidae. To date, we have collected 69 species of true water beetles, adding new occurrence records for two species to the fauna of the state. Keys are modified from the works of various authors. Distribution records are provided with district specific records for Maharashtra. Keys, species lists, and distribution records are based on our survey results. Species were identified following the works of various authors, and affirmed by dissecting male genitalia. Provided with keys are habitus images, images of male genitalia for 59 species, and digital drawings & scanning electron micrographs of taxonomically important structures wherever necessary. These surveys were conducted to revive the work on aquatic beetles that have been neglected for about 40 years, and to prepare a revised checklist.

Keywords: Dytiscidae, escarpments, freshwater ecosystems, Hydrophilidae, inland waters, orographic rain, water beetles.

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Author contributions: SDS has collected data. SDS and HVG have identified the research material and performed all photography. SDS, HVG, and ADP have prepared the manuscript.

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INTRODUCTION

The taxonomy of most of the aquatic beetles has been thoroughly studied worldwide, and to date more than 13,000 species are described under this group (Short 2018). The Oriental region harbours about 3,580 species of aquatic beetles (Jäch & Balke 2008). According to Ghosh & Nilsson (2012), there are over 250 dytiscid species found in India, and the same catalogue records 48 species from Maharashtra. It was essential to revisit the aquatic beetle fauna of Maharashtra as the previous work was done 40–45 years before (Vazirani 1967, 1968, 1969, 1970a,b, 1971, 1977a,b, 1984). A recent literature-based checklist of aquatic beetles from Maharashtra reports 57 species of beetles under the families Dytiscidae Leach, 1815; Gyrinidae Latreille, 1810; Noteridae Thomson, 1860, and Hydrophilidae Latreille, 1802 (Sharma & Bano 2012). A series of papers by Vazirani (1967, 1968, 1969, 1970a,b, 1971, 1977a,b, 1984) included past as well as new records, and also added new species of water beetles, a majority of which belong to Dytiscidae. Tonapi & Ozarkar (1969a,b) in their studies on aquatic beetles from the Pune region included water beetle species with brief descriptions and short notes on their ecology. Data on the family Haliplidae Aube, 1936 from Maharashtra is available (Sheth et al. 2016). Additionally, Sheth et al. (2018) revised the dytiscid genus *Copelatus* Erichson, 1832 with the discovery of three new species. Further, a recent study presented a record of 15 species of water beetles from Pune (Deb et al. 2023). The taxonomic keys and descriptions are available for many, if not all, species of Indian Dytiscidae, and Noteridae (e.g., Vazirani 1967, 1968, 1969, 1970a,b, 1971, 1977a,b, 1984; Pederzani 1995; Miller & Wewalka 2010), Gyrinidae, and Haliplidae (Vazirani 1984); however, some of these keys need revision. Also, compiled literature and keys for the Indian Hydrophilidae, another large group of aquatic beetles, are not readily available.

Here, for the first time, we are providing digital images of 59 species of aquatic beetles, collected from western Maharashtra. These exclude a total of 12 species as detailed information is already available for 10 species under the genera *Eretes* Laporte, 1833, *Copelatus* Erichson, 1832, and *Haliplus* Latreille 1802 (Sheth & Ghate 2014; Sheth et al. 2016, 2018). Additionally, due to a lack of intact specimens, two species, namely *Microdytes svensoni* K.B. Miller & Wewalka, 2010 and *M. boukali* Wewalka, 1997 were also omitted. Keys provided by Vazirani (cited earlier) are updated and modified wherever necessary. The earlier and latest literature (Balfour-Browne 1946; Vazirani 1967, 1968, 1969, 1970a,b, 1971, 1977a,b, 1984; Biström & Silfverberg 1981; Biström 1982, 1983, 1986, 1988, 1996; Brancucci 1983; Nilsson et al. 1989; Hansen 1991; Schödl 1992, 1993; Pederzani 1995; Wewalka 1979, 1997; Miller 2002; Biström & Nilsson 2003; Brancucci 2003; Komarek 2003; Balke et al. 2004; Miller et al. 2006; Miller & Wewalka 2010; Bouchard et al. 2011; Nilsson 2011; Ghosh & Nilsson 2012; Miller & Bergsten 2012; Hendrich & Brancucci 2013; Short & Fikáček 2013; Bilton 2015; Biström & Bergsten 2015; Nilsson 2015; Hajek & Brancucci 2015; Nasserzadeh & Komarek 2017; Villastrigo et al. 2017) was followed for identification and nomenclature. In the previous Indian literature, line drawings were also poorly produced or lacking. Hence, taxonomically important structures of aquatic beetles are illustrated also with line drawings, wherever necessary. Latest names of species are used. To restrict the size of this paper earlier synonymies and species distributions outside Maharashtra are not presented, as these are already available in the familywise catalogues (cited earlier). For the same purpose keys to families, subfamilies, and genera are not given.

MATERIALS AND METHODS

Study area

For the present work, we focused on freshwater habitats in the northern Western Ghats (hereafter referred to as NWG) of Maharashtra State (locality and habitat details are according to Sheth et al. 2019). NWG are one of eight parts of the Deccan plateau formed due to volcanic eruptions (Image 1A). Based on the geology and geography, there exists an altitudinal gradient in NWG. The altitude in NWG (Image 1B) ranges 600–1,375 m with the highest at Kalasubai peak (1,650 m) in Maharashtra State. The escarpments (900–1,375 m) act as barriers for summer winds because of which the Ghats receive orographic rain. During the southwest monsoon (June–October) the Ghats receive maximum rainfall followed by the dry period for the rest of the year. The rainfall ranges from 3,500–6,500 mm and decreases northwards and eastwards (Image 1C). The heat waves and cold waves are experienced in NWG. Temperature reaches as high as 42 °C to as low as 4 °C. The eastern side of the Ghats have lower temperature ranges as opposed to the western side. The annual mean temperature (Image 1D) in the Western Ghats proper is somewhat lower as 18–24 °C (Mani 1974).

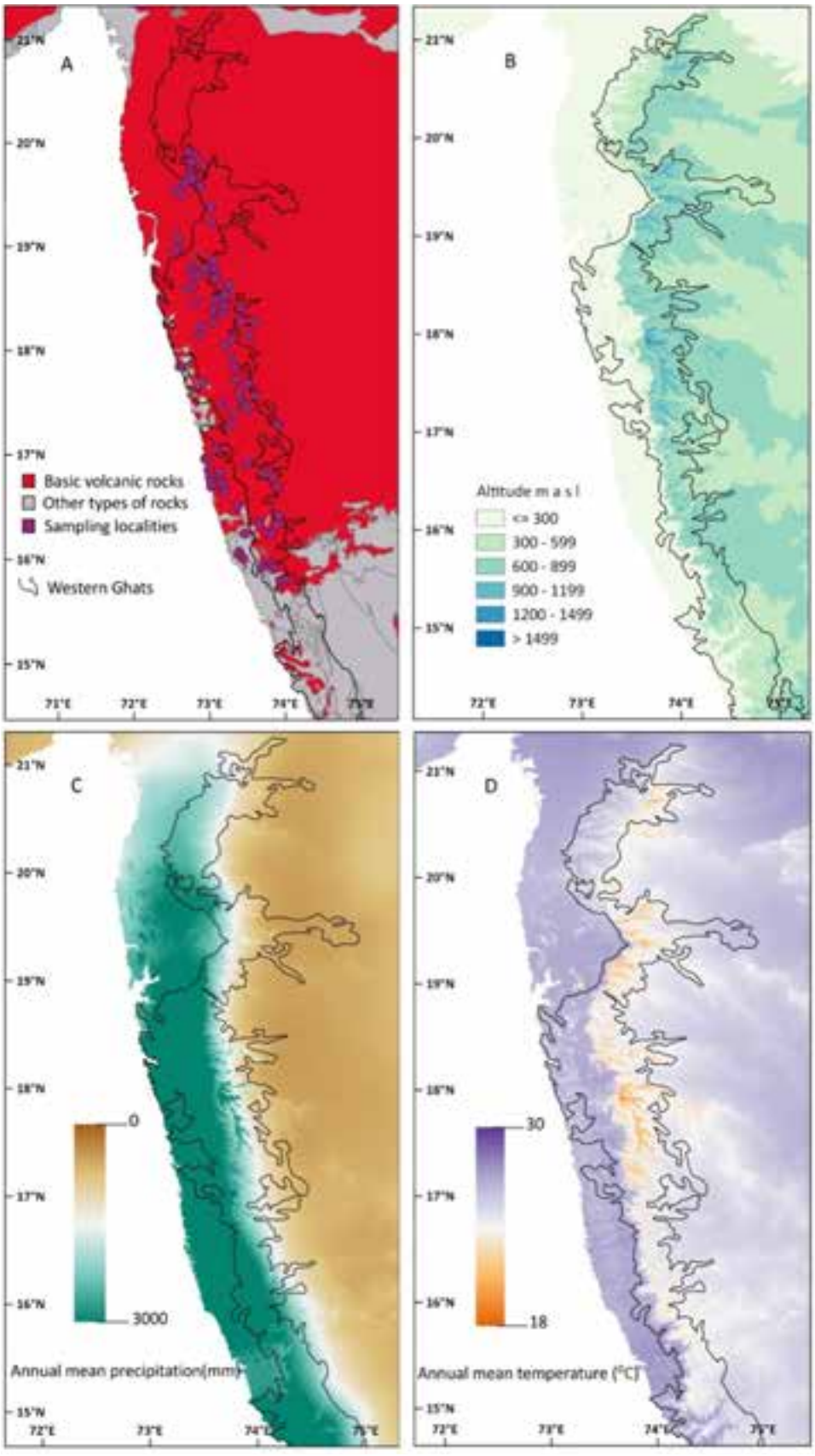

Image 1. A—Types of rocks and sampling localities in northern Western Ghats | B—Altitudinal gradient in NWG | C—Gradient of precipitation in NWG | D—Gradient of temperature in NWG.

Methods

Specimen collection, identification, and preparation of illustrations follows Sheth & Ghate 2014 and Sheth et al. 2019 (please refer to the reference list provided as a supplementary file Sheth et al. 2019 as a comparative literature). All these references for the identification of specimens are provided with keys for respective taxa in the present paper. The checklist is prepared from our surveys. The specimens are deposited in the Hemant Vasant Ghate collection (HVGC) at Modern College, Pune. The specimens will be subsequently deposited in the Zoological Survey of India, Akurdi, Pune.

RESULTS

Checklist of aquatic beetles of NWG

[*new record to Maharashtra; #already published in Sheth & Ghate 2014**,** Sheth et al. 2016 and Sheth et al. 2018]

Family Dytiscidae Leach, 1815

Subfamily: Hydroporinae Aubé, 1836

Tribe: Hyphydrini Gistel, 1848

1. *Hyphydrus lyratus flavicans* Régimbart, 1892

Material examined and distribution: Seven males and 10 females from Pune and Nashik.

2. *Hyphydrus intermixtus* (Walker, 1858)

Material examined and distribution: 45 males and 40 females were studied from Pune, Satara, Ahmednagar, Nashik, Raigad, and Kolhapur.

3. *Hyphydrus renardi* Severin, 1890

Material examined and distribution: 30 males and 30 females were studied from Pune, Satara, Ahmednagar, Thane, Nashik, Kolhapur, and Ratnagiri.

4. *Microdytes sabitae* Vazirani, 1968

Material examined and distribution: 24 males and 23 females were studied from Pune, Satara, and Ahmednagar.

5. *Microdytes whitingi* K.B. Miller & Wewalka, 2010

Material examined and distribution: three females and one male from Pune.

Tribe: Hydrovatini Sharp, 1880

6. *Hydrovatus cardoni* Severin, 1890

Material examined and distribution: seven males and eight females were studied from Kolhapur and Ratnagiri.

***7. Hydrovatus rufoniger rufoniger**(Clark, 1963)**

Material examined and distribution: one male and one female from Ratnagiri.

8. *Hydrovatus acuminatus* Motschulsky, 1859

Material examined and distribution: three males and two females studied from Nashik, Pune, Sangli, and Sindhudurg.

Tribe: Bidessini Sharp, 1880

9. *Clyeodytes hemani* Vazirani, 1968 (Image 4C, 5C)

Material examined and distribution: 20 males and 30 females from Satara.

10. *Hydroglyphus flammulatus* (Sharp, 1882)

Material examined and distribution: 60 males and 65 females were examined from Pune, Satara, Thane, Nashik, Kolhapur, and Sindhudurg.

11. *Hydroglyphus inconstans* (Régimbart, 1892)

Material examined and distribution: More than 100 males and females were examined from Pune, Satara, Thane, Raigad, Nashik, and Ratnagiri.

12. *Yola indica* Biström, 1983 (Image 4F, 5F)

Material examined and distribution: five males and five females from Pune, Ahmednagar, Sangli, and Kolhapur.

13. *Peschetius quadricostatus* (Aubé, 1838) (Image 6A, 7Aa, 7Ab)

Material examined and distribution: 50 males and 50 females were studied from Pune, Thane, Raigad Nashik, Ratnagiri, and Sindhudurg.

14. *Peschetius toxophorus* Guignot, 1942 (Image 6A, 7Aa, 7Ab)

Material examined and distribution: 50 males and 50 females were studied from Pune, Satara, and Nashik.

Tribe: Hygrotini Portevin, 1929

15. *Hygrotus (*s.str.*) musicus* (Klug, 1834) (Image 6C, 7C)

Material examined and distribution: two males and two females from Pune.

16. *Hygrotus nilghiricus* Régimbart, 1903 (Image6D, 7D)

Material examined and distribution: Five males and eight females from Pune.

Subfamily: Laccophilinae Gistel, 1856

Tribe: Laccophilini Gistel, 1856

17. *Laccophilus ceylonicus* Zimmermann, 1919

Material examined and distribution: 18 males and 23 females from Pune and Satara.

18. *Laccophilus flexuosus* Aubé, 1838

Material examined and distribution: more than 100 males and females studied from Pune, Satara, Thane, Nashik, Kolhapur, and Ratnagiri.

Image 2. Dorsal habitus: A—*H. flavicans* | B—*H. intermixtus* | C—*H. renardi* | D—*M. sabitae* | E—*M. whitingi* | F—*H. cardoni*. © S.D. Sheth, A.D. Padhye & H.V. Ghate.

19. *Laccophilus inefficiens* (Walker, 1859)

Material examined and distribution: more than 150 males and females were studied from Kolhapur, Pune, Satara, Ahmednagar, Nashik, Thane, and Sindhudurg.

20. *Laccophilus parvulus parvulus* Aubé, 1838

Material examined and distribution: 15 males and 18 females were studied from Pune, Satara, Ratnagiri, and Sindhudurg.

21. *Laccophilus parvulus obtusus* Sharp, 1882

Material examined and distribution: 10 males and eight females from Pune, Nashik, Thane, Ratnagiri, and Sindhudurg.

Subfamily: Colymbetinae Erichson, 1837

Tribe: Colymbetini Erichson, 1837

22. *Rhantus taprobanicus* Sharp, 1890 (Image 9D, 10D)

Material examined and distribution: eight males and eight females were studied from Raigad, Satara, Pune, Ahmednagar, Kolhapur, and Nashik.

Subfamily: Copelatinae Branden, 1885

Tribe: Copelatini Branden, 1885

23. *Copelatus schuhi*# Hendrich & Balke, 1998

Material examined and distribution: two males and six females from Pune and Ratnagiri.

24. *Copelatus deccanensis*# Sheth, Ghate & Hájek, 2018

Material examined and distribution: two males and six females from Nashik, Ahmednagar, and Pune.

25. *Copelatus bezdeki*# Sheth, Ghate & Hájek, 2018

Material examined and distribution: one male and four females were studied from Kolhapur, Satara, and Pune.

26. *Copelatus indicus*# Sharp, 1882

Material examined and distribution: one male and one female were studied from Satara.

27. *Copelatus schereri*# Wewalka, 1981

Material examined and distribution: one male was studied from Satara.

28. *Copelatus mysorensis*# Vazirani, 1970

Material examined and distribution: three males and five females were studied from Pune.

29. *Copelatus cryptarchoides*# Régimbart, 1899

Material examined and distribution: one male and one female from Pune.

30. *Lacconectus lambai* Vazirani, 1977

Material examined and distribution: 20 males and 23 females were studied from Satara.

31. *Lacconectus andrewesi* Guignot, 1952

Material examined and distribution: six females and four males from Pune.

Subfamily: Dytiscinae Leach, 1815

Tribe: Eretini Crotch, 1873

32. *Eretes griseus*# (Fabricius, 1781)

Material examined and distribution: 10 males and 10 females from Nashik, Pune, Kolhapur, and Sindhudurg.

Tribe: Aciliini Thomson, 1867

33. *Sandracottus festivus* (Illiger, 1801)

Material examined and distribution: eight males and seven females were studied from Satara, Pune, and

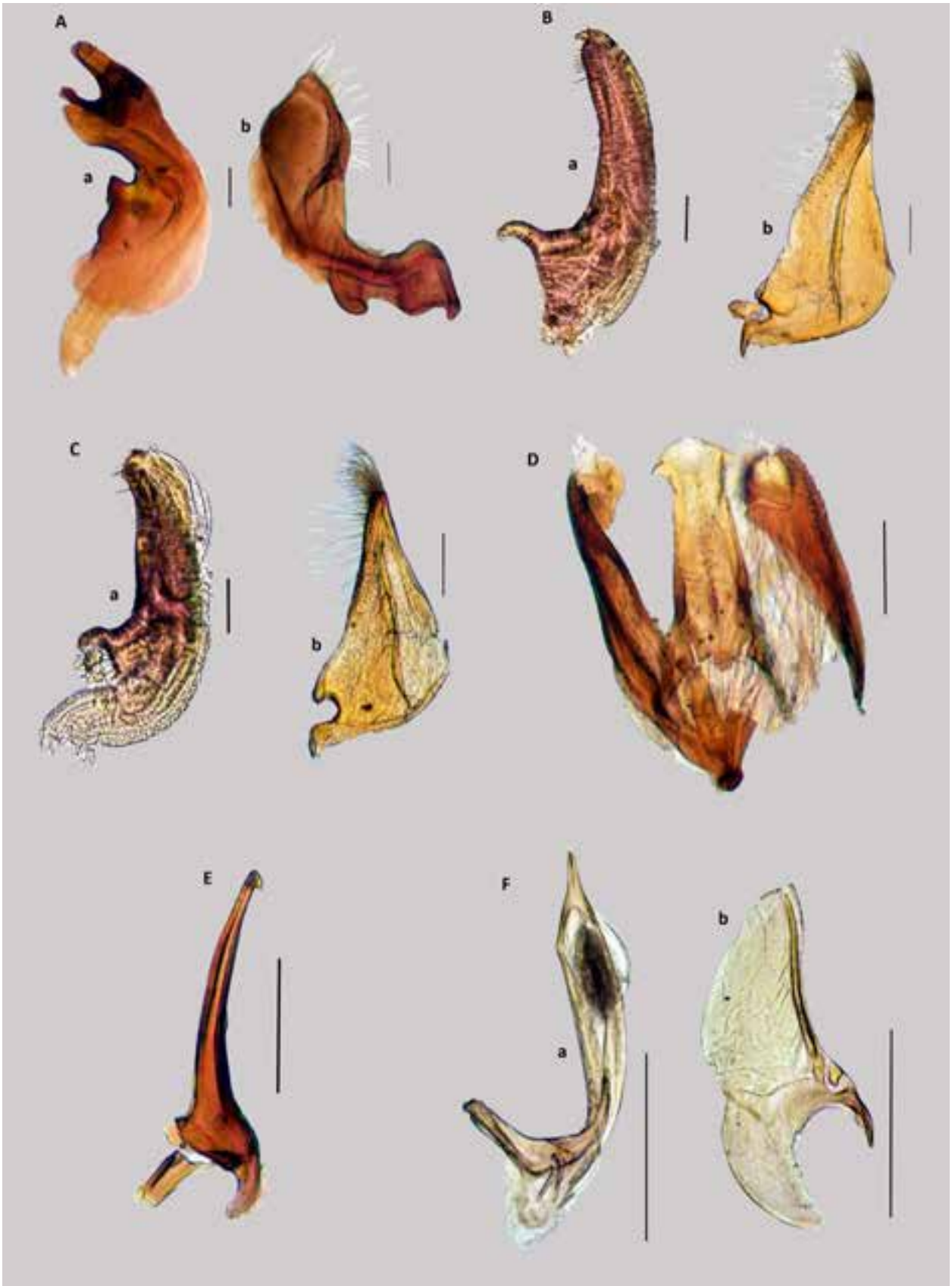

Image 3. Lateral view of male genitalia (a: aedeagus, b: paramere): A—*H. flavicans* | B—*H. intermixtus* | C—*H. renardi* | D—*M. sabitae* (dorsal view) | E—*M. whitingi*. Scale for A–E: 100 µm | F—*H. cardoni* (500 µm). © S.D. Sheth, A.D. Padhye & H.V. Ghate.

Ahmednagar.

34. *Sandracottus dejeanii* (Aubé, 1838)

Material examined and distribution: seven males and nine females were studied from Raigad and Pune.

Tribe: Hydaticini Sharp, 1880

35. *Hydaticus incertus* Régimbart, 1888

Material examined and distribution: 25 males and 26 females were studied from Pune, Nashik, and Kolhapur.

36. *Hydaticus luczonicus* Aubé, 1838

Material examined and distribution: 40 males and 47 females were studied from Pune, Ahmednagar, Nashik, and Satara.

37. *Hydaticus vittatus vittatus* (Fabricius, 1775)

Material examined and distribution: 30 males and 30 females were examined from Kolhapur, Pune, Satara, Ahmednagar, and Nashik.

38. *Hydaticus satoi satoi* Wewalka, 1975

Material examined and distribution: 15 males and 15 females from Raigad, Pune, Satara, Ahemdnagar, Nashik, and Sindhudurg.

Subfamily: Cybistrinae

Tribe: Cybistrini Sharp, 1880

39. *Cybister sugillatus* Erichson, 1834

Material examined and distribution: three males and four females studied from Pune, Satara, Raigad, and Sindhudurg.

40. *Cybister cardoni* Severin, 1890

Material examined and distribution: one male and one female from Ratnagiri.

41. *Cybister tripunctatus lateralis* (Fabricius, 1798)

Material examined and distribution: two males and four females were studied from Pune, Nashik, Raigad, and Ratnagiri.

42. *Cybister confusus* Sharp, 1882

Material examined and distribution: two males and four females from Pune, Raigad, and Ratnagiri.

43. *Cybister cognatus* Sharp, 1882

Material examined and distribution: three males and three females from Pune and Nashik.

Family: Gyrinidae Latreille, 1810

Subfamily: Gyrininae Latreille, 1810

Tribe: Enhydrini Régimbart, 1882

44. *Dineutus indicus* Aubé, 1838

Material examined and distribution: 50 males and 52 females were studied from Raigad, Pune, Satara, Ahmednagar, Nashik, and Sindhudurg.

Image 4. Dorsal habitus: A—*H. rufoniger rufoniger* | B—*H. acuminatus* | C—*C. hemani* | D—*H. flammulatus* | E—*H. inconstans* | F—*Y. indica* © S.D. Sheth, A.D. Padhye & H.V. Ghate.

45. *Dineutus unidentatus* Aubé, 1838

Material examined and distribution: one male and two females from Nashik.

Tribe: Orectochilini Régimbart, 1882

46. *Patrus productus* (Régimbart, 1883)

Material examined and distribution: two males and two females from Ratnagiri.

47. *Patrus discifer* (Walker, 1859)

Material examined and distribution: 10 males and 12 females were examined from Pune, Kolhapur, and Ratnagiri.

48. *Patrus* cf *haemorrhous* (Régimbart 1891)

Material examined and distribution: one female

Image 5. Lateral view of male genitalia (a: aedeagus, b: paramere): A—*H. rufoniger rufoniger* (dorsal view) | B—*H. acuminatus* | C—*C. hemani* | D—*H. flammulatus* | E—*H. inconstans* | F—*Y. indica*. Scale for A–B: 500 µm | scale for C–F: 100 µm.

from Pune.

49. *Patrus assimilis* (Ochs 1957)

Material examined: 10 males and 10 females from Ratnagiri and Sindhudurg.

50. *Patrus limbatus* (Régimbart, 1883)

Material examined: One male and one female from Pune

Family: Noteridae Thomson, 1860
Subfamily: Noterinae Thomson, 1860
Tribe: Noterini Thomson, 1860

51. *Canthydrus laetabilis* (Walker, 1858)

Material examined and distribution: 12 males and 14 females were studied from Pune.

52. *Canthydrus luctuosus* (Aubé, 1838)

Material examined and distribution: 20 males and 20 females were studied from Pune, Nashik, and Kolhapur.

Tribe: Neohydrocoptini Zalat, Saleh, Angus & Kaschef, 2000

53. *Neohydrocoptus bivittis Motschulsky 1859**

Material examined and distribution: two males and three females from Ratnagiri (collected by SVP & MRK).

54. *Neohydrocoptus* sp. 2

Material examined and distribution: one male and two females from Ratnagiri (collected by SVP & MRK) and one specimen from Pune.

Family: Haliplidae Aube, 1936
Subfamily: Haliplinae, Tribe: Haliplini

55. *Haliplus arrowi*# Guignot, 1936

Material examined and distribution: 22 males and 15 females from Pune and Satara.

56. *Haliplus angustifrons*# Régimbart, 1892

Material examined and distribution: one male form Pune.

Family: Hydrophilidae Latreille, 1802
Subfamily: Hydrophilinae Latreille, 1802

57. *Sternolophus inconspicuus* (Nietner, 1856)

Material examined and distribution: five males and three females were studied from Pune district.

58. *Sternolophus rufipes* (Fabricius, 1792)

Material examined and distribution: five males and 10 females were studied from Pune, Nashik, Ratnagiri, and Sindhudurg.

59. *Hydrobiomorpha spinicollis* (Eschscholtz, 1822) (Image 20C, 21C)

Material examined and distribution: three females and two males from Pune and Kolhapur.

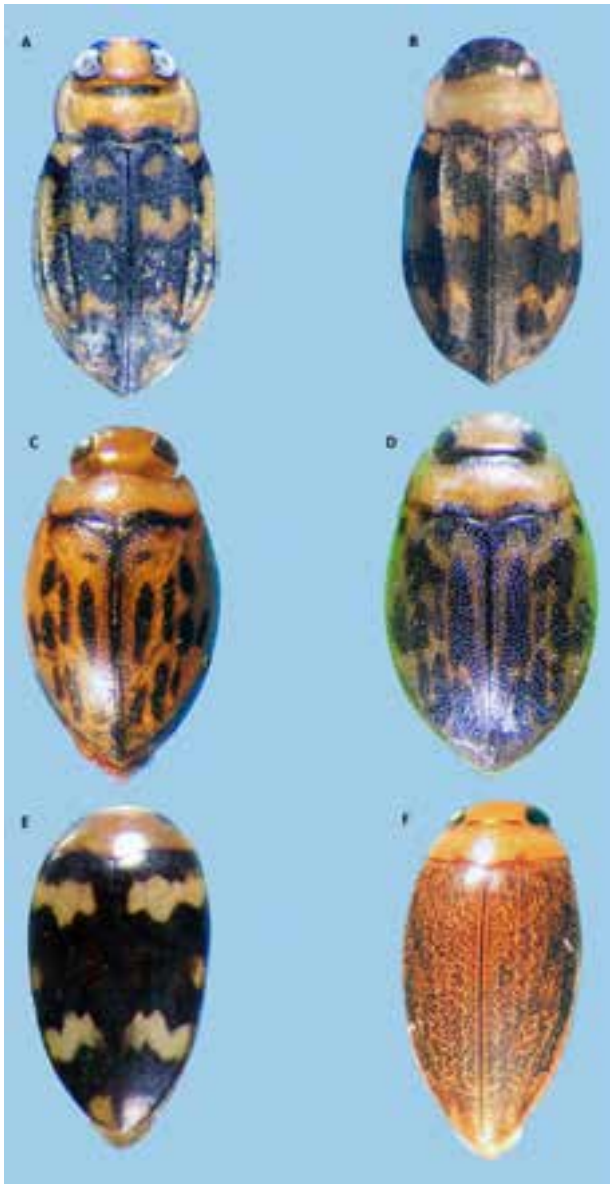

Image 6. Dorsal habitus: A—*P. quadricostatus* | B—*P. toxophorus* | C—*H. musicus* | D—*H. nilghiricus* | E—*L. ceylonicus* | F—*L. flexuosus*. © S.D. Sheth, A.D. Padhye & H.V. Ghate.

60. *Hydrophilus olivacious* Fabricius, 1781 (Image 20D, 21D)

Material examined and distribution: Three males and six females from Nashik, Pune, Raigad, and Goa.

61. *Berosus pulchellus* MacLeay, 1825

Material examined and distribution: 11 females and six males from Pune, Nashik, Raigad, and Sindhudurg.

62. *Berosus chinensis* Knisch, 1922

Material examined and distribution: two females and two males from Pune.

63. *Berosus indicus* (Motschulsky, 1861)

Material examined and distribution: eight females

Image 7. Lateral view of male genitalia (a: aedeagus, b: paramere): A—*P. quadricostatus* | B—*P. toxophorus* | C—*H. musicus* | D—*H. nilghiricus*. (Scale for A–D: 500 µm) | E—*L. ceylonicus* | F— *L. flexuosus*. (Scale for E and F: 100 µm).

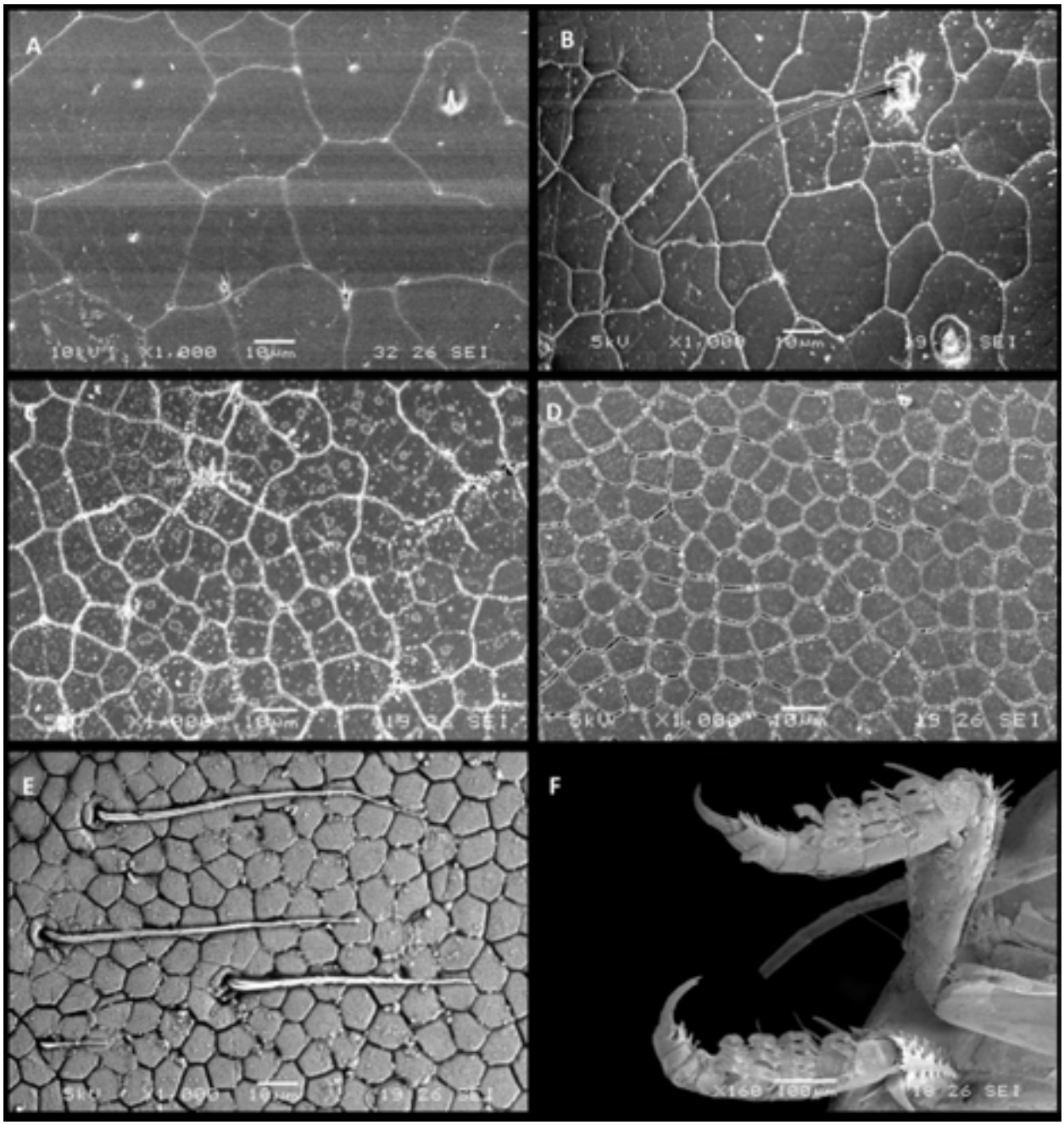

Image 8. Elytral microsculpture: A—*L. ceylonicus* | B—*L. flexuosus* | C—*L. inefficiens* | D—*L. parvulus* | E—*L. obtusus* | F—Adhestive setae on Laccophilus male pro and meso tarsi.

and eight males from Pune, Nashik, Satara, and Sindhudurg.

64. *Berosus indiges* Schödl, 1992

Material examined and distribution: two males and two females from Nashik.

65. *Regimbartia attenuata* (Fabricius, 1801) (Image 22E, 24E)

Material examined and distribution: two males and four females from Pune, Satara, Kolhapur, Ratnagiri, and Sindhudurg.

66. *Allocotocerus* sp1 (Image 22F, 24F)

Material examined and distribution: seven males and eight females from Kolhapur, Ratnagiri, and Sindhudurg districts.

67. *Amphiops* sp1 (Image 25A, 25B)

Material examined and distribution: three females and two males from Pune, Ratnagiri, and Sindhudurg.

Remarks: Size: 3.5–4 mm

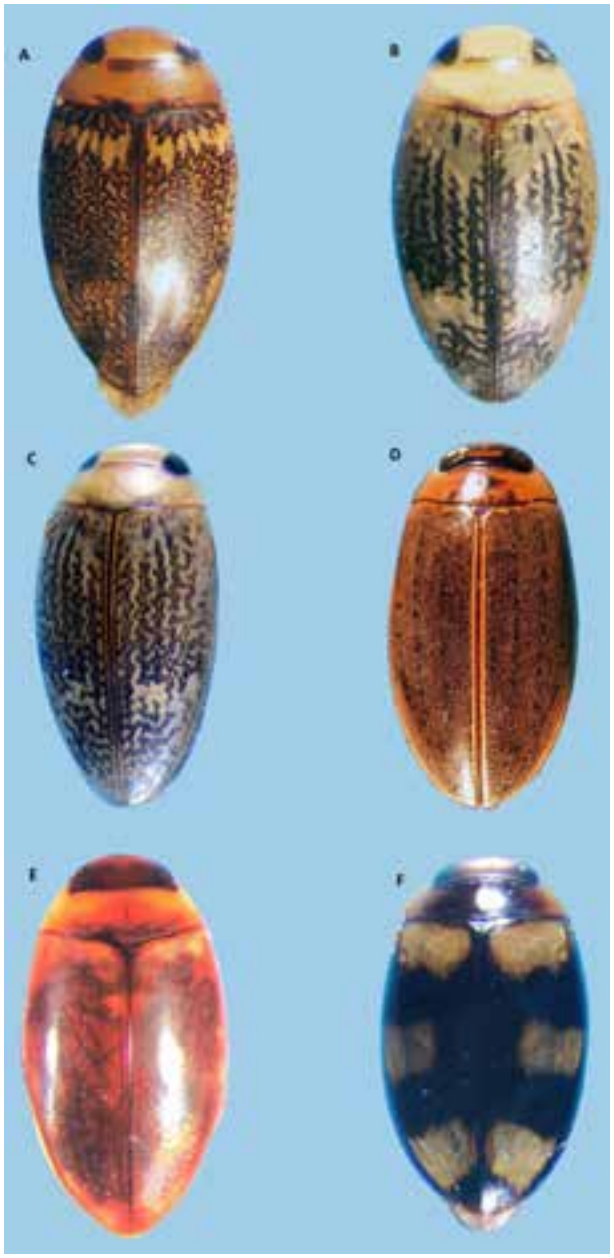

Image 9. Dorsal habitus: A—*L. inefficiens* | B—*L. parvulus* | C—*L. obtusus* | D—*R. taprobanicus* | E—*Lacconetcus lambai* | F—*L. andrewesi*. © S.D. Sheth, A.D. Padhye & H.V. Ghate.

68. ***Helochares*** **sp1** (Image 25C, 25D)

Material examined and distribution: two females and four males from Nashik, Pune, Ratnagiri, and Sindhudurg.

Remarks: Size: 5.3–5.6 mm

69. ***Helochares*** **sp2** (Image 25E, 25F)

Material examined and distribution: three females and two males from Nashik and Ratnagiri.

Remarks: Size: 4.5–4.8 mm.

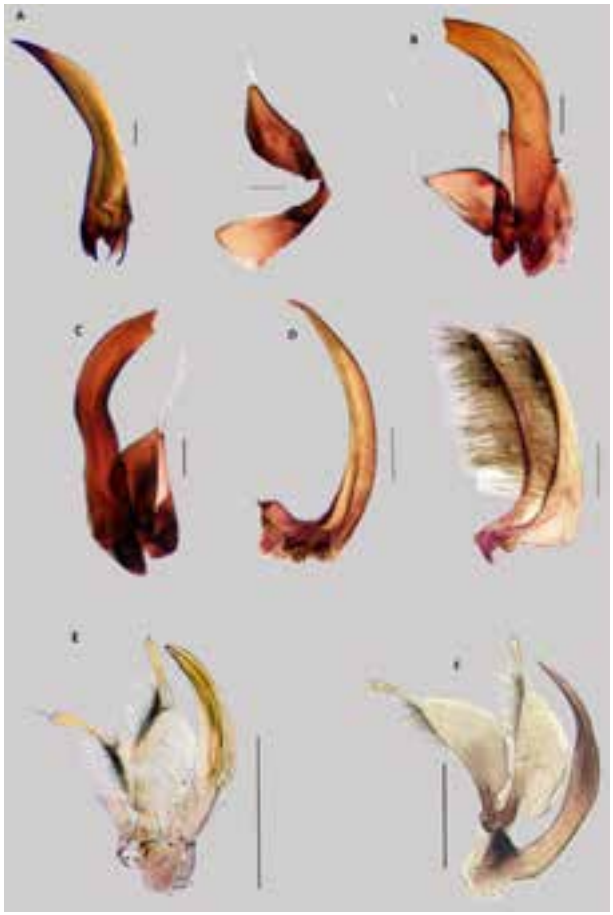

Image 10. Lateral view of male genitalia (a: aedeagus, b: paramere): A—*L. inefficiens* | B—*L. parvulus* | C—*L. obtusus* | D—*R. taprobanicus* | E—*L. lambai* | F—*L. andrewesi*. (Scale for A–C : 100 µm | scale for D, E, and F: 500 µm.). © S.D. Sheth, A.D. Padhye & H.V. Ghate.

Illustrated taxonomic keys to the aquatic beetles of NWG

Family Dytiscidae

Subfamily: Hydroporinae Aubé, 1836

Genus *Hyphydrus* Illiger, 1802

Biström (1982) was followed for generic as well as species level identification.

Illustrations and additions to the keys to *Hyphydrus* species:

1. Pronotum with distinct black marking at posterior margin (Figure 1A); in male last abdominal segment with tubercles; second abdominal segment of male with spine like process (Figure 1B); in female each elytron with longitudinal depression; size large, 4–5mm (Image 2A); male genitalia (Image 3A)…***H. l. flavicans*** **Régimbart, 1892**

- Pronotum with distinct black markings at anterior and posterior margins; in male last abdominal segment

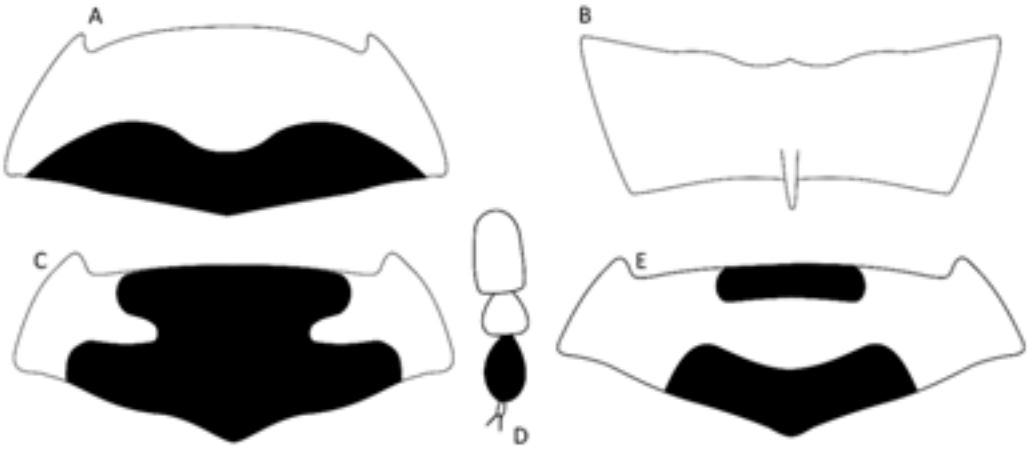

Figure 1. Pronotal maculation A—*H. flavicans* | B—Second abdominal segment of male *H. flavicans* | C—*H. intermixtus* | D—Pro and meso tarsi of *H. intermixtus* | E—*H. renardi*. © S.D. Sheth, A.D. Padhye & H.V. Ghate.

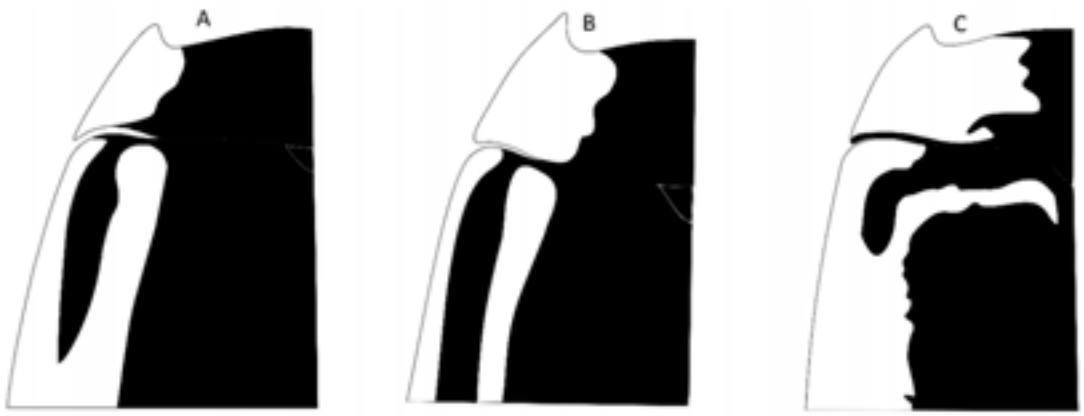

Figure 2. Pronotal and elytral maculation: A—*H. vittatus* | B—*H. satoi* | C—*H. luczonicus*. © S.D. Sheth, A.D. Padhye & H.V. Ghate.

without tubercles; male without spine like process on second abdominal segment; female without longitudinal depression per elytron; size small, 3–4 mm...2

2. Pronotum with anterior and posterior black markings connected on disc (Figure 1C); elytra less shiny; pro and mesotarsi with last segment dark (Figure 1D); size 3.5–4mm (Image 2B); median lobe of male genitalia with a hook like apical process in lateral view (Image 3B)...***H. intermixtus* (Walker, 1858)**

- Pronotum with anterior and posterior black markings separate (Figure 1E); elytra shiny; last segment of pro and mesotarsi not darkened; size 3–4mm (Image 2C); median lobe of male genitalia without a hook like apical process in lateral view (Image 3C)...***H. renardi* Severin, 1890**.

Genus *Microdytes* J. Balfour-Browne, 1946

Species were identified using the descriptions and keys provided by Wewalka (1997) and Miller & Wewalka (2010).

Illustrations and keys to *Microdytes* species (Image 3D, 3E):

1. Body globular oval, size 2 mm (Image 2D); dorsal-ventral sides with coarse punctures...***M. sabitae* Vazirani, 1968**

- Body oblong oval, size 1.5 mm (Image 2E); dorso-ventrally flat, punctures on dorsal-ventral sides obsolete...***M. whitingi* K.B. Miller & Wewalka, 2010**

Genus *Hydrovatus* Motschulsky, 1853

The species were identified using keys by Biström (1996).

Illustrations and keys to *Hydrovatus* species (Image 3F, 5A, and 5B):

1. Elytron black with pale yellow transverse fasciae, sutural region black; size 3 mm (Image 2F)...***H. cardoni* Severin, 1890**

- Elytron concolourous...2

Image 11. Dorsal habitus: A—*S. festivus* | B—*S. dejeanii* | C—*H. incertus* | D—*H. luczonicus*. © S.D. Sheth, A.D. Padhye & H.V. Ghate.

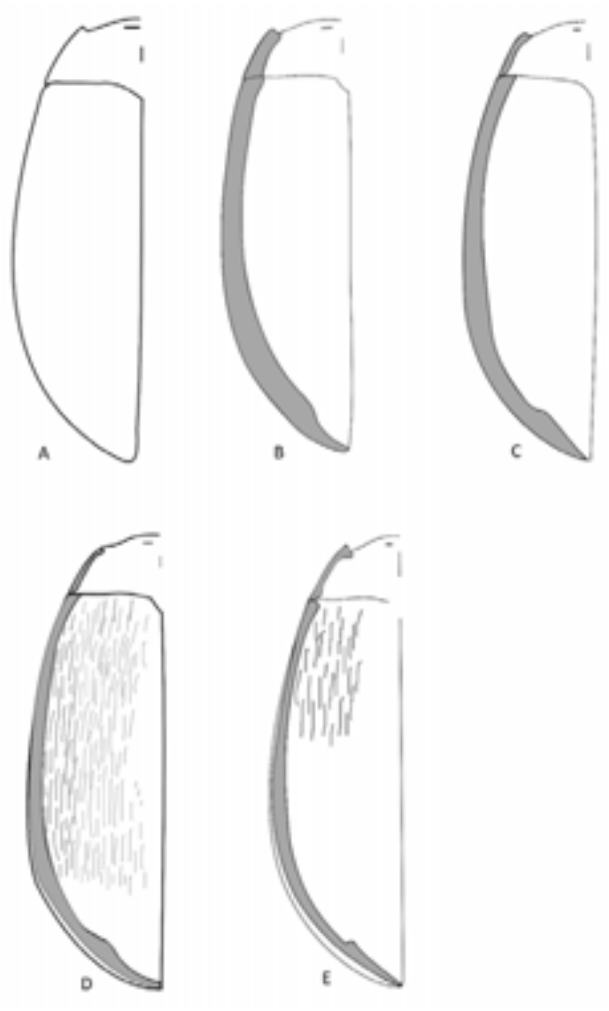

Figure 3. Elytral sexual sculpture: A—*C. sugillatus* | B—*C. cardoni* | C—*C. tripunctatus* lateralis | D—*C. confusus* | E—*C. cognatus*. © S.D. Sheth, A.D. Padhye & H.V. Ghate.

2. Size 3.5 mm (Image 4A) ...***H. rufoniger rufoniger*** **(Clark, 1963)**

- Size 2.5 mm (Image 4B)...***H. acuminatus*** **Motschulsky, 1859**

Genus *Hydroglyphus* Motschulsky, 1853

The species were identified using keys by Vazirani (1968).

Illustrations and keys to *Hydroglyphus* species:

1. Pronotal plicae do not continue on elytra; size 2.5 mm (Image 4D); median lobe of male genitalia abruptly narrows to apex (Image 5D)...***H. flammulatus*** **(Sharp, 1882)**

- Pronotal plicae continue on elytra; size 1.5 mm (Image 4E); median lobe of male genitalia gradually narrows to apex (Image 5E)...***H. inconstans*** **(Régimbart, 1892)**

Genus *Hygrotus* Stephens, 1828

Illustrations and keys to *Hygrotus* species

1. Median lobe of male genitalia broad from base to apex (Image7 Ca,b); body Size 3 mm (Image 6C)... ***Hygrotus musicus*** **(Klug, 1834)**

- Median lobe of male genitalia broad at base, bulges in middle, narrows towards apex (Image7Da,b); body Size 4.5 mm (Image 6D)...***Hygrotus nilghiricus*** **Régimbart, 1903**

Remarks: Villastrigo et al. (2017) proposed a new classification of tribe Hygrotini based on molecular phylogeny. The former genus *Herophydrus* was synonymized with a subgenus *Hygrotus* s. str. and the genus *Hyphoporus* was given a new status of a subgenus under the genus *Hygrotus* (Villastrigo et al. 2017).

Image 12. Lateral view of male genitalia (a: aedeagus, b: paramere): A—*S. festivus* | B—*S. dejeanii* | C—*H. incertus* | D—*H. luczonicus*. Scale 500 µm.© S.D. Sheth, A.D. Padhye & H.V. Ghate.

Subfamily: Laccophilinae Gistel, 1856

Genus *Laccophilus* Leach, 1815

The generic identification is based on keys provided by Pederzani (1995) and Brancucci (1983), and species level identification is based on Brancucci (1983) and Vazirani (1968).

Illustrations and additions to the keys to *Laccophilus* species:

1. Elytra dark brown or black with 3 yellow fasciae and a median yellow spot per elytron (fasciae: 1st—sub-basal fascia well separated from base, 2nd—post median and 3rd—apical) elytral microsculpture (Image 8A); size 4 mm (Image 6E); male genitalia (Image 7E)...***L. ceylonicus* Zimmermann, 1919**

- Elytra with black lines or irrotations; overall pale yellow to reddish yellow dorsally...2

2. Ventrally concolourous; size 3.5–4.5 mm...3

- Ventrally without uniform colouration (metacoxal plates and some abdominal segments darker); smaller species (size 3 mm);...4

3. Each elytron with several irregular and thin black lines, uniformly distributed except most lateral region,

Figure 4. Pattern of hydrofuge pubescence on elytra and epiplural spine of *Dineutus* and *Patrus* species (not to the scale): A—*D. indicus* | B—*D. unidentatus* | C—*P. productus* | D—*P. limbatus* | E—*P. discifer* | F—lateral *P.* cf. *haemorrhous* | G—*P. assimilis*. © S.D. Sheth, A.D. Padhye & H.V. Ghate.

elytral microsculpture consists of irregular hexagons within which place small hexagons(Image 8B); anterior and posterior margins of pronotum with thin black band medially; size 4–4.5 mm (Image 6F); median lobe of male genitalia broad from base to apex (Image 7F)...***L. flexuosus* Aubé, 1838**

- Each elytron with several irregular and thick black lines connected at many points forming irrotations, these lines become thinner or obsolete in sub-basal region and in apical half, appear as fasciae, elytral microsculpture consists of small hexagons (Image 8C); anterior and posterior margins of pronotum with thick black band medially; size 3.5mm (Image 9A); median lobe of male genitalia broad at base narrowly tapers towards apex, angled near base (Image 10A)...***L. inefficiens* (Walker, 1859)**

4. Each elytron with 5–6 double, solid parallel lines (on disc) interrupted largely at base and in apical half (Image 9B), elytral microsculpture consists of small hexagons (Image 8D); median lobe of male genitalia broad at apex (Image 10B)...***L. parvulus parvulus* Aubé, 1838**

- Each elytron with 5–6 double, parallel lines (on disc) less interrupted at base and in apical half (Image 9C), elytral microsculpture consists of small hexagons (Image 8E); median lobe of male genitalia distinctly narrow at

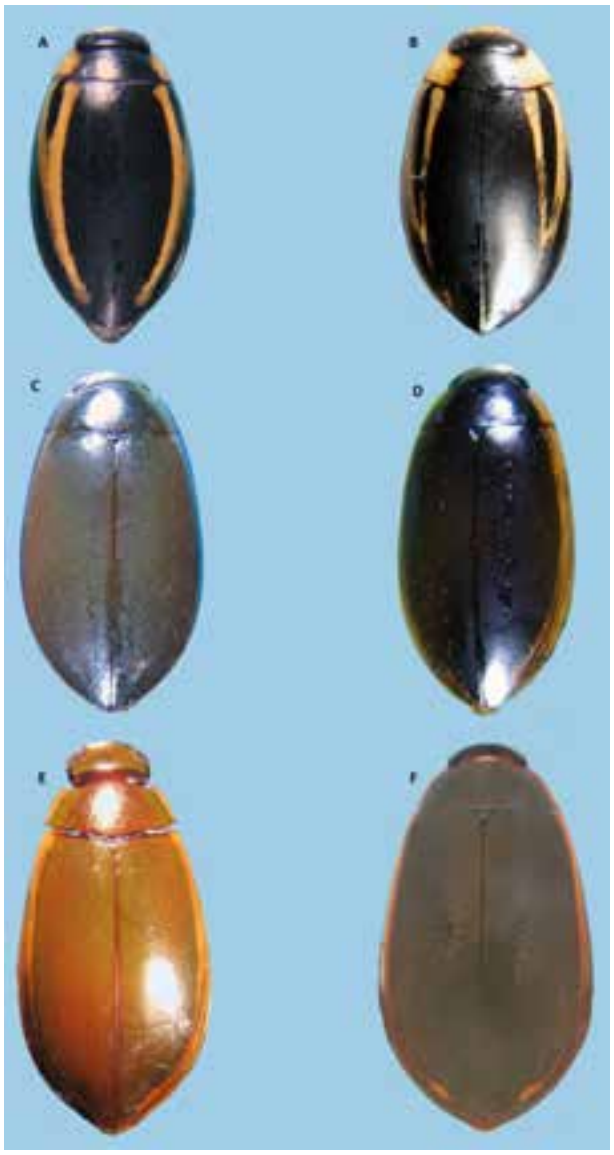

Image 13. Dorsal habitus: A—*H. vittatus* | B—*H. satoi* | C—*C. sugillatus* | D—*C. cardoni* | E—*C. tripunctatus* lateralis | F—*C. confusus*. © S.D. Sheth, A.D. Padhye & H.V. Ghate.

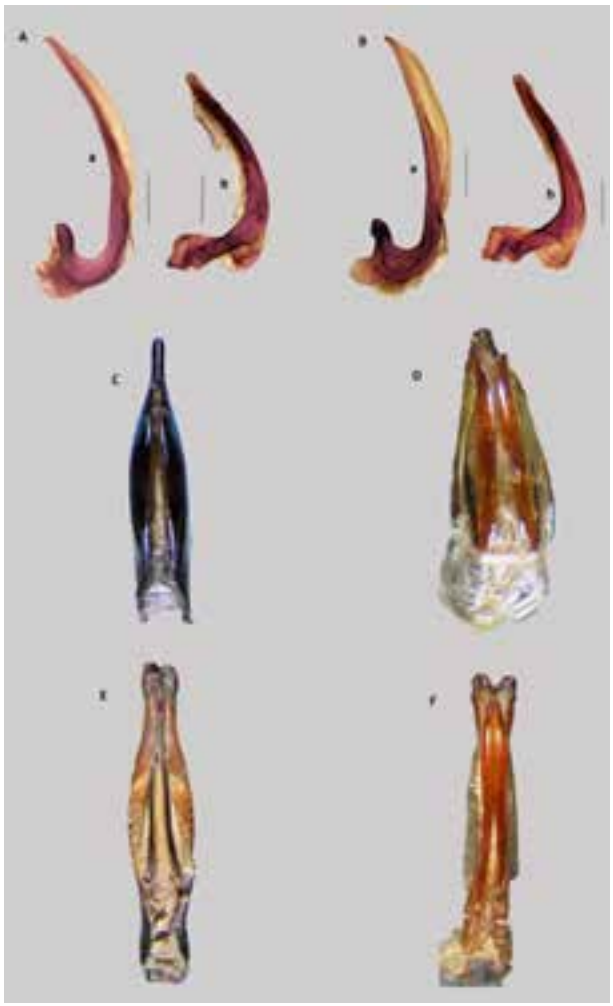

Image 14. Lateral view of male genitalia (a: aedeagus, b: paramere): A—*H. vittatus* (500 µm) | B—*H. satoi* (500 µm) | C—*C. sugillatus* (4 mm) | D—*C. cardoni* (3.5 mm) | E—*C. tripunctatus* lateralis (5.1 mm) | F—*C. confusus* (7 mm). © S.D. Sheth, A.D. Padhye & H.V. Ghate.

apex (Image 10C)...***L. parvulus obtusus*** **Sharp,1882**

Remarks: Pro and meso tarsi of male bear adhesive setae arranged in four rows (Image 8F).

Subfamily: Copelatinae Branden, 1885

Genus *Lacconectus* Motschulsky, 1855

Species were identified using keys and description provided by Vazirani (1970a, 1977a) and Brancucci (2003).

Illustrations and additions to the keys to *Lacconectus* species:

1. Body elongate oval, elytra uniformly yellowish-brown, with narrow faint basal streak, but without yellow fasciae per elytron; size 5–5.5 mm (Image 9E); apex of median lobe broadly pointed (Image 10Ea), apical lobes on parameres almost uniformly broad (Image 10Eb) ...***L. lambai*** **Vazirani, 1977**

- Body oblong oval, elytra dark brown to black with 3 broad yellow fasciae; size 5 mm (Image 9F); apex of median lobe narrow (Image 10Fa), apical lobes on parameres narrow at base while broad at apex (Image 10Fb) ..***L andrewesi*** **Guignot, 1952**

Remarks: *Lacconectus andrewesi* was found in the same habitat along with *Laccophilus ceylonicus*, which has similar elytral pattern as that of *L. andrewesi*.

Subfamily: Dytiscinae Leach, 1815

Genus *Sandracottus* Sharp, 1882

Illustrations and additions Keys to the *Sandracottus*

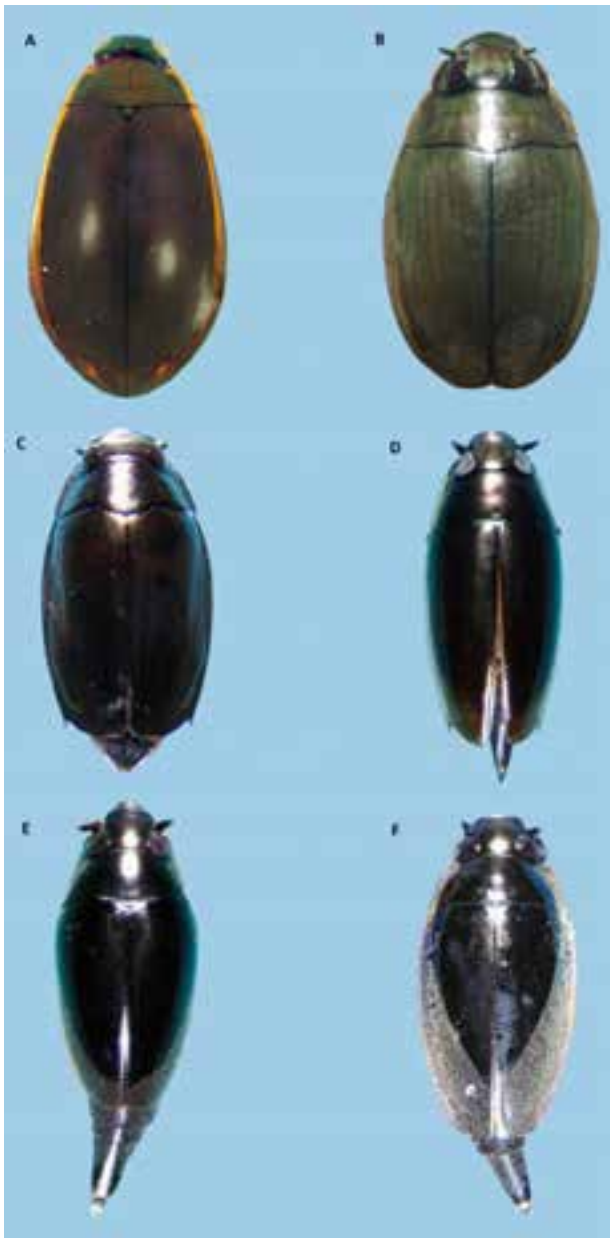

Image 15. Dorsal habitus: A—*C. cognatus* | B—*D. indicus* | C—*D. unidentatus* | D—*P. productus* | E—*P. limbatus* | F—*P. discifer*. © S.D. Sheth, A.D. Padhye & H.V. Ghate.

Image 16. Dorsal view of male genitalia: A—*C. cognatus* | B—*D. indicus* | C—*D. unidentatus* | D—*P. productus* | E—*P. limbatus* | F—*P. discifer*. Scale 500 µm. © S.D. Sheth, A.D. Padhye & H.V. Ghate.

species:

1. Head with black mark not continuous; pronotal anterior and posterior median black bands connected by a thin black line; two yellow stripes parallel to suture initiate just after the elytral base terminate in basal half; size 14–15mm (Image 11A); tip of median lobe continuous in dorsal view of male genitalia (Image 12A)...***S. festivus* (Illiger, 1801)**

- Head with black mark continuous; pronotal anterior and posterior median black bands connected by a thick black band; two yellow large spots instead of yellow stripes present just after the elytral base; size 11–13 mm (Image 11B); tip of median lobe bifurcated in dorsal view of male genitalia (Image 12B)...***S. dejeanii* (Aubé, 1838)**

Genus *Hydaticus* Leach, 1817

According to Ghosh & Nilsson (2012) in India all nine species belong to *H*. (*Prodaticus*) Sharp, 1882, out of which four are known from Maharashtra. However, Miller et al. (2009) and Pederzani (1995) consider *Hydaticus* and *Prodaticus* as two separate genera.

Illustrations and additions to the keys to the *Hydaticus* species:

1. Smaller species, size 10 mm (Image 11C); elytra yellow with confluent black spots; pronotum on

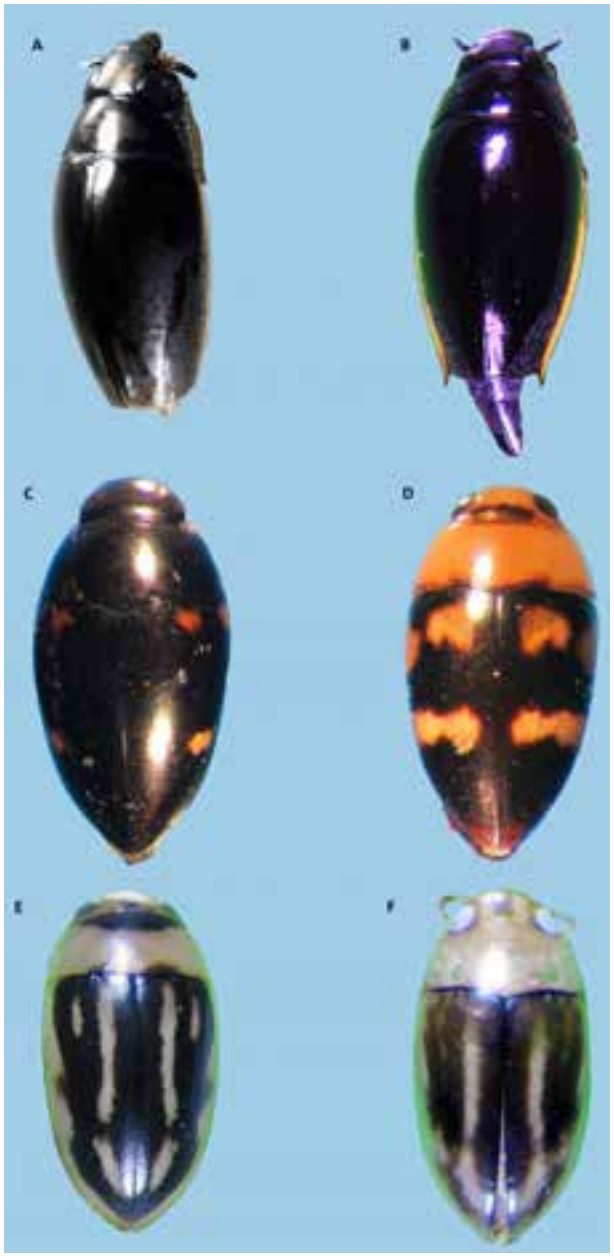

Image 17. Dorsal habitus: A—*P.* cf *haemorrhous* (female) | B—*P. assimilis* | C—*C. luctuosus* | D—*C. laetabilis* | E—*N. bivittis* | F—*Neohydroptus* sp. 2. © S.D. Sheth, A.D. Padhye & H.V. Ghate.

disc (anterior and posterior margins) with faint, well separated black bands; short tuft of setae present at apex of median lobe of male genitalia (Image 12 Ca,b)...***H. incertus* Régimbart, 1888**

- Larger species, size more than 10 mm; elytra black with lateral yellow patterns; pronotal disc black, lateral margins yellow; short tuft of hair absent at apex of median lobe of male genitalia...2

2. Two lateral yellow vittae present on elytra; male mesotarsomeres with two rows of adhesive cups...3

- Elytral yellow vittae replaced by large yellow band (nearly half the width of elytron) posteriorly extends up to the tip, a transverse, narrow yellow band connected to lateral yellow band extend towards suture sub-basally; male mesotarsomeres with four rows of adhesive cups; form broadly oval, large as 13 mm (Image 11D); pronotal lateral yellow band extends largely on disc, leaving narrow, median black region (Figure 2C); male genitalia (Image 12Da,b)...***H. luczonicus* Aubé, 1838**

3. Form oval, narrow (Image 13A); lateral vittae broad, join each other well before reaching mid of elytron, terminate just before apex; pronotal yellow band not extending beyond elytral humeral vitta (Figure 2A); size 12.5 mm; median lobe of male genitalia narrowly explanate from base to apex (Image 14Aa,b)...***H. vittatus vittatus* (Fabricius, 1775)**

- Form oval, broad (Image 13B); lateral vittae narrow, join each other beyond mid of elytron, terminate well before apex; pronotal yellow band extending beyond elytral humeral vitta (Figure 2B); size 12.8–13.0 mm; median lobe of male genitalia broadly explanate from base to apex (Image 14Ba,b)...***H. satoi satoi* Wewalka, 1975**

Genus *Cybister* Curtis, 1827

According to Miller et al. (2007) there are four subgenera under the genus as *Cybister* (*Megadytoides*) Brinck, *Cybister* (*Melanectes*) Brinck, *Cybister* (*Cybister*) Curtis and *Cybister* (*Neocybister*) Miller, Bergsten and Whiting. This classification was based 47 adult and larval characters, and molecular work on Cytochrome oxidase I (COI), Cytochrome oxidase I (COII), Histone 3 (H3) and wingless genes (Miller et al. 2007). Our specimens belong to *C.* (*Melanectes*) Brinck and *C.* (*Cybister*) Curtis. The generic identification is based on keys provided by Pederzani (1995) and Miller et al. (2007), and species identification is based on Vazirani (1968).

Illustrations and additions to the keys to the *Cybister* species:

1. Pronotum with red lateral margins; elytra without lateral yellow bands or stripes (Image 13C); ventrally uniformly dark brown; only 3rd and 4th abdominal sternites with lateral pale yellow spots; mesotarsi of male without sexual pubescence; median lobe of male genitalia without bifurcated apex, widest at the middle in ventral view (Image 14C); female with second rudimentary claw; female without sexual sculpture on elytra (Figure 3A)...***C.* (*Melanectes*) *sugillatus* Erichson, 1834**

- Both pronotum and elytra with lateral yellow bands

Image 18. Lateral view of male genitalia: A—*P. assimilis* (500 µm) | B—*C. luctuosus* | C—*C. laetabilis* | D—*N. bivittis* | E—*Neohydrocoptus* sp. 2. Scale 100 µm. © S.D. Sheth, A.D. Padhye & H.V. Ghate.

Image 19 Noterid platform: A—Canthydrus, C—*Neohydrocoptus* | Male adhesive setae B—*Canthydrus*, D—*Neohydrocoptus*. © S.D. Sheth, A.D. Padhye & H.V. Ghate.

or stripes; 3rd, 4th, and 5th abdominal sternites bear yellow spots laterally; mesotarsi of male with sexual pubescence; median lobe of male genitalia with or without bifurcated apex in ventral view; female without second metatarsal claw; females with or without sexual sculpture on elytra...2

2. Total Size less than 25 mm (Image 13D); apex of median lobe of male genitalia not bifurcated anteriorly in ventral view (Image 14D), female without sexual sculpture on elytra (Figure 3B)...***C. cardoni* Severin, 1890**

- Size 25 or more than 25 mm...3

3. Size 25 mm (Image 13E); elytral band wider than that on pronotum, extend on elytral epipleura, reach at elytral apex; ventrally largely brown with metaventrite and metacoxal plates yellow laterally; apex of median lobe male genitalia bifurcated (Image 14E); female without sexual sculpture on elytra (Figure 3C)...***C.* (*cybister*) *tripunctatus lateralis* (Fabricius, 1798)**

- Size more than 25 mm; female with sexual sculpture on elytra...4

4. Elytral yellow band gradually narrows towards apex leaving lateral-most area brown; female with secondary sexual sculpture prominent (Figure 3D), in the form of short strioles, cover entire elytra except region near suture and apex (1/5th of elytral size); male with both first and second mesotarsomeres completely covered with sexual hairs; size 36 mm (Image 13F); apex of median lobe of male genitalia bifurcated (Image 14F)...***C.* (*cybister*) *confusus* Sharp, 1882**

- Elytral yellow band as wide as pronotal band, narrows in basal half; female elytral sculpture in the form of short, deep, sparsely placed strioles, present in basal half only, leaving posterior half shiny (Figure 3E); male with only first mesotarsomere completely covered with sexual hairs while second mesotarsomere incompletely covered; size 32–34 mm (Image 15A); apex of median lobe of male genitalia (Image 16A)...***C.*(*cybister*) *cognatus* Sharp, 1882**

Family: Gyrinidae Latreille, 1810
Subfamily: Gyrininae Latreille, 1810
Genus *Dineutus* MacLeay, 1825

1. For identification of Gyrinidae, work by Miller & Bergsten (2012), and Vazirani (1984) was used. Vazirani (1984) followed the classification of the family Gyrinidae in three subfamilies viz, Orectochilinae, Enhydrinae, and Gyrininae. However, Miller & Bergsten (2012) re-classified the family in three subfamilies Spanglerogyrinae, Heterogyrinae, and Gyrininae based on 42 morphological characters and molecular work on 12S rRNA, cytochrome c oxidase I and II, elongation factor 1 alpha and histone III. The tribe Enhydrini is now included under the subfamily Gyrininae (Miller & Bergsten 2012).

Illustrations and additions to the keys to *Dineutus* species:

Larger species, size 12–15 mm (Image 15B); elytral dorsal striae weakly impressed, elytral apical margin not denticulate, elytral epipleura not produced into spine (Figure 4A); median lobe and parameres equal in size,; parameres subparallel and with smoothed apex (Image 16B)...***D. indicus* Aubé, 1838**

- Smaller species, size 6–7 mm (Image 15C); elytral dorsal striae shallow but distinctly impressed, elytral apical margin denticulate, elytral epipleura produced into spine (Figure 4B); median lobe and parameres sub-equal in size, parameres subparallel in apical region, apex rounded (Image 16C)...***D. unidentatus* Aubé, 1838**

Remarks- The individuals were found in groups on the water surface at the edge of large water body as well as in open water. When disturbed, the beetles go under water, move fast to escape from the view and reappear

Image 20. Dorsal habitus: A—*S. inconspicuus* | B—*S. rufipes* | C—*H. spinicollis* | D—*H.* cf. *olivaceous*. © S.D. Sheth, A.D. Padhye & H.V. Ghate.

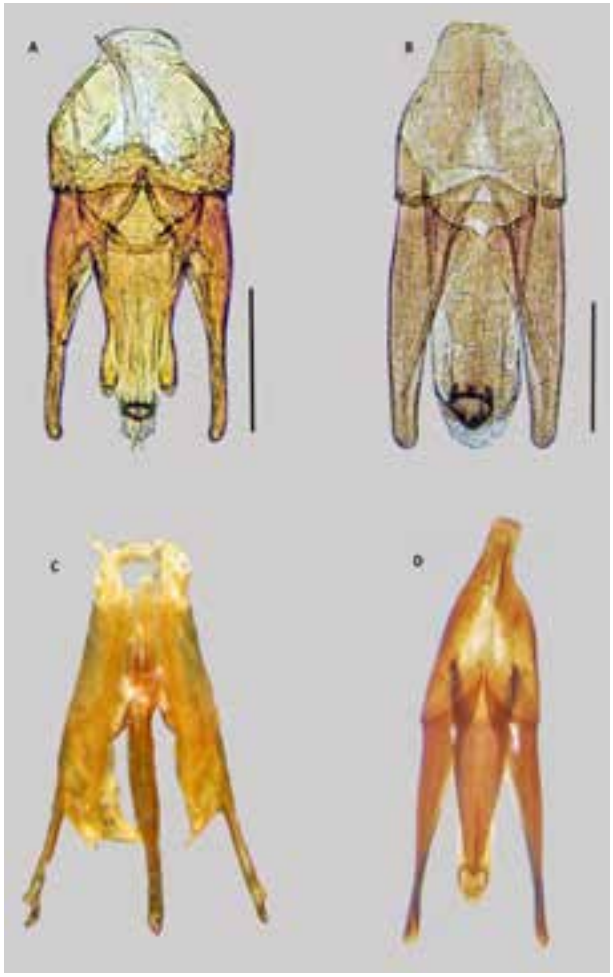

Image 21. Male genitalia (a: median lobe | b: paramere): A—*S. inconspicuus* | B—*S. rufipes* | C—*H. spinicollis* | D—*H.* cf. *olivaceous*. Scale for A and B: 500 µm. © S.D. Sheth, A.D. Padhye & H.V. Ghate.

on the surface.

Genus *Patrus* Aubé, 1838

Miller & Bergsten (2012) raised the subgenus *Patrus* to genus rank; it was formerly under the *Orectochilus* Dejean, 1833. Vazirani (1984) classified 43 Indian species of *Patrus* species into six groups.

Illustrations and additions to the keys to *Patrus* species:

1. Labrum 3–4 times broader than long…2

- Labrum less than 3 times broader than long…4

2. Epipleura produced into spine (Figure 4C); median lobe as equal as parameres in size, median lobe broad at base while largely tapers towards apex (Image 16D); total size 4–5 mm (Image 15D)…***P. productus* (Régimbart, 1883)**

- Epipleura not produced into spine…3

3. Smaller species, size 4–5 mm (Image 15E, Figure 4D); median lobe as equal as parameres in size, apex blunt (Image 16E)…***P. limbatus* (Régimbart, 1883)**

- Larger species, size 7 mm (Image 15F, Figure 4E); median lobe 2/3rd the size of parameres, apex narrow, bifid at tip (Image 16F)…***P. discifer* (Walker 1859)**

4. Epipleura not produced into spine; inner margin of lateral pubescence on elytra with 3 lobes (Figure 4F); size 5mm (Image 17A)…***P.* cf *haemorrhous* (Régimbart 1891)**

- Epipleura produced into spine; inner margin of lateral pubescence on elytra without 3 lobes (Figure 4G); size 7–7.25 mm (Image 17B); median lobe shorter than parameres, broadly pointed at apex (Image 18A)…***P. assimilis* (Ochs 1957)**

Image 22. Dorsal habitus: A—*B. pulchellus* | B—*B. chinensis* | C—B. indicus | D—*B. indiges* | E—*R. attenuata* | F—*Allocotocerus* sp. 1. © S.D. Sheth, A.D. Padhye & H.V. Ghate.

Family: Noteridae Thomson, 1860
Subfamily: Noterinae Thomson, 1860
Genus *Canthydrus* Sharp, 1882

Miller (2009) provided systematics of world Noteridae Thomson, 1860. Miller (2009) and Vazirani (1968) was followed for genus level and species level identification, respectively.

Illustrations and additions to the keys to *Canthydrus* species:

1. Head and pronotum largely yellow with medial short black streak at posterior margin; size 2.5 mm (Image 17D); male genitalia (Image 18C)...***C. laetabilis* (Walker, 1858)**

- Head black, pale anteromedially; pronotum largely black with corners yellow; size 3 mm (Image 17C); male genitalia (Image 18B)...***C. luctuosus* (Aubé, 1838)**

Remarks: Scanning electron micrographs revealed noterid platform of *Canthydrus* species is more or less uniformly covered with dense setae (Image 19A).

Genus *Neohydrocoptus* Satô, 1972

Previously the genus *Neohydrocoptus* was a subgenus under the genus *Hydrocoptus* Motschulsky (1853) but, later it was raised to genus level by Nilsson et al. (1989) (Nilsson 2011). Vazirani (1968) reported *N. subvittulus* and *N. bivittis* species from India under the genus *Hydrocoptus* Motschulsky (1853). Keys provided by Miller (2009) were followed for generic identification.

Illustrations and additions to the keys to *Neohydrocoptus* species:

1. Head with prominent black streak posteriorly; pronotum anteromedially with broad black mark, posteriorly with a narrow band; size 3.5 mm (Image

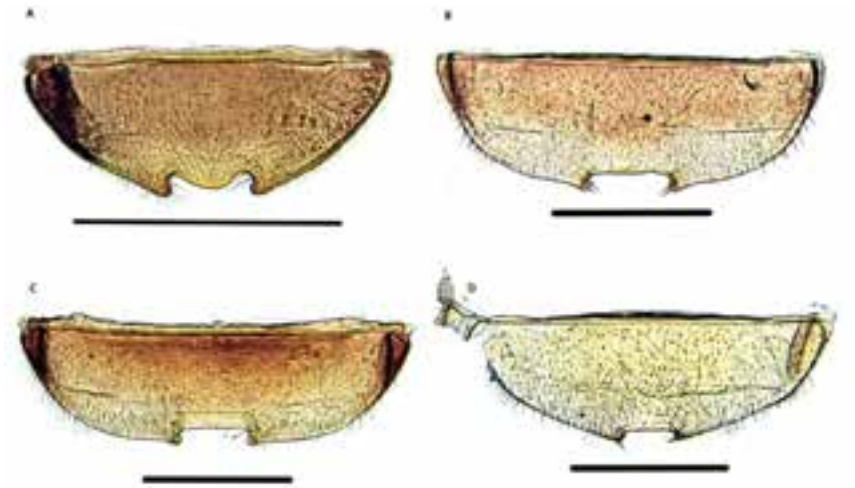

Image 23. Last abdominal ventrite of male: A—*B. pulchellus* | B—*B. indiges* | C—*B. indicus* | D—*B. chinensis*. Scale: 500 µm. © S.D. Sheth, A.D. Padhye & H.V. Ghate.

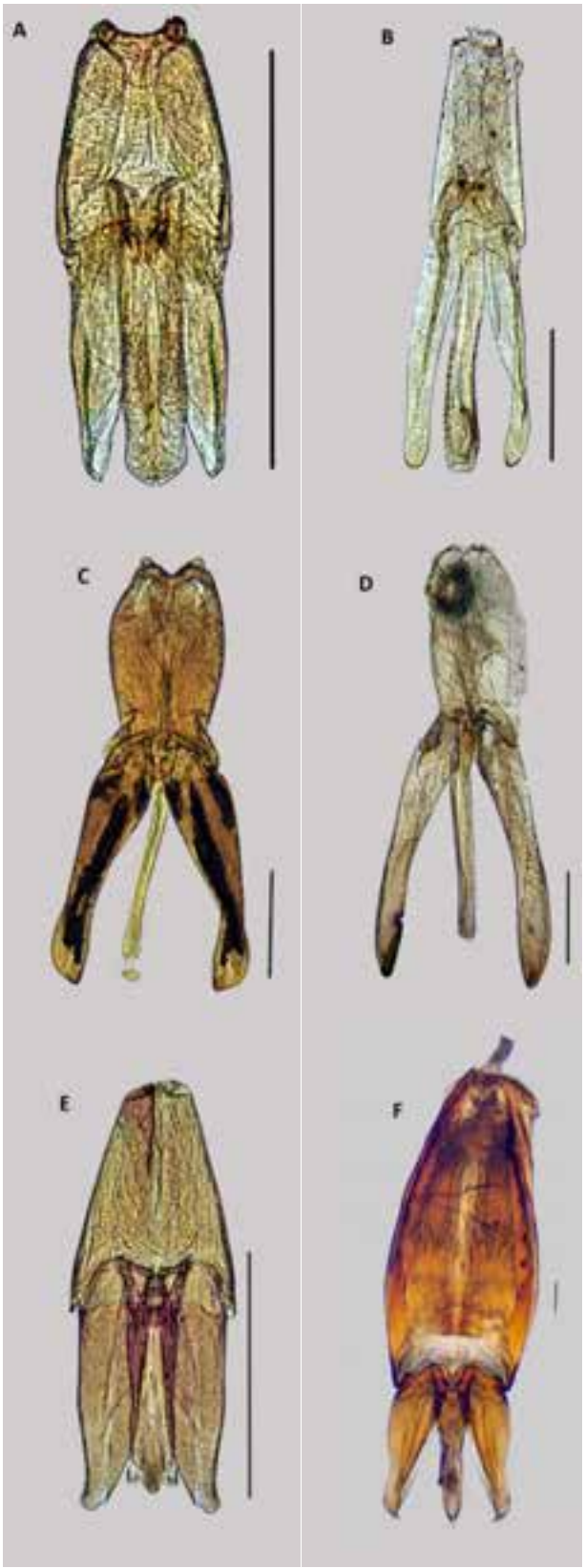

Image 24. Dorsal view of male genitalia: A—*B. pulchellus* | B—*B. chinensis* | C—*B. indicus* | D—*B. indiges* | E—*R. attenuata* | F—*Allocotocerus* sp. 1 (Scale 100 µm). Scale for A–E: 500 µm. © S.D. Sheth, A.D. Padhye & H.V. Ghate.

17E); median lobe of male genitalia anteriorly spatulate, large paramere narrowly triangular, bear numerous setae from base to apex (Image 18D)...***N. bivittis** Motschulsky 1859**

- Head without prominent black streak; pronotum anteromedially without broad black mark, posteriorly with little narrow band; size 2 mm (Image 17F); median lobe of male genitalia slightly bulging subapically, large paramere broadly pointed, bear hardly any setae (Image 18E)... ***Neohydrocoptus* sp2**

Remarks: Scanning electron micrographs revealed noterid platform of *Neohydrocoptus* species is covered with sparse and short setae (Image 19C). Adhesive structure of male Indian *Neohydrocoptus* species (Image 19D) differs than that of male *Canthydrus* species (Image 19B).

Family Hydrophilidae Latreille, 1802
Subfamily Hydrophilinae Latreille, 1802
Genus *Sternolophus* Solier 1834

Komarek (2003) was followed for generic identification. Nasserzadeh & Komarek (2017) was followed to identify species.

Illustrated keys to *Sternolophus* species:

1. Metaventral spine short, not extending on the abdominal ventrite; size 9 mm (Image 20A); lobules of median lobe of male genitalia large (Image 21A)...***S. inconspicuus* (Nietner, 1856)**

- Metaventral spine long, extends on the abdominal ventrite; size 10 mm (Image 20B); lobules of median lobe of male genitalia small (Image 21B)...***S. rufipes* (Fabricius, 1792)**

Genus *Berosus* Leach 1817

Illustrated keys to *Berosus* species: Schödl (1992; 1993) was referred for identification.

1. Size small, 2.5–3.0 mm (Image 22A); last abdominal sternite of male with medial bulge (Image 23A); male genitalia (Image 24A)...***B. pulchellus* MacLeay, 1825**

- Size large, 4.5–6.5 mm; last abdominal sternite of male without median bulge...2

2. Elytral intervals 2–5 with irregular punctures...***B. chinensis* Knisch, 1922** (Image 22B, 23D, 24B)

- Elytral intervals 2–5 without irregular punctures...3

3. Bulge present in front of metaventral projection; last abdominal ventrite of male without median bulge (Image 23C); parameres of male genitalia broad (Image 24C); habitus (Image 22C)... ***B. indicus* (Motschulsky, 1861)**

- Bulge absent in front of metaventral projection, last abdominal ventrite of male without median bulge

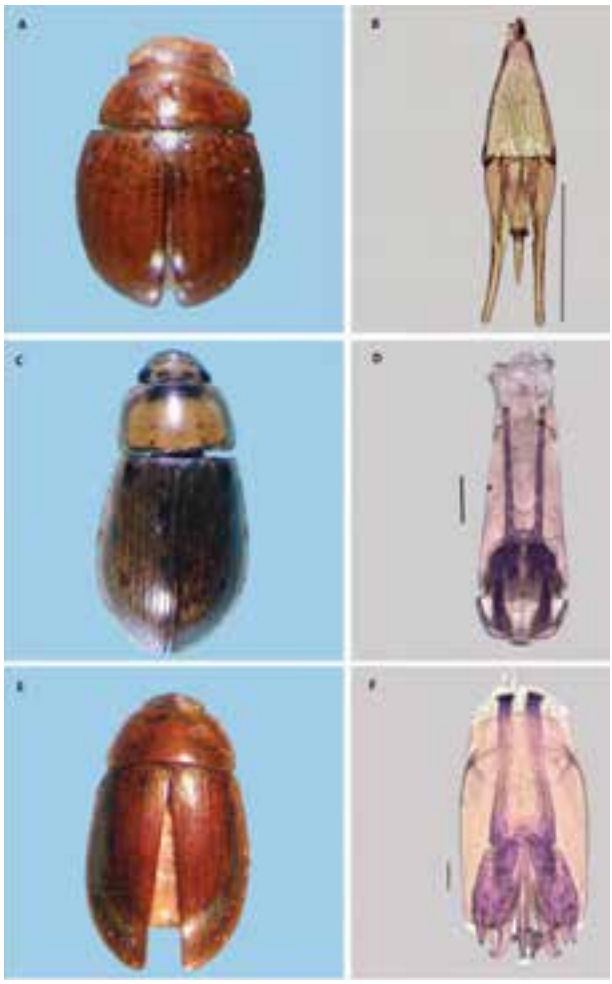

Image 25. Dorsal habitus (A, C, E): A—*Amhiops* sp. 1 | C—*Helochares* sp. 1 | E—*Helochares* sp. 2. Male genitalia (B, D, F): B—*Amhiops* sp. 1 (500 µm) | D—*Helochares* sp. 1 (100 µm) | F—*Helochares* sp. 2 (100 µm). © S.D. Sheth, A.D. Padhye & H.V. Ghate.

(Image 23B); parameres of male genitalia slender (Image 24D); habitus (Image 22D)...***B. indiges* Schödl, 1992**

DISCUSSION

The present study was initiated to revive the work carried out during the 1970s by Vazirani, Tonapi & Ozarkar (1969a,b) on aquatic beetles in Maharashtra after a gap of 40 years. Although there are a few other short reports on species from Maharashtra, most of these earlier works provide only line drawings of a few species. However, good quality photos of many of Indian species are still not available. In fact, this may be the first attempt from India to provide well-curated digital images of several species of aquatic beetles in one place. Not only that, many checklists and other short reports still use old nomenclature (as discussed below). Some recent checklists are probably based only on published literature and are incomplete, inaccurate and, hence, misleading.

The checklist of aquatic beetles of Maharashtra (Sharma & Bano 2012) missed some previously reported species from this region such as *Cybister sugillatus* Erichson, 1834*, Clypeodytes hemani* Vazirani, 1968, and *Microdytes whitingi* Miller & Wewalka, 2010. Among these are the species for which the type locality (e.g., *C. hemani* and *M. whitingi*) is Maharashtra (Vazirani 1967; Miller & Wewalka 2010), respectively. The checklist still includes 52 species, even though there are these omissions. We have collected 68 species from different types of water bodies in western Maharashtra with descriptions of new species (Sheth et al. 2018). Further, *Hydrovatus rufoniger rufoniger* was recorded earlier from Bihar in the eastern part of India (Vazirani 1970b). The present work extends its range westward in India. Similarly, *Neohydrocoptus bivittis* is recorded for the first time from the Konkan region, westward to the northern Western Ghats of Maharashtra. This suggests that the water beetle fauna of Maharashtra has perhaps been underestimated and intensive surveys may reveal a few more known species or even new species (Sheth et al. 2019).

Secondly, updated nomenclature (mentioned below) is not followed in the latest checklist (Sharma & Bano 2012). For example, the genus *Guignotus* Houlbert, 1934, still used by Sharma & Bano (2012), was synonymised with the genus *Hydroglyphus* Motschulsky, 1853 (Biström & Silverberg 1981). Miller et al. (2006) also shifted the genus *Peschetius* from the tribe Hydroporini to the tribe Bidessini. Likewise, Miller & Bergsten (2012) published valid subfamily-group, tribe-group and genus-group names under the family Gyrinidae. They raised the former subgenus *Patrus* to the genus level. Vazirani (1984) followed the classification of the family Gyrinidae in three subfamilies, namely- Orectochilinae [genera *Orectochilus s.str* and *Orectochilus* (*Patrus*)], Enhydrinae (genus *Dineutus*), and Gyrininae (genera *Gyrinus*, *Aulogyrinus* and *Metagyrinus*). Miller & Bergsten (2012) included all the above-mentioned genera under the single subfamily Gyrininae Latreille, 1810, with three tribes, based on a detailed study of morphology and DNA sequences for the phylogenetic analysis.

During the course of our surveys, we also collected specimens of additional hydrophilid genera *Laccobius* Erichson, 1837 and *Enochrus* Thomson, 1859 other than those presented here. These species have much size variation; females appear similar for many species

within these genera and revised keys for species-level identification are scanty. Therefore, we could identify most specimens to the genus level only. Due to this uncertainly, these genera were not included in this chapter. However, the work on their species-level identification is in progress.

Within the period of 5–6 years, we have collected diverse species of beetles adapted to freshwater ecosystems. However, this includes submerged species and water surface dwellers only. We further intend to work on other water associated beetles and also survey other type of inland waters, namely saline ecosystems.

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COMMUNICATION

A checklist of wild mushroom diversity in Mizoram, India

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Abstract: The northeastern part of India is one of the biodiversity hotspots having a wide variety of flora and fauna. High humidity during monsoon provides ideal conditions for the growth of diverse group of macrofungi. Mizoram is one of the northeastern states of India which has a large number of edible and non-edible mushroom species. Wild edible mushrooms are an important food source for rural communities of Mizoram and provide additional income to the households if sold in regional markets. The key objective of this study was to explore the macrofungal diversity, and its richness in Mizoram with the aim of preparing a checklist along with the present geographical distribution of the important wild edible mushrooms. The macrofungal survey was undertaken during 2017–2020 in 24 different sites in Mizoram. A total of 152 (54 edible and 98 inedible) mushroom species have been documented belonging to 85 genera, 54 families, and 19 orders. Habitat-wise distribution of macrofungi revealed that maximum species were found on soil (61), followed by associated with roots (36), dead wood (30), living trees (22), and associated with termite mound (three). From a morphological point of view, the wild mushrooms have been divided into gilled fungi (95), boletes (18), polypores (17), coral fungi (10), chanterelles (3), puffballs (3), jelly fungi (3), stinkhorns (2), and cup fungi (1). This documentation of wild mushrooms of Mizoram will be a reference database for future.

Keywords: Coral fungi, ectomycorrhizae, jelly fungi, macrofungi, northeastern India, polypores, puffballs.

Assamese: ভাৰতৰ উত্তৰ-পূব অংশ জৈৱ বৈচিত্ৰ্যৰ অন্যতম হটস্পট য'ত বিভিন্ন ধৰণৰ উদ্ভিদ আৰু প্ৰাণী আছে। বাৰিষাৰ সময়ত উচ্চ আৰ্দ্ৰতাই বিভিন্ন গোটৰ কাঠফুলা বৃদ্ধিৰ বাবে আদর্শ পৰিস্থিতিৰ সৃষ্টি কৰে। মিজোৰাম ভাৰতৰ উত্তৰ-পূবৰ অন্যতম ৰাজ্য য'ত বৃহৎ সংখ্যক খাব পৰা আৰু অখাদ্য কাঠফুলাৰ প্ৰজাতি আছে। বন্য খাব পৰা কাঠফুলা মিজোৰামৰ গ্ৰাম্য জনগোষ্ঠীৰ বাবে এক গুৰুত্বপূৰ্ণ খাদ্যৰ উৎস আৰু আঞ্চলিক বজাৰত বিক্ৰী হ'লে পৰিয়ালক অতিৰিক্ত উপাৰ্জন প্ৰদান কৰে। এই অধ্যয়নৰ মূল উদ্দেশ্য আছিল গুৰুত্বপূৰ্ণ বন্য খাব পৰা কাঠফুলা বৰ্তমানৰ ভৌগোলিক বিতৰণৰ লগতে এখন পৰীক্ষা তালিকা প্ৰস্তুত কৰাৰ লক্ষ্যৰে মিজোৰামত কাঠফুলাৰ বৈচিত্ৰ্য, আৰু ইয়াৰ সমৃদ্ধি অন্বেষণ কৰা। ২০১৭-২০২০ চনৰ ভিতৰত মিজোৰামৰ ২৪টা ভিন্ন স্থানত এই কাঠফুলাৰ জৰীপ কৰা হৈছিল। মুঠ ১৫২টা (৫৪টা খাব পৰা আৰু ৯৮টা অখাদ্য) কাঠফুলাৰ প্ৰজাতি ৮৫টা বংশ, ৫৪টা গোত্ৰ আৰু ১৯টা বৰ্গ অন্তৰ্গত ৰুলি নথিভুক্ত কৰা হৈছে। বাসস্থান অনুসৰি কাঠফুলাৰ বিতৰণে প্ৰকাশ কৰে যে সৰ্বোচ্চ প্ৰজাতি মাটিত পোৱা গৈছিল (৬১), তাৰ পিছত শিপাৰ সৈতে জড়িত (৩৬), মৰা কাঠ (৩০), জীৱিত গছ (২২), আৰু উই হাফলুৰ সৈতে জড়িত (তিনি)। ৰূপগত দৃষ্টিকোণৰ পৰা বন্য কাঠফুলাবোৰক গিলযুক্ত ভেঁকুৰ (৯৫), বলেটছ (১৮), পলিপৰ (১৭), প্ৰবাল ভেঁকুৰ (১০), চেণ্টেৰেল (৩), পাফবল (৩), জেলী ভেঁকুৰ (৩), ষ্টিংকহৰ্ণ (২), আৰু কাপ ভেঁকুৰ (১) ত ভাগ কৰা হৈছে। মিজোৰামৰ বন্য কাঠফুলাৰ এই নথিপত্ৰ ভৱিষ্যতৰ বাবে এটা ৰেফাৰেন্স ডাটাবেছ হ'ব।

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Author contributions: RK collected and identified the mushrooms of Mizoram. He also wrote the introduction, methodology and conclusion part of the manuscript. GG arranged the images of mushrooms, searched the current names of the mushrooms in index fungorum and mycobank. He analyzed the data and prepared the figures. He also wrote the result and discussion part of the manuscript.

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INTRODUCTION

Mushrooms are the fruiting bodies of higher fungi that release spores for dissemination. Spores are only a small part of a much larger organism. Mushrooms are integral part of the forest ecosystem that helps in the recycling of forest waste. They are fleshy and seen in (on) the forest soils, dead wood, twigs, dung, and litter as saprobes, symbionts, or on the living trees as parasites. Their edibility, poisonous nature, psychotropic properties, mycorrhizal and parasitic associations with the forest trees make them economically important. Fungi play an incredibly important role in breaking down organic material and returning those nutrients to the soil. Ectomycorrhizal mushrooms establish mutually beneficial relationships with the roots of trees and other plants, increasing their capabilities to absorb water and nutrients that help them to survive and flourish. They also play a significant role in the daily life of human beings besides their utilization in industry, agriculture and medicine. Wild edible mushrooms are appreciated not only for texture and flavor but also for their chemical and nutritional potential (Manzi et al. 2001; Sanmee et al. 2003). Their consumption is increasing due to a good content of proteins and trace minerals. It is important to understand their existence in plant communities, their ecological functions and their impact on nature (Martin et al. 2011). In India, the first fungal list was published by Butler & Bisby (1931, 1960) and later revised by Vasudeva (1960). Sathe & Rahalkar (1987) reported a checklist of 44 species of wild edible mushrooms from southwestern India. Natarajan et al. (2005a) reported a checklist of Indian agarics and boletes. Natarajan et al. (2005b) also reported 195 species of agarics from Tamil Nadu and 28 species from Kerala. Brown et al. (2006) published 163 morphotypes of macrofungi from Kodagu District of Karnataka. Swapna et al. (2008) published 778 species of macrofungi from Shivamogga district of Karnataka. Mani & Kumaresan (2009a,b) reported 18 and 39 macrofungal species from Tamil Nadu; Mohanan (2011) reported 550 species of macrofungi from Kerala. Pushpa & Purushothama (2012) recorded 90 species of mushrooms in and around Bangalore (Karnataka). Farook et al. (2013) reported a literature-based checklist of agarics with 616 species occurring in Kerala. Pradhan et al. (2013) recorded 120 species of macrofungi in the lateritic region of West Bengal. Usha & Janardhana (2014) published 135 species of macrofungi from Karnataka.

According to Myers et al. (2000), northeastern India (a part of Indo Burma) is a biodiversity hotspot of the world. The northeastern India is very rich in macrofungal diversity and very few reports on macrofungal diversity have been carried out in this region (Verma et al. 1995). Tapwal et al. (2013) reported 30 macrofungal species from six different sites in wet evergreen tropical forest of Assam. Gogoi & Parkash (2014, 2015a,b) reported wild macrofungi from Assam. Debnath et al. (2020) reported 217 macrofungi from different districts of Tripura. Roy et al. (2022) published a literature-based checklist of macrofungi of northeastern India and listed 733 species.

Wild edible mushrooms are important as a food source for rural communities of Mizoram. They also provide additional income to the households, if the collected mushrooms are sold in the local markets. People go to forests and collect the edible mushrooms with help of the knowledge acquired from their forefathers but sometimes they turn out to be poisonous and have harmful effects. The people of Mizoram have very limited knowledge on edible mushrooms. Only few species of edible mushrooms are known and consumed by the Mizo people at present. In order to know the distribution of a particular fungal species a checklist is very important. A checklist of wild mushrooms of Mizoram was not prepared earlier by any author. The present study was conducted (made) to deal with the status of macrofungal diversity and its distribution pattern in the State of Mizoram and to prepare a checklist of wild mushrooms

MATERIALS AND METHODS

Study Area

The state has a geographical area of 21,081 km^2, which lie between 21.967–24.583 ^{0}N and 92.250–93.483 ^{0}E. The total forest cover of Mizoram is 17,820 km^2 and it has the highest percentage cover (84.53%) with respect to total geographical area of the state (ISFR 2021). Mizoram falls within a region which receives heavy annual rainfall with an average of 250–300 cm. Tropical semi-evergreen, tropical moist deciduous, subtropical broad-leaved hill, and subtropical pine forests are the most common vegetation types found in Mizoram. Survey and collection of mushrooms were undertaken during 2017–2020 in different localities, namely: Aibawk, Hmuifang, Muallunghu, Murlen, Ngengpu, Reiek, Sialsuk, Siphir, Sapianmaksak, Zokawthar, Zote, College Veng, Durtlang, Gosen Veng, Project Veng, Hnahthial, Lungpuitlang, Tlabung, Lengte, Phura, Sangyu, Tipa, Buangpui, and Chhim Veng. These localities are belonging to different forest types of Mizoram. A map of Mizoram showing different forest types is given in the Image 1.

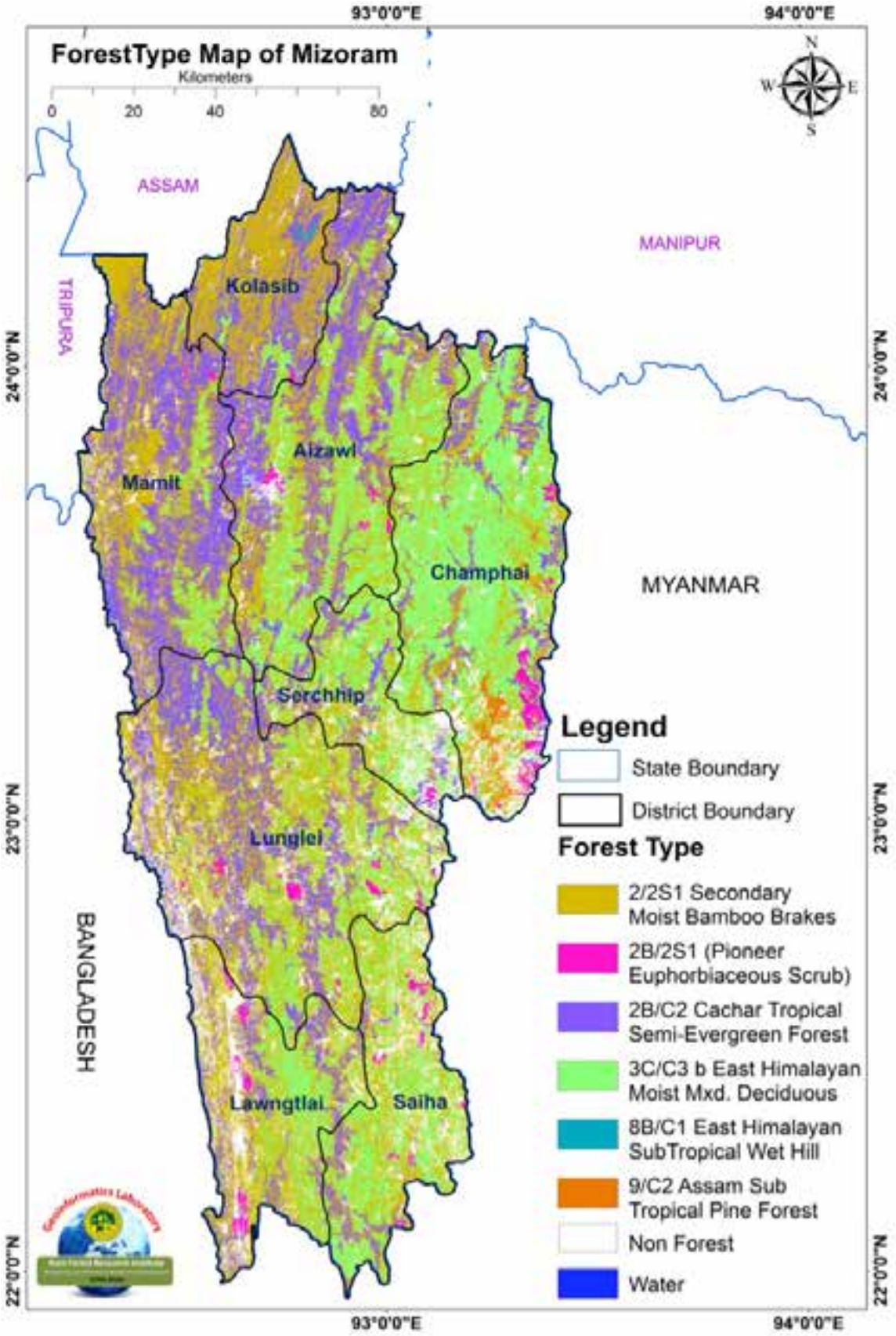

Image 1. Forest type map of Mizoram.

The current names, systematic positions and nomenclature of mushrooms were taken from Index Fungorum and MycoBank. In the checklist of wild mushrooms, species are arranged alphabetically followed by accession number, families, orders, and classes.

Mushroom survey and collections

The sampling and collection of mushrooms were done from April 2017 to February 2020 as per the method suggested by Largent (1977). Field notes such as habit, habitat, odour, colour, and size of the pileus (cap), stipe and the presence or absence of volva, indusium or veil, and ring were noted in the field before collection and the samples were photographed in their natural habitats. The colour terminology as suggested by Kornerup & Wanscher (1978) was used to confirm mushroom colour. The macrofungi with leathery texture were preserved in 4% FAA solution (formaldehyde + acetic acid + ethyl alcohol + distilled water) whereas samples with soft texture were preserved in 2% FAA solution. Dried specimens were also preserved for identification, characterization, and documentation. Identification of the specimen was carried out by standard microscopic methods (Roy & De 1996) also considering various morphological characteristics of mushrooms such as their size, colour, presence or absence of volva, stipe, ring, scales, reticulum, zonation, striation, warts, cap, areolae, and gills. Identification of the specimens were carried out by standard microscopic methods (Gilbertson & Ryvarden 1986) using microscope (Olympus BX-50). All the dry mushroom samples were deposited in the mycology division under the Forest Protection Department of ICFRE-Rain Forest Research Institute, Assam for future reference.

RESULTS AND DISCUSSION

A total of 152 wild mushrooms (Images 2–9) have been documented from 24 different localities of Mizoram which belong to 85 genera, 54 families, 19 orders, six classes, and two phyla (Table 1, Table 2 & Table 3). Out of the 152 wild mushrooms, 143 spp. belong to the phylum Basidiomycota and nine spp. to Ascomycota. The class Agaricomycetes (142 spp.) was found dominant followed by Pezizomycetes (3 spp.), Sordariomycetes (3 spp.), Leotiomycetes (two spp.), Dacrymycetes (1 sp.) and Geoglossomycetes (1 sp.) (Table 3). The order Agaricales (55 spp.) was found dominant followed by Polyporales (30 spp.), Boletales (21 spp.), Russulales (14 spp.), Hymenochaetales (6 spp.), Cantharellales (5 spp.) and so on (Table 2). The family Polyporaceae was found dominant with 19 species followed by Boletaceae (18 spp.), Russulaceae (11 spp.), Agaricaceae (6 spp.), Amanitaceae (6 spp.), Hydnaceae (5 spp.), Hymenochaetaceae (4 spp.), Clavariaceae (4 spp.), Hydnangiaceae (4 spp.), Inocybaceae (4 spp.), Omphalotaceae (4 spp.), and so on (Table 2). The five most represented genera were *Ganoderma* (7 spp.), *Amanita* (6 spp.), *Russula* (5 spp.), *Boletus* (5 spp.) and *Lactarius* (5 spp.). The frequency of occurrence was found maximum in *Clavulina rugosa* (83.33%) and *Lactarius croceus* (83.33%) followed by *Lysurus periphragmoides* (79.16%), *Cantharellus formosus* (70.83%) and so on (Table1).

Termitomyces heimii and *Termitomyces clypeatus*, have been characterized based on their vast heterogenous phylogeny, morphological traits, habitat and phenotypical appearance, such as the shape of their perforatorium, stipe length (cm), pileus length, margin and colour of fruiting body, gills, flesh, annulus, pseudorrhiza and spore print. Which was similar to earlier reported by Kumari et al. (2022). Genus Identification was done as per key given by Antonio (2020).

Recently, Akshaya et al. (2023) reported 62 macrofungi belonging to 43 genera, 24 families, and eight orders. Out of the eight orders, seven orders belong to the phylum Basidiomycota and the order Xylariales belongs to Ascomycota and they found Polyporaceae as the dominant family in the wet evergreen forests of Agasthyamala Biosphere Reserve, Western Ghats. They also found that Russulaceae is the most dominant family followed by Hygrophoraceae, Amanitaceae, Polyporaceae and so on. Gogoi & Parkash (2015b) found the order Agaricales with the highest number of species followed by Russulales, Polyporales, Cantharellales, and Boletales in Hollongapara Gibbon Wildlife Sanctuary, Assam. They reported the family Agaricaceae with the highest number of species followed by Tricholomataceae, Russulaceae, Marasmiaceae, Lyophyllaceae, and Psathyrellaceae. Roy et al. (2022) also found the order Agaricales with the highest number of species followed by Polyporales in northeastern India. They also found the three most represented genera, viz.: *Russula*, *Amanita*, and *Lactarius.* Paul et al. (2019) found the highest number of macrofungal species in the family Polyporaceae in Assam. They reported 82 species belonging to 51 genera, 34 families and 12 orders, out of which 11 orders belong to the phylum Basidiomycota and only one order – Xylariales belongs to Ascomycota. They also reported *Ganoderma lucidum*, *Pleurotus*

Table 1. List of mushroom species, their accession numbers, and families collected from Mizoram, India.

	Name of species	Accession no.	Family	Frequency (%)
1	*Abortiporus biennis* (Bull.) Singer	RFRI-MZ-93	Podoscyphaceae	54.16
2	*Agaricus bisporus* (J.E.Lange) Imbach	RFRI-MZ-46	Agaricaceae	37.50
3	*Agaricus bitorquis* (Quél.) Sacc.	RFRI-MZ- 1	Agaricaceae	33.33
4	*Agaricus silvaticus* J.C.Schäffer	RFRI-MZ-2	Agaricaceae	41.66
5	*Albatrellus ellisii* (Berk. ex Cooke & Ellis) Pouzar	RFRI-MZ-15	Albatrellaceae	37.50
6	*Amanita citrina* Pers.	RFRI-MZ-179	Amanitaceae	37.55
7	*Amanita fulva* Fr.	RFRI-MZ-20	Amanitaceae	54.16
8	*Amanita macerisolum*	RFRI-MZ-173	Amanitaceae	37.55
9	*Amanita marmorata* (Cleland & E.-J.Gilbert) E	RFRI-MZ-23	Amanitaceae	41.66
10	*Amanita phalloides* (Vaill. ex Fr.) Link	RFRI-MZ-105	Amanitaceae	33.33
11	*Amanita vaginata* (Bull.) Lam.	RFRI-MZ-21	Amanitaceae	45.83
12	*Auricularia cornea* Ehrenb.	RFRI-MZ-48	Auriculariaceae	33.33
13	*Baorangia bicolor* (Kuntze) G.Wu	RFRI-MZ-170	Boletaceae	41.66
14	*Bisporella citrina* (Batsch) Korf & S.E.Carp.	RFRI-MZ-72	Helotiaceae	66.66
15	*Boletinellus merulioides* (Schwein.) Murrill	RFRI-MZ-16	Boletinellaceae	37.50
16	*Boletus bicolor* Raddi	RFRI-MZ-34	Boletaceae	50.00
17	*Boletus edulis* Bull.	RFRI-MZ-13	Boletaceae	16.66
18	*Boletus luridiformis* Rostk.	RFRI-MZ-51	Boletaceae	66.66
19	*Boletus mirabilis* (Murrill) Murrill	RFRI-MZ-49	Boletaceae	58.33
20	*Boletus zelleri* (Murrill) Murrill	RFRI-MZ-50	Boletaceae	41.66
21	*Calbovista subsculpt*a Morse	RFRI-MZ-131	Lycoperdaceae	50.00
22	*Campanella caesia* Romagn.	RFRI-MZ-28	Marasmiaceae	41.66
23	*Cantharellus formosus* Corner	RFRI-MZ-32	Hydnaceae	70.83
24	*Cantharellus lateritius* (Berk.) Singer	RFRI-MZ-61	Hydnaceae	37.50
25	*Cerrena unicolor* (Bull.) Murrill	RFRI-MZ-83	Cerrenaceae	41 .66
26	*Clavaria fragilis* Holmsk.	RFRI-MZ-18	Clavariaceae	58.33
27	*Clavaria miniata* Purton	RFRI-MZ-17	Clavariaceae	33.33
28	*Clavaria zollingeri* Lév.	RFRI-MZ-27	Clavariaceae	45.83
29	*Clavulina cristat*a (Holmsk.) J.Schröt.	RFRI-MZ-60	Hydnaceae	45.83
30	*Clavulina rugosa* (Bull.) J.Schröt.	RFRI-MZ-59	Hydnaceae	83.33
31	*Coltricia cinnamome*a (Jacq.) Murrill	RFRI-MZ-11	Hymenochaetaceae	29.16
32	*Coltricia montagne*i (Fr.) Murrill	RFRI-MZ-3	Hymenochaetaceae	41.66
33	*Coltricia perennis* (L.) Murrill	RFRI-MZ-66	Hymenochaetaceae	45.83
34	*Conocybe apala* (Fr.) Arnolds	RFRI-MZ-126	Bolbitiaceae	37.50
35	*Cookeina tricholom*a (Mont.) Kuntze	RFRI-MZ-75	Sarcoscyphaceae	45.83
36	*Coprinus disseminatus* (Pers.) Gray	RFRI-MZ-134	Agaricaceae	45.83
37	*Coprinus leiocephalus* P.D.Orton	RFRI-MZ-7	Agaricaceae	37.55
38	*Coprinus plicatilis* (Curtis) Fr.	RFRI-MZ-8	Agaricaceae	54.16
39	*Cortinarius corrugatus* Peck	RFRI-MZ-30	Cortinariaceae	16.66
40	*Cortinarius crassus* Fr.	RFRI-MZ-136	Cortinariaceae	62.50
41	*Craterellus tubaeformis* (Fr.) Quél.	RFRI-MZ-169	Hydnaceae	29.16
42	*Dacrymyces palmatus* Bres.	RFRI-MZ-62	Dacrymycetaceae	37.50
43	*Daldinia concentric*a (Bolton) Ces. & deNotaris	RFRI-MZ-316	Hypoxylaceae	20.83

	Name of species	Accession no.	Family	Frequency (%)
44	*Enteridium splendens* (Morgan) T.Macbr.	RFRI-MZ-74	Reticulariidae	20.83
45	*Entoloma abortivum* (Berk. & M.A.Curtis) Donk	RFRI-MZ-84	Entolomataceae	29.16
46	*Entoloma lividum* Quél.	RFRI-MZ-73	Entolomataceae	33.33
47	*Entoloma squamatum* Hesler	RFRI-MZ-129	Entolomaceae	41.66
48	*Fomes fomentarius* (L.) Fr.	RFRI-MZ-94	Polyporaceae	25.00
49	*Fomitopsis ochracea* Ryvarden & Stokland	RFRI-MZ-87	Fomitopsidaceae	37.50
50	*Fomitopsis pinicola* (Sw.) P.Karst.	RFRI-MZ-88	Fomitopsidaceae	45.83
51	*Galiella rufa* (Schwein.) Nannf. & Korf	RFRI-MZ-76	Sarcosomataceae	37.50
52	*Ganoderma adspersum* (Schulzer) Donk	RFRI-MZ-81	Polyporaceae	16.66
53	*Ganoderma applanatum* (Pers.) Pat.	RFRI-MZ-90	Polyporaceae	58.33
54	*Ganoderma formosanum* T.T.Chang & T.Chen	RFRI-MZ-9	Polyporaceae	20.83
55	*Ganoderma lucidum* (Curtis) P.Karst.	RFRI-MZ-91	Polyporaceae	29.16
56	*Ganoderma oregonense* Murrill	RFRI-MZ-89	Polyporaceae	33.33
57	*Ganoderma sinense* J.D.Zhao	RFRI-MZ-112	Polyporaceae	41.66
58	*Ganoderma tsugae* Murrill	RFRI-MZ-137	Polyporaceae	50.00
59	*Geoglossum fallax* E.J.Durand	RFRI-MZ-24	Geoglossaceae	62.50
60	*Gloeophyllum sepiarium* (Wulfen) P.Karst.	RFRI-MZ-65	Gloeophyllaceae	45.83
61	*Grifola frondosa* (Dicks.) Gray	RFRI-MZ-92	Grifolaceae	45.83
62	*Gymnopilus junonius* (Fr.) P.D.Orton	RFRI-MZ-31	Hymenogastraceae	16.66
63	*Gymnopilus luteofolius* (Peck) Singer	RFRI-MZ-68	Hymenogastraceae	70.83
64	*Helvella atra* J.König	RFRI-MZ-57	Helvellaceae	29.16
65	*Hericium coralloides* (Scop.) Pers.	RFRI-MZ-111	Hericiaceae	16.66
66	*Heterobasidion annosum* (Fr.) Bref.	RFRI-MZ-110	Bondarzewiaceae	29.16
67	*Hygrocybe coccinea* (Schaeff.) P.Kumm.	RFRI-MZ-78	Hygrophoraceae	50.00
68	*Hygrocybe conica* (Schaeff.) P.Kumm.	RFRI-MZ-319	Hygrophoraceae	66.66
69	*Hypholoma fasciculare* (Huds.) P.Kumm	RFRI-MZ-86	Strophariaceae	33.33
70	*Inocybe flocculosa* Sacc.	RFRI-MZ-37	Inocybaceae	41.66
71	*Inocybe lapponica* Kokkonen & Vauras	RFRI-MZ-164	Inocybaceae	45.83
72	*Inocybe napipes* J.E.Lange	RFRI-MZ-71	Inocybaceae	29.16
73	*Inocybe sindonia* (Fr.) P.Karst.	RFRI-MZ-38	Inocybaceae	37.50
74	*Ischnoderma resinosum* (Schrad.) P.Karst.	RFRI-MZ-85	Ischnodermataceae	45.83
75	*Kuehneromyce smutabilis* (Schaeff.) Singer & A.H.Sm.	RFRI-MZ-45	Strophariaceae	25.00
76	*Laccaria affinis* (Singer) Bon	RFRI-MZ-36	Hydnangiaceae	29.16
77	*Laccaria fraterna* (Sacc.) Pegler	RFRI-MZ-133	Hydnangiaceae	37.50
78	*Laccaria laccata* (Scop.) Cooke	RFRI-MZ-35	Hydnangiaceae	50.00
79	*Laccaria vinaceoavellanea* Hongo	RFRI-MZ-26	Hydnangiaceae	58.33
80	*Lactarius croceus* Burl.	RFRI-MZ-166	Russulaceae	83.33
81	*Lactarius fragilis* (Burl.) Hesler & A.H.Sm.	RFRI-MZ-115	Russulaceae	37.50
82	*Lactarius piperatus* (L.) Pers.	RFRI-MZ-33	Russulaceae	29.16
83	*Lactarius vietus* (Fr.) Fr.	RFRI-MZ-82	Russulaceae	45.83
84	*Lactarius volemus* (Fr.) Fr.	RFRI-MZ-147	Russulaceae	29.16
85	*Lactifluus corrugis* (Peck) Kuntze	RFRI-MZ-128	Russulaceae	54.16
86	*Laetiporus cincinnatus* (Morgan) Burds.	RFRI-MZ-108	Laetiporaceae	16.66
87	*Laetiporus sulphureus* (Bull.) Murrill	RFRI-MZ-106	Laetiporaceae	41.66
88	*Leccinum scabrum* (Bull.) Gray	RFRI-MZ-179	Boletaceae	29.16

	Name of species	Accession no.	Family	Frequency (%)
89	*Lentinula lateritia* (Berk.) Pegler	RFRI-MZ-6	Omphalotaceae	45.83
90	*Lentinus polychrous* Lév.	RFRI-MZ-130	Polyporaceae	41.66
91	*Lentinus sajor-caju* (Fr.) Fr.	RFRI-MZ-95	Polyporaceae	37.50
92	*Lentinus tigrinus* (Bull.) Fr.	RFRI-MZ-143	Polyporaceae	54.16
93	*Lenzites betulinus* (L.) Fr.	RFRI-MZ-96	Polyporaceae	16.66
94	*Leotia lubrica* (Scop.) Pers.	RFRI-MZ-77	Leotiaceae	29.16
95	*Lepiota brunneoincarnata* Chodat & C.Martín	RFRI-MZ-41	Agaricaceae	33.33
96	*Lepiota rubrotinctoides* Murrill	RFRI-MZ-10	Agaricaceae	41.66
97	*Lysurus periphragmoides* (Klotzsch ex Hook.) Dring	RFRI-MZ-79	Phallaceae	79.16
98	*Macrolepiota dolichaula* (Berk. & Broome) Pegler & R.W.Rayne	RFRI-MZ- 123	Agaricaceae	33.33
99	*Marasmiellus candidus* (Fr.) Singer,	RFRI-MZ-39	Omphalotaceae	45.83
100	*Marasmiellus ramealis* (Bull.) Singer	RFRI-MZ-40	Omphalotaceae	37.50
101	*Marasmius corrugatiformis* Singer	RFRI-MZ-19	Marasmiaceae	29.16
102	*Marasmius crinis-equi* F.Muell. ex Kalchbr.	RFRI-MZ-59	Marasmiaceae	58.33
103	*Mycena pura* (Pers.) P.Kumm.	RFRI-MZ-314	Mycenaceae	41.66
104	*Omphalotus illudens* (Schwein.) Bresinsky & Besl	RFRI-MZ-107	Omphalotaceae	42.67
105	*Panus rudis* Fr.	RFRI-MZ-22	Panaceae	20.83
106	*Phaeotrametes decipiens* (Berk.) J.E.Wright	RFRI-MZ-103	Polyporaceae	45.83
107	*Phallus indusiatus* Vent.	RFRI-MZ-80	Phallaceae	50.00
108	*Phellinus igniarius* (L.) Quél.	RFRI-MZ-67	Hymenochaetaceae	70.83
109	*Phylloporus rhodoxanthus* (Schwein.) Bres.	RFRI-MZ-55	Boletaceae	33.33
110	*Piptoporus betulinus* (Bull.) P.Karst.	RFRI-MZ-101	Fomitopsidaceae	62.50
111	*Pleurotus floridanus* Singer	RFRI-MZ-125	Pleurotaceae	54.16
112	*Pleurotus pulmonarius* (Fr.) Quél.	RFRI-MZ-127	Pleurotaceae	20.83
113	*Polyporus arcularius* (Batsch) Fr.	RFRI-MZ-100	Polyporaceae	50.00
114	*Polyporus badius* (Pers.) Schwein.	RFRI-MZ-109	Polyporaceae	54.16
115	*Postia caesiac* (Schrad.) P.Karst.	RFRI-MZ-120	Polyporaceae	58.33
116	*Psathyrella candolleana* (Fr.) Maire	RFRI-MZ-43	Psathyrellaceae	41.66
117	*Pycnoporus cinnabarinus* (Jacq.) P.Karst.	RFRI-MZ-99	Polyporaceae	29.16
118	*Pycnoporus sanguineus* (L.) Murrill	RFRI-MZ-98	Polyporaceae	33.33
119	*Ramaria formosa* (Pers.) Quél.	RFRI-MZ-176	Gomphaceae	25.00
120	*Ramaria myceliosa* (Peck) Corner	RFRI-MZ-64	Gomphaceae	50.00
121	*Ramaria stricta* (Pers.) Quél.	RFRI-MZ-63	Gomphaceae	70.83
122	*Ramariopsis kunzei* (Fr.) Corner	RFRI-MZ-29	Clavariaceae	25.00
123	*Russula brevipes* Peck	RFRI-MZ-175	Russulaceae	54.16
124	*Russula cremoricolor* Earle	RFRI-MZ-113	Russulaceae	16.66
125	*Russula emetica* (Schaeff.) Pers.	RFRI-MZ-114	Russulaceae	54.16
126	*Russula ochroleuca* Fr.	RFRI-MZ-116	Russulaceae	58.33
127	*Russula variata* Banning	RFRI-MZ-117	Russulaceae	33.33
128	*Schizophyllum commune* Fr.	RFRI-MZ-44	Schizophyllaceae	50.00
129	*Schizopora paradoxa* (Schrad.) Donk	RFRI-MZ-69	Schizoporaceae	50.00
130	*Scleroderma cepa* Pers.	RFRI-MZ-56	Sclerodermataceae	41.66
131	*Scleroderma citrinum* Pers.	RFRI-MZ-124	Sclerodermataceae	33.33
132	*Strobilomyces confusus* Singer	RFRI-MZ-52	Boletaceae	20.83

	Name of species	Accession no.	Family	Frequency (%)
133	*Strobilomyces strobilaceus* (Scop.) Berk.	RFRI-MZ-53	Boletaceae	45.83
134	*Suillus bovinus* (L.) Roussel	RFRI-MZ-168	Boletaceae	50.00
135	*Suillus granulatus* (L.) Roussel	RFRI-MZ-135	Boletaceae	41.66
136	*Suillus luteus* (L.) Roussel	RFRI-MZ-58	Boletaceae	16.66
137	*Termitomyces clypeatus* R.Heim	RFRI-MZ-12	Lyophyllaceae	16.66
138	*Termitomyces fuliginosus* R.Heim	RFRI-MZ-102	Lyophyllaceae	25.00
139	*Termitomyces heimii* Natarajan	RFRI-MZ-4	Lyophyllaceae	29.16
140	*Thelephora anthocephala* (Bull.) Fr.	RFRI-MZ-119	Thelephoraceae	37.50
141	*Thelephora palmata* (Scop.) Fr.	RFRI-MZ-118	Thelephoraceae	35.12
142	*Trametes pubescens* (Schumach.) Pilát	RFRI-MZ-97	Polyporaceae	41.66
143	*Trichia decipiens* (Pers.) T.Macbr.	RFRI-MZ-121	Trichiidae	20.83
144	*Tylopilus badiceps* (Peck) A.H.Sm. & Thiers	RFRI-MZ-54	Boletaceae	54.16
145	*Tylopilus felleus* (Bull.) P.Karst.	RFRI-MZ-104	Boletaceae	45.83
146	*Tylopilus griseocarneus* Wolfe & Halling	RFRI-MZ-14	Boletaceae	37.50
147	*Volvariella bombycine* (Schaeff.) Singer	RFRI-MZ-42	Pluteaceae	54.16
148	*Volvariella taylorii* (Berk. & Broome) Singer	RFRI-MZ-5	Pluteaceae	58.33
149	*Xerocomus ripariellus* Redeuilh	RFRI-MZ-301	Boletaceae	58.33
150	*Xerocomus subtomentosus* (L.) Quél.	RFRI-MZ-174	Boletaceae	41.66
151	*Xylaria nigripes* (Klotzsch) Cooke	RFRI-MZ-122	Xylariaceae	33.33
152	*Xylaria polymorpha* (Pers.) Grev.	RFRI-MZ-25	Xylariaceae	33.33

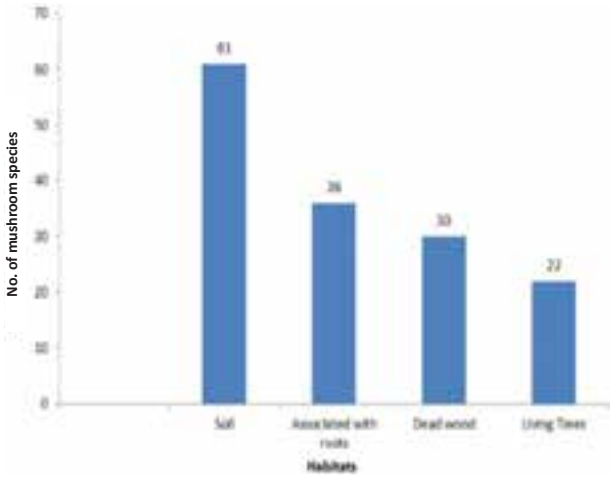

Figure 1. Ecological preference of habitats of wild mushrooms of Mizoram.

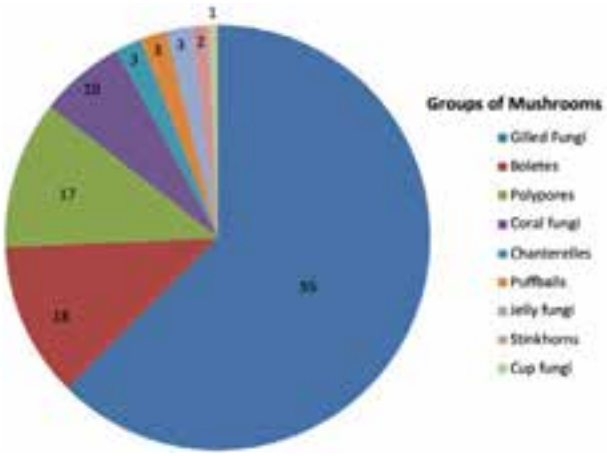

Figure 2. General groups of wild mushrooms of Mizoram.

ostreatus and *Pycnoporous sanguineus* are the species having the highest frequency of occurrence (100%) while the lowest frequency of occurrence was recorded for *Cyathus striatus* (10%).

Habitat-wise distribution of wild mushrooms of Mizoram revealed that maximum number of species were found on soil (61 spp.), followed by species associated with roots (30 spp.), dead wood (30 spp.), living trees (22 spp.), and termite mounds (3 spp.) (Figure 1). On the basis of morphological features, the collected species were grouped into nine groups, viz.: gilled fungi (95 spp.), boletes (18 spp.), polypores (17 spp.), coral fungi (10 spp.), chanterelles (3 spp.), puffballs (3 spp.), jelly fungi (3 spp.), stinkhorns (2 spp.), and cup fungi (1 sp.) (Figure 2). Based on living behaviour, they have been classified into three groups, viz.: saprobes (94 spp.),

Table 2. Number of mushroom species present in each family and order.

	Name of families	No. of species	Name of orders	No. of species
1	Agaricaceae	9	Agaricales	55
2	Albatrellaceae	1	Auriculariales	1
3	Amanitaceae	6	Boletales	21
4	Auriculariaceae	1	Cantharellales	5
5	Bolbitiaceae	1	Dacrymycetales	1
6	Boletaceae	18	Geoglossales	1
7	Boletinellaceae	1	Gloeophyllales	1
8	Bondarzewiaceae	1	Gomphales	3
9	Cerrenaceae	1	Helotiales	1
10	Clavariaceae	4	Hymenochaetales	6
11	Cortinariaceae	2	Leotiales	1
12	Dacrymycetaceae	1	Liceales	1
13	Entolomataceae	3	Pezizales	3
14	Fomitopsidaceae	3	Phallales	2
15	Geoglossaceae	1	Polyporales	30
16	Gloeophyllaceae	1	Russulales	14
17	Gomphaceae	3	Thelephorales	2
18	Grifolaceae	1	Trichiidia	1
19	Helotiaceae	1	Xylariales	3
20	Helvellaceae	1	**Total species**	152
21	Hericiaceae	1		
22	Hydnaceae	5		
23	Hydnangiaceae	4		
24	Hygrophoraceae	2		
25	Hymenochaetaceae	4		
26	Hymenogastraceae	2		
27	Hypoxylaceae	1		
28	Inocybaceae	4		
29	Ischnodermataceae	1		
30	Laetiporaceae	2		
31	Leotiaceae	1		
32	Lycoperdaceae	1		
33	Lyophyllaceae	3		
34	Marasmiaceae	3		
35	Mycenaceae	1		
36	Omphalotaceae	4		
37	Panaceae	1		
38	Phallaceae	2		
39	Pleurotaceae	2		
40	Pluteaceae	2		
41	Podoscyphaceae	1		
42	Polyporaceae	19		
43	Psathyrellaceae	1		
44	Reticulariidae	1		
45	Russulaceae	11		
46	Sarcoscyphaceae	1		
47	Sarcosomataceae	1		
48	Schizophyllaceae	1		
49	Schizoporaceae	1		
50	Sclerodermataceae	2		
51	Strophariaceae	2		
52	Thelephoraceae	2		
53	Trichiidae	1		
54	Xylariaceae	2		
	Total species	152		

Table 3. Numbers of mushroom species present in each order and division.

	Name of classes	No. of species	Name of divisions	No. of species
1	Agaricomycetes	142	Ascomycota	9
2	Pezizomycetes	3	Basidiomycota	143
3	Sordariomycetes	3	**Total species**	152
4	Leotiomycetes	2		
5	Dacrymycetes	1		
6	Geoglossomycetes	1		
	Total species	152		

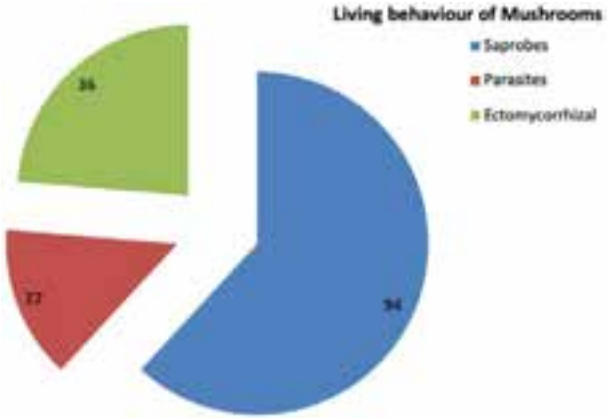

Figure 3. Habit of wild mushrooms of Mizoram.

ectomycorrhizal (36 spp.), and parasites (22 spp.) (Figure 3). Tapwal et al. (2013) reported that the ecological preference of the fungal species was maximum as saprophyte followed by ectomycorrhizal and parasites in wet ever green tropical forest in Assam.

CONCLUSION

The wild edible mushrooms play a vital role in strengthening the livelihood of the tribal people. The current environmental issues of global warming and climate change would adversely affect the delicate fungi's regeneration and growth pattern, which requires a specific micro-climate. Meticulous scientific screening of the wild edible mushrooms of Mizoram will help in understanding their henceforth unknown medicinal properties which will consequently be the source of nutritionally enriched diet to the tribal community along with additional therapeutic benefits.

Many reports have been published about the deaths caused by mushroom poisoning. There needs to be an immediate effort to prevent future loss of life. An awareness program should be initiated using radio, television, and newspapers to make people better aware of the hazards of mushroom poisoning. Exploration of hitherto unknown wild edible mushrooms will facilitate in developing and popularizing their artificial cultivation technology among the tribal masses which will ultimately be a new source of their livelihood.

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Image 2. Wild mushrooms of Mizoram: 1—*Abortiporus biennis* | 2—*Agaricus bisporus* | 3—*Agaricus bitorquis* | 4—*Agaricus silvaticus* | 5—*Albatrellus ellisii* | 6—*Amanita citrina* | 7—*Amanita fulva* | 8—*Amanita macerisolum* | 9—*Amanita marmorata* | 10—*Amanita phalloides* | 11—*Amanita vaginata* | 12—*Auricularia cornea* | 13—*Baorangia bicolor* | 14—*Bisporella citrina* | 15—*Boletinellus merulioides* | 16—*Boletus bicolor* | 17—*Boletus edulis* | 18—*Boletus luridiformis* | 19—*Boletus mirabilis* | 20—*Boletus zelleri*. © Rajesh Kumar.

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Image 3. Wild mushrooms of Mizoram: 21—*Calbovista subsculpta* | 22—*Campanella caesia* | 23—*Cantharellus formosus* | 24—*Cantharellus lateritius* | 25—*Cerrena unicolor* | 26—*Clavaria fragilis* | 27—*Clavaria miniata* | 28—*Clavaria zollingeri* | 29—*Clavulina cristata* | 30—*Clavulina rugosa* | 31—*Coltricia cinnamomea* | 32—*Coltricia montagnei* | 33—*Coltricia perennis* | 34—*Conocybe apala* | 35—*Cookeina tricholoma* | 36—*Coprinus disseninatus* | 37—*Coprinus leiocephalus* | 38—*Coprinus plicatilis* | 39—*Cortinarius corrugatus* | 40—*Cortinarius crassus.*

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Image 4. Wild mushrooms of Mizoram: 41—*Craterellus tubaeformis* | 42—*Dacrymyces palmatus* | 43—*Daldinia concentrica* | 44—*Enteridium splendens* | 45—*Entoloma abortivum* | 46—*Entoloma lividum* | 47—*Entoloma squamatum* | 48—*Fomes fomentarius* | 49—*Fomitopsis ochracea* | 50—*Fomitopsis pinicola* | 51—*Galiella rufa*| 52— *Ganoderma adspersum* | 53—*Ganoderma applanatum* | 54—*Ganoderma formosanum*| 55—*Ganoderma lucidum* | 56—*Ganoderma oregonense* | 57—*Ganoderma sinense*| 58—*Ganoderma tsugae* | 59—*Geoglossum fallax* | 60—*Gloeophyllum sepiarium.* © Rajesh Kumar.

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Image 5. Wild mushrooms of Mizoram: 61—*Grifola frondosa* | 62—*Gymnopilus junonius* | 63—*Gymnopilus luteofolius* | 64—*Helvella atra* | 65—*Hericium coralloides* | 66—*Heterobasidion annosum* | 67—*Hygrocybe coccinea* | 68—*Hygrocybe conica* | 69—*Hypholoma fasciculare* | 70—*Inocybe flocculosa* | 71—*Inocybe lapponica* | 72—*Inocybe napipes* | 73—*Inocybe sindonia* | 74—*Ischnoderma resinosum* | 75—*Kuehneromyces mutabilis* | 76—*Laccaria affinis* | 77—*Laccaria fraterna* | 78—*Laccaria laccata* | 79—*Laccaria vinaceoavellanea* | 80—*Lactarius croceus.* © Rajesh Kumar.

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Image 6. Wild mushrooms of Mizoram: 81—*Lactarius fragilis* | 82—*Lactarius piperatus* | 83—*Lactarius vietus* | 84—*Lactarius volemus* | 85—*Lactifluus corrugis* | 86—*Laetiporus cincinnatus* | 87—*Laetiporus sulphureus* | 88—*Leccinum scabrum* | 89—*Lentinula lateritia* | 90—*Lentinus polychrous* | 91— *Lentinus sajor-caju* | 92—*Lentinus tigrinus* | 93—*Lenzites betulinus* | 94—*Leotia lubrica* | 95—*Lepiota brunneoincarnata* | 96—*Lepiota rubrotinctoides* | 97—*Lysurus periphragmoides* | 98—*Macrolepiota dolichaula* | 99—*Marasmiellus candidus* | 100—*Marasmiellus ramealis.* © Rajesh Kumar.

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Image 7. Wild mushrooms of Mizoram: 101—*Marasmius corrugatiformis* | 102—*Marasmius crinis-equi* | 103—*Mycena pura* | 104—*Omphalotus illudens* | 105—*Panus rudis* | 106—*Phaeotrametes decipiens* | 107— *Phallus indusiatus* | 108—*Phellinus igniarius* | 109—*Phylloporus rhodoxanthus* | 110—*Piptoporus betulinus* | 111—*Pleurotus floridanus* | 112—*Pleurotus pulmonarius* | 113—*Polyporus arcularius* | 114—*Polyporus badius* | 115—*Postia caesia* | 116—*Psathyrella candolleana* | 117—*Pycnoporus cinnabarinus* | 118—*Pycnoporus sanguineus* | 119—*Ramaria formosa* | 120—*Ramaria myceliosa.* © Rajesh Kumar.

Image 8. Wild mushrooms of Mizoram: 121—*Ramaria stricta* | 122—*Ramariopsis kunzei* | 123—*Russula brevipes* | 124—*Russula cremoricolor* | 125—*Russula emetica* | 126—*Russula ochroleuca* | 127—*Russula variata* | 128—*Schizophyllum commune* | 129—*Schizopora paradoxa* | 130—*Scleroderma cepa* | 131—*Scleroderma citrinum* | 132—*Strobilomyces confusus* | 133—*Strobilomyces strobilaceus* | 134—*Suillus bovinus* | 135—*Suillus granulatus* | 136—*Suillus luteus* | 137—*Termitomyces clypeatus* | 138—*Termitomyces fuliginosus* | 139—*Termitomyces heimii* | 140—*Thelephora anthocephala.* © Rajesh Kumar.

Image 9. Wild mushrooms of Mizoram: 141—*Thelephora palmata* | 142—*Trametes pubescens* | 143—*Trichia decipiens* | 144—*Tylopilus badiceps* | 145—*Tylopilus felleus* | 146—*Tylopilus griseocarneus* | 147—*olvariella bombycina* | 148—*Volvariella taylorii* | 149—*Xerocomus ripariellus* | 150—*Xerocomus subtomentosus* | 151—*Xylaria nigripes* | 152—*Xylaria polymorpha.* © Rajesh Kumar.

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COMMUNICATION

New plant records for the flora of Saudi Arabia

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Abstract: Our goal was to find and record new plants that had not previously been recorded for the flora of Arabian Peninsula, particularly for Saudi Arabia. Collections were made in several ecologically important areas of Saudi Arabia, particularly in Faifa region. It was revealed that eight new vascular plant species and one liverwort (Bryophyte) belonging to eight families were recorded for the first time. The investigation was done between January 2021 and May 2022.

Keywords: Al-Balace, Al-Lawz, biodiversity, Arabian Peninsula, Faifa region, new records.

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Author contributions: All authors contributed equally to the manuscript.

INTRODUCTION

According to estimates made by Gatti et al. (2022) and Pimm & Joppa (2015), 400,000 of the estimated 15 million species on the planet are vascular plants. Discovering new species aids in their conservation. Furthermore, new plant species enrich a country's flora and its economy if these plants are economically significant. The inventory of Saudi's flora is far from complete, and more work is needed to document the country's missing floristic knowledge, particularly in less explored areas like southwestern highland regions, and thereby improve the conservation of its floristic wealth and reap the economic benefits.

Several new species or records, published in various papers and books, have been added in the past to the flora of Saudi Arabia (e.g., Mandaville 1990; Alfarhan et al. 1997; Chaudhary 1999; Collenette 1999; Chaudhary 2000, 2001; Al-Turki 2004; AlFarhan et al. 2005; Fayed & Alzahrani 2007; Al-Surour 2018; El-Shaboury et al. 2018; Al-Gifri et al. 2019; Alzahrani et al. 2022).

In previous trips, authors discovered several plants that recorded for the first time for the flora of Saudi Arabia, such as *Celtis toka* (Forssk.) Hepper & J.R.I.Wood (Al-Surour 2020), *Aspilia kotschyi* (Sch.Bip. ex Hochst.) Oliv. (Al-Khulaidi et al. 2021), *Alysicarpus vaginalis* (L.) DC., *Commiphora schimperi* (O.Berg) Engl., *Maerua angolensis* DC. ssp. *angolensis*, *Peperomia leptostachya* Hook. & Arn. (Piperaceae), and *Vigna vexillata* (L.) A.Rich. (Al-Khulaidi et al. 2023).

In this study, a botanical exploration was carried out in this framework between January 2021 and May 2022 in some parts of Saudi Arabia, specifically in the Faifa region and surrounding areas, and resulted in the discovery of eight new vascular plant species and one liverwort (Bryophyta) belonging to eight families that had not previously been recorded for the flora of the Kingdom of Saudi Arabia.

MATERIALS AND METHODS

Floral studies and atlas of the Arabian Peninsula and other countries (e.g., Post 1932**;** Miller 1996; Wood 1997**;** Collenette 1999; Chaudhary 1999, 2000, 2001; Kürschner 2000; Miller & Morris 2004; Al-Khulaidi 2013) were used to identify and search for the newly recorded plants along with the researchers' own experiences. ArcMap version 10.8 software was utilized to prepare the distribution maps of the plants.

Study Area

The investigated areas are located in southwestern Saudi Arabia in Asir region particular in Raidah Sanctuary and around Jabal Al-Balace, and in Faifa mountains in region of Jazan, and in the north of Saudi Arabia, Jabal Al-Lawz, in Tabuk Region (Figure 1, Table 1).

Field Surveys

Field trips for plant survey and collections have been done between January 2021 and May 2022 in different parts of Saudi Arabia. All the collected specimens are deposited in the herbarium (MUZ) of King Abdulaziz City for Science and Technology (KACST).

RESULTS

This study adds eight new vascular plant species and one liverwort (bryophyte) belonging to eight families, of which five species are angiosperms and three are pteridophytes to the Saudi Arabian flora, namely: *Asplenium dalhousiae* Hook., *Bolanthus hirsutus* (Labill.) Barkoudah, *Hemionitis viridis* (Forssk.) Christenh., *Grewia flavescens* Juss. var. *flavescens*, *Nicandra physalodes* (L.) Gaertn., *Oxymitra incrassata* (Brot.) Sérgio & Sim-Sim, *Hemionitis calomelanos* (Sw.) Christenh., *Pentodon pentandrus* (Schum. & Thonn.) Vatke. var. *pentandrus*, and *Zornia glochidiata* Rchb. ex DC.

1. *Asplenium dalhousiae* Hook**.,** Icon. Pl. 2: t. 105. 1837 (Aspleniaceae) (Figure 2 & Image 1)

A perennial tufted fern. Frond simple, pinnatifid, up to 15 cm high, glabrous above, scaly below; sori linear; petiole brown. Pinnae alternate, triangular-ovate to oblong, up to 17 mm long.

Specimen examined: Faifa Region, on moist shady crevices, 17.264667° N, 43.110083° E, 1,695 m, March 2021. M. AlFaifi, MUZ-20235 (KACST),

2. *Bolanthus hirsutus* (Labill.) Barkoudah Wentia 9: 168 (1962) (Caryophyllaceae) (Figure 3 & Image 2).

Perennial herb, up to 20 cm high, glandular-pubescent, cushion-forming; leaves 1–1.5 x 0.2–0.5 cm, elliptic to linear, apex acute, base obtuse, margin entire; calyx tubular, 3–4 mm long, 5-toothed; flowers white with purple veins, short-pedicellate.

Specimen examined: Jabal Al-Lawz, Tabuk Region, in crevices of granite, 28.735095° N, 35.338322° E, 1,900 m, 17.vii.2021, A. Alzahrani 301, MUZ-20230 (KACST),

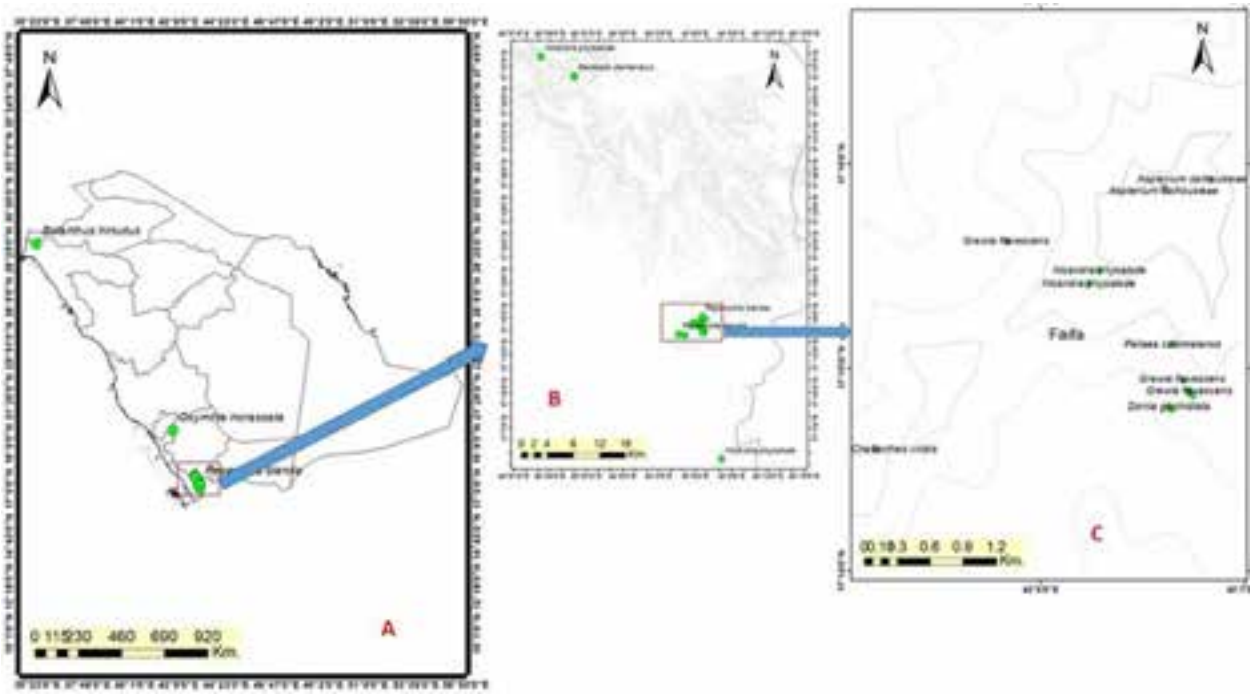

Figure 1. A—areas investigated during the present study (Tabuk, Asir and Jazan) | B—distribution of the plants within Jazan region | C—distribution of the plants within Faifa district.

Image 1. *Asplenium dalhousieae*: A—Life form | B—Leaf shape | C—Close-up of under surface of frond, showing linear sori | D—The upper surface of frond. © Eisa Ali Al-Faify.

3. *Hemionitis viridis* (Forssk.) Christenh., Global Fl. 4: 22. 2018 (Pteridaceae) (Figure 4 & Image 3)

Rhizomes short, creeping. Fronds tufted, erect to arching, up to 60 cm high; stipe dark brown to blackish, glabrous or with hair-like scales, up to 20 cm long; lamina herbaceous, 2-pinnate, lanceolate to ovate; pinnules green to dark green, variable, glabrous, ovate to triangular, apex obtuse, base rounded to hastate,

Table 1. The plant species with their number of individuals, habitat information and world distribution.

Latitude	Longitude	Plant name	Individuals	Altitude (m)	World distribution	Habitat
17.26467	43.11008	*Asplenium dalhousieae* Hook.	17	1,695	Afghanistan, Arizona, East Himalaya, Eritrea, India, Mexico, Nepal, Pakistan, western Himalaya, Yemen	wall terraces
17.26538	43.11392	*Asplenium dalhousieae* Hook.	13	1,663		
28.73514	35.33832	*Bolanthus hirsutus (Labill.) Barkoudah*	2	2,009	Syria, Palestine, and Egypt	in crevices of granite
17.24330	43.08645	*Hemionitis viridis* (Forssk.) Christenh.	50	1,300	Yemen, South Africa, eastern tropical Africa, Cape Verde, the Comoro Islands	shady crevices
17.24810	43.11210	*Grewia flavescens* var. *flavescens*	2	1,330	Yemen, tropical Africa, South Africa to India	slope
17.26030	43.09730	Grewia *flavescens* var. flavescens	2	1,250		slope
17.24900	43.11170	*Grewia flavescens* var. *flavescens*	2	1,340		slope
17.24790	43.11220	*Grewia* flavescens var. *flavescens*	2	1,327		road side
17.24776	43.11244	*Grewia flavescens* var. *flavescens*	2	1,327		road side
17.25680	43.10390	*Nicandra physalodes* (L.) Gaertn.	3	1,530	Yemen, South America (Peru to northwestern Argentina), widespread in the world	terraces
17.25790	43.10480	*Nicandra physalode* (L.) Gaertn.	2	1,553		terraces
17.07410	43.13640	*Nicandra physalode* (L.) Gaertn.	1	1,116		rocky slope
17.62932	42.88751	*Nicandra physalode* (L.) Gaertn.	3	1,689		rocky slope
19.82817	41.86146	*Oxymitra incrassata* (Brot.) Sérgio & Sim-Sim	10	1,996	Texas, Mexico, Europe and northern Africa	beneath rocks
17.25179	43.11077	*Hemionitis calomelanos* (Sw.) Christenh.	1	1,400	Eastern and southern Africa	shady crevices
17.60190	42.93360	*Pentodon pentandrus (Schum.& Thonn.)* Vatke, var. *pentandrus*	2	1,257	Yemen, Oman, tropical Africa, South Africa, and Madagascar	wadi
17.60220	42.93350	*Pentodon pentandrus (Schum.& Thonn.)* Vatke, var. *pentandrus*	4	1,252		wadi
17.24660	43.11070	*Zornia glochidiata* Rchb. ex DC.	5	1,276	Yemen, tropical Africa, South Africa, and Madagascar.	road side
17.24680	43.11050	*Zornia glochidiata* Rchb. ex DC.	2	1,270		road side

Table 2. A comparison of Grewia species found in Saudi Arabia with the new ones (Wood 1997; https://powo.science.kew.org 2021). Grewia flavescens Juss". Plants of the World Online. Board of Trustees of the Royal Botanic Gardens, Kew. Retrieved 27 May 2021.).

Plant name	Leaves	Flowers	Fruits
Grewia villosa Willd.	Orbicular cordate up to 120 mm	Reddish-brown	Unlobed
Grewia tembensis Fresen.	Ovate to elliptic, up to 140 mm	White with pink filament	3-4 lobed
Grewia tenax (Forssk.) Fiori	Orbicular, up to 15 mm	White with white filament	2–4 lobed
Grewia erythraea Schweinf.	Obovate to elliptic, up to 30 mm	White with white filament	2–4 lobed
Grewia flavescens Juss.	Oblong to lanceolate, up to 80 mm	White with yellow to golden filament	Single, or 2–4 lobed
Grewia gillettii Sebsebe & B.Mathew	Obovate to oblanceolate, up to 40 mm	Yellow with yellow filament	2 lobed or unlobed
Grewia velutina (Forssk.) Lam.	Obovate, up to 60 mm	Yellow	Unlobed
Grewia trichocarpa Hochst. ex A.Rich.	Ovate, up to 70 mm	Yellow	Unlobed

margins minutely crenate; sori marginal.

H. viridis is reported for the first time from two locations in southwest Saudi Arabia, where it is growing under dense shade along terraces of Jabal Faifa and in shady crevices of Raidah Sanctuary, near Abha city.

Specimen examined: Jabal Faifa, Jazan Region, in deep shade on terraces, 17.243302° N, 43.086448° E, 1,300 m, 25.vii.2021, A. Alzahrani 302, MUZ-20232; Raidah Sanctuary, Asir Region, in shady crevices, 18.197737° N, 42.408689° E, 1,200 m, 23.ii.2021, A.

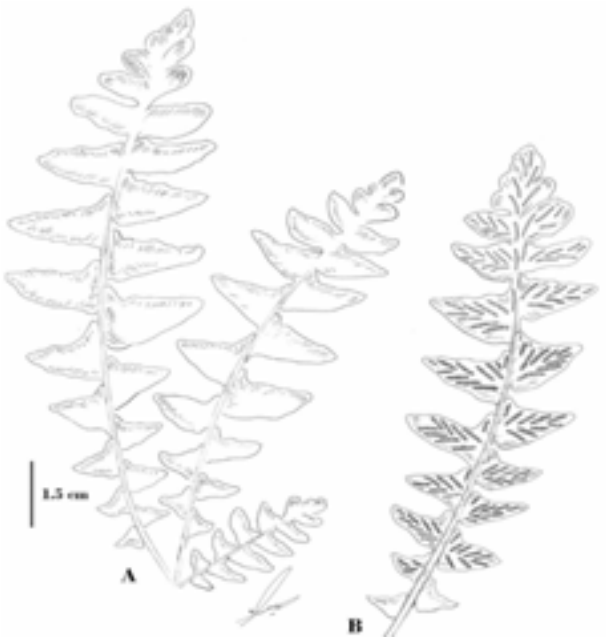

Figure 2. *Asplenium dalhousieae*: A—habitat | B—under surface of frond showing linear sori.

Image 2. *Bolanthus hirsutus*: A—Habitat | B—calyx | C—Flowers. © Ali M. Alzahrani.

Image 3. *Hemionitis viridis* (Forssk.) Christenh.: A—frond (white arrow indicates rachis) | B—sori marginal (white arrow) | C—pinna. © Ali M. Alzahrani

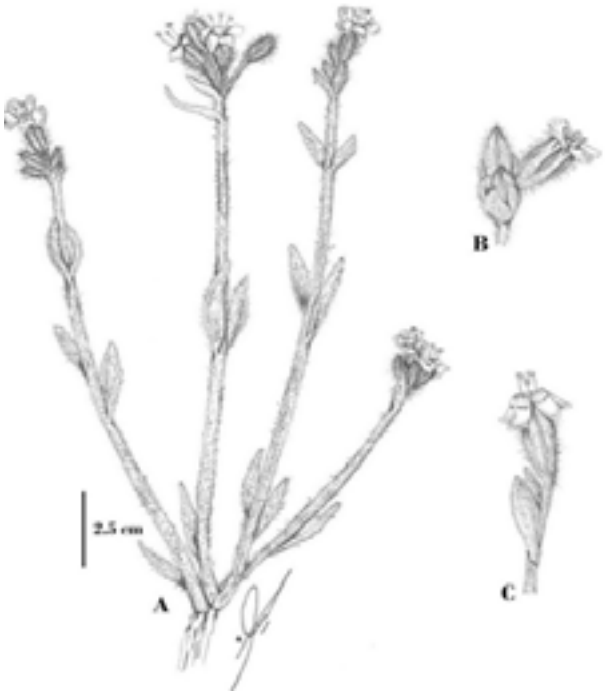

Figure 3. *Bolanthus hirsutus*: A—Habit | B—Calyx | C—Flower.

Alzahrani 303, MUZ-20233 (KACST).

4. *Grewia flavescens* Juss**.** Ann. Mus. Natl. Hist. Nat. 4: 91. 1804, **var. *flavescens*** (Malvaceae; Grewioideae) (Figure 5 & Image 4).

A small bushy tree with deeply grooved four-angled stems. Leaves alternate oblanceolate, up to 80 mm long. Inflorescence solitary with two or three bright yellow flowers in axillary cyme, with yellow to golden colour filament. Fruits single, or 2–4-lobed, covered with rough white hairs.

Widespread throughout tropical Africa. The species has been recorded in Yemen in the Arabian Peninsula only. We did not find a published paper mentioning the occurrence of this plant species in Saudi Arabia, except on the KEW site Plants of the World Online (POWO 2023), which is likely to be based on a study of the plant specimen collected from Sudan

Specimen examined: Faifa Region, on rocky slope, 17.2481° N, 43.1121° E, 1,330 m, 25.v.2021, E. AlFaifi MUZ-20220 (KACST),

5. *Nicandra physalodes* (L.) Gaertn., Fruct. Sem. Pl. 2: 237, t. 131, f. 2. 1791 (Solanaceae) (Figure 6 & Image 5).

Annual herb, up to 20 cm high. Leaves alternate,

Image 4. *Grewia flavescens* var. *flavescens*: A—inflorescence | B—close-up of a flower showing stamens | C—leaves | D—deeply grooved four-angled stems | E—fruits | F—fruits with two–four lobes. © Mohammed Musa Alfaifi.

Figure 4. *Hemionitis viridis*: A—habit showing a general view of frond | B—sori marginal (black arrow).

ovate to elliptic, margins toothed and undulated or almost lobed. Flowers solitary, axillary, bell-shaped, c. 4 cm in diam., blue-purple. Fruit spherical, with swollen and winged calyx.

Introduced species, found on terraces and rocky slopes, probably has also long been cultivated as an ornamental plant, besides Faifa region, the plant found in Jabal Al-Qahar at an elevation of 1,689 m, between latitude 17.6293 and longitude 42.8875.

135 Km. SE Abha, Saudi ArabiaThe plant is recorded in some countries as a weed in many types of crops as well as in disturbed sites, roadsides, rangelands (Holm et al. 1997; CABI 2011), and may become invasive with time.

Specimen examined: Faifa Region, on terraces, 17.2568° N, 43.1039° E, 1,530 m, 28.ix.2021, E. AlFaifi MUZ 20215 (KACST),

6. *Oxymitra incrassata* (Brot.) Sérgio & Sim-Sim, J. Bryol. 15: 662. 1989 **(Oxymitraceae)** (Figure 7 & Image 6)

Thalli 5–10 mm long, dark green to greyish, simple or in branching rosettes; epidermal pores prominent, with a deep midline; with hyaline, narrowly acuminate ventral scales extending beyond thallus edges.

Specimen examined: Near Jabal Al-Balace, Asir Region, in shallow soil beneath rocks, 19.828173° N, 41.861464° E, 1,996 m, 27.ii.2022, A. Alzahrani 304, MUZ-20234 (KACST),

Figure 5. *Grewia flavescens* var. *flavescens*: A—flowering-twig | B—a leaf | C—flower | D—fruit.

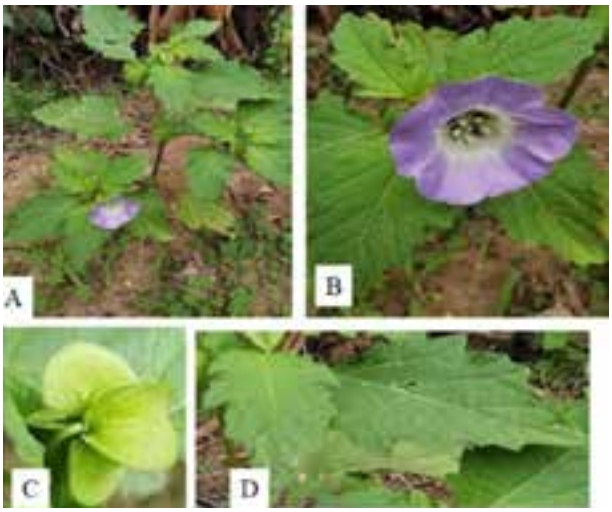

Image 5. *Nicandra physalodes*: A—habit | B—flower with five stamens | C—fruits with winged calyx | D—leaves with coarsely sinuate-dentate margins. © Mohammed Musa Alfaifi.

Image 6. *Oxymitra incrassata*: A—habitat and habit, showing a general view of thalli | B— thalli branching | C—silvery ventral scales (white arrow). © Ali M. Alzahrani.

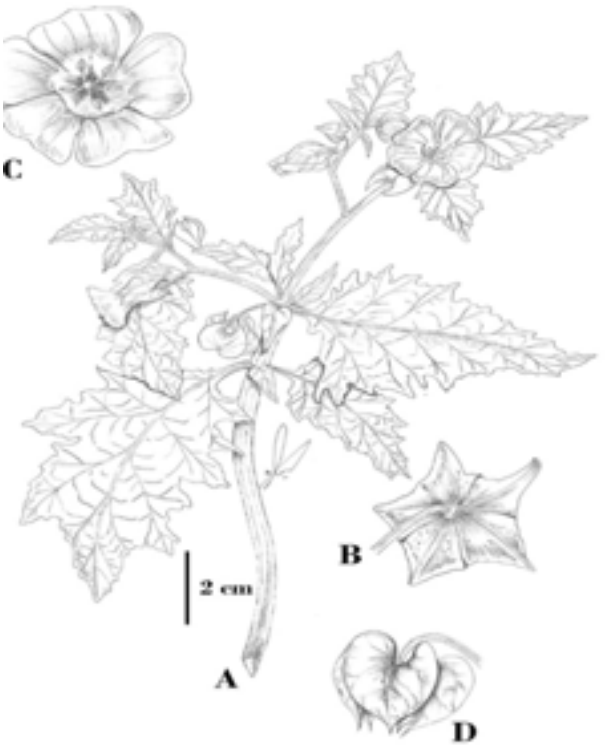

Figure 6. *Nicandra physalodes*: A—habit | B—calyx | C—flowers | D—fruits with winged calyx.

7. *Hemionitis calomelanos* (Sw.) Christenh. Global Fl. 4: 11. 2018. (Pteridaceae) (Figure 8 & Image 7).

Rhizomes erect or shortly creeping, c. 6 mm in diam. Frond pinnate; Lamina ovate-lanceolate to narrowly triangular, blue-green to light green, glaucous, with pale-brown margins and shiny black rachis; the upper with (1–)2-pinnate, often the lower pinnae 2- or 3-pinnate; pinnae opposite to slightly alternate; sori borne on a continuous ridge along the margins.

Specimen examined: Faifa, in crevices of granite, 17.251785° N, long. 43.110767° E, 1,400 m, 18.xii.2021,

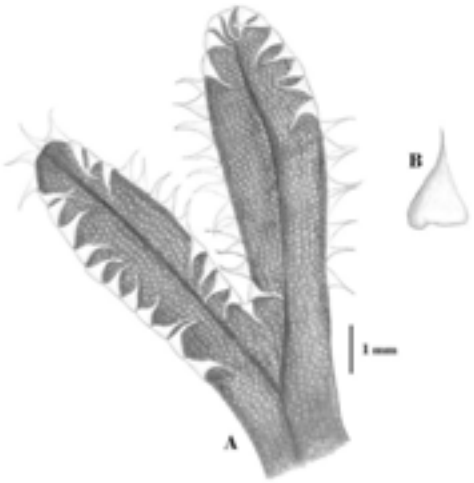

Figure 7. *Oxymitra incrassata*: A—thallus | B—silvery ventral scale.

Figure 8. *Hemionitis calomelanos*: A—the habit | B—fronds with marginal sporangia.

Image 7. *Hemionitis calomelanos* (Sw.) Christenh.: A—the fronds with sporangia| B— habit. © Ali M. Alzahrani.

Mohamed Alfaifi MUZ-20219 (KACST).

8. *Pentodon pentandrus* (Schumach. & Thonn.) Vatke Oesterr. Bot. Z. 25: 231. 1875, var. *pentandrus* (Rubiaceae) (Figure 9 & Image 8).

Annual herb. Stem soft, succulent, shiny, glabrous. Leaves simple, opposite-decussate, sessile, linear-lanceolate, margins entire. Flowers on long peduncle in axillary panicle, 6–13-flowered. Flowers pedicelled, pale blue or mauve. Calyx with lobed sepals, narrowly extended with five triangular teeth. Corolla usually small, up to 3 mm long, cylindrical, with five stamens.

Specimen examined: Faifa Region, on wadi, 17.6019° N, 42.9336° E, 1,257 m, 26.iii.2021, M. AlFaifi MUZ-20211.

Figure 9. *Pentodon pentandrus* var. *pentandrus*: A—a flowering-twig | B—leaf | C—calyx with five triangular teeth | D—flower.

Image 8. ***Pentodon pentandrus*** **var.** ***pentandrus*****: A—habit | B—opposite, sessile leaves | C— flowers on long peduncles in axillary panicle | D—pale blue flowers | E—calyx with five triangular teeth. © Eisa Ali Al-Faify.**

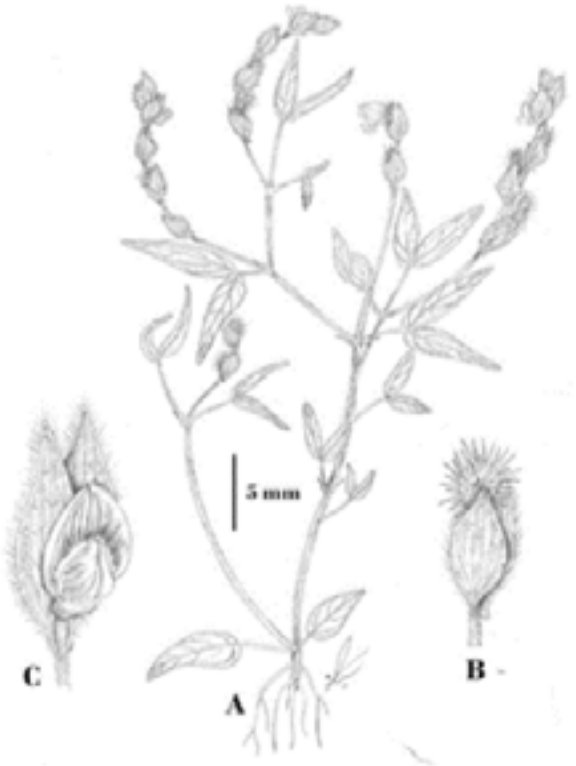

Figure 10. ***Zornia glochidiata*****: A—habit | B—a Loment enclosed between hairy leaf-like bracts | C—flower.**

9. ***Zornia glochidiata*** Rchb. ex DC., Prodr. 2: 316. 1825 (Fabaceae) (Figure 10 & Image 9)

Annual, erect herb. Leaves 2-foliolate, with two asymmetrical leaflets at the end of a long petiole; upper leaflets lanceolate, up to 40 mm long, acute, sparsely and obscurely glandular beneath, especially near margins. Flowers enclosed between two hairy leaf-like bracts, shorter than the bracts. Petals yellow, with red markings. Pods of constricted segments, covered in spiny bristles.

Specimen examined: Faifa Region, on roadsides, 17.2466° N, 43.1107° E, 1,276 m, 20.viii.2021, M. AlFaifi MUZ-20217.

DISCUSSION

Recently, new plant records have been documented in the Saudi flora, and the number of these plants is estimated to be 17 new records and five new taxa (Fayed & Alzahrani 2007; Thomas et al. 2014; El-Shaboury et al. 2018; Basahi & Masrahi 2019; Alzahrani et al. 2022; Al-Khulaidi et al. 2021; Al-Robai et al. 2022; Al-Khulaidi et al. 2023). The number of new records is relatively low compared to the number of new taxa discovered in Africa. The low number discovered in Saudi Arabia may be related to the lack of studies and surveys in the field of plants, and perhaps the lack of specialists in botany. Some of the plants listed in this paper are widely recognized as weeds, so we advise treating them with caution and making an effort to stop their spread so they do not establish themselves as invasive weeds in the area, and pose a challenge to control or eradicate them in the future.

Image 9. *Zornia glochidiata* floral and vegetative parts: A—habit | B—flowers enclosed between hairy leaf-like bracts | C—loment enclosed between hairy leaf-like bracts, showing two segments | D—loment of the plant, with curved bristles | E—two asymmetrical leaflets | F—flower. © Mohammed Musa Alfaifi.

In Arabian Peninsula, *Asplenium dalhousiae* were previously recorded from Yemen only (Wood 1997). The genus *Bolanthus* (Ser.) Rchb. belongs to the tribe Caryophyllaceae (Bittrich 1993). *Bolanthus hirsutus* is native to Syria, Palestine, and Egypt (Post 1932; Boulos 1999). For the Arabian Peninsula the plant is only known from Jabal Al-Lawz, northwestern Saudi Arabia. *Hemionitis viridis* is a native species of South Africa, tropical East Africa, Cape Verde, the Comoro Islands, Madagascar, and the Mascarene Islands (Roux 2009). In addition to Yemen in Arabian Peninsula (Miller 1996; Wood 1997). The species *Nicandra physalodes* is so far, recorded as an introduced species in Soqotra Island, Yemen (Miller & Morris 2004). The genus *Oxymitra* Bisch. ex Lindenb., comprises two species: *O. cristata* Garside and *O. incrassata* (Brot.) Sérgio & Sim-Sim (Söderström et al. 2016). *Oxymitra cristata* is found in southern Africa (Perold, 1993), whereas *O. incrassata* is widely distributed (Kürschner 2003). In fact, in the Arabian Peninsula, *O. incrassata* was recorded only from Yemen by Kürschner (2000). The species is documented for the first time in Saudi Arabia, where it is found in shallow soil beneath rocks near Jabal Al-Balace, Asir Region. In the Arabian Peninsula, the plant *Pentodon pentandrus* is recorded only from Yemen (Wood 1997) and Oman (Ghazanfar 2007; Patzelt et al. 2014). The plant occurs in Tanzania as a weed, as well as in some countries of the world (Burkill 1997). In the Arabian Peninsula, *Zornia glochidiata* is recorded only from Socotra Island, Yemen (Miller & Morris 2004). The plant is recorded as weed in some parts of the world (Ekeleme & Chikoye 2003).

CONCLUSION

The recorded plant species suggest that further botanical study is necessary in the Faifa region and other unexplored regions farther north of the country (e.g., Tabuk and Al-Ula). The study areas' proximity to Yemen, Sinai (Egypt), and Jordan might also have helped some plants spread to nearby areas, such as Tabuk and Faifa. Some of the species observed, like *Nicandra physalodes*, are aggressive and well-known weeds worldwide. Over time, they may establish themselves in Saudi Arabia as invasive species. The results of this study and the previous studies that have been mentioned have added

new plants to the Saudi Arabia's flora, and enriched it.

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Seagrass ecosystems of Ritche's Archipelago in the Andaman Sea harbor 'Endangered' *Holothuria scabra* Jaeger, 1833 and 'Vulnerable' *Actinopyga mauritiana* (Quoy & Gaimard, 1834) sea cucumber species (Echinodermata: Holothuroidea)

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Abstract: This study reports the presence of 'Endangered' sea cucumber *Holothuria scabra* for the first time from the mixed seagrasses of Havelock Island, and the 'Vulnerable' *Actinopyga mauritiana* from the monospecific *Thalassia hemprichii* meadows from Neil Island of Ritche's Archipelago of Andaman & Nicobar Islands (ANI). Both species were found during field survey of intertidal seagrass ecosystems of Ritche's Archipelago. Morphometric measurements were carried out in the field using a vernier caliper, and identification was confirmed using the identification guide for sea cucumbers of ANI provided by the Zoological Survey of India. The total body length of the *H. scabra* specimen was 15.7 cm, mouth width of 3.2 cm and body circumference of 5.7 cm. The specimen was a juvenile, grey in color with a total of 17 black and yellow transverse stripes along the body. The average body length of *A. mauritiana* specimens examined differed between those from seagrass meadows (20.4 cm) non-seagrass areas (15.7 cm) as did mouth width and total circumference. Mono and mixed seagrass meadows of ANI are critical habitats for sea cucumbers and require monitoring and protection for conservation of declining populations.

Keywords: Andaman & Nicobar Islands, biodiversity, *Cymodocea rotundata,* Echinoderm, India, tropical islands.

Editor: Anonymity requested.

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INTRODUCTION

Sea cucumbers are marine invertebrates of the family Holothuroidea, that possess unique morphological characteristics such as leathery skins, feeding tentacles and elongated bodies, which aid in their survival as bottom detritus feeders (Idreesbabu & Sureshkumar 2017; Mohammednowshad et al. 2021). These animals play an important role as a biotic component in the benthic zone of coastal marine ecosystems (Gamage et al. 2021) by regulating micro-algae growth, nutrient recycling and mixing the upper sediment layers through bioturbation (Costa et al. 2014; Arnull et al. 2021). These ecological interactions also allow the sea cucumbers to inhabit soft bottom coral reef areas and intertidal seagrass ecosystems (Navarro et al. 2014; Floren et al. 2021).

The coastal ecosystems of India are home to 200 species of holothurians, of which 98 species are found in the Andaman & Nicobar Islands (ANI; Raghunathan & Venkataraman 2014; Vinod et al. 2017). *Holothuria scabra* Jaeger, 1833 and *Actinopyga mauritiana* (Quoy & Gaimard, 1833) have high value leading to increased fishing and over exploitation. *H. scabra* is economically important and famous for 'beche-de-mer' or 'trepang' which is highly valued in traditional diets and for medicinal purposes in China, Japan, Malaysia, Thailand, Vietnam, Indonesia and the Philippines (Purcell et al. 2012; Arnull et al. 2021; Aulia et al. 2021). Similarly, *A. mauritiana* is also heavily fished for its commercial importance in traditional Chinese medicines (Raghunathan & Venkataraman 2014), and by subsistence fisheries as a direct food source (Kinch & Friedman 2008). In the late 1990's Indian fishermen exported more than 50 tonnes of 'beche-de-mer' to other Asian countries (Vinod et al. 2017). This led to overexploitation of both species and collapse of populations from the coast of India. The Ministry of Environment, Forests and Climate Change (MoEFCC) imposed a blanket ban on fishing and trading of all holothurian species from Indian waters in 2001, under schedule I of the Indian Wildlife Protection Act, 1972 (MoEFCC 2001). However, the illegal fishing of sea cucumbers in the Indo-Pacific region, including the areas around Andaman Sea is still active and has pushed some species towards being endangered (*H. scabra*) and vulnerable (*A. mauritiana*) according to the last IUCN assessment (Conand et al. 2013; Hamel et al. 2013).

In India, for better conservation and management actions, understanding the population trends, habitat settings and effects of presence of various coastal keystone ecosystems (such as coral reefs, seagrass, and macroalgae systems) on sea cucumber distribution in shallow waters is important (Idreesbabu & Sureshkumar 2017; Mohammednowshad et al. 2021). In ANI, there is a single study showcasing the positive role of different habitat types (such as intertidal reef flats, rock pools, dead coral rubbles covered with macroalgae and mono-specific seagrass beds) and role of various abiotic factors (such as pH, sea surface temperature, salinity) on the distribution of five sea cucumber species, i.e., *H. atra*, *H. leucospilota*, *Stichopus chloronotus*, *Synapta maculata*, and *Actinopyga mauritiana* has been recorded (Gole et al. 2022). The distribution of *A. mauritiana* in the above study was restricted to only intertidal hard substratum (Gole et al. 2022). However, studies showcasing the importance of the presence or absence of intertidal seagrass meadows on sea cucumber distribution in these islands are less understood. Therefore, this study aimed to assess the presence of various sea cucumber species from areas with and without seagrass meadows of Andaman & Nicobar Islands.

METHODS

This study surveyed two islands of the Ritche's Archipelago (RA) situated in southern part of Andaman Islands of ANI of India that consists of eight islands including both Swaraj Dweep and Shaheed Dweep (Figure 1). We selected Swaraj Dweep (hereafter Havelock) and Shaheed Dweep (hereafter Neil) islands, as both islands are most visited by tourists and is inhabited by mixed and monospecific seagrass meadows (Mishra & Mohanraju 2018; Mishra & Apte 2020; Mishra et al. 2021). In each location, we selected two sites, i.e., one with seagrass meadows and another without seagrass. At each site, we surveyed an area with seagrass meadow (site 1: 500 ha) and another area without seagrass (site 2: 500 ha) situated 2 km away from site 1 (Figure 1). The survey was carried out during low tide for collection of sea cucumber specimens. All morphometric measurement of the sea cucumbers were recorded in situ. The threatened sea cucumber *H. scabra* was found within the mixed seagrass (i.e., *Thalassia hemprichii*, *Cymodocea rotundata*, *Halophila ovalis*, *Halodule uninervis*, and *Syringodium isoetifolium*) areas of the Vijay Nagar beach of Havelock Island (Image 1a). It is important to note here, that the presence of *H. scabra* was opportunistic and we did not observe a second specimen even after surveying the entire intertidal area of our site at Havelock Island. There was no observation of *H. scabra* from the intertidal areas without seagrass (site 2) of Havelock Island. The

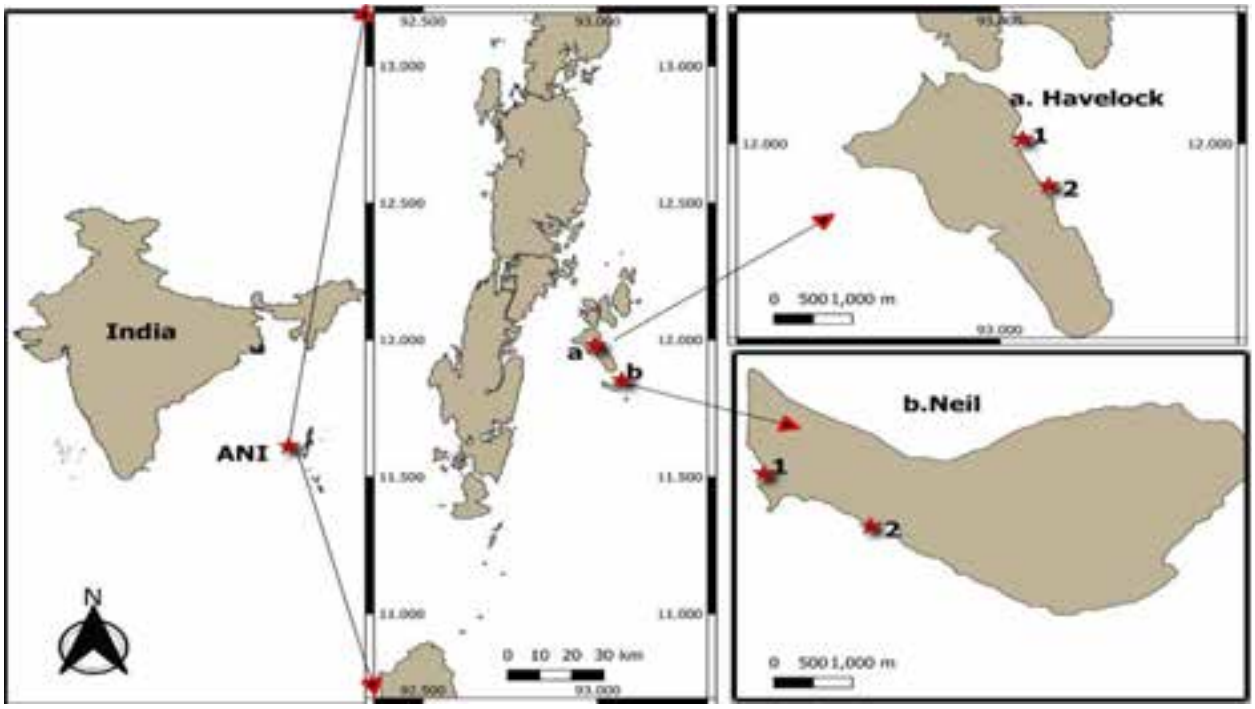

Figure 1. Andaman & Nicobar Islands showing the locations: a—Havelock | b—Neil Island where the sea cucumbers were recorded. The site (1) and (2) of each location represent areas without seagrass and with seagrass respectively.

threatened sea cucumber *A. mauritiana* was found inhabiting both the intertidal monospecific seagrass (*T. hemprichii*) meadows and areas without seagrass at Neil Island (Gole et al. 2022). Morphometric traits (such as body length, mouth width and circumference of the body) were measured in the field using a vernier caliper and measurement tape. An unpaired t-test was carried out to check the statistical significance between body morphometrics of only *A. mauritiana* with and without seagrass meadows. The specimen was identified using the field guide to sea cucumbers of ANI of India (Purcell et al. 2012; Raghunathan & Venkataraman 2014) and pictures were taken for photographic evidence. Due to the Schedule-I status of India's sea cucumber species (MoEFCC 2001), no specimen was collected from the field for any laboratory analysis. However, ban on collection of specimen samples in India also hinders scientific research for sea cucumbers. Furthermore, to address this issue, short-term permits may be provided for restricted sample collection, so that it can help in generating data on current population trends and increase our understanding on the various sea cucumber species of India.

RESULTS & DISCUSSION

Havelock Island

In Havelock Island, we did not find any sea cucumber species within the areas without seagrass. However, in the mixed seagrass species we observed a single specimen of *H. scabra* within *C. rotundata* and *T. hemprichii* mixed meadows (Image 1a). The total body length of *H. scabra* was 15.72 cm, mouth width of 3.19 cm and body circumference of 5.69 cm (Table 1). *Holothuria scabra* specimen was grey in color with a total of 17 black and yellow transverse stripes along the body (Image 1). The average width between these stripes was 1.49 ± 0.47 cm with a maximum width of 2.57 cm and minimum of 0.80 cm (Table 2). The specimen in our study is considered a juvenile as matured individuals have total body length > 40 cm for the Indian Ocean region (Purcell et al. 2012). The specimen in our study was also smaller than the *H. scabra* specimens observed from the coast of the Philippines (Jontila et al. 2017). Furthermore, we believe our specimen was a juvenile because the observed band widths on our specimen was within the range for juvenile, i.e., 1.50–2.57 cm (Purcell et al. 2012), as observed in this study (Table 2). The presence of *H. scabra* within seagrass meadows indicates favorable habitats for the threatened species, possibly due to: (i) high organic matter content in the sediment in seagrass

Table 1. Morphometric traits of *Holothuria scabra* collected from the intertidal seagrass and non-seagrass ecosystems of Neil and Havelock Islands, ANI, India. Maximum length (ML) was obtained from FAO 2012 guidelines. No record (Nr).

Location	Species (number of specimens)	Length (cm)	Mouth width (cm)	Body width (cm)	FAO 2012
Havelock (with seagrass)	*H. scabra* (n = 1)	15.72	3.19	5.69	ML: 40 cm
Havelock (non- seagrass)	Nr	-	-	-	-

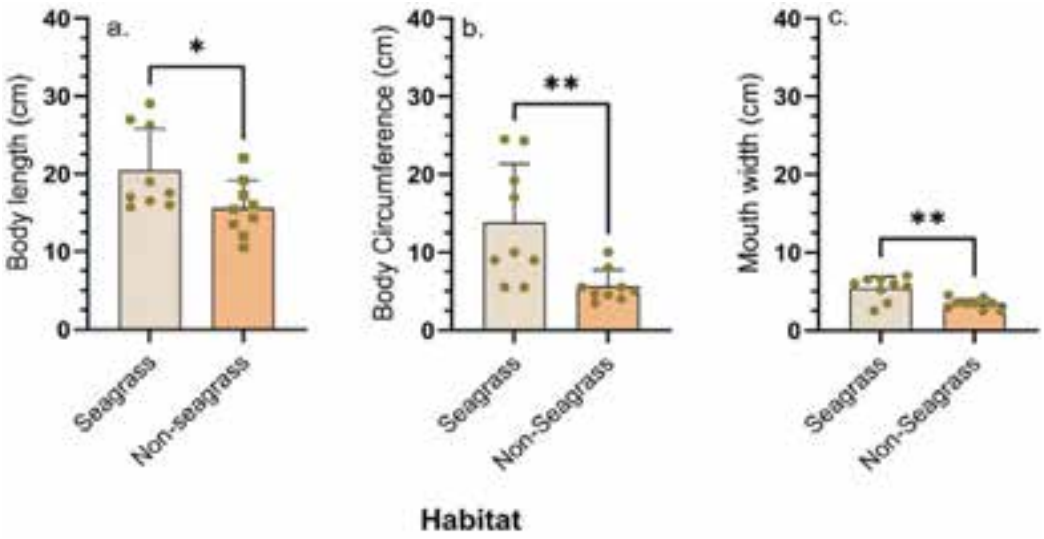

Figure 2. Mean ± standard deviation and range of morphometric traits: a—body length | b—circumference | c—mouth width presented only for *A. mauritiana*. Significance (p <0.05) was tested with unpaired t-test (<0.05*, 0.005) between seagrass and non-seagrass areas from ANI, India.**

areas (51.55%) compared to the non-vegetated (35%) areas (Mishra & Farooq 2022; Mishra et al. 2023) and (ii) fine grain sediment structure within seagrass meadows for burial of this species (Mishra & Apte 2020; Mishra et al. 2021). The first record of this species from Havelock Island also indicates the migration of this species from South Andaman region (Raghunathan & Venkataraman 2014) to these island ecosystems probably due to less exploitation or pressure from clandestine fishing activities as these regions are more tourism dependent.

Neil Island

From Neil Island, *A. mauritiana* was observed both from monospecific seagrass meadows and the adjacent areas without seagrass (Image 1). The average total body length of *A. mauritiana* differed between seagrass and non-seagrass areas (Image 1a). The body length within the seagrass meadows (20.4 ± 5.3 cm) was 1.3-fold higher than that of non-seagrass (15.7 ± 4.2 cm) areas (Figure 2a). Similarly, total circumference of the body and mouth width differed between seagrass and non-seagrass areas (Figure 2). The overall body circumference of *A. mauritiana* was 2.5-fold higher within seagrass

Table 2. Unique bands of *Holothuria scabra* (Image 2b) and the respective band widths (in cm) recorded in-situ from the mixed seagrass ecosystems of Havelock Island, ANI, India.

Species	Band order (from mouth towards back)	Band width (cm)
Holothuria scabra	1	2.57
	2	1.18
	3	1.82
	4	1.52
	5	1.20
	6	1.22
	7	1.42
	8	2.0
	9	1.10
	10	1.21
	11	1.00
	12	0.80
	13	1.68
	14	1.69
	15	2.48
	16	1.18
	17	1.38

Image 1. a—*Actinopyga mauritiana* | b—*Holothuria scabra* specimen recorded in the field during seagrass surveys in Neil and Havelock Island of Ritche's Archipelago of ANI, India. The yellow and black band widths of *H. scabra* are unique to their identification. © Amrit Kumar Mishra.

(13.7 ± 7.6 cm) areas than the non-seagrass (5.47 ± 2.02 cm) areas (Figure 2b). Similarly, the mouth width of *A. mauritiana* of seagrass areas (5.4± 1.5 cm) was 1.6-fold higher than non-seagrass (3.3± 0.6 cm) areas (Figure 2c). The *A. mauritiana* specimens of our study are juvenile individuals, as the average mature individuals in the Indian Ocean region reach 23 cm (Purcell et al. 2012). This difference in average body length was more prominent in the areas without seagrass, probably due to less organic matter content and lack of fine grain sediments (Mishra et al. 2023). Our findings agree with previous study from Neil Island, which suggested these vulnerable sea cucumber species prefers mono-specific seagrass meadows rich in organic matter and fine grain sediments to fulfill their energy needs (Gole et al. 2022).

The presence of threatened sea cucumber species from intertidal seagrass meadows of ANI, indicates the importance of these mono and mixed seagrass species and their food and habitat provisions for infauna organisms, which has been observed for other seagrass ecosystems of the Indo-Pacific region (Kinch & Friedman 2008; Costa et al. 2014; Aulia et al. 2021; Arnull et al. 2021; Gole et al. 2022). This positive association between declining sea cucumber populations of India and intertidal seagrass species also emphasizes the need for continuous monitoring of seagrass ecosystems of ANI and India, and maintain the health of these seagrass ecosystems, which are under decline in Neil and Havelock islands of ANI (Mishra & Apte 2020; Mishra et al. 2021). The decline of intertidal keystone systems and their

negative effects on sea cucumber population of India have been documented from the islands of Lakshadweep (Idreesbabu & Sureshkumar 2017; Mohammednowshad et al. 2021) and Gulf of Mannar region of Sri Lanka (Gamage et al. 2021) showcasing the ecosystem services of these systems to India's declining sea cucumber populations. Similarly, migration of endangered *H. scabra* from South Andaman to Ritche's Archipelago also calls for monitoring and surveys of other island systems of ANI to assess the presence of this species and create subsequent protection and management action plans.

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COMMUNICATION

Stypopodium Kütz. - a new generic record for India from the Bay of Bengal

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Abstract: The study highlights the first-ever documentation of the genus *Stypopodium* along the Indian coastline, specifically in Andhra Pradesh. Previously reported in various Indian Ocean regions but not in India, this discovery fills a significant gap in understanding its distribution. The species *Stypopodium zonale* is thoroughly examined, including its physical characteristics, microscopic features, habitats, distribution, and taxonomic notes, complemented by accompanying photo plates. Additionally, the proposal of a lectotype for heterotypic synonyms, namely *Fucus zonalis*, *Zonaria lobata*, and *Zonaria fuliginosa* is presented.

Keywords: Andhra Pradesh, Dictyotaceae, generic report, phaeoplast, *Stypopodium zonale,* taxonomic conflicts, typification.

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Author contributions: YASK—contribution towards the field survey, collection, preservation, identification of the specimens and consultation of herbaria; development of research concept and manuscript preparation. MP—contribution towards the field survey; supervision of research, identification of the specimen, supervision of research, and finalization of the manuscript. SV—assisted with the survey and collection of the specimens.

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INTRODUCTION

Dictyotales is a unique group characterized by their exclusive morphological characters such as erect or prostrate, flattened, dichotomously branched, or flabby thallus with numerous phaeoplasts, without pyrenoids and exhibit isomorphic diplohaplophase life cycle. Presently, this order embraces a single family Dictyotaceae with 349 taxa belonging to 27 genera (Guiry & Guiry 2022). *Dictyopteris, Dictyota*, *Lobophora*, *Stoechospermum, Stypopodium,* and *Zonaria* of this family are referred to be the dominant components of the phytobenthos. In view of the generic composition of the family Dictyotaceae, *Lobophora*, *Padina*, *Stoechospermum*, *Stypopodium* and *Zonaria* are the analogous genera that possess strong morphological similarity (De Clerck et al. 2006).

The genus *Stypopodium* is a pervasive group of algae spread over tropical and temperate regions. This genus is characterized by strongly lacerated or clefted flabellate thallus, bands of hyaline filaments (pheophytic hairs), cells on the margins of the thallus; parenchymal structure with abundant phaeoplasts in cortical cells with several epidermal cells; sporangia with four spores and lack of paraphyses on sporangia sori (Misra 1996; Abbas & Shameel 2014). This genus was established by Kützing (1843) with 3 species viz., *Stypopodium fuliginosum*, *S. flavum* and *S. atomaria*. The species constitution of this genus had many controversies regarding their identity with other similar genera (Mayhoub & Billard 1991). The distinctness of this genus was initially not accepted by Borgesen (1914), Howe (1918), Taylor (1985), Allender and Kraft (1983), and this genus was placed under the genera *Padina* and *Zonaria*. Later, the exclusive characters of this genus were examined and taxonomically validated by Weber-van (1913), Papenfuss (1940, 1977); Nizamuddin & Aisha (1991).

A sum of 19 infraspecific binomials was proposed and 8 taxa were accepted taxonomically (Guiry & Guiry 2022). The occurrence of this genus in the Indian Ocean was reported from Kenya, Madagascar, Pakistan, Singapore, South Africa, Sri Lanka, and Tanzania, except for the coastline of India (Abbas & Shameel 2014). The existence of this genus was not reported from the shoreline of India. But, Misra (1996) has included *Stypopodium zonale* in his Phaeophyceae in India without referring to any specimen. Later, Silva et al. (1996); Oza & Zaidi (2001); Krishnamurthy & Ezhili (2013) included this species in the algae flora of India based on Misra's report. Thorough literature indicates that earlier workers specified this genus without proper details on the type, occurrence, taxonomic treatments, specimen examinations, etc.

Stypopodium zonale was collected for the first time from the coastline of India, during the field explorations of the Appughar coastline, Andhra Pradesh (Image 1). The collected samples exhibit unique characteristics resembling known genera such as *Padina, Lobophora, Stoechospermum, Stypopodium*, and *Zonaria* within the family Dictyotaceae. Preservation followed standard methodologies of Wet Preservation (Liquid preservation) and Dry Preservation (Herbarium), as outlined by Srinivasan (1969). To ensure accurate species identification, both external and internal morphology of specimens were examined using optical microscopes (Nikon Eclipse 50i; Carl Zeiss. Axio Lab. A1) equipped with a computer-attached DSLR camera. Selected herborized specimens underwent Scanning Electron Microscope (SEM) analysis following standard protocols of Carl Zeiss (Model No: Evo 18). Reference sources consulted include contributions by Agardh (1824), Martius (1828), Kützing (1843), Howe (1918), Mayhoub & Billard (1991), Lamouroux (1805, 1809), Papenfuss (1940, 1977), Nizamuddin and Aisha (1996). Additionally, herbarium specimens housed at CAL, BSIS, Kolkata; MH, Coimbatore; and NFMAH, Mandapam, Ramanathapuram were consulted, along with specimen images from Digital Herbaria of Paris Museum (P); British Museum (BM); Kew (K); Muséum National d'Histoire Naturelle (MNHN); The National Herbarium of Victoria (MEL); and New York Botanical Garden (NY). Further systematic details on *Stypopodium zonale* are enumerated as follows:

Taxonomic Treatment: *Stypopodium zonale* (J.V.Lamour.) Papenf.,

Bot. Not.205. 1940. *Zonaria zonalis* (J.V.Lamour.) Howe, Fl. Bermuda. 507. *Fucus zonalis* J.V.Lamour., Diss. Fucus., 38. 1805.

Type: Haiti, Saint Domingue (in Sancti-Dominici insulæ oris habitat), *Lamouroux* (1805: pl. 25, fig.1!) *Lectotype is* designated here.

Stypopodium lobatum (C.Agardh) Kütz. Tab. Phyc. 25. 1859.

Zonaria lobata C.Agardh, Syst. Alg. 265.1824.

Type: Mari Atlantico, Teneriffam, s.d., *s.col.*, *48220,* (NY [02136680, digital image!]); Residual syntype: Mari Atlantico, Teneriffam, s.d., *s.col.*, *48222* (n.v.) *Lectotype is* designated here.

Stypopodium fuliginosum (C.Martius) Kütz. Phycol. General.341. 1843.

Zonaria fuliginosa C.Martius, Icon. Pl. Crypt.16. 1828.

Type: Brazil, In litore Brasiliae, Cabo Frio s.d.,

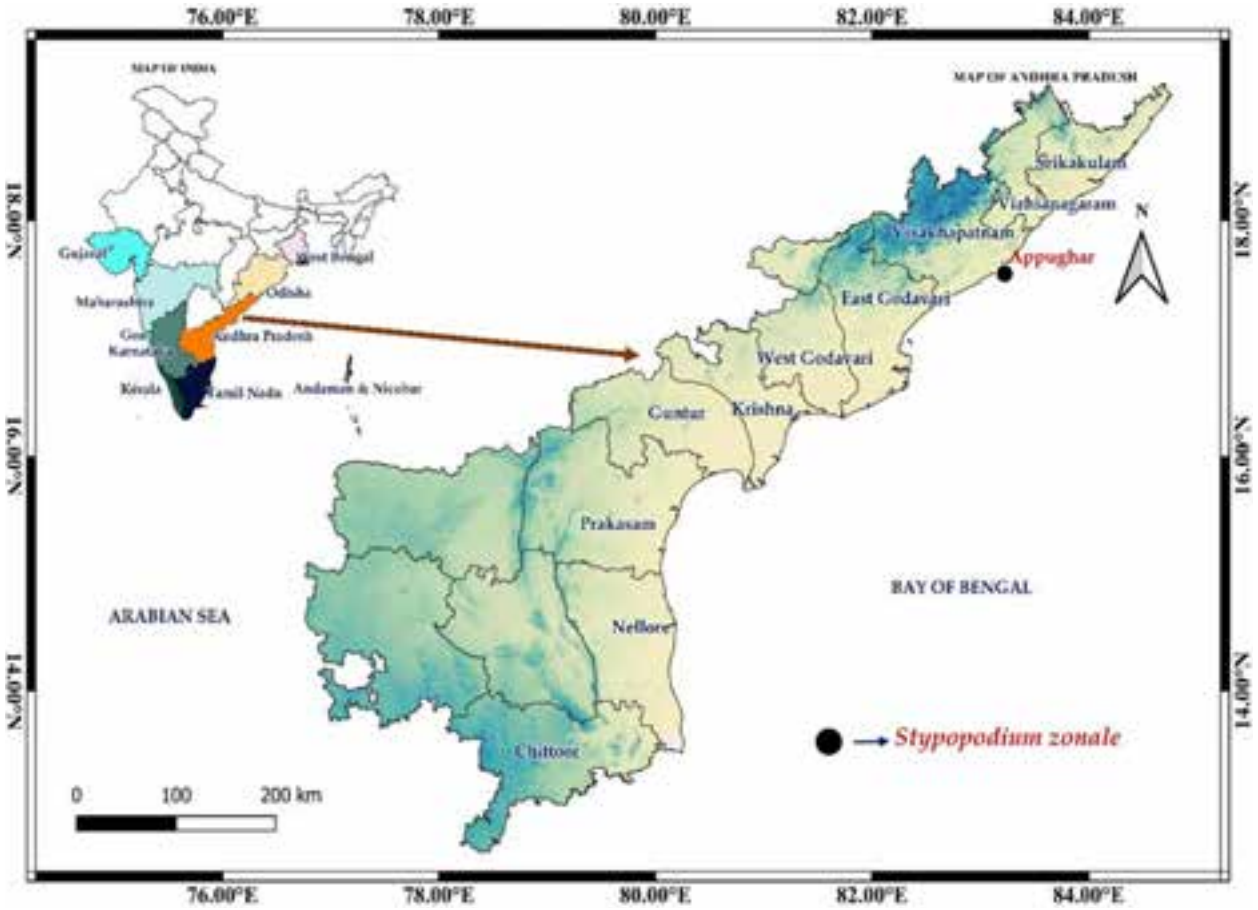

Image 1. Coastline of Andhra Pradesh with the collection locality of *Stypopodium zonale*

C.F.P.Martius, s.n. (MEL [MEL537302, digital image!]); Residual syntype: Brasilia, s.d., *s.cl.* s.n. (MEL [MEL537303, digital image!] *Lectotype is* designated here

Habit: Thalli erect or prostrate, tawny to dark brown, fine to membranous or slightly coriaceous, flabellate with broad blades. Solitary or clustered patches forming groups of 3–10 individual blades, 4–11 cm in height, 8–5 cm in broad, lacerated or clefted with cuneate bases. Thallus differentiated into rhizoidal-shaped holdfast, compressed or flattened stipe (sometimes reduced), and flabellate blades (Image 2. a–d); The thallus is transversely zoned with concentric rows of hairs on both surfaces in regular intervals of 2.5–16 mm (Image 2. f & g). Holdfast rhizoidal or disc-shaped, firmly attached on the substratum, 5–8 mm in diameter. Stipe flatted or reduced, erect, 10–18 mm long. Blades flabellate, broadly obtuse at apex, attenuate at base, 3–9 x 3.5–4.3 cm, entire to undulate at the margin (Image 2. e). Generative assemblies are scattered throughout the dorsal surface of the thalli (Image 2. k).

Microscopic observation: The surface view of the cells variously sized, slightly squarish or rectangular, elongated in vertical rows, dark brown, 15–28 x 5–12 µm (Image 2. l). Hair bands present on both surfaces, hairs filamentous, uniseriate, 2–4 celled, subcylindrical to cylindrical, 14–17 x 80–120 µm (Image 2. j & m). The upper apical zone consists of 3–6 layers of cells, outer and inner peripheral cells squarish, thin-walled with dense phaeoplasts (Image 2. o), 6–13 x 8–14 µm; cortical cells 2–3 layers, thick-walled, quite larger, elongated with intercellular spaces arranged in regular tiers, 18–37 x 18–26 µm (Image 2. n). The middle portion contains 2–7 layers, cells in a peripheral region are small, thin-walled cubical to quadrate or squarish, 12–19 µm x 13–21 µm; the cortical region consists of 2–4 layers, cells large, thick-walled with intercellular spaces (Image 2. i). The basal zone consists of 4–9 layers; cells in upper and lower peripheral regions, small, thin-walled, squarish, 13–23 x 12–26 µm; the cortical cells thick-walled, slightly elongated, intercellular spaces, 31–35 x 25–29 µm (Image 2. h & o). Numerous groups of dark brown sporangia were observed on both surfaces of the thallus, sessile, lightly rounded or oval, 40–54 µm in

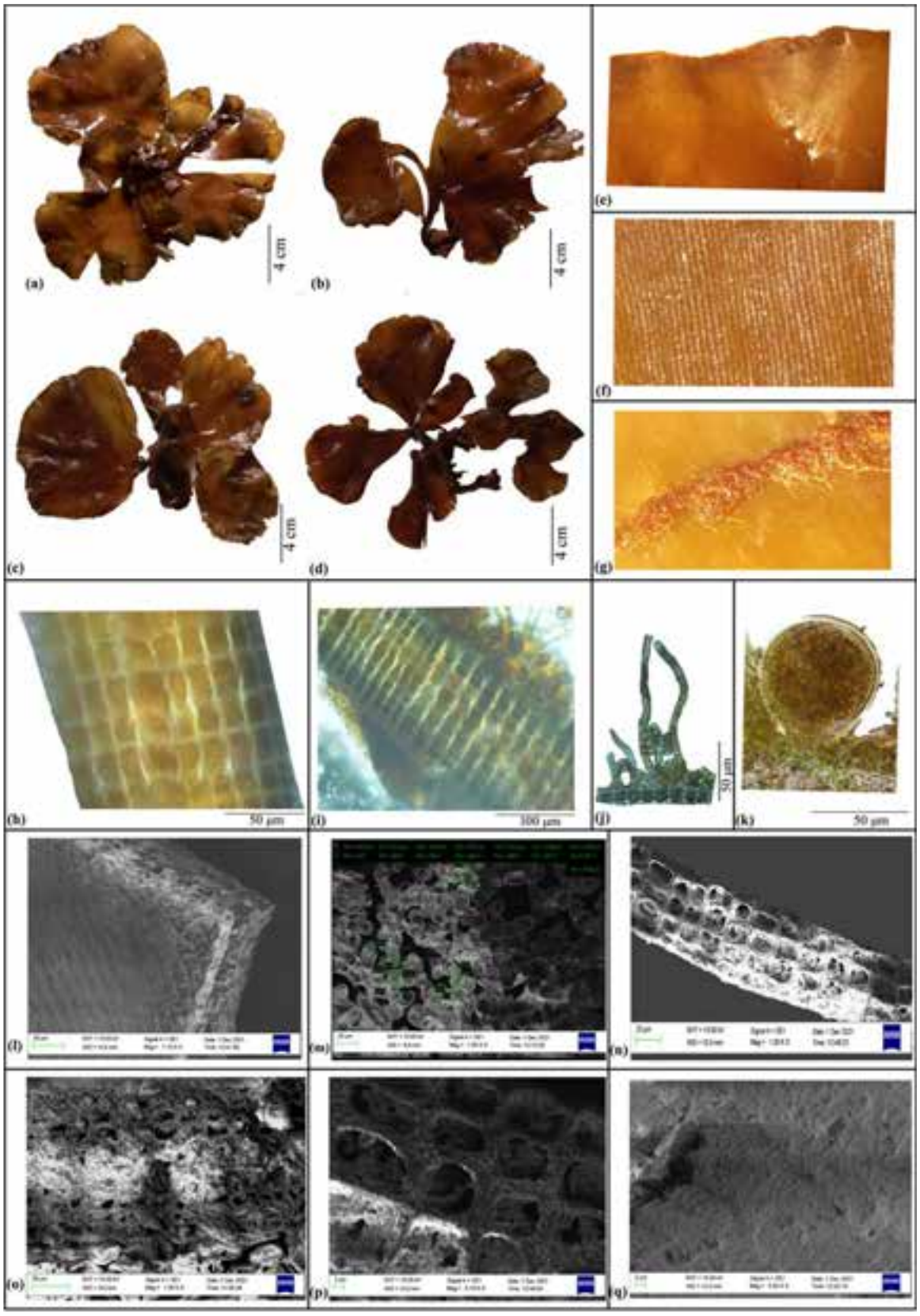

Image 2. a–d—Morphological variations on thallus of *S. zonale*; e, Entire to Undulate margin | f & g—Surface view of the thallus with phaeophytic hairs | h & i—C.S. of basal and middle portion *S. zonale* | j & k—Phaeophytic hairs and immature sporangium | l—Surface view of thallus | m & n—Cross section of phaeophytic hairs and middle portion | o & p—Abundance of phenoplasts and cubic to squarish shaped cortical cells | q—Granular to globular texture of thallus on surface view under SEM.

diameter; each sporangia has four spores.

Habitat: Moderately growing at intertidal and shallow water zones of Appughar on the rocky substrate at depths of 0.8–1 m during pre-monsoon seasons. This species has a communal association with *Amphiroa fragilissima* (L.) J.V.Lamour., and *Jania rubens* (L.) J.V.Lamour.

Distribution: Africa, Caribbean Islands, China, Ghana, Indonesia, Islands of Australia & and New Zealand, Islands of the Atlantic Ocean, Japan, Pacific Islands, Pakistan, Philippines, Sri Lanka, Spain, South America, Western Atlantic, and India (Andhra Pradesh).

Specimen Examined: INDIA: Andhra Pradesh, Visakhapatnam, Appughar, 17°44'26.8»N 83°20'42.1»E, 23 March 2017, *Palanisamy M & Aron Santhosh Kumar Y 137233* (MH).

Note: The epithets *Fucus zonalis* J.V.Lamour., *Dictyota zonata* Lamour., *Zonaria zonalis* (J.V.Lamour.) Howe (1918), *Zonaria lobata* C.Agardh, *Stypopodium lobatum* (C.Agardh) Kütz., *Zonaria fuliginosa* C.Martius and *Stypopodium fuliginosum* (C.Martius) Kütz. are currently regarded as a synonym of *Stypopodium zonale* (J.V.Lamour.) Papenfuss (1977) due to the morphological orientation. In the protologue of *Fucus zonalis*, it is stated that the specimen was collected from the coastline of Saint Domingue and did not specify the type details of this species (Lamouroux, 1805). Later, this transferred as *Dityota zonata* and mentioned the collection locality from Antillis by Lamoroux (1809) which was the heterotypic locality of *F. zonalis*. The collections of the *D. zonata* from Caen (CN) herbarium were examined by Mayhoub and Billard (1991) and they denoted *D. zonata* as the type specimen of the epithet *F. zonalis.* But their proposal was ambiguous since both the specimens were collected from different localities as per the protologues of Lamouroux. Hence, the illustration (1805: pl. 25, fig.1!) mentioned in the protologue of *F. zonalis* is designated here as lectotype based on articles, 9.3 of the International Code of Nomenclature for algae, fungi, and plants (Turland et al. 2018).

Syntypes of *Zonaria lobata* (Nos. 48220 and 48222) from Teneriffam of Mari Atlantico were deposited in LD (Herbarium Agardh). Now, the photograph of *Z. lobata* (Nos. 48220) is maintained in NY (02136680, digital image!) detailed with habitat (Teneriffam). On the other hand, the specimen Nos. 4822.20 was not spotted or traceable in any of the herbaria anywhere. Therefore, No. 48220 (02136680, digital image!) could be the type specimen of *Z. lobata* as per the protologue furnished by Agardh (1824). Likewise, *Zonaria fuliginosa* was proposed by Martius (1828) typified from the coastline of Brazil (In litore Brasiliae); later, it was placed under the genus *Stypopodium* and synonymised to *S. fuliginosum* by Kützing (1843). The type of the species epithet *Z. fuliginosa* was indistinct. The collection deposited in MEL contains two specimens (MEL537302 & MEL537303, digital image!) collected from Brazil. The specimen MEL537302 was annotated with the proper details of *Z. fuliginosa* with collector's name (Martius), Habitat (In litore Brasiliae), and without collection number pencilled by Sonder. But the specimen MEL537303 was not specified in detail except on habitat. Therefore, specimen MEL537302 could be the type specimen of *Z. fuliginosa* as per the prologue proposed by Martius (1828). Hence, the lectotype of *Z. fuliginosa* and *Z. lobata* is designated here based on articles, 9.1, 9.2, and 9.3 of the International Code of Nomenclature for algae, fungi, and plants (Turland et al. 2018).

Significance: The lipophilic extract of this species produces an atomaric acid with anti-Leishmania amazonensis activities (Soares et al. 2016). Also, the compound Stypoldione inhibits microtubule polymerization and sperm motility (Pal et al. 2014).

DISCUSSION

The species *Stypopodium zonale* of Dictyotaceae (Dictyotales) under the class Phaeophyceae has morphological affinities among the other species of this same genus and with other genera of this same family (Shameel 2012). The distribution of this species has been documented worldwide, covering the Indian Ocean from Pakistan to South Africa (Abbas & Shameel 2014). However, the occurrence of *S. zonale* from the Indian Ocean has a lacuna on the species' identity and needs to be inspected in view of Verlaque & Boudouresque (1991) and Silva et al (1996). In this present study, the gross morphological characters (Image 2. a–q), such as the surface view of the cells (squarish or rectangular), hair bands (filamentous and uniseriate), cortical cells (2–3 layers), with intercellular space (18–37 x 18–26 µm), cells in middle portion (cubical to quadrate or squarish) and sporangia (sessile with 4 spores) were observed to limelight the presence of this species from India.

The thallus of the species is erect or prostrate thalli with strong laceration and transversely zoned by bands of pheophytic hairs on both sides of the thallus. Also, concentric rows were found on both thallus surfaces in regular intervals. Blades flabellate, broadly obtuse at the apex, attenuate at the base with undulate. The layers of cells in the thallus show great variation in their position;

the upper apical zone with 3–6 layers of cells (squarish), the middle portion with 2–7 layers (cubical to quadrate or squarish), the basal zone with 4–9 layers (squarish) with intercellular spaces. Also, it contains groups of dark brown rounded or oval-shaped sessile sporangia (four spores) on both thallus surfaces. The observation from this study shows minor variations from the specimens of Nizamuddin & Perveen (1986) and Nizamuddin & Aisha (1996) from Pakistan. However, the morphological characteristics found in the specimens from India agree with those previously carried out in Atlantic localities (Taylor 1960; Verlaque & Boudouresque 1991; Dawes & Mathieson 2008) and Pakistan specimens (Abbas & Shameel 2014). Also, the observation of the present study is confined to the protologue of the type species (Lamouroux 1805).

CONCLUSION

In India, the occurrence of *Stypopodium zonale* was not validated with the collection of this specimen. Its occurrence on the Indian coastline has been considered for a long time due to the report of Misra (1996). But in the present study, the ascertaining features of this species were clarified and discussed in detail by obtaining the gross morphology and anatomy of the species. The present study deals with the taxonomically significant features to resolve the uncertainty regarding the identity of S. *zonale* distributed in India. The outcomes of the present attempt furnished the type details, habit, habitat, and specimens examined and significant notes on the erroneous reference cited by various authors. Also, the lectotypification of 3 binomials (*Zonaria zonalis, Z. lobate,* and *Z. fuliginosa*) was designated here in favor of articles 9.3 of the International Code of Nomenclature for algae, fungi, and plants (Turland et al. 2018). For many species of the genus *Stypopodium* no data are available on recent morphological studies towards the difficulties on the distinctive characteristics of each species. Hence, it is necessary to attempt morphological and molecular phases to establish the boundaries between species. Additionally, our present study highlights the morphological and microscopic features that provide more precise credentials and clarification to the taxonomic conflicts of *Stypopodium zonale* from India.

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COMMUNICATION

First report of *Macrochaetus sericus* Thorpe, 1893 and *Lecane tenuiseta* Harring, 1914 (Rotifera: Monogononta) from Jammu waters (J&K), India

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Abstract: Water bodies, apart from having aesthetic value, harbor a great diversity of both macro and microorganisms. Rotifers or wheel animalcules are cosmopolitan aquatic invertebrates that play a key role in aquatic food chain. Presently, two species of rotifers (*Macrochaetus sericus* & *Lecane tenuiseta*) have been recorded for the first time from Jammu. *M. sericus* is first record from Union territory of J&K while *L. tenuiseta* has already been reported from Kashmir. During the one year study period, *M. sericus* was observed in the plankton sample during the monsoon season while *L. tenuiseta* was collected from the periphytic zone during the winter season. *M. sericus* differed from related congeneric species by absence of anal segment and anal spines. *L. tenuiseta* is distinguished by its long separated claws and long toes. The first report of these two species from Jammu has further expanded their distributional ranges in the Indian subcontinent.

Keywords: Diagnosis, distribution, first reports, habitat, invertebrates, Jammu & Kashmir, morphology, periphytic, plankton, seasonality, water, wheel animalcules.

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Author contributions: Deepanjali Slathia: field surveys, identification, data analyis, interpretation and preparation of manuscript. Supreet Kour: Data collection, review and editing. Sarbjeet Kour: study design, supervision, confirmation of species and final approval of manuscript.

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INTRODUCTION

Phylum Rotifera includes a group of microscopic, primarily freshwater pseudocoelomate animals, commonly called wheel animalcules because of the presence of corona or wheel organ which resembles rotating wheels. Being cosmopolitan, they occur in a variety of habitats (aquatic and semi-aquatic) ranging from lakes to small puddles and about 75% of all known species of rotifers inhabit littoral zones of water bodies (Pennak 1989; Smith 2001; Wei & Xu 2014). Forming an important part of the aquatic food chain, they are the most preferred food organisms for small fish larvae because of their small size and slow movement (Loveson et al. 2020). They are regarded as the most suitable water quality indicators as they are more sensitive and respond more rapidly to environmental alterations in comparison to crustaceans (Gannon & Stemberger 1978). The highest rotifer diversity has been observed in the tropics (Segers 2008). The work of Anderson (1889) represents the very first study on Indian rotifers. Since then, the appreciable amount of work on rotifer fauna of India has been done by many workers (Edmondson & Hutchinson 1934; Arora 1963; Nayar 1968; Sharma 1976; Sharma 1980; Sharma & Michael 1980; Battish 1992; Dhuru et al. 2003; Sharma & Sharma 2009; Vanjare et al. 2017). A total of 434 valid species of rotifers (belonging to 68 genera, 25 families) are known from India, making Indian Rotifer fauna the most diverse compared to southern Asia and southeastern Asia (Sharma & Sharma 2021). The Union Territory of Jammu & Kashmir, an important component of biodiversity hotspot (The Himalaya), is bestowed with unique physiography, diverse climate, and a variety of water bodies ranging from high mountain lakes, wetlands, hot water springs to small rivers, streams, and ponds (Sharma & Sharma 2018). Presently, 173 valid rotifer species are known from J&K (Sharma & Sharma 2018). Much work on the rotifer fauna of J&K has been concentrated in Kashmir (Pandit 1999; Wanganeo & Wanganeo 2006; Shah et al. 2015; Sharma & Sharma 2018). From Jammu, limited valid information is available (Sharma & Shrivastava 1986; Dalpatia 1998; Baba 2002; Kour 2006). There are still many unexplored small lentic water bodies in Jammu which if explored will add to the faunal biodiversity of the region. Present study was conducted on a completely unexplored pond of Jammu. In total we observed 31 rotifer species from the pond, of which two species were first reports from Jammu. This short communication briefly describes their diagnostic features, distribution, and comparison with related congeneric species.

MATERIAL AND METHODS

In the present study the area selected was a sacred perennial pond (32.701321˚N & 74.747988˚E) located in the Sohanjana region of Jammu (Figure 1, Image 1). The pond holds great religious significance. Many devotees make holy dips into the pond believing that it can wash their sins and will help them in getting rid of diseases. The pond is roughly rectangular-shaped and has an area of 2,295.45 m^2 and concrete embankments. The sampling was done and both the presently discussed species were observed during our preliminary seasonal study conducted on Sohanjana pond (from January 2020 to December 2020). *Macrochaetus sericus* Thorpe, 1893 was observed in the plankton sample while *Lecane tenuiseta* Harring, 1914 was recorded in the sample collected from the periphytic zone. Plankton samples were collected by filtering 50 litres of pond water through a plankton net made of bolting silk (mesh size 40 µm). About 20 ml of planktonic concentrate was then stored in 4% formalin in polyethylene vials for further observation. For periphytic sampling, periphyton was scrapped from stones and twigs with the help of a fine scalpel blade, washed with water, and then filtered through a plankton net. The periphytic sample was also transferred to vials and stored in 4% formalin for further observation. In the laboratory, preserved samples were observed under an Olympus compound light microscope. Identification was done by following standard identification keys (Koste & Shiel 1990; Segers 1995; Sharma 1998; Sharma & Sharma 2013). The taxonomical terminology was adopted from Segers (2002). The reference materials were deposited in the Museum of Department of Zoology, University of Jammu. An ocular micrometer was used for taking measurements. Glass camera lucida and Rotring Germany 1928 pens were used for making drawings of preserved specimens. For measuring abiotic parameters, water samples from the study area were collected in sterilized bottles. Water temperature was recorded using a glass mercury thermometer. pH was determined using a digital pH meter (Hanna instruments-HI 96107). Water transparency was measured with the help of a Secchi disc. Free carbon dioxide (FCO_2), dissolved oxygen (DO), and biological oxygen demand (BOD) were analyzed by using standard methods given in APHA (2017).

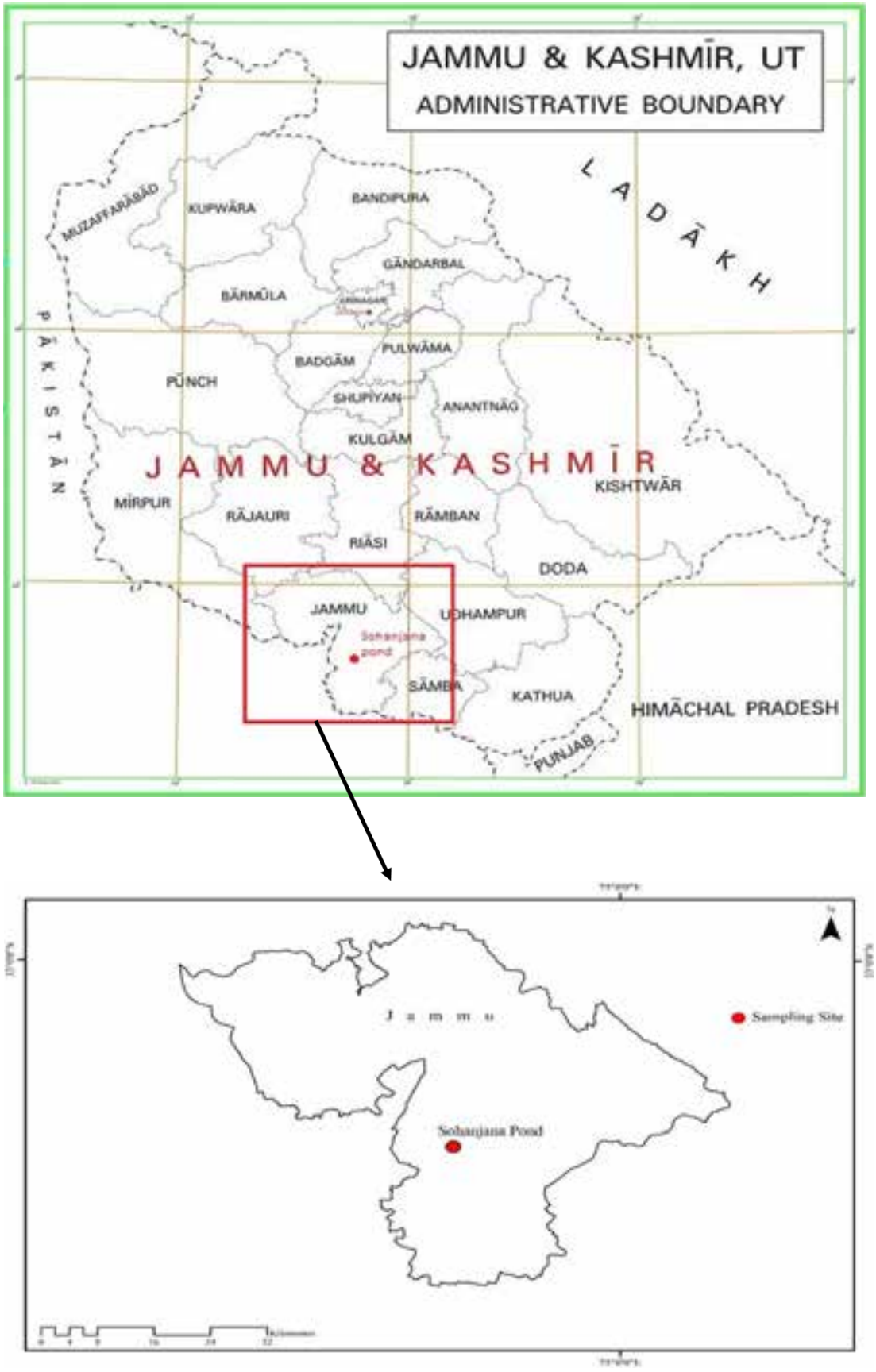

Figure 1. a—Map of Union Territory of J&K indicating sampling site | b—Map of Jammu indicating sampling site

Image 1. Satellite view of sampling station (Sohanjana pond)

RESULTS AND DISCUSSIONS

a). *Macrochaetus sericus* (Thorpe 1893) (Image 2a–c, Figure 2)

Phylum: Rotifera Cuvier, 1817
Class: Eurotatoria De Ridder, 1957
Subclass: Monogononta Plate, 1889
Order: Ploima Hudson & Gosse, 1886
Family: Trichotriidae, Harring 1913

Synonym: *Dinocharis serica* Thorpe, 1893

Material examined: Four contracted specimens were studied for morphological features.

Environmental data: Water temperature: 31^{0}C, pH: 6.9, Free carbon dioxide: 24.64 mg/l, Dissolved Oxygen: 4.82 mg/l, Transparency: 31.5 cm, and BOD: 1.32 mg/l.

Diagnosis: Lorica is broad than long, shaped like a horse- shoe and covered with minute spines or tubercules at outer angles. Its dorsal surface is characterized by the presence of eight spines (four anterior and four posterior) which are symmetrically placed with reference to mid-line. Anal segment and anal spines are absent. Mastax is malleate type. Toes are small and spindle-shaped.

Distribution: It is a warm stenothermal, pantropical species (Sharma & Sharma 2018). In India, it has been reported from Maharashtra (Vanjare et al. 2017), Andhra Pradesh, Madhya Pradesh, Tamil Nadu, Orissa, Meghalaya, West Bengal, and Assam (Sharma & Sharma 2013). No previous record of this species is known from J&K.

Remarks: Species was observed during the monsoon season when temperature was high and water was less transparent. This seasonal appearance might be attributed to the preference of this genus for specific environmental conditions like warm temperature, low pH and low water transparency (de Paggi et al. 2000). The numerical count of this species was very low in the plankton sample (0.102 No./ litre) as the appearance of members of this genus in open waters is quite rare due to their affinity for epiphytic or benthic habitat and they appear in open water of reservoirs at the time of seasonal flushing (Koste & Shiel 1989). *Macrochaetus sericus* Thorpe, 1893 can be confused with congener *Macrochaetus collinsi* Goose, 1867. But absence of anal segment and anal spines easily distinguish *Macrochaetus sericus* from *Macrochaetus collinsi*.

b). *Lecane tenuiseta* (Harring 1914) (Image 2d) (Figure 3)

Phylum: Rotifera Cuvier, 1817
Class: Eurotatoria De Ridder, 1957
Subclass: Monogononta Plate, 1889
Order: Ploima Hudson & Gosse, 1886
Family: Lecanidae Remane, 1933

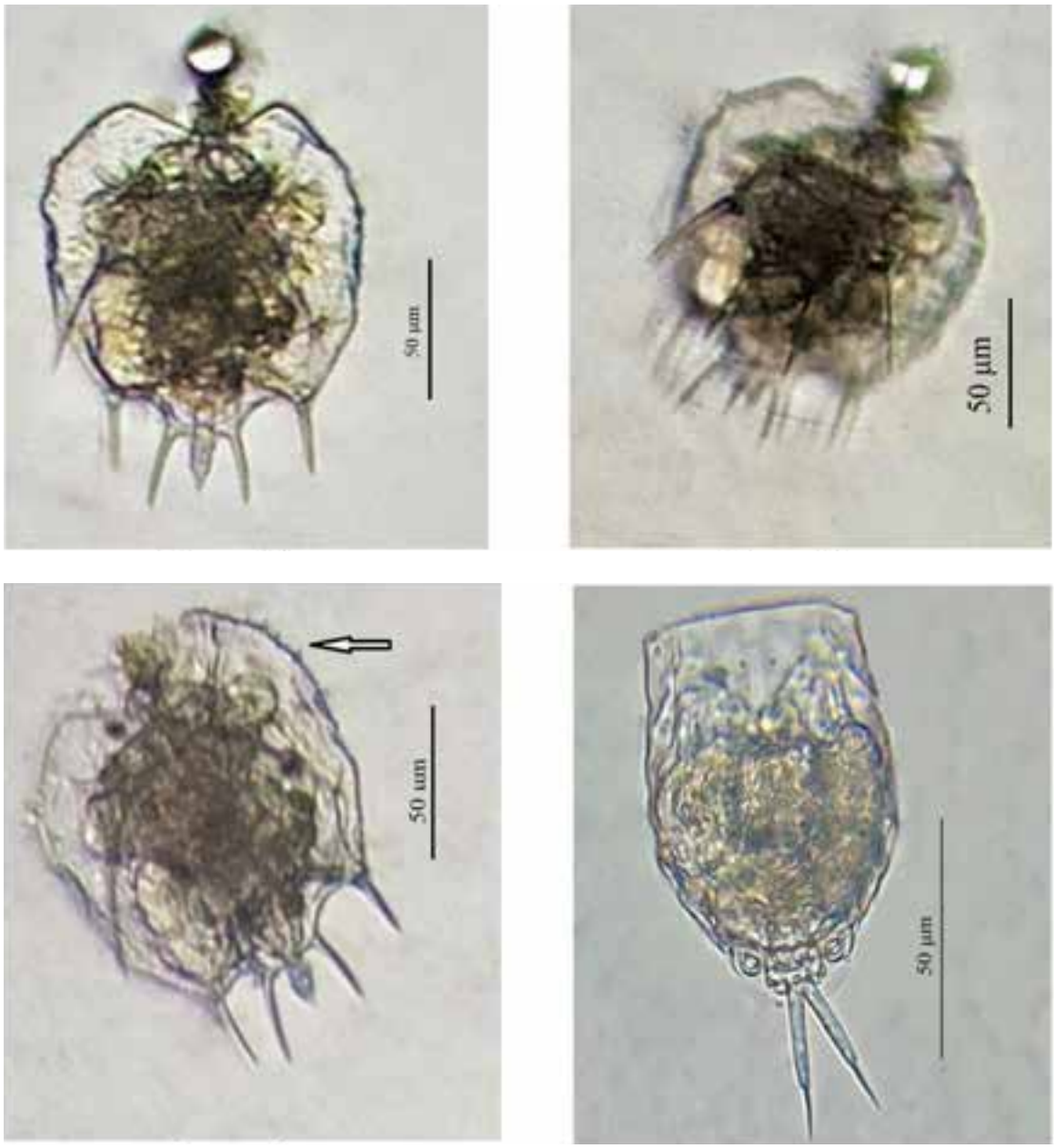

Image 2. a—*Macrochaetus sericus* (Thorpe, 1893) showing 4 posterior spines | b—*Macrochaetus sericus* (Thorpe, 1893) showing 4 anterior spines | c—*Macrochaetus sericus* (Thorpe, 1893) showing minute spines at outer angles | d—*Lecane tenuiseta* (Harring, 1914)

Synonym: *Lecane punctata* Carlin- Nilsson, 1934

Material examined: Six specimens were examined for studying morphological features.

Environmental data: Water temperature: 14^{0}C, pH: 7.8, Free carbon dioxide: 14.08 mg/l, Dissolved Oxygen: 6.24 mg/l, Transparency: 58 cm, and BOD: 0.64 mg/l.

Diagnosis: Lorica is elongated and distinct. Anterior head aperture with nearly parallel margins. The anterio-lateral corners of lorica are angulated. Ventral plate is more longer than broad, along with incomplete longitudinal and transverse folds. Foot pseudo segment is either slightly or completely not projecting. Mastax is malleate type. Toes with claws that are long and completely separated from each other with claw to toe length ratio of approximately 0.5.

Distribution: It is a cosmopolitan species. In India, *Lecane tenuiseta* currently shows a discontinuous distribution pattern (Sharma & Sharma 2014) and has been recorded from Delhi (Sharma & Sharma 2013), Kerala (Kakkassery 2003) and Northeastern states like

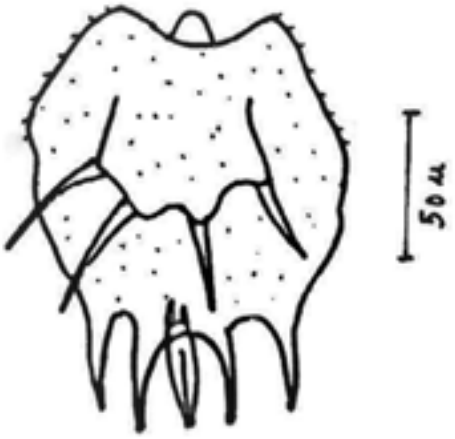

Figure 2. Camera lucida drawing of *Macrochaetus sericus* (Thorpe, 1893).

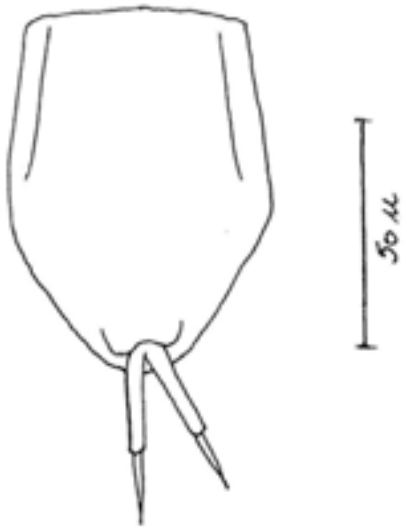

Figure 3. Camera lucida drawing of *Lecane tenuiseta* (Harring, 1914)

Assam (Sharma 2014) and Manipur (Sharma 2007).

Remarks: Although cosmopolitan, it is a rare species due to its restricted habitat preference (typically littoral) (Glime 2017). Presently it was observed only during the winter season as this species best proliferates at colder temperatures (Fiałkowska et al. 2016) and represented only 6% of the total periphytic rotifer fauna. Some other lecanidae species which were exclusively observed from the periphytic zone of the pond were *Lecane luna* (O.F. Muller, 1776), *Lecane hamata* (Stokes, 1896) and *Lecane closterocerca* (Schmarda, 1859). *Lecane tenuiseta* can be confused with *L. aeganea* (Harring, 1914), *L. doryssa* (Harring, 1914) or *L. inermis* (Bryce, 1892). But *L. inermis* has comparatively soft lorica. Both *L. aeganea* and *L. dorysaa* differs from *L. tenuiseta* by their stiffer lorica. But *L. aeganea* has shorter claws and *L. dorysaa* has typically projecting foot pseudo segment.

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OPEN ACCESS

COMMUNICATION

Spider diversity (Arachnida: Araneae) at Saurashtra University Campus, Rajkot, Gujarat during the monsoon

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Abstract: The present work deals with the diversity of spiders during the monsoon within the Saurashtra University Campus, Rajkot, Gujarat. A total of 38 species of spiders belonging to 32 genera and 14 families were recorded. Araneidae (25.81%) was found to be the most dominant family, with nine species from five genera. Guild structure analysis revealed seven feeding guilds, among all 31% most dominant feeding guilds represented by orb-web builders and stalkers, followed by ground runners (13%), irregular webs (10%), ambushers (7%), foliage hunters (6%), and space-web builders (2%). Ecological indices reveal high species richness (Margalef's d = 8.97) and diversity (Shannon Index H' = 3.526, Fisher alpha diversity α = 41.73). It concludes that the abundance of spider species at this study site was high and the evenness index was also high (e >0, e = 0.8944). These findings suggest the absence of stress elements in the study area.

Keywords: Climate, evenness, feeding guilds, habitat, H' index, predatory status, Rajkot, species distribution, western India.

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Competing interests: The authors declare no competing interests.

General ethics: The author declares that this work is carried out within an appropriate ethical framework and voucher specimens were deposited at museum of Department of Biosciences, Saurashtra University, Rajkot, Gujarat and specimens were registered under SUBZ1 – SUBZ60.

Author details: Following the completion of his master's degree at Saurashtra University, Rajkot, Jyotil K. Dave is presently pursuing a PhD scholar at the Tropical Ecology and Evolution (TrEE) lab, Indian Institute of Science Education and Research Bhopal (IISER Bhopal). His master's work focused on the ecology and taxonomy of spiders. Additionally, he studied the ecological aspects in the polymorphism of *Cellana karachiensis* (Gastropoda). He focused his B. Sc. thesis on the foraging habits of the Jungle Babbler *Turdodies straita*. In the International Science Symposium, he received first place for his poster and second place for his oral presentation. He was a volunteer for WII's CAMPA Dugong Conservation Program and Wildlife Crime Control Bureau (WCCB, Western region). Varsha Trivedi is a retired professor in Zoology, Department of Biosciences, Saurashtra University, worked since 1998- 2021. Research Interest: Work carried out in avian biology related to functional anatomy and eco-morphology in Columbiformes birds in PhD; other fields with research team animal taxonomy & ecology - spider, moth, butterfly, birds, amphibians and reptilians; Behavioral and habitat ecology; Wildlife & Conservation Biology. Mentored Dissertation Thesis -70 MSc., 06 MPhil. and 03 PhD.

Author contributions: JD undertook field data collection, field photography and preservation and handling of spiders, organized and assimilated the data, table and graphic preparation and drafted the manuscript. VT has done Spider Identifications, field and microscopic generic photography, final manuscript preparation, analysis, read, approval and communication.

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INTRODUCTION

Spiders are ubiquitous predatory organisms in the animal kingdom (Riechert & Lockley 1984). They are abundant predators in many terrestrial ecosystems, with populations estimated to approach one million individuals per hectare in the wild (Bristowe 1971). They are primarily entomophagous, while few are involved in arachnophagy (Wise 1993). Many spider families contain species capable of capturing vertebrate prey, which are termed ''habitual vertebrate-eaters'' and ''occasional vertebrate-eaters''; some larger spider species occasionally feed on small mice, birds and lizards (Nyffeler & Gibbons 2022). Spiders play a significant ecological role as exclusive predators and regulate insect populations (Wise 1993). Being ectothermic organisms, the food, feeding behaviors, metabolic rate and activity levels of spiders vary with temperature (Barghusen et al. 1997).

Currently, 51,733 species of spiders, belonging to 4,355 genera and 136 families, are reported worldwide (World Spider Catalog 2023). Their diversity in India is represented by 1,968 species in 498 genera and 62 families (Caleb & Sankaran 2023) and in Gujarat with 533 species under 190 genera and 41 families (Singh et al. 2023).

The present work intends to study the diversity and predatory functional group of spider species, during the monsoon and add information to the database of spider species on the Saurashtra University Campus, Rajkot.

Study area

Saurashtra University Campus (SUC) is situated in Rajkot City (22.291˚N, 70.743˚E, 140 m), in central Gujarat, State in western India (Figure 1). Biogeographically, the area falls within the biotic province 4B — Gujarat Rajputana — of the 4 - semi-arid zone (Rodgers & Panwar 1988). The climate of Rajkot is tropical semi-arid with three distinct seasons each year: monsoon, winter and summer. The annual rainfall is erratic in its occurrence, duration, and intensity. The annual rainfall was high (1,187.5 mm) during 2021; the average temperature varies between 21.73 ˚C and 34.62 ˚C, and the average annual humidity ranges from 59.0–93.8 % (morning) and 16.5–83.9 % (evening). The area spans 1.456 km^2 (360 acres) with hilly terrain (Figure 1B).

The SUC has centrally congregated concrete buildings, many parking sites where human activities are more common, habitat structures, and vegetation layers including many small to large water catchment areas, large ponds, check dam, a landscape with flat and hilly rocky terrain covering herbs and grassland patches, a large sports complex, wasteland on the periphery, vegetative implant areas like Dhanvantri Aaushadhi Udayan, forest lands, and a large botanical garden with a newly developed Miyawaki dense garden, which comprises a floristic diversity of 71 species in 62 genera belonging to 32 families (Lagariya & Kaneria 2021).

METHODS

The present work was conducted from August to October 2021 at SUC, Rajkot, comprising 31 visits conducted randomly in morning and evening sessions. On average, two hours were spent during each visit using techniques such as beating vegetation, aerial handpicking from buildings, vegetation and the ground surface handpicking technique during active visual searching.

Preservation and identification

The captured spiders were stored in plastic bottles with small holes for aeration. In the laboratory, only voucher specimens were transferred to 70% alcohol for later identification and kept in specimen tubes with labeling and the remaining live specimens after microscopic examination were freed into the wild. Detailed species identification was carried out under a stereo-zoom dissecting binocular microscope (Stemi 305 Zeiss ISH500) up to the generic and species levels. Microscopic photographs of the spider were captured using a Canon Power Shot A2300 HD Digital Camera and a Tucsen Camera (ISH500) mounted on the stereomicroscope.

Taxonomic identification was performed using the following references: Tikader (1971, 1982), Tikader & Biswas (1981), Tikader & Malhotra (1980), Sethi & Tikader (1988), Majumder & Tikader (1991), Beatty et al. (2008), Gajbe (1999, 2008), Chen & Chen (2002), Shukla & Broome (2007), Han & Zhu (2010), Kim & Lee (2014), Pravalikha & Srinivasulu (2015), Hänggi & Sandrine (2016), Caleb et al. (2017), Caleb & Acharya (2020), Prajapati & Kamboj (2020), Sankaran et al. (2021), Caleb & Wijesinghe (2022) and other relevant literature from the World Spider Catalog (WSC 2023).

Voucher specimens were deposited at the museum of the Department of Biosciences, Saurashtra University, Rajkot, Gujarat, with registration numbers from SUBZ1 to SUBZ62. Shannon diversity – (H'), evenness – (e^H/S), Margalef's species richness (d) and Fisher

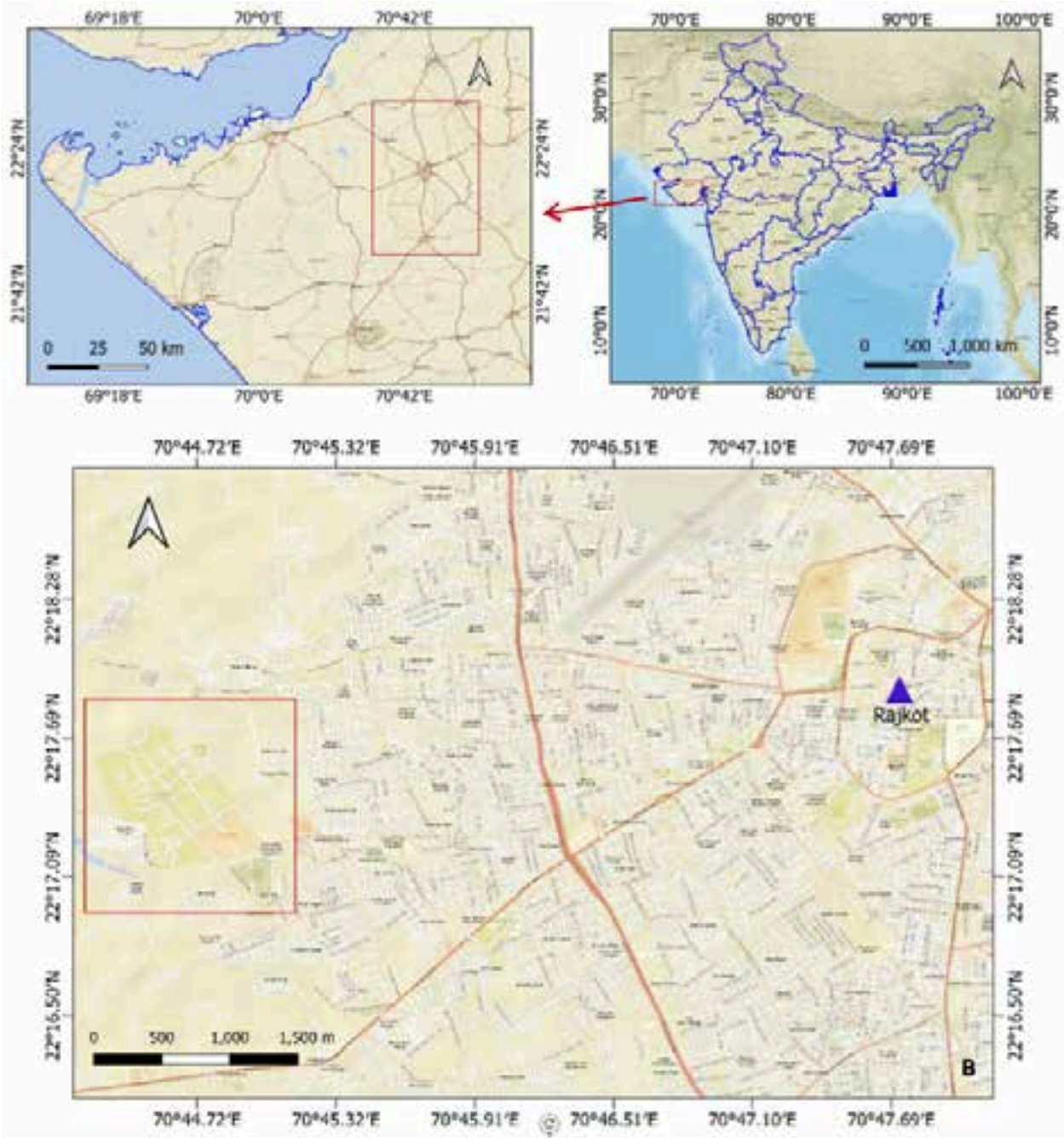

Figure 1. Map showing study areas: A—Location of Rajkot (red square) in Gujarat state of Western India | B —Location of Saurashtra University Campus (red square) in Rajkot. (Mapping by QGIS 3.28.3). Prepared by Varsha Trivedi.

alpha diversity (α) were computed using PAST software (Hammer et al. 2001) and their interpretations followed Magurran (2004).

RESULTS AND DISCUSSION

Out of the 62 spider specimens collected, a total of 38 species classified under 32 genera and 14 families were recorded during the monsoon at Saurashtra University Campus (Table 1). This represents 22.58% of the total 62 families reported from India (Caleb & Sankaran 2023). The family Araneidae exhibited the

Table 1. Checklist of spiders of Saurashtra University Campus areas.

Common name / Feeding guild	Registration no.	Scientific name	No. of specimens, sex & stage
True-orb weavers /Orb-web builders	**Family: Araneidae Clerck, 1757**		**16**
	SUBIOZ1	1. *Argiope anasuja* Thorell,1887	1♀
	SUBIOZ2	2. *Argiope* sp. 1	1♀J
	SUBIOZ3	3. *Argiope* sp. 2	1Y
	SUBIOZ4	4. *Eriovixia excelsa* (Simon, 1889)	3♀
	SUBIOZ7	5. *Eriovixia* sp.	1♂J, 1VY
	SUBIOZ54	6. *Guizygiella* sp.	1Y
	SUBIOZ9	7. *Neoscona theisi* (Walckenaer, 1841)	1♀
	SUBIOZ10	8. *Neoscona* sp.	2♀J, 1Y,1VY
	SUBIOZ14	9. *Poltys* sp.	2♀J
Sac spider/Foliage hunters	**Family: Clubionidae Simon, 1878**		**1**
	SUBIOZ16	10. *Clubiona* sp.	1♀J
Ground sac spiders/ Ground runners	**Family: Corinnidae Karsch, 1880**		**1**
	SUBIOZ17	11. *Castianeria* sp.	1♀J
Ground spider/ Ground runners	**Family: Gnaphosidae Banks, 1892**		**1**
	SUBIOZ18	12. *Eilica tikaderi* Platnick, 1976	1♂
Two tailed spiders/ Foliage hunters	**Family: Hersiliidae Thorell, 1869**		**2**
	SUBIOZ19	13. *Hersilia savignyi* Lucas,1836	1♀, 1♀SA
Wolf spiders/Ground runners	**Family: Lycosidae Sundevall, 1833**		**6**
	SUBIOZ21	14. *Evippa shivajii* Tikader & Malhotra, 1980	1♀
	SUBIOZ22	15. *Hippasa* sp.	1♀J
	SUBIOZ23	16. *Wadicosa fidelis* (O. Pickard-Cambridge, 1872)	1♀, 1♂
	SUBIOZ25	17. *Wadicosa* sp.	2♂J
Lynx spiders/ stalkers	**Family: Oxyopidae Thorell, 1869**		**5**
	SUBIOZ27	18. *Oxyopes bharatae* Gajbe, 1999	2♀
	SUBIOZ29	19. *Oxyopes hindostanicus* Pocock, 1901	3♀
Daddy long-leg spiders/irregular webs	**Family: Pholcidae C. L. Koch, 1850**		**6**
	SUBIOZ32	20. *Artema atlanta* Walckenaer, 1837	1♀
	SUBIOZ33	21. *Crossopriza lyoni* (Blackwall, 1867)	3♀
	SUBIOZ36	22. *Pholcus phalangioides* (Fuesslin, 1775)	1♀, 1♂
Nursery web Spiders/ambushers	**Family: Pisauridae Simon, 1890**		**1**
	SUBIOZ38	23. *Perenethis* sp.	1 Y
Jumping spiders/ Stalkers	**Family: Salticidae Blackwall, 1841**		**14**
	SUBIOZ40	24. *Hasarius* sp.	1♀J, 1♂J
	SUBIOZ42	25. *Hyllus semicupreus* (Simon, 1885)	1♀, 1♂
	SUBIOZ44	26. *Langona* sp.	1♂
Jumping spiders/ Stalkers	SUBIOZ45	27. *Menemerus* sp.	1♀J, 1♂J, 1Y
	SUBIOZ39	28. *Mogrus* sp.	1♀
	SUBIOZ51	29. *Phintelloides undulatus* (Caleb & Karthikeyani, 2015)	1♂
	SUBIOZ48	30. *Plexippus paykulli* (Audouin, 1826)	1♀, 2♂
	SUBIOZ52	31. *Thyene imperialis* (Rossi, 1846)	1♀
Huntsman spiders/ Foliage hunters	**Family: Sparassidae Bertkau, 1872**		**1**
	SUBIOZ53	32. *Olios obesulus* (Pocock, 1901)	1♀

Common name / Feeding guild	Registration no.	Scientific name	No. of specimens, sex & stage
Comb-footed/ Space web builders	**Family: Theridiidae Sundevall, 1833**		**2**
	SUBIOZ55	33. *Latrodectus geometricus* C. L. Koch, 1841	1♀,1♂
Crab spiders/ Ambushers	**Family: Thomisidae Sundevall, 1833**		**3**
	SUBIOZ57	34. *Monaeses* sp.	1♂
	SUBIOZ58	35. *Thomisus* sp.	1♀J
	SUBIOZ59	36. *Tmarus kotigeharus* Tikader, 1963	1♀
Feather legged lace weaver/ Orb-web builders	**Family: Uloboridae Thorell, 1869**		**3**
	SUBIOZ60	37. *Miagrammopes* sp.	1♀SA
	SUBIOZ61	38. *Uloborus* sp.	2♀

SA—Sub adult | J—Juvenile | Y—Young | VY—Very young | SUBIOZ—Saurashtra University, Museum of Department of Biosciences, Zoology.

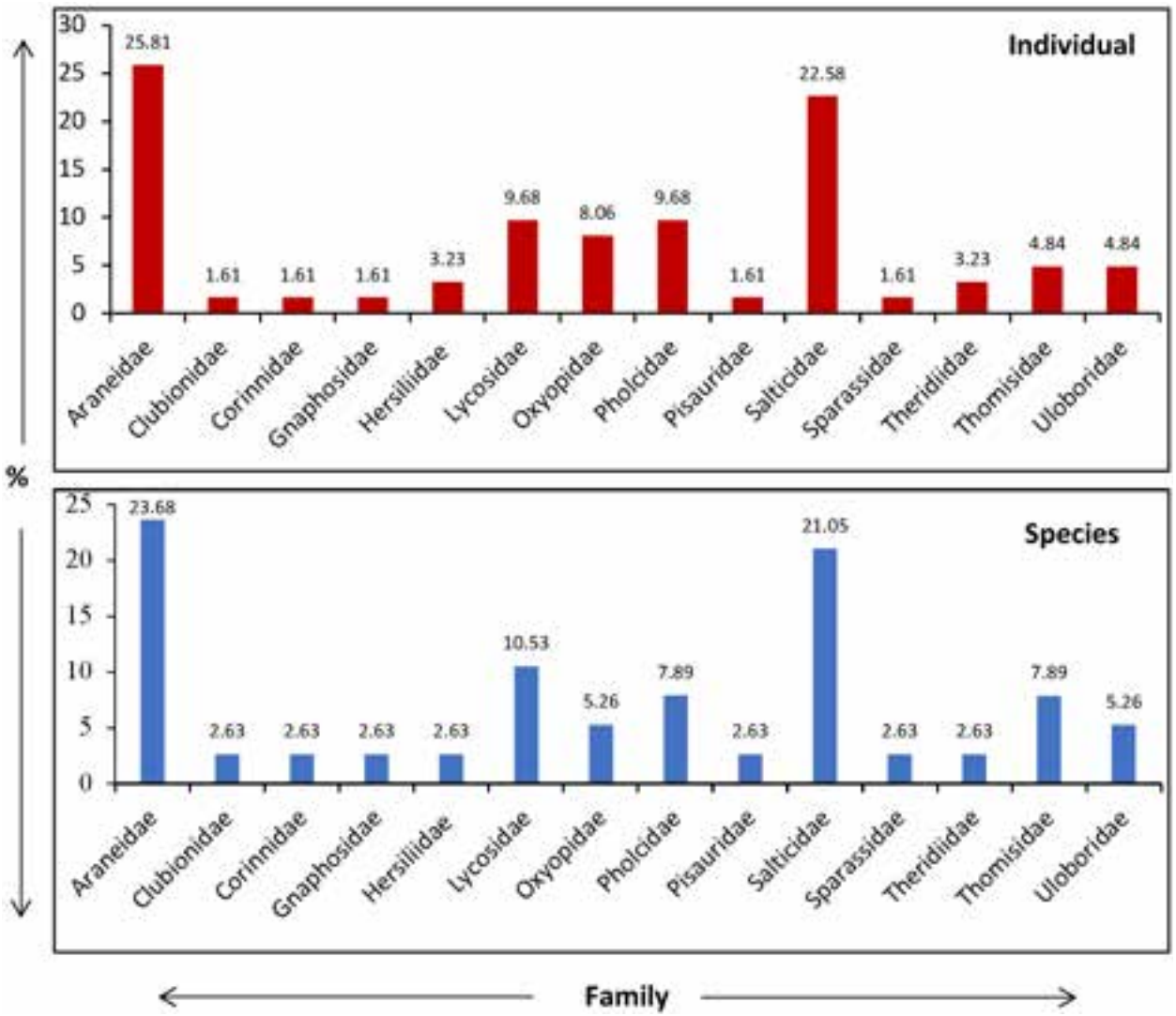

Figure 2. Familial percentages of individuals and species of spider during monsoon.

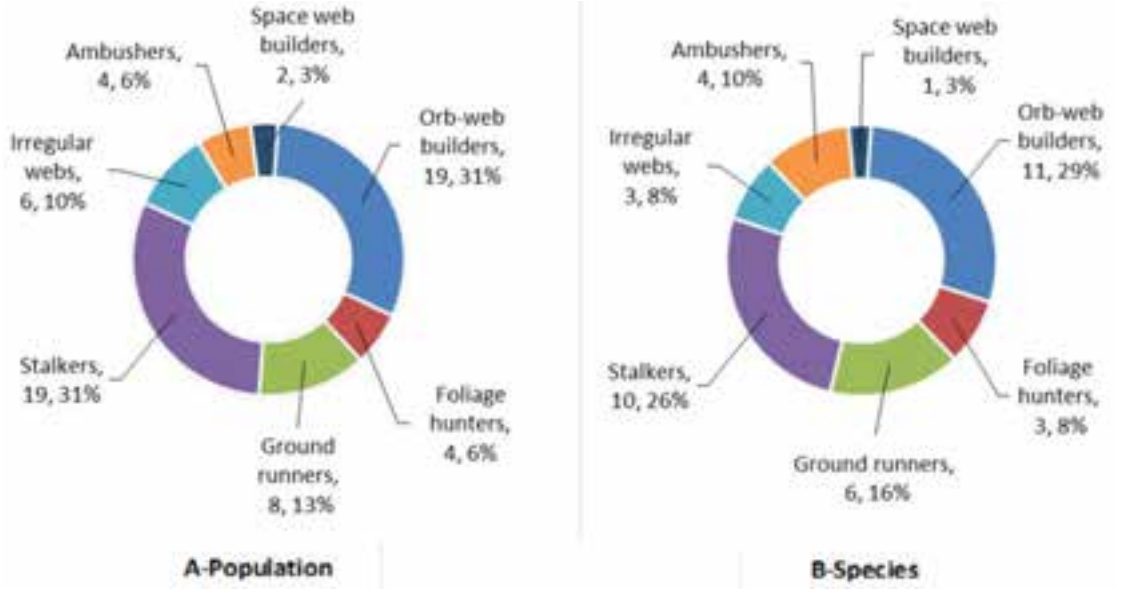

Figure 3. Predatory functional group of spiders with population (A) and species (B).

maximum representative with 16 individuals (25.81%), comprising nine species from five genera, followed by the family Salticidae with 14 individuals (22.58%), comprising eight species from eight genera (Table 1, Figure 2).

The relative abundance analysis of the age and sex status of the collected spiders revealed that females (73%) were almost three times as many as males (27%). The proportion of the potential group (adults) to non-potential individuals was almost one and a half (1.5P:1NP). Age and sexual maturity of spiders may provide a broad range of mate choice decisions for males, as males of a sexually cannibalistic spider chemically assess relative female quality and mate with adaptive females (Cory & Schneider 2020).

Seven feeding guild structures (Uetz et al. 1999), including orb-web builders (31%), stalkers (31%), ground runners (13%), irregular webs (10%), ambushers (6%), foliage hunters (6%) and space-web builders (3%) were recorded. Among these, the most dominant were orb-web builders (19 individuals from 11 species) and stalkers (19 individuals from 10 species). Among orb-web builders, araneids were dominant with nine species compared to Uloboridae (two species), while stalkers (31%) were primarily from the families Oxyopidae and Salticidae. Ground runners (13%) included members from the families Corinnidae, Gnaphosidae and Lycosidae, while irregular webs (10%) included pholcids. Ambushers (6%) included Pisauridae and Thomisidae. Foliage hunters (6%) include clubionids, hersiliids and sparassids and only 3% were space web builders (theridiids) (Table 1, Figure 3).

Among the 38 spider species, 21 were habitat-specific and were found in the Miyawaki forest in the botanical garden and Nandanvan forest areas. Species such as *Poltys* sp., *Clubiona* sp., *Evippa shivajii* Tikader & Malhotra, 1980, *Hippasa* sp., *Hyllus semicupreus* (Simon, 1885), *Mogrus* sp., *Thyene imperialis* (Rossi, 1846), *Olios obesulus* (Pocock, 1901), *Thomisus* sp., *Tmarus kotigeharus* Tikader, 1963, and *Miagrammopes* sp. were among those found. Another 17 species, including *Guizygiella* sp., *Castianeria* sp., *Eilica tikaderi* Platnick, 1976, *Perenethis* sp., *Langona* sp., *Phintelloides undulatus* (Caleb & Karthikeyani, 2015), *Monaeses* sp., and *Uloborus* sp. were found near buildings, parking lots and ground surface areas. *Latrodectus geometricus* C.L.Koch, 1841, was found to be more common at parking spots along the corners of iron pole joints.

The Shannon Weiner Index (H') in the current study was high (H'= 3.526). A high H' value would indicate an even distribution of species. It allows us to not only know the number of species but also the abundance of the community. Typical values of the Shannon-Weiner Index (H') are generally between 1.5 and 3.5 in most ecological studies, and the index is rarely greater than 4. The Shannon index increases as both the richness and the evenness of the community increase. It can be concluded that the abundance of spider species at this study site is high. The evenness index (e) was high (e >0, 0.8944). As the evenness index increases with a decrease in stress (Pielou 1966), this indicates that the study areas have very minimal to no stress elements.

Margalef's species richness indicated a higher value (d = 8.97), and this minimizes the effect of sample size bias (Odum 1971). Species richness as a measure on its own takes no account of the number of individuals of each species present. It gives as much weight to those species that have very few individuals as compared to those that have many individuals (Magurran 2004). Fisher's alpha diversity (α = 41.73) is also significantly high. This may reflect comparatively less stress in their environment.

The feeding guild analysis represents 31% of orb-web weavers and stalkers. This may be due to flourishing vegetation layers during monsoon, including trees, shrubs, grasses and herbs landscapes that provide a healthy environment and shelters to other faunal invertebrate and vertebrate organisms; vegetation stratifications reveal ideal substrate for orb-web weaver spiders such as araneids and uloborids. The web-spinning activities are usually influenced by physiological factors, i.e., temperatures, humidity and rainfall (Barghusen et al. 1997). Stalkers, including salticids and oxyopids, feed on similar prey. Web-weavers are almost strictly insectivorous, while stalkers and wandering spiders exhibit a mixed strategy of insectivorous and araneophagic foraging patterns (Nyffeler 1999). The presence of diverse spider species (Table 1) indicates healthy surroundings, availability of food resources, habitat structures, prey occurrence and feeding activities during the study period at Saurashtra University Campus.

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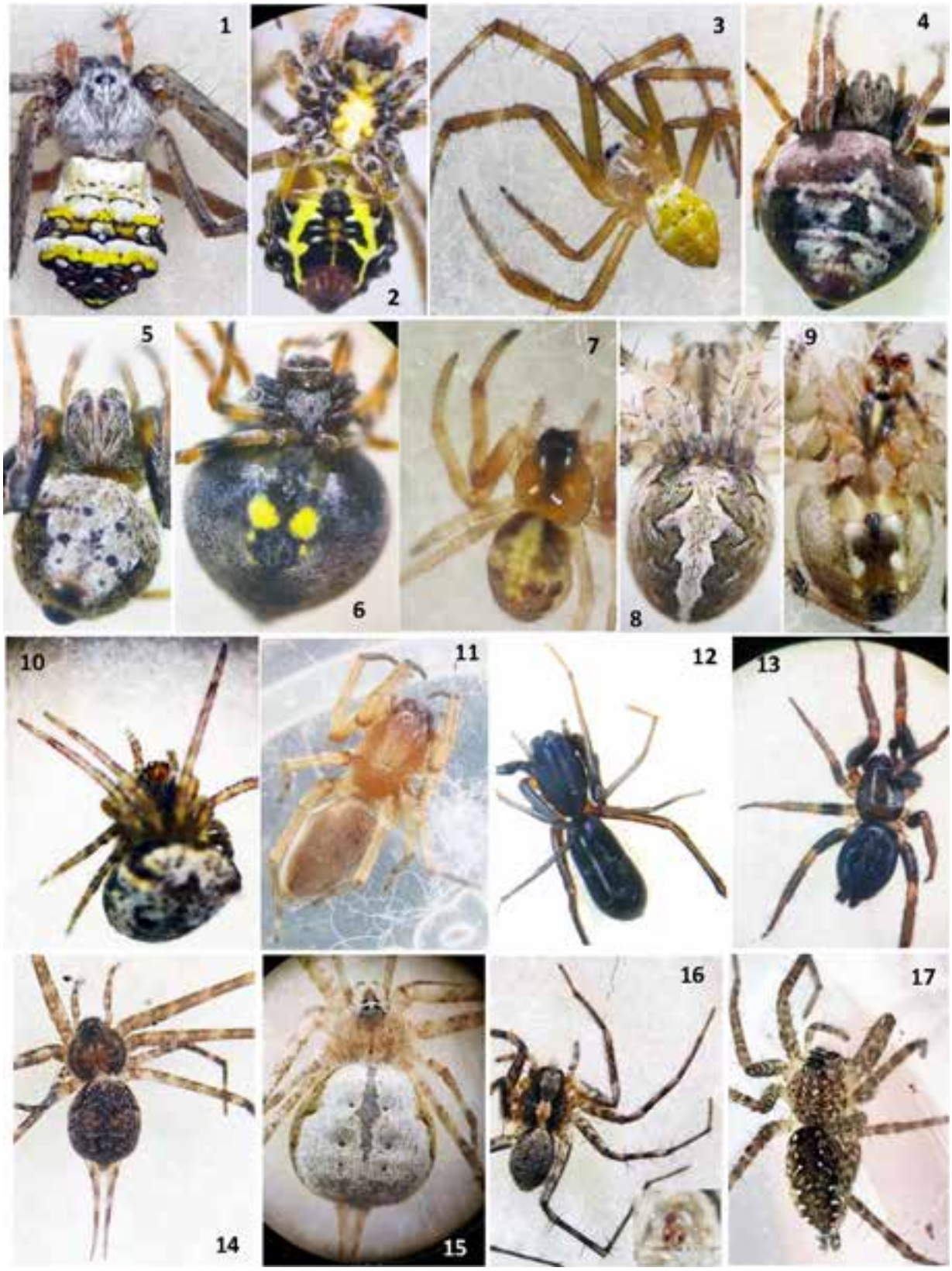
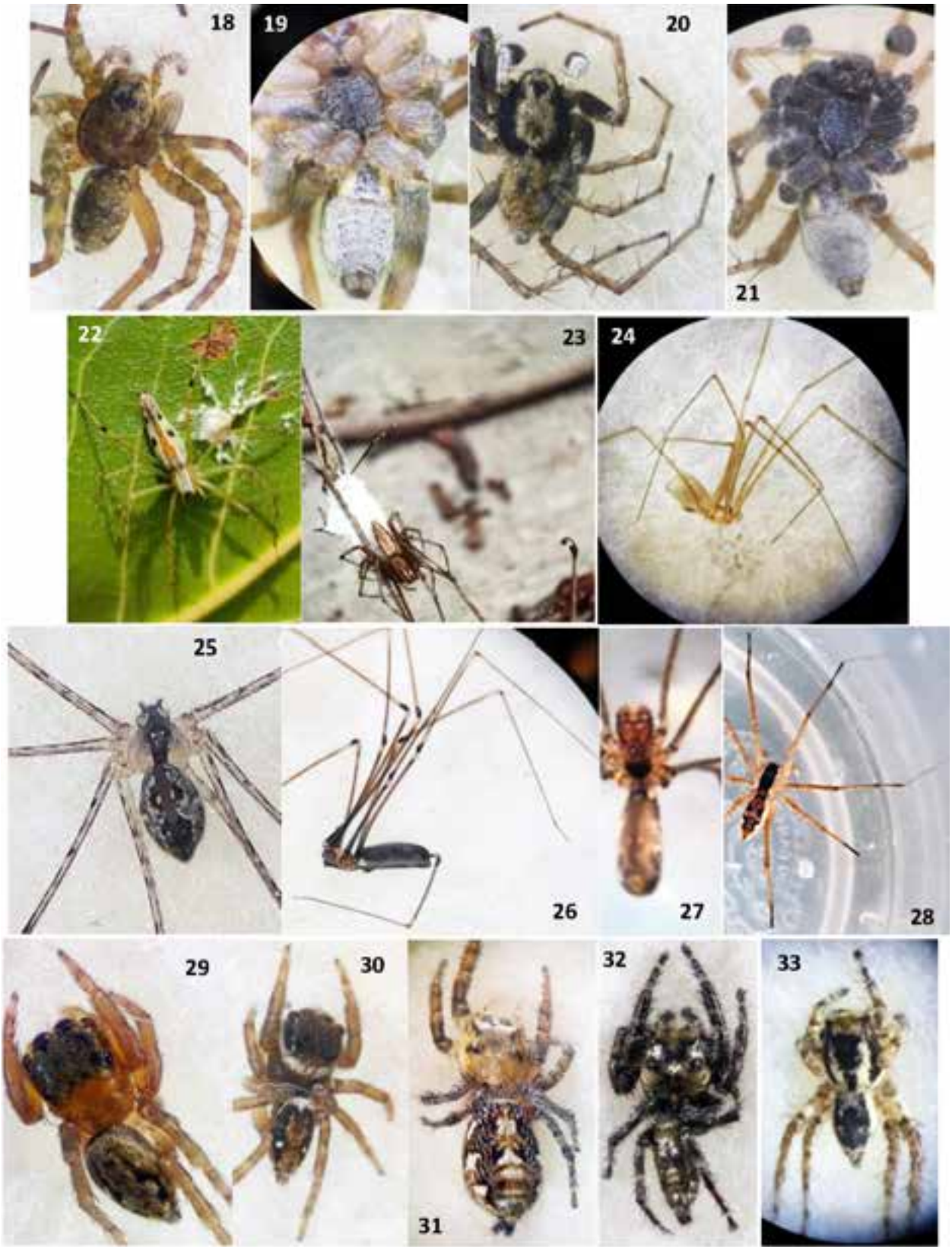
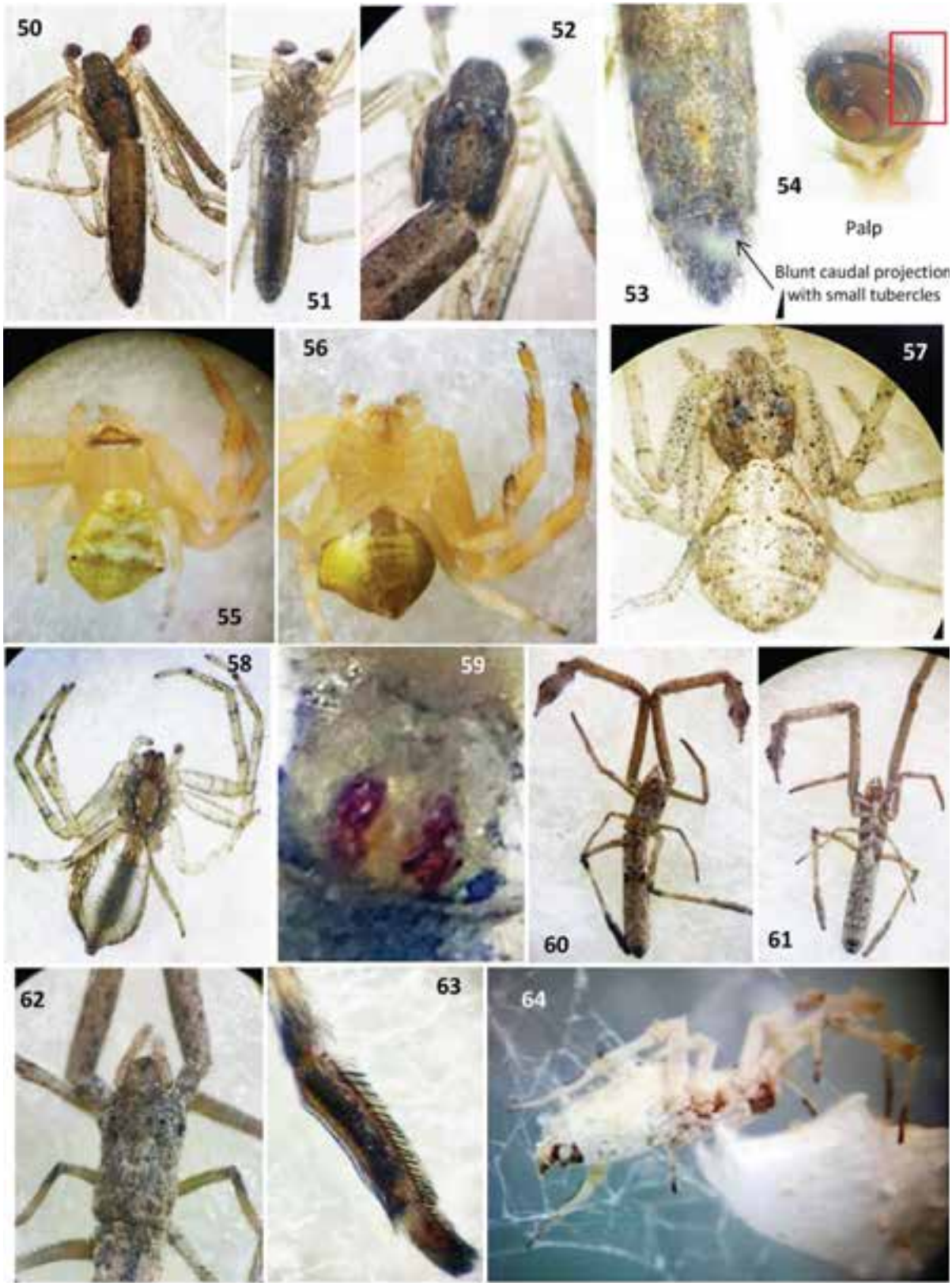


Images 1 to 17 represent spiders of SUC.
1—*Argiope anasuja* ♀ dorsal | 2— Same, ventral | 3—*Argiope* sp.2 | 4—*Eriovixia excelsa* ♀ reddish brown dorsal | 5—*Eriovixia excelsa* ♀ yellowish white dorsal | 6—*Eriovixia excelsa* ♀ ventral | 7—*Guizygiella* sp. | 8—*Neoscona theisi* ♀ dorsal | 9— Same, ventral | 10—*Poltys* sp. ♀ | 11—*Clubiona* sp. ♀ | 12—*Casteineria* sp. ♀ | 13—*Elica tikaderi* ♂ | 14—*Hersilia savignyi* ♀ dorsal dark brown | 15—*Hersilia savignyi* ♀ dorsal white brown | 16—*Evippa shivajii* ♀ dorsal and external epigyne in the inset | 17—*Hippasa* sp. ♀. © Jyotil Dave & Varsha Trivedi.



Images 18 to 33 represent spiders of SUC.
18—*Wadicosa fidelis* ♀ dorsal | 19—Same, ventral | 20—Wadicosa fidelis ♂ dorsal | 21—Same, ventral | 22—*Oxyopus bhartae* ♀ with eggs | 23—*Oxyopus hindostanicus* ♀ with eggs | 24—*Aretema atlanta* ♀ with eggs | 25—*Crossopriza lyoni* ♀ | 26—*Pholcus phalangioides* ♀ lateral | 27—*Pholcus phalangioides* ♂ ventral | 28—*Perenethis* sp. | 29—*Hasarius* sp. ♀ | 30—*Hasarius* sp.♂ | 31—*Hyllus semicupreus* ♀ dorsal | 32—*Hyllus semicupreus* ♂ dorsal | 33—*Langona* sp. ♂.

Images 34 to 49 represent spiders of SUC.
34—*Menemerus* sp. ♀ dorsal | 35—*Menemerus* sp. ♂ dorsal | 36—*Mogrus* sp. ♀ dorsal | 37—*Mogrus* sp. ♀ ventral | 38—*Phintelloides undulatus* ♂ dorsal | 39—Same, ventral | 40—*P. undulatus* ♂ ventral palp | 41—*Plexippus paykulli* ♀ | 42—*Plexippus paykulli* ♂ | 43—*Thyene imperialis* ♀ dorsal | 44—*Thyene imperialis* ♀ ventral | 45—*Olios obesulus* ♀ dorsal | 46—Same, ventral | 47—*O. obesulus* ♀ external epigyne | 48—*Latrodectus geometricus* ♀ dorsal | 49—*Latrodectus geometricus* ♂.



Images 50 to 64 represent spiders of SUC.
50—*Monaeses* sp. ♂ dorsal | 51—Same, ventral | 52—Same, carapace | 53—Same, caudal abdomen dorsal | 54—Same, ventral palp | 55—Thomisus sp. ♀ dorsal | 56—Same, ventral | 57—*Tmarus kotigehrus* ♀ dorsal | 58—Same, ventral | 59—Same, external epigyne | 60—*Miagrammopes* sp. ♀ dorsal | 61—Same, ventral | 62—Same, carapace | 63—Same, calamistrum on 4th leg | 64—*Uloborus* sp. ♀ with egg mass.

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COMMUNICATION

Records of three gobioid fishes (Actinopterygii: Gobiiformes: Gobiidae) from the Gujarat coast, India

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Abstract: We report for the first time three gobioid fishes: *Amblygobius semicinctus* (Bennett, 1833), *Istigobius diadema* (Steindachner, 1876), and *Yongeichthys nebulosus* (Forskål, 1775) from the Gujarat coast of India. We present short descriptions with species diagnostic characters, habitat and present distributions.

Keywords: Coral reef, first record, gobies, Gulf of Kachchh, lower intertidal zone.

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Author contributions: PV Survey, photography and identification of fishes and preparation of the draft of paper. HK Survey, photography and identification of fishes and preparation of the draft of paper. IB Identification of fishes and preparation of the manuscript. PB Survey and identification of fishes.

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INTRODUCTION

Gobiidae (Cuvier, 1816) is a large and geographically widespread fish family encompassing 171 genera/subgenera and 1,401 species/subspecies (Scharpf & Lazara 2023). Gobioids are mostly small to medium-sized (up to 30 cm, usually less than 10 cm) bottom-dwelling cryptic fishes found in tropical to temperate marine, freshwater and brackish water ecosystems (Murugan & Namboothri 2012; Parenti 2021). They live in sheltered areas such as sandy areas, coral reefs, aquatic weeds, rubbles, and rock crevices (Murdy & Hoese 2002; Thacker & Roje 2011; Parenti 2021). They feed on various invertebrates such as polychaetes, crustaceans, mollusks, sponges and insects, plus algae and plankton (Parenti 2021). A few species are associated with different organisms such as coral, sponges, shrimp and other fishes (Murdy & Hoese 2002; Herler et al. 2009). Gobiidae comprises 190 species belonging to 71 genera, distributed in India (Gopi & Mishra 2015), of which about 75% (143 species belonging to 28 genera) have been recorded from the Andaman & Nicobar Islands (Rajan & Mishra 2018). Several authors reported gobioid fishes (17 species; 13 genera) in Gujarat waters (Soni & George 1986; Barman et al. 2000; Bhatt et al. 2009; Shukla 2014; Bhakta et al. 2018, 2021; Thakkar et al. 2018; Kumar et al. 2022). In the present study, we report the occurrence of three gobioid fish from the Gujarat coast for the first time. As a result, a total of 20 species from 16 genera have been recorded from Gujarat to date (Table 1).

MATERIALS AND METHODS

The present study was conducted at the Sikka coast (22.458^{0}N, 69.801^{0}E) in the Gulf of Kachchh, Gujarat. The lower intertidal area of the Sikka coast consists of a sandy-rocky substratum and several tide pools surrounded by dead and living coral reefs and pebbles. Live specimens were collected by scoop net from the lower intertidal area of the Sikka coast. The collected specimens were transferred to the laboratory of the Fisheries Research Station, Junagadh Agricultural University, Sikka. Fish was narcotized using menthol and clove oil for photography, fin formula, and meristic characteristics.

Individual specimens were observed and measured for various morphometric parameters, including total length, standard length, body depth, head length, orbit diameter, inter orbital width, caudal peduncle depth, predorsal length, prepelvic length, preanal length, base of first and second dorsal fin, pectoral, pelvic and caudal fin length. Additionally, scales and fin rays were carefully examined for meristic counts, contributing to a comprehensive understanding of the fish's morphological profile. Special attention was given to variations in pigmentation and the presence of unique markings.

In meristic counts specific attention was directed towards the quantification of fin rays as a crucial morphological gobioid parameter. Fin rays were counted using the standardized procedure of Murdy (1989) and Gut et al. (2020). The counting process initiated from the anterior region of each fin and proceeded posteriorly, ensuring consistency across all specimens. To enhance precision, a magnifying glass was employed for smaller gobies, facilitating a meticulous examination of the individual rays. Fin ray counts were recorded for both the left and right sides of each fin, and any variations or anomalies were duly documented. Taxonomical identification was carried out through the standard taxonomic literature of Koumans (1941), Herre (1945), and Winterbottom & Emery (1986). The specimens were preserved in formaldehyde solution and deposited in the Museum of Fisheries Research Station, Junagadh Agricultural University, Sikka. The size of the specimen is indicated by the total length (TL) measured from the snout to the end of the caudal fin and the standard length (SL) measured from the snout to the base of the caudal fin (Table 2).

RESULTS

Phylum: Chordata Haeckel, 1874
Class: Actinopterygii Klein, 1885
Order: Gobiiformes Günther, 1880
Family: Gobiidae Cuvier, 1816
Genus: *Amblygobius* Bleeker, 1874

***Amblygobius semicinctus* (Bennett, 1833) (Image 1a)**

Gobius semicinctus Bennett, 1833, Proc. Zool. Soc. Lond., 1: 32 [type locality: Mauritius].

Amblygobius semicinctus Parenti, 2021, Iran. J. Ichthyol., 8 (Suppl. 1): 90.

Materials examined: FRSCVG-09, 04 specimens, unsexed; SL: 70–94 mm; Sikka reef, Gulf of Kachchh, Gujarat, coll. Sidik Mepani, 17.v.2022.

Diagnosis: Dorsal fin rays VI, 15; anal fin rays I, 15; pectoral fin rays 19; caudal fin rays 16–17; pelvic fin rays 6. Dorsal spine - VI, 2nd, 3rd, 4th and 5th dorsal spine prolonged and filamentous which reaches up to the base of 1st to 5th ray of second dorsal fin; pelvic

fin with spine and joined with a frenum with five soft rays at both distal end; Lateral series scale 52–53 and lateral transverse scale rows 19–20; cycloid scales present on head and nape while ctenoid scales found at distally; predorsal scale 23–25, prepelvic and pectoral base scaled; gill rackers 0+7; gill opening restricted and opening extending to below a posterior third of opercle; snout obtusely rounded; mouth terminal, inclined dorsally; upper jaw with multiple rows of conical teeth; two enlarged canines on sides, approximately one-third of distance towards the cleft of mouth. Anterior nostril tubular and marked with dark pigment, posterior nostril pore-like. Colour is highly variable. Body is typically greyish brown or dark brown on the dorsal side, grading to yellow-brown on the ventral side, and the ventral half of the head has little blue-green dots and short lines. On the upper part of the body, there are typically 4 or 5 narrow black bars, a double band of dark brown colour running from the front of the nose to the eye, and three parallel rows of dark-edged orange dots on the nape. Cream-colored chest and pectoral bases with tiny yellow-brown spots. Three visible black spots on the second dorsal fin. Two black spots on the caudal fin. A black patch is visible on the caudal peduncle.

Habitat: The species is commonly found on the sandy bottom, dead coral crevices and tide pools.

Distribution: Eastern Africa and Scychellus to Andaman Sea (Allen & Erdmann 2012); western Indian Ocean (Parenti 2021).

India: Andaman & Nicobar Islands (Ramakrishna et al. 2010). Presently this species is reported for the first time from the Gulf of Kachchh, Gujarat, India.

Remarks: Taxonomical characteristics of the present specimen examined agree well with the detailed description of Winterbottom & Emery (1986). *Amblygobius semicinctus* resembles its closely related congeners *Amblygobius albimaculatus* (Rüppell, 1830) but it is immediately distinguished in having a black spot on the upper hypural/caudal fin region and other details (Lachner & Gomon 1974).

Genus: *Istigobius* Whitley, 1932

***Istigobius diadema* (Steindachner, 1876) (Image 1b)**

Gobius diadema Steindachner, 1876, *Sitzungsber. Akad. Wiss. Wien,* 74: 232 [type locality: Hong Kong, South China Sea].

Ctenogobius perspicillatus Herre, 1945, *Copeia,* 1: 5 [type locality: Vizagapatnam, Andhra Pradesh, India].

Istigobius diadema Parenti, 2021, *Iran. J. Ichthyol.,* 8(Suppl. 1): 187.

Materials examined: FRSCVG-02, 04 specimens, unsexed; SL: 46 - 80 mm; Sikka reef, Gulf of Kachchh, Gujarat, coll. Sidik Mepani, 18.v.2022.

Diagnosis: Dorsal fin rays VI, 11–12; anal fin rays 10–11; pectoral fin rays 18–19; caudal fin rays 16–17; pelvic fin rays 5. Cheeks and operculum scaleless, lateral series scale 31–32 and lateral transverse scale rows 10–11, mouth inferior with a rounded overhanging snout. The body moderately elongated and upper half of sides pale grey to brownish colour pattern that fades to white on the lower half; presence of a bold dark black line running from rear edge of eye to above base of the pectoral fin; a dark spot mottled on anal, pelvic as well as lower part of caudal fin; fully united pelvic fins, presence of well-developed frenum; caudal fin rounded, gill opening not extending anteriorly to a vertical through pre-opercular margin, sensory canals and pores present on the head. Scale ctenoid except for breast, operculum and pectoral fin base, a pair of short sensory papillae just behind chin, a dark stripe connecting both the eyes anteriorly.

Habitat: It is sand-dwelling and reef-associated fish, generally found in a sandy area surrounded by live and dead coral colonies.

Distribution: India to northern Australia, north to Hong Kong (Parenti 2021).

India: Goa (Sreekanth et al. 2015, 2018); Tamil Nadu (Kumar et al. 2015; Moulitharan et al. 2021); Andhra Pradesh (Herre 1945); Andaman & Nicobar Islands (Devi & Chakkaravarthy 2010). Presently, this species is reported for the first time from the Gulf of Kachchh, Gujarat, India.

Remarks: The taxonomical characters of the present specimen examined agree well with the detailed description of Herre (1945). *Istigobius diadema* closely resembles *Istigobius goldmanni* (Bleeker, 1852) but it is differentiated in a greater number of predorsal scales (17 vs. 7–9 in *I. goldmanni*); lesser first dorsal fin rays (6 vs. 7 in *I. goldmanni*) and having a uniquely thick, single black stripe on post-orbital to the point of the shoulder adjacent to dorsal fin origin on both sides of the head (Bleeker 1852; Bray 2023).

Genus: *Yongeichthys* Whitley, 1932

***Yongeichthys nebulosus* (Forsskål, 1775) (Image 1c)**

Gobius nebulosus Forskål, 1775, *Descr. Animalium*, 24, x [type locality: Jeddah, Saudi Arabia, Red Sea].

Gobius brevifilis Valenciennes in Cuvier & Valenciennes, 1837, *Hist. Nat. Poiss.,* 12: 90. [type locality: Puducherry, India].

Yongeichthys nebulosus Parenti, 2021, *Iran. J. Ichthyol.*, 8(Suppl. 1): 257.

Materials examined: FRSCVG-08, 04 specimens,

Image 1. a—*Amblygobius semicinctus* (Bennett, 1833) | b—*Istigobius diadema* (Steindachner, 1876) | c—*Yongeichthys nebulosus* (Forskål, 1775). © Fisheries Research Station, Junagadh Agricultural University, Sikka.

Table 1. Checklist of gobioid fishes recorded in Gujarat water.

	Genus	Species	References (Gujarat water)
Family: Gobiidae			
1	*Odontamblyopus*	*Odontamblyopus rubicundus* (Hamilton, 1822)	Shukla 2014
2	*Taenioides*	*Taenioides anguillaris* (Linnaeus, 1758)	Shukla 2014
3	*Trypauchen*	*Trypauchen vagina* (Bloch & Schneider, 1801)	Thakkar et al. 2018
4	*Acentrogobius*	*Acentrogobius andhraensis* (Herre, 1944)	Barman et al. 2000
5	*Amblygobius*	*Amblygobius semicinctus* (Bennett, 1833)	Present study
6	*Glossogobius*	*Glossogobius giuris* (Hamilton, 1822)	Barman et al. 2000
7	*Gobiopsis*	*Gobiopsis canalis* Lachner & McKinney, 1978	Kumar et al. 2022
8	*Istigobius*	*Istigobius diadema* (Steindachner, 1876)	Present study
9	*Parachaeturichthys*	*Parachaeturichthys polynema* (Bleeker, 1853)	Kumar et al. 2022
10	*Yongeichthys*	*Yongeichthys nebulosus* (Forsskål, 1775)	Present study
11	*Apocryptes*	*Apocryptes bato* (Hamilton, 1822)	Shukla 2014
12	*Boleophthalmus*	*Boleophthalmus boddarti* (Pallas, 1770)	Barman et al. 2000
13		*Boleophthalmus dussumieri* Valenciennes, 1837	Soni & George 1986; Shukla 2014
14	*Periophthalmodon*	*Periophthalmodon schlosseri* (Pallas, 1770)	Bhakta et al. 2018
15		*Periophthalmodon septemradiatus* (Hamilton, 1822)	Bhatt et al. 2009
16	*Periophthalmus*	*Periophthalmus barbarus* (Linnaeus, 1766)	Barman et al. 2000
17		*Periophthalmus waltoni* Koumans, 1941	Shukla 2014; Bhakta et al. 2021
18	*Pseudapocryptes*	*Pseudapocryptes elongatus* (Cuvier, 1816)	Bhakta et al. 2018
19	*Scartelaos*	*Scartelaos cantoris* (Day, 1871)	Barman et al. 2000
20		*Scartelaos histophorus* (Valenciennes, 1837)	Barman et al. 2000; Shukla 2014

unsexed; SL: 60–70 mm; Sikka reef, Gulf of Kachchh, Gujarat, coll. Piyush Vadher, 18.iv.2022.

Diagnosis: Dorsal fin rays VI, I, 9-10; anal fin rays I, 9-10; pectoral fin rays I, 18; caudal fin rays 16; pelvic fin rays I, 5. Body elongate and compressed. Head rounded, lower jaw longer than broad, mouth small aligned with anterior margin of the eye. Head and nape smooth above but a strip of rudimentary scales runs forward to the orbit. Cheek with two rows of sensory papillae on the lateral side below the eye. Maxillary reaches about the middle of the orbit. Jaws equal. Teeth in several rows, the outer row slightly larger than the inner rows. Tongue emarginated, free at the tip. Head and cheek are naked. Scales smaller on anterior than posterior region. Lateral series scale 31–32 and lateral transverse scale rows 11–12; seven rows of rudimentary scales found on front dorsal fin. Second and third dorsal spines elongate, second spine longer; ventral fins united with well developed basal membrane, tips not reaching vent. Caudal fin rounded.

Habitat: It is commonly found in the sandy-muddy bottom near coral reefs.

Distribution: Red Sea, Western Indian Ocean to Society Islands, Australia, New Caledonia (Parenti 2021).

India:12 Andhra Pradesh (Koumans 1941 as *Ctenogobius criniger*; Ray et al. 2022); Odisha (Roy et al. 2019); Puducherry (Cuvier & Valenciennes 1837 as *Gobius brevifilis*); Tamil Nadu (Koumans 1941 as *Ctenogobius criniger*; Mogalekar et al. 2018); Kerala (Koumans 1941 as *Ctenogobius criniger*); Andaman & Nicobar Islands (Koumans 1941 as *Ctenogobius criniger*). The present report forms its first record from the Gulf of Kachchh, Gujarat, India.

Remarks: Taxonomical characteristics of the present specimen examined well agreed with the detailed description of Koumans (1941). *Yongeichthys nebulosus* (Forsskål, 1775) is identical to *Yongeichthys tuticorinensis* (Fowler, 1925) but immediately distinguished by head size. *Yongeichthys tuticorinensis* has a larger head compared to *Y. nebulosus* (3.0 vs 3.3–3.6 in SL) and lower numbers of lateral scales (28–30 vs 30–32) (Roy et al. 2019).

CONCLUSION

This study report provides the diversity and distribution of three gobioid species for the first time from Gujarat water. A total of 20 species from 16 genera were reported in Gujarat waters (Table 1). *Amblygobius semicinctus* (Bennett, 1833) was recorded for the first time from the Indian mainland, *Yongeichthys nebulosus* (Forskål, 1775) and *Istigobius diadema* (Steindachner, 1876) were recorded for the first time from Gujarat coast. These species were mostly observed burrowing near live or dead coral reefs, tide pools and rock crevices. Maximum numbers of species were reported from the Gulf of Kachchh compared to other coastal and sea areas. Surveys of unexplored areas of the Gulf of Khambhat and the Saurashtra coast are recommended in order to obtain a more comprehensive picture of species diversity.

Table 2. Morphometric measurements of new gobioid fishes collected from the Gulf of Kachchh, Gujarat.

	Characters	*Amblygobius semicinctus* (n = 4)		*Istigobius diadema* (n = 4)		*Yongeichthys nebulosus* (n = 4)	
		Value (mean ± SD)	Range	Value (mean ± SD)	Range	Value (mean ± SD)	Range
1	Total length (mm)	108 ± 6.03	90–118	82.25 ± 6.03	57–99	78.5 ± 6.03	72–85
2	Standard length (mm)	85 ± 4.99	70–94	66.5 ± 4.99	46–80	64.75 ± 4.99	60–70
3	Body depth (mm)	24.25 ± 1.5	21–29	15.25 ± 1.5	10–18	15.75 ± 1.5	14–17
4	Head length (mm)	23 ± 1.5	20–24	19 ± 1.5	13–23	19.25 ± 1.5	18–21
5	Orbit diameter (mm)	6 ± 0.5	5–7	5.75 ± 0.5	4–7	6.25 ± 0.5	6–7
6	Inter-orbital width (mm)	6.75 ± 0.25	6–8	8.5 ± 0.25	5–10	2.125 ± 0.25	2–2.5
7	Caudal peduncle depth (mm)	13.5 ± 0.95	11–15	9 ± 0.95	6–11	8.25 ± 0.95	7–9
8	Pre-dorsal length (mm)	28.5 ± 1.5	23–32	22.5 ± 1.5	17–26	22.75 ± 1.5	21–24
9	Pre-pelvic length (mm)	23.5 ± 1.73	21–28	23.5 ± 1.73	17–28	22.5 ± 1.73	21 –24
10	Pre-anal length (mm)	48.5 ± 2.06	43–52	38.25 ± 2.06	28–46	39.75 ± 2.06	38–42
11	Base of first dorsal fin (mm)	15 ± 0.81	12–17	9 ± 0.81	7–10	9 ± 0.81	8–10
12	Base of second dorsal fin (mm)	24.5 ± 1	19–28	18.5 ± 1	14–22	15.5 ± 1	14–16
13	Base of anal fin (mm)	24.75 ± 0.57	19–29	15.5 ± 0.57	13–17	13.5 ± 0.57	13–14
14	Pectoral fin length (mm)	24.5 ± 0	18–29	15.25 ± 0	10–18	15 ± 0	15–15
15	Pelvic fin length (mm)	~~16.25~~ ± 0.57	13–18	13 ± 0.57	9–16	13.5 ± 0.57	13–14
16	Caudal fin length (mm)	22.5 ± 1.57	19–24	16 ± 1.57	11–18	14.25 ± 1.57	13–15

*n = number of individuals

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COMMUNICATION

Species distribution modelling of Baya Weaver *Ploceus philippinus* in Nagaon District of Assam, India: a zoogeographical analysis

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Abstract: Identification and mapping of the spatial distribution of species is an important aspect of zoogeographical enquiry. The habitats of many species are facing the threat of depletion in increasingly human-influenced environments. This has already led to the extinction of many species in different localities, making understanding the linkages between anthropogenic threats and species distribution of utmost importance. A GIS-based model was applied to gain an overall picture of the potential distribution of *Ploceus philippinus* (Baya Weaver) in and around Nagaon District in Assam. The used maxent model in the GIS environment gives a highly significant Area Under Curve (AUC) validation statistic of 0.99. Out of the total area of 3,975 km^2, 596.86 km^2 (15%) is demarcated as a high-potential area. Such predictions are highly useful in assisting in the conservation of threatened species under current and future climatic conditions.

Keywords: AUC, birds, environment, GIS, habitat, mapping, Maxent, potential, northeastern India, spatial distribution.

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INTRODUCTION

The Baya Weaver *Ploceus philippinus*, is distributed throughout the Indian subcontinent and southeastern Asia. There are five species in the *Ploceus* clade: *P. philippinus*, *P. manyar*, *P. benghalensis*, *P. hypoxanthus*, and *P. megarhynchus* (De Silva et al. 2019*).* The Baya Weaver has a unique courtship display involving the nest-building that it is known for, and has multiple adaptations to its ecological niche. The male weaver bird puts a lot of effort and time into making a beautiful hanging nest and then invites a female bird by flapping its wings to choose it as their nesting place (Arigela et al. 2021). The weaver selects various trees, bushes, and other sites for building its nests, showing a preference for thorny acacias and specific palm species. The avian population in a particular region tends to favor a distinct type of nesting location (Davis 1974). Indian Baya Weavers have been observed to establish colonies on a remarkable range of plants. They have also been known to choose unconventional structures such as house eaves (Davis 1971), telegraph and power lines (Ambedkar 1970), and the sides of irrigation wells (Ali 1931; Crook 1960, 1963) as occasional sites for suspending their nests (Davis 1972). Over 84 percent of the colonies in the Assam region were on Areca palm (Davis 1972).

Maxent (Maximum entropy model) is a machine learning technique that can be used for SDM (Species distribution modelling) due to its use of maximum entropy to determine the probability of a species' presence and absence in each area. This method combines a variety of independent regional climate, land-use, topography, and other environmental and ecological variables into a single model of species' distributions. It then applies the principle of maximum entropy to the dataset. It is an increasingly popular machine learning algorithm used in SDM, which is a technique that can be used to predict the locations where species may occur, by examining the potential environmental, ecological, and socioeconomic factors associated with their distribution. Maxent is a machine learning algorithm that has become an increasingly popular choice for SDM (Phillips & Dudik 2008).

Several works have been done on species distribution model and habitat suitability analysis using Maxent model in India and across the world. The works of Reside et al. (2010), Syfert et al. (2013), Booth et al. (2014), Fourcade et al. (2014), Padalia et al. (2014), Jathar et al. (2015), Sarma et al. (2015), Moya et al. (2017), Bradie & Leung (2017), Rhoden et al. (2017), Palacio & Girini (2018), Nameer & Sanjo (2020) are worth mentioning as they have found the Maxent model has the ability to provide accurate predictions with different species and with different environmental variables .

The current paper analyzes the distribution or range of Baya Weaver in Nagaon District of Assam, India. Through the use of geographic information systems, species distribution modelling and remote sensing data, the habitat suitability classes like least potential, moderate potential, good potential and high potential classes for the Baya Weaver is identified. The Maxent (Phillips & Dudik 2008) model is popular among many scientists in investigating the potential distribution of floral and faunal species. Through this analysis we will gain insight into the bird's current and probable habitat and hopefully be able to provide recommendations for management and conservation efforts suitable for this species.

MATERIALS AND METHODS

Study Area

The present Nagaon and Hojai districts (Figure 1) are situated in the middle part of Assam between 25.72 & 26.75 ^{0}N and 93.42 & 93.33 ^{0} E. It is surrounded by Sonitpur District in the north, Karbi Anglong and North Cachar hills in the south, Karbi Anglong and Golaghat districts in the east, and Morigaon District in the west. The mighty river Brahmaputra flows along the northern periphery of the district. Three Important Bird Areas (IBA) fall within Nagaon District: Deobali Jalah (IN-AS-11), Kaziranga National Park and Tiger Reserve (IN-AS-25) and Laokhowa-Burhachapori WS (IN-AS-28) (Rahmani et al. 2016). Nagaon District also falls under the range state of central Asian flyway.

Methods

The field survey was conducted randomly at several locations in Nagaon District of Assam to cover both summer (March to August) and winter seasons (January to February) and GPS points were collected using handheld GPS devices. While surveying the locations, local residents were interacted with to gather information about nesting sites of Baya Weaver. During the surveys, opportunistic sightings of nesting sites of Baya Weaver were also recorded. After that, the maxent model (Phillips & Dudik 2008) was used for predicting the habitat suitability of Baya Weaver in Nagaon District of Assam. During the run, six presence records were used for training and two for testing, 10,006 points were used to determine the Maxent distribution (background

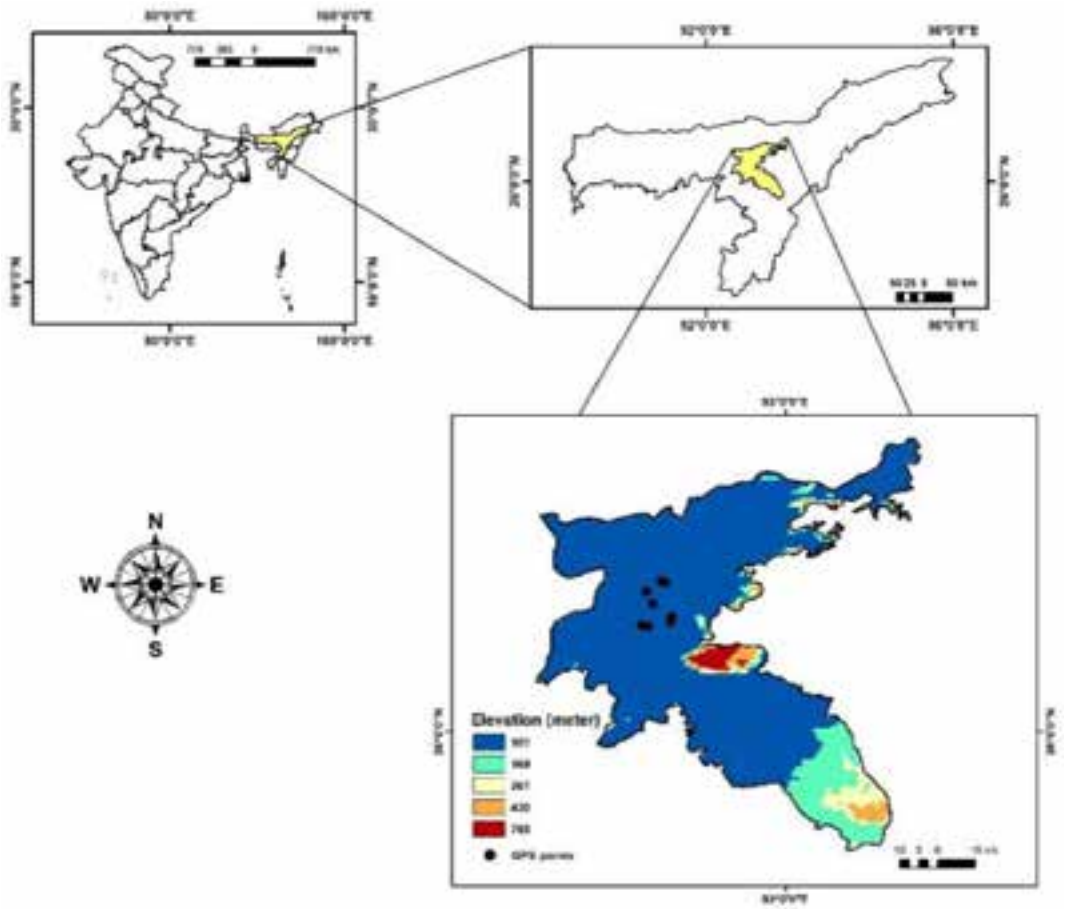

Figure 1. Location of the study area showing GPS points of Nagaon district of Assam, India.

points and presence points). Regularized training gain is 5.245, training AUC is 0.999, unregularized training gain is 6.310. Unregularized test gain is 5.668. Test AUC is 0.999.

Nineteen environmental variables (BIO1 = Annual Mean Temperature, BIO2 = Mean Diurnal Range (Mean of monthly (max temp - min temp)), BIO3 = Isothermality (BIO2/BIO7) (×100), BIO4 = Temperature Seasonality (standard deviation ×100), BIO5 = Max Temperature of Warmest Month, BIO6 = Min Temperature of Coldest Month, BIO7 = Temperature Annual Range (BIO5-BIO6), BIO8 = Mean Temperature of Wettest Quarter, BIO9 = Mean Temperature of Driest Quarter, BIO10 = Mean Temperature of Warmest Quarter, BIO11 = Mean Temperature of Coldest Quarter, BIO12 = Annual Precipitation, BIO13 = Precipitation of Wettest Month, BIO14 = Precipitation of Driest Month, BIO15 = Precipitation Seasonality (Coefficient of Variation), BIO16 = Precipitation of Wettest Quarter, BIO17 = Precipitation of Driest Quarter, BIO18 = Precipitation of Warmest Quarter, BIO19 = Precipitation of Coldest Quarter) with a spatial resolution of 30 arc second (Fick & Hijmans 2017) were downloaded from worldclim.org along with slope, elevation and aspects raster and a multicolinearity test was conducted (Mehmud et al. 2022). Variables with a cross correlation of ±8 or more were excluded from the model to reduce the data redundancy and improve the performance of the model (Figure 2). The Shuttle Radar Topography Mission (SRTM) (Rodrıguez et al. 2005) elevation raster and the Terra and Aqua combined Moderate Resolution Imaging Spectroradiometer (MODIS), MCD12Q1 (Friedl & Sulla-Menashe 2019) land cover type was also used in the study and LULC map is prepared. The products give yearly intervals of global land cover categories (2001-2018). In the study, a classification scheme based on the leaf area index (Friedl & Sulla-Menashe 2019) was applied. Leaf area index in a classification scheme for categorizing land cover types based on the amount of leaf area per unit ground area. It also measures the density and structure of vegetation which affects the exchange of energy, water and carbon between the land surface and the atmosphere.

RESULTS AND DISCUSSION

Habitat

In our study, it was observed that the Baya Weaver prefers to make nests in trees located near grasslands and wet plains where there is standing water or small pools to forage for food. They also thrive in wetlands and cultivated areas. During the field visits, it was observed that this species mostly occupies trees in agricultural fields and even few pockets of urban settings (Figure 3). It is common to observe the bird creating huge loosely woven, roof-like nests made of dried leaves, grass, and coconut fronds out of its environment (Davis 1974). The nests are usually located in shrubs, trees, and other tall vegetation. These nests (Image 1) provide ideal shelter for them and also help in attracting a mate. The Baya Weaver also has a preference for nesting near other birds, which helps in its defense if it comes under attack by predators (Street et al. 2022). They are also found in large flocks during migratory season, due to their go-it-alone personalities.

Spatial modelling

Identifying and charting the spatial distribution of species is a critical element of any zoogeographical investigation. It gives us a great insight into the current habitats of species many of which are now facing severe threats from a human-altered harsh environment. Owing to human activities and the growing pressure of human populations put on habitats, many species are becoming threatened. As such, a GIS based study has been applied to gain an understanding of the potential distribution of species in and around the Nagaon District of Assam. The habitat suitability map generated by Maxent in GIS was based on selected environmental parameters. The results showed by the maxent model suggest that among these environmental variable number 17 (Precipitation of Driest Quarter), 14 (Precipitation of Driest Month), slope and land use have 38.3,21.6, 24.7, and 5.7 percent contribution. Pearson's correlation coefficient (r) was used to conduct multicollinearity test (Mehmud et al. 2022) for the region of Assam. The test AUC and training AUC of the maxent model is 0.99. The importance of environmental variable can be identified by looking at the Jackknife test (Figure 4). Maximum iteration was set to 1,000 for the analysis.

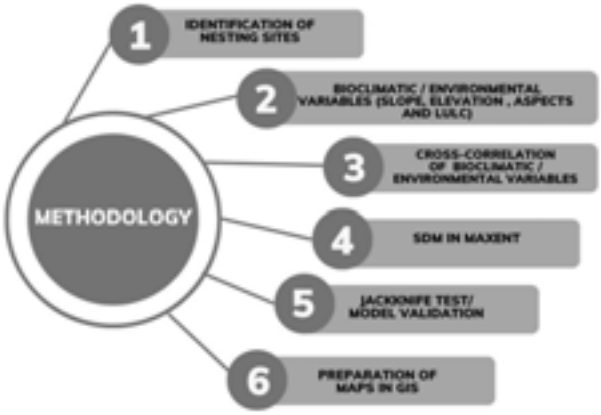

Figure 2. Methodology used in species distribution modelling of Baya Weaver..

The potential habitat (Figure 3) suitable for the nesting sites of Baya Weaver is estimated from the model within the periphery of the availability of water sources. The model also suggests that the rainfall in the driest quarter and rainfall in the driest month are a significant role in the spatial distribution of the said bird species. Out of the total area of 3,975 km^2, 596.86 km^2 (15%) area is demarcated as a good and high-potential area. Using the map as a guide, another field visit was conducted and discovered a few colonies in and around the areas identified as suitable. One of the observations was that, in one location, it was found nesting in banyan trees, rather than the more common tree species of *Areca* Palm.

CONCLUSION

The zoogeographical analysis of Baya Weaver in Nagaon District of Assam was aimed to detect the optimum environment for its favorable distribution and viable long-term conservation. The study showed that anthropogenic land-cover such as agriculture, water bodies and infrastructure play significant roles in determining the potential range of the bird species. In addition, precipitation of driest quarter (bio 17) and precipitation of driest month (bio 14) were also found to be suitable for the species. The associated vegetation cover of the habitat played an important role in the increased number of individuals and their distribution area as observed from the Land use and land cover map and field visits. These findings clearly demonstrate the importance of robust species conservation models for Baya Weaver in Nagaon. Therefore, this study provides a useful perspective on determining landscape features in order to conserve this species in the future. This study represents the first zoogeographical investigation into habitat suitability mapping of Baya Weaver in the Nagaon region of Assam. It provides researchers with valuable insights into the potential locations of said

Image 1. Nesting sites of Baya Weaver in various locations of Nagaon district of Assam, India. © N. Bora.

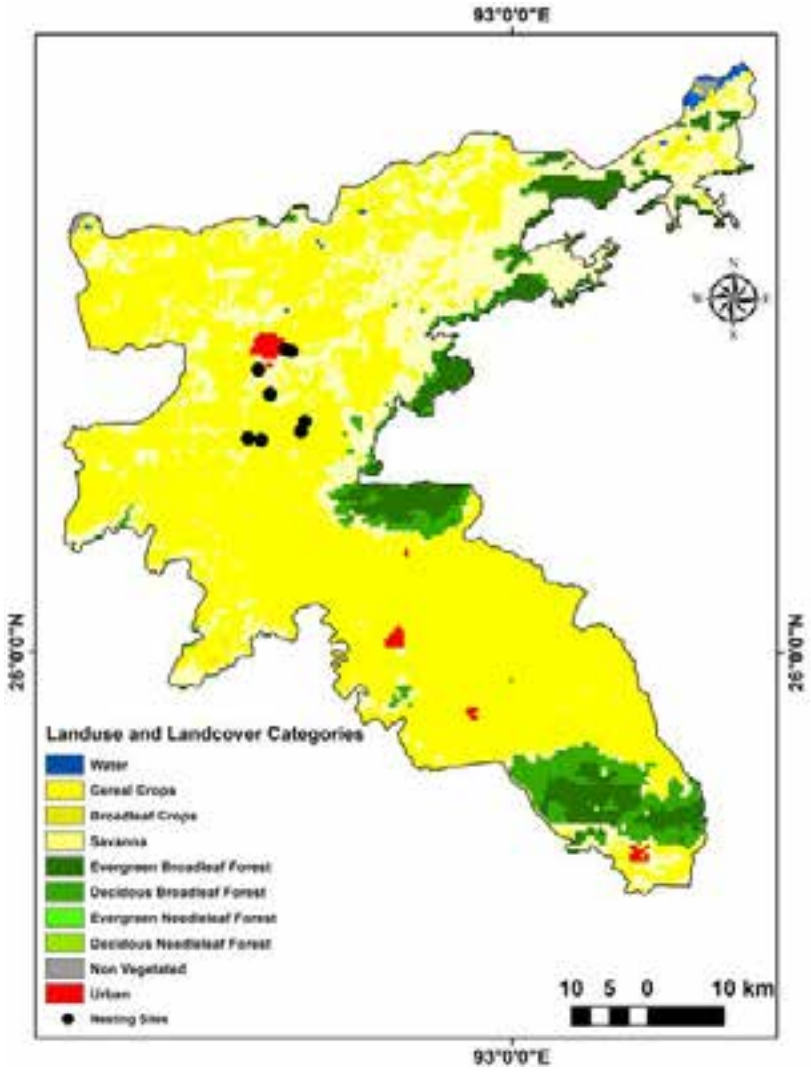

Figure 3. Land use and land cover map of the study area with location of nesting sites.

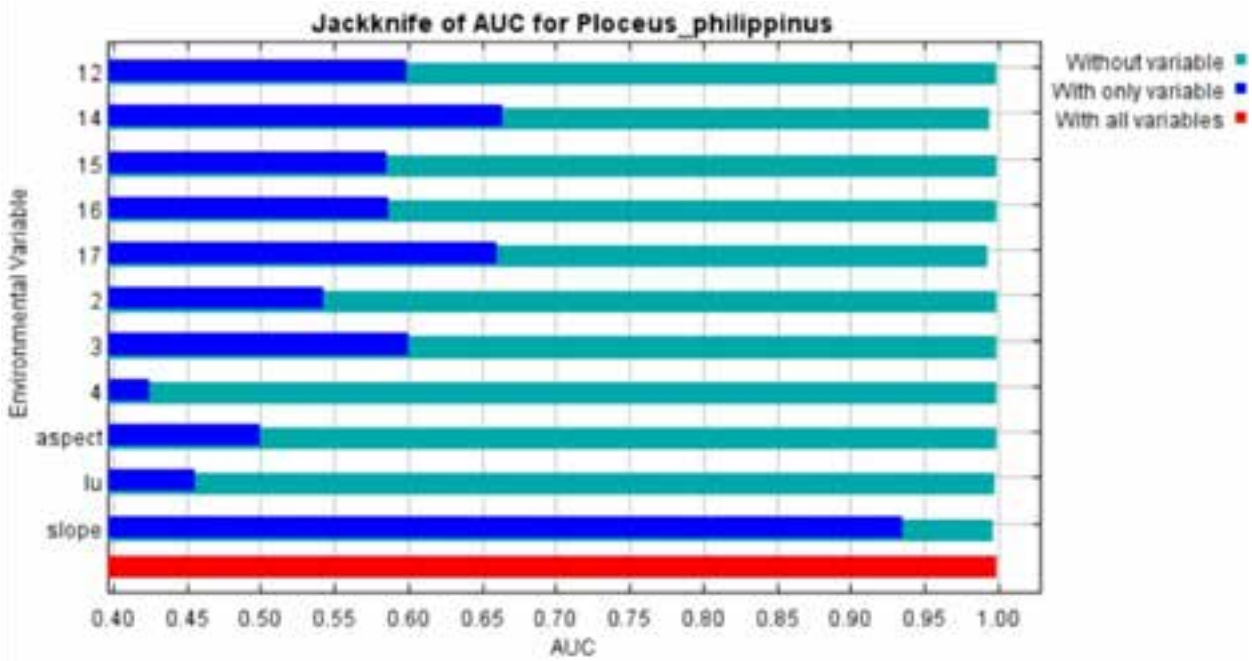

Figure 4. Jackknife test of environmental variables used in Maxent model.

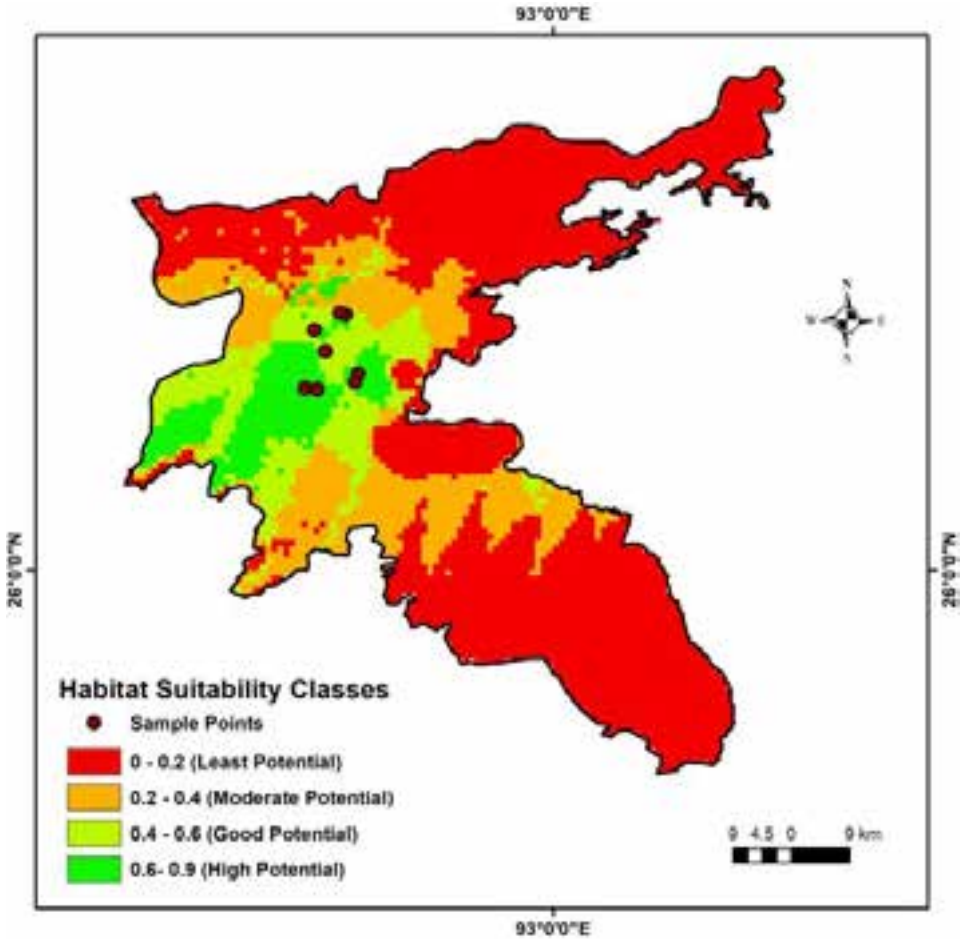

Figure 5. Habitat suitability map of Baya Weaver *Ploceus philippinus* in Nagaon District in Assam.

bird species in the area, utilizing bioclimatic variables. Subsequent research endeavors can build upon this habitat mapping to explore the reasons behind the low geographical coverage (15 % geographical area) of Baya Weaver population in the region.

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COMMUNICATION

Diversity and species richness of avian fauna in varied habitats of Soraipung range and vicinity in Dehing Patkai National Park, India

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Abstract: Dehing Patkai National Park, nestled in Assam's Upper Brahmaputra valley, features a distinctive lowland forest landscape dominated by *Dipterocarpus* trees, teeming with fauna encompassing reptiles, birds, and mammals. Avian surveys were conducted from October 2021 to September 2023 to document avifaunal diversity within and surrounding the park. Point-transect method was used. One-hundred-and-fifty-one species from 54 families were recorded, including 43 terrestrial and 11 aquatic bird families. One-hundred-and twenty-seven species were residents, 18 winter migrants, five summer migrants, and one was a local migrant. Habitat disturbance was assessed across five transects; undisturbed habitats in T1 and T2 showed the highest Shannon-Wiener diversity index, while moderately and highly disturbed habitats in T3, T4, and T5 exhibited lower diversity. The analysis revealed a significant positive correlation ($p \leq 0.05$) among different transects. A total of seven species (Ashy-headed Green Pigeon, Lesser Adjutant, White-cheeked Partridge, Alexandrine Parakeet, Red-breasted Parakeet, Austen's Brown Hornbill, and Oriental Darter) are classified as 'Near Threatened' in the IUCN Red List of Threatened species; 12 species are in Schedule 1 under the Wildlife (Protection) Act, 1972. This investigation underscores Dehing Patkai National Park's significance as a sanctuary for diverse bird populations, including threatened and near-threatened species. The decline in bird populations in disturbed areas emphasizes the urgency of implementing effective conservation and management strategies within the park, alongside continued research and monitoring to support its unique avian ecosystem.

Keywords: Avian fauna, climate change, community, ecosystem, degradation, forest, migratory, northeastern India, resident, undisturbed.

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Competing interests: The authors declare no competing interests.

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Author contributions: Conceptualization: AD and AP; Data collection: AB, SB, NJH and SS; Formal analysis: AB and SB; Investigation: AD; Methodology: AB and AD; Software: SB, NJH, SS and BT; Supervision: AD, AP, NG and SH; Validation: AD and AP; Visualization: AD and AP; Writing-original draft: AB and SB; Writing- review and editing: AB, AD and SB. All authors read and approved the final manuscript.

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INTRODUCTION

Avian fauna contribute to direct and indirect ecological processes in forest ecosystems. The most significant contributions are pest control and seed dispersal during forest regeneration. Their cosmopolitan nature allows birds to traverse different habitats, from open forests to dense woodlands, deserts to mountains, in search of sustenance, shelter, and reproductive sites (Morrison 1986; Koli 2014; Zakaria et al. 2016). It was reported that 77.9% of threatened bird species are supported by forest habitat (BirdLife International 2017). Among different tropical forests, lowland rainforest has a large variety of species diversity, and it provides all the necessaries to complete the life cycle of birds (Stratford & Şekercioğlu 2015). In India, a total of 942 bird species have been reported in 2023 and based on conservation priority for India, 178 species are under high priority, 323 are moderate priority. and 441 categorize as low priority (SoIB 2023). Sirur (2023) reported approximately 60% of the bird species have decline over a period of 30 year which might be attributed to decreasing ecosystem functionality, limited resource availability, or the decline of habitats. The impacts of climate change, habitat fragmentation, drought, and weather conditions are considered the most severe and widespread threats to declining bird population size that affect directly or indirectly the entire bird community (Janzen 1986; Murphy 1988; Lubchenco et al. 1991; Hannah et al. 1994; Sintayehu 2018). Hence studying the avian diversity, distribution patterns, and their ecological associations holds a significant contribution in relation to comprehend overall conservation of habitat and species diversity.

The northeastern region of India is home to a wide range of ecosystems, such as forests, grasslands, and wetlands, which include marshes, swamps, wetlands, beels, lakes, streams, and rivers. Due to its diverse topography and forest types, the northeastern region of India is home to a vast array of faunal diversity, including mammals, birds, reptiles, and associated species. Amidst the variety of forests in northeastern India, Dehing Patkai National Park, is characterized by lowland tropical forests predominantly dominated by Dipterocarpus in the Upper Brahmaputra valley of Assam, India. The region is considered one of the most species-rich regions in the Indian Subcontinent and is an important part of the Indo Myanmar bio-diversity hotspots (Gogoi et al. 2023). The park encompasses diversity of faunal species and fosters a rich variety of avifaunal species. However, despite the richness in faunal diversity of the national park, comprehensive studies on avian fauna are crucially lacking. While previous studies have been conducted on avian species compositions in various habitats of northeastern India (Ali et al. 1983; Choudhury 1998; Saikia & Saikia 2000; Chatterjee 2006; Mize et al. 2014; Chakdar et al. 2016; Chandra et al. 2021; Mahanta et al. 2022; Rahmani et al. 2023). However, there remains a lack of data regarding the species composition of the avian fauna from Dehing Patkai National Park. Lack of such avian database highlights a research gap in the current knowledge and stresses the necessity for thorough avian studies to better understand and conserve the bird species within the national park. The present study aims to document and analyze the species richness and diversity of avian fauna present within and around the Dehing Patkai National Park. By specifically studying the varied habitats, the study endeavours to unveil if there are any differences in avian species composition in different disturbances gradient.

MATERIALS AND METHODS

Study site

The Dehing Patkai Landscape is situated between the Tinsukia and Dibrugarh districts of Assam. It underwent a significant transformation on 9 June 2021. Formerly recognized as the Dehing Patkai Wildlife Sanctuary, it was officially upgraded to the status of a national park by the forest department of Assam. The present investigation has been carried out in the Soraipung Range and its areas within the Dehing Patkai Landscape, i.e., Digboi- Duliyajan highway passes through the adjacent areas of Soraipung range (Figure 1). The surveys were conducted between October 2021 and September 2023. Located at coordinates 27.299°N and 95.516°E, the entire landscape boasts a vast lowland rainforest dominated by *Dipterocarpus*, covering an approximate area of 231.6 km^2. Being a rainforest, this national park is rich in biodiversity status encompassing different strata providing a great environment for non-human primates like Slow Loris, Assamese Macaque, Stump-tailed Macaque, Pig-tailed Macaque, Rhesus Macaque, Capped Langur, and Hoolock Gibbon. With a tropical climate, the national park experiences an average annual rainfall of around 4,000 mm and forms the largest stretch of tropical lowland rainforest in India (Ahmed 2023). The dominant and essential tree species of the study area are *Dipterocarpus retusus*, *Mesua ferrea*, *Castanopsis indica*, *Vatica lanceaefolia*, *Shorea assamica*, *Delonix regia*, *Shorea robusta*, *Dillenia indica* and *Amoora*

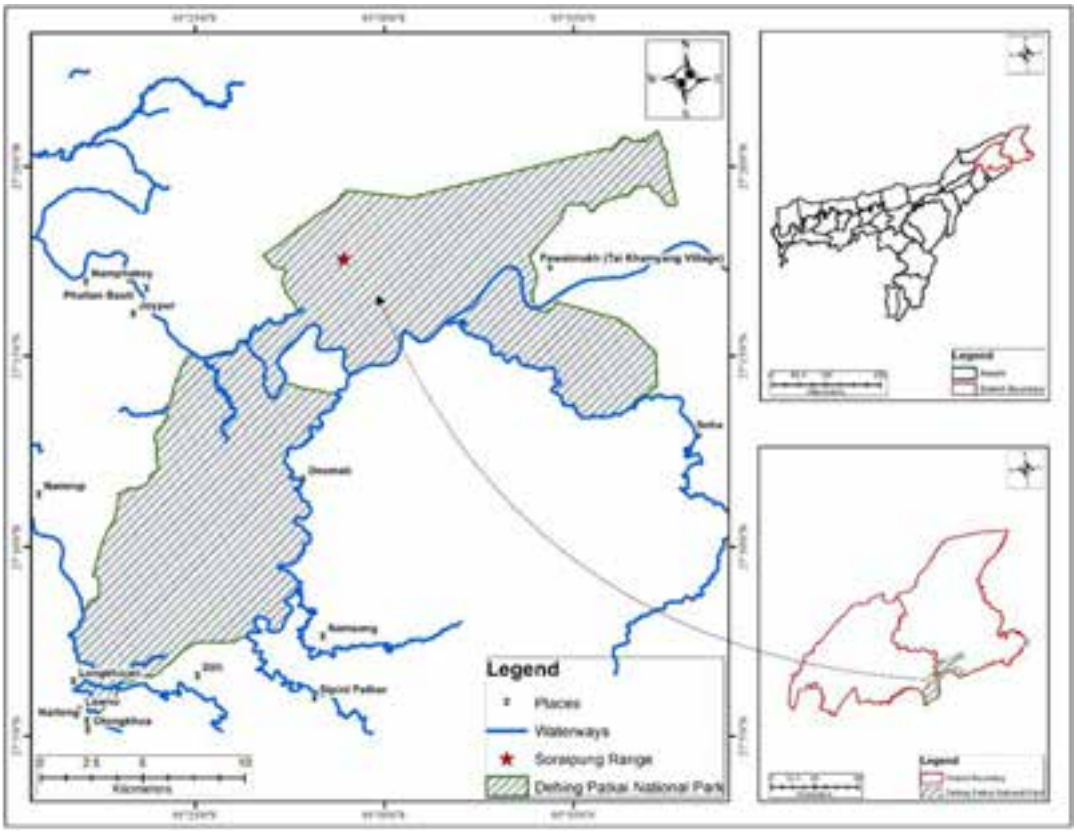

Figure 1. Map showing the Soraipung Range of Dehing Patkai National Park.

wallichii. The shrubs and herbs layers include species such as *Lantana camera*, *Ipomea species*, wild banana, ground and epiphytic ferns and wild pepper.

Methods

The bird surveys were carried out in the selected sites from October 2021 to September 2023 using point-transect method (Kumar & Sahu 2020). Three different habitats were selected for the study based on disturbance gradients which include undisturbed habitat (T1 and T2), moderately disturbed habitat (T3 and T4) and highly disturbed habitat (T5) shown in Table 1. The transects T1, T2, T3, T4, and T5 were randomly established in three different habitats. The transacts T1 and T2 are laid inside the forest of undisturbed natural habitats which are not significantly impacted by anthropogenic pressure. The transects T3 and T4 are in moderately disturbed habitats characterized adjacent to the forest of national park spreading across paddy fields and sporadic vegetation patches that support large number of grassland-dwelling birds. The transect T5 is in highly affected area by human activities like construction of roads, oil pipelines establishment and vehicular movement. In order to determine the species compositions in these habitats a total of 15 sampling points (S1, S2, S3, S4, S5, S6, S7, S8, S9, S10, S11, S12, S13, S14, and S15) were established on the transects, each transect with three sampling points and these points were surveyed at bi-monthly intervals. The surveys were carried out during peak periods in the early morning (0500–1030 h) and late evening (1530–1830 h). The birds were observed with the help of field binoculars (10 x 8) and a Nikon D3300 DSLR camera. A global positioning system (GPS) was used to designate the locations and save the tracks (Kazmierczak & Van Perlo 2009; Tiwari 2021). The identification of avian fauna was done consulting field guidebooks (Ali et al. 1983; Grimmett et al. 1999). The recorded avifauna is classified into distinct categories based on their frequency of occurrence (Saikia & Saikia 2000; Devi et al. 2012). During the survey, the species that are frequently observed in each transect are categorized as C-common, with a frequency of eight times out of 10 survey period. On the other hand, species that are encountered less frequently are categorized as r-rare, with a frequency of one or two times out of 10 surveys. The species found within the study area are referred to as R-resident. Additionally, species that are exclusively encountered during the winter season within the habitat are denoted

as WM-winter migratory. Similarly, species that are exclusively encountered in the summer season within the habitat, referred to as SM-summer migratory. Lastly, species that migrate locally within the area are referred as LM-local migratory.

Data analysis

The species richness is determined by the number of species found in each transect.

Shannon diversity index (H'; Shannon & Wiener 1964) was used to determine the species diversity,

$H' = -\Sigma pi * \ln(pi)$

where pi = the proportion of the entire community made up of species i

Species evenness (E; Pielou 1966) was calculated using the formula,

$E = H'/\ln(s)$.

where s = the species richness (total number of species).

Pearson's correlation coefficient was used to statistically assess the correlation between the transects. Pearson's correlation coefficient was carried out in IBM SPSS Statistics 21 and figures were created in Microsoft Excel spreadsheet 2021.

RESULTS

In the Soraipung range and its adjacent area of Dehing Patkai National Park, a total of 3,630 individuals of avian fauna were encountered from 151 species (Appendix 1). The recorded species belonged to 54 different families, of which 43 families are terrestrial and 11 families are aquatic in nature. Out of 151 species, 114 species (1,887 individuals) were recorded from undisturbed habitats (T1 and T2), 106 species (1,382 individuals) from moderately disturbed habitats (T3 and T4), and 59 species (361 individuals) from disturbed habitat (T5). A total 26 species (17.22%) of birds are found common in all the three study sites, undisturbed, moderately disturbed and disturbed habitats. The Shannon-Weiner diversity index (H'), which measures diversity in terms of the number of species range from 3.66 (T5) to 4.25 (T1). Pielou's evenness index also showed a variation in different transects which range from 0.61 to 0.66 (Table 2). When comparing the diversity indices, it was observed that undisturbed habitats in T1 and T2 exhibited higher species diversity compared to the moderately and highly disturbed habitats in T3, T4, and T5 (Figure 2). The Pearson correlation between the transects showed a strong highly significant positive relation ($p \leq 0.05$) (Table 3).

The families of Accipitridae, Columbidae, Ardeidae, Dicruridae, Pycnonotidae, Sturnidae, Corvidae, and Megalaimidae (Figure 3) which comprised the vast majority of the resident birds observed in the study area. Among the total 151 species, 127 species are recorded as resident birds (R). In addition, the study also recorded 18 species as winter migratory (WM), five species of birds are summer migratory (SM), and one species is categorized as a local migratory (LM) bird (Figure 4). From 151 bird species, it was found that 128 species were common, followed by 14 species as rare, five species as most common, and four species as occasional (sporadically encountered). Similarly, the migratory birds that visit the study area during both the winter and summer seasons were classified as rare (R), occasional (O) and common (C) species. The winter and summer migrant species were identified from the families of Muscicapidae, Cuculidae, Laniidae, Motacillidae, Scolopacidae, Bucerotidae, Phylloscopidae, Turdidae, Cettiidae, and Pittidae. While, there is just one species of Muscicapidae family among local migrants in the study area. Overall, from the studied habitats, Muscicapidae family exhibits the highest species (11), followed by Cuculidae, which is the second largest family with nine species, the Columbidae with eight species represents the third largest family, and Accipitridae the fourth largest family with seven species.

As per the IUCN Red List of Threatened Species, seven species (Ashy-headed Green Pigeon *Treron phayrei*, Lesser Adjutant *Leptoptilos javanicus*, White-cheeked Partridge *Arborophila atrogularis*, Alexandrine Parakeet *Psittacula eupatria*, Red-breasted Parakeet *Psittacula alexandri*, Austen's Brown Hornbill *Anorrhinus austeni*, and Oriental Darter *Anhinha melanogaster*) are 'Near Threatened'; the rest are 'Least Concern' (Appendix 1). Twelve species are recorded in Schedule 1 under the Indian Wildlife (Protection) Act, 1972.

DISCUSSION

The present study was carried out in Dehing Patkai National Park, which exhibits a significant richness of avian species in terms of diversity status. A comprehensive understanding of avian fauna in these habitats, particularly in and around the Soraipung range of the national park provides crucial insights into the diversity and population status of avian species. It has been asserted that biodiversity of the rainforest is relatively higher than that of the other protected areas

Table 1. Descriptions of transect lines used during the survey of avian fauna in Dehing Patkai National Park, Assam.

Transect	Descriptions	Dominant vegetation
Transect 1 (T1): Undisturbed and natural forest	Hollong-dominated landscape with woodland, streams, open land, and shrublands.	*Dipterocarpus retusus*, *Mesua ferrea*, *Castanopsis indica*, *Shorea assamica*, *Vatica lanceaefolia*, *Shorea robusta*, and *Dillenia indica*.
Transect 2 (T2): Undisturbed and natural Forest	Hollong-dominated landscape with woodland, scrublands, and streams.	*Dipterocarpus retusus*, *Castanopsis indica*, and *Vatica lanceaefolia*
Transect 3 (T3): Moderately disturbed	Human-dominated landscape with agricultural land, scrubland, and a few small ponds and cannels.	*Dipterocarpus retusus*, *Dipterocarpus macrocarpus, Ficus religiosa*, and *Ficus rumphii*
Transect 4 (T4): Moderately disturbed	Human-dominated landscape with water and a few small ponds.	*Dipterocarpus retusus*, *Mesua ferrea*, *Delonix regia*, *Shorea robusta*, and *Dillenia indica*.
Transect 5 (T5): Highly disturbed human-dominated	Landscape along the national highway.	*Dipterocarpus macrocarpus*, *Mesua ferrea*, *Shorea assamica*, *Delonix regia*, *Shorea robusta*, and *Dillenia indica*.

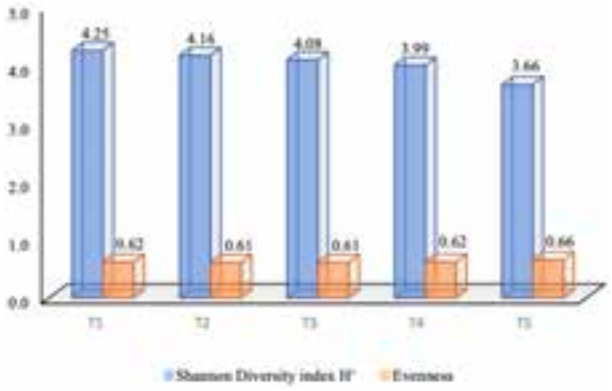

Figure 2. Diversity indices of birds recorded along different transect within Dehing Patkai National Park.

Table 2. Shannon diversity index and species evenness of birds recorded from the study sites with a 5% level of significance.

Transects	Shannon diversity index H'	Lower 95%	Upper 95%	Evenness
T1	4.25	4.17	4.26	0.62
T2	4.16	4.08	4.18	0.61
T3	4.08	4.03	4.13	0.61
T4	3.99	3.91	4.03	0.62
T5	3.66	3.56	3.74	0.66

Table 3. Correlation between different transect studied in Dehing Patkai National Park.

Habitat	T1	T2	T3	T4
T2	0.872**			
T3	0.266**	0.316**		
T4	0.325**	0.424**	0.827**	
T5	0.196*	0.223*	0.582**	0.597**

(Beehler et al. 1987). The study reveals that the family Muscicapidae is more abundant than other bird families which is similar to the findings of Rai et al. (2017), wherein the Muscicapidae family contributed the most species of terrestrial birds to the Basai wetlands in Haryana. Similarly, Mize et al. (2014), reported that the family Muscicapidae was dominant in Dehing-Dibang Biosphere Reserve. This prevalence of Muscicapidae family could be attributed to their wide adaptability across various habitats including forests, grassland, and agricultural fields, making them primarily dependent on small insectivores. The findings of the present study indicates that the highest species diversity exists in the least disturbed areas (T1 and T2), followed by the moderately disturbed (T3 and T4) and severely disturbed areas (T5). Similar trends were reported by Devi et al. (2012) at the Gauhati University Campus, and Nidup & Gyeltshen (2021) in the disturbed and undisturbed winter forests of Gogona Forest Management Unit of Bhutan. A significant positive correlation was observed among transects in different habitats, potentially due to the coexistence of closely related species across the transect lines. The presence of 26 'common' species in all the three studied habitats can be attributed to their adaptability to diverse conditions including, adequate food sources, suitable shelter, favourable climate, and essential resources. The varied strata within the national park, encompassing natural woodlands, grasslands, shrublands, water bodies, and diverse climatic conditions, contribute to its overall diversity. Large trees within the habitat provide nesting locations and abundant food sources, particularly in undisturbed areas. Notably, forest degradation and habitat loss impact species distribution leading to 'rare' occurrences of species, such as the Asian Koel, Cuckoo, Kingfishers, and Rollers. These remote bird species are quite comparable to those reported from earlier research in northeastern region of India (Saikia & Saikia 2000; Choudhury 2000).

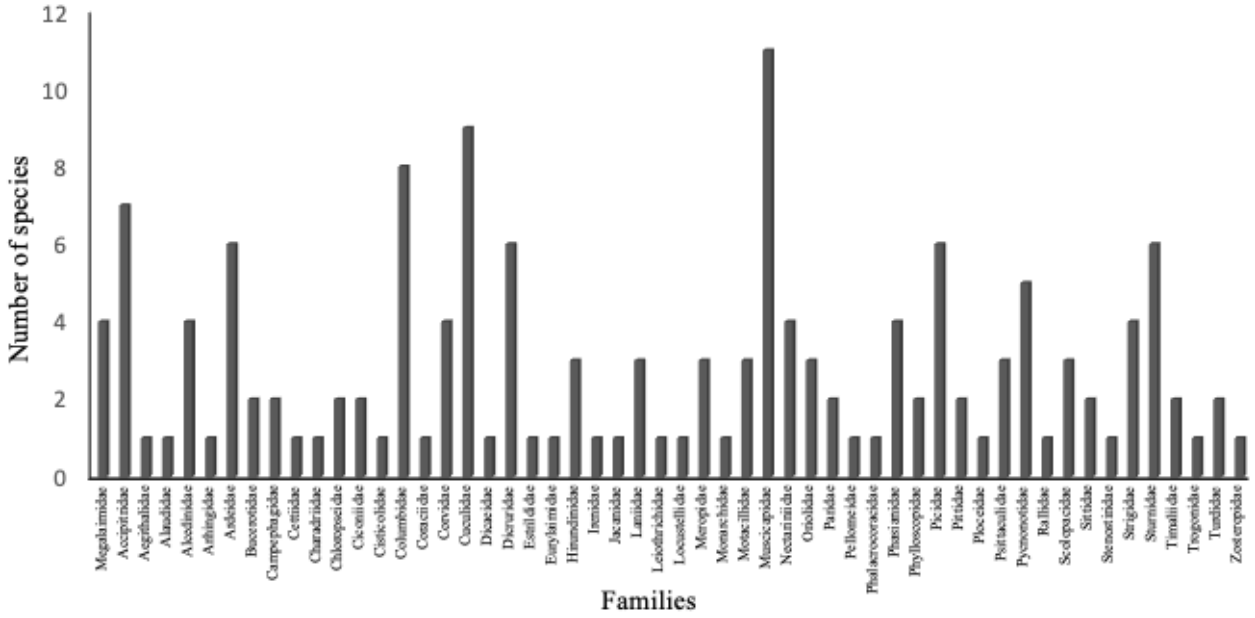

Figure 3. Bar diagram representing the distribution of avian fauna in different families.

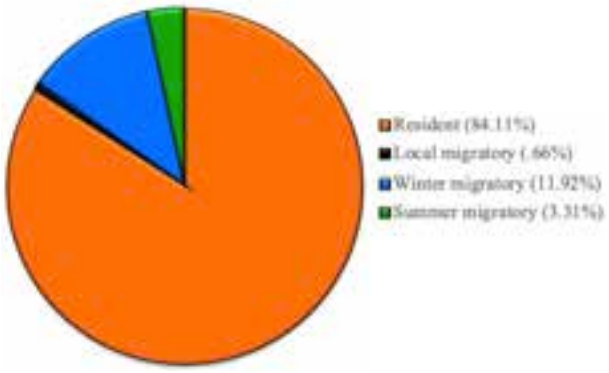

Figure 4. Pie chart showing the current residential status of avian species.

The findings were also reported by Sauvajot et al. (1998) and Jain et al. (2005) where they found that birds are sensitive to their surroundings, and changes in the local vegetation can have an impact on the bird population. The presence of Oriental Magpie-robin, Jungle Myna, Common Myna, Red-vented Bulbul, Spotted Dove, Cattle Egret, Large-billed Crow, Black-hooded Oriole, Cinereous Tit, Little Cormorant, Black Kite, Fulvous-breasted Woodpecker, Barn Swallow, and Asian Koel in human-dominated and disturbed habitats (T3, T4, and T5) is attributed to their remarkable adaptability to urban and peri-urban landscapes.

However, it is concerning that disturbed areas display a significant decline in diversity, with direct human disturbance and expanding urbanization identified as major factors. Habitat fragmentation, road construction, oil mining, and increased vehicle traffic along the national highway may contribute to the observed decline. Human activities, including hunting and fishing, also pose threats to the natural habitat of avian fauna. The noise and disturbance activities have the potential to disrupt the behaviour of birds, leading to alterations in their breeding, feeding, and communication patterns. Shahabuddin & Kumar (2006), Morris (2010), and Prabhakar et al. (2020) also noted that factors such as rapidly changing demography and changes in traditional natural resource management practises are areas of concern and large-scale development projects affects the composition of avian diversity.

CONCLUSION

The study has exhibited that the diversity of avian fauna in Dehing Patkai National Park varies with its habitat and is influenced by the characteristics of its environment. The documentation of 151 species including seven 'Near Threatened' species, highlights the park's crucial role as an ecosystem supporting a broad spectrum of bird species. Despite the park's capacity to support a variety of avian fauna including migratory birds, there is noticeable decline in their numbers particularly in areas characterised by high disturbance levels. The main factors contributing to declination of bird species are excessive human activity and habitat deterioration.

Hence, the disparity in species diversity between disturbed and undisturbed areas poses a substantial threat to the potential extinction of certain species in the future. As a result of decrease of avian diversity, the physical characteristics of natural ecosystems in the present study area may change. Therefore, it is imperative to established effective management strategies in order to safeguard the conservation of the habitats and overall biodiversity of the national park. The implementation of long-term management plans integrating the indigenous knowledge of local community and encouraging their participation in habitat restoration practices, is crucial in formulating sustainable conservation strategies. Also, monitoring on the population status, resilience, and behavioural changes will aid in conservation of threatened and vulnerable species.

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Appendix 1. Checklist of avian fauna recorded in the Soraipung range of Dehing Patkai National Park.

	Common name	Scientific name	Family	WPA 1972	IUCN Red List status	Status and abundance	Habitat
1	Black-backed Forktail	*Enicurus immaculatus*	Muscicapidae	Sch II	LC	R, C	RS/SL
2	Black Redstart	*Phoenicurus ochruros*		Sch II	LC	WM, r	CL/ RS
3	Blue Whistling Thrush	*Myophonus caeruleus*		Sch II	LC	R, C	NF
4	Oriental Magpie-robin	*Copsychus saularis*		Sch II	LC	R, MC	RS
5	Pale Blue Flycatcher	*Cyornis unicolor*		Sch II	LC	R, C	NF/SL
6	Pied Bush Chat	*Saxicola caprata*		Sch II	LC	LM, r	CL/ GL
7	Pygmy Flycatcher	*Ficedula hodgsoni*		Sch II	LC	R, C	NF/SL
8	Siberian Stonechat	*Saxicola maurus*		Sch II	LC	WM, C	GL
9	Taiga Flycatcher	*Ficedula albicilla*		Sch II	LC	WM, O	RS/ NF
10	Verditer Flycatcher	*Eumyias thalassinus*		Sch II	LC	WM, r	NF
11	White-rumped Shama	*Copsychus malabaricus*		Sch II	LC	SM, C	SL/ GL
12	Asian Koel	*Eudynamys scolopaceus*	Cuculidae	Sch II	LC	R, C	NF
13	Banded Bay Cuckoo	*Cacomantis sonneratii*		Sch II	LC	R, C	NF
14	Common Cuckoo	*Cuculus canorus*		Sch II	LC	WM, r	NF
15	Common Hawk-cuckoo	*Hierococcyx varius*		Sch II	LC	R, r	NF/ RS
16	Greater Coucal	*Centropus sinensis*		Sch II	LC	R, C	GL
17	Green-billed Malkoha	*Phaenicophaeus tristis*		Sch II	LC	R, C	NF/RS
18	Hodgson's Hawk-cuckoo	*Hierococcyx nisicolor*		Sch II	LC	R, r	NF
19	Lesser Coucal	*Centropus bengalensis*		Sch II	LC	R, C	GL
20	Plaintive Cuckoo	*Cacomantis merulinus*		Sch II	LC	R, C	NF
21	Ashy-headed Green Pigeon	*Treron phayrei*	Columbidae	Sch II	NT	R, r	NF
22	Common Emerald Dove	*Chalcophaps indica*		Sch II	LC	R, r	NF
23	Oriental Turtle Dove	*Streptopelia orientalis*		Sch II	LC	R, C	NF/ RS
24	Pin-tailed Green Pigeon	*Treron apicauda*		Sch II	LC	R, r	NF
25	Red-collared Dove	*Streptopelia tranquebarica*		Sch II	LC	R, C	RS
26	Spotted Dove	*Spilopelia chinensis*		Sch II	LC	R, C	SA/ RS
27	Thick-billed Green Pigeon	*Treron curvirostra*		Sch II	LC	R, r	NF
28	Yellow-footed Green Pigeon	*Treron phoenicopterus*		Sch II	LC	R, C	NF/ RS/ SA
29	Besra	*Accipiter virgatus*	Accipitridae	Sch I	LC	R, C	NF/ SA
30	Black Kite	*Milvus migrans*		Sch II	LC	R, C	RS/ NF
31	Black-winged Kite	*Elanus caeruleus*		Sch II	LC	R, C	RS/ NF
32	Crested Honey Buzzard	*Pernis ptilorhynchus*		Sch II	LC	R, C	NF
33	Crested Serpent Eagle	*Spilornis cheela*		Sch I	LC	R, C	NF
34	Eurasian Sparrowhawk	*Accipiter nisus*		Sch I	LC	R, C	SA
35	Shikra	*Accipiter badius*		Sch I	LC	R, C	RS/ NF
36	Cattle Egret	*Bubulcus ibis*	Ardeidae	Sch II	LC	R, C	WB/RS/SA
37	Cinnamon Bittern	*Ixobrychus cinnamomeus*		Sch I	LC	R, C	SL
38	Indian Pond Heron	*Ardeola grayii*		Sch II	LC	R, C	WB/ RS/CL
39	Intermediate Egret	*Ardea intermedia*		Sch II	LC	R, C	WB/ CL
40	Little Egret	*Egretta garzetta*		Sch II	LC	R, r	WB
41	Purple Heron	*Ardea purpurea*		Sch II	LC	R, C	WB/ CL

	Common name	Scientific name	Family	WPA 1972	IUCN Red List status	Status and abundance	Habitat
42	Ashy Drongo	*Dicrurus leucophaeus*	Dicruridae	Sch II	LC	R, C	NF
43	Black Drongo	*Dicrurus macrocercus*		Sch II	LC	R, MC	NF/ RS/ SA
44	Bronzed Drongo	*Dicrurus aeneus*		Sch II	LC	R, C	NF
45	Greater Racket-tailed Drongo	*Dicrurus paradiseus*		Sch II	LC	R, r	NF
46	Lesser Racket-tailed Drongo	*Dicrurus remifer*		Sch II	LC	R, r	NF
47	Spangled Drongo	*Dicrurus bracteatus*		Sch II	LC	R, C	NF
48	Chestnut-tailed Starling	*Sturnia malbarica*	Sturnidae	Sch II	LC	R, C	NF/ RS
49	Common Hill Myna	*Gracula religiosa*		Sch I	LC	R, C	NF
50	Common Myna	*Acridotheres tristis*		Sch II	LC	R, MC	RS/SA
51	Great Myna	*Acridotheres grandis*		Sch II	LC	R, C	GL/RS
52	Indian Pied Myna	*Gracupica contra*		Sch II	LC	R, MC	RS/ SA
53	Jungle Myna	*Acridotheres fuscus*		Sch II	LC	R, C	SA/RS
54	Black-rumped Flameback	*Dinopium benghalense*	Picidae	Sch II	LC	R, C	NF/RS
55	Bay Woodpecker	*Blythipicus pyrrhotis*		Sch II	LC	R, r	NF
56	Greater Yellownape	*Chrysophlegma flavinucha*		Sch II	LC	R, C	NF
57	Grey-capped Pygmy Woodpecker	*Yungipicus canicapillus*		Sch II	LC	R, C	NF/RS
58	Fulvous-breasted Woodpecker	*Dendrocopos macei*		Sch II	LC	R, r	NF/RS
59	Speckled Piculet	*Picumnus innominatus*		Sch II	LC	R, C	NF/RS
60	Ashy Bulbul	*Hemixos flavala*	Pycnonotidae	Sch II	LC	R, C	NF
61	Black-crested Bulbul	*Pycnonotus flaviventris*		Sch II	LC	R, C	NF
62	Red-vented Bulbul	*Pycnonotus cafer*		Sch II	LC	R, MC	SA/RS
63	Red-whiskered Bulbul	*Pycnonotus jocosus*		Sch II	LC	R, C	NF
64	White-throated Bulbul	*Alophoixus flaveolus*		Sch II	LC	R, r	NF
65	Blue-eared Kingfisher	*Alcedo meninting*	Alcedinidae	Sch II	LC	R, C	WB/RS
66	Common Kingfisher	*Alcedo atthis*		Sch II	LC	R, C	WB
67	Oriental Dwarf Kingfisher	*Ceyx erithaca*		Sch II	LC	R, r	NF/WB
68	White-throated Kingfisher	*Halcyon smyrnensis*		Sch II	LC	R, MC	SA/WB
69	Common Green Magpie	*Cissa chinensis*	Corvidae	Sch II	LC	R, C	NF/RS
70	Grey Treepie	*Dendrocitta formosae*		Sch II	LC	R, r	NF
71	Large-billed Crow	*Corvus macrorhynchos*		Sch II	LC	R, C	SA/RS
72	Rufous Treepie	*Dendrocitta vagabunda*		Sch II	LC	R, C	NF/RS/SA
73	Blue-eared Barbet	*Psilopogon cyanotis*	Megalaimidae	Sch II	LC	R, r	NF
74	Blue-throated Barbet	*Psilopogon asiaticus*		Sch II	LC	R, C	NF/SA/RS
75	Coppersmith Barbet	*Psilopogon haemacephalus*		Sch II	LC	R, C	NF/SA/RS
76	Lineated Barbet	*Psilopogon lineatus*		Sch II	LC	R, C	NF
77	Crimson Sunbird	*Aethopyga siparaja*	Nectariniidae	Sch II	LC	R, C	SL
78	Little Spiderhunter	*Arachnothera longirostra*		Sch II	LC	R, C	NF
79	Purple Sunbird	*Cinnyris asiaticus*		Sch II	LC	R, C	NF/SL
80	Streaked Spiderhunter	*Arachnothera magna*		Sch II	LC	R, C	NF
81	Grey Peacock-pheasant	*Polyplectron bicalcaratum*	Phasianidae	Sch I	LC	R, r	NF
82	Kalij Pheasant	*Lophura leucomelanos*		Sch I	LC	R, C	NF/RS
83	Red Junglefowl	*Gallus Gallus*		Sch II	LC	R, C	NF/RS
84	White-cheeked Partridge	*Arborophila atrogularis*		Sch II	NT	R, O	NF

	Common name	Scientific name	Family	WPA 1972	IUCN Red List status	Status and abundance	Habitat
85	Asian Barred Owlet	*Glaucidium cuculoides*	Strigidae	Sch II	LC	R, C	NF/RS
86	Brown Hawk-owl	*Ninox scutulata*		Sch II	LC	R, O	NF
87	Collared Owlet	*Taeniopteryx brodiei*		Sch II	LC	R, r	NF
88	Spotted Owlet	*Athene brama*		Sch II	LC	R, C	SA/RS
89	Asian House Martin	*Delichon dasypus*	Hirundinidae	Sch II	LC	R, r	RS
90	Barn Swallow	*Hirundo rustica*		Sch II	LC	R, C	RS/NF
91	Red-rumped Swallow	*Cecropis daurica*		Sch II	LC	R, C	RS
92	Brown Shrike	*Lanius cristatus*	Laniidae	Sch II	LC	WM, C	CL/GL
93	Grey-backed Shrike	*Lanius tephronotus*		Sch II	LC	WM, C	CL
94	Long-tailed Shrike	*Lanius schach*		Sch II	LC	WM, C	SL/GL
95	Asia Green Bee-eater	*Merops orientalis*	Meropidae	Sch II	LC	R, C	NF/RS
96	Blue-tailed Bee-eater	*Merops philippinus*		Sch II	LC	R, C	NF
97	Chestnut-headed Bee-eater	*Merops leschenaulti*		Sch II	LC	R, r	NF
98	Citrine Wagtail	*Motacilla citreola*	Motacillidae	Sch II	LC	WM, C	RS/GL
99	Rosy Pipit	*Anthus roseatus*		Sch II	LC	WM, C	GL
100	White Wagtail	*Motacilla alba*		Sch II	LC	WM, C	RS/GL
101	Black-hooded Oriole	*Oriolus xanthornus*	Oriolidae	Sch II	LC	R, C	NF/SA/RS
102	Indian Golden Oriole	*Oriolus kundoo*		Sch II	LC	R, C	NF
103	Maroon Oriole	*Oriolus traillii*		Sch II	LC	R, C	NF
104	Alexandrine Parakeet	*Psittacula eupatria*	Psittaculidae	Sch II	NT	R, O	NF
105	Red-breasted Parakeet	*Psittacula alexandri*		Sch II	NT	R, C	NF/RS
106	Rose-ringed Parakeet	*Psittacula krameri*		Sch II	LC	R, C	NF/RS
107	Common Sandpiper	*Actitis hypoleucos*	Scolopacidae	Sch II	LC	WM, C	WB/GL
108	Green Sandpaper	*Tringa ochropus*		Sch II	LC	WM, O	WB
109	Wood Sandpiper	*Tringa glareola*		Sch II	LC	WM, r	WB
110	Austen's Brown Hornbill	*Anorrhinus austeni*	Bucerotidae	Sch I	NT	SM, r	NF/RS
111	Oriental Pied Hornbill	*Anthracoceros albirostris*		Sch I	LC	R, O	NF/RS
112	Scarlet Minivet	*Pericrocotus speciosus*	Campephagidae	Sch II	LC	R, C	NF
113	Small Minivet	*Pericrocotus cinnamomeus*		Sch I	LC	R, C	NF
114	Asian Openbill	*Anastomus oscitans*	Ciconiidae	Sch II	LC	R, C	RS/GL/CL
115	Lesser Adjutant	*Leptoptilos javanicus*		Sch I	NT	R, C	CL
116	Golden-fronted Leafbird	*Chloropsis aurifrons*	Chloropseidae	Sch II	LC	R, C	NF
117	Jordon's Leafbird	*Chloropsis jerdoni*		Sch II	LC	R, C	NF
118	Cinereous Tit	*Parus cinereus*	Paridae	Sch II	LC	R, C	SA/RS/NF
119	Sultan Tit	*Melanochlora sultanea*		Sch II	LC	R, r	NF
120	Blyth's Leaf Warbler	*Phylloscopus reguloides*	Phylloscopidae	Sch II	LC	WM, r	NF/SL
121	Greenish Warbler	*Phylloscopus trochiloides*		Sch II	LC	WM, C	SL
122	Blue-naped Pitta	*Hydrornis nipalensis*	Pittidae	Sch II	LC	R, r	NF/SL
123	Hooded Pitta	*Pitta sordida*		Sch II	LC	SM, r	NF/SL
124	Chestnut-bellied Nuthatch	*Sitta cinnamoventris*	Sittidae	Sch II	LC	R, r	NF
125	Velvet-fronted Nuthatch	*Sitta frontalis*		Sch II	LC	R, C	NF
126	Large Scimitar Babbler	*Erythrogenys hypoleucos*	Timaliidae	Sch II	LC	R, O	SL
127	Pin-striped Tit Babbler	*Mixornis gularis*		Sch II	LC	R, r	NF
128	Green Cochoa	*Cochoa viridis*	Turdidae	Sch II	LC	R, C	NF
129	Orange-headed Thrush	*Geokichla citrina*		Sch II	LC	R, C	NF

	Common name	Scientific name	Family	WPA 1972	IUCN Red List status	Status and abundance	Habitat
130	Common Iora	*Aegithina tiphia*	Aegithainidae	Sch II	LC	R, C	NF/ RS
131	Bengal Bushlark	*Mirafra assamica*	Alaudidae	Sch II	LC	R, C	RS/SL
132	Oriental Darter	*Anhinga melanogaster*	Anhingidae	Sch II	NT	R, O	WB/RS
133	Slaty-bellied Tesia	*Tesia olivea*	Cettiidae	Sch II	LC	R, C	NF
134	Red-wattled Lapwing	*Vanellus indicus*	Charadriidae	Sch II	LC	R, C	GL/RS
135	Common Tailorbird	*Orthotomus sutorius*	Cisticolidae	Sch II	LC	R, C	NF/SL
136	Indochinese Roller	*Coracias affinis*	Coraciidae	Sch II	LC	R, C	RS
137	Scarlet-backed Flowerpecker	*Dicaeum cruentatum*	Dicaeidae	Sch II	LC	R, r	NF
138	Scaly-breasted Munia	*Lonchura punctulata*	Estrildidae	Sch II	LC	R, C	CL/SA/SL
139	Silver-breasted Broadbill	*Serilophus lunatus*	Eurylaimidae	Sch II	LC	R, O	NF
140	Asian Fairy-bluebird	*Irena puella*	Irenidae	Sch II	LC	R, C	NF/SL
141	Bronze-winged Jacana	*Metopidius indicus*	Jacanidae	Sch II	LC	R, C	WB/GL
142	Greater Necklaced Laughingthrush	*Pterorhinus pectoralis*	Leiothrichidae	Sch II	LC	R, r	NF/SL
143	Striated Grassbird	*Megalurus palustris*	Locustellidae	Sch II	LC	R, C	GL/SL
144	Black-naped Monarch	*Hypothymis azurea*	Monarchidae	Sch II	LC	R, C	SL/NF
145	Puff-throated Babbler	*Pellorneum ruficeps*	Pellorneidae	Sch II	LC	R, r	SL/NF
146	Little Cormorant	*Microcarbo niger*	Phalacrocoracidae	Sch II	LC	R, C	WB
147	Baya Weaver	*Ploceus philippinus*	Ploceidae	Sch II	LC	R, C	NF/RS
148	White-breasted Waterhen	*Amaurornis phoenicurus*	Rallidae	Sch II	LC	R, C	WB/SA
149	Grey-headed Canary-flycatcher	*Culicicapa ceylonensis*	Stenostiridae	Sch II	LC	R, C	NF
150	Red-headed Trogon	*Harpactes erythrocephalus*	Trogonidae	Sch II	LC	R, r	NF
151	Indian White-eye	*Zosterops palpebrosus*	Zosteropidae	Sch II	LC	R, C	NF/SA/RS

LC—Least Concern | NT—Near Threatened | C—Common | MC—Most common | R—Resident | O—Occasional | r—Rare | WM—Winter migratory | SM—Summer migratory | LM—Local migratory | RS—Roadside | CL—Cultivated land | GL—Grassland | SL—Scrubland | NF—Natural forest | WB—Water body & swamp | SA—Settlement area.

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COMMUNICATION

D'Ering Memorial Wildlife Sanctuary, a significant flyway and a preferred stopover (refuelling) site during the return migration of the Amur Falcon *Falco amurensis* (Radde, 1863)

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Abstract: This communication reports the repeated sighting records of the Amur Falcon *Falco amurensis* with photographic evidence in the D'Ering Memorial Wildlife Sanctuary (DEMWS) of Arunachal Pradesh during the summer. Though there are many sighting reports of the Amur Falcon from many places in India, all are onward journeys (October and November). Hence, not only the repeated sighting of the Amur Falcon but also its sighting during the month of May in DEMWS is the record of its kind. This is significant information for ornithologists, as the recent sighting in the sanctuary is the second record of this raptor during the summer in the state, which also demonstrated that DEMWS is a significant flyway and a preferred stopover or refuelling site during the return migration of this raptor towards their breeding grounds.

Keywords: Arunachal Pradesh, breeding ground, DEMWS, East Siang, Longding, Niausa, northeastern India, Pasighat, raptors, trans-equatorial migrant

Adi abstract: Si lukan lutom namsí kapang yarnam Pémí Píong *Falcon amurensis* ém lobo todí lo Bomong kíbung Gíté lok Daying Ering me Mípangpe Simon-sili Dumsukeng (DEMSD) lo mimang kíng saki pe latbom dola lukan binam é. India solo sim Pémí Píong sim kapang ém lukan namé deddiné idokom takam si déngun ko mílí eke (Yite delokke Disang polo). Delok legape Pemí Píong em kapang yarnam petom mang, delok leko-leko pe Lukíng polo lo DEMSD lo kapang namsi atíkon pe ina donggenyana kope idung. Pettang mikín legape si kenyek rupe kengap penam kope idung, legang de Dumsukeng solok kapang tunam petom si Gítekone solo Pemí sok lobo todí lok donggen kope idung, si seke pekom lengkan bidung DEMSD si gairuna pettang détak ko delokke si biakgé-biakkur na Pemí kídí solok apí píko gídang pe biaklat sidak kuem mibang runam nottí kope lang dengge nana alang píten silíkko motet kope idung.

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Author contributions: TT did the field survey, data collection, and manuscript preparation. AKT managed the preparation of maps using GIS and GBIF data, while DM supervised the data analysis and provided important inputs for the study. All three authors contributed to the writing of the manuscript.

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INTRODUCTION

The Amur Falcon *Falco amurensis*, also known as the Eastern Red-Footed Falcon, is a sexually dimorphic small bird of prey in the family Falconidae of the order Falconiformes. The species has a red to pale orange cere, eye ring, legs, and feet in all plumages, with an overall size of 28–31 cm from bill to tail. The males are dark grey with rufous thighs and undertail coverts and white underwing coverts. Typical features of females include dark grey upperparts, a short moustachial stripe, whitish underparts with dark spotting and barring, and orange-buff thighs and undertail coverts (Grimmett et al. 2011). The Amur Falcon is a long-distance, trans-equatorial migrant (Bildstein 2006) that migrates across three flyways, namely, the East Asia/East Africa Flyway, the Central Asian Flyway, and the East Asia/Australasia Flyway (BirdLife International 2015). The breeding range is currently restricted to northeastern China, southeastern Russia, North Korea, and eastern Mongolia (Corso & Catley 2003). Amur Falcons typically prefer temperate grassland, temperate forest, and inland wetland as breeding habitats (BirdLife International 2023). The available literature has shown that Amur Falcons depart from their Asian breeding range usually in the month of October, refuel at many stopovers before ultimately arriving at their wintering sites like Eswatini (BirdLife International 2023), Angola (Pinto 1983), Botswana (Penry 1994), Africa (Bildstein et al. 2000; Bildstein 2006; Darren & Craig 2010), Lesotho (Kopij 2012), Mozambique (Symes & Woodborne 2010), Namibia (Symes & Woodborne 2010), South Africa (Clement & Holman 2001; Bildstein 2006; Symes & Woodborne 2010), Zambia (Dowsett et al. 2008; Symes & Woodborne 2010), and Zimbabwe (Irwin 1981; Symes & Woodborne 2010). Northeastern India is one of the stopover sites to prepare for an arduous journey across the Indian mainland, Arabian Sea, and the Indian Ocean (Ali & Ripley 1987; Naoroji 2011) before arriving at the African continent (Clement & Holman 2001; Bildstein 2006).

Although D'Ering Memorial Wildlife Sanctuary in Arunachal Pradesh is a well-known important bird area (IBA), there has been relatively little ornithological research on it, as a review of the ornithological work indicated that reports and literature on the birds of this sanctuary are scarce. Additionally, there are no detailed reports of Amur Falcons from this sanctuary except a photographic record of one individual nine years ago with limited details (Dhar 2013), which indicates no proper scientific documentation of this species in the sanctuary. Hence, we conducted a study to evaluate avian diversity and seasonal changes of avifaunal species and assess threatened species in the sanctuary. The present paper is part of the study in which we report the repeated summer record of Amur Falcons *Falco amurensis* to promote protection of the bird as well as avian tourism in the area.

MATERIALS AND METHODS

Study site

The study was conducted in the D'Ering Memorial Wildlife Sanctuary (Image 1), hereinafter DEMWS, located in the East Siang district of Arunachal Pradesh, 13 km away from the district headquarter, Pasighat. It has coordinates of 27.850–28.083 N and 95.366–95.483 E, an elevation range of 135–140 m, and covers an area of 190 km^2. The sanctuary is mostly grassland (80% of the total area), and the rest is riverine forests and patches of sub-tropical forests. DEMWS falls under Indo-Malayan Biogeographic zone along with rest of the north eastern region of India.

Methods

The modified line transects method (Bibby et al. 2000) was used during the bird surveys; observation was done at 0500–1000 h and 1500–1800 h in the afternoon. Using a Garmin GPS (geographic positioning system) device, the locations of sightings were recorded and marked. Birds were properly identified following the field guides of Grimmet et al. (2011) and Arlott (2015). A Nikon D5200 fitted with a Sigma 150–600 mm telephoto lens was used to capture photos of birds as part of a routine procedure.

RESULTS

On 14 May 2021, while surveying for avian diversity and seasonal changes in the Jeepghat Range of DEMWS (Image 1), the team came across a pair of raptors at 27.8559˚N, 95.4217˚E and 27.8554˚N, 95.4205˚E coordinates, roosting in a Silk Cotton tree *Bombax ceiba* (Image 2). Later on, it was identified as a pair of Amur Falcons. Subsequently, the team surveyed the same area on 16 May 2021, to confirm the occurrence of the Amur Falcon at the site. Following this, the team subsequently spotted a flock of Amur Falcons, consisting of nine males and 15 females, sitting on a Candahar tree *Gmelina arborea*, in the same area. Again, the team captured

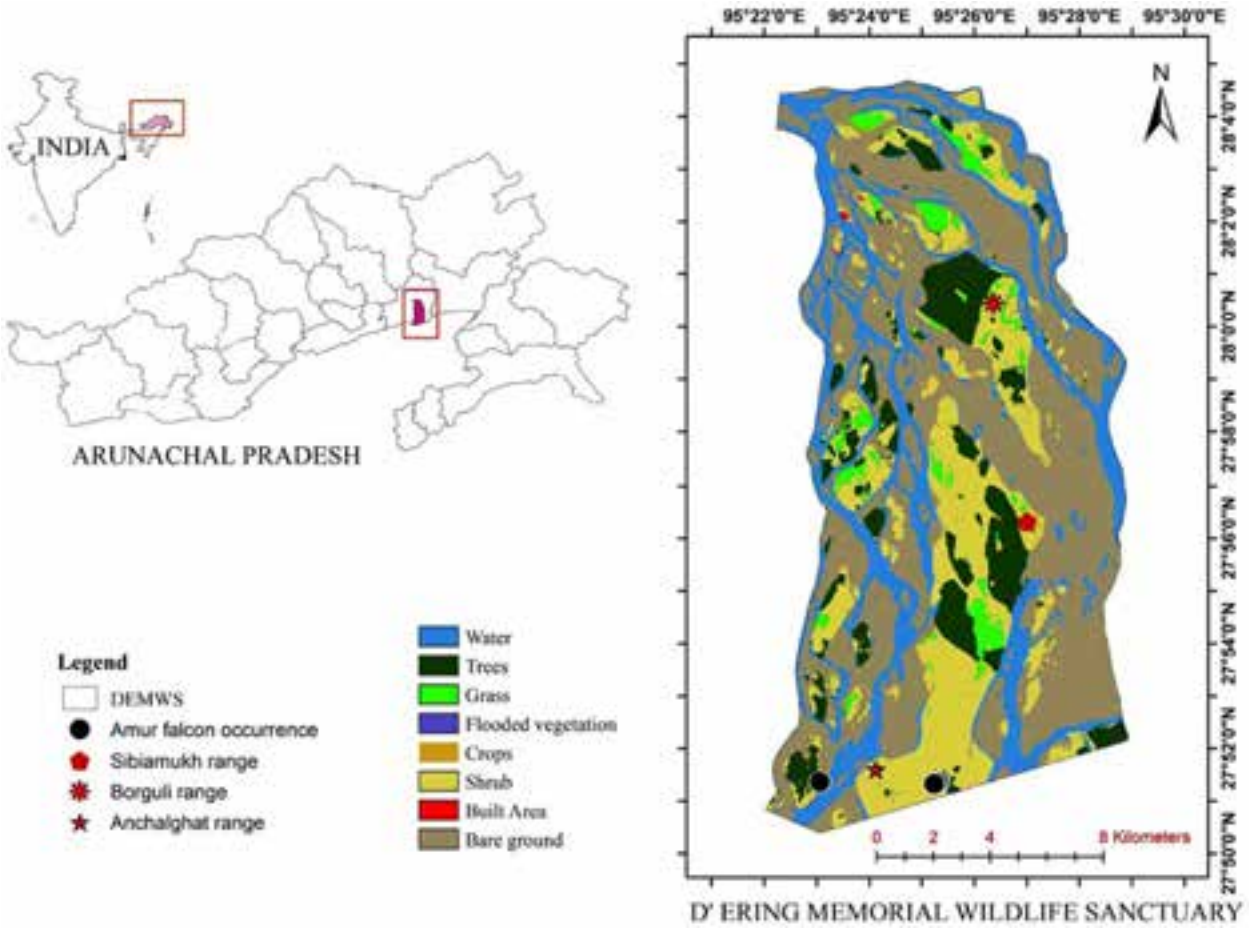

Image 1. Map of D'Ering Memorial Wildlife Sanctuary with the sighting location (developed by using Arc GIS Version 10.4).

images of the birds to substantiate the sighting (Image 3). Thereafter, the bird was sighted in the same area for around a week. The surrounding habitat types where the species were spotted were open grassland with scattered trees and shrubs (Image 4). Recently, on 09 May 2023, while surveying in the Anchalghat near Jeepghat range of the sanctuary at 27.8557˚N & 95.3848˚E coordinates, a total of 28 Amur Falcons were sighted hovering over the sky.

DISCUSSION

In northeastern India, there are reports of sightings at Krungming Reserve Forest, Khorongma and Kopili-Umrangsu Reservoirs, Habang, Karbi Anglong District in Assam, Doyang reservoirs and Pangti forest in Nagaland, and Dailong Rongku forest in Manipur (BirdLife International 2022). The first ever sighting of an Amur Falcon in Arunachal Pradesh was reported in October 1992 in Naharlagun (Singh 1995). Thereafter, it was completely unknown about further sightings in the same area. In November 2020, a flock of Amur Falcons in good numbers in flight was reported, and a killed specimen at the market was spotted at Niausa Village in the Longding District of Arunachal Pradesh (Echo of Arunachal, 2020), approximately 200 km from the Doyang stopover site in Nagaland. Other recent records of this species in India include Madhya Pradesh (Naoroji 2011), Gujarat (Ganpule 2011), Uttar Pradesh (Bhargava et al. 2014), Chhattisgarh (Dutta 2016), and various unpublished sighting records are available in the Global Biodiversity Information Facility (GBIF, 2023). Various published and unpublished sighting locations of the Amur Falcon *Falco amurensis* are presented in Image 5. The published sighting records of the Amur Falcon at all the aforementioned sites in the north-east and other parts of India occurred during the month of November, i.e., winter. It is therefore likely that all sites are stopover or refuelling sites for the onward leg of the journey. Similarly, there are a few unpublished sighting reports of the Amur Falcon from several places in the Longding

Image 2. Pair of Falcon *Falco amurensis* in D'Ering Memorial Wildlife Sanctuary.

Image 3. Flock of Amur Falcon *Falco amurensis* in D'Ering Memorial Wildlife Sanctuary.

Image 4. Surrounding habitat types of the Amur Falcon sighting location.

district of Arunachal Pradesh, all of which occurred during October and November, i.e., during the winter season (Northeast Now 2022). Hence, not only the repeated sighting of the Amur Falcon but also a sighting during the month of May in DEMWS is a record of its kind, as there is no earlier report in the month of May in Arunachal Pradesh.

Although this raptor has been classified as 'Least Concern' due to their large population size and vast range, because of their flocking behaviour during migration and the density at which it occurs, they are vulnerable to hunting and extremely high levels of persecution along their migration routes (BirdLife International 2023). Despite efforts to enforce strict measures to prevent the hunting of amur falcons, illegal hunting of these raptors continues to take place in certain areas of northeastern India. For instance, recent reports of some people engaged in the illegal practice of hunting these birds by using catapults in certain areas of the Wokha district of Nagaland (Nagaland Post 2023). Also, there was a report circulated on social media (WhatsApp) recently that some roasted Amur Falcons were being sold in Longding

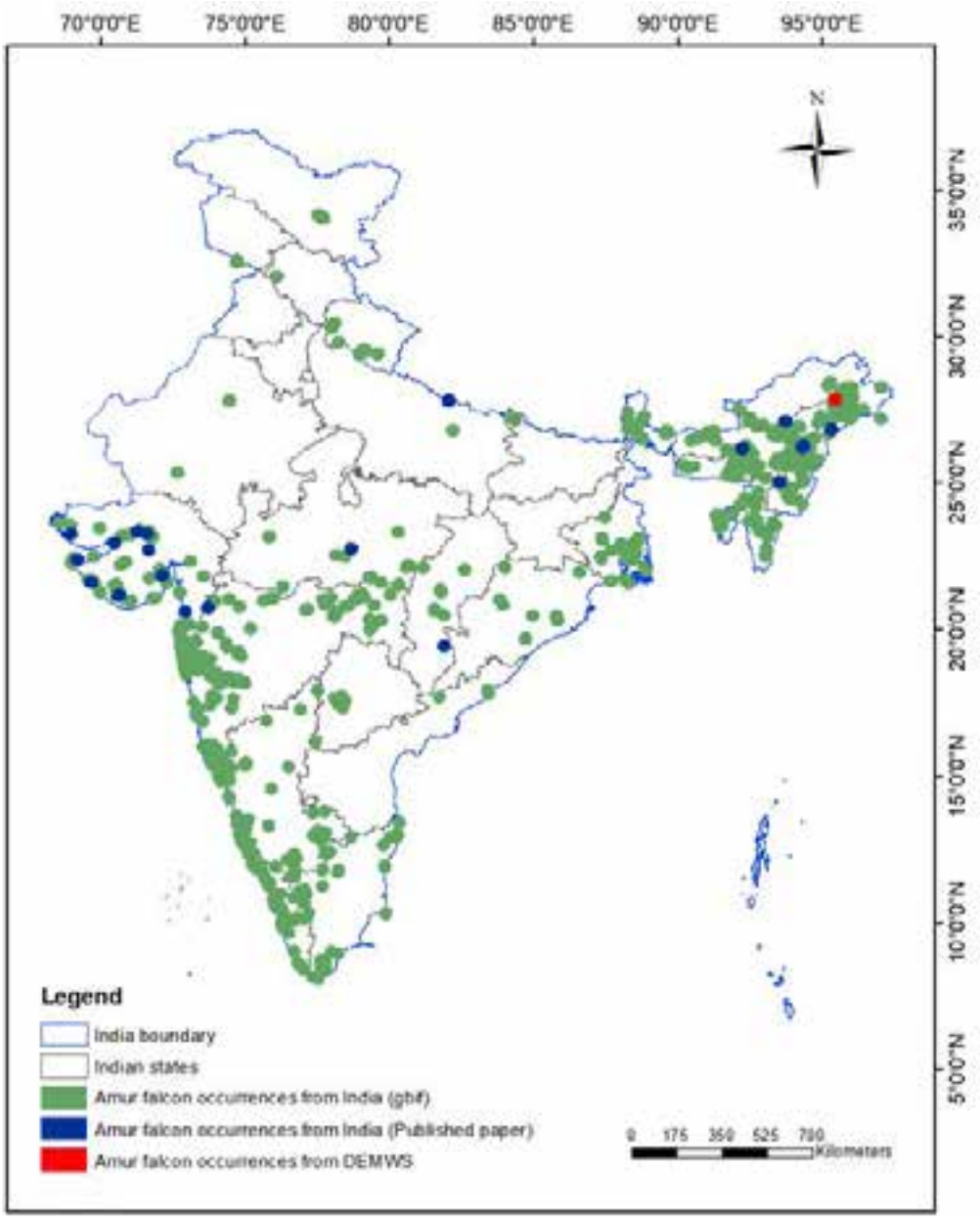

Image 5. Map of India indicating the various published and unpublished sighting locations of the Amur Falcon Falco amurensis (developed by using Arc GIS Version 10.4).

Market. This is concerning for the conservation of this bird. Most of these hunters belong to economically backward and uneducated villagers; therefore, it is of utmost importance to educate these villagers with frequent awareness programmes. It is also essential to identify and develop the areas where these migratory birds rest during their journey as tourist spots, which would attract tourists, especially wildlife enthusiasts. Therefore, as DEMWS is a protected area, it will be a safe stopover site as human disturbances are lower than in other north-eastern migratory routes such as the Doyang roosting site in Nagaland (Dalvi et al. 2013) and Manipur (Sharma 2018). Moreover, most parts of DEMWS are grasslands; they support various insects for this insectivorous raptor, like Caelifera (grasshoppers), Ensifera (crickets), and Coleoptera (beetles). Thus, DEMWS may be a significant flyway for this migratory species and a preferred stopover or refuelling site in the future. Therefore, the present paper is an attempt to report the repeated summer record and to highlight DEMWS as likely one of the important stopover sites during the backward journey from the wintering grounds

of this migratory raptor to promote protection of the bird as well as avian tourism in the area.

CONCLUSIONS

The presented report is the substantiated record of the Amur Falcon *Falco amurensis*, with photographic evidence in the DEMWS of Arunachal Pradesh during May, i.e., the summer season, the time for the backward journey of this migratory raptor from its wintering place to its breeding ground. It is significant information for ornithologists, as the recent sighting in the sanctuary is the second well documented records of the raptor during the summer in the state. Though there are many sighting reports of the Amur Falcon from many places in India, all are onward journeys (October and November). Hence, not only the repeated sighting of the Amur Falcon but also its sighting during the month of May in DEMWS is the record of its kind.

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OPEN ACCESS

COMMUNICATION

Breeding of the 'Critically Endangered' White-rumped Vulture *Gyps bengalensis* in the Shan Highlands, Myanmar

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Abstract: Recent studies have shown the importance of Myanmar for the conservation of three 'Critically Endangered' vulture populations. From November 2022 to March 2023, we carried out rapid surveys on vulture nests and nesting tree characteristics in Ke Hsi Township, Shan Highlands. We recorded 10 nests of White-rumped Vultures, *Gyps bengalensis*, on five nesting trees from four different localities. Six nests were active, and six nestlings were observed; four nests were inactive or abandoned. Most of the nests were recorded on *Ficus* spp. and the mean nest height was 13.6 m (SD ± 4.1) above ground. This represents the first confirmed record of the breeding success of White-rumped Vultures from Shan Highlands and confirms the ongoing presence of the species in Shan States. The population of *G. bengalensis* in Shan Highlands is small, but the confirmed breeding is significant in the wider context for this species.

Keywords: Breeding success, *Ficus* spp., nestlings, Shan states, viable population, vulture nest.

Burmese: မြန်မာနိုင်ငံသည် မျိုးသုဉ်းရန် အလွန်နီးကပ်နေသော လင်းတ မျိုးစိတ်(၃)မျိုး ထိန်းသိမ်းရေး အတွက် အရေးကြီးသော အခန်းကဏ္ဍ၌ ပါဝင်နေကြောင်း မကြာသေးမီက ပြုလုပ်ခဲ့သော လေ့လာတွေ့ရှိမှုများကဖော်ပြပါသည်။ လင်းတအသိုက်နှင့် အသိုက်ရှိသော သစ်ပင်များ၏ ထူးခြားမှုလက္ခဏာများနှင့် ပက်သက်၍ လေ့လာမှုများကို နိုဝင်ဘာလ ၂၀၂၂ မှ မတ်လ ၂၀၂၃ အထိ ရှမ်းပြည်တောင်ပိုင်း ကျေးသီး မြို့နယ်တွင် ပြုလုပ်ခဲ့ပါသည်။ထိုင်းလေ့လာမှုတွင် လင်းတကျောဖြူ *Gyps bengalensis* ၏ အသိုက်(၁၀)သိုက် တွေ့ရှိခဲ့ ရပြီး မတူညီသော နေရာအသီးသီးရှိ သစ်ပင်(၅)ပင်ပေါ်တွင် အသိုက်များ ဆောက်ထား ကြောင်းတွေ့ရှိရသည်။ အသိုက်(၆)သိုက်တွင် လင်းတအကောင်ပေါက်များ တွေ့ရှိခဲ့ရပြီး၊ (၄)ခုတွင် အသိုက်ဟောင်း များ ဖြစ်သဖြင့် မည်သည့်လင်းတမျှ မတွေ့ခဲ့ရပါ။ လင်းတကျောဖြူသည် ညောင်ပင်ပေါ်တွင် အများဆုံး အသိုက်ဆောက်ခဲ့ကြပြီး၊ အသိုက်များ၏ ပျမ်းမျှအမြင့်မှာ ၁၃.၆ မီတာ (SD ± ၄.၁) ဖြစ်ပါသည်။ ယခုလေ့လာတွေ့ရှိမှုသည် ရှမ်းပြည်၌ လင်းတကျောဖြူ၏ ပထမဆုံးသားပေါက် အောင်မြင်မှု မှတ်တမ်းဖြစ်ပြီး၊ ၎င်းမျိုးစိတ် ဆက်လက်ရှင်သန်နေထိုင်နိုင်ကြောင်းကိုလည်း ပိုမိုခိုင်မာလာ စေပါသည်။ ရှမ်းပြည်တွင် လင်းတကျောဖြူ၏ ဦးရေမှာ နည်းပါးသော်လည်း ၎င်း၏ သားပေါက်မှုမှတ်တမ်းသည် ယင်းမျိုးစိတ်အတွက် ပိုမိုကျယ်ပြန့်သော အကြောင်းအရာများကို ဆက်လက် လေ့လာနိုင်ရန်အတွက် အလွန်အရေးကြီးကြောင်း သိသာထင်ရှား စေပါသည်။

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INTRODUCTION

In Myanmar, each year new records of birds and range extensions are published (Zöckler et al. 2010, 2020; Oo et al. 2022), or records of species, which have been declared locally extinct, re-emerge (Oo et al. 2019). Myanmar hosts five vulture species: The White-rumped Vulture *Gyps bengalensis*, Red-headed Vulture *Sarcogyps clavus*, Slender-billed Vulture *Gyps tenuirostris*, Cinereous Vulture *Aegypius monachus*, and Himalayan Vulture *Gyps himalayenis* (Robson 2008; Hla et al. 2011), and three of these are classified as 'Critically Endangered' by the IUCN Red List of Threatened Species. Among these, the White-rumped Vulture has a widespread distribution across Bangladesh, Bhutan, Cambodia, India, Myanmar, Nepal, and Pakistan (BirdLife International 2021a,b,c) but has also suffered the most drastic declines of over 99.9% across India (Prakash et al. 2012). Literature records suggest that vultures were once widely distributed throughout Myanmar, mainly the northern half of the country with records from Kachin State, Shan State, Chin State, and Sagaing Region (Hla et al. 2011). Also *Gyps bengalensis* was recorded 78 times from Myanmar, most of these records are sights of non-breeding birds in Kachin (68), while only nine records are from the two Shan states (GBIF 2023). The Shan records are all from 2009 to 2023, which indicates a rare visitor to the Shan Highlands (Image 1).

All but the Himalayan Vulture have been considered relatively common throughout these areas in the past (Tordorf et al. 2007; Hla et al. 2011; Shwe & Aung 2016; Oo et al. 2019). The earliest record of the White-rumped Vulture dates back to the late 19th Century for Southern Shan State, where it was once a common species (Rippon 1901). The Shan states remained relatively unexplored by ornithologists due to political instability, security issues, and inaccessibility of the region (Smythies 2001).

In the early 20th Century, White-rumped Vultures were abundant and considered the most common vulture throughout Myanmar's central plains (Smythies 2001; Naing et al. 2012). However, their population has declined across their historical range because of food shortages, breeding-habitat loss, chemical poisoning, habitat loss, and anthropogenic impacts (Bildstein 2017). This decline was so severe in the region that the White-rumped Vulture population crashed by almost 95% between the 1990s and 2000s (Bildstein 2017).

Hla et al. (2011) estimated a population of 62 White-rumped Vultures based on observations at vulture feeding sites in all of Myanmar for 2006 and 2007. The first White-rumped Vulture survey in northern Shan State documented 31 individuals, including juveniles (Oo et al. 2019). While the two studies had different temporal and spatial scales as well as methods, we assume that the stronghold of the White-rumped Vulture population of Myanmar is likely located in Shan today, while another hotspot for the species within Myanmar is found in the Hukaung Valley, Kachin State (Thet Zaw Naing pers. comm. 2023).

White-rumped Vultures typically build their nests in tall trees (Khan 2013; Ghimire et al. 2019; Samson & Ramakrishnan 2020; Jha et al. 2021), as these trees reduce predators' access and support mobility for the vultures.

METHODS AND SURVEY SITES

Fieldwork was conducted in Ke Hsi Township (alternatively spelled Kehsi), located in the southern region of Shan State, with specific localities and coordinates detailed in Table 1 and Image 1. Our team undertook surveys of vulture nests, leveraging local knowledge to identify these sites. Nesting trees were identified using GPS coordinates, and these sites were subsequently revisited on a bi-weekly basis. Ke Hsi Township is situated on the elevated plains of southern Shan State, at an approximate altitude of 1,000 m.

The vulture survey covered 35 days, from 15 November 2022 to 31 March 2023. During this period, we collected data on the characteristics of nesting trees, adopting the nest categorization framework established by Jha et al. (2020), which delineates nests as active (housing adults along with juveniles, chicks, or eggs), inactive (only occupied or frequented by adults), or abandoned (without any occupants).

Measurements of tree height and nest elevation were taken using a clinometer, while the diameter at breast height (DBH) was measured with a tape measure, and canopy density was assessed with a densitometer. The relative canopy cover of each nesting tree site was evaluated using the "CanopyApp" (University of New Hampshire), where a photograph taken beneath the tree provided the percentage of canopy coverage as an output.

We also recorded the proximity of nesting trees to the nearest water bodies, which, within the study area, averaged 11.7 hectares in size (N = 4). Observations of nests were conducted from a non-intrusive distance of 100–200 m using Kowa Japan YF30-8 binoculars (8 × 30), to minimize disturbance for the birds. Documentation of birds and their nests was accomplished with a Nikon

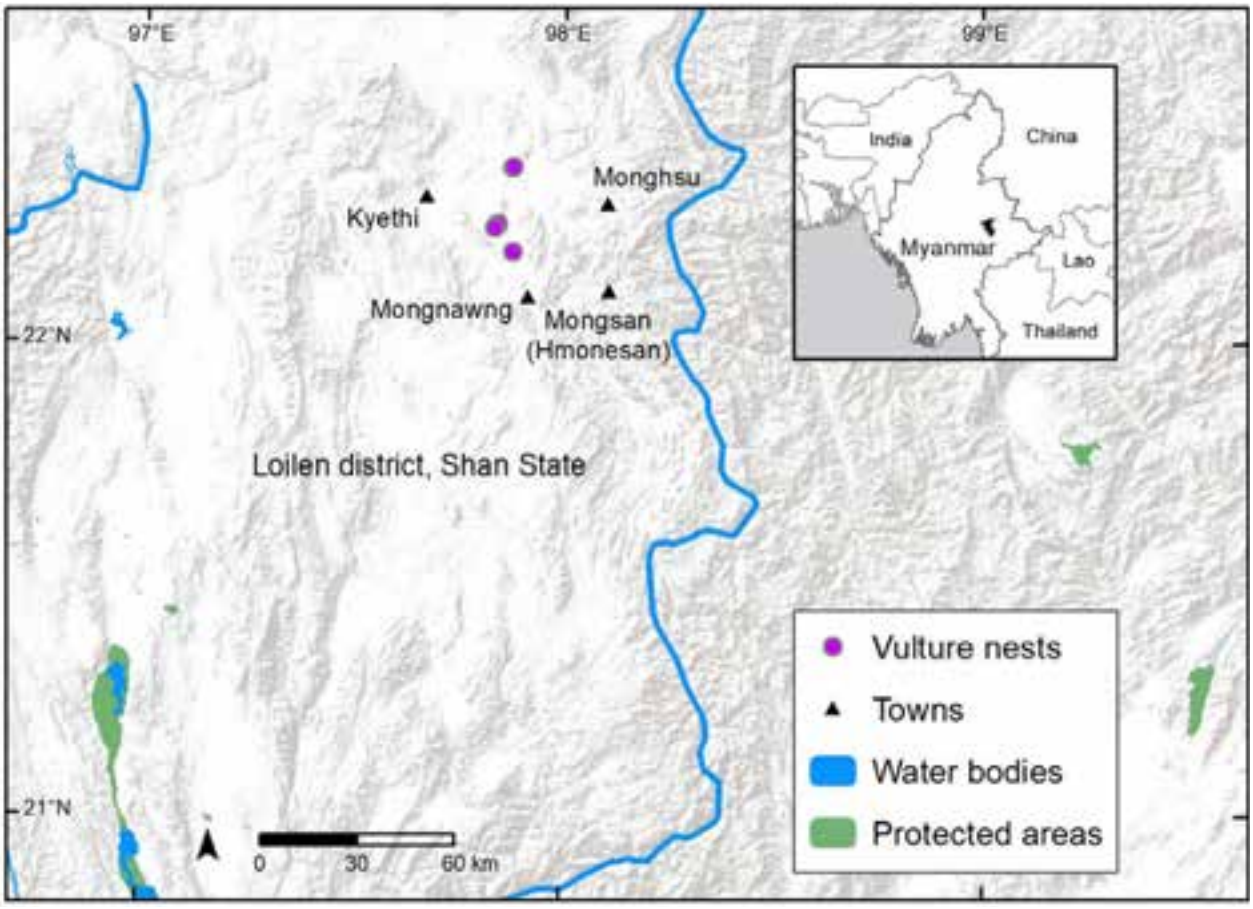

Image 1. Map showing the nesting sites within Loilen District (black area in map inset) of Southern Shan state. Depicted are distances to the nearest protected areas as well as waterbodies mentioned in the text. © Prepared by Marcela Suarez-Rubio.

P1000 digital camera, with results presented in Images 2–6. Each site visit lasted approximately 15 minutes, during which we assessed the breeding status of the nests. Observation periods were conducted from 0800 h to 1600 h.

The climate of Ke Hsi Township is predominantly subtropical, characterized by a mean annual temperature of approximately 23°C and an average annual rainfall of about 1,100 mm (General Administration Department 2020).

RESULTS

During our research period, we identified and monitored 10 nests of White-rumped Vultures, situated within five nesting trees across four distinct locations. Within these locations, three were categorized as loose colonies, notably with one tree hosting four nests. The nesting trees were, on average, 10.4 km apart, with a range from 0.4 to 25.0 km. All nests, discovered in November 2022 at the onset of our survey, exhibited vulture activity during our initial inspection. Throughout our study, six nests remained active, while the remaining four exhibited signs of inactivity or abandonment. Of the five nesting trees, three were positioned within agricultural fields (specifically, corn and peanut farms), and the other two were adjacent to religious sites (a pagoda and a monastery). *Ficus* trees emerged as the preferred nesting choice, representing four of the five identified nesting trees (Table 1). The average height of these nesting trees was 20.7 m, with nests situated at an average height of 13.6 m (Table 1). The canopy cover of these trees averaged 39.9% (SD ± 10.59, N = 5).

By January 2023, all active nests were home to six vulture chicks, with observations typically noting chick presence alongside at least one adult until late March 2023 (Table 2).

Our observations also included five colonies of White-rumped Vultures, each comprising two to 20 individuals (N = 5), and vulture groups ranging 29–57 individuals, with an average of 41 individuals (N = 4),

Table 1. Locations and records of trees with White-rumped Vulture *Gyps bengalensis* nests in the Shan Highlands. Note: * one out of the four nests was in the crown of the tree and we could not confirm the presence of nestling.

Place	Tree species	Tree height m	# nests	Nest height m	DBH cm	Altitude m	Roosting individuals	Number of nests	Number of chicks	Fledged	North	East
Wan Mut	*Ficus tinctoria*	23.9	2	19.1; 17.6	980	830	5	2	n/a	n/a	22.0	98.1
Wan Mut	*F. tinctoria*	20.3	2	11.3; 7.6	1,210	870	7	2	1	1	22.0	98.1
Wan Narr	*Schima wallichii*	18.3	1	16.5	245	1,000	2	1	1	1	21.7	98.1
Kone Mont	*F. tinctoria*	21.3	1	19.5	1,100	1,030	2	1	1	1	21.8	98.0
Nam Linn	*F. lacor*	20.1	4	16.5; 16.5; 12.6; 6.6	750	1,040	14	4*	3	3	21.8	98.0

feeding on carcasses. These groups encompassed three vulture species: White-rumped Vulture, Slender-billed Vulture, and Himalayan Vulture. Throughout the study, we located three cattle and one buffalo carcasses, with three in cropland and one in a paddy field. Near each carcass, two to three stray dogs were observed feeding alongside the vultures. The cause of livestock mortality was undetermined, and no information was collected on the availability of diclofenac, a veterinary drug causing casualties in vultures, in the area. According to the local veterinarian, diclofenac was not utilized for treating cattle within the township. No deceased vultures were discovered during our research period.

Despite observing Slender-billed and potentially Himalayan Vultures feeding on carcasses, nesting sites for the Slender-billed Vulture were not identified. Himalayan Vultures are noted as winter visitors to Myanmar. Moreover, Red-headed Vultures were not observed throughout the duration of this study.

Image 2. A crow on the nest of White-rumped Vulture on 5 February 2023 in Kone Mont Village.

Image 3. A head of nestling visible in the nest in Nam Linn on 5 February 2023.

DISCUSSION

With this survey, we documented the breeding success of the 'Critically Endangered' White-rumped Vulture in Myanmar's Shan Highlands, representing the first confirmed breeding record in the eastern part of the country. It also sheds light on their nesting site preferences and food availability. Between November 2022 and March 2023, we observed nestlings in six nests, and all six nestlings successfully fledged. This is a positive sign for vulture conservation in Myanmar (Hla et al. 2011). Our findings suggest that these vultures have sufficient food sources in the study areas, as evidenced by frequent observations of vulture flocks and recorded carcasses. The availability of food is crucial for vulture presence, especially considering their role as obligate scavengers. This is further supported by the presence of a substantial cattle population in the region, as has been found in southern India (Manigandan et al. 2023).

Although Slender-billed Vultures were observed feeding on carcasses, we could not locate their nests. Similarly, Red-headed Vultures were not observed during the study, suggesting their rarity compared to the other vulture species.

Table 2. Records of White-rumped Vulture *Gyps bengalensis* nestling found in nests of the study area. 1 observed, 0 not observed.

Date	Kone Mont	Nam Linn	Wan Mut	Wan Narr
8 Jan 2023	0	0	1	1
13 Jan 2023	1	1	1	1
5 Feb 2023	1	1	0	1
11 Mar 2023	1	1	1	1
15 Mar 2023	0	0	1	1

The preference of White-rumped Vultures in our study was for large, tall trees, often *Ficus* spp., while others reported that *Terminalia arjuna*, and *Spondias mangifera* were utilized for nesting by White-rumped Vultures in India (Majgaonkar et al. 2018; Samson & Ramakrishnan 2020). The average nesting tree height in India was 25.4 m (Majgaonkar et al. 2018) and 26.7 m (Samson & Ramakrishnan 2020), respectively.

Since the study areas are located outside of protected areas (compare Image 1), it is needed to introduce conservation awareness and management practices to local communities. In addition, it is required to raise awareness for protecting nesting trees. The vulture colonies we recorded, as well as the flocks attending domestic livestock carcasses, indicate that these birds continue to play an essential role in the ecosystem by cleaning up carrion. Hla et al. (2011) had previously postulated, but not observed, the presence of viable populations of *Gyps bengalensis* and *G. tenuirostris* in Myanmar, and our current findings confirm this claim at least for *G. bengalensis*.

Majgaonkar et al. (2018) emphasized that nesting and reproductive success serve as indicators of specific site-use by the vultures. Therefore, it is demonstrated that habitats and food availability for *Gyps* species still exist in the Shan Highlands of Myanmar. While the population of *G. bengalensis* in Shan State may be relatively small, its breeding success is of significance, indicating that these populations are healthy and successfully reproducing. Based on the study results, Ke Hsi Township emerges as particularly crucial for White-rumped Vulture populations due to its large open habitats, food availability, low disturbance levels, and relatively low human density. Vultures can find and detect carcasses and feed in such open areas, making these habitat characteristics vital for nesting choices. In conclusion, the findings of this study offer promising insights into vulture conservation opportunities in Myanmar.

Image 4. An adult vulture in the nest with its nestling on 13 January 2023 in Wan Mut Village.

Image 5. A fledgling White-rumped Vulture in nest on 15 March 2023.

Image 6. A flock of vultures loitering around the carcass with dog and crows on 27 February 2023.

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COMMUNICATION

Nurturing orphaned Indian Grey Wolf at Machia Biological Park, Jodhpur, India

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Abstract: The Indian Grey Wolf *Canis lupus pallipes* is an iconic species of grassland in India. It is a Schedule 1 species according to the Wildlife Protection Act, 1972 and CITES Appendix 1 species. In the absence of parental care, five wolf pups were rescued from Baavarla on 26 November 2020 and brought into Machia Biological Park for hand rearing. In the absence of colostrum, a milk replacer formula (PetLac) was provided to the pups. The pups were kept at an ambient room temperature of 101°F as an adjustment to their natural surroundings. Gripe water, Vitamin A, and multivitamins were administered orally. The temperature and body growth parameters were measured and recorded weekly. Rabies vaccine was administered in the 26th week from the date of rescue. The diet of the wolf was gradually changed and from the 37th week, raw meat was included in their diet. Antibiotics Ciplox-TZ (ciprofloxacin and tinidazole tablet) Brand-Cipla and SPORLAC-DS (lactic acid bacillus tablets 120M) Brand-sanzyme Ltd. were given periodically to restore the gut fauna of the pups.

Keywords: Captive, conservation, ex-situ, hand rearing, rehabilitation, rescue, Thar Desert, veterinary care, wolf, zoo.

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Author contributions: Research design, concept & supervision—Hemsingh Gehlot Data collection and hand rearing—Mahendra Gehlot & Hemsingh Gehlot. Data analysis, literature search and manuscript preparation—Tapan Adhikari, Gaurav, Prakash Suthar & Hemsingh Gehlot.

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INTRODUCTION

A total of eight wolves are in captivity in the Machia Biological Park, Jodhpur. Out of the total, five wolves are nurtured. Hand rearing wild animals is very demanding and should be performed in extraordinary circumstances. Infants require hand-rearing only if the mother dies or is unable to feed them. Similarly, in the absence of the mother, orphan, feral, sick, injured, or rescued infants need human intervention to grow and sustain themselves (Mohapatra et al. 2019). Hand-rearing varies from species to species. Five wolf cubs were rescued from Baavarla village on 26 November 2020. This paper puts forward an elaborative explanation for nurturing an Indian Grey Wolf pup. It also explains the veterinary assistance required from the neonatal stage to adulthood. Distributed widely across Eurasia and North America, the Grey Wolf *Canis lupus* is an iconic grassland species. The Indian Grey Wolf *Canis lupus pallipes* and the Mongolian/Himalayan Wolf *Canis lupus chanco* are among the subspecies of Grey Wolf distributed in India (Anonymous 2023). The Indian Peninsular Wolf or the Indian Grey Wolves *Canis Lupus pallipes* exhibit a wide distribution, ranging from India in the east to Turkey in the west, with populations reported from Pakistan, Iran, Syria, and Israel (Wildlife Institute of India 2017). The Indian Grey Wolves evolved to occupy diverse habitats and are the top predators of the arid, semi-arid, and Deccan plateau region (Jhala & Giles 1993; Singh & Kumara 2006). Andhra Pradesh, Karnataka, Maharashtra, Madhya Pradesh, Gujarat, Rajasthan, Orissa, Bihar, West Bengal, Uttar Pradesh, and Haryana are said to have isolated areas of Indian Grey Wolves (Singh & Kumara 2006). The wolf population in Asia is data deficient, endangered, and evolutionarily distinct (Hamid et al. 2019). Several attempts were made to assess the population and occupancy of Indian Grey Wolves (Jhala & Giles 1991; Kumar & Rahmani 1997; Singh & Kumara 2006; Karanth & Chellam 2009; Srivathsa et al. 2020). Estimates of earlier wolf populations, wolf ecology, and their habitat assessment were primarily based on surveys and local-level information from pastoralists (Jhala & Giles 1991; Kumar & Rahmani 1997). A recent study using camera traps and a review of literature have suggested the presence of 3,170 Grey Wolves across the Indian subcontinent (Jhala et al. 2022). The number of Indian Peninsular Wolves in the wild is equivalent to that of the royal Bengal Tigers *Panthera tigris* making it an Endangered species (Azad 2022). The Grey wolf is the least concerned species as per the IUCN Red List, CITES Appendix 1, and Schedule 1 species under the Wildlife Protection Act, 1972. Despite the decreasing population of the Indian Peninsular Wolves, residents surrounding the habitat of the same don't share a good bond with the species (Aggarwal 2003). Livestock depredation is the root cause of human-wolf conflict over the Indian subcontinent (Krithivasan et al. 2009). India has 87 Grey Wolves in captivity (Wildlife Institute of India 2017).

MATERIAL AND METHODS

The villagers from the Baavarla had called and reported the presence of a wolf den with orphaned cubs to the Machia Rescue and Rehabilitation Centre. Team members from the centre rushed to the den site and kept the wolf pups under observation. After 72 hours, when confirmed that the mother was nowhere to be seen the rescued wolves were brought to the veterinary unit of Machia Biological Park. Separate units are available for treating different species groups like canid, avian felid, ungulate, primate, etc. The orphaned pups were quarantined for 15 days in the rescue ward of Machia Biological Park. Adjacent to the canid centre is a kraal which provides the pups for playing and recreation and natural bedding was provided to the growing pups. In the absence of colostrum, a milk replacer formula (PetLac) with 33% crude protein, 18% crude fat, 0.5% crude fiber, and 5% moisture commercially available closest to mothers' milk was provided to the pups. The composition of wolf milk is 23.6% solid, 9.6% fat, 9.2% protein, and 3.4% carbohydrate (Das et al. 2013; Mohapatra et al. 2019). Available literature on canids with special emphasis on wolves regarding housing, feeding schedules, diet, and veterinary needs were consulted and utilized for nursing and management of the pups. Body measurements and other physiological parameters are recorded weekly to ensure whether the pups were showing proper growth as per their age. Environmental parameters, viz., humidity, temperature, and moisture were maintained as required for the species using an air conditioner (Gehlot et al. 2020) and hygiene and biosafety measures were taken as much as possible as this is crucial while raising orphaned young animals. An assistant was appointed round the clock to look after pups in case emergency or complications arise. The assistant and the veterinary staff alongside the doctor were advised to keep off-hand until it is extremely necessary because excessive human habituation can cause behavioral issues during release into the wild (Palmer & Malone 2018; Hansen et al. 2022).

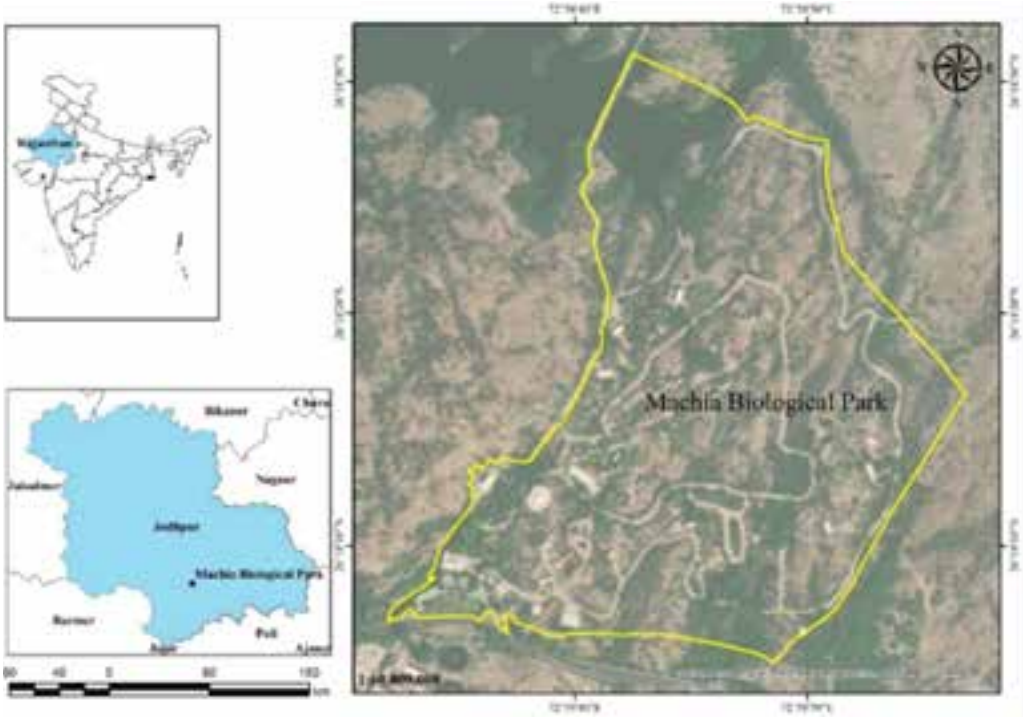

Image 1. Machia Biological Park.

Study Area

The Machia Biological Park is located on the western outskirt at the bank of Kaylana Lake of Jodhpur city at 26.3000 N & 72.9778 E. The park was founded on 13 February 2011 and subsequently old heritage zoo of Jodhpur was shifted here. The park encloses 41 ha of Machia forest block (680 ha), Jodhpur forest division. Under the Rajasthan Forest Act 1953, Machia forest block is protected as forest, notified vide notification number II 9(6), forest/90, dated 01/07/1990. The study area is undulating and the substratum is made of Rhyolite. The vegetation of the area consists of dry scrub forest with scanty tree cover of species like *Acacia senegal, Prosopis cineraria, Prosopis juliflora, Capparis decidua, Zizyphus nummularia,* and *Commiphora wightii*. The forest department has also planted several native species to increase tree cover inside the park. The park has 24 enclosures inhabited by several species of wild animals. Out of 24 enclosures, four are dedicated for big cats and canids, three for ungulates and deer, three for reptiles and avian species, two for bears and civets, and one each for porcupine, Jungle Cat, and Star Tortoises. Alongside the conservation, the park is well known for rescue and treatment of wildlife species under the wild animal rehabilitation program. "Recognition of Zoo Rules, 2009," also stated that zoos serve as an ideal place for nurturing the young of wild animals. From tourists' viewpoint, tiger, lion, leopard, Sloth Bears, Himalayan bears, Indian Peninsular wolves, and Desert Cats are the major attractions of the Machia Biological Park.

RESULTS

Five wolf cubs were rescued on 26 November 2020 from an unattended den site on the outskirts of Baavarla village near the forest Boundary. The den resembles a step-less stair structure with a depth of 14 feet. The upper portion of the den is 1 m deep and the base of the den is 3.5 m deep. The den is a complex maze in the upper part. Two pups were residing in the upper part, and the rest were on the floor. The male-to-female ratio of the litter was 2:3. Observations of only one male and one female from the litter were recorded. All the pups were raised with identical conditions and procedures. The wolf pups were kept under observation in their den site for 72 hours prior to hand rearing. During the rescue, the pups were estimated to be around a month old. The pups were observed to have no apparent infection or injury, however, they were dehydrated and malnourished which could be attributed to the absence of mother's milk. The first day in the rescue centre is very critical as the cub has to adjust to its new surroundings. The cub was kept at an ambient room temperature of

101°F as an adjustment to their natural surroundings. 0.5 g of Rintose electrolyte diluted in 10 ml of water was provided twice in 24 hours to prevent dehydration on the day of rescue. Petlac, Hampshire, USA was bottle fed to the pups. From the date of rescue till the seventh week, 2 g in 10 ml of water was fed every day to the pups, subsequently after the 7th week till the 12th week, 4 g in 20 ml water was fed daily. The initial frequency of feeding was four times in 24 hours and was reduced to two times from 28th week. Along with petlac powder, 0.2 ml gripe water which serves as an antacid was also given to the pups. To supplement vitamins in the diet, Intavita syrup, and a Mecovet xl syrup was availed to the pups at 0.2 ml and 0.5 ml QD, respectively. Physical parameters of growth were recorded. Along with the multivitamin supplement, Caldipet syrup was given to the pups from the 15th week to the 33rd week, initially starting with 1 ml per day and subsequently increasing the dosage to 3 ml from the 27th week till the 33rd week. During the initial time of rescue, the temperature of the male was recorded to be 99.8ºF and female 99.9ºF. The temperature variation has also remained almost identical over 42 weeks. Similarly, at the initial time of rescue, the male weighed 600 g and female weighed 585 g. The mean weight and mean temperature of the litter during the initial time of rescue were 587.94 ± 11.10 g and 99.7 ± 0.05 °F respectively. Successive weekly variation in body weight was measured, recorded (Figure 1).

Combined vaccine Megvec-7 against leptospirosis, canine distemper, and parvovirus was administered in the mid of 20th week. Boiled eggs were introduced into the diet after the 08th week along with petlac powder for adjusting to new dietary habits. The weaning is progressive. In the mid of the 12th week, petlac powder was removed from the diet and two boiled eggs along with 25 ml chicken soup were introduced to the diet. This diet was maintained till the 17th week. On the 18th week, with three boiled eggs and 50 ml carabeef soups dietary increment was followed. The pups were responding very well to the dietary increment. From the 21st week, gripe water was removed from the diet because gastritis issues relating to feeding liquid food were over by then. In the 25th week, two tablets of Sporlac DS (1/4th) and Ciflox TZ (1/8th) were given once a day for three consecutive days to combat gastro-intestinal disorders. Sporlac DS helps in restoring normal microbial fauna of the intestine as it contains lactic acid Bacillus which is a probiotic. In the mid of the 26th week, the Rabigen mono vaccine was availed to the pups as a countermeasure for rabies. From the 34th week, the pups were given a kilo of boiled meat once a day during morning hours at 0930 h and in the

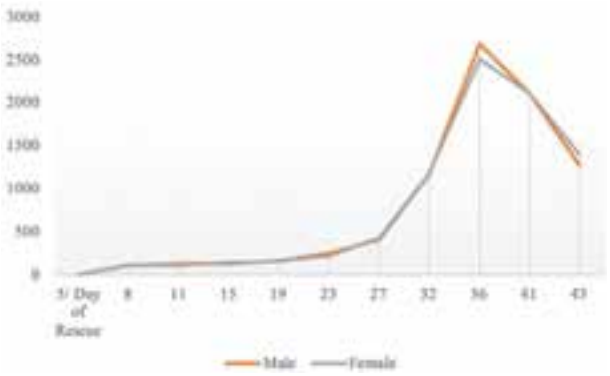

Figure 1. Weekly rate of change in weight of pups (in g). The successive change in weight shows exponential growth till the first 36th week and gradually decreases after it.

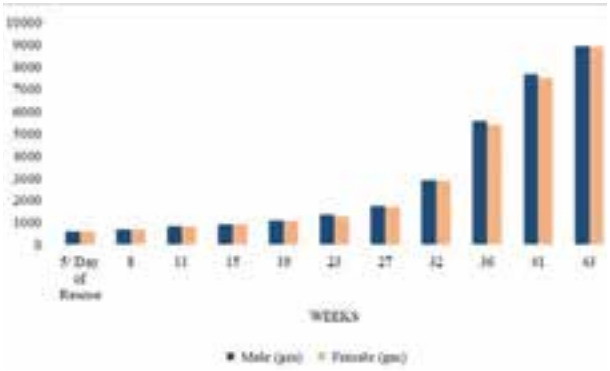

Figure 2. Weekly weight record of rescued pups.

37th week, boiled meat was replaced by raw carabeef. Along with feeding regime and schedule weekly body growth parameters *viz.* height, chest girth, cervical length, tail length, etc. were also recorded (Figures 2–4).

DISCUSSION

Literature on hand raising orphaned canids has been studied and followed to raise wolf pups into an adult. Hand-raising has been done in zoos in instances where the mother is unwilling to rear the young one or in circumstances in the wild where pups are being abandoned by the mother (Dhoot et al. 2003; Gehlot et al. 2020). Indian Peninsular Wolf or the Grey Wolf is the only sub-species of wolf that mates in winter (Jhala 2013). It has a gestation period of 62–63 days. The average litter size of pups ranges from four–six individuals (International Wolf Center 2022). In previous studies, pups were provided electrolytes to prevent dehydration as electrolytes are a great source of energy

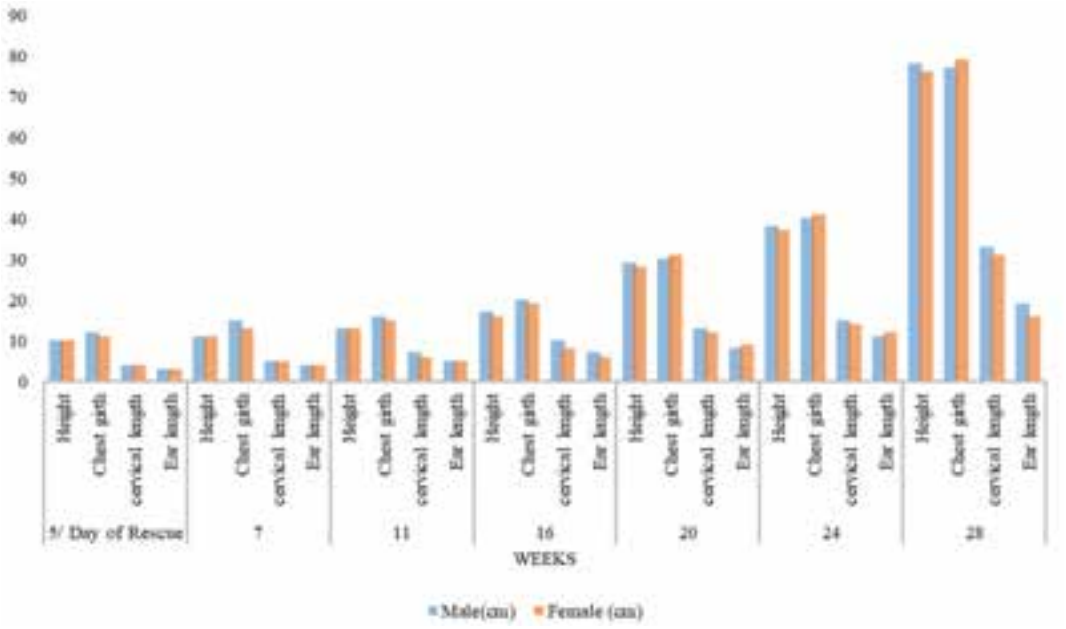

Figure 3. Weekly record of body growth parameters of rescued wolf pups.

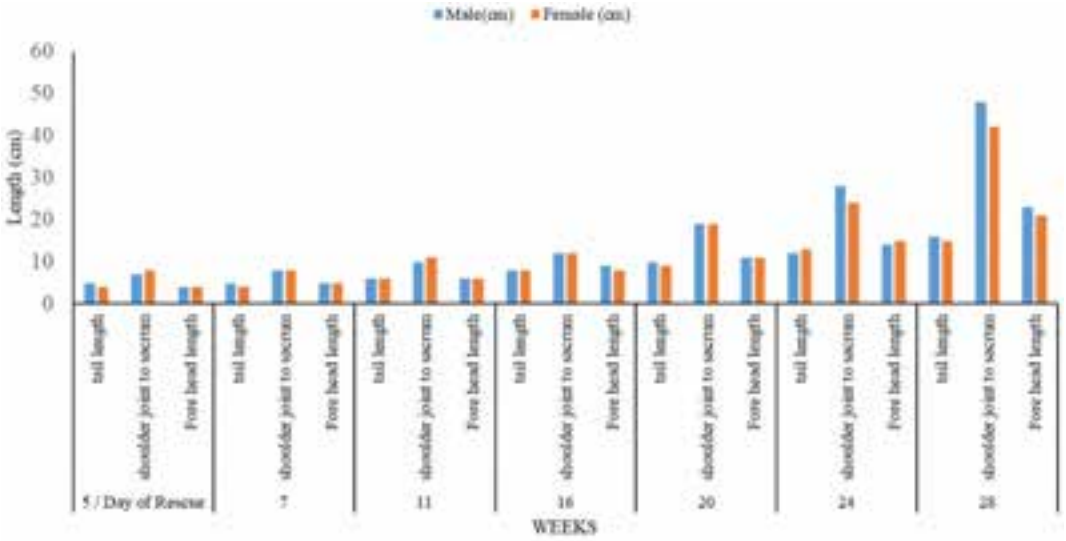

Figure 4. Weekly record of body growth parameters of rescued wolf pups.

and are easily digestible at any temperature. Commercial milk replacers were given and daily intake did not exceed 20% of body weight/day and was divided into frequent feedings (Nijboer 2020). Daily food intakes were recorded and changed progressively in hand-rearing (Dhoot et al. 2000). The Jackal *Canis aureus* shows a very close affinity to the Grey Wolf *Canis lupus* (Viranta et al. 2017). Four jackal pups were hand-reared at Maharajbag Zoo. The pups were given 30 ml of milk in the 1st week and 60 ml in the 6th week of growth. The amount was reduced to 25 ml at the end of the 10th week of growth. From the 4th week, a boiled egg was introduced to the feeding schedule. From the 8th week, two raw eggs and 30 g of raw kheema were introduced to their diet. The raw kheema was increased to 100 g in the 11th week (Dhoot et al. 2003). The weaning should be progressive and adjustable for wild cubs (Dhoot et al. 2003; Rivas et al. 2009). To restore gut fauna, tab Sporlac was introduced to the diet of leopard cubs at the Maharajbag Zoo (Dhoot et al. 2000). To combat vitamin and calcium deficiency, Ciflox TZ, Caldipet, Intavita syrup, and Mecovet XL syrup were used as supplementary diets (Gehlot et al. 2020).

Image 2. Rescue, feeding, housing, and morphological parameters of rescued Indian peninsular wolves. © Hemsingh Gehlot & Mahendra Gehlot.

In ex situ programs, mate selection should be carefully chosen for reproduction to maintain genetic variability within the wolf species. Field studies are very important for the conservation and relocation of captive animals in ex situ programs (Maia & Gouveia 2002).

CONCLUSION

Hand rearing involves the meticulous handling of premature wolf puppies that are only a few days old. They lack an efficient immune system. They can be nurtured carefully in a proper environment. The most important factor in nurturing an animal is its purpose, viz., captive breeding, reintroduction, and public display. Preserving natural behavior is an important aspect if an animal needs reintroduction. A good amount of time should be devoted to hand-rearing. The time, energy, and knowledge of the veterinarian and team who constantly efforts in the development of puppies relate to the success and failure in growth and reintroduction. The pups are now matured and thriving well in the captivity of Machia Biological Park of Jodhpur.

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SHORT COMMUNICATION

New records of forty-nine herbaceous plant species from lateritic plateaus for Ratnagiri District of Maharashtra, India

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Abstract: Ratnagiri is a coastal district and a part of Konkan region of Maharashtra. During our floristic studies on ephemeral and herbaceous plants of lateritic plateaus of Ratnagiri district from year 2020 to 2022, we have collected 49 herbaceous and ephemeral flowering plant species new addition to the Ratnagiri district. Newly added above said plant species belonging to 19 families and among them 16 species are endemic to India. This paper provides detailed checklist with herbarium specimen numbers for all the collected species and photographs of 16 endemic species.

Keywords: Additions, checklist, diversity, endemic, ephemeral, floristic, flowering plants, herbs, Konkan.

Ratnagiri is a coastal district of Maharashtra and it is divided into nine tehsils for administrative purpose viz., Chiplun, Dapoli, Guhagar, Khed, Lanja, Mandangad, Rajapur, Ratnagiri, and Sangameshwar. The area of Ratnagiri district is 8,208 km^2 and most of the areas are covered by low elevated lateritic plateaus. which is a distinct geographical feature of district. Laterites are iron-rich duricrusts which have formed directly from the breakdown of materials in their immediate vicinity, and so do not contain any readily identifiable allochthonous component, whereas, ferricretes are duricrusts which incorporate materials non-indigenous to the immediate locality (Widdowson 2003). Short-lived species of monsoon vegetation are usually neglected and missed by botanists as they complete their life cycle in short period from June to August. Such short-lived ephemeral and herbaceous species usually restricted to these plateaus. As a part of the research project on the 'Floristic studies on ephemeral and herbaceous plants of lateritic plateaus of Ratnagiri District (Maharashtra)' field explorations have been conducted throughout the Ratnagiri district on lateritic plateaus. During our explorations, total 548 herbaceous flowering plant species are collected of

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which 49 species are reported first time from Ratnagiri district. After scrutiny of literature (Cooke 1905–1908; Almeida & Mistry 1983–1986; Almeida 1996–2014; Ansari 2009; Cook 1996; Lakshminarasimhan et al. 1996; Singh & Karthikeyan 2000; Mishra & Singh 2001; Singh et al. 2001; Kattukunnel & Antony 2008; Potdar et al. 2012; Wadoodkhan 2015; Darshetkar et al. 2017) revealed that these species were not reported from Ratnagiri district so far, we report these species for the first time.

Material and Methods

The continuous field visits were made on lateritic plateaus of Ratnagiri district for survey, collection and documentation of plant species during different seasons from last three years (2020–2022). Habit and habitat photography was made with the help Canon M-50 DSLR Camera. The specimens were identified by referring to various floras and literature (Cooke 1905–1908; Almeida & Mistry 1983–1986; Almeida 1996–2014; Cook 1996; Lakshminarasimhan et al. 1996; Singh & Karthikeyan 2000; Mishra & Singh 2001; Singh et al. 2001; Yadav et al. 2004; Kattukunnel & Antony 2008; Ansari 2009; Potdar et al. 2012; Wadoodkhan 2015; Darshetkar et al. 2017). Herbarium specimens were prepared as per Jain & Rao (1977) standard methods and deposited at the Shivaji University of Kolhapur (SUK). Recent nomenclature and endemism are updated by using online databases, viz., International Plant Names Index (IPNI), Plants of the World Online (POWO), and Protologues & Shenzhen Code (Turland et al. 2018) has been followed.

Results

Detailed checklist of newly reported herbaceous plants with family and herbarium specimens' number are provided in the Table 1. Photographs of endemic plants species have also been provided in Image 1. and the photographs of lateritic plateaus from early monsoon to summer are provided in Image 2.

Conclusion

The total of 49 species (34 genera) of ephemeral and herbaceous flowering plants belonging to 19 families is reported for the first time from Ratnagiri district of Maharashtra of which 16 species (about 33%) are endemic to India which are marked with an asterisk in Table 1.

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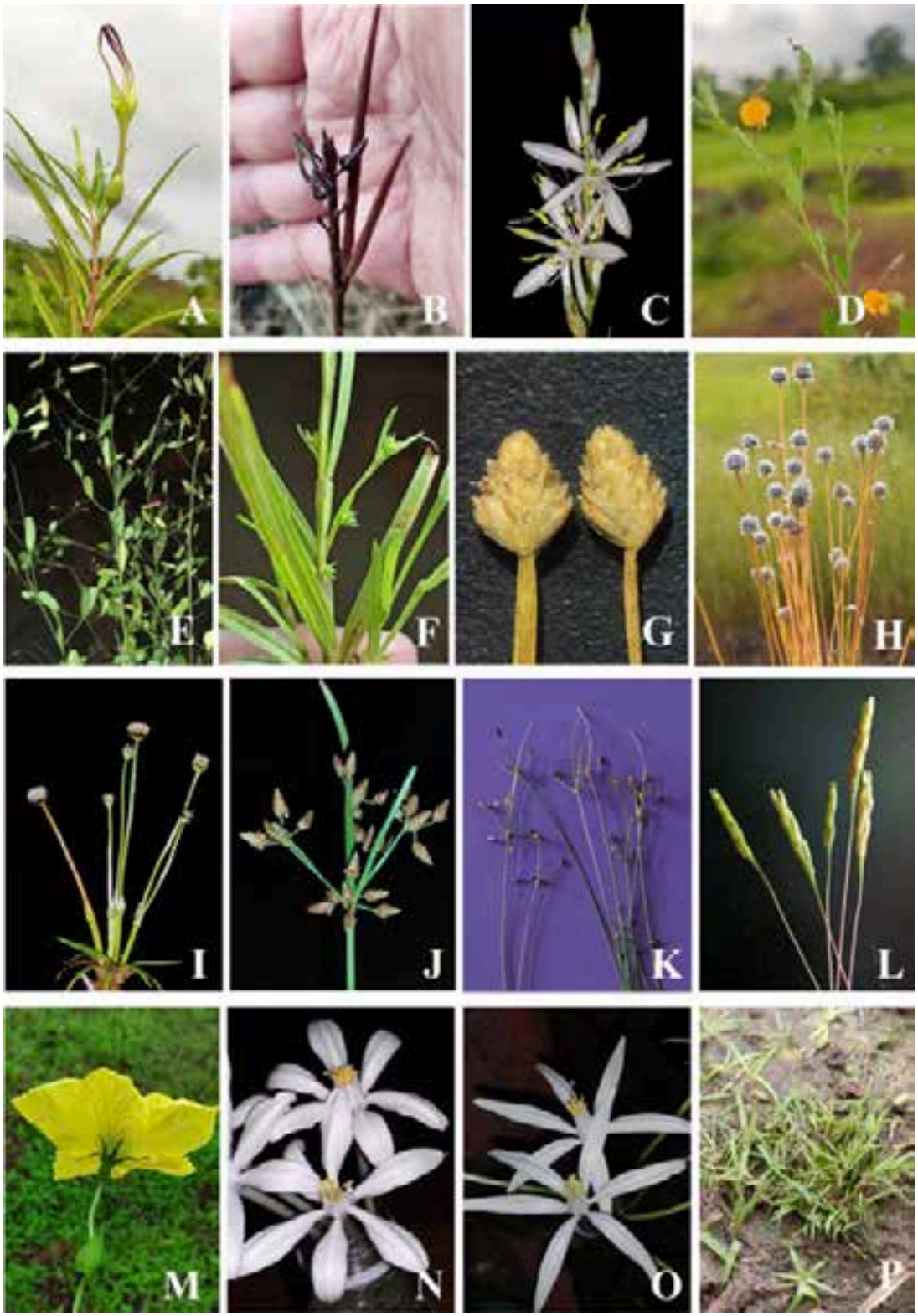

Image 1. Endemic plant species: A—*Ceropegia anantii* S.R.Yadav, Sardesai & S.P.Gaikwad | B—*Ceropegia malwanensis* (S.R.Yadav & N.P.Singh) Bruyns | C—*Chlorophytum borivilianum* Santapau & R.R.Fern| D—*Crotalaria filipes* var. *panthakii* M.R.Almeida & S.M.Almeida | E—*Crotalaria stocksii* Benth. ex Baker | F—*Diplacrum poklei* (Wad.Khan) K.C.Mohan | G—*Eleocharis zatei* W.Khan & Lakshmin | H—*Eriocaulon konkanense* Punekar, Malpure & Lakshmin. | I—*Eriocaulon parvicephalum* Darsh., R.K. Choudhary, Datar & Tamhankar | J—*Fimbristylis bhuskutei* W.Khan & R.D.Taur | K—*Fimbristylis sanjappae* W.Khan & Solanke | L—*Ischaemum bolei* Almeida | M—*Momordica sahyadrica* Kattuk. & V.T.Antony | N—*Pancratium donaldii* Blatt. | O—*Pancratium parvum* Dalzell | P—*Trithuria konkanensis* S.R.Yadav & Janarth. © A.N. Chandore, D.B. Borude and P.P. Bhalekar.

Table 1. Detailed checklist of newly reported herbaceous plants species for Ratnagiri district with family name, localities, habitat/note, phenology, and herbarium specimens' number.

	Scientific name	Family	Locality	Habitat	Phenology	Voucher specimens
1	*Rostellularia quinqueangularis* (J.Koenig ex Roxb.) Nees [*Rostellularia vahlii* Nees]	Acanthaceae	Guhagar; Varveli	Terrestrial erect herbs	October–December	ANC-2274; DBB-767
2	*Strobilanthes crossandra* (Steud.) J.R.I.Wood [*Hemigraphis crenata* (Benth. Ex Hohen.) Bremek.]	Acanthaceae	Rajapur; Hativale, Vikhare-Gothane	Terrestrial herbs	December–March	ANC-2495; DBB-145
3	*Crinum lorifolium* Roxb. [*Crinum pratense* Herb.]	Amaryllidaceae	Rajapur; Dhartale, Rantale, Vikhare-Gothane	Bulbous herbs	June–August	ANC-2014; DBB-512
4	**Pancratium donaldii* Blatt.	Amaryllidaceae	Rajapur; Rantale	Bulbous herbs	May–June	ANC-2013; DBB-507
5	**Pancratium parvum* Dalzell	Amaryllidaceae	Rajapur; Rantale	Bulbous herbs	May–June	ANC-2012; DBB-506
6	**Ceropegia anantii* S.R.Yadav, Sardesai & S.P.Gaikwad	Apocynaceae	Rajapur; Vikhare-Gothane	Tuberous herbs	July–August	ANC-2657; DBB-850
7	*Ceropegia bulbosa* Roxb.	Apocynaceae	Rajapur; Kasheli. Dapoli; Harne	Tuberous herbs, grows on rocky crevices	July–October	ANC-2617; DBB-810, 840
8	**Ceropegia malwanensis* (S.R. Yadav & N.P. Singh) Bruyns *[Brachystelma malwanense* S.R. Yadav & N.P. Singh]	Apocynaceae	Rajapur; Rantale	Tuberous herbs	April–May	ANC-2569; DBB-219
9	*Amorphophallus bulbifer* (Schott) Blume	Araceae	Rajapur; Saundal	Cormatous herbs, grows in shady places	June–July	ANC-2641; DBB-835
10	*Amorphophallus paeoniifolius* (Dennst.) Nicolson	Araceae	Rajapur; Hativale	Cormatous herbs, grows in shady places	June–July	ANC-2642; DBB-835
11	**Chlorophytum borivilianum* Santapau & R.R. Fern.	Asparagaceae	Rajapur; Prindavan	Tuberous roots herbs	July–August	ANC-2019; DBB-513
12	*Blumea hieraciifolia* (Spreng.) DC.	Asteraceae	Rajapur; Kharvate	Terrestrial herbs	December–March	ANC-2542; DBB-192
13	*Ipomoea pileata* Roxb.	Convolvulaceae	Rajapur; Rantale	Climbing herbs	August–November	ANC-2382; DBB-32
14	**Momordica sahyadrica* Kattuk. & V.T.Antony	Cucurbitaceae	Rajapur; Vikhare-Gothane	Climbing herbs	July–November	ANC-2643; DBB-836
15	*Cyperus squarrosus* L.	Cyperaceae	Rajapur; Hativale	Terrestrial herbs	August–November	ANC-2064; DBB-557
16	**Diplacrum poklei* (Wad.Khan) K.C.Mohan [*Scleria poklei* Wad.Khan]	Cyperaceae	Rajapur; Hativale	Terrestrial herbs, grows along stream side	November–January	ANC-2252; DBB-745
17	*Eleocharis equisetina* J. Presl & C. Presl	Cyperaceae	Rajapur; Kasheli	Aquatic herbs, grows in marshy areas on plateaus	August–November	ANC-2612; DBB-805
18	**Eleocharis zatei* W. Khan & Lakshmin.	Cyperaceae	Rajapur; Gavkhadi	Grows in marshy areas on plateaus	August–December	ANC-2609; DBB-802
19	**Fimbristylis bhuskutei* W.Khan & R.D. Taur	Cyperaceae	Rajapur; Saundal	Grow in grassland on plateaus	August–November	ANC-2152; DBB-644
20	*Fimbristylis pubisquama* J.Kern	Cyperaceae	Rajapur; Mudgund	Grows in marshy areas on plateaus	August–December	ANC-2083; DBB-576
21	**Fimbristylis sanjappae* W. Khan & Solanke	Cyperaceae	Rajapur; Vikhare-Gothane	Grows in marshy areas on plateaus	August–December	ANC-2106; DBB-598
22	*Fimbristylis stolonifera* C.B.Clarke	Cyperaceae	Rajapur; Hativale. Ratnagiri; Ganpatipule	After first shower of monsoon grows on plateaus	July–October	ANC-2058; DBB-551
23	*Fimbristylis woodrowii* C.B.Clarke	Cyperaceae	Rajapur; Vikhare-Gothane	Grows in grassland on plateaus: stamen solitary	August–December	ANC-2059; DBB-552
24	*Schoenoplectiella articulata* (L.) Lye [*Schoenoplectus articulates* (L.) Palla]	Cyperaceae	Ratnagiri; Ganpatipule	Aquatic herbs, grows in marshy areas on plateaus	August–December	ANC-2294; DBB-787
25	*Schoenoplectiella corymbosa* (Roth ex Roem. & Schult.) J.R.Starr & Jim.Mejias [*Schoenoplectus corymbosus* (Roth ex Roem. & Schult.) J.Raynal]	Cyperaceae	Rajapur; Padave, Upale	Aquatic herbs, grows in marshy areas on plateaus	August–December	ANC-2031; DBB-527
26	*Scleria lithosperma* (L.) Sw.	Cyperaceae	Rajapur; Barsu	Terrestrial herbs	October–December	ANC-2050; DBB-543
27	**Eriocaulon konkanense* Punekar, Malpure & Lakshmin.	Eriocaulaceae	Rajapur; Vikhare-Gothane	Terrestrial herbs	July–October	ANC-2182; DBB-674

	Scientific name	Family	Locality	Habitat	Phenology	Voucher specimens
28	**Eriocaulon parvicephalum* Darsh., R.K. Choudhary, Datar, and Tamhankar	Eriocaulaceae	Rajapur; Vikhare-Gothane	Terrestrial herbs	July–October	ANC-2187; DBB-679
29	*Eriocaulon setaceum* L.	Eriocaulaceae	Rajapur; Hativale	Aquatic herbs, Grow along streams on plateaus; submerged plant	August–November	ANC-2197; DBB-690
30	*Eriocaulon xeranthemum* Mart.	Eriocaulaceae	Rajapur; Arekarvadi, Jaitapur, Vikhare-Gothane	Terrestrial herbs	August–November	ANC-2180; DBB-672
31	*Aeschynomene americana* L.	Fabaceae	Rajapur; Tervan	Grows on plateaus along road side	August–September	ANC-2201; DBB-27
32	**Crotalaria filipes* var. *panthakii* M.R. Almeida & S.M. Almeida	Fabaceae	Rajapur; Hativale, Vikhare-Gothane	Terrestrial herbs, grows on plateaus	September–December	ANC-2415; DBB-65
33	**Crotalaria stocksii* Benth. Ex Baker	Fabaceae	Rajapur; Vikhare-Gothane	Grows in Grasses on plateaus	August–November	ANC-2482; DBB-132
34	*Desmodium scorpiurus* (Sw.) Desv. ex DC.	Fabaceae	Rajapur	Grows on road side: straggling herbs	August–October	ANC-2506; DBB-156
35	*Teramnus mollis* Benth.	Fabaceae	Rajapur; Taral, Hativale	Climbing herbs, grows on plateaus	August–October	ANC-2392; DBB-42
36	**Trithuria konkanensis* S.R. Yadav & Janarth.	Hydatellaceae	Rajapur; Karshingewadi, Hativale	Tiny herbs, grows in grasses on plateau	July–August	ANC-2136; DBB-628
37	*Blyxa echinosperma* (C.B.Clarke) Hook.f.	Hydrocharitaceae	Ratnagiri; Ganpatipule	Aquatic herbs, grows in streams on plateaus	August–September	ANC-2601; DBB-794
38	*Blyxa octandra* (Roxb.) Planch. Ex Thwaites	Hydrocharitaceae	Rajapur; Sakhar	Aquatic herbs, grows in ponds on plateaus	August–September	ANC-2156; DBB-648
39	*Najas graminea* Delile	Hydrocharitaceae	Rajapur; Nanar	Aquatic herbs, grows in ponds on plateaus	August–November	ANC-2096; DBB-589
40	*Pogostemon quadrifolius* (Benth.) F.Muell.	Lamiaceae	Rajapur; Saundal	Grows in undershrub on plateaus	August–December	ANC-2565; DBB-215
41	*Lindernia procumbens* (Krock.) Borbas	Linderniaceae	Rajapur; Adivare	Grows in paddy fields on plateaus	August–November	ANC-2618; DBB-811
42	*Microcarpaea minima* (J.Koenig ex Retz.) Merr.	Phrymaceae	Rajapur; Kasheli	Grows in marshy areas on plateaus	July–September	ANC-2616; DBB-809
43	**Ischaemum bolei* Almeida	Poaceae	Rajapur; Vikhare-Gothane	Grows on plateaus	July–September	ANC-2476, DBB-126
44	*Leersia hexandra* Sw.	Poaceae	Rajapur; Sakhar	Grows on plateaus in marshy places	July–October	ANC-2460; DBB-110
45	*Setaria parviflora* (Poir.) Kerguelen [*Pennisetum polystachion* (L.) Schult.]	Poaceae	Guhagar	Grows on plateaus along roadsides	October–December	ANC-2276; DBB-769
46	*Dentella repens* var. *serpyllifolia* (Wall. Ex Craib) Verdc.	Rubiaceae	Rajapur; Hativale	Grows on plateaus in marshy places	December–February	ANC-2502; DBB-152
47	*Oldenlandia affinis* (Roem. & Schult.) DC. [*Hedyotis affinis* Roem. & Schult.]	Rubiaceae	Rajapur; Prindavan	Grows in grasses on plateaus	October–September	ANC-2007; DBB-501
48	*Curcuma neilgherrensis* Wight	Zingiberaceae	Rajapur; Hativale	Rhizomatous herbs, grows on plateaus	July–October	ANC-2531; DBB-514
49	*Kaempferia rotunda* L.	Zingiberaceae	Rajapur	Rhizomatous herbs, grows on plateaus	August–September	ANC-2641; DBB-835

*- Endemic to India

Image 2. A–D—Lateritic plateaus from first shower of monsoon to summer. © A.N. Chandore.

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SHORT COMMUNICATION

First report of moth species of the family Tineidae (Lepidoptera) in regurgitated pellets of harriers in India

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Abstract: Caterpillars of Tineidae moths mainly feed on keratin sources and require moisture and warm temperature for emergence. The presence of Tineidae moth caterpillars, pupae, and adults in regurgitated pellets of harriers, diurnal migratory raptors wintering in India, suggests a potential dietary association and highlights the importance of considering associated organisms in raptor diet estimation studies. The caterpillars preferred rodent hairs present in the pellets over feather and arthropod remains. This is the first record of Tineidae moths on the pellets of harriers.

Keywords: Arthropods, caterpillar, diet, grassland, Harrier, Maharastra, Monopis, pellets, pupae, raptor, regurgitate, Tineidae, Tirunelveli, undigested.

Regurgitating pellets to eject indigestible matter from the gizzard is observed in about 330 species of birds belonging to more than 60 families (Glue 1973). Among these families, pellets ejected by raptors usually contain undigested prey materials such as fur, feathers, bones, scales, and chitin (Philips & Dindal 1979). Pellets generally decompose within a few weeks to months (Wilson 1938; Marti 1974), but it can also remain intact for several years (Brooks 1929; Prestt & Wagstaffe 1973). Most times, pellets either disintegrate on their own due to local weather conditions or are eaten by a variety of arthropods, including ants and beetles. Caterpillars are rarely found in pellets since they mainly feed on plant parts such as leaves, floral tissue, or fruits (Young 1997).

However, a particular group of moth caterpillars belonging to the family Tineidae feed on resources other than plant parts such as fur, feathers, arthropod remains, guano, wool, and hair (Robinson & Nielsen 1993) that are rich in keratin and chitin. Tineidae caterpillars are commonly found in bird nests, and undigested prey contents in raptor pellets form a significant part of their diet (Robinson & Nielsen 1993; Robinson 1998; Terry 2004; Sato et al. 2019). They aid in pellet decomposition by feeding on the fur and feather remains in pellets (Philips & Dindal 1979). Tineidae caterpillars also construct a tube-like larval case made out of the fur and feather remains in pellets (Nasu et al. 2007). Raptor pellets are known to support many invertebrates such as ants, trogid beetles and Tineidae moths for their breeding, feeding, and shelter requirements (Philips &

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Dindal 1979). Previous studies have recorded several moth species of the Tineidae family, i.e., *Monopis congestella*, *M. pavlovskii*, *M. crocicapitella*, and *M. longella* in the nests and pellets of the Great Horned Owl (Philips & Dindal 1979), Ural Owl and Goshawk (Nasu et al. 2008), eagles (Sharkov et al. 2003), and in bat droppings (Byun et al. 2014; Heckford & Beavan 2018). In New York, a single pellet of the Great Horned Owl had 60 caterpillars of Tineidae moths in it (Philips & Dindal 1979). However, Tineidae moths have not been recorded from harrier pellets previously.

Here, the occurrence of Tineidae moth caterpillars in harrier pellets and their potential role in influencing raptor diet estimation studies is described.

Materials and Methods

The study focused on investigating the diet of harriers in their Indian wintering range, specifically in Rengarajapuram, Tamil Nadu state (8.5474, 77.7039) and Dahiwadi, Maharashtra (17.8243, 76.0504), from 2016 to 2022. Harrier pellets, regurgitated remnants of prey, were collected from roosting sites predominantly utilized by Montagu's Harrier *Circus pygargus*, Pallid Harrier *Circus macrourus*, and Western Marsh Harrier *Circus aeruginosus*. To prevent fungal attacks and ensure the preservation, the collected pellets were sun-dried and subsequently packed in zip-lock covers. Morphological measurements including length and breadth were taken for each pellet in the laboratory. Prior to dissection, the pellets were soaked in water, facilitating the identification of prey items. Observations were made within the zip-lock packets to monitor caterpillar emergence, followed by a week-long observation period to determine the number of pupae present in the disintegrated pellets, thus providing an estimate of the emerged larvae or adults. These methods enabled a comprehensive analysis of the harriers' diet in the specified region and time frame.

Results and Discussion

The study provides the first record of Tineidae moth caterpillar, pupae, and adults occurring in harrier pellets. A total of 160 pupae were found in the pellets with a maximum of 38 pupae from one single pellet collected from Maharashtra in 2017; 15 pellets were collected from this harrier roost site and stored in a zip-lock cover. While examining these pellets to ascertain the diet of harriers, we initially observed a few dead caterpillars in the zip-lock packets. The caterpillars were white colored with brownish heads (Image 2). The adult moths were also present on the pellets with creamy white heads, and erect scales on vertex and frons. They had a filiform antenna; scape with black and brownish scales; basal of the wing black; forewings with black and white color in

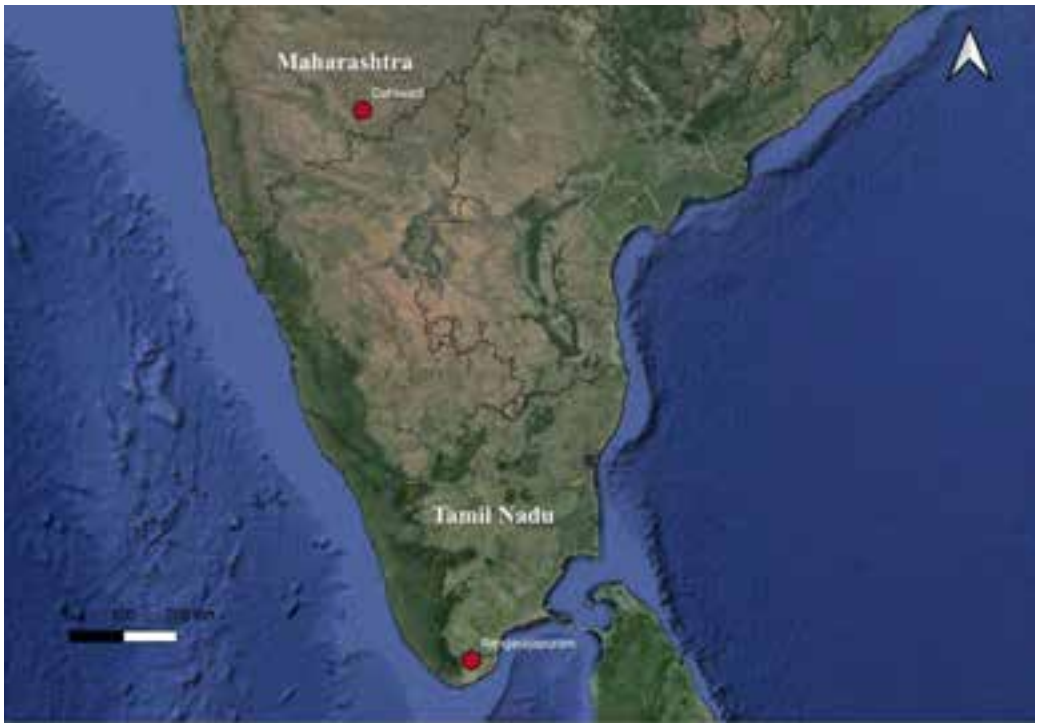

Image 1. Map showing harrier roost sites from where the collected pellets contained Tineidae moths.

Image 2. Water-soaked pellet with Tineidae moth caterpillars.

Image 3. The adult Tineidae moths found from the pellets: a—*Monopis* sp. | b—*Monopis* cf. *monachella*.

equal proportions and the apex was dull black and the termen white. There was a trace of a darker subterminal line originating from the apex and retracting in the middle before which there were two tiny black dots. Based on the above morphological characteristics, the moths were identified to be belonging to the genus *Monopis* (Kristensen 1999).

In 2021, during the collection of pellets from a roosting site in Tamil Nadu, a caterpillar belonging to the genus *Monopis* sp. was once again recorded. Despite the complete disintegration of the pellets, a total of 132 pupae were identified. Notably, within the same set of pellets, another *Monopis* species, specifically *Monopis* cf. *monachella* (Huang et al. 2011), was documented. This species exhibited distinctive characteristics, including a vertex and frons covered with erect white piliform scales (Image 3), filiform antennae, elongated wings with a moderately rounded apex, and a simple forewing pattern consisting of a round, purple-black color with a large rectangular oblique white marking on the costa, encompassing the subhyaline spot at the end of the discoidal cell (Robinson et al. 1994). Significantly, the collection of these pellets occurred shortly after a period of significant rainfall in the region. Despite the inability to determine the exact number of pellets, these findings provide valuable insights into the presence of *Monopis* species and their association with the harrier diet in the Tamil Nadu roosting site.

Based on the analysis of pellet remains, it was evident that caterpillars exhibited a clear preference for consuming pellets that contained rodent hairs, followed by bird feathers (Figure 1). However, it is noteworthy that the caterpillars did not consume the available grass, seeds, bones, bird gizzard, or eggshells found within the pellets. The outer surface of the pellets remained intact, and the presence of caterpillar frass was observed inside

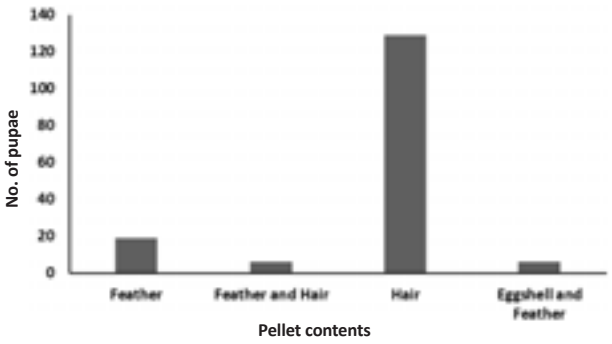

Figure 1. Graph showing the number of pupae in pellets with different prey contents.

the pellets, indicating that the caterpillars had actively fed on the pellet contents.

The life cycle stages of tineid moths, including their eggs, larvae, and pupae, are known to be sensitive to environmental variables, such as temperature and humidity (Griswold & Crowell 1936). Temperature fluctuations have been shown to significantly influence the egg-laying behavior of these moths (Brimblecombe & Lankester 2013). Although the pellets were thoroughly dried and carefully packed, the emergence of caterpillars and a few adults from the zip-lock packets indicated that the moths may have laid their eggs while the pellets were still in the field before collection. Subsequently, these eggs remained dormant until they were exposed to moisture upon opening the bags in the laboratory. An alternative explanation could be that the larvae were already feeding on the pellet contents from within, and the water soaking process stimulated to come out from the pellet. It is important to note that certain moth species can maintain prolonged dormancy as eggs,

caterpillars, or pupae (Young 1997). To further validate these assumptions, additional in-depth investigations on the ecology and behavior of Tineidae moths are warranted.

This observation marks the first-ever documented instance of Tineidae moth caterpillars within harrier pellets. The identification of Tineidae moths as the decomposers of these pellets highlights the need to explore the factors that facilitate their egg-laying and pupation processes, as not all collected pellets across the years showed signs of infestation. Understanding these conditions is crucial, as they can potentially affect the availability of pellets and introduce biases in dietary estimates, not only for harriers but also for other raptors. If Tineidae moths frequently disintegrate harrier pellets containing feathers and hairs, it can lead to a skewed representation of the dietary preferences of these birds, favoring alternative prey categories in the estimations. Therefore, further investigations into the interaction between Tineidae moths and harrier pellets are essential for accurate dietary assessments and to avoid potential biases in ecological studies involving raptors.

The distribution of tineid moth species in India is currently poorly documented. The presence of *M. monachella* in the pellets collected from Tamil Nadu is noteworthy, as previous records of this species were limited to Kerala and Karnataka, where it was identified using light traps (Pathania & Rose 2004). Therefore, our study provides the first distribution record of *M. monachella* in Tamil Nadu. On the other hand, the tineid moth in the pellets collected from Maharashtra could not be identified at the species level due to the unavailability of type specimens. This highlights the pressing need for comprehensive taxonomic studies on moths, particularly within grassland ecosystems, which have received limited attention thus far. Such preliminary information is crucial for studying host-specificity and can provide valuable insights into the conservation status of these moths, especially considering the declining status of harrier populations due to landscape changes and the loss of grasslands (Ganesh & Prashanth 2018; Saravanan et al. 2021).

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NOTE

Capturing the enchanting glow: first-ever photographs of bioluminescent mushroom *Mycena chlorophos* in Tamil Nadu, India

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Mushrooms belong to the group of organisms known as macrofungi under the phylum Ascomycotina and Basidiomycotina within the fungal kingdom. Mushrooms are fleshy, spore bearing-fruiting bodies of the fungus (Chang & Miles 1987). Bioluminescent fungi are members of the order Agaricales, typically found in tropical, sub-tropical, and temperate climates, except for *Xylaria hypoxylon* (L.) Grev., which is an Ascomycete. Bioluminescence in fungi relies on oxygen and involves the interaction of substrates broadly categorized as luciferins. Luciferins are catalyzed by one or more diverse enzymes collectively referred to as luciferases (Kaskova et al. 2017; Patil & Yadav 2022). The chemical reaction results in the emission of light, characterizing it as cold light. The phenomenon of bioluminescence is primarily exhibited by 103 species of mushrooms (Desjardin et al. 2008; Chew et al. 2014; Desjardin et al. 2016; Weinstein et al. 2016; Karunarathna et al. 2020; Dauner et al. 2021; Oba & Hosaka 2023) of which seven species have been found in India, viz, *Mycena indica* Sarwal & Rawla (Manimohan & Leelavathy 1988), *Omphalotus olearius* (DC.) Singer (Vrinda et al. 1999), *Nohopanus eugrammus* (Mont.) Singer (Vrinda et al. 1999), *Mycena deeptha* Aravind. & Manim. (Aravindakshan et al. 2012), *Roridomyces phyllostachydis* (Karunarathna et al. 2020), *Mycena chlorophos* (Berk. & M.A.Curtis) Sacc. (Arya et al. 2021) and *Armillaria mellea* (Vahl) P. Kumm. (Patil & Yadav 2022).

An opportunistic survey was conducted within the protected area of Kanyakumari Wildlife Sanctuary (KKWS) of Tamil Nadu by a team of researchers in the Kulasekharam forest range (8.4064 °N, 77.4327 °E) during the monsoon season (July–September) on 21 Sept 2023. Around 1900 h, we encountered mycelial growth which was recognized as bioluminescent mushroom in the dead and decaying bamboo culms. The fungus was identified based on the current literature available as *M. chlorophos* (Berkeley & Curtis 1860; Kushwala & Hajirrnis 2016). The mushrooms were photographed using Canon EOS R3 with specific setting f/3.5, ISO-800, Exposure 10 sec. *M. chlorophos* exhibits luminescent basidiomata and mycelium, whereas its closely related species, *M. deeptha* (Aravindakshan et al. 2012) in Trivandrum, does not exhibit luminescent basidiomata.

M. chlorophos, was described in 1860 on the Bonin Islands, Japan (Berkeley & Curtis 1860). Recent

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studies have reported the distribution of this species in both the old world and the new world from recent studies (Desjardin et al. 2010). Hence, it is considered a pantropical distribution (Desjardin et al. 2010). In *M. chlorophos*, the mature fruiting body is characterized by a pristine white disc morphology featuring a shallow central depression. It emits bright, greenish light in the dark from the basidioma and mycelium (Image 1c). The basidiomata is spherical in buds and has a shallow depression with whitish grey or brown disc like shape when matured. In wet weather, it looks viscid with a thick gluten/gelatinous cover (Image 1b). Pileus 25 mm diameter, parabolic to spherical in buds, surface dark brown to greyish brown, pellucid striate, glabrous, shiny, lamellae adnexed (Image 1d), white, edge concolorous to the sides. Basidioma with discoid stipe base. Mostly the luminescent mushroom (*M. chlorophos*) habitat was solitary to scattered on dead, decaying bamboo culms rarely on other dead trees. The present study is the first photographic record of bioluminescent fungi in Kanyakumari, Tamil Nadu, India. Earlier *M. chlorophos* was reported from Western Ghats parts of Kerala (Arya et al. 2021).

The benefits of bioluminescent in fungi include their capacity to attract insects, facilitating their spore dispersal (Bermudes et al. 1992). An alternative hypothesis suggests that bioluminescence may be an incidental outcome of biochemical reactions, devoid of any discernible ecological function (Bermudes et al. 1992). The unsystematic collection/over exploitation of mushrooms inside protected areas leads to depletion of the macro fungal diversity. Habitat destruction is posing a serious threat to mushrooms, leading to their extinction (Swapana et al. 2008). Mushrooms are very sensitive to environmental changes such as increase in global temperature and change in rainfall pattern. This

Image 1. a—Mushroom buds | b—Basidiomata with viscoid pileus | c—Dark exposure photograph of basidiomata | d—Lamellae | e—Bioluminescenc observed in the early morning hours. © Jude D. and M. Siva Kumar.

leads to species diversity loss and change in mushroom species distribution. A detailed study on the spatio-temporal distribution of mushrooms is the need of the hour. At this juncture, it would also be highly desirable in understanding the ecological importance of the taxa around KKWLS.

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Extended distribution of *Clematis wightiana* Wall. (Ranunculaceae) in the Indian State of Arunachal Pradesh – a hitherto endemic species of the Western Ghats, India

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The genus *Clematis* L. belongs to the family Ranunculaceae, distributed throughout the world, specifically in temperate and subtropical regions of the North Hemisphere, and comprises c. 280–350 species globally (Tamura 1987, 1995; Wang & Li 2005). In India, the genus comprises 49 taxa viz. 42 species, one subspecies, and six varieties (Mao & Dash 2020) of which 13 taxa are endemic to India. From a taxonomic point of view, the genus is the most difficult one in the family Ranunculaceae, and has been treated variously from time to time. De Candolle (1818), in his revisionary study, treated 84 taxa of the genus *Clematis* L., into four (04) Sections. Spach (1839) classified the genus into three (03) Sections. In 1888, Prantl proposed a new sub-sectional classification of the genus which was later supported by Schneider (1906), Rehder & Wilson (1913), Handel-Mazzetti (1939), and Rehder (1940). In 1950–1967, Tamura made a comprehensive study of the genus *Clematis* L. which was based on Prantl's framework. However, after 20 years, in his revised system of classification (1987), Tamura introduced a new character, i.e., phyllotaxy of seedling leaves and proposed a subgeneric classification of the genus. This treatment was later followed by Snoeijer (1992) and Grey-Wilson (2000) with few modifications. However, Johnson (1997, 2001), in his recent revisionary studies, did not accept the newer sub-generic classification of the genus *Clematis* L. of Tamura and rather he was fond of his earlier classification of this genus with 07 subsections of the section *Clematis* L. (Wang 2004).

Clematis wightiana Wall. belongs to the family Ranunculaceae, and has been reported as an endemic to the Western Ghats in India. A thorough review of the literature along with a meticulous study of herbarium specimens has indicated the occurrence of this species from Karnataka (Saldanha 1984), Kerala (Daniel 2005), Maharashtra (Cooke 1958; Singh & Karthikeyan 2000), and Tamil Nadu (Nair & Henry 1983). Further consultation of herbarium specimens deposited at MH, RHT, TBGT, and appraisal of relevant literature (Hook.f. & Thomson 1872) was done for authenticating the distribution of the species in the Western Ghats. As part of the Action Plan Project, entitled 'Flora of West Siang District, Arunachal Pradesh', extensive field trips were carried out during 2010–2013 to different areas of West Siang district of Arunachal Pradesh during which

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an interesting species of the family Ranunculaceae was collected from the villages of Mechuka (28.60027N, 94.13444E), Rego (28.53456N, 94.21392E), near Tato (28.52798N, 94.37317E) and way from Rego to Tato (27.79944N, 94.07472E). A total of 12–15 smaller patches were noticed from each locality which was part of a scattered population. The identification of the species was confirmed by consultation of protologue, authentic literature, and type specimen. During the consultation of Ranunculaceae specimens in ASSAM herbarium, two (2) similar collections of G. Panigrahi 15601 & 6636 and one (01) collection of D.B. Deb 30844, collected from Kameng District, Arunachal Pradesh, and Mizoram respectively, identified as *Clematis wightiana*, were examined. Based on Deb's collection, the species was included in the Flora of Mizoram (Singh 2002), but unfortunately was overlooked in any of the published flora of Arunachal Pradesh. However, until the discovery of *Clematis wightiana* Wall. from the state of Arunachal Pradesh, the species was reported as a narrow endemic to Western Ghats, especially to the states of Karnataka, Kerala, Maharashtra, and Tamil Nadu (Singh et al. 2015) and occasionally in Bailadilla, Madhya Pradesh (Arora 1968). However, no specimen was found in any of the National Herbarium from the mentioned region which at present belongs to the state of Chhattisgarh. Further, thorough literature survey also concludes uncertain distribution of the species *Clematis wightiana* in the state of Chhattisgarh. The present report of the species represents an extended distributional range to the state as well as a new record for the state of Arunachal Pradesh, earlier known from Western Ghats and the state of Mizoram. In the present communication, detailed descriptions of the species with citation, type, flowering & fruiting data, ecology, and distribution status are provided along with herbarium images.

Clematis wightiana

Wall. [Cat. No. 4674. 1828, *nom. nud.*] ex Wight & Arn., Prodr. 2. 1834; Hook.f. & Thomson in Hook.f., Fl. Brit. India 1: 5. 1872; Dunn in Gamble, Fl. Madras 3(2): 1915; Deb & Dutta in J. Econ. Tax. Bot. 10(1): 28. 1987; M.A. Rau in B. D. Sharma & al. (ed.), Fl. India 1: 80. 1993; Singh et al., Endemic Vasc. Plts. India 222. 2015; V.K. Mastakar et al. in A.A. Mao & S.S. Dash (ed.), Checkl. Flower. Pl. India (Dicot.) 1: 19. 2020.

Type: India, without locality, R. Wight s.n. (MH)

Large woody climbers, c. 2–5 m high, covered with shining greyish or brownish hairs throughout; branches curved, 12-ribbed, villous. Leaves opposite, pinnately 3–5-foliolate; leaflets oblong-ovate or ovate-lanceolate, 6–10 x 3–5 cm, entire, often 3–5-lobed, ovate-cordate at base, margin irregularly dentate, acute or mucronate at apex, chartaceous, softly silky, villous, dark above, brown sericeo tomentose beneath; nerves prominent, thick beneath; petioles long, silky hairy. Inflorescences axillary or terminal, paniculate; bracts and bracteoles present; bracts ovate, 0.3–0.5 cm long, hairy; bracteoles linear, 0.1–0.2 cm long, hairy, narrowly linear. Flowers white or pale cream or golden yellow, *c.* 6cm across; perianth uniseriate, petaloid; tepals 4, ovate to ovate-elliptic, 1.5–3 x 0.5–0.8 cm, ribbed, soft tomentose outside, glabrous inside; stamens many; filaments linear, glabrous at apex and base, hairy at middle, 7–10 cm long; pistils many; style feathery, hairy, white, 0.3–0.5 cm long. Achene ovate, 0.4–0.5 x 0.2–0.3 cm, compressed, silky hairy, crowned with persistent elongated feathery style (Image 1).

Flowering & fruiting: November–March; January–May

Distribution: India: Arunachal Pradesh, Karnataka, Kerala, Maharashtra, Mizoram, Tamil Nadu

Habitat, Ecology & Conservation Status: These woody climbers grow in open forests, on hill slopes at 1,300–1,800 m altitude. The species is facing a shrinking population in its natural habitat due to overgrazing by domestic animals, collection of fire wood by localities, deforestation for rapid urbanization, development of the tourism sector, increased number of scientific field tours throughout the year, and uncontrolled collection of specimens in bulk, etc. Although no measure has been proposed for this species till now, to prevent the reduction of the population size of the species in nature, in situ as well as ex situ conservation measures are to be adopted at the government level.

Specimens examined: 25157 (ARUN), 13.xi.2010, India, Arunachal Pradesh, West Siang, Mechuka, 28.60027N, 94.13444E, 1,800 m., coll. M Bhaumik; 25159 (ARUN), 13.xi.2010, India, Arunachal Pradesh, West Siang, Rego to Tato, 27.79944N, 94.07472E, 1,200 m, coll. M Bhaumik; 15601 (ASSAM), India, Arunachal Pradesh, West Kameng, Brukpata, 27.37666N, 92.28583E, 1,960 m., coll. G. Panigrahi; without coll. no. (ASSAM), 08.iv.1957, India, Arunachal Pradesh, Hill slope near Rupa upto Jegaon, 27.20250N, 92.39805E, 1,515 m., coll. unknown; without coll. no. (MH), without coll. date, India, Karnataka, Chamarajnagar, 11.92254N, 76.94515E, 733 m., coll. unknown; without coll. no. (MH), without coll. dt., India, Karnataka, Kolar, 13.13615N, 78.12879E, 872 m, coll. unknown; without coll. no. (MH), without coll. dt., India, Kerala, Wayanad, 11.69334N, 76.12997E, 765 m, coll. unknown (MH);

Image 1. Herbarium specimen of *Clematis wightiana* Wall. deposited in ARUN, BSI.

30884 (ASSAM), 16.i.1963, India, Mizoram, Aizawl, Sialsuk, 23.39833N, 92.74218E, 1,315 m., coll. D.B. Deb; 40336 (MH), 28.ii.1972, India, Tamil Nadu, Nilgiri, Snowdown R.F., 11.57444 N, 76.75416E, 800 m., coll. B.D. Sharma.

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NOTE

Smilax borneensis A.DC. (Smilacaceae): an addition to the flora of India

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The floristic diversity of the northeastern region of India is not well-documented due to its inaccessibility and difficult terrain. Although a detailed floristic study has already been done on *Smilax* L. from the state of Arunachal Pradesh (Chowdhery et al. 2009) and other parts of eastern Himalaya (Rae 1994; Baruah et al. 2022), however proper documentation of the genus in the northeastern region is yet to be accomplished. Traditionally, the family Smilacaceae comprised of two genera, *Smilax* L. and *Heterosmilax* Kunth, which differ by their connate tepals and the variable number of stamens (3, 6, 9–12) with connate filaments. Qi et al. (2013) merged *Heterosmilax* Kunth with *Smilax* L. based on the molecular phylogeny, by which only one genus *Smilax* exists in the family.

Smilax L. is the type genus of the family Smilacaceae, with 261 species (POWO 2023). These are widely distributed mostly in tropical and subtropical areas, but also found in temperate regions in the Southern and Northern Hemispheres (Chen et al. 2006; Qi et al. 2013). Koyama (1963, 1971, 1975), Noltie (1994), and Baruah et al. (2011, 2017) have reported many species from the eastern Himalayan region. In India, the genus is represented by 33 species, three subspecies and two varieties, which are distributed in almost all parts of India, especially in Uttar Pradesh, Tamil Nadu, Bihar, Uttarakhand, Jammu & Kashmir, northeastern states, West Bengal, and Andaman & Nicobar Islands. Northeastern India hosts 29 species of *Smilax*, of which 13 species and two varieties are reported from Arunachal Pradesh (Murthy & Bhaumik 2020). However, like other monocots of Northeast India, the Smilacaceae is also yet to be properly documented and studied.

During the botanical exploration trips in the Papum Pare district of Arunachal Pradesh, the authors collected specimens belonging to the genus *Smilax*. For preliminary identification, all the detailed morphological characters, i.e., leaves, stems, inflorescence, flowers, and fruits were studied (Image 1). A perusal of relevant literature and herbarium materials housed at various Indian herbaria (e.g., CAL, ASSAM, ARUN, BSIS, BSHC, BLAT) the specimens were identified as *Smilax borneensis* A.DC., a species so far not reported from India. This was further compared and confirmed with the photograph of the type specimen deposited at Kew Herbarium (K) (available at https://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:541318-1). A detailed description, ecology, and distribution along with colour photographs are provided for easy identification of the species.

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Figure 1. Distribution of *Smilax borneensis* in Arunachal Pradesh.

Measurements and morphological character assessments of the specimens examined based on freshly collected material. Three numbers of specimens were collected with flowers and fruits and it was pressed in blotting papers for drying for about one month. After proper drying the specimens were mounted in herbarium sheets and finally deposited in ASSAM and GUBH herbaria. The data have been compared with published descriptions of morphologically similar species (Candolle & Candolle 1878; Heckroth et al. 2004; Siti & Sulistyaningsih 2019) and type specimens in herbaria (K, FL, CAL). *S. borneensis* is closely similar to *S. gigantea* Merr., a native species of Borneo. Both species develop ovate to acute domatia which encloses the stem from all sides, but *S. borneensis* can be easily differentiated from *S. gigantea* which have larger leaves (about 35 cm long and wide) and long inflorescence (up to 30 cm) (Siti & Sulistyaningsih 2019).

Smilax borneensis A.DC., Monogr. Phan. 1: 202. 1878.

A large, coarse, perennial woody vine, inflorescence-bearing branches terete, with numerous secondary branches, brown, striate, 8–10 mm in diameter, armed with scattered, very stout, narrowly pyramidal spines about 2–3 mm in length. Leaves broadly ovate, 9–18 × 5–10 cm, base broadly rounded and deeply cordate, apex very shortly and abruptly acuminate, coriaceous to subcoriaceous, upper surface smooth, glabrous and shining, lower surface softly and densely pubescent; petioles stout, about 2–3.5 cm long; domatia broadly clasping nodes, ovate to acute, light brown in colour; primary veins 7–9, outer four less prominent, sometimes outermost two barely noticeable. Inflorescence of 1–3 umbels, borne in leaf axil; peduncles 2–4 cm long, straight, slightly compressed; umbel 15–28-flowered. Male flowers slightly greenish, 1.5–2 cm in length, pedicels 1–1.8 cm long; outer tepals broad 4–8 × 1–3 mm; inner tepals thin, 4–6 × 0.2–0.5 mm; stamens 6, 7–12 mm long; anthers white, basifixed. Female flowers pinkish-green, pedicels 1–1.8 cm long; outer tepals broad, 5–9 × 1–3 mm; inner tepals thin, 5–9 × 0.1–1.5 mm; ovary 3-chambered, stigma 3-lobed. Fruits greenish, become red when ripened, fleshy, globose, c. 1 cm in diam., 15 to 28 in each umbel.

Specimens examined: Female plant of Smilax borneensis; India, Arunachal Pradesh, Papum Pare district, Kimin, 27.3229°N & 93.9725°E (Figure 1), 25 August 2021, coll. K. Deka, 2574 (ASSAM), 2575 & 2576 (GUBH).

Flowering May to July, Fruiting August to November.

Habitat & Ecology: Grows in gaps of primary hill forests and scrub jungles, up to 9,000 m. The species is associated with *Calamus inermis, Calamus latifolius, Castanopsis indica, Castanopsis tribuloides*, *Vatica lanceaefolia*, and *Ficus semicordata* in the same ecological community. *Smilax borneensis* is a facultative

Image 1. *Smilax borneensis*: A—Habit | B—Female flower | C—Mature fruit with domatia. © Kishor Deka.

ant-plant that provides both shelter (domatia) and food (extrafloral nectar) for opportunistically nesting ants. The native range of this species is Borneo and here reported for the first time from Arunachal Pradesh, India. There is a possibility of its occurrence in Myanmar and Thailand.

IUCN status: Not assessed.

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Recent record of True Giant Clam *Tridacna gigas* from the Sulu Archipelago and insight into the giant clam fisheries and conservation in the southernmost islands of the Philippines

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The Philippines, being part of the Coral Triangle region, is known for its rich marine biodiversity. It is a global hotspot for giant clam diversity, where eight of the 12 species of living giant clams, including the largest, *Tridacna gigas,* have been documented. Studies from the 1980s indicated that the population of *T. gigas* had been significantly reduced to less than two individuals per hectare and became locally extinct in many of its natural reef habitats across the country (Juinio et al. 1989).

Responding to this alarming decline, the UP Marine Science Institute's initiatives in the late 1980s became instrumental in the recovery of *T. gigas* population. By developing hatchery-produced individuals from Solomon Islands broodstock, they have successfully restocked over 70,000 individuals of *T. gigas* and other giant clam species to more than 40 sites nationwide (Gomez & Mingoa-Licuanan 2006; Lebata-Ramos et al. 2010). This restoration effort has paved the way for the establishment of several giant clam sanctuaries in places like Bolinao in Pangasinan and Samal Island in Davao del Norte, which contributed to the local economy through eco-tourism (Gomez & Mingoa-Licuanan 2006; Chavez 2019).

All species of giant clams are listed in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), which means they are not necessarily threatened with extinction but may become so unless trade is closely controlled. In the Philippines, this classification means that the harvest and trade of these species are prohibited under Republic Act (RA) 9147, otherwise known as the Wildlife Act of the Philippines (https://www.officialgazette.gov.ph/2001/07/30/republic-act-no-9417/), and also under RA 10654 or An Act to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing (https://www.officialgazette.gov.ph/2015/02/27/republic-act-no-10654/) that amended RA 8550 or The Philippine

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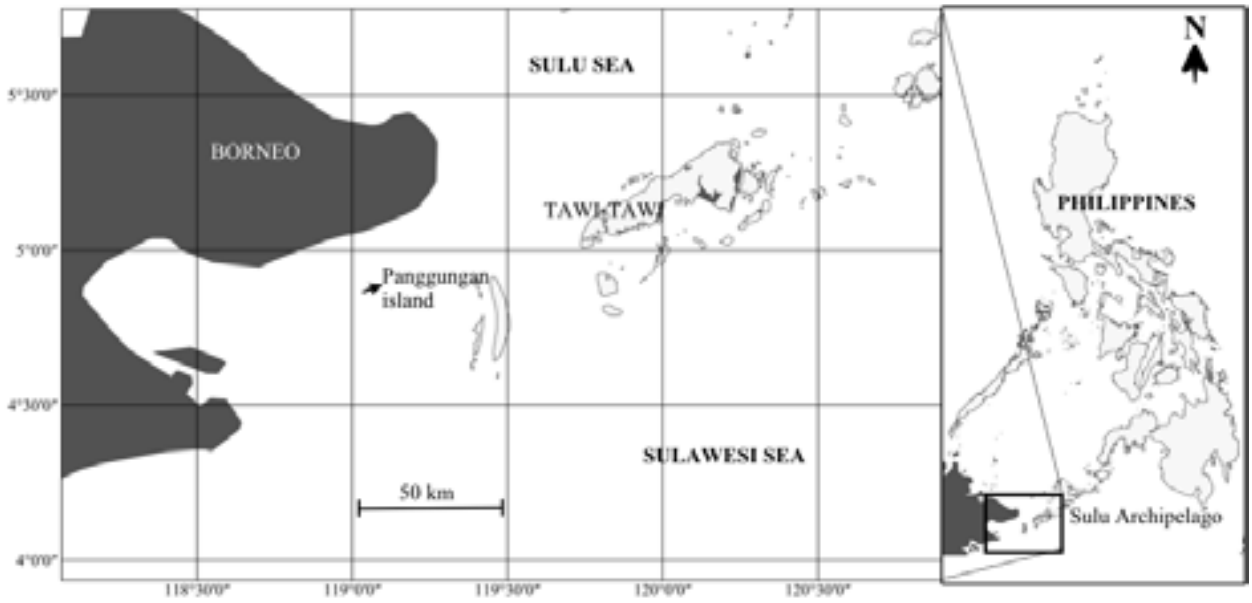

Figure 1. Geographic map highlighting the location of our study site in the Sulu Archipelago.

Fisheries Code of 1998 (https://www.officialgazette.gov.ph/1998/02/25/republic-act-no-8550/). Despite their protected status, we discovered prevalent harvesting of these species in the southernmost islands of the Philippines, posing both a conservation challenge and a unique opportunity for sustainable management.

The study aimed to provide a quick documentation of wild *T. gigas* and giant clam fishery in Panggungan island (also known as Mallamanuk island) in Barangay Datu Baguinda Puti, Sitangkai, Tawi-Tawi in the southernmost part of the Philippines (Figure 1). The island has a land area of about 0.06 km^2 (6 ha) and has a population of about 200 people, mostly composed of the Sama Dilaut or the Badjaos. There is also a military base in the area to fortify the country's border and mitigate maritime security threats. Our assessment was conducted on 4–5 January 2024, following a ship-grounding incident on the said island, and involved direct observation, interviews with local fishers, and the documentation of giant clam specimens and empty shells across the said island.

During the assessment, we encountered numerous empty shells of various giant clam species scattered across the area indicating active consumption by the community. (Image 1). We also discovered that locals were cultivating live giant clams close to shore, including the true giant clam species, *T. gigas* (Image 2). We identified two individuals as *T. gigas*, which is locally called 'antulang'. The larger individual had a shell length of approximately 60 cm, and the smaller measured 30 cm.

Through interviews with locals, we discovered that they harvest giant clams by handpicking or skindiving in the surrounding reefs, using both non-motorized and motorized boats that can accommodate 1–3 people. The presence of numerous empty clam shells across the island confirms that giant clams are the main species harvested by the locals. Giant clams are harvested for both subsistence and trade, with the flesh sold fresh or dried to the market in Sitangkai or directly to Sabah, Malaysia. Locals also collect and sell pearls from giant clams (Image 3). The largest pearl we recorded had a diameter of about 2 cm, which was sold for about US$ 100.00 (PhP 5,000.00).

Our study provides the first documentation of wild adult *T. gigas* in the Sulu Archipelago, a region not included in the nationwide assessment conducted in the 1980s (Juinio et al. 1989). In the Philippines, the only other sightings of wild adult *T. gigas* have been in the nationally protected Tubbataha Reefs Natural Marine Park and at resorts in Palawan (Dolorosa et al. 2015; Mecha & Dolorosa 2020). However, it remains uncertain whether these clams are descendants of the restocking efforts in the province, or if they were introduced by tourists or others visiting the area. There was also recent sighting of a wild *T. gigas* juvenile near a giant clam sanctuary in Pangasinan, likely a descendant of restocked clams (Cabaitan & Conaco 2017). Furthermore, our study marks the first account of giant clam trade within the Philippines since the early 1980s. Villanoy et al. (1988) reported the export industry of *T. gigas* and other

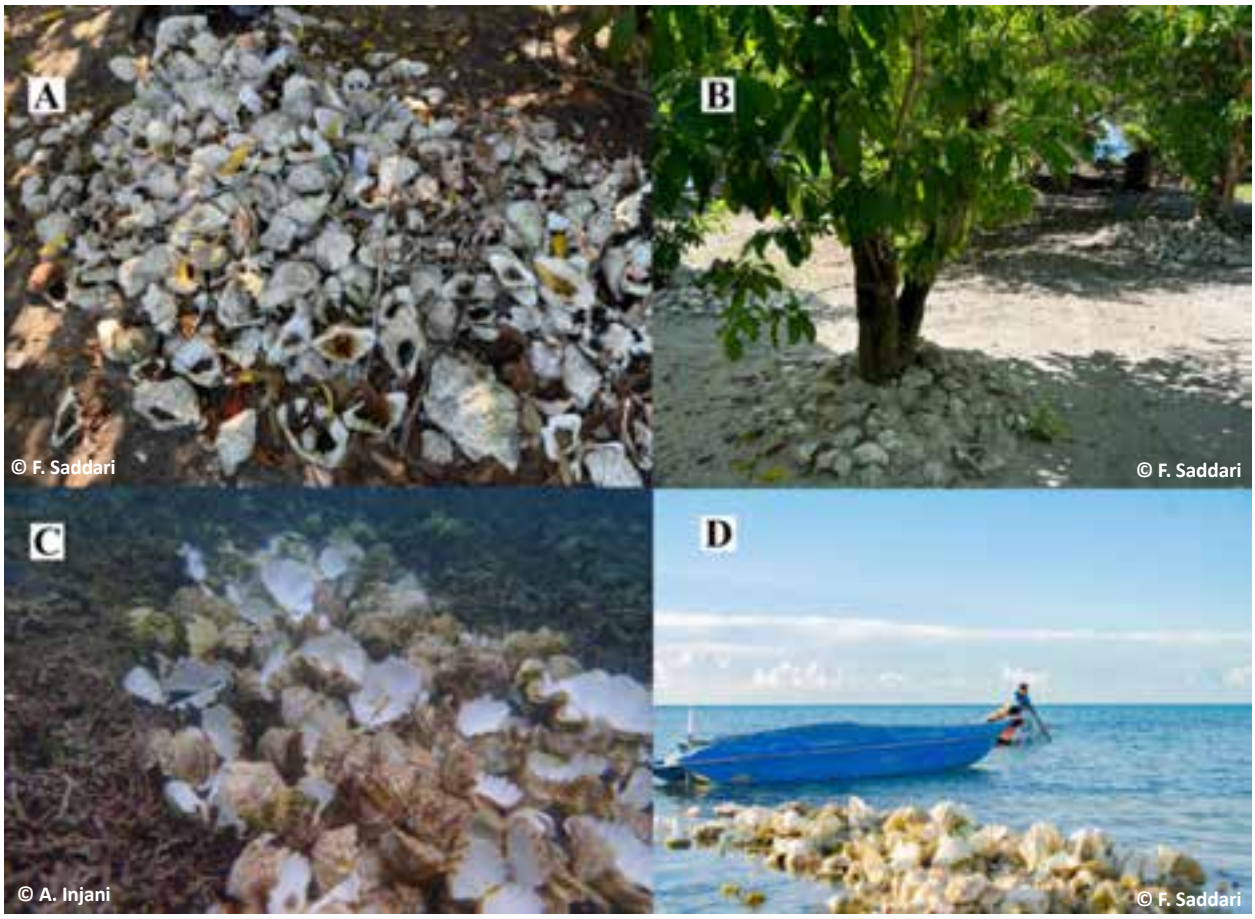

Image 1. Empty giant clam shells observed at various locations: A, B—land | C—submerged along the shoreline | D—at the shore.

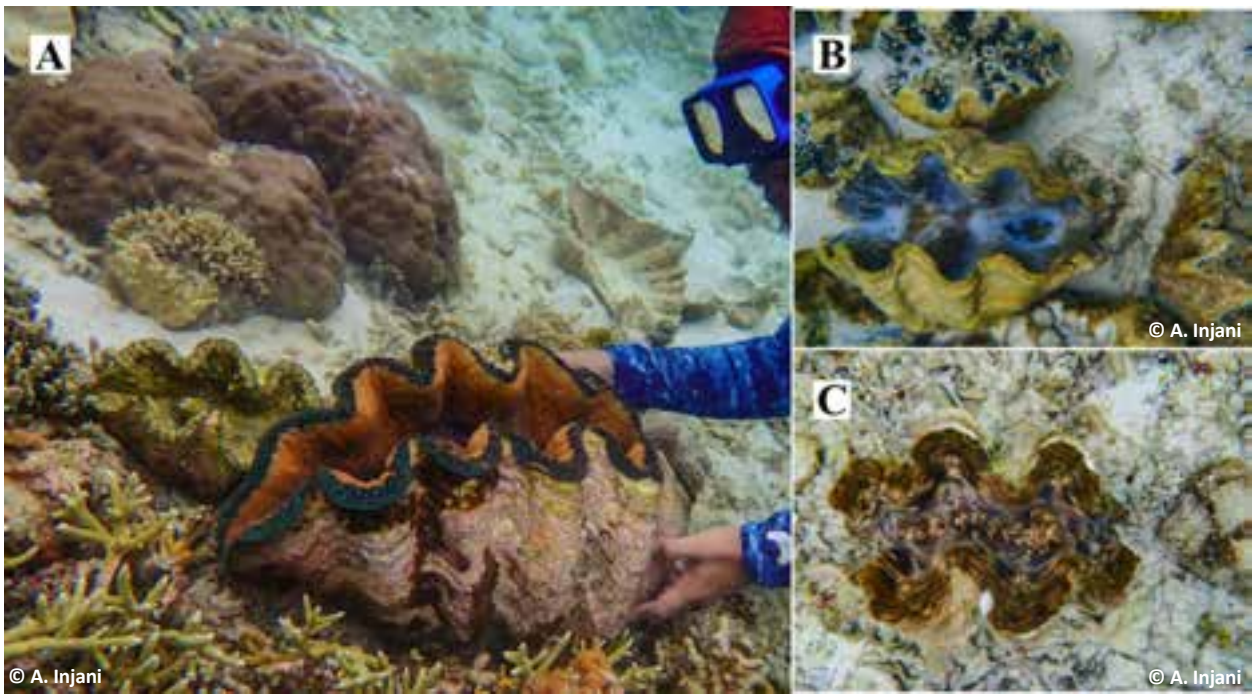

Image 2. Different species of giant clams being cultivated by the locals in shallow waters adjacent to their homes: A—adult and juvenile *Tridacna gigas* | B—*Hippopus porcelanus* | C—*Tridacna squamosa*.

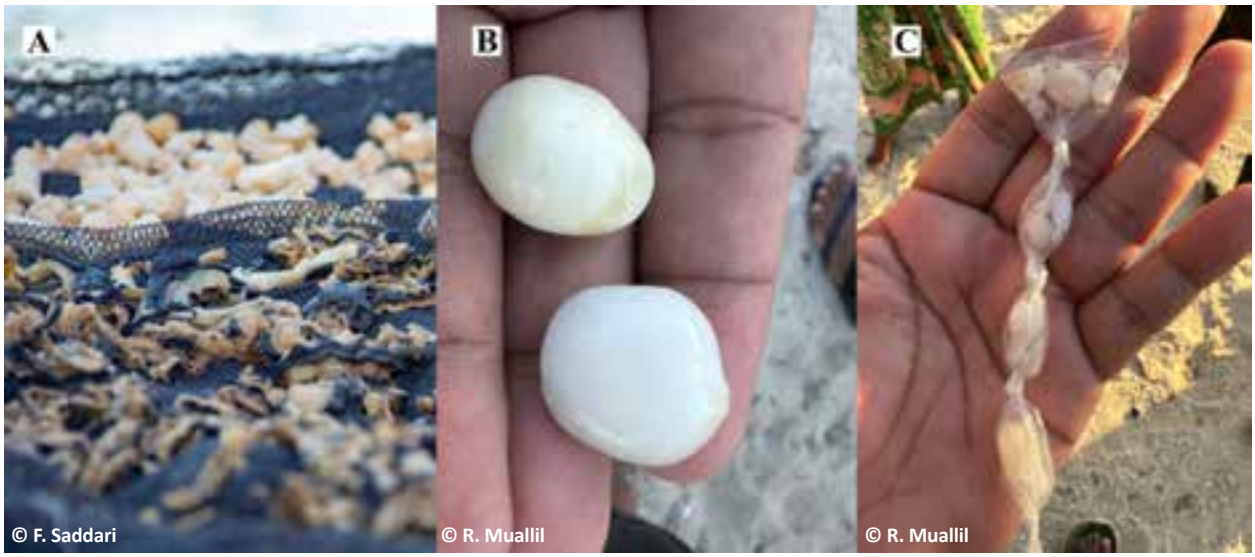

Image 3. Local economic uses of giant clams: A—Sun-dried giant clam meat prepared for sale | B, C—Pearls extracted from giant clams displayed by the locals.

clams from the Sulu Archipelago, but such activities ceased following the implementation of a total ban on the gathering and export of giant clams by the Bureau of Fisheries and Aquatic Resources in 1987.

The rediscovery of wild *T. gigas*, which was considered extinct in many areas in the Philippines as early as 1980s, underscores the importance of our study. Giant clams are vital to reef health, enhancing water quality and biodiversity (Neo et al. 2015). However, overfishing and destructive fishing methods threaten their survival and the reefs they inhabit (Amling et al. 2019). To bolster conservation, an extensive assessment of both the giant clam populations and the fisheries within the biodiversity-rich Sulu Archipelago is vital (Muallil & Hapid 2020; Muallil et al. 2020). Effective conservation of giant clams and the surrounding reefs will ensure the future of our marine ecosystems and the communities that rely on them.

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NOTE

A record of the Hoary Palmer *Unkana ambasa* (Moore, [1858]) (Insecta: Lepidoptera: Hesperiidae) from Assam, India

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Among the known members of the genus *Unkana* Distant, 1886, *Unkana ambasa* (Moore, [1858]) or the Hoary Palmer is a relatively large skipper belonging to the family Hesperiidae that was described from Java, southeastern Asia (Moore 1857). The Hoary Palmer has a fairly wide distribution throughout the tropical forests of southern and southeastern Asia, including northeastern India, Bangladesh, Sundaland, Myanmar, Thailand, Philippines, Vietnam, Malaysia, Singapore, Borneo, Java, and Indonesia (Evans 1932; de Jong & Treadaway 1993; Eliot 2006; van Gasse 2013; Varshney & Smetacek 2015). Nonetheless, this species requires a brief taxonomic revision and has been considered as an overlooked taxa for decades as several morphologically similar subspecies, namely, *ambasa* (Moore, [1858]) (type locality: Java), *batara* Distant, 1886 (type locality: Malaysia), *mindanaensis* Fruhstorfer, 1911 (type locality: Mindanao), *attina* Hewitson, 1886 (type locality: India), and *tranga* Evans, 1949 (type locality: Nias, Indonesia) were described by earlier researchers (Evans 1949), often creating difficulties in assigning sub-populations of different regions to their respective sub-specific names (de Jong & Treadaway 1993; Kunte et al. 2023). Moreover, lack of sampling and the absence of molecular phylogenetic data from their respective type localities make the validity of these subspecies questionable. In India, this species occurs 'very rarely' as it has been recorded only from a handful of localities confined to regions in and around the eastern and northeastern states, particularly Sikkim and West Bengal (Varshney & Smetacek 2015; Kunte et al. 2023). Surprisingly, in recent years, the maximum numbers of sightings have been reported from Buxa Tiger Reserve situated in Alipurduar district of West Bengal (Kunte et al. 2023).

Currently, Assam has only a single recent record of *U. ambasa* based on an egg laid on the top of a leaf that was photographed by Paresh Churi on 15 April 2019 in Rani (Kunte et al. 2023) which necessarily needs further confirmation following methods like rearing. However, prior to this observation, no record of this species existed from Assam, allowing us to confirm the occurrence of an adult *U. ambasa* for the first time from the state based on photographic evidence from the Nilachal hills, Guwahati (26.1675^{0}N, 91.7111^{0}E) situated on the southern bank of River Brahmaputra in the Kamrup Metropolitan district. On 11 March 2023, at 1316 h,

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we encountered an individual of *U. ambasa* which was identified following Evans (1949), clearly saying "Unh (Underside of the hindwing) mostly whitish with dark veins, Uph (Upperside of the hindwing) with a dark brown border reaching dorsum, Upf (Upperside of the forewing) dark brown with well separated hyaline white or pale yellow discal and apical spots". Furthermore, the individual is a female since it matches with the description provided in Evans (1932) which states, "Unh in males dark brown with obscure purple wash, veins black, whitish central area extending to base 7, obscurely paler between veins near termen; females with a broad transverse white area crossed by black veins from base to below apex". The butterfly was observed perching somewhat perpendicular to partially visible sunlight for approximately 15 minutes on the leaf of a low-lying bush, probably a *Boehmeria* sp. occurring roughly 1.2 m above the ground, before hovering and flying away towards the bamboo thickets. The Nilachal Hill has a small area of approximately 2.6 km^2 representing an overall habitat of significant disturbance due to human settlements with a few undisturbed dense patches in between, comprising of mixed moist deciduous-semi evergreen forests in association with a narrow hill stream surrounded by rocky cliffs, loose soils and small temporary pools (max. height 243 m).

Based on the above observation, the occurrence of *U. ambasa* from Assam is confirmed, leading to a range extension of the species by approximately 222 km south-eastwards from its nearest previously known locality, i.e., Buxa Tiger Reserve, West Bengal, making it another significantly important state record from northeastern India. Again, another specimen photographed on 18 December 2016 from Nilam Bazaar (uploaded by Vijay Anand Ismavel on https://indiabiodiversity.org/group/birdwatch/observation/show/1809834?lang=en) situated in the Karimganj District was presumed to be *U. ambasa* as mentioned in the Indian Biodiversity Portal requires a taxonomic reconfirmation since the photograph does not match with the descriptions

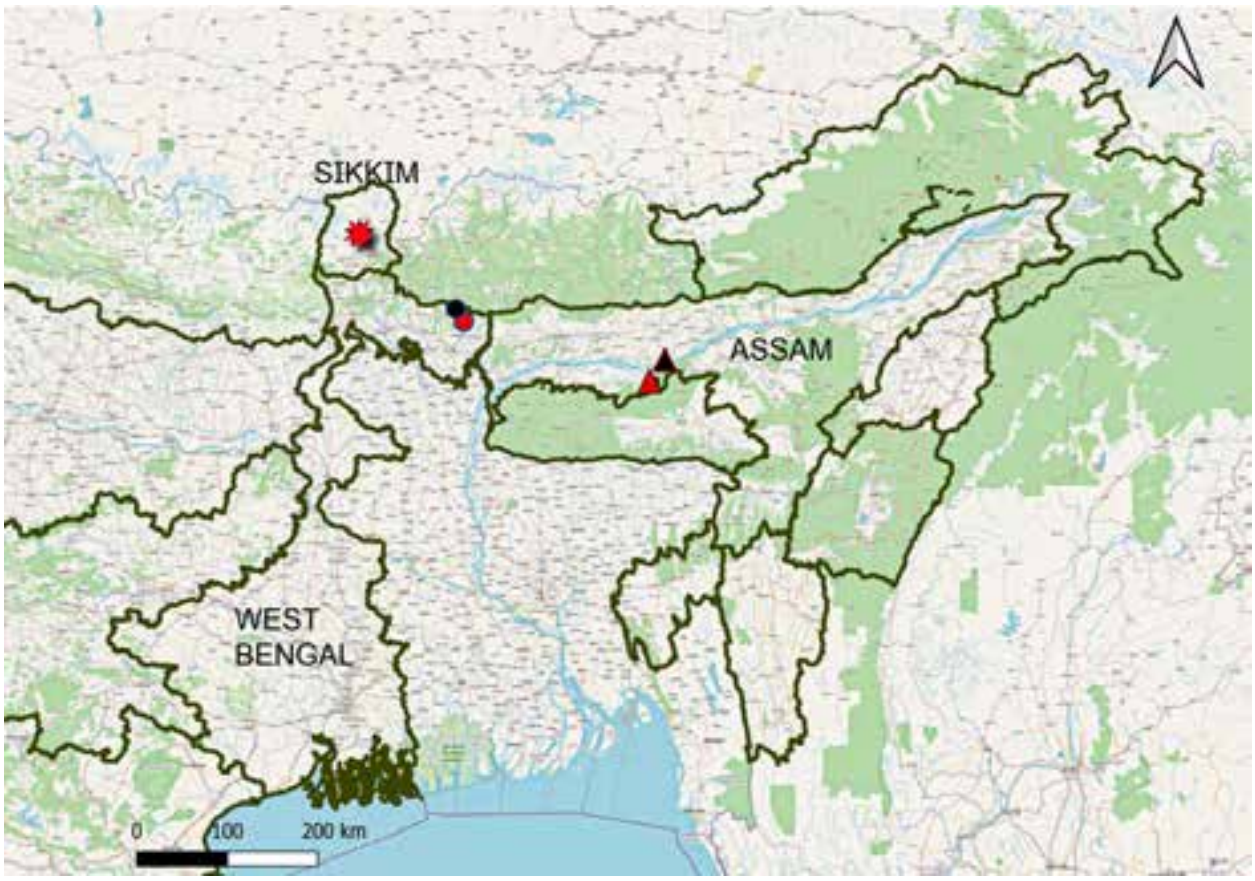

Image 1. Map of eastern and northeastern India showing the only known locality records of *Unkana ambasa* from the country: Black triangle—new as well as the present record of an adult specimen of U. ambasa from Nilachal hills, Guwahati, Assam | Red triangle—previously known locality, i.e., Rani Reserve Forest, Assam from where the egg of the species was photographed | Red & black circles—forests of Buxa Tiger Reserve and Raimatang situated in Alipurduar and Jalpaiguri districts of West Bengal, respectively | Red star—the hills of Sikkim.

Image 2. An adult *Unkana ambasa* in life from the Nilachal Hills of Guwahati, Assam, India.

Image 3. Microhabitat of *Unkana ambasa* in Nilachal Hills of Guwahati, Assam, India.

provided in Evans (1932, 1949), thereby representing a case of misidentification (Tarun Karmakar & Monish Kumar Thapa in litt. July 2023).

We suggest further field investigations from other states of northeastern India as well to accurately determine the distributional pattern as well as conservational status of this lesser-known species.

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NOTE

Sighting of Large Branded Swift *Pelopidas sinensis* (Mabille, 1877) (Hesperiidae: Hesperiinae) in Delhi, India

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The butterfly, Large Branded Swift *Pelopidas sinensis*, was first described by Mabille in 1877 from China (Mabille 1877). It is distributed in China and several southeastern Asian and southern Asian countries including India (Devyatkin 2012; Huang 2016; Kehimkar 2016; Rehman et al. 2016; Sajan et al. 2022). In India, *P. sinensis* is found in the Himalaya from Himachal Pradesh to Arunachal and other northeastern states (Moore 1882; Swinhoe 1912–13; Wynter-Blyth 1957; Gogoi 2013; Naro 2014; Varshney & Smetacek 2015; Kehimkar 2016; Sondhi et al. 2018; Irungbam et al. 2020). There are also reports of sightings of this butterfly from Gosekhurd Reservoir near Nagpur in Peninsular India (Patil et al. 2019), Lalwan Community Reserve, and Ranjit Sagar Conservation Reserve, Punjab (Singh et al. 2021). The Lalwan Community Reserve is located in the hilly terrains of the Himalaya at the border of Punjab and Himachal Pradesh, whereas and Ranjit Sagar Conservation Reserve is at the border of Jammu & Kashmir and Punjab. However, both the records of *P. sinensis* (i.e., from Nagpur and Punjab) cannot be confirmed due to the absence of pictorial evidence or unclear representative images provided in the published articles (Patil et al. 2019; Singh et al. 2021). In India, the status of *P. sinensis* has been reported as common by Van Gasse (Van Gasse 2021) and Sondhi (Sondhi et al. 2018), and uncommon by Kehimkar (Kehimkar2016). This species has not been reported from arid and semi-arid areas of northwestern India. The present communication reported the sighting of *P. sinensis* from Delhi–a state with a semi-arid climate. Hence, this is the first report of this species from the semi-arid areas of northwestern India, and it is probably a range extension of this species.

Three male hesperid butterflies were spotted roosting on foliage in a private farm compound (28.5444444N, 77.0047222E) on 30 July 2023, at 1700–1800 h, in Najafgarh, southwestern Delhi. The weather was humid, the temperature was about 33–34°C, and the sky was clear. The butterflies were photographed, and the species was identified as *P. sinensis* by referring to the literature (Moore 1882; Evans 1932; Wynter-Blyth 1957; Kehimkar 2016). The farm compound where the species was sighted is planted with medicinal herbs, grasses, ornamental plants, and fruit plants. The compound is surrounded by agricultural fields, and there flows a perennial canal with the growth of reeds and aquatic flora (Image 2). About 5–6 km from the site where the butterflies were spotted, exists a large freshwater reservoir—the 'Najafgarh Lake'. In the rainy

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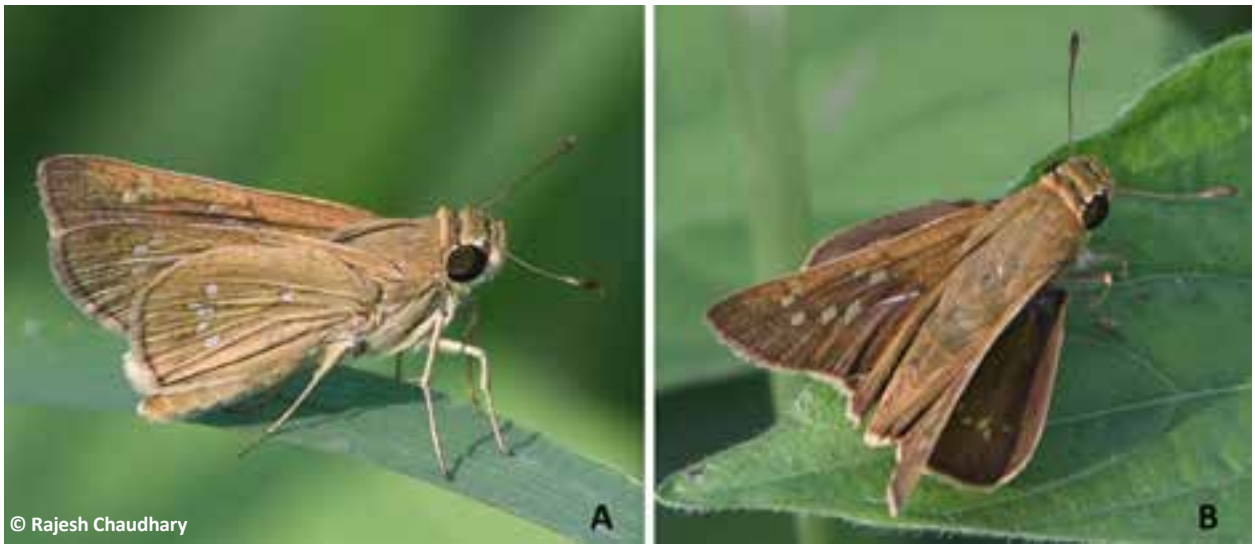

Image 1. The male Large Branded Swift *Pelopidas sinensis* photographed in Delhi: A—underside | B—upperside of the same individual.

Image 2. Aerial view of *Pelopidas sinensis* sighting spot (red circle) and its surroundings (https://www.google.com/maps).

season the land near the lake becomes marshy and is used to cultivate paddy (Image 2).

The butterfly *P. sinensis* has dark olive-brown upperside and paler undersides. Males of *P. sinensis* can be differentiated from those of other members of the same genus found in Delhi (*P. mathias* and *P. thrax*) by larger size, forewings with prominent spots on upperside, narrow yellowish or whitish brand below cell extending from vein1–spot in space 2. The underside of hindwings has prominent spots in space 2–6 and cells, which are usually also noticeable on the upperside of the wings (Moore 1882; Evans 1932; Wynter-Blyth 1957).

The range of distribution of *P. sinensis* covers the part of the globe that is humid or wet (Peel et al.

2007; Devyatkin 2012; Sayre et al. 2014; Huang 2015; Kehimkar 2016). In India, it is found in the Himalaya up to 2,500 m and in northeastern states (Wynter-Blyth 1957; Kehimkar 2016; Van Gasse 2021), which are relatively more humid or moist than northwestern and western India (Peel et al. 2007; Attri 2010; Kulkarni et al. 2020). Sighting of this butterfly in Delhi, with its semi-arid climate, is therefore unexpected. It is possible that the sighted individuals of *P. sinensis* are strays or chance migrants from their known range of distribution and settled temporarily in this humid environment. Alternatively, the larva and pupa of this butterfly might have been accidentally transported from other parts of India along with the larval host plants, or the chrysalis that might have been brought accidentally with some object may have emerged as an adult. It will be interesting to search for *P. sinensis* in Delhi and neighbouring areas in the future to elucidate if it has expanded its range to the semi-arid areas of India or is a temporary settler in Delhi. Also, the examination of the genitalia of a series of specimens from Delhi would be useful to support the findings further and elucidate infra-specific variation in wing marking patterns.

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NOTE

Rodent - a part of culture and revolution in India

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The term rodent came from the Greek word 'rodere', meaning gnaw (Legendre 2003). Rodents are characterised by prominent, continuously growing incisors which are present in both the upper and lower jaw (Waggoner 2000). Rodents fall under the order Rodentia of the class Mammalia. With 35 families comprising more than 534 genera and 2,652 species (Mammal Diversity Database 2023), they constitute 40% of all mammals. Rodents are found native to all continents except Antarctica, New Zealand, and certain other islands (Nowak 1999; Macdonald 2009). They inhabit a wide range of ecological niches, encompassing terrestrial landscapes and human-constructed environments. According to their habitat preferences, species may exhibit arboreal, fossorial (burrowing), saltatorial, or semi-aquatic behaviour. Rodents play important ecological roles like seed dispersal and are an important part of the food chain in maintaining a healthy prey-predator relationship. Apart from being important to the ecosystem rodents are also responsible for various diseases and health problems. Rodents are vectors for many viruses and pathogens. The infamous bubonic plague which claimed 70–200 million human lives was spread through rodents (Glatter & Finkelman 2021).

India is home to 102 rodent species distributed among 47 different genera (Srinivasulu & Srinivasulu 2012). Of these, 19 species are categorized as agricultural and commensal pests (Tripathy et al. 2017). Some species are widely distributed, while some are locally important (Sridhara & Tripathi 2005). It is important to note that India suffers a huge economic loss because of rodents. Different crops like rice, wheat, maize, vegetables, fruits, and poultry farms face a great threat because of different rodent species (Singleton 2003; Tripathi 2014). While there is a prevailing negative perception of rodents, there are also instances of rodents being an inseparable part of cultures and being responsible for some important historical events.

Rodents as a part of culture

From Krauncha to Mushakraj

The oldest mentioned and the most famous rodent which is a part of culture is Mushakraj, the vahana (mount) of Lord Ganesha. As the name suggests Mushakraj was a rat. Legend has it that Krauncha, a

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musician-God, stepped on the foot of Muni Vamadeva, who in turn cursed Krauncha to become a giant mouse. Upon recovering from his anger Vamaveda told Krauncha that a day would come when the gods would bow down to him (Krauncha). One day Ganesha was invited to the Ashram of Maharishi Parashar. But Krauncha ended up stepping on the Ashram thereby destroying it. Ganesha then wanted to meet Krauncha and teach him a lesson. Upon meeting him, he unleashed his weapon 'pasha' which looped around Krauncha's neck and brought him down to his (Ganesha's) feet. Krauncha asked for forgiveness and begged Ganesha to make him his mount. But Krauncha was unable to bear the weight of Ganesha and requested him to become lightweight, to which Ganesha obliged. And thus, Krauncha became Mushakraj, the mount of Ganesha (Astroved 2022).

Karni Mata and Rats

In a temple in Deshnoke, Bikaner, Rajasthan, devoted to goddess Karni Mata, rats are not seen as pests or vermin but are revered, so much so that it can be called a temple of rats. The legend is prevalent here is, that the stepson of Karni Mata, Lakshman, drowned in a pond named Kapil Sarovar when he tried to drink water from it. Karni Mata then approached Yama, the god of death, to revive Lakshman. At first, Yama refused, but he then relented, permitting Lakshman and all the male children of Karni Mata to be reincarnated as rats; hence, rats are revered in this temple. The temple is home to about 25,000 Black Rats *Rattus rattus* (Lostal 2021).

A dowry of rodent

Within the Adi tribe of Arunachal Pradesh, the Orange-bellied Himalayan Squirrel *Dremomys lokriah*, holds significant cultural importance. In the Adi language, this species is referred to as "Leiboh/Leipoh." It plays a pivotal role in the traditional marital customs of this community (Chetia et al. 2022). As part of the marriage ritual, the groom is required to present a dowry consisting of two pairs of these squirrels to the bride's family.

The Adi tribe has a captivating folklore explaining the rationale behind using the squirrel as a bride price. According to the legend, in ancient times, Doying Bote, the King of Knowledge, fell in love with Kine Nane, the Queen of Abundance. However, Doying Bote found it exceedingly challenging to persuade Kine Nane's family to accept their union. He attempted to send various forms of life to convince them, but none of these emissaries succeeded.

In the end, it was the turn of Leiboh/Leipoh, the squirrel, to go and mediate on behalf of Doying Bote. Remarkably, this attempt proved successful, and the marriage was allowed to proceed. As a result of the squirrel's pivotal role as an intermediary in the union of Doying Bote and Kine Nane, it has become an integral and inseparable element of the Adi tribe's cultural heritage (Chetia et al. 2022).

Rodents as a part of Revolution: The Birth of a State

Until 1987, Mizoram was part of the undivided state of Assam. Mizoram is home to a type of bamboo known as *Melocanna baccifera*, which covers 31% of its total geographical area. This bamboo species blooms every 45–50 years, leading to a sudden increase in the population of Black Rats *Rattus rattus.* This phenomenon, known as a 'rat flood', occurs when the bamboo dies and regrows from seeds, the rats feed on the seeds, which boosts the size of rat litter. This surge in the rat population results in widespread destruction of food sources, leading to large-scale famines. In the Mizo language, this cyclic famine is referred to as 'mautam'.

In 1958–59, a mautam event resulted in the loss of 100 lives and crop and property damage (Goswami 2008). When the people of Mizoram sought assistance from the Assam and Indian governments, their concerns were not taken seriously. This negligence led to the establishment of the Mizo National Famine Front (MNFF) by Pu Laldenga, which provided relief to the remote famine-affected areas. On 22 October 1961, the famine front evolved into the Mizo National Front (MNF). The armed wing of MNF, known as the Mizo National Army (MNA), demanded the creation of a sovereign state for the Mizo people on 28 February 1966. On 1 March 1966, they declared independence from Assam by launching attacks on government offices and security force posts.

Conclusion

Human civilization is deeply intertwined with myth and history, often influenced by the surrounding environment and cultural elements. In many civilizations, various animals hold significant cultural roles within hierarchical structures. The unique reverence for rodents in Indian mythology and history is particularly intriguing. Nowhere else in the world has there been a revolution resulting in the birth of a new state, with rats playing a central role, as seen in India.

Therefore, it's evident that beyond their ecological significance, rodents hold immense mythological and historical importance, contributing significantly to the shaping of India's culture and history.

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