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Caption: ***Pinda concanensis*** **an endemic plant from Anjaneri Hills. © Dr. K.V.C. Gosavi.**

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EDITORIAL

Pakshirajan Lakshminarasimhan: a plant taxonomist who loved plants and people alike

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Dr. Pakshirajan Lakshminarasimhan, a very prominent figure in Indian plant taxonomy passed away in Pune on 15 July 2020 due to COVID-19 infection. He retired merely a year back as the in-charge of the Western Regional Centre, Botanical Survey of India, Pune in August 2019. His farewell function attended by a large gathering of his colleagues, friends, and students speak volumes about how he nurtured relationship with his colleagues and mentored his students during the course of research activities.

DR. P. LAKSHMINARASIMHAN
(28.8.1959 - 15.7.2020)

Dr. Lakshminarasimhan was born in Pune on 28 August 1959. He opted for M.Sc. in Botany at Pune University and wanted to specialize in cytogenetics. However, he was offered plant taxonomy as a specialization, and on the advice of one of his professors, decided to go with it. After completion of his master's degree in 1982, he joined as Research Scholar in the western circle, Pune of Botanical Survey of India and worked there until 1987. BSI Pune at that point of time was renowned for producing eminent taxonomists and was preparing district Floras under the circle's jurisdiction. Young Lakshminarasimhan was offered to work on the 'Flora of Nashik District' and simultaneously registered for his Ph.D. under the guidance of Dr. Brahma Datta Sharma. Nashik District is a significant district of the northern region of Western Ghats. Lakshminarasimhan did extensive fieldwork in the district and, based on the work, was awarded Ph.D. in October 1987 by the University of Pune. A new species, *Dicliptera nasikensis* Lakshmin. &

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B.D. Sharma, was published by him during this work, the first of the many. His thesis was further modified and updated for the book and was published by BSI in 1991 under the name 'Flora of Nasik District'. Simultaneously, he joined BSI on permanent positions as botanist first and later as scientist in 1989. When nobody preferred, he gracefully accepted his first posting as Scientist B in Andaman and Nicobar circle, Port Blair. It was a good opportunity. He studied with deep interest the flora of oceanic islands. At this new venue, he started work on the flora of Andaman & Nicobar Islands for 17 plant families and a project for documenting Flora of Interview Island, North Andamans. His stay at Port Blair yielded a large number of publications on the flora of Andaman & Nicobar. His first transfer brought him to Pune Circle in 1993 and he joined hands with stalwarts like Dr. S. Karthikeyan, Dr. B.D. Sharma, and Dr. N.P. Singh for bringing out the Flora of Maharashtra State. After Cooke's Flora, which was published a century ago, this was going to be a major compilation for this biodiversity-rich state. The first volume on Monocotyledons was published in 1996 while the dicot volumes appeared in 2000 and 2001. Simultaneously, he also worked on the Flora of Karnataka State, Monocotyledones and soon submitted the draft. In association with Dr. Tetali of Nowroji Godrej Centre of Plant Research and other like-minded scientists, he published a book on endemic plants of Maharashtra State. At the beginning of the new millennium, the Ministry of Environment and Forests launched an ambitious project of documenting plant diversity of national parks and sanctuaries of the country under the scheme 'Protected Area Network'. Lakshaminarasimhan, by that time in a lead scientist's role, post-retirement of many senior personals from the Pune circle, coordinated this activity for the western Indian region. He started work on the flora of Anshi and Nagarhole in Karanataka, Molem in Goa, and Gugamal in Maharashtra. I was fortunate to get picked to work on this project and Lakshminarasimhan allotted me the work on Molem National Park. This opportunity to work with him and subsequent Ph.D. under his guidance changed my life completely.

In the mid of 2002, he got a golden chance to go to Royal Botanic Garden, Kew on deputation as the Indian Botanical Liaison Officer. He worked there between May 2002 and November 2004. Going beyond his official obligations, he not only helped numerous taxonomists from India with their literature and other requests but also further fine-tuned his own skills as a taxonomist. His association with Dr. K.N. Gandhi, a world-renowned nomenclature expert started from there. With new

Shrinath Kavade, P. Lakshminarasimhan, K.N. Gandhi, Rajendra Shinde and Mandar Datar (from left).

crafts learned, and new perspectives developed to look at taxonomy, he came back to India and joined the Central National Herbarium in 2004. He initiated works on the Flora of wildlife sanctuaries in Jharkhand, Flora of Lakshadweep, and the editing of Flora of West Bengal volumes III and IV immediately. In 2007 and 2008 his first three students were awarded Ph.D. from Pune University and the next batch of Ph.D. scholars promptly registered under him. The beginning of the new decade in 2010 came with new responsibilities for him as he was offered the in-charge position of Central National Herbarium, the largest and prime herbarium in India. The same year saw the establishment of ENVIS Centre on Floral Diversity of BSI, Howrah with support from MoEF, and Dr. Lakshminarasimhan was the undoubted choice for heading the responsibilities. The year 2010 was the best in his career not just due to these new responsibilities but also for felicitations coming from reputed national organizations like IAAT and APT. The appreciation of his efforts to shape Indian plant taxonomy came in the form of M.B. Raizada Gold Medal 2010 by the Association for Plant Taxonomy and V.V. Sivarajan Gold Medal 2010 by the Indian Association for Angiosperm Taxonomy.

Through ENVIS centre of MoEF, he published bibliographies and abstracts of states like Maharashtra, Kerala, Goa, Karnataka, West Bengal, Andaman & Nicobar in the coming years. Around the same time, three floras of the protected areas worked under the PAN project were published. Anshi National Park by Biosphere, Pune, and Nagarhole, and Molem by Botanical Survey of India. Following this, Flora of India Volume 23 was also published where he was co-editor. His obsession with endemic plants which started with a book on endemic plants of Maharashtra, lead to the publication

With Dr. Mao, current Director of Botanical Survey of India.

of 'Endemic vascular plants of India' in association with others. This is an important compilation for a biodiversity-rich country like India as this can pave way for many interesting ecological hypotheses on endemism. Flora of West Bengal came out in three volumes in 2015, 2016 and 2020 with Dr. Lakshminarasimhan as co-editor and co-author.

He was transferred to the Western Regional Centre, Pune (erstwhile Western Circle) in 2015, and worked there for four years before retiring as Scientist E in August 2019. During his stay in Pune circle as in-charge, he successfully organized many activities like Biodiversity Day Celebrations, Green Skill Development Programs, a workshop for mangroves and a few more. These endeavours immensely helped young students to hand-pick their paths in botanical careers. His association with Dr. K.N. Gandhi gave enormous opportunities to budding Indian taxonomists through organizations of botanical nomenclature courses. Lakshminarasimhan took a lead in systematizing these courses which took place in Kolkata, Pune, Coimbatore, and Shillong in 2013, 2017, 2019, and 2020, respectively. One can see the on-ground effect of these nomenclature courses organized by him in a subsequent increase in the nomenclature publications in India, especially from young researchers. Apart from these activities, he went on taking up new projects and continuing research on various aspects. In 2018, a species *Portulaca lakshminarasimhaniana* S.R.Yadav & Dalavi was named in honour of his contribution by Shivaji University group. Post retirement he continued working on Flora of India project for families like Gesneriaceae and Acanthaceae. It looked from his post-superannuation commitments towards the work, that the best out of Dr. Lakshminarashiman was yet to come.

Dr. Lakshminarasimhan had a distinguished botanical career that spanned over more than 35 years. To sum

Presenting Flora of Molem National Park, Goa to Manohar Parrikar, the then Defence Minister of India.

up his achievements in a nutshell, he has published about 155 papers, authored and edited 25 books and contributed book chapters in 15 books, guided seven students for their Ph.D., published/named 39 taxa in association with others, and conducted several workshops and conferences. But his impact on taxonomy and taxonomic fraternity is beyond these numbers. This gentle soft speaking person was an inspiration to many through his discipline, dedication, and hard-working abilities. He helped immensely to almost everyone who went to him with queries or requests. He was an excellent resource person on nomenclature and methodology of writing Floras. Many of us would vividly recall several discussions with him about multiple aspects of taxonomy. He always had up to date information on various taxonomic and revisionary works carried out in India. He was on the editorial boards of the *Journal of Threatened Taxa*, Rheedea, Nelumbo, Journal of Economic & Taxonomic Botany, and Phytotaxonomy. A good reviewer contributes immensely in the overall growth of the subject, and Dr. Lakshminarasimhan by handling hundreds of papers as a reviewer in his career influenced the growth of the plant taxonomy in a significant way. He also served as a member of 'India Checklist Editorial Committee' of Missouri Botanic Garden, United States. Being a member of many project reviewing committees, he would encourage and guide people about project submissions. His sad, sudden, and unfortunate demise has created a big void in the area of plant taxonomy research which is difficult to fill. We have lost not only a thoughtful plant taxonomist but an amazing person too. We are surely going to miss Dr. Lakshminarasimhan for years to come.

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PHD STUDENTS

Completed

1. M.N. Datar - An Assessment of Floristic Diversity of Molem National Park, Goa - Pune University.
2. S.A. Punekar - An Assessment of Floristic Diversity of Anshi National Park, Karnataka - Pune University.
3. R. Manikandan - An Assessment of Rajiv Gandhi National Park, Karnataka - Pune University.
4. Debatri Panja (Kundu) - Studies on Taxonomy of the Tribes Acantheae, Nelsonieae and Thunbergieae (Acanthaceae) in India - Visva-Bharati University, Santiniketan.
5. Shyam Biswa - Floristic Diversity of Koderma Wildlife Sanctuary, Jharkhand - Visva-Bharati University, Santiniketan.
6. Bandana Bhattacharjee - Revision of the tribe Vernonieae Cass. (Asteraceae) - Kalyani University.
7. Vijay Kumar Masatkar - Floristic Diversity of Palkot Wildlife Sanctuary, Jharkhand - Barkatullah University, Bhopal.

Present

1. Sameer Patil- Flora of Pushpagiri Wildlife Sanctuary, Karnataka – Pune University.
2. Akramul Hoque- Taxonomic Revision of the family Dioscoreaceae in India - Calcutta University, West Bengal.
3. S. Shalini- A Taxonomic Revision of the Tribe Argyreieae Choisy ex G. Don (Convolvulaceae) in India - Calcutta University, West Bengal.

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COMMUNICATION

The worrisome conservation status of ecosystems within the distribution range of the Spectacled Bear *Tremarctos ornatus* (Mammalia: Carnivora: Ursidae) in Ecuador

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Abstract: The distribution range of Spectacled Bear in Ecuador has been strongly fragmented owing to human activities, thus studying the conservation status of the remaining patches in which this species inhabits is essential to ensure its conservation. We performed a descriptive analysis of the conservation status of the ecosystems that form part of the Spectacled Bear distribution range in Ecuador, using values of five indicators (fragmentation, connectivity, threat, vulnerability and fragility) provided by the Ecuadorian Ministry of Environment. Moreover, we compared the conservation status between scrubland & pastures and evergreen forest ecosystem according to the five indicators. Overall, the Spectacled Bear distribution in Ecuador is covered by a greater surface area of ecosystems classified with a medium level of fragmentation (58.8%), low connectivity (45.1%), high fragility (45.6%), high (38.2%) and medium threat (39.2%), as well as high (33.7%) and medium (33.1 %) vulnerability. Scrubland and pastures ecosystems had worse conservation status than evergreen forests, with 98% of their surface classified as having low or very low connectivity, 77.3% as high fragility and 77.4% as high threat. These results showed the worrisome conservation status of the ecosystems shaping the distribution range of Spectacled Bear in Ecuador, particularly the scrubland and pastures, and therefore, a wider national strategy (inside and outside the limits of the bear distribution range) should be applied to ensure the preservation of these ecosystems.

Keywords: Andean Bear, conservation, ecosystem, endangered species, habitat loss, human activities, species distribution.

Resumen. El área de distribución del oso de anteojos en Ecuador ha sido fuertemente fragmentada debido a actividades antropogénicas, y por lo tanto, estudiar el estado de conservación de los parches remanentes en los cuales esta especie habita es esencial para asegurar su conservación. Se realizó un análisis descriptivo del estado de conservación de los ecosistemas que forman parte del área de distribución del oso de anteojos en Ecuador, usando valores de cinco indicadores (fragmentación, conectividad, amenaza, vulnerabilidad y fragilidad) proporcionados por el Ministerio del Ambiente de Ecuador. Además, se comparó el estado de conservación entre los ecosistemas de matorral & pastizal y bosques siempreverdes de acuerdo con los cinco indicadores. En general, el área de distribución del oso de anteojos está cubierta por una mayor superficie de ecosistemas clasificados con un nivel medio de fragmentación (58.8%), baja conectividad (45.1%), alta fragilidad (45.6%), alta (38.2%) y media (39.2%) amenaza, así como alta (33.7%) y media (33.1%) vulnerabilidad. Los ecosistemas de matorral y pastizales tuvieron peor estado de conservación que los bosques siempreverdes, con un 98% de su superficie con baja o muy baja conectividad, 77.3% con alta fragilidad, y 77.4% con alta amenaza. Los resultados muestran el preocupante estado de conservación de los ecosistemas que conforman el área de distribución del oso de anteojos en Ecuador, particularmente los ecosistemas de matorral y pastizal, y por lo tanto, una estrategia nacional más amplia (dentro y fuera de los límites de área de distribución del oso) deberían ser aplicados para asegurar la preservación de estos ecosistemas.

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INTRODUCTION

Habitat loss and degradation are major threats for the world's mammals (Brooks et al. 2002; Fahrig 2003; Dobson et al. 2006). Apart from constraining the distribution range of mammal species, habitat loss entails the fragmentation and isolation of remaining populations, increasing the risk of extinction as a consequence of the loss of genetic flow and adaptive genetic variation (Ernest et al. 2011), inbreeding (Keller & Waller, 2002), demographic and environmental stochastic phenomena (Shaffer 1981; Crooks et al. 2011), and lower colonization rate (Fahrig 2003). Large mammals are most vulnerable to habitat loss and fragmentation owing to their extensive home ranges, lower densities, and lower population growth rates (Cardillo et al. 2005). Furthermore, large mammals are more prone to poaching and direct persecution, and are often implicated in various kinds of human-wildlife interactions such as damage to agriculture or attacks on livestock (Woodroffe et al. 1998; Kansky & Knight 2014), which are more frequent in smaller populations surrounded by a human-dominant matrix (Michalski & Peres 2005).

As a large mammal, the Andean Bear or Spectacled Bear *Tremarctos ornatus* F.G. Cuvier, 1825 needs large areas to fulfil its biological requirements (Cuesta et al. 2003; Castellanos 2011). This species is endemic to the Tropical Andes and was formerly distributed widely across the mountain range (Peyton et al. 1998; Kattan et al. 2004; Velez–Liendo & García-Rangel 2017), however, its current populations are distributed in fragmented areas from Bolivia to Venezuela, which led to the species being assessed as Vulnerable (VU) on the IUCN Red List (Velez–Liendo & García-Rangel 2017). In Ecuador, this species is listed as Endangered (EN) in the Red Book of Mammals of Ecuador (Castellanos et al. 2011), owing to a reduction in both population size and distribution as a consequence of habitat alteration (Peyton et al. 1998; Kattan et al. 2004; Peralvo et al. 2005), thus affecting strongly the viability of the species (Kattan et al. 2004). Therefore, it is important to assess the remaining patches in terms of threat, vulnerability, and fragmentation, to establish measures favouring bear conservation. Most studies in Ecuador have been conducted to assess habitat preferences at small scales (Suarez 1988; Cuesta et al. 2003; Peralvo et al. 2005; Clark 2008; Castellanos 2011; Demay et al. 2014; Filipczyková et al. 2017), but none have characterized the remaining fragments at national scale in which this species inhabits. The aim of this study was to characterize all the remaining fragments of Andean Bears in Ecuador, taking into account five indicators of the conservation status of the ecosystems (fragmentation, connectivity, vulnerability, threat, and fragility) provided by the Ecuadorian Ministry of Environment, in order to comprehensively assess the conservation status of ecosystems in which the Spectacled Bear inhabits in Ecuador.

MATERIAL AND METHODS

Species distribution range

The geo-referenced current range of the bear within Ecuador was obtained from the IUCN Red List webpage (Velez–Liendo & García-Rangel 2017; Figure 1). An area is considered as extant if the species is known or thought very likely to occur there presently, which encompasses localities with current or recent (data updated in 2017) records where suitable habitat at appropriate altitudes remain (IUCN 2018).

Ecosystem features

Geo-referenced shapefiles were obtained from the Ecuador Ministry of Environment (available at http://ide.ambiente.gob.ec/mapainteractivo/) wherein the ecosystems of mainland Ecuador are classified into 91 types according to biotic and abiotic factors (Ministerio del Ambiente del Ecuador 2013). This shapefile also contains information concerning fragmentation, connectivity, vulnerability, threat, and fragility of each ecosystem. The rate of fragmentation was calculated using three variables: the number of patches, their mean size, and the coefficient of variation of the size of the patch (Ministerio del Ambiente del Ecuador 2015b). These variables were used to rank the fragmentation of each ecosystem on four levels (very high, high, medium, and low) according to the method of Jenks' natural breaks (for more details see the previous reference). Connectivity was measured by the equivalent connected area index, which is defined as the size of a single habitat patch (maximally connected) that would provide the same value of the probability of connectivity than the actual habitat pattern in the landscape (Saura et al. 2011). Using also Jenks' natural breaks, the connectivity rates of the ecosystems were classified into four categories: high, medium, low, and very low (Ministerio del Ambiente del Ecuador 2017). The vulnerability index was calculated at species level by using the number of species listed in CITES, the number of endemic species, the number of plants with a commercial value, and the number of endangered plant species according

Figure 1. Andean Bear distribution range (green shapes) in Ecuador according to the IUCN Red List.

to the IUCN Red List in Ecuador. At the landscape level, vulnerability was calculated by the degree of representativeness, fragmentation, and connectivity. The threat to ecosystems was assessed by five variables: climate change, water resource use, forest exploitation, extraction of natural resources, and the probability of land conversion. Vulnerability and threat were classified in three categories (high, medium, and low) by using quantiles, and both indicators were combined to get five levels of fragility (very high, high, medium, low, and very low; Ministerio del Ambiente del Ecuador 2015a). No values were assigned to areas identified as non-natural ecosystems, such as crops, urban areas, or planted forests. These indexes provided by the Environmental Ministry have been used in previous scientific papers (e.g. Rivas et al. 2020).

Three different descriptive analyses were performed. Firstly, the proportions of each level (e.g., high, medium, low) of each of the five indicators (fragmentation, connectivity, vulnerability, threat, and fragility) were calculated in the whole bear distribution range, which was done by adding the surface area of every ecosystem with the same level of each indicator. Secondly, these proportions were calculated separately in each of 17 distribution patches, which allows us to estimate the mean values and the variation among patches. Thirdly, the ecosystems were grouped into the two main habitats of Andean Bears in Ecuador (Peralvo et al. 2005): forests and scrubland & pastures (including paramo), to compare the conservation status between both habitats in accordance with the five indicators.

RESULTS

According to the IUCN data, Spectacled Bears in Ecuador are located in 17 different patches (Figure 1) covering an area of 19,940km^2, with a mean patch size of 1,172km^2 (± 890). This distribution range includes 42 distinct ecosystems: 14 natural pastures and/or scrublands covering 35.7% of the range, 28 different forest ecosystems covering 57.4%, and the remaining 6.9% classified as non-natural areas. Overall, in the whole distribution range, the bear distribution contains a higher proportion of ecosystems classified as medium fragmented (58.8%), with low connectivity (45.1%), high fragility (45.6%), high (38.2%), and medium threat (39.2%), as well as high (33.7%) and medium (33.1%) vulnerability (Figure 2). The mean values obtained in the 17 patches in which the Andean Bear inhabits showed greater average values of medium level of fragmentation, low connectivity, high fragility, medium threat, and high vulnerability (Table 1).

Finally, the comparison between forests and scrublands & pastures, showed that the latter ecosystem type has a poorer conservation status (Figure 3). For instance, 98% of the area covered by scrublands & pastures are classified as having low or very low connectivity, 77.3% with high fragility, and 77.4% with high threat (Figure 3).

DISCUSSION

Habitat fragmentation and its consequent isolation of populations is one the main conservation problems for the majority of large mammals (Crooks et al. 2011), including the Spectacled Bear (Castellanos et al. 2005). The development of the road network, land-use changes, and the establishment of human settlements (Armenteras et al. 2003; Kattan et al. 2004; Peralvo et al. 2005) have fragmented continuous populations into smaller and isolated patches (Figure 1), which could jeopardize bears population viability. It is, therefore, important to understand the features of these fragments, such as the conservation status of the ecosystems shaping the distribution range of the Spectacled Bear, which could help to establish remedial measures to conserve its habitats. In this work, however, we have

Table 1. Mean values ± standard deviation (SD) of the percentage of surface area of the different levels of the five indicators for the 17 distribution patches in which the Andean Bear inhabits in Ecuador.

Indicator	Mean	±SD
Fragmentation		
Very High	7.94	6.77
High	17.43	25.6
Medium	55.28	27.28
Low	9.35	15.46
Connectivity		
High	10.83	17.47
Medium	27.17	22.84
Low	43.96	25.6
Very Low	8.24	12.01
Fragility		
Very High	15.28	29.13
High	49.77	31.06
Medium	6.21	8.47
Low	10.81	15.6
Very Low	8.14	12.54
Threat		
High	32.11	25.1
Medium	45.54	26.76
Low	12.55	13.65
Vulnerability		
High	43.2	32.3
Medium	29	27.22
Low	17.99	23.55

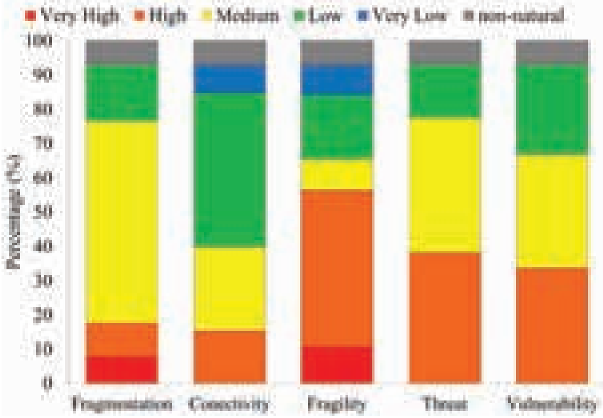

Figure 2. Proportion of the area covered by the different categories of the five ecosystems indicators within the distribution range of the Spectacled Bear. The five indicators were divided in five, four or three categories (see methods for more details), and therefore, some categories are missing for some indicators.

shown that the ecosystems occupied by this species are not always the best preserved, since a great proportion of the potential distribution range of the Spectacled Bear in Ecuador are ecosystems with some degree of threat.

Overall, a large proportion of the distribution range of the Spectacled Bear in Ecuador is covered by ecosystems catalogued as fragmented, poorly connected, fragile, threatened, and vulnerable (Figure 2). This relatively poor conservation status has important implications for the Spectacled Bear if no measures are applied to conserve these ecosystems. A fragmented and poorly connected ecosystem under high human pressure is vulnerable to reduction in surface area or even complete disappearance. Therefore, the ecosystems in Andean Bear's range could be replaced by other land uses that are less suitable as Andean Bear habitats.

Several scientific works have suggested that connectivity among patches still inhabited by Andean Bear is essential to ensure the conservation of its populations (Kattan et al. 2004; Velez–Liendo et al. 2014). According to our results, however, apart from connecting the reaming patches, a wider strategy (inside and outside of the distribution range) aimed at boosting the conservation status of the important ecosystems for this species is also necessary. One strategy could be to use the Andean Bear as an umbrella species (Crespo-Gascón & Guerrero-Casado 2019) in order to conserve those ecosystems with a high degree of threat that this species inhabits.

Furthermore, our results show that scrublands and pastures (including paramo or moorland) which are an important part of the Andean Bear's distribution range are more threatened than evergreen forests. The paramo in Ecuador has been extensively replaced by other land uses (e.g., pine plantations, crops or artificial pastures) (Ross et al. 2017) and although it covers a large area in the Andes region, it is highly threatened by anthropogenic activities (Ministerio del Ambiente del Ecuador 2015b). Therefore, since the paramo is an important ecosystem for the Andean Bear (Demay et al. 2014), it covers an important proportion of its distribution, and is a fragile ecosystem, conservation efforts should be also targeted at preserving this ecosystem at the national scale, which in turn could help to conserve the Spectacled Bear habitats.

Evergreen montane forests are the main habitats for the Spectacled Bear in Ecuador (almost 60 % according to our data), and as we have shown in this study, almost 50% of the distribution range of the Spectacled Bear is covered by forests considered as high or very high fragility (Figure 3). These ecosystems have a high alpha diversity and they are well represented in

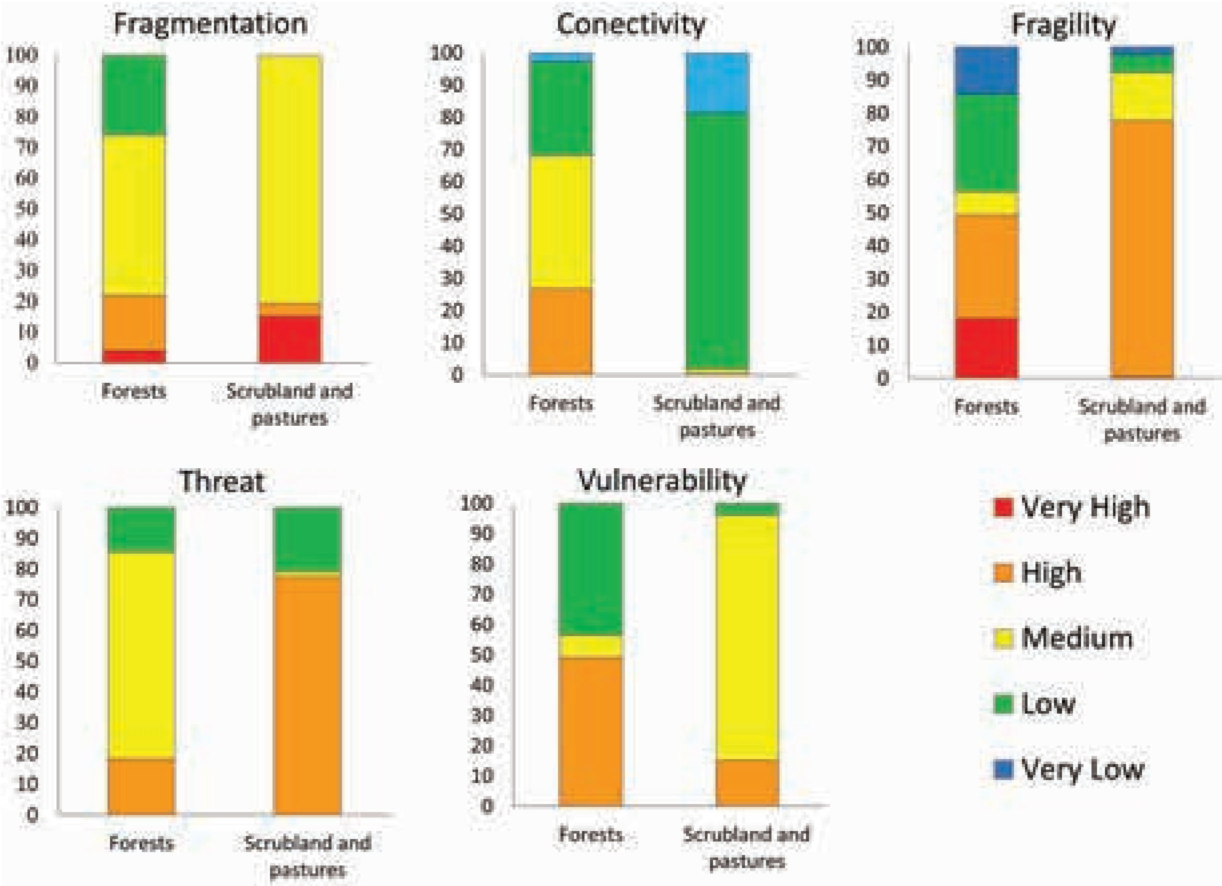

Figure 3. Proportion of the area covered by the different categories of the five ecosystem indicators for forest and scrublands & pastures separately. The five indicators were divided in five, four or three categories (see methods for more details), and therefore, some categories are missing for some indicators.

protected areas (Sierra et al. 2002), although they have been intensely deforested, thus, they are very fragile ecosystems. Therefore, conserving the larger blocks which this species inhabits (Kattan et al. 2004) as well as smaller patches of evergreen forests to promote the connectivity (Peralvo et al. 2005) should be implemented to ensure the preservation of these ecosystems and the habitat of the Andean Bear.

CONCLUSION

In summary, our results show that the ecosystems in which the Spectacled Bear inhabits have a poor conservation status, with an important proportion of the distribution range covered by ecosystems classified as fragmented, poorly connected, vulnerable, threatened, and fragile. Therefore, a national conservation strategy should be developed to enhance the conservation status of these ecosystems, which should include actions performed not only in areas where bears are present, but also in areas where they are not. This would contribute to the conservation of these ecosystems at a national scale, which would effectively preserve Spectacled Bear habitats.

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COMMUNICATION

Living with Leopard *Panthera pardus fusca* (Mammalia: Carnivora: Felidae): livestock depredation and community perception in Kalakkad-Mundanthurai Tiger Reserve, southern Western Ghats

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Abstract: Livestock depredation by large carnivores and retaliatory killings have become worldwide conservation issues. Leopard depredation of livestock across their range undermines public support for their conservation, resulting in contentious coexistence between the leopard and humans. Lack of knowledge on the patterns of livestock depredation often hinders the formulation of effective conservation management policies. We conducted a questionnaire survey on 656 respondents to assess the extent of livestock depredation and their attitudes towards leopards. Leopard kills included goats (49%) as the main prey, followed by the domestic dog (28%), hen (12%), sheep (5%), cow (4%), and cat (2%). Our results show that depredation varied significantly across seasons (KW = 30.33, df = 2, $P < 0.05$); 47% of domestic animals were killed during monsoon, followed by 33% in winter, and 20% in summer. Leopards killed 49.96% of goats as they grazed, 50% of sheep when tethered at the house, 67% of cows while in the corral, and 59% of dogs while they roamed freely around the house. Though local people experienced significant levels of livestock losses, about 68% expressed positive attitudes towards leopard conservation. Positive attitudes were revealed by their awareness about conservation and by moral consciousness towards killing of animals, which is forbidden in their religion. In the present study site, fodder cultivation and stall feeding would reduce the grazing-related attack. Similarly, simple changes in the husbandry practices such as closed fence type instead of stockade, effectively reduce enclosure-related depredation.

Keywords: Attitude, depredation, human-wildlife interaction, KMTR, Leopard, livestock kill.

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INTRODUCTION

Globally, the interaction between people and wildlife is ubiquitous and has been one of the main daunting challenges to wildlife conservation (Khorozyan et al. 2015). The ever-increasing human population encroaching habitats of large carnivores has resulted in a major reduction in their habitat which is also essential for their prey species to endure and thrive (Mijiddorj et al. 2018). In consequence, carnivores pose a direct, real or perceived threat to humans and livestock resulting in human and livestock losses (Dhungana et al. 2019). Depredation of livestock is the most frequent between humans and large carnivores (Linnell et al. 2001; Mwakatobe et al. 2013). It becomes extremely grave when rural people reside close to the protected areas and share the space as that of wildlife (Khorozyan et al. 2015). Other influential factors include high predator density following successful reintroduction or conservation effort (Suryawanshi 2013; Sidhu et al. 2017), low density of natural prey (Meriggi & Lovari 1996; Mizutani 1999; Stoddart et al. 2001; Polisar et al. 2003), abundance of livestock (Bagchi & Mishra 2006), rainfall (Patterson et al. 2004; Woodroffe & Frank 2005; Dhungana et al. 2019), livestock husbandry practices (Meriggi & Lovari 1996; Ciucci & Boitani 1998; Stahl et al. 2001; Madhusudan 2003; Ogada et al. 2003), lack of anti-predatory behaviour in livestock (Landa et al. 1999; Bagchi & Mishra 2006), and characteristics of attacked farms, villages, and livestock enclosures (Mech et al. 2000; Ogada et al. 2003). Areas that provide concealment for carnivores to come within range of livestock without being seen (Woodroffe & Ginsberg 1998) is also one of the important influencing factors

Among the big cats, the leopard is the most widespread species (Nowell & Jackson 1996) across Africa, Asia, and from the Middle East to the Pacific Ocean (Jacobson et al. 2016). Presently, it occupies 25–37 % of its historic range (Jacobson et al. 2016). Regardless of large range and greater adaptability, the IUCN Red List assessment (2016) has categorized the species as Vulnerable owing to >30% decline of their population worldwide over three generations (Stein et al. 2016) following habitat loss, hunting, prey reduction, and negative interactions with humans (Ripple et al. 2014; Jacobson et al. 2016). The Indian subspecies, *Panthera pardus fusca*, exists in all the forested habitats of the country, and is absent only in the arid deserts and above the timberline in the Himalaya (Prater 2005; Ramesh 2010). In the Western Ghats, it occupies an area of c. 43,353km^2 (Jhala et al. 2008)

Historically, there is continuous interaction between humans and large carnivores in India (Seidensticker & Lumpkin 1991). Among the large carnivores, the leopard is reported to cause the greatest percentage of livestock depredation in certain regions (Sangay & Vernes 2008; Dar et al. 2009; Karanth et al. 2013; Thorn et al. 2013). This creates a hostile attitude towards leopards among the local people, occasionally leading to the persecution or retaliatory killing of the leopard (Athreya & Belsare 2007; Ogra 2008; Lorraine 2014; Acharya et al. 2016). Conservation of large carnivores is of great concern when local communities present a negative attitude towards them (Lucherini & Merino 2008).

Lack of knowledge on the patterns of livestock depredation often hinders the formulation of effective conservation management policies. An explicit understanding of the extent of livestock depredation inclusive of areas, periods with high levels of depredation, and perception of local communities is crucial to address human-carnivore negative interactions (Dar et al. 2009). Though predation of livestock by large carnivores has been widely studied in India (Badola 1998; Bagchi & Mishra 2006; Allendrof 2007; Ogra 2008; Selvan 2013; Athreya et al. 2013; Bhatia et al. 2013; Suryawanshi et al. 2014; Acharya et al. 2016), the pattern of livestock depredation in the Kalakkad-Mundanthurai Tiger Reserve in Tamil Nadu (hereafter referred as KMTR), remains unclear, hence impeding the development of effective leopard conservation and conflict management strategies.

Basing on the above premise, we investigated the degree of livestock predation by leopard and the attitudes of local communities towards conservation of large carnivores in KMTR. We hypothesized high percentage of livestock depredation during monsoon season as the increased plant productivity would facilitate stalking cover for leopard. Our present study will provide an important baseline for further research and evaluation of conservation initiatives aimed at leopards and carnivores in general. Further, we also proposed the conservation implications of the present study and discussed the practical actions to mitigate the human-leopard interactions.

MATERIAL AND METHODS

Study area

KMTR (900km^2) is located in the Asahmbu Hills, in the Agasthiyamalai region (8.357–8.33° N & 77.169–77.574° E), at the southern end of the Western Ghats, in

Tamil Nadu, India (Figure 1). The terrain is mountainous with elevation ranging 100–1,866 m and the vegetation type ranges from dry thorn scrub to montane evergreen forest. KMTR receives rainfall from both southwest (June–September) and northeast (October–January) monsoons. The annual rainfall is about 3,000mm, and the temperature fluctuates between 17°C and 37°C over a year. KMTR is bordered by agricultural lands with human settlements (about 145 villages) in the east (Arjunan et al. 2006), whereas in the west there are extensive forests of Kerala. The rivers Peyar, Karaiyar, Kavuthalaiyar, Servalar, Chithar, and Pambar and their tributaries drain into a perennial river called the Tamiraparani. The sympatric carnivore species include the Tiger *Panthera tigris*, Leopard *Panthera pardus* and Wild Dog *Cuon alpinus*. The major wild ungulate prey species available to these sympatric carnivores are Gaur *Bos gaurus*, Sambar *Rusa unicolor*, Spotted Deer *Axis axis*, Wild Boar *Sus scrofa*, Nilgiri Tahr *Hemitragus hylocrius*, Barking Deer *Muntiacus muntjak*, and Indian Chevrotain *Moschiola indica*. Additionally, several smaller prey species such as Tufted Grey Langur *Semnopithecus priam priam*, Nilgiri Langur *Semnopithecus johnii*, Bonnet Macaque *Macaca radiata*, Lion-tailed Macaque *Macaca silenus*, Indian Hare *Lepus nigricollis*, Indian Crested Porcupine *Hystrix indica*, Indian Giant Squirrel *Ratufa indica*, Indian Peafowl *Pavo cristatus*, Grey Junglefowl *Gallus sonneratii*, and Red Spurfowl *Galloperdix spadicea* also exist (Johnsingh 2001). The reserve also supports Sloth Bear *Melursus ursinus* and wide diversity of medium and small-sized carnivores such as Jungle Cat *Felis chaus*, Leopard Cat *Prionailurus bengalensis*, Rusty Spotted Cat *Prionailurus rubiginosus*, Common Palm Civet *Paradoxurus hermaphroditus*, Small Indian Civet *Viverricula indica*, Brown Palm Civet *Paradoxurus jerdonii*, Grey Mongoose *Herpestes edwardsii*, Ruddy Mongoose *Herpestes smithii*, Brown Mongoose *Herpestes fuscus*, and Stripe-

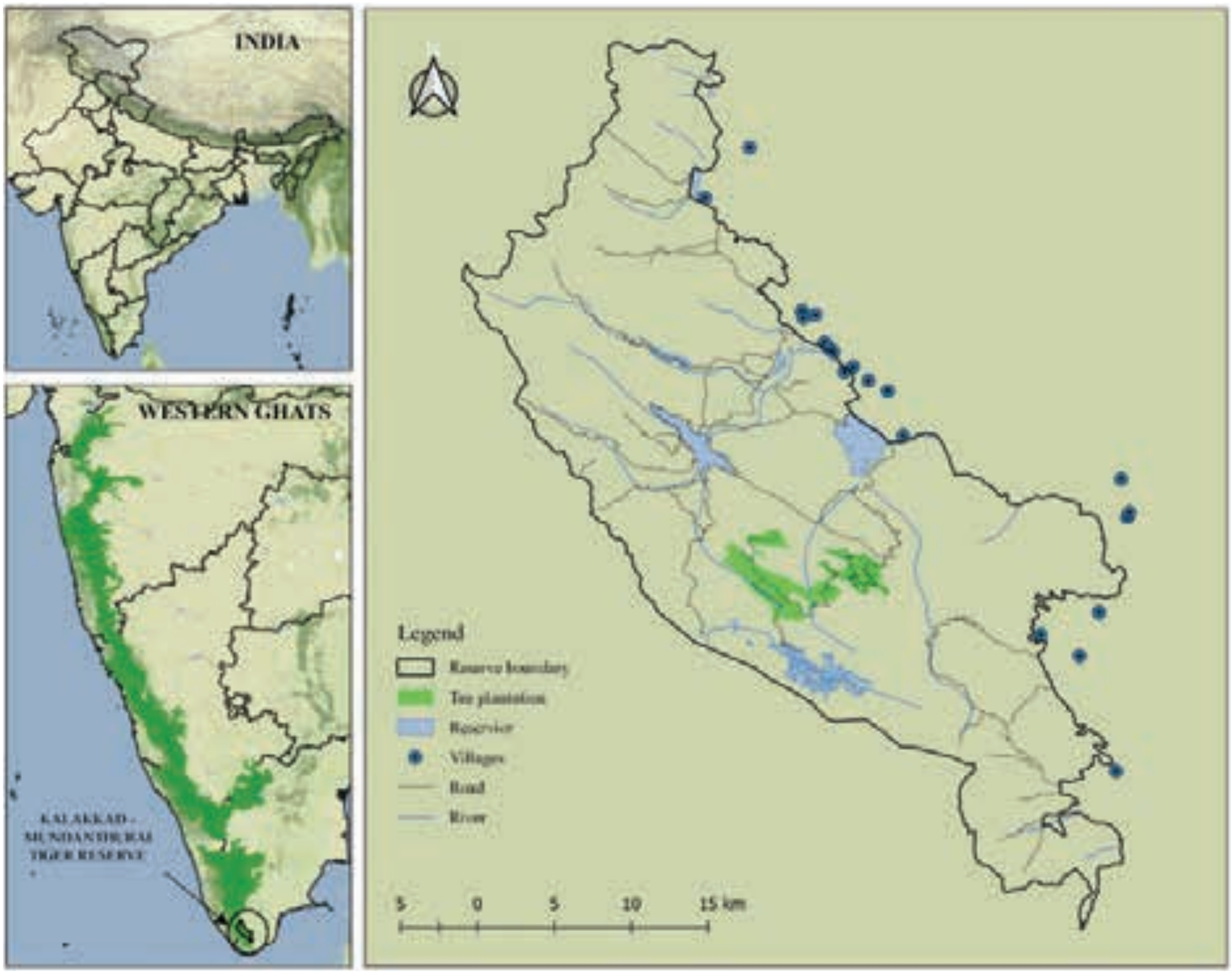

Figure 1. Location of surveyed villages in the periphery of Kalakkad-Mundanthurai Tiger Reserve.

necked Mongoose *Herpestes vitticollis* (Mudappa 1998; Johnsingh 2001; Mudappa et al. 2007). The people inhabiting in this region are either agro-pastoralists or pastoralists. Local people raise cattle, sheep and goats, herded them during the day to the foothill of KMTR and brought back home.

Data collection and analyses

The data for the present study were collected between the years December 2016 and December 2018. The sample included 19 randomly selected villages along one kilometer distance from the eastern boundary of the reserve. Incidents of livestock depredation and the attitudes of local residents were investigated through questionnaires distributed to 656 respondents. Majority of the livestock graze at the foothills of KMTR, usually attended by herdsman, and occasionally by domestic dogs. Respondents included resident adults (≥ 18 years old) were interviewed (Suryawanshi et al. 2014). All the interviewees were assured of anonymity, and were priory informed of the aims and objectives of the study, befor their participation in the interview. The questionnaire was divided into two sections, wherein the first section provided information on the following aspects to assess the pattern of predation: (1) species of livestock killed (goat, sheep, dog, hen, and cow), (2) season, (3) activity of livestock at the time of kill (grazing, corral, tethered at house, untethered at house, and guarding), and (4) attack by large carnivore on family members within the previous three years. The second section was structured questionnaire that was scored as described by Suryawanshi et al. (2014) to understand the attitudes of the local people towards conservation of leopards. The questionnaire in the second section included the following questions: 1) Do you support the conservation of leopards in KMTR? 2) Would you like to see a leopard in your village or agricultural land? 3) Do you think the conservation of these animals is beneficial for the environment of KMTR? 4) What should be done when a leopard kills your livestock? The total of scores could vary from -2 to 2, with -2 signifying the most negative attitude on a relative scale and 2 signifying the most positive reply. Attitude scores of -1 and -2 was considered negative and 0 was considered unsure, whereas scores > 1 were considered positive (Suryawanshi et al. 2014). To determine the difference in livestock depredation by leopards, the Kruskal-Wallis one way ANOVA was used. All the analyses were conducted in R v. 3.5.2. (R development Core Team 2018).

RESULTS

Livestock depredation by leopard

Of the 656 respondents, 62.3% (n = 409) were males and 35.1% were females (n = 230). Among female respondents 2.6% (n = 17) refused to participate. The oldest respondent was 95 years old, and the mean age was 47.0 ± 12.3 SD. During 2017–2018, a total of 233 domestic animals were reportedly killed by leopards. Leopards primarily killed goat *Capra aegagrus hircus* (49%), followed by domestic dog *Canis lupus familiaris* (28%), hen *Gallus gallus domesticus* (12%), sheep *Ovis aries* (5%), cow *Bos taurus* (4%), and cat *Felis catus* (2%) (Figure 2). Livestock depredation was recorded in all the surveyed villages. Among the sampled villages, we found Pethanpillaikudiyiruppu (27%), Anavankudiyiuruppu (17%), and Vembaiyapuram (12%) to be highly prone to depredation. According to the respondents in 19 villages, none of the fatal attacks on human beings or kills by large carnivores had occurred in the park in the last three years.

There was significant difference in livestock depredation by leopards among various seasons (KW = 30.33, df = 2, $P < 0.05$). About 47% (n = 108) domestic animals were killed during monsoon, followed by 33% (n = 74) in winter and 20% (n = 46) in summer (Figure 3). Correspondingly, 29% (n = 66) attacks were during day time and 71% (n = 162) during night, and the difference was marginally significant (KW = 45.82, df = 1, $P < 0.05$). The presence of a herdsman while livestock were grazing did not deter leopard attack, in any of the cases. About 58% (n = 108) livestock had been depredated while grazing and 25% (n = 47) while in the corral. In terms of location of livestock prior to attack, 50% (n = 54) of goats were killed while grazing, whereas, 50% (n = 6) sheep were killed when tethered near to the house, 67% (n = 6) cows were killed in the corral (Figure 4), and 59% (n = 38) dogs had been killed while roaming freely around the house (Figure 5). There was significant difference in location of livestock depredation among goats (KW = 50.3, df = 3, $P < 0.05$) and dogs (KW = 36, df = 3, $P < 0.05$), whereas this was not significant in case of sheep (KW = 3.5, df = 3, $P > 0.05$) and cows (KW = 5.15, df = 3, $P > 0.05$).

Local people's attitude

Despite the livestock depredation, the respondent's (68%) overall attitude towards conservation of leopards was generally positive, while 22% were unclear about conservation. There was significant difference between gender, with the males exhibiting more support towards

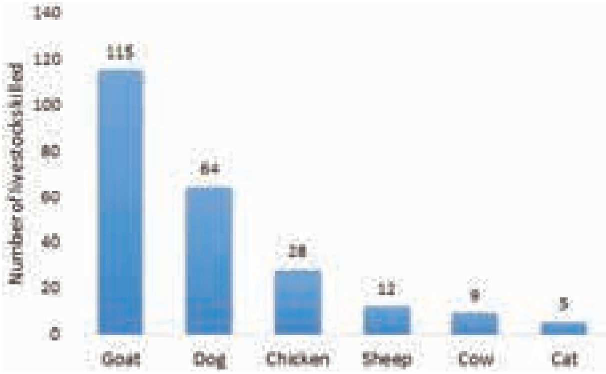

Figure 2. Total number of different domestic and livestock animals killed by leopard from December 2016 to December 2018 in the periphery villages of Kalakkad-Mundanthurai tiger reserve, Tamil Nadu, India.

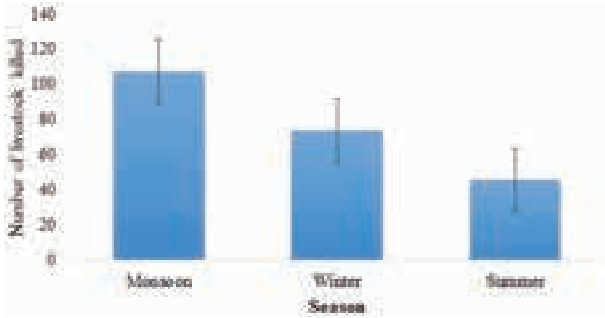

Figure 3. Seasonal variation (Mean±SD) in livestock and domestic animals killed by leopard in the periphery villages of Kalakkad-Mundanthurai Tiger Reserve during the study period.

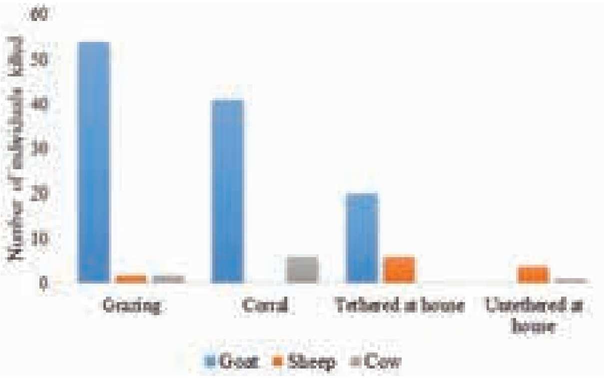

Figure 4. Number of livestock and domestic animals killed in different locations around the house by leopard in Kalakkad-Mundanthurai Tiger Reserve.

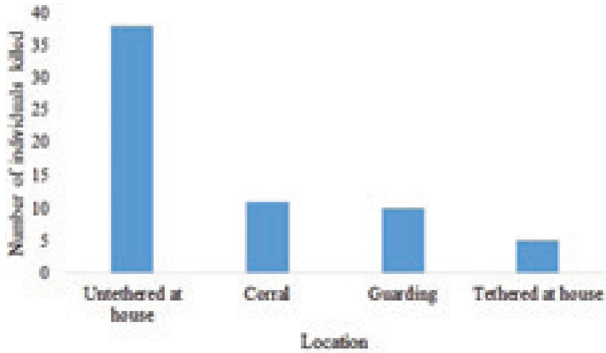

Figure 5. Number of dogs killed by leopard in different locations in the periphery villages of Kalakkad-Mundanthurai Tiger Reserve.

leopard conservation than females (χ^2 = 55.4, df = 2, P < 0.05). About 74% of the respondents opined to not wanting the leopard within the village or agricultural land, while 2% differed with this, and there was no significant difference between the genders (χ^2 = 7.3, df = 2, P>0.05). Among the respondents, only 5% of them showed positive attitudes towards support large carnivore conservation in KMTR, while 51% were unsure and 44% exhibited negative attitudes. There was significant difference between gender, with the males being more aware of large carnivore conservation in KMTR than females (χ^2 = 67.1, df=2, P < 0.05). Respondents were asked about their views on livestock predation by leopard. Of them, only 27% replied that leopard should be translocated to another area, while 26% replied could not do anything about it, 18% accepted their livestock loss, 13% were unsure about this and finally 8% of each respondents replied leopards should be eliminated from their area and they also require food. In the interest of examining the level of interaction following the translocation programme, the effectiveness of such operations were questioned. For which 72% respondents replied the programmes being inefficient. Out of 136 livestock (goat, sheep, and cow) depredation, only 25% people had applied for compensation, while 75% did not. In most instances, people were dissatisfied with the compensation provided by the forest department for livestock losses.

DISCUSSION

Livestock depredation by leopard

Our study showed that leopards mostly predated on medium-sized livestock, such as goats and sheep (54% of all killings), and hence it is concurs with the report of Sangay & Verne (2008), and Dar et al. (2009). Though, leopard kill wide range of prey species, from arthropods to adult sambar or gaur (Seidensticker 1976), they usually prefer prey species weighing between10–40 kg (Hayward et al. 2006) and 2–25 kg (Lovari et al. 2013). The optimal body size of goats (5–25 kg; Lovari et al.

2013) combined with their non-defensive behaviour, and the relative ease of killing and lugging to a safe place after extermination (Kabir et al. 2013) may have contributed to higher goat depredation rates in KMTR.

It was found that among the sampled villages, Pethanpillaikudiyiruppu, Anavankudiyiuruppu, and Vembaiyapuram were highly prone to livestock depredation. Davidar (2018) reviewed the terms used in human-wildlife conflict. As the areas located close to the forest boundary and frequently had significant livestock depredation and therefore the areas are considered as conflict hotspots. More incidents of depredation occurred during monsoon compared with summer. This could be ascribed to highest rainfall during monsoon resulting in increased vegetation cover such as shrub and undergrowth which provide good cover for leopards (Balme et al. 2007) as recorded elsewhere (Patterson et al. 2004; Kolowski & Holekampt 2006). Though livestock was killed in corral or shed, 58% of livestock kill were reported when grazing near the forest boundary, since animals grazing near protected areas expose them to predators. Such grazing associated losses are common elsewhere, and often difficult to limit or alter (Karanth & Nepal 2012; Karanth et al. 2012), however, it is suggested that cultivation of fodder and stall feeding could be effective against such grazing associated depredation. Livestock in corrals are usually safe against predators (Kaczensky 1999), but still suffer predation in KMTR. In the present study, it was observed that the corral or shed was covered on four sides with a palisade to a height averaging four feet either with a top cover or the shed had only the top cover. Thus, imperfect sheds with restricted movement of livestock made them vulnerable to predation at night compared with daylight. Similar depredation patterns were observed in the Bandhavgarh Tiger Reserve (Chouksey et al. 2017), Pir Lasoora National Park (Kabir et al. 2017), and the Macharia National Park (Kabir et al. 2013; Dar et al. 2009). Even with such experience, the livestock owners did not appear to improve the shed to reduce further loss (Krishnakumar pers. obs. 2018), and were more likely to devote time and resources to improve their livestock protection strategies. Husbandry practices can significantly impact the risk of livestock predation by large carnivores (Ogada et al. 2003; Stein et al. 2010). Therefore, fencing livestock instead wooden stockade could effectively reduce enclosure related depredation.

The dog was the most killed domestic animal than livestock, as 59% of them were killed when roaming freely around the house. Since the dog is reared for the purpose of guarding, it is left untethered, making it vulnerable to predation which can be easily killed and dragged. In addition, the dog plays a significant role in the diet of leopards across India (Mukerjee & Mishra 2001; Edgaonkar & Chellam 2002; Athreya et al. 2004). In spite of the fact that dogs are impotent against a leopard attack, local villagers rear dogs believing that livestock losses would be higher without dogs, and that a leopard would attack humans in the absence of dogs. This kind of thinking has been observed in Iran also (Khorozyan et al. 2017).

Local people's attitudes

The support of local people and their contribution to the conservation of carnivores is mostly due to the value they place on large carnivores (Gusset et al. 2009). In the present study, majority of the respondents presented an optimistic attitude towards the leopard and its conservation. This may be attributed to awareness about conservation, and to some extent, moral conscience or being forbidden by their religion to kill animals, and may help potential long-term conservation of this species in the reserve. More positive attitudes towards leopard conservation were observed among men when compared with women, and is probably ascribed to greater fear about carnivores in women (Zaffar et al. 2015), who tend to dislike fearsome species (Schlegel & Rupf 2009). In most cases, men tended to have a more positive attitude towards conservation than women (Butler et al. 2003; Røskaft et al. 2007). Majority of the respondents were disinclined to see the leopard either in their village or agricultural land due to fear. All the respondents expressed dissatisfaction over the existing compensation scheme, and were unwilling to report cattle losses by predators to the local wildlife authority due to the long administrative process that resulted in delayed payments, insufficiency in amount, and precondition for applying compensation such as difficulties in verifying leopard attacks.

The capture and translocation of problematic animal is the existing mitigation policy and is most widely used in India, besides the compensation payment (Athreya et al. 2010). In KMTR, the forest managers are often forced to remove animals in response to complaints from people. But such translocation programme does not appear to reduce the level of negative interactions, however, 27% of the respondents expressed that the depredating leopard should be translocated, may be because in certain villages, it had not been translocated so far. Translocation of carnivores can have undesirable effects (Athreya et al. 2010), as majority of post translocation studies have reported that such animals perish due to capture-related stress, injuries, and extensive post release movements (Linnell et al. 1997; Miller et al. 1999; Letty et al. 2007). Moreover, following translocation, carnivores often reappear at the captured site in a relatively short time (Rogers 1988). A few studies have reported that translocated carnivores continue to engage in greater negative interactions (Stander 1990; Bradley et al. 2005).

The high proportion of livestock loss is attributed to leopards in the present study area, and hence is of prime concern. Educating people to improve livestock husbandry skills is highly recommended. Although people are infuriated due to livestock depredation by leopards, they do not persecute them as in other parts of central Asia (Mishra & Fitzherbert 2004) because of strict statutes. Considering the increasing number of depredations by leopards in human-dominated habitats outside KMTR, where communities might incur significant economic loss, the conservation of leopards will depend on support from local communities. This can be ensured by addressing the issue of human-leopard interactions in an effective manner. It is also emphasized that assessing the extent of predation alone is not likely to lead to effective conservation planning as people are hostile towards wildlife officials. Field experience has shown that crop damage is a significant responsible factor for negative attitude towards the staff of the forest department, so reducing crop damage could have a strong positive effect.

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Threatened Taxa

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Author contribution: Conceptualization—BMK, KMS and RN; methodology—KMS, and RN; formal analysis—BMK, KMS and RN; conducting field work—BMK; preparing manuscript—All author contributed equally.

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COMMUNICATION

An updated checklist of mammals of Odisha, India

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Abstract: Based on available literature and field surveys, an updated checklist of mammals of Odisha State is presented in this communication. Their updated scientific binomen, IUCN status, Wildlife (Protection) Act schedules, CITES appendices, and last reported sighting of each species in Odisha are also given. Odisha has around 102 species of mammals under 34 families and 12 orders, among which 27 species have been included under the different threatened categories of the IUCN Red List.

Keywords: CITES, eastern India, Indian Wildlife (Protection) Act, IUCN.

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Author contribution: Both authors contributed equally to the study.

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INTRODUCTION

Mammals are one of the most charismatic group and represented by 6,399 extant species under 1,314 genera, 167 families and 27 orders worldwide (Burgin et al. 2018). India is one of the 17 megadiverse countries in the world, and has over 427 extant mammalian species representing 199 genera, 52 families and 14 orders (Thong et al. 2018; Srinivasulu 2019). India is classified into 10 different biogeographic zones (Rodger & Panwar 1988), and each of these zone has some uniqueness in their mammalian fauna (Menon 2014).

The state of Odisha (formerly Orissa) (17.816–22.566 ^{0}N and 81.483–87.483 ^{0}E; Figure 1) spread over an area of 155,707km², is situated along the east coast of India within the Deccan peninsular biogeographic zone (No. 6). Because of its unique geographic location within the transitional zone of Chhotanagpur Plateau (No. 6B), Eastern Ghats Highlands (No. 6C), Lower Gangetic Plain (No. 7B), and the Eastern Coastal Plain's (No. 8B) biogeographic provinces (Ray 2005), Odisha's biodiversity represents a mixture of Indo-Malayan and Afro-Mediterranean elements (Das et al. 2015). About 37% of the total geographic area of Odisha is under forest cover (Forest Survey of India 2019), which is mainly composed of tropical moist deciduous, tropical dry deciduous, tropical semi-evergreen, scrub and mangrove forests (Champion & Seth 1968). The coastline of Odisha is about 480km long, characterized by sand dunes, tidal creeks, backwaters, brackish water lagoons, estuaries, mangroves, mudflats, and salt marshes. There are 22 protected areas (19 wildlife sanctuaries (WS)), one national park and two tiger reserves in Odisha which covers about 4.73% of the state's geographical area.

Documented information on mammalian fauna of Odisha dates back to the second half of 19th century. It can be found referred in the first book on Indian mammals "The Mammals of India" by Jerdon (1867). Subsequently, other important publications also dealt with mammals of Odisha (Ball 1877; Sterndale 1884; Blanford 1888–1891). Although the Bombay Natural History Society's systematic Mammal Survey of India, Burma and Ceylon was held during 1911–1930, it could not cover parts of then princely states of Odisha (Das et al. 1993). A few species of mammals, however, were collected near Chilika Lake and Koira area in Odisha and the results were reported in Annandale (1915), Thomas (1915), Wroughton (1915), and Hinton & Lindsay (1926a,b). Subsequently, mammals of Odisha were also referred in several volumes of "Fauna of British India" (Pocock 1939, 1941) and "Fauna of India" (Ellerman 1961a,b). Behura & Guru (1969) compiled a checklist of mammals of Odisha and reported 34 species. During 1970–1983, the Zoological Survey of India made a series of mammalian surveys throughout Odisha, the results of which comprising 76 species were then reported in the state fauna series (Das et al. 1993). Mishra et al. (1996) also made a comprehensive checklist of wildlife of Odisha and reported 85 species of mammals within the political boundary of the state.

During the last two decades, there have been increasing efforts to document mammals of Odisha. These studies were focused on several protected areas, important hill ranges and sacred groves. Tiwari et al. (2002) first compiled 37 species of mammals from Chandaka-Dampara WS. Ramakrishna et al. (2006) reported 55 species of mammals from Similipal Biosphere Reserve encompassing the Similipal WS and Similipal Tiger Reserve. Mohapatra et al. (2009, 2012, 2013) reported 36 species of mammals from different hill forests of southern Odisha, 43 species from Kotgarh WS, and 47 species from several sacred groves in Sundargarh District. Sahu et al. (2012, 2014) reported 36 species of mammals from Hadagarh WS, and 43 species of mammals from Kuldiha WS. Murmu et al. (2013a,b) also reported 23 species of mammals of Kuldiha WS, and 42 species of mammals from Hadagarh WS. Khan et al. (2015) reported 18 species of cetaceans from Odisha. Debata et al. (2016) reported 25 species of bats within the geographic limits of Odisha. Besides these, Venkatraman et al. (2016) reported 24 species of mammals from Bhitarkanika mangroves. Very recently, Debata & Swain (2020) surveyed the mammalian fauna of an urban-influenced zone of Chandaka-Dampara WS using camera traps and reported 14 species of mammals. Some of the recent additions to mammalian fauna of Odisha are Bryde's Whale *Balaenoptera edeni* Anderson, 1879 (John et al. 2012), Lesser False Vampire Bat *Megaderma spasma* Linnaeus, 1758 (Debata et al. 2013), Asian Small-clawed Otter *Aonyx cinereous* (Illiger, 1815) (Mohapatra et al. 2014), Cantor's Roundleaf Bat *Hipposideros galeritus* Cantor, 1846 (Debata et al. 2015), Dwarf Sperm Whale *Kogia sima* (Owen, 1866), Bottle-nosed Dolphin *Tursiops truncatus* Montagu, 1821, Indian Ocean Humpback Dolphin *Sousa plumbea* (Cuvier, 1829), and Pantropical Spotted Dolphin *Stenella attenuata* (Gray, 1846) (Khan et al. 2015). As there is no recent updated information on mammals of Odisha, preparation of a checklist with updates was, thus, considered necessary for further conservation management of mammals of the state.

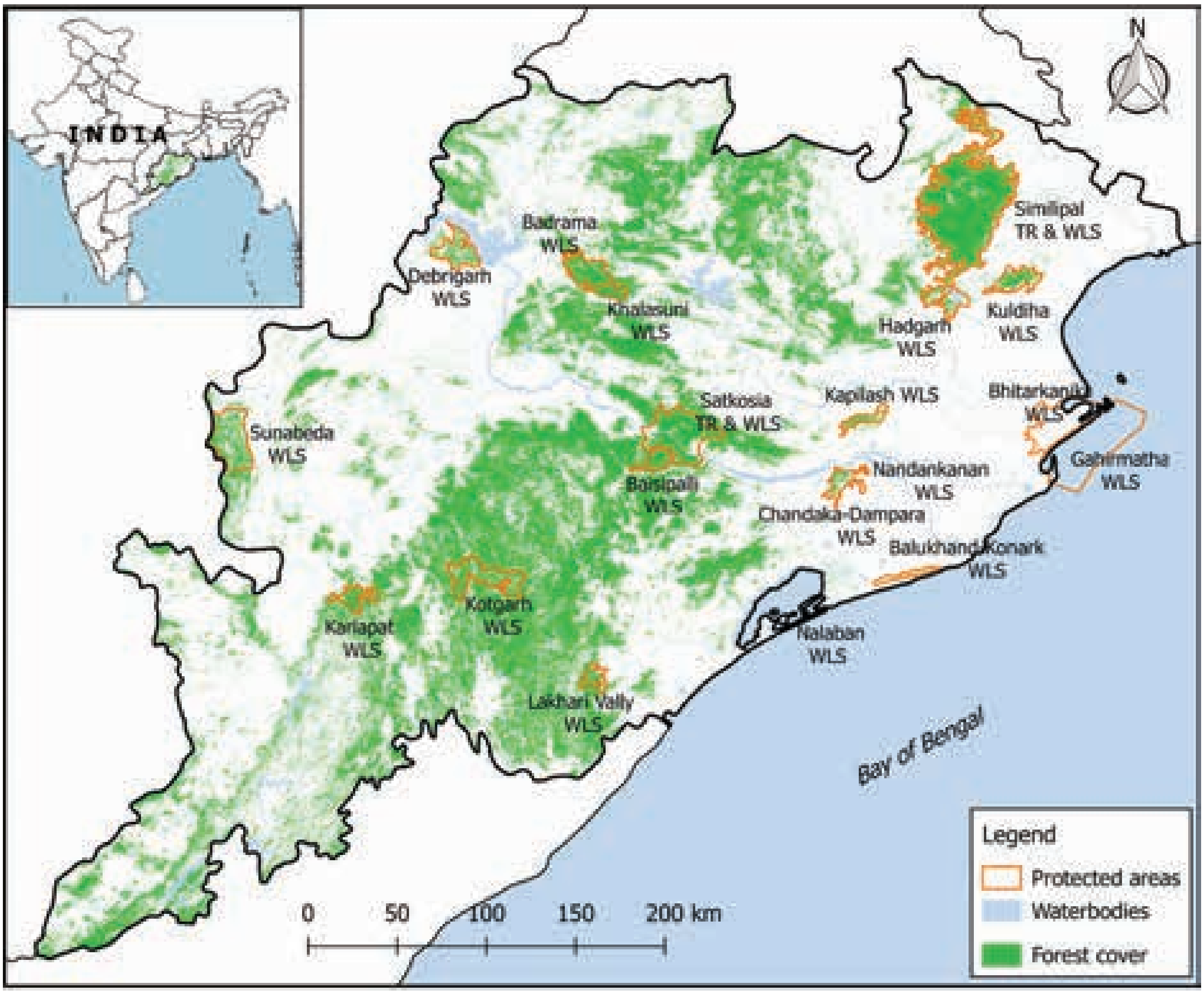

Figure 1. Map of Odisha showing the political boundary, forest cover and Protected Areas.

METHODS

The checklist given in this communication is based on a thorough review of available literature, books, and technical reports on mammals of Odisha along with author's field surveys. While preparing the checklist, we followed IUCN (2020) for the scientific and common names of the species. The conservation status of the species provided in the checklist is based on the IUCN Red List, Indian Wildlife (Protection) Act, 1972 and Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

RESULTS AND DISCUSSION

A total of 102 species of mammals under 34 families and 12 orders are listed in the current checklist of Odisha (Table 1). Among all, the order Chiroptera is the largest group of mammals with 25 species (24.5%) followed by Carnivora (23 species; 22.6%), Cetacea (18 species; 17.6%), Rodentia (15 species; 14.7%), and Artiodactyla (12 species; 11.8%) (Figure 2). The rest of the groups represented less than 10% of the total mammalian diversity (Figure 2). As many as 22 species (21.6%) are threatened (nine Endangered and 13 Vulnerable), five (4.9%) are Near Threatened, 72 (70.6%) are Least Concern, and three (2.9%) are Data Deficient species (IUCN 2020).

Mammals excluded from the Odisha list

We have excluded a few species from the checklist because they could be locally extirpated, inaccurately mentioned in the literature, or have not been formally recognized as a separate species. A detailed description on their distribution in Odisha is summarized below in

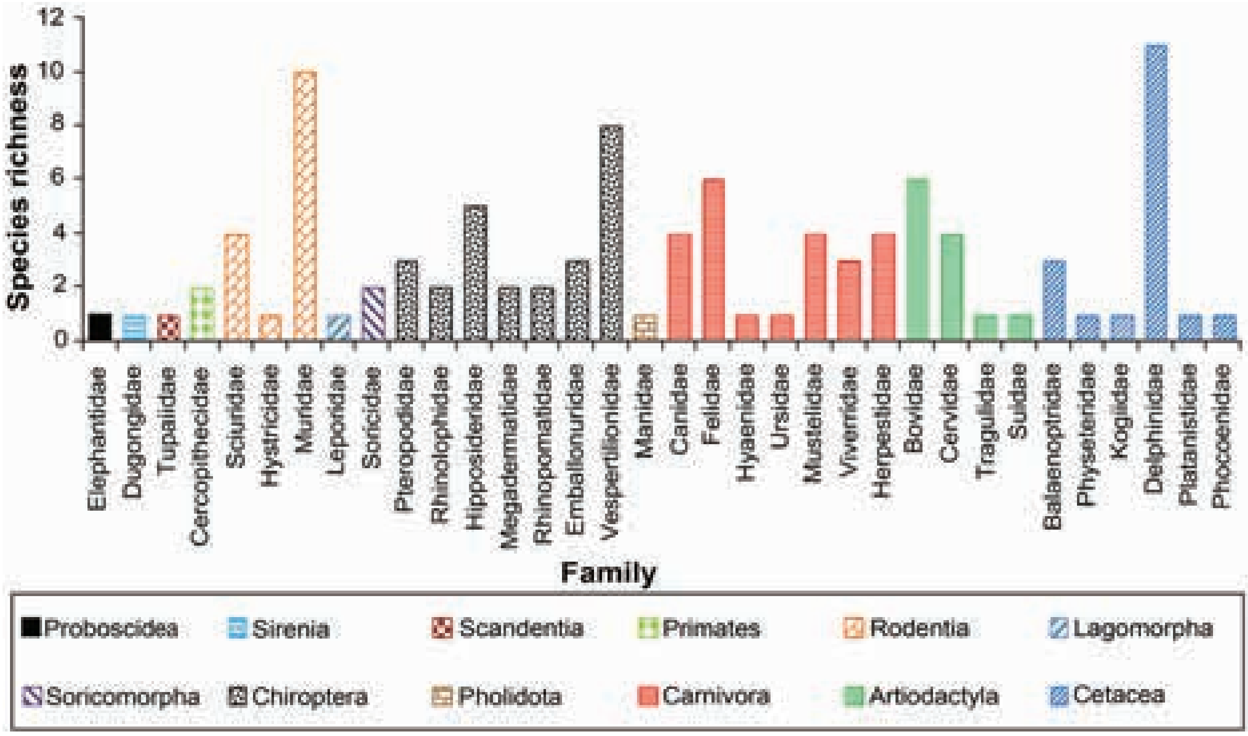

Figure 2. Mammalian species richness in different families in Odisha, India.

support of their exclusion from this list.

Cheetah *Acinonyx jubatus* (Griffith, 1821): Cheetah was stated to be present in Odisha based on various sighting records in Sambalpur District during 1880, Sundargarh District during 1910, Angul District during 1932 (Divyabhanusingh & Kazmi 2019), near Odisha-Andhra Pradesh border during 1952 (Mukherjee 1982) and in Dhenkanal District during 1960 (Behura & Guru 1969). Since then there is no report of sighting of Cheetah in Odisha and it is already considered extinct in India. We, therefore, excluded the species from the current checklist.

Bonnet Macaque *Macaca radiata* (E. Geoffroy, 1812): Bonnet Macaque was reported to occur only in Malkangiri District of southern Odisha (Mishra et al. 1996). Acharjyo (2001), however, raised doubt on its occurrence in Odisha. Moreover, Das et al. (1993) did not mention its occurrence in Odisha. Recently, Kumar et al. (2011) mapped the distribution of Bonnet Macaque in India, but did not report any troops from Odisha. We, therefore, excluded this species from Odisha checklist.

Caracal *Caracal caracal* (Schreber, 1776): Based on a newspaper report published in The Statesman, Calcutta on 10 March 1962, Behura & Guru (1969) reported the presence of Caracal in Mayurbhanj District, northern Odisha. Apart from this, there is no further valid evidence of its occurrence in the state so far. The known eastern most range of this species in India extends up to Madhav National Park in Madhya Pradesh (Kushwaha & Kumar 1999). The species, therefore, might have been inaccurately mentioned or might have become locally extirpated in Odisha.

Marbled Cat *Pardofelis marmorata* (Martin, 1836): There is a mention that two young individuals (possibly kittens) of Marbled Cat captured in Phulbani District and displayed in the first wildlife exhibition held at Bhubaneswar in 1956 (Mishra et al. 1996). Besides that there is no further valid evidence on its occurrence in Odisha. As Leopard Cat *Prionailurus bengalensis* (Kerr, 1792) is a very common and widely distributed species in the forests of Odisha (Mishra et al. 1996), the captured kittens were probably misidentified Leopard Cats. The Marbled Cat is found in the mountain region of Himalaya, Himalayan foothills, and northeastern states in India (Ross et al. 2016). We, therefore, ruled out the presence of Marbled Cat in Odisha, and exclude it from the updated checklist.

Clouded Leopard *Neofelis nebulosa* (Griffith, 1821): There is a mention on occurrence of Clouded Leopard from Similipal WS by Ramakrishna et al. (2006). The authors mentioned its distribution in Chahala, Kabatghai, and Talbandh areas in Similipal with no valid evidence.

Table 1. Checklist of mammals of Odisha, India. IUCN Status: EN—Endangered, VU—Vulnerable, NT—Near Threatened, LC—Least Concern, DD—Data Deficient.

	Scientific name	Common name	IUCN status	WPA, 1972 schedule	CITES appendix	Latest source
	A. ORDER PROBOSCIDEA					
	I. Family Elephantidae (Elephants)					
1	*Elephas maximus* Linnaeus, 1758	Asian Elephant	EN	I	I	Debata & Swain (2020)
	B. ORDER SIRENIA					
	II. Dugongidae (Dugongs)					
2	*Dugong dugon* (Müller, 1776)	Dugong	VU	I	I	Mishra et al. (1996)
	C. ORDER SCANDENTIA					
	III. Family Tupaiidae (Treeshrews)					
3	*Anathana ellioti* (Waterhouse, 1850)	Madras Treeshrew	LC	Not listed	II	Sahu et al. (2014)
	D. ORDER PRIMATES					
	IV. Family Cercopithecidae (Old world monkeys)					
4	*Macaca mulatta* (Zimmermann, 1780)	Rhesus Macaque	LC	II	II	Debata & Swain (2020)
5	*Semnopithecus entellus* (Dufresne, 1797)	Northern Plains Gray Langur	LC	II	I	Debata & Swain (2020)
	E. ORDER RODENTIA					
	V. Family Sciuridae (Squirrels)					
6	*Funambulus palmarum* (Linnaeus, 1766)	Three-striped Palm Squirrel	LC	Not listed	Not listed	Sahu et al. (2014)
7	*Funambulus pennantii* Wroughton, 1905	Northern Palm Squirrel	LC	IV	Not listed	Murmu et al. (2013a, b)
8	*Petaurista philippensis* (Elliot, 1839)	Indian Giant Flying Squirrel	LC	II	Not listed	Murmu et al. (2013b)
9	*Ratufa indica* (Erxleben, 1777)	Indian Giant Squirrel	LC	II	II	Palei et al. (2017)
	VI. Family Hystricidae (Porcupines)					
10	*Hystrix indica* Kerr, 1792	Indian Crested Porcupine	LC	IV	Not listed	Debata & Swain (2020)
	VII. Family Muridae (Rats and Mice)					
11	*Bandicota bengalensis* (Gray, 1835)	Lesser Bandicoot Rat	LC	V	Not listed	Sahu et al. (2014)
12	*Bandicota indica* (Bechstein, 1800)	Greater Bandicoot Rat	LC	V	Not listed	Mohapatra et al. (2013)
13	*Golunda ellioti* Gray, 1837	Indian Bush-rat	LC	V	Not listed	Tiwari et al. (2002)
14	*Madromys blanfordi* (Thomas, 1881)	White-tailed Wood Rat	LC	V	Not listed	Mohapatra et al. (2013)
15	*Mus booduga* (Gray, 1837)	Common Indian Field Mouse	LC	V	Not listed	Sahu et al. (2014)
16	*Mus musculus* Linnaeus, 1758	House Mouse	LC	V	Not listed	Sahu et al. (2014)
17	*Rattus norvegicus* (Berkenhout, 1769)	Brown Rat	LC	V	Not listed	Mishra et al. (1996)
18	*Rattus rattus* (Linnaeus, 1758)	House Rat	LC	V	Not listed	Sahu et al. (2014)
19	*Tatera indica* (Hardwicke, 1807)	Indian Gerbil	LC	V	Not listed	Sahu et al. (2014)
20	*Vandeleuria oleracea* (Bennett, 1832)	Asiatic Long-tailed Climbing Mouse	LC	V	Not listed	Sahu et al. (2014)
	F. ORDER LAGOMORPHA					
	VII. Family Leporidae (Hares)					
21	*Lepus nigricollis* F. Cuvier, 1823	Black-naped Hare	LC	IV	Not listed	Debata & Swain (2020)
	G. ORDER SORICOMORPHA					
	VIII. Family Soricidae (Shrews)					
22	*Suncus etruscus* (Savi, 1822)	Savi's Pygmy Shrew	LC	Not listed	Not listed	Sahu et al. (2014)

	Scientific name	Common name	IUCN status	WPA, 1972 schedule	CITES appendix	Latest source
23	*Suncus murinus* Linnaeus, 1766	House Shrew	LC	V	Not listed	Sahu et al. (2014)
	H. ORDER CHIROPTERA					
	IX. Family Pteropodidae (Fruit Bats)					
24	*Cynopterus sphinx* (Vahl, 1797)	Greater Short-nosed Fruit Bat	LC	V	Not listed	Debata et al. (2016)
25	*Pteropus giganteus* (Brünnich, 1782)	Indian Flying Fox	LC	V	II	Debata et al. (2016)
26	*Rousettus leschenaultii* (Desmarest, 1820)	Leschenault's Rousette	LC	V	Not listed	Debata et al. (2016)
	X. Family Rhinolophidae (Horseshoe Bats)					
27	*Rhinolophus lepidus* Blyth, 1844	Blyth's Horseshoe Bat	LC	Not listed	Not listed	Debata et al. (2016)
28	*Rhinolophus rouxii* Temminck, 1835	Rufous Horseshoe Bat	LC	Not listed	Not listed	Debata et al. (2016)
	XI. Family Hipposideridae (Roundleaf Bats)					
29	*Hipposideros ater* Templeton, 1848	Dusky Roundleaf Bat	LC	Not listed	Not listed	Debata et al. (2016)
30	*Hipposideros fulvus* Gray, 1838	Fulvus Roundleaf Bat	LC	Not listed	Not listed	Debata et al. (2016)
31	*Hipposideros galeritus* Cantor, 1846	Cantor's Roundleaf Bat	LC	Not listed	Not listed	Debata et al. (2016)
32	*Hipposideros speoris* (Schneider, 1800)	Schneider's Roundleaf Bat	LC	Not listed	Not listed	Debata et al. (2016)
33	*Hipposideros lankadiva* Kelaart, 1850	Kelaart's Roundleaf Bat	LC	Not listed	Not listed	Debata et al. (2016)
	XII. Family Megadermatidae (False Vampire Bats)					
34	*Megaderma lyra* E. Geoffroy, 1810	Greater False Vampire Bat	LC	Not listed	Not listed	Debata et al. (2016)
35	*Megaderma spasma* (Linnaeus, 1758)	Lesser False Vampire Bat	LC	Not listed	Not listed	Debata et al. (2016)
	XIII. Family Rhinopomatidae (Mouse-tailed Bats)					
36	*Rhinopoma hardwickii* Gray, 1831	Lesser Mouse-tailed Bat	LC	Not listed	Not listed	Debata et al. (2016)
37	*Rhinopoma microphyllum* (Brünnich, 1792)	Greater Mouse-tailed Bat	LC	Not listed	Not listed	Debata et al. (2016)
	XIV. Family Emballonuridae (Sheath-tailed Bats)					
38	*Saccolaimus saccolaimus* (Temminck, 1838)	Pouch-bearing Tomb Bat	LC	Not listed	Not listed	Debata et al. (2016)
39	*Taphozous longimanus* Hardwicke, 1825	Long-winged Tomb Bat	LC	Not listed	Not listed	Debata et al. (2016)
40	*Taphozous melanopogon* Temminck, 1841	Black-bearded Tomb Bat	LC	Not listed	Not listed	Debata et al. (2016)
	XV. Family Vespertilionidae (Evening Bats)					
41	*Hesperoptenus tickelli* (Blyth, 1851)	Tickell's Bat	LC	Not listed	Not listed	Debata et al. (2016)
42	*Kerivoula picta* (Pallas, 1767)	Painted Woolly Bat	LC	Not listed	Not listed	Debata et al. (2016)
43	*Pipistrellus ceylonicus* (Kelaart, 1852)	Kelaart's Pipistrelle	LC	Not listed	Not listed	Debata et al. (2016)
44	*Pipistrellus coromandra* (Gray, 1838)	Indian Pipistrelle	LC	Not listed	Not listed	Debata et al. (2016)
45	*Pipistrellus tenuis* (Temminck, 1840)	Least Pipistrelle	LC	Not listed	Not listed	Debata et al. (2016)
46	*Scotophilus heathii* (Horsfield, 1831)	Greater Asiatic Yellow House Bat	LC	Not listed	Not listed	Debata et al. (2016)
47	*Scotophilus kuhlii* Leach, 1821	Lesser Asiatic Yellow House Bat	LC	Not listed	Not listed	Debata et al. (2016)
48	*Scotozous dormeri* Dobson, 1875	Dormer's Pipistrelle	LC	Not listed	Not listed	Debata et al. (2016)

	Scientific name	Common name	IUCN status	WPA, 1972 schedule	CITES appendix	Latest source
	I. ORDER PHOLIDOTA					
	XVI. Family Manidae (Pangolins)					
49	*Manis crassicaudata* E. Geoffroy, 1803	Indian Pangolin	EN	I	II	Anonymous (2019)
	J. ORDER CARNIVORA					
	XVII. Family Canidae (Dogs)					
50	*Canis aureus* Linnaeus, 1758	Golden Jackal	LC	II	III	Debata & Swain (2020)
51	*Canis lupus* Linnaeus, 1758	Grey Wolf	LC	I	I*	Palei et al. (2019)
52	*Cuon alpinus* (Pallas, 1811)	Dhole	EN	II	II	Debata & Swain (2018)
53	*Vulpes bengalensis* (Shaw, 1800)	Bengal Fox	LC	II	III	Anonymous (2018)
	XVIII. Family Felidae (Cats)					
54	*Felis chaus* Schreber, 1777	Jungle Cat	LC	II	II	Debata & Swain (2020)
55	*Prionailurus bengalensis* (Kerr, 1792)	Leopard Cat	LC	I	I	Palei et al. (2016)
56	*Prionailurus rubiginosus* (I. Geoffroy Saint-Hilaire, 1831)	Rusty-Spotted Cat	NT	I	I	Palei et al. (2019)
57	*Prionailurus viverrinus* (Bennett, 1833)	Fishing Cat	VU	I	II	Palei et al. (2018)
58	*Panthera pardus* (Linnaeus, 1758)	Leopard	VU	I	I	Anonymous (2019)
59	*Panthera tigris* (Linnaeus, 1758)	Tiger	EN	I	I	Anonymous (2019)
	XIX. Family Hyaenidae (Hyaenas)					
60	*Hyaena hyaena* (Linnaeus, 1758)	Striped Hyaena	NT	III	III	Debata & Swain (2020)
	XX. Family Ursidae (Bears)					
61	*Melursus ursinus* (Shaw, 1791)	Sloth Bear	VU	I	I	Anonymous (2019)
	XXI. Family Mustelidae (Otters and Honey Badger)					
62	*Aonyx cinerea* (Illiger, 1815)	Asian Small-clawed Otter	VU	I	II	Mohapatra et al. (2014)
63	*Lutra lutra* (Linnaeus, 1758)	European Otter	NT	I	I	Adhya (2020)
64	*Lutrogale perspicillata* (I. Geoffroy Saint-Hilaire, 1826)	Smooth-coated Otter	VU	II	II	Anonymous (2019)
65	*Mellivora capensis* (Schreber, 1776)	Honey Badger	LC	I	III	Debata & Swain (2020)
	XXII.Family Viverridae (Civets and Palm Civets)					
66	*Paradoxurus hermaphroditus* (Pallas, 1777)	Common Palm Civet	LC	II	III	Debata & Swain (2020)
67	*Viverra zibetha* Linnaeus, 1758	Large Indian Civet	LC	II	III	Mohapatra & Palei (2014)
68	*Viverricula indica* (E. Geoffroy Saint-Hilaire, 1803)	Small Indian Civet	LC	II	III	Debata & Swain (2020)
	XXIII. Family Herpestidae (Mongooses)					
69	*Herpestes auropunctatus* (Hodgson, 1836)	Small Indian Mongoose	LC	II	III	Debata & Swain (2018)
70	*Herpestes edwardsii* (E. Geoffroy Saint-Hilaire, 1818)	Indian Grey Mongoose	LC	II	III	Debata & Swain (2020)
71	*Herpestes smithii* Gray, 1837	Ruddy Mongoose	LC	II	III	Sahu et al. (2012)
72	*Herpestes vitticollis* Bennett, 1835	Striped-necked Mongoose	LC	II	III	Nayak et al. (2014)
	K. ORDER ARTIODACTYLA					
	XXIV. Family Bovidae (Cattle)					
73	*Antilope cervicapra* (Linnaeus, 1758)	Blackbuck	LC	I	III	Anonymous (2019)
74	*Bos gaurus* C.H. Smith, 1827	Gaur	VU	I	I	Anonymous (2019)
75	*Boselaphus tragocamelus* (Pallas, 1766)	Nilgai	LC	III	III	Anonymous (2019)

	Scientific name	Common name	IUCN status	WPA, 1972 schedule	CITES appendix	Latest source
76	*Bubalus arnee* (Kerr, 1792)	Wild Water Buffalo	EN	I	III	Mishra et al. (1996)
77	*Gazella bennettii* (Sykes, 1831)	Indian Gazelle	LC	I	III	Kotwal (1997)
78	*Tetracerus quadricornis* (de Blainville, 1816)	Four-horned Antelope	VU	I	III	Anonymous (2019)
	XXV. Family Cervidae (Deers)					
79	*Axis axis* (Erxleben, 1777)	Spotted Deer	LC	III	Not listed	Debata & Swain (2020)
80	*Muntiacus vaginalis* (Boddaert, 1785)	Northern Red Muntjac	LC	III	Not listed	Anonymous (2019)
81	*Rucervus duvaucelii* (G. Cuvier, 1823)	Swamp Deer	VU	I	I	Mishra et al. (1996)
82	*Rusa unicolor* (Kerr, 1792)	Sambar	VU	III	Not listed	Palei et al. (2019)
	XXVI. Family Tragulidae (Mouse Deer)					
83	*Moschiola indica* (Gray, 1852)	Indian Spotted Chevrotain	LC	I	Not listed	Anonymous (2019)
	XXVII. Family Suidae (Wild Pigs)					
84	*Sus scrofa* Linnaeus, 1758	Wild Boar	LC	III	Not listed	Debata & Swain (2020)
	L. ORDER CETACEA					
	XXVIII. Family Balaenoptridae (Rorquals)					
85	*Balaenoptera edeni* Anderson, 1879	Bryde's Whale	LC	I	I	Khan et al. (2015)
86	*Balaenoptera acutorostrata* Lacépède, 1804	Common Minke Whale	LC	I	I	Khan et al. (2015)
87	*Balaenoptera borealis* Lesson, 1828	Sei Whale	EN	I	I	Khan et al. (2015)
	XXIX. Family Physeteridae (Sperm Whales)					
88	*Physeter macrocephalus* Linnaeus, 1758	Sperm Whale	VU	I	I	Khan et al. (2015)
	XXX. Family Kogiidae (Pygmy Sperm Whales)					
89	*Kogia sima* (Owen, 1866)	Dwarf Sperm Whale	DD	I	II	Khan et al. (2015)
	XXXI. Family Delphinidae (Marine Dolphins)					
90	*Delphinus capensis* Gray, 1828	Long-beaked Common Dolphin	DD	II	II	Khan et al. (2015)
91	*Grampus griseus* (G.Cuvier, 1812)	Risso's Dolphin	LC	I	II	Khan et al. (2015)
92	*Orcaella brevirostris* (Owen in Gray, 1866)	Irrawady Dolphin	EN	I	I	Anonymous (2018)
93	*Pseudorca crassidens* (Owen, 1846)	False Killer Whale	NT	II	II	Khan et al. (2015)
94	*Sousa chinensis* (Osbeck, 1765)	Indopacific Humpback Dolphin	VU	II	II	Anonymous (2018)
95	*Sousa plumbea* (Cuvier, 1828)	Indian Ocean Humpback Dolphin	EN	II	I	Anonymous (2018)
96	*Stenella attenuata* (Gray, 1846)	Pantropical Spotted Dolphin	LC	II	II	Anonymous (2018)
97	*Stenella coeruleoalba* (Meyen, 1833)	Striped Dolphin	LC	II	II	Khan et al. (2015)
98	*Stenella longirostris* (Gray, 1828).	Spinner Dolphin	DD	II	II	Khan et al. (2015)
99	*Tursiops aduncus* (Ehrenberg, 1833)	Indopacific Bottle-nosed Dolphin	NT	Not listed	II	Khan et al. (2015)
100	*Tursiops truncatus* Montagu, 1821	Bottle-nosed Dolphin	LC	II	II	Khan et al. (2015)
	XXXII. Family Platanistidae (River Dolphins)					
101	*Platanista gangetica* (Roxburgh, 1801)	Ganges Dolphin	EN	I	I	Anonymous (2018)
	XXXIII. Family Phocoenidae (Porpoises)					
102	*Neophocaena phocaenoides* (G. Cuvier, 1829)	Finless Porpoise	VU	I	II	Anonymous (2018)

* Only the populations of India, Bhutan, Nepal and Pakistan.

In India, this species is confined to the northeastern region (Menon 2014) and their occurrence in Odisha is, therefore, questionable. In fact, intensive camera trap monitoring in Similipal failed to report this species (Palei et al. 2016). Hence, we excluded it from the updated checklist.

Greater Hog Badger *Arctonyx collaris* F.G. Cuvier, 1825: Ramakrishna et al. (2006) reported this species from Jamuani area in Similipal Biosphere Reserve, Odisha. In India, Hog Badger is reported from West Bengal, Sikkim, and northeastern region of India (Menon 2014). A recent camera trap monitoring in Similipal Tiger Reserve did not report this species (Palei et al. 2016). Distribution of Hog Badger in Odisha is, therefore, ruled out.

White-banded Palm Civet *Paradoxurus jorandensis*: Ali et al. (1988) described a new species of palm civet as White-banded Palm Civet from Similipal Tiger Reserve, Odisha referring to a broad white band encircling the abdomen of an animal. This was later reported to be based on an individual specimen of Common Palm Civet which was partially albinistic (Das et al. 1993). Pocock (1933) also earlier mentioned the polymorphism in both colour and pattern in some species of Viveridae. In fact, there is photographic evidence on both normal and partially albinistic pups in a litter of Common Palm Civet (Image 1) from Baripada, Mayurbhanj District near Similipal Tiger Reserve.

Although 102 species of mammals have been included in the checklist, current status of certain species within the political boundary of Odisha needs to be further verified. Some of the most important among them are the Dugong *Dugong dugon* (Müller, 1776), Wild Water Buffalo *Bubalus arnee* (Kerr, 1792), Swamp Deer *Rucervus duvaucelii* (G. Cuvier, 1823), and Indian Gazelle *Gazella bennettii* (Sykes, 1831). Dugong was reported to occur in Odisha based on a single sighting record during 1902 from Chilika Lake (Mishra et al. 1996; Dash 2010). Since then there has been no record of its occurrence in Odisha. There are reports that during 1969 two herds of Wild Buffalo existed in some pockets of Kalahandi and Koraput districts (Behura & Guru 1969). Mishra et al. (1996) also mentioned about their occurrence in Sunabeda WS in Odisha and the adjoining Udanti WS in Chhattisgarh. Recently, on June 2011 an adult bull strayed into human habitation in Kundura area of Koraput District (Image 2). So, there are possibilities that a small population may still survive in some remote areas in western Odisha. Currently, Swamp Deer are reported to be confined in five isolated pockets in central, northern and northeastern India (Menon

Image 1. The clutch of a Common Palm Civet from Mayurbhanj District near Similipal Tiger Reserve showing the pups with normal and polymorphic coat color. © Abhishek Acharya.

Image 2. The Wild Buffalo that strayed into human habitation in Kundura area of Koraput District. The animal was sighted in close proximity with domestic buffalos. © Kamal Lochan Purohit.

Image 3. Antler of a Swamp Deer kept as trophy in Khariar Palace, Odisha. The animal was shot in Sunabeda WS during the 1st half of 20th century. © Subrat Debata.

2014). Earlier, small populations of Swamp Deer were also known to occur in Sunabeda WS in the undivided Kalahandi District and Padmapur forests of Sambalpur District; the Sunabeda population was also believed to migrate between the Sunabeda plateau and forests of the then undivided state of Madhya Pradesh (Mishra et al. 1996). In fact, there is ample evidence that Swamp Deer were present in Sunabeda WS (Image 3). The Indian Gazelle is distributed in the arid and semi-arid regions of western and central India bordering the western Odisha region (Menon 2014). Sterndale (1884) earlier reported its occurrence along the Mahanadi Valley in Odisha. Although not very recently, Kotwal (1997) also reported sighting of 35 Indian Gazelles in Sunabeda WS. Based on a recent informal discussion with local residents of Sunabeda WS by the first author during December 2018, it is revealed that the Wild Buffalo, Swamp Deer, and Indian Gazelle were very common in Sunabeda during the mid-20th century, however, habitat encroachment and hunting have resulted in sharp decline in these animals. As per the views of the locals, although all these animals have become extremely rare in Sunabeda, they are sighted occasionally. Due to frequent Maoist activities, however, regular wildlife monitoring activities in Sunabeda WS have ceased. The proposed Sunabeda Tiger Reserve with an area of 956.17km² encompassing the Sunabeda WS (591.75km²) and adjoining Patdhara forest block (364.42km²), is one of the important wildlife habitat adjoining the central Indian landscape. Therefore, targeted and species-specific long term surveys along the western Odisha region in general and proposed Sunabeda Tiger Reserve in particular should be the utmost priority to assertion the current status of the aforementioned species in Odisha.

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PLATINUM OPEN ACCESS

COMMUNICATION

Negative human-wildlife interactions in traditional agroforestry systems in Assam, India

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Abstract: Traditional agroforestry systems are designed to provide maximum and diverse yield (ranging from agricultural crops, forest trees, livestock and fish) to people. They also act as sources of food and shelter to wild animals leading to crop destruction, livestock depredation and injuries to people giving rise to negative human-wildlife interactions. The present study was carried out in three different agroforestry systems namely tea gardens, homegardens, and agrisilvicultural systems in Assam to document the attitude of people towards wild animals which damage the crops and livestock, through questionnaire surveys. In agroforestry systems, 13 animals were reported as destructive; rodents at 13% followed by Indian Hare at 12%. The least destructive were birds and bats with 4% each. In tea gardens majority of the people killed animals for meat (95%) and the most common method for killing was the use of catapults (77%). In homegardens and agrisilvicultural systems, owners chased the animals away (82%) by using catapults (68%). Hunting of animals and intolerance of people towards crop destruction and livestock depredation done by wild animals were the two main reasons causing negative human-wildlife interactions in agroforestry systems. The present study concludes that wildlife species found in the agroforestry system in Assam were threatened by local inhabitants and thus, a suitable conservation awareness and policy action plan should be developed in consultation with the owners of agroforestry systems by considering the ecological significance of the wildlife species found therein.

Keywords: Agrisilvicultural systems, agroforestry systems, crop destruction, destructive wildlife species, homegardens, tea gardens.

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INTRODUCTION

Agroforestry system is a traditional cultivation practice carried out in Assam, a northeastern state of India (Yashmita-Ulman et al. 2018). This system includes growing of agricultural crops along with trees. Agroforestry systems are also frequently used by wild animals either as food resources (Lees & Peres 2008; Lenz et al. 2011; Mueller et al. 2014) or for shelter or as a corridor (Kumar et al. 2004; Yashmita-Ulman et al. 2020). As these systems are close to human habitations and mainly human-centric as a product of centuries, decades or years of destruction of natural forests or wilderness areas, they are prone to negative human-wildlife interactions, usually inappropriately called 'conflicts'. The two main threats to wildlife in agroforestry systems are: (i) killing of animals as revenge for crop damage or livestock depredation and (ii) hunting for subsistence or as a part of culture and tradition or for trade. Conover & Chasko (1985) found that 89% of farmers in Kansas, USA, were of an opinion that wildlife caused damage in the farms. There are many such reports on crop predation. Elephants are known to be the most destructive wild animals (Shrivastava 2002). They feed on ripened paddy, banana, coconut, corn (Nyhus et al. 2000; Bandara & Tisdell 2002; Santiapillai et al. 2010; Bal et al. 2011; Chartier et al. 2011), maize, millet, sorghum, green gram, soyabean, cowpeas, mustard, beans, green chillies (Bandara & Tisdell 2002), vegetables (Kumar et al. 2004), and cashew nut (Varma et al. 2008). The macaques feed on maize and wheat (Wang et al. 2006). In cacao plantations of Cameroon, squirrels, primates (Chimpanzee, Agile Mangabey, Moustached Guenon) and Sitatunga Antelopes destroy ripen pods of cacao causing very serious damage (Arlet & Molleman 2010). They also reported that the cacao growers either hunted or used passive methods like making noise, guarding, and using scarecrows to drive away these animals and thus prevent or reduce the damage caused. So, in most cases, the wild animals like elephants (Nyhus et al. 2000; Kushwaha & Hazarika 2004; Santiapillai et al. 2010) and primates (Wadley et al. 1997; Hill 1997) are killed by people in revenge for crop destruction.

Hunting in northeastern India has both economic and cultural importance (Aiyadurai 2007; Velho & Laurance 2013). There are many studies in northeastern India which suggest that hunting is a serious threat to many wild species (Pawar & Birand 2001; Datta 2002; Mishra et al. 2006). Hunting has a more negative effect on the abundance and diversity of mammals than the vegetation disturbance (Naughton-Treves et al. 2003; Datta et al. 2008). Naughton-Treves et al. (2003) in Tambopata, Peru observed that the farmers living near forests experienced crop raiding and livestock losses and to offset these losses, they resorted to hunting. So, all these are some of the threats that wild animals face in most agroforestry systems which might otherwise act as a second home or refuge for wild animals. This study is designed to identify the reasons for negative human-animal interactions in agroforestry systems and the methods used for killing these wild animals. Questionnaire surveys were conducted to 1) document the factors responsible for such human-wildlife interactions (types of crops destroyed or livestock killed, attitudes of people and their response in form of tolerance or retaliation by killing), 2) identify the most destructive wild animal in different agroforestry systems, and 3) document the methods used to kill, chase or avoid wild animals in different agroforestry systems.

STUDY AREA

Two districts of Lakhimpur and Sonitpur (undivided) located on the north bank landscape of Bramhaputra River were selected for the documentation of human-wildlife interactions in agroforestry systems in Assam (Fig. 1). Homegardens and agrisilvicultural systems were chosen from both the districts while the tea gardens were chosen only from Sonitpur District. Lakhimpur district is situated approximately between 26.800–27.883 ^{0}N & 93.700–94.333 ^{0}E. Sonitpur lies between 26.500–27.167 ^{0}N & 92.267–93.717 ^{0}E covering an area of around 5,324km^2. Tea garden tribes, Mishing, Bodos, Assamese, Nepalis, and Bengalis are some of the predominant ethnic groups living in the study area (Namsa et al. 2011).

METHOD

A questionnaire survey was conducted from September 2016 to February 2017 in the selected study areas. A total of 148 respondents, which included 54 agrisilvicultural system owners, 54 homegarden owners and 40 tea gardens labourers were interviewed. All these 148 respondents interviewed were the ones who worked in these agroforestry fields (homegarden and agrisilvicultural system owners themselves worked in their respective lands but in tea gardens, labourers were employed and therefore, tea garden labourers were interviewed and not the tea garden owners). All the respondents were well aware of the wild animals causing destruction and the type of destruction caused. Information was collected on the wildlife species sighted, crops destroyed by wildlife species

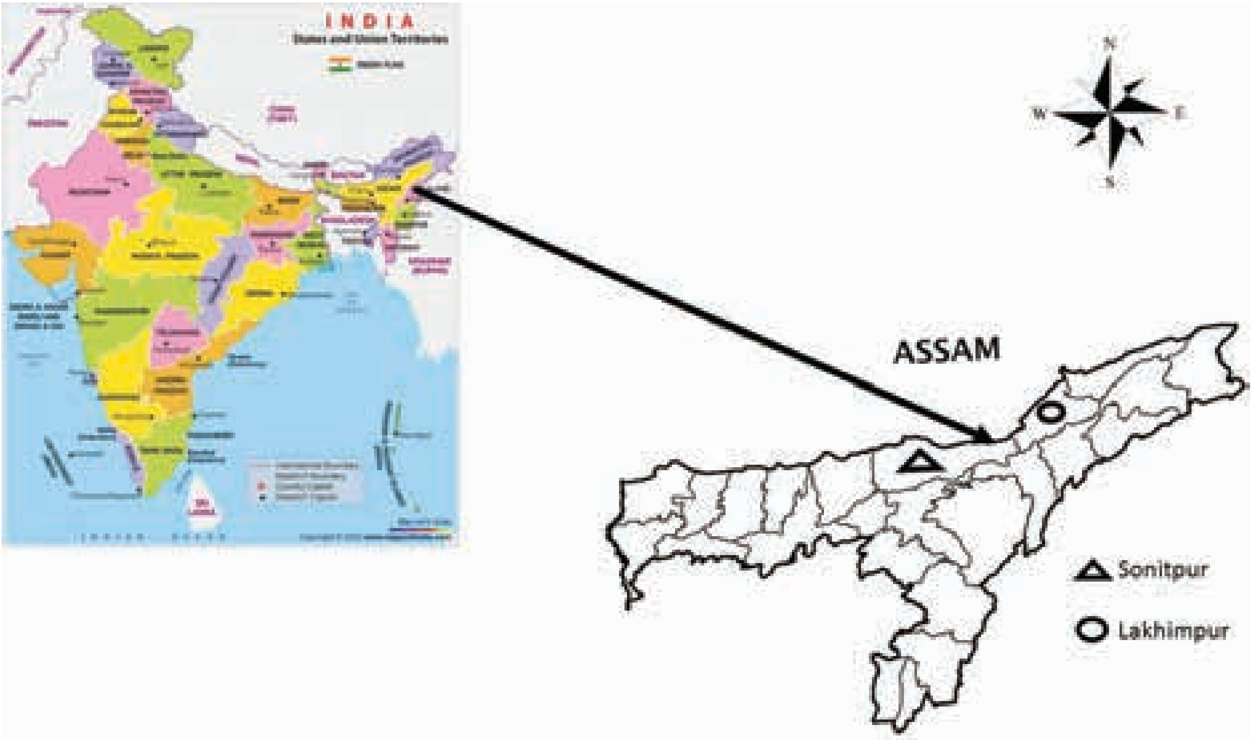

Figure 1 . Districts surveyed for understanding negative human-wildlife interaction in agroforestry systems practiced in Assam.

in the agroforestry system and the preventive measures adopted to control the loss. They were questioned over the prevalent techniques used for hunting and killing of wild animals (Mishra et al. 2006). Any wild animal product like skin, bone, trophy, and hunting tools kept in their houses were photographed for identification and confirmation of threat. To find out the most destructive animal for the crops and livestock in agroforestry systems as per owners'/labourers' opinion, the method used by Ahire & Kumar (2006) was followed. In this method, the owners were asked to give a score (1–13) to each animal they viewed as destructive for their crops and livestock in their agroforestry system. The most destructive animal had the highest score and the rest of the animals got the score in descending order.

RESULTS

The major destruction done by wild animals inhabiting the agroforestry systems was crop damage. The details of the crops destroyed by the various wildlife species in the different agroforestry systems are presented in Table 1. In all the three agroforestry systems combined, 13 animals were reported as destructive for the crops and livestock present in the agroforestry systems (Fig. 2). The most destructive wildlife species were rodents (13%) followed by Indian Hare *Lepus nigricollis* (12%) (Fig. 2). The least destructive were birds and bats (4% each) (Fig. 2).

Homegardens recorded the highest number of destructive animals (13) (Fig. 3), followed by agrisilvicultural systems (8) (Fig. 4) and the lowest was found in tea gardens (7) (Fig. 5). Out of the 13 animals viewed as destructive in homegardens, Hoary-bellied Himalayan Squirrel *Callosciurus pygerythrus* (15%) was reported to be the most destructive followed by Indian Grey Mongoose *Herpestes edwardsii* (13%) (Fig. 3). The least destructive was Indian porcupine *Hystrix indica* (2%) (Fig. 3). Among the eight wildlife species recorded as destructive in agrisilvicultural systems, the most destructive animal was rodent (29%) followed by birds (23%) and the least destructive was Indian Porcupine (6%) (Fig. 4). Out of the seven destructive wildlife species reported in tea gardens, Asian Elephant *Elephas maximus* (24%) followed by Wild Boar *Sus scrofa* (19%) were the most destructive animals in tea gardens (Fig. 5). The least destructive was the Rhesus Macaque *Macaca mulatta* (5%) (Fig. 5).

In all the three agroforestry systems as a whole, majority (59%) chased the wild animals away followed by killing of the animals (37%) and the least tolerated the presence of wildlife in their agroforestry systems (4%) (Fig. 6). Among the chasing techniques, the most common was use of catapults (49%) followed by use of scarecrow (7%)

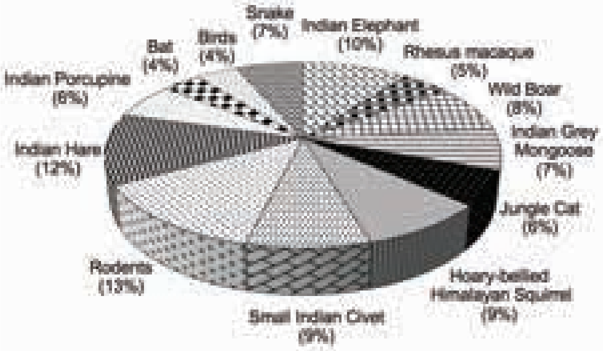

Figure 2. Destructive wildlife species as ranked by the respondents of agroforestry systems.

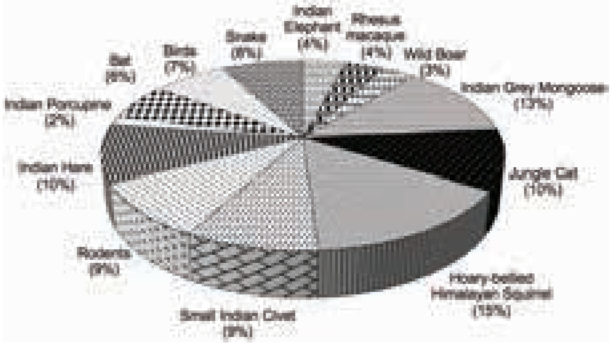

Figure 3. Destructive wildlife species as ranked by the respondents of homegarden.

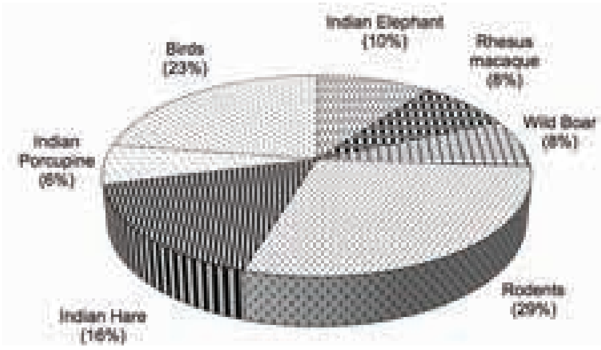

Figure 4. Destructive wildlife species as ranked by the respondents of agrisilvicultural system.

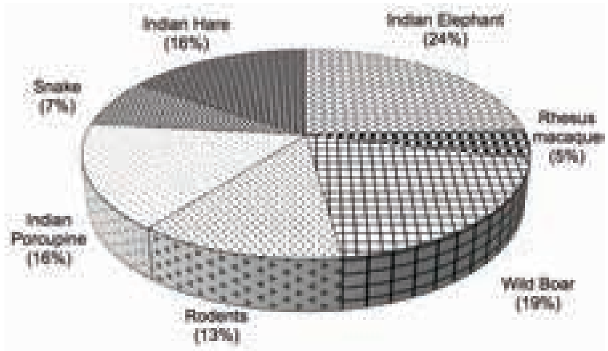

Figure 5. Destructive wildlife species as ranked by the respondents of tea garden.

and the least common was the use of drums and noise to chase the animals away (3%) (Fig. 7). The most frequently used killing methods was the use of catapults (28%) followed by leg traps, bows and arrows (3% each) and the least used methods were sticks, air rifles and poison (1% each) (Fig. 7). About 4% respondents chose to ignore the presence of wildlife in their agroforestry systems (Fig. 7). It was observed that 82% of the respondents in both homegardens and agrisilvcultural systems chased the animals away, 13% killed the animals for meat as well as a kind of retaliation for livestock depredation and the remaining 5% ignored the menace caused by wildlife (Fig. 6). The highest number of respondents (68%) used catapults to chase the animals, 10% made use of scare crows, 8% killed the animals with catapult, 5% ignored the presence of animals, 4% used drums or other forms of noise to scare away the animals, 3% used leg traps, and 2% used poison to kill the animals (Fig. 7). The trend was different in tea gardens. It was observed that in the tea gardens, majority of the respondents (95%) killed the animals for meat, 3% chased the animal away and 2% chose to ignore the presence of the animal (Fig. 6). Among the various methods used to kill the animals the most common was the use of catapults (77%) followed by use of bows and arrow (9%) and leg traps (5%) (Fig. 7). The least used method was use of stick and air rifles (2%) each (Fig. 7). The pictographic representation of the animals killed by the agroforestry system owners and the methods used by them are shown in Plate 1 & 2.

DISCUSSION

In the current study, animals like elephants, wild pigs, porcupine, hare, rodents, rhesus macaque, jungle cats, birds and bats were reported as destructive animals in agroforestry systems. Squirrel was recorded as top most destructive animal in homegardens and rodents in agrisilvicultural systems. The squirrels were notorious for damaging the cash crop yields of Areca nut *Areca catechu,* Coconut *Cocos nucifera,* Pepper vines *Piper* spp*.,* etc. The rodents and birds were known to destroy paddy crops, bamboo seeds, etc. and the bats were observed feeding on the fruits of Lychee *Litchi chinensis*, Wax Jambu *Syzygium samarangense*. Yashmita-Ulman et al. (2017) observed flocks of Baya Weaver *Ploceus philippinus* feeding on mature paddy grains in agroforestry systems. Similar observations of crop depredation by rabbits (Conover

Table 1. Record of wildlife species for crop destruction in selected agroforestry systems.

	Name of animal	Crops destroyed/other problems		
		ASS	HG	TG
1.	*Elephas maximus* (Asian Elephant)	*Oryza sativa* (Rice), *Zea mays* (Maize), *Bambusa* spp. (Bamboo)	*Musa* spp. (Banana), *Bambusa* spp. (Bamboo), *Areca catechu* (Areca nut), *Cucurbita moschata* (Squash), *Cocos nucifera* (Coconut)	Uprooted shade trees and *Camellia sinensis* (Tea) plants
2.	*Macaca mulatta* (Rhesus Macaque)	*Oryza sativa (Rice), Mangifera indica* (Mango), *Artocarpus heterophyllus* (Jackfruit)	*Oryza sativa* (Rice), *Vigna unguiculata* (Cowpea), *Vigna mungo* (Black gram), *Moringa olerifera* (Drumstick), *Areca catechu* (Areca nut), *Mangifera indica* (Mango), *Artocarpus heterophyllus* (Jackfruit), *Carica papaya* (Papaya), *Citrus* spp., *Musa* spp. (Banana), *Psidium gujava* (Guava), *Piper* spp. (Pepper), *Luffa cylindrical* (Sponge gourd), *Luffa acutangula* (Ridge gourd), *Cucurbita moschata* (Squash), *Lagenaria siceraria* (Bottle gourd), *Abelmoschus esculentus* (Okra), *Daucus carota* (Carrot), *Allium cepa* (Onion), *Pisum sativum* (Peas), *Phaseolus lunatus* (Lima bean), *Saccharum officinarum* (Sugarcane), *Solanum tuberosum* (Potato), *Ananas comosus* (Pineapple)	
3.	*Sus scrofa* (Wild Boar)	*Oryza sativa* (Rice)	*Oryza sativa* (Rice), *Vigna unguiculata* (Cowpea), *Vigna mungo* (Black gram), *Solanum tuberosum* (Potato), *Manihot esculenta* (Cassava), *Daucus carota* (Carrot), *Allium cepa* (Onion), *Ananas comosus* (Pineapple)	Uprooted shade trees and *Camellia sinensis* (Tea) seedlings
4.	*Herpestes edwardsii* (Indian Grey Mongoose)		*Gallus gallus domesticus* (Chicken) eggs, *Anas* spp. (Duck), *Columba livia domestica* (Pigeon) and fish	
5.	*Felis chaus* (Jungle Cat)		*Gallus gallus domesticus* (Chicken) eggs, *Anas* spp. (Duck), *Columba livia domestica* (Pigeon) and fish	
6.	*Callosciurus pygerythrus* (Hoary-bellied Himalayan Squirrel)	*Oryza sativa* (Rice), *Mangifera indica* (Mango), *Artocarpus heterophyllus* (Jackfruit), *Syzygium cumini* (Jamun)	*Cocos nucifera* (Coconut), *Musa* spp. (Banana), *Citrus grandis* (Pomelo), *Carica papaya* (Papaya), *Citrus reticulata* (Madarin orange), *Pyrus communis* (Pear), *Syzygium cumini* (Jamun), *Terminalia chebula* (Myrobalan), *Elaeocarpus floribundus* (Indian olive), *Phaseolus lunatus* (Lima bean), *Luffa acutangula* (Ridge gourd), *Trichosanthes anguina* (Snake gourd), *Cucurbita moschata* (Squash), *Cucumis sativus* (Cucumber)	
7.	*Viverricula indica* (Small Indian Civet)		*Musa* spp. (Banana), *Gallus gallus domesticus* (Chicken) eggs, *Anas* spp. (Duck), *Columba livia domestica* (Pigeon)	
8.	*Vulpes bengalensis* (Indian Fox)		*Capra* spp. (Goat), *Gallus gallus domesticus* (Chicken) eggs, *Anas* spp. (Duck)	
9.	Rodents	*Oryza sativa* (Rice)	*Oryza sativa* (Rice), *Vigna unguiculata* (Cowpea), *Vigna mungo* (Black gram), *Solanum tuberosum* (Potato), *Manihot esculenta* (Cassava), *Daucus carota* (Carrot), *Allium cepa* (Onion), *Ananas comosus* (Pineapple), *Cucurbita moschata* (Squash), *Lagenaria siceraria* (Bottle gourd)	Cuts shade trees and *Camellia sinensis* (Tea) plants roots
10.	*Lepus nigricollis* (Indian Hare)	*Oryza sativa* (Rice)	*Musa* spp. (Banana), *Brassica juncea* (Mustard), *Brassica oleracea* (Cabbage), *Abelmoschus esculentus* (Okra), *Solanum tuberosum* (Potato), *Cucurbita moschata* (Squash), *Lagenaria siceraria* (Bottle gourd), *Pisum sativum* (Peas), *Raphanus sativus* (Raddish), *Spinacia oleracea* (Spinach), *Solanum lycopersicum* (Tomato), *Daucus carota* (Carrot)	Uprooted shade trees and *Camellia sinensis* (Tea) plants seedlings
11.	*Hystrix indica* (Indian Porcupine)	*Oryza sativa* (Rice)	*Solanum tuberosum* (Potato), *Alocasia* spp.	Uprooted shade trees and *Camellia sinensis* (Tea) plants seedlings
12.	Bat	*Syzygium samarangense* (Wax Jambu), *Mangifera indica* (Mango), *Artocarpus heterophyllus* (Jackfruit)	*Mangifera indica* (Mango), *Artocarpus heterophyllus* (Jackfruit), *Citrus* spp., *Musa* spp. (Banana), *Litchi chinensis* (Lychee), *Psidium gujava* (Guava), *Syzygium samarangense* (Wax Jambu)	
13.	*Varanus bengalensis* (Bengal Monitor)		*Gallus gallus domesticus* (Chicken) eggs, *Anas* spp.	
14.	Birds	*Oryza sativa* (Rice),*Terminalia chebula* (Myrobalan), *Syzygium samarangense* (Wax Jambu), *Mangifera indica* (Mango), *Artocarpus heterophyllus* (Jackfruit)	*Oryza sativa* (Rice), *Vigna unguiculata* (Cowpea), *Vigna mungo* (Black gram), *Terminalia chebula* (Myrobalan), *Musa* spp. (Banana), *Psidium gujava* (Guava), *Averrhoa carambola* (Star fruit), *Phaseolus lunatus* (Lima bean), *Capsicum* spp., Fish	
15.	Snakes		*Gallus gallus domesticus* (Chicken) eggs, fish	-

ASS=Agrisilvicultural system, HG=Homegarden, TG=Tea garden.

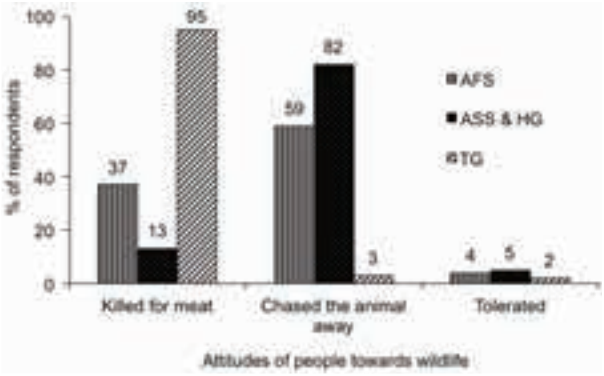

Figure 6. Attitudes of people towards wildlife present in selected agroforestry systems. AFS—agroforestry systems | ASS—agrisilvicultural systems | HG—homegarden | TG—tea garden

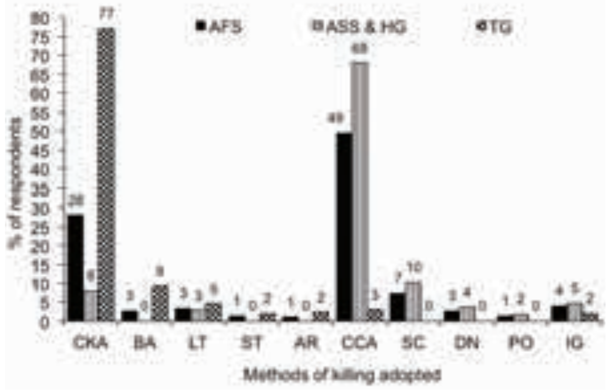

Figure 7. Methods adopted for avoiding or killing of wildlife species in selected agroforestry systems. CKA—catapults to kill animals | BA—bows and arrows | LT—leg traps | ST—sticks | AR—air rifles | CCA—catapults to chase away animals | SC—scarecrow | DN—drums and noise | PO—poison | IG—ignore.

1994) and by birds (Gillingham & Lee 2003; Naughton-Treves & Treves 2005) have been reported. Some other small mammals like mongoose and Small Indian Civet were also reported to be destructive in the homegardens of the current study area. These were reported to depredate upon the livestock (hens, ducks, pigeons, and goats) reared by the homegarden owners. Similar results were obtained by Weladji & Tchamba (2003).

In the current study, animals like elephants, wild pigs, porcupine, rabbits, rodents and rhesus macaques were recorded to destroy the young tea seedlings and uproot the shade trees in tea gardens. Similarly, elephants are reported to damage the coffee bushes, fruit trees and associated pepper vines (Bal et al. 2011) and roots of shade tree Indian Coral Tree *Erythrina mysorensis* in coffee agroforests of southern India (Kumar et al. 2004). The Wild Boars and porcupines are reported to dig the root systems of tea plants causing damage to the tea gardens (Kumara et al. 2004) in the Western Ghats of India.

Conover & Chasko (1985) in Kansas, USA observed that 56% of the farmers reported that the losses incurred due to wildlife were higher than they were willing to tolerate. Similar results were found in the present study where it was observed that in the tea gardens, 95% of the respondents killed the animals for meat and 13% of the respondents in homegardens killed wildlife in retaliation and for meat. Only 2% respondents in tea gardens and 5% in homegardens choose to ignore or tolerate the presence of the wild animals. Killing small carnivores in retaliation for depredation of livestock is similar to other studies by Datta et al. (2008) and Lyngdoh et al. (2011). All these factors may explain such high rate of killing of wildlife in the current study area.

In the present study, methods like making sounds through clapper and drum, using catapults, scarecrows were usually employed by the local people to chase the wild animals away from their agroforestry systems. Similar methods were also used to control wildlife damage in Bhutan (Wang et al. 2006), Indonesia (Marchal & Hill 2009) and Rajasthan (Chhangani et al. 2010). The homegarden and agrisilvicultural system owners belong to the Kalita caste who usually neither indulge in hunting nor is it a part of their tradition. As a result, these people either tolerated the animals or tried to deter the wildlife species present in the agroforestry systems to protect their crops. Only very few killed the wild animals in doing so. Whereas, the labourers in tea gardens are tribes and indulge in hunting as a part of their culture and food habits. The tea tribes used primitive hunting techniques like catapults, bows & arrows and leg traps to hunt the animals for bush meat. Similar hunting techniques were observed in Arunachal Pradesh (Aiyadurai 2011) and the Western Ghats (Gubbi & Linkie 2012).

CONCLUSION

The main cause of negative human-wildlife interactions is the lower rate of tolerance of humans to crop and livestock depredation by wild animals in the agroforestry systems of Assam. Another major factor which contributes to killing of wild animals is the practice and tradition of people. The fact that majority of the people in tea gardens resorted to hunting of wild animals primarily for subsistence or as a tradition and also killed them as a revenge for livestock depredation and crop destruction is a matter of concern. But the brighter side is that the homegarden and agrisilvicultural system owners prefer to chase the animals using catapults which shows positive signs for their conservation. Understanding people's

Image 1. Photographs showing threats to wildlife in selected agroforestry systems a—captured *Nycticorax nycticorax* (Black-crowned Night Heron) | b—killed *Lepus nigricollis* (Indian Hare) | c—killed *Phaenicophaeus tristis* (Green-billed Malkoha) | d—killed *Zosterops palpebrosus* (Oriental White-eye) | e—Turtle shell used for medicinal purpose | f—skull of *Varanus bengalensis* (Bengal Monitor) used for medicinal purpose | g—skin and bones of *Varanus bengalensis* (Bengal Monitor) used for medicinal purpose. © Yashmita-Ulman.

Image 2. Photographs showing different traps used to kill wildlife in selected agroforestry systems a—wire trap | b—bows and arrows | c—leg trap | d—spearheads | e—rodent trap | f—catapult | g—gun. © Yashmita-Ulman.

attitude towards wild animals in their agroforestry systems helps to develop wildlife conservation strategies in agroforestry systems which otherwise provides refuge to wild animals in the current scenario of deforestation and habitat loss.

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COMMUNICATION

Prevalence and morphotype diversity of *Trichuris* species and other soil-transmitted helminths in captive non-human primates in northern Nigeria

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Abstract: A study to determine the prevalence and morphotype diversity of soil-transmitted helminths in captive non-human primates (NHPs) in northern Nigeria was conducted. Simple flotation and sedimentation methods were used to examine fecal samples. A Morphometric analysis was done on Trichuris spp. eggs to determine the diversity of whipworm circulating in NHPs in the study area. High prevalence (60%) of infection was recorded in captive NHPs; Patas Monkey (n=17), Tantalus Monkey (n=9), Mona Monkey (n=7), Vervet Monkey (n=2), Mangabey Monkey (n=1), Baboon (n=14), and Chimpanzee (n=8) from parks and zoological gardens located in four Nigerian states (Borno, Gombe, Kano, and Plateau) and the Federal Capital Territory (FCT), Abuja. Captive NHPs examined were infected with helminths either as single, double or triple infections. Four zoonotic soil transmitted helminth (STH) genera, Trichuris, Strongyloides, Ancylostoma, and Enterobius were detected in the examined animals. Eggs of Trichuris spp. were the most prevalent with four morphotypes suggesting several morphotypes of whipworm were circulating among the NHPs in this region. Further studies are required to elucidate the epidemiologic and public health implications of these findings.

Keywords: Helminths, morphotype, non-human primates, northern Nigeria, zoonosis.

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Author contribution: JK—conceive and design study, Investigation and data analyses, writing of the manuscript. JPY—sample collection, data analyses, writing of manuscript. AS—sample collection, data analysis. EGM—Sample collection, investigation, writing of manuscript. UAT—sample collection, data analyses, writing of manuscript.

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INTRODUCTION

Non-human primates (NHPs) enclosures in zoological gardens or parks in Nigeria are among the most popular attractions to visitors, especially children; however, the maintenance of wild animals in captivity is fraught with numerous challenges particularly that of parasitic disease conditions due to high contamination of the environment (Rao & Acharjyo 1984; Vanitha et al. 2011). This is exacerbated by lowered immunity of the animals due to the stress of captivity, consequently diminishing their resistance to parasitic diseases (Gracenea et al. 2002; Perez Cordon et al. 2008). Therefore, gastrointestinal parasite infections are among the most common diseases found in non-human primates (Bezjian et al. 2008; Strait et al. 2012). Although the captive animals do not show alarming signs of parasitism, it has been reported that some of the helminth parasites they harbor have zoonotic potential and are, therefore, considered to be a threat to public health (Gillespie et al. 2008; Klaus et al. 2017). Soil-transmitted helminths (STHs) such as *Ascaris* spp., *Trichuris* spp., *Ancylostoma* spp., and *Strongyloides* spp. that can easily be transferred from NHPs to humans and vice versa through contaminated environments are a major concern (Ranglack & Yeager 1986; Bethony et al. 2006; Lynn 2010). Single or mixed infections of zoonotic STHs have often been recorded in NHPs from different countries: Bangladesh (Raja et al. 2014), Central African Republic (Hasegawa et al. 2014), Tanzania (Petrželkova et al. 2010), China (Li et al. 2017), India (Hussain et al. 2013), Sri Lanka (Aviruppola et al. 2016), Malaysia (Klaus et al. 2017), and Spain (Perez Corden et al. 2008). Several studies have been carried out on the prevalence of helminth infection in NHPs in various zoological gardens and/or parks in the southern part of Nigeria: Oyo State (Adedokun et al. 2002; Emikpe et al. 2002; Adetunji 2014), Ondo State (Egbetade et al. 2014), Cross River State (Mbaya & Udendeye 2011), and Imo state (Opara et al. 2010). Comparatively, only a few studies have been conducted on the helminth infections of NHPs in northern Nigeria (Nwosu 1995; Mbaya & Nwosu 2006; Mbaya et al. 2006a,b; Dawet et al. 2013). The aim of this study, therefore, was to determine the prevalence and diversity of helminths in captive NHPs in northern Nigeria and to discuss the public health implications.

MATERIALS AND METHODS

Sampling sites

The study was conducted in Zoological Gardens and Parks in four northern states and Abuja (9.076^{0}N, 7.398^{0}E) the Federal Capital Territory (FCT) of Nigeria. The four states; Borno (11.831^{0}N, 13.151^{0}E), Gombe (10.279^{0}N, 11.173^{0}E), Kano (12.002^{0}N, 8.592^{0}E) and Plateau (9.896^{0}N, 8.858^{0}E) were selected based on convenience and accessibility of NHPs for sample collection.

Sample collection

Fecal samples were collected opportunistically from individual captive NHP with the help of the caretakers over a period of six months (November 2017 to April 2018). Fresh feces were collected from the ground under the nest of individual NHPs. Approximately 5g of feces was scooped from the surface of each fecal mass using a disposable hand glove and transferred into a screw capped bottle. Each sample was labeled appropriately and transported in a cold box to the laboratory for analysis.

Fecal analysis

Samples were processed and analyzed in the Helminthology Research Laboratory, National Veterinary Research Institute (NVRI), Vom, Plateau State, Nigeria. First, each sample was examined macroscopically for the presence of helminths or taenid segments.

Microscopic analysis

Simple tube flotation and sedimentation: Fecal samples were individually processed by simple tube flotation in saturated sodium chloride solution (SG 1.20) and simple sedimentation techniques (Greiner & McIntosh 2009). The preparation was then examined using direct light microscope (100X and 400X magnifications) for the presence of parasite eggs. The identification of the parasites was based on egg morphology, shape, size and color according to standard keys (Samuel et al. 2001; Hasegawa et al. 2009).

Morphometry analysis

Helminth eggs were measured (length and width) by using a calibrated light microscope. Mean values of measurements were given in micrometers (µm) ± standard deviations (SD).

RESULTS

Fifty-eight captive NHPs in five zoological gardens located in Jos (n=15), Kano (n=9), Maiduguri (n=3), Gombe (n=9) & FCT Abuja (n=4) and two Parks located in Jos (n=8) & FCT Abuja (n=10) were examined. Seven NHP species including 17 Patas Monkey *Erythrocebus patas,* 14 Baboons *Papio* sp., nine Tantalus Monkey *Chlorocebus tantalus*, eight Chimpanzees *Pan troglodytes*, seven Mona Monkeys *Cercopithecus mona*, two Vervet Monkeys *Chlorocebus pygerythrus*, and one Mangabey Monkey *Cercocebus* sp. were sampled during this study (Table 1).

Prevalence of helminths in NHPs from northern Nigeria

Helminth eggs were detected in fecal samples of NHPs from zoos or parks in all the states studied. Overall, 60% of the animals studied had helminth eggs in their feces. The highest prevalence (100%, n=4/4) was recorded in samples from the Abuja Children Park and Zoo, followed by (89%, n=8/9) in samples from the Gombe Zoo and the lowest prevalence (33%, n=1/3) was recorded in samples from the Maiduguri Zoological Garden (Table 1). Prevalence according to NHP species was highest (78%) for Tantalus Monkeys *Chlorocebus tantalus*. The lowest prevalence (47%, n=8/17) was observed in Patas Monkeys while the fecal sample of the only Mangabey Monkey *Cercocebus* sp. screened in this study was negative for helminth eggs (Table 1).

Diversity of helminths

Four helminth genera: *Trichuris*, *Ancylostoma*, *Strongyloides*, and *Enterobius* and one unidentified parasite egg were detected from the feces of NHPs from northern Nigeria. *Trichuris* spp. eggs were detected with a high prevalence (31/44) across all the NHP species screened in the study. This was followed by *Strongyloides* spp. (4/44) and *Ancylostoma* spp. (3/44) both affecting three NHP species each. An unidentified egg that resembled an egg of *Opisthorchis* sp. was detected in

Table 1. Prevalence of helminths in captive non-human primates in zoological gardens and parks in northern Nigeria.

Study location	Habitat	Number of animal positive/ no. screened according to NHP species							Total (%)
		Patas Monkey *Erythrocebus patas*	Tantalus Monkey *Chlorocebus tantalus*	Mona Monkey *Cercopithecus mona*	Vervet Monkey *Chlorocebus pygerythrus*	Mangabey Monkey *Cercocebus* sp.	Baboon *Papio* sp.	Chimpanzee *Pan troglodytes*	
Jos	Zoo	0/4	0	2/3	1/2	0	3/3	0/3	6/15 (40)
Jos	Wildlife Park	2/3	1/1	1/1	0	0	2/2	0/1	6/8 (75)
Gombe	Zoo	5/5	0	0	0	0	1/2	2/2	8/9 (89)
Maiduguri	Zoo	0/1	0/1	0	0	0	1/1	0	1/3 (33)
Abuja	Park/ Zoo	1/1	1/1	1/1	0	0	1/1	0	4/4 (100)
Abuja	National Park	0/1	4/5	0/1	0	0	1/3	0	5/10 (50)
Kano	Zoo	0/2	1/1	1/1	0	0/1	1/2	2/2	5/9 (56)
Total		8/17	7/9	5/7	1/2	0/1	10/14	4/8	35/58 (60)

Table 2. Prevalence of soil transmitted helminths in different species of non-human primates in northern Nigeria.

Host species	No of NHP tested	No positive (%)	Single infection	Dual infection	Triple infection
Patas Monkey *Erythrocebus patas*	17	8 (47)	7	1	0
Tantalus Monkey *Chlorocebus tantalus*	9	7 (78)	5	2	0
Mona Monkeys *Cercopithecus mona*	7	5 (71)	2	2	1
Vervet Monkey *Chlorocebus pygerythrus*	2	1 (50)	1	0	0
Baboon *Papio* sp.	14	10 (71)	1	3	0
Chimpanzee *Pan troglodytes*	8	4 (50)	10	0	0
Mangabey Monkey *Cercocebus* sp.	1	0 (0)	0	0	0
Total	58	35	26	8	1

Table 3. Morphologic and morphometric analyses of helminth eggs detected in non-human primates in northern Nigeria

Helminth genera	Morphology and morphometric characteristics of helminth eggs				
	Morphotype	Egg size (um + SD)		Egg shape	Egg shell appearance and color
		Length	Width		
Trichuris sp.	T1	43.1 ± 5	25.1 ± 1	Ellipsoidal	Thick with prominent bipolar plugs, dark brown
	T2	50.8 ± 2.5	30.5 ±1.5	Rounded lemon	Thick less prominent bipolar plugs, light brown
	T3	54.7 ± 0.1 58.2	22.9 ± 5.7	Barrel-like	Thick prominent bipolar plugs, dark brown
	T4	± 1.0	22.4 ± 3.2	Lemon	Thick, flat bipolar transparent plugs, dark brown
Ancylostoma sp.	A	73.5 ± 5.3	31.5 ± 2.3	Ellipsoidal	Thin transparent light color
Strongyloides sp.	S	48.3 ± 8.8	34.3 ± 4.7	Ellipsoidal	Thin transparent folded motile larva light color
Enterobius sp.	E	54.5 ± 5.3	30.5 ± 2.3	Irregular	Thin with folded larva light color

the fecal sediments of a female baboon from Abuja. Parasite order richness (POR) ranged from 0 to 3 per fecal sample. Most of the positive samples harboured eggs of a single parasite genus (45%), followed by dual infections (12%) and triple infections in only 2% of the samples (Table 2).

Egg morphotypes detected in NHP examined

Four morphotypes of *Trichuris* spp. eggs (T1–T4) were detected in this study. All the trichurid egg morphotypes were thick-shelled, with prominent bipolar plugs but varied in shape, size, and colour. Egg morphotypes T1 and T2 appear to be more common in the various species of monkeys examined and occur as mixed infections, while T3 and T4 were commonly associated with baboons and chimpanzees. The eggs of other helminth genera, *Ancylostoma*, *Strongyloides*, and *Enterobius* detected in this study occurred as single morphotypes (Table 3).

DISCUSSION

Captive NHPs in Nigerian zoological gardens and parks attract attention due to their agility and playfulness. Thus, their wellbeing and survival is paramount to conservationists, veterinarians and zoo administrators. Parasitic diseases, particularly helminth infections have been reported to constitute a challenge to the health of NHPs (Samuel et al. 2001; Vanitha et al. 2011; Wren et al. 2015). The results from this survey showed that more than half (60%) of the examined NHPs in northern Nigeria were infected with helminth parasites. Four helminth genera of zoonotic importance, viz., *Trichuris*, *Ancylostoma*, *Strongyloides*, and *Enterobius* were detected in the NHPs examined in this study. These helminths have a high potential for transmission to humans because of their simple life cycles (Li et al. 2017). Thus, they are listed among the major cause of soil-transmitted helminth infections globally (Bethony et al. 2006). The differences in prevalence of these helminths observed in the study locations could be attributed to differences in host species susceptibility to helminth infections and the variations in climatic conditions between the study sites. Such observation on the effects of climate on parasite prevalence have been reported (Cordon et al. 2008; Wren et al. 2015).

Trichuris eggs were the most prevalent (70.5%) in the infected NHPs in this study. This finding is in accord with an earlier survey of NHPs in northern (Dawet et al. 2013) and southern (Mbaya & Udendeye, 2011; Adetunji 2014) parts of Nigeria. High prevalence of *Trichuris* sp. was also observed in NHPs in Côte d'Ivoire (Kouassi et al. 2015), Sri Lanka (Aviruppola et al. 2016), Peru (Kimberley et al. 2004), Malaysia (Lim et al. 2008; Klaus et al. 2017), China (Li et al. 2017), India (Singh et al. 2009), and Spain (Perez Cordon et al. 2008) signifying its global distribution among NHP population. This study provides additional information on the metric details of the trichurid eggs present in the NHPs in northern Nigeria suggesting the diversity of this parasite in the region. It appears that NHPs in northern Nigeria are infected with various *Trichuris* spp. based on the morphology and dimensions of the eggs detected during this study. A similar observation was earlier made in a study in south west Nigeria but the authors did not provide any metric details of the *Trichuris* eggs detected (Egbetade et al. 2014). Therefore, our study is the first to provide morphometric analyses of *Trichuris* eggs infecting NHPs in Nigeria. Four morphotypes (T1–T4) of *Trichuris* eggs, with mean size ranging from 43–53 x 22–30 µm (length x width) were detected in this study suggesting a diversity of this parasite in the NHPs examined. Indeed, even among the NHP species there is variability in the morphology of *Trichuris* eggs detected. Similar observations have been reported (Petrzelkova et al. 2010; Klaus et al. 2017). Thus, our findings agree with several reports on morphometric and molecular studies of trichurid eggs in NHPs conducted in areas with different climatic conditions from Nigeria (Hasegawa et al. 1983; Dupain et al. 2009; Ghai et al. 2014; Raja et al. 2014; Cavallero et al. 2015; Klaus et al. 2017; Li et al. 2017).

It is noteworthy that the dimensions of some of the eggs of *Trichuris* spp. detected in this study are similar to those of human *T. trichiura*, suggesting zoonotic or reverse zoonotic transmissions. This finding has implications for veterinarians, public health workers, and wildlife managers, in terms of the epidemiology of the disease and the choice of treatment and control measures to be adopted (Melfi & Poyser 2007). Therefore, the assumption hitherto, among wildlife parasitologists that all the *Trichuris* infecting NHPs are the same as *T. trichiura* of humans should be reconsidered, however, the other three zoonotic helminths genera; *Ancylostoma, Strongyloides* and *Enterobius* detected in this study occurred as monotypes each with dimensions similar to those of the species infecting human, suggesting possible circulation of these worms between humans and NHPs in the study area.

Taken together, our results demonstrate the presence of zoonotic helminths and a diversity of *Trichuris* sp. infection amongst NHPs. Therefore, a comprehensive study to elucidate the genetic diversity of Trichurids infection NHPs in Nigeria is desirable. This will assist to distinguish the species and genotypes of this parasite in NHPs in northern Nigeria and to determine their pathogenicity. Therefore, molecular studies on pinworm diversity in Nigerian NHPs are needed in order to elucidate the species and morphotypes circulating in the country.

CONCLUSION

Captive NHPs in zoological gardens and parks in northern Nigeria are infected with helminths of public health significance. High prevalence of *Trichuris* spp. coupled with a diversity of their egg morphotypes were observed in the NHPs examined. Further investigation using modern tools like molecular phylogenetics in order to fully understand their epidemiology and zoonotic potentials is warranted.

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COMMUNICATION

Detection of hemoparasites in bats, Bangladesh

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Abstract: A cross sectional study was conducted (2010–2013) to determine the diversity of hemoprotozoa among bats of Bangladesh. Microscopic examination of blood smears (N=533; *Pteropus medius* (377), *Rousettus leschenaultii* (111), *Megaderma lyra* (45)) revealed 9% of bats (95% confidence interval CI: 7–12%) were positive for hemoprotozoa. The overall prevalence of hemoparasites among *P. medius* was 5% (n=20, 95% CI: 3–8%); where *Babesia* sp. was 3% (n=12, 95% CI: 2–5%) and *Hepatocytis* sp. was 2% (n=8, 95% CI: 1–4%). Moreover, 13% of *R. leschenaultii* were positive (n=14, 95% CI: 7–20%) where prevalence of *Babesia* sp. was 10% (n=11, 95% CI: 5–17%) and prevalence of *Hepatocystis* sp. was 3% (n=3, 95% CI: 1–8%). Twenty-nine percent (n=13, 95% CI: 16–44%) of *M. lyra* harbored hemoparasites, among which 20% (n=9, 95% CI: 10–35%) were *Babesia* sp. and 9% (n=4, 95% CI: 2–21%) were *Hepatocystis* sp. The study indicates bats remain important hosts for various zoonotic parasites and suggests further research.

Keywords: *Babesia*, Bangladesh, Bat, Hemoprotozoa, *Hepatocystis*, prevalence.

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Author contribution: Conceptualization, validation, project administration, investigation and supervision: AI and AI; Methodology and data curation: RUA, MKR, MHU, SA, AAF, AI & AI; Formal analysis: SI & JF; Writing—Original draft: SI & JF; Writing—Review & editing: SI, JF, MMH & AI. All authors have read and agreed to the published version of the manuscript.

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INTRODUCTION

Bats, classified under the order Chiroptera, have long been postulated to play an important role in arthropod suppression, seed dispersal, and pollination. The rich diversity in bat dietary habits assists in maintaining ecosystem health. In Bangladesh, 31 bat species are found, three of which are fruit-eating. Of all frugivorous bats, *Pteropus medius* and *Rousettus leschenaultii* are common and widely distributed in the country. The False Vampire Bat *Megaderma lyra*, largest of insectivorous bats, is also quite common and widespread in Bangladesh (Khan 2001).

Bats are associated with zoonotic transmission of coronaviruses including severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2), middle-east respiratory syndrome coronavirus (MERS-CoV), Ebola, Nipah, and Hendra viruses (Calisher et al. 2006; Zhang & Holmes 2020), as well as malaria-causing protozoa like *Plasmodium* sp., *Hepatocystis*, *Nycteria*, and *Polychromophilus* (Schaer et al. 2013). Among nine hemosporidian genera, *Hepatocystis* infects a wide range of hosts including primates, bats, ungulates, and rodents, in addition to *Plasmodium* (Manwell & Kuntz 1966). Parasites of seven other hemosporidian genera, however, have been found exclusively in bats, emphasizing that they might harbor the most diverse set of hemosporidian parasites within the mammalian clade. The prevalence of hemosporidian parasites among fruit and insectivorous bats has been detected previously to be 40% (Schaer et al. 2013). *Hepatocystis* sp. was identified from a species of flying fox, *P. hypomelanus* (Olival et al. 2007), displaying an unusually high diversity and is also prevalent in Epauletted Fruit Bats *Epomophorus wahlbergi* (Schaer et al. 2013).

In light of these findings, bats have been identified as possible reservoirs of hemoprotozoa. They are included in epidemiological surveys, and particularly for the detection of bat-specific blood protozoa. Due to the gross destruction of habitat with rapid urbanization, contact between human and bats is showing an increasing trend. Frugivorous bats usually suck the juice of fruits instead of eating the whole fruits. They may play an important role in the transmission of infectious agents to rural communities, particularly small children, who collect those bat-wasted fruits (Rahman et al. 2012). In addition, ectoparasites which feed on hemoprotozoa-infected bats, could serve as a route of transmission to humans. The potential public health threats posed by bats thus suggests the importance of studying hemoprotozoa towards its proper control and better management of human diseases related to bats. Maximum research has led on emerging viruses in bats; however, bacterial and parasitic agents in bats have been least studied and most neglected. For a better understanding of parasitic pathogens in bats, we conducted this study to identify the hemoparasites of bats in Bangladesh.

MATERIALS AND METHODS

As part of a larger study through the United States Agency for International Development (USAID) Emerging Pandemic Threats PREDICT project and associated Ecology of Nipah virus survey, we captured bats in seven districts within or near human settlements across Bangladesh (Figure 1). A total of 533 (*P. medius* 377, *R. leschenaultii* 111, *M. lyra* 45) blood samples were collected randomly from bats during 2010 and 2013. The methods of bat sampling, species identification; age, weight, sex, physiological, and reproductive status determination were done based on PREDICT One Health Consortium (2017) and Epstein et al. (2008). The bats were released immediately after sample collection.

Blood smears were stained with Romanowsky-Giemsa solution (working solution) for 25–30 minutes, examined by an Olympus BX61 light microscope (Olympus, Shinjuku Monolith, 2-3-1 Nishi-Shinjuku, Shinjuku-ku, Tokyo 163-0914, Japan) equipped with Olympus DP70 digital camera (Olympus, Tokyo, Japan) and imaging software AnalySIS FIVE (Olympus, Tokyo Japan). A skilled parasitologist examined one blood film from each bat. Approximately 100 fields were examined at low magnification (400), and then at least 100 fields were studied at high magnification (1,000). In total, the approximate number of screened red blood cells was 5×10^5 for each blood film. The intensity of infection was estimated as a percentage by counting the number of parasites per 10,000 erythrocytes examined, as recommended (Godfrey et al. 1987). Parasites were identified using previously published works (Marinkelle 1996; Olival et al. 2007). The data were recorded in MS Excel-2007 (Microsoft Corporation, Redmond, WA 98052-6399 USA) and transferred to the STATA/IC-13.0 software (StataCorp, 4905, Lakeway Drive, College Station, Texas 77845, USA).

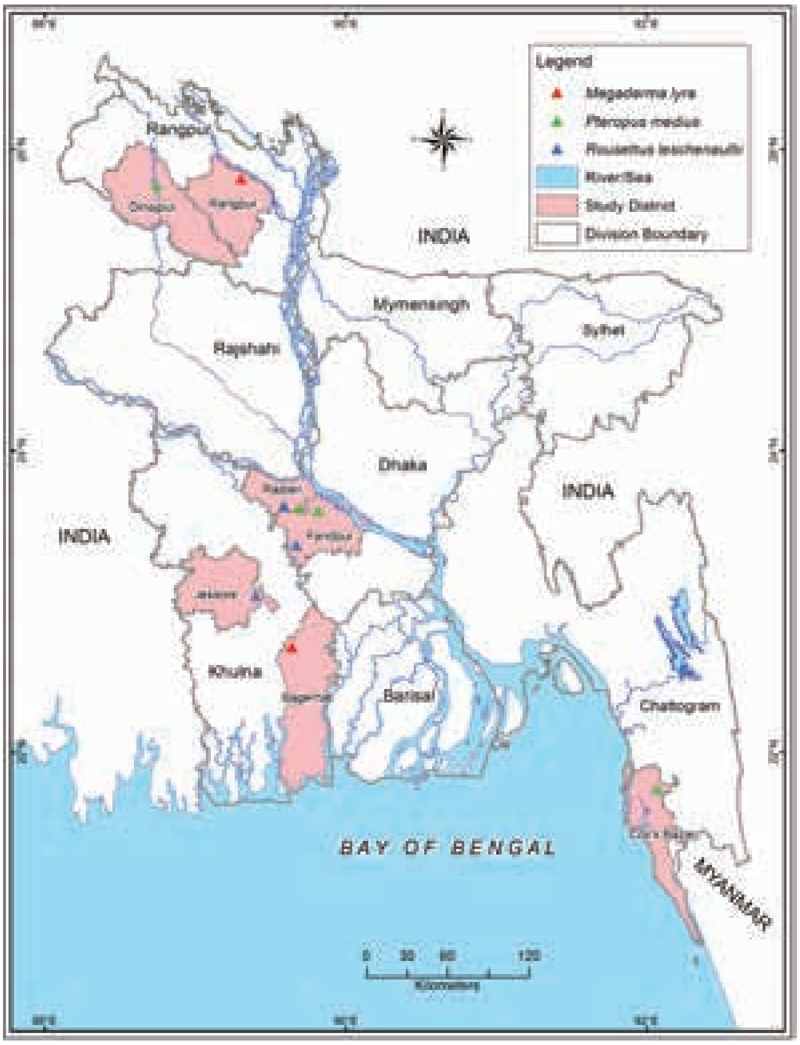

Figure 1. Bat sampling sites in Bangladesh 2010–2013.

RESULTS

Nine percent (n=47; 95% CI: 6.6-11.6%) of the total sample was found to be positive for hemoprotozoa. The overall prevalence of hemoprotozoa was 5%, 13%, and 29%, respectively in *P. medius* (n=20, 95% CI: 3–8), *R. leschenaultii* (n=14, 95%CI: 7–20), and *M. lyra* (n=13, 95%CI: 16–44).

In *P. medius*, *Babesia* sp. was found at the same percentage in both sexes (3%), *Hepatocystis* sp. was found higher in females (3%). The prevalence of *Babesia* sp. was higher in adults (4%) while *Hepatocystis* sp. prevalence was higher in neonates (6%). Both *Babesia* sp. (4%) and *Hepatocystis* sp. (3%) prevalence were higher in peri-urban area compared to rural settings (Table 1). In *M. lyra*, male were more infected (25%) by *Babesia* sp. than females (16%) whereas *Hepatocystis* sp. infection was higher in females (12%) than in males (5%). On the other hand, *Babesia* sp. infection is more prevalent in adult *M. lyra* (20%) and bats of rural areas (20%) than *Hepatocystis* sp. (9%) (Table 1). In case of *R. leschenaultii*, *Babesia* sp. infection was higher in males (13%) than in females (6%) but *Hepatocystis* sp. was found to be at higher percentage in females (4%) than males (2%). Juveniles were more prone to *Babesia* sp. (13%) than adult bats (8%). No *Hepatocystis* sp. infection was found in juveniles. In rural areas, *Babesia* sp. infection was more frequent (10%) than *Hepatocystis* sp. (2.7%). No associations, however, were found to be statistically significant (Table 1).

DISCUSSION

To the authors' knowledge, this is the first study to report the prevalence of hemoprotozoa in bats of Bangladesh. The study identified *Babesia* sp. and *Hepatocystis* sp. in three different bat species (Figure

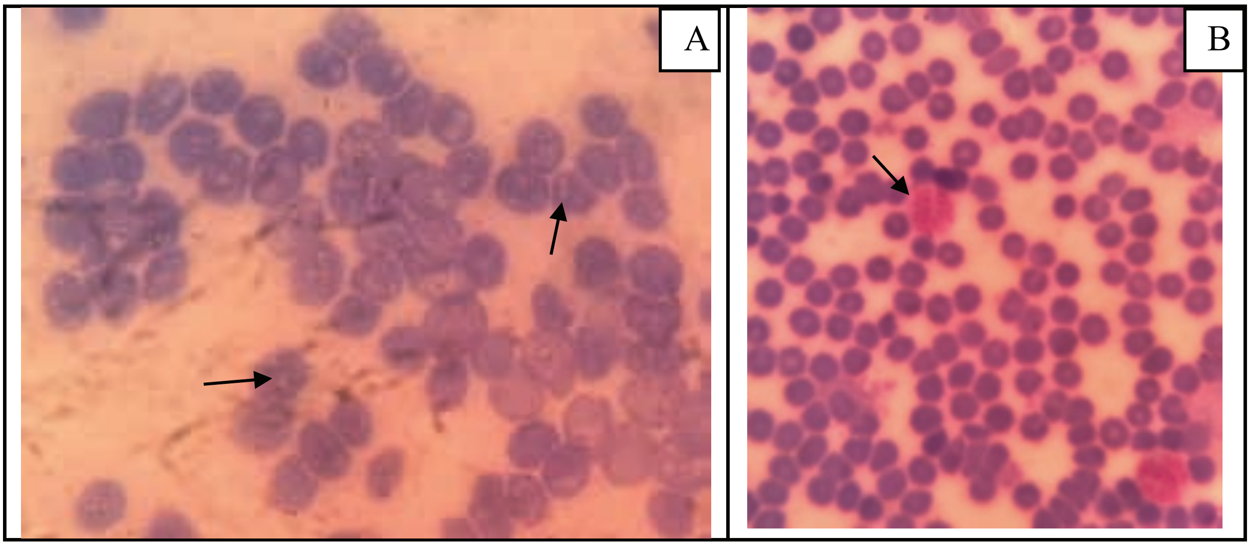

Image 1. A—*Babesia* sp. | B—*Hepatocystis* sp. found in microscopic examination of *Pteropus medius* from Bangladesh. © Rakib Uddin Ahmed, Abdullah Al Faruq & Sazeda Akter.

Table 1. Prevalence of hemoparasites in 03 bat species (N=533) from Bangladesh (2010–2013).

Bat species	Variables (n)	Babesia % (n)	95% CI	Hepatocystis % (n)	95% CI
P. medius	Male (211)	3 (7)	1.3–6.7	1.4 (3)	0.3–4.1
	Female (166)	3 (5)	0.9–6.8	3 (5)	0.99–6.9
	Adult (199)	4 (8)	1.8–7.8	1 (2)	0.1–3.6
	Sub-adult (143)	2 (3)	0.4–6.0	3 (4)	0.8–7.0
	Juvenile (35)	3 (1)	0.07–14.9	6 (2)	0.7–19.2
	Peri-urban (237)	4 (10)	2.0–7.6	3 (6)	0.9–5.4
	Rural (140)	1 (2)	0.2–5.1	1 (2)	0.2–5.1
Sub-total	377	3 (12)	1.7–5.5	2 (8)	0.9–4.1
M. lyra	Male (20)	25 (5)	8.7–49.1	5 (1)	0.1–24.9
	Female (25)	16 (4)	4.5–36.1	12 (3)	2.6–31.2
	Adult (45)	20 (9)	9.6–34.6	9 (4)	2.5–21.2
	Rural (45)	20 (9)	9.6–34.6	9 (4)	2.5–21.2
Sub-total	45	20 (9)	9.6–34.6	9 (4)	2.5–21.2
R. leschenaultii	Male (62)	12.9 (8)	5.7–23.9	2 (1)	0.04–8.7
	Female (49)	6.1 (3)	1.3–16.9	4 (2)	0.5–14.0
	Adult (103)	9.7 (10)	4.8–17.1	3 (3)	0.6–8.3
	Juvenile (8)	12.5 (1)	0.3–52.7	-	-
	Rural (111)	9.9 (11)	5.1–17.0	3 (3)	0.6–7.7
Sub-total	111	9.9 (11)	5.1–17.0	3 (3)	0.6–7.7
Total (N)	533	6.0 (32)	4.1–8.4	3 (15)	1.6–4.6

2). The identified hemoparasites in bats are similar to other reports from bats globally (Hornok et al. 2015; Manwell & Kuntz 1966; Marinkelle 1996; Olival et al. 2007; Schaer et al. 2015, 2017). Bats have harbored a diverse set of hemosporidian species for centuries (Schaer et al. 2013) and *Hepatocystis* was found to be at a high endemic level in Pteropodidae (Schaer et al. 2017). Although the identified parasite species have not been associated with public health implications, there is evidence of co-infection of primates and crossing of the primate barrier by *Hepatocystis* sp. (Thurber et al. 2013). Furthermore, some of the hemosporidian species from bats resemble rodent mammalian parasites (Schaer et al. 2013). The potential for bat-human, bat-rodent-human, and bat-arthropod-human cross-species transmission of hemoprotozoa is not known but warrants further investigation, particularly as the bat species included in the study are native to Bangladesh and share habitat as well as food and water sources with humans, suggesting potential plausible routes of accidental transmission.

The overall prevalence of blood protozoa (9%) was lower than that of earlier reports from various countries (Nartey 2015; Schaer et al. 2013). Hemoparasites in bats can be found as a result of feeding habits (e.g., feeding on insect vectors from which they may acquire the hemoprotozoa). The prevalence of *B. canis* in bats was reported as 2.7% by Hornok et al. (2015) which is much lower than the present study. Other studies reported 50% (Gardner & Molyneux 1987) and 23% (Lord 2010) prevalence of *Babesia* sp. in bats. Most of the previous studies identified *B. vesperuginis* (Gardner & Molyneux 1987; Marinkelle 1996; Lord 2010) in bat species throughout the world. The role of bats in the ecology of *Babesia* sp. and the vectors involved in transmission of *Babesia* sp. among them warrants further investigation. In the present study, the protozoa were identified up to the level of genus. *Hepatocystis* sp. prevalence was lower in this study than in a previous study in Malaysia (Olival et al. 2007). These findings, however, may vary due to the study area, duration of the study, resistance of bats and lack of bat fly vectors in Bangladesh.

Infection with *Babesia* sp. was higher in males (*M. lyra* and *R. leschenaultii*) whereas in case of *Hepatocystis* sp. the prevalence was higher for females. These differences can be attributed to variation in behavior, feed composition, and body mass between sexes (Wilson et al. 2002). Besides, sex hormone, testosterone increase the susceptibility to parasitism (Wilson et al. 2002). Moreover, parasite development and transmission is favored by the colonial habits of females (Christe et al. 2000). Adult *P. medius* had higher *Babesia* percentage than juvenile, may be due to increased growing host age. Young animals are less susceptible to *Babesia* due to inverse age resistance (Christensson 1989). But the same hemoparasite was higher in juvenile *R. leschenaultii* which can be attributable to the ability of the parasite's vertical transmission. *Hepatocystis* was higher in juvenile *P. medius*, because they have low body mass, naive immune system, and nearly no anti-parasite behavior. The pattern of parasitism in bats, however, should be explored in-depth in future studies.

CONCLUSION

We report a survey of hemoparasites in bats undertaken over three consecutive years at habitat fragmented landscape in human settlements areas in Bangladesh, where the prevalence and diversity of bat-infecting hemosporidian parasites have not been studied before. Molecular screening should be undertaken in future to overlay data in the microscopy with those from molecular biology. Molecular characterization is the only way to definitively confirm the species of a hemoparasite. The findings, however, remain of great interest. Further studies are needed to determine the species of parasites harbored in bats of Bangladesh.

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PLATINUM OPEN ACCESS

COMMUNICATION

Ecology of the Critically Endangered Singidia Tilapia (Teleostei: Cichlidae: *Oreochromis esculentus*) of lake Kayanja, Uganda and its conservation implications

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Abstract: Singidia Tilapia *Oreochromis esculentus* is a Critically Endangered native tilapia fish species endemic to lakes Victoria and Kyoga basins of East Africa, however, it disappeared from these main lakes due to overfishing, environmental degradation and predation by the introduced Nile Perch *Lates niloticus*. Remnant populations of this fish species is now restricted to satellite lakes including Lake Kayanja of the Victoria basin. This study provides updated information about the population abundance, critical habitat, threats and diet of Singidia Tilapia to inform conservation decisions to revive its populations in the wild. Fish data collection and mapping of nursery and breeding habitats of Singidia Tilapia on Lake Kayanja was conducted between February 2016 and October 2017. In all the areas mapped and sampled, Singidia Tilapia (with a size range of 11–27 cm TL) was the most abundant (43%) relative to exotic Nile Tilapia *Oreochromis niloticus* (21%) and Redbelly Tilapia *Coptodon zillii* (36%). The emergence of introduced (exotic) tilapias like Nile Tilapia recorded in this study could be attributed to cage fish farming being carried out in this Lake. The diet of *Oreochromis esculentus* consisted mainly of detritus (60.8 %), plant materials (27.7%) and blue-green algae (5.5%). Destruction of critical habitats and presence of introduced fish species were noted as the major threats to this fish and its habitats. The generated information could contribute to guiding stakeholders to undertake appropriate actions to conserve this threatened fish species and its habitats.

Keywords: Africa, conservation, Cichlid fishes, recovery, threatened fishes.

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INTRODUCTION

Singidia Tilapia *Oreochromis esculentus* is a Critically Endangered indigenous tilapiine cichlid (Twongo et al. 2006), endemic to lakes Victoria and Kyoga basins of eastern Africa (Nagayi-Yawe et al. 2006). This fish species has suffered a large reduction in extent of occurrence and is now restricted to a few refuge impoundments and satellite lakes such as Kayanja of the Victoria basins (Balirwa et al. 2000; Ogutu-Ohwayo & Balirwa 2006). Many researchers have documented factors attributing to the decline in the populations of Singidia Tilapia including the aggressive competition for food, spawning, and nursery grounds with introduced Nile Tilapia *Oreochromis niloticus*, predatory actions of Nile Perch (Mwanja et al. 2012), and environmental degradation like pollution, habitat modification, fragmentation & loss (Balirwa et al. 2003;Dudgeon et al. 2006; Ogutu-Ohwayo & Balirwa 2006; Chapman et al. 2008; Njiru et al. 2008; Lowe-McConnell 2009). Since this species was assessed and published as Critically Endangered (Twongo et al. 2006), no active research has been carried out to learn more about its distribution patterns and population status, therefore, additional research was needed to provide updated information and data about the feeding behavior, population status, threats to its critical habitat and distribution to inform conservation actions to halt the extinction of this species in the wild.

METHODS AND MATERIALS

The study was implemented on Lake Kayanja, one of the satellite lakes of Lake Victoria basin. It is geographically located at 0.283^{0}S & 31.867^{0}E (Figure 1). This Lake is administratively found in the sub-county of Bukakata, Masaka District in the central region of Uganda and lying west of lake Victoria. The habitats of lake Kayanja are dominated by wetlands and riverine forests which provide structural heterogeneity for fish to escape from predators, and thus having special significance for conservation of lake Victoria's fauna. A reconnaissance survey was conducted to identify the sampling sites within the lake based on indigenous knowledge of fishermen and key habitat characteristics including lake depth, vegetation cover, and human activities in the vicinity. Three sites namely; Kawunguli, Kasanje, and Bugiri were selected for fish surveys to collect primary data on Singidia Tilapia.

Collection of fish data

Fish surveys were conducted at pre-selected experimental sites for collection of primary fish data. Experimental gill-netting and electro-fishing techniques (Image 1 and 2) were used to collect fish samples. At each site, three fleets of graded multi-filament gill nets of mesh sizes ranging from 25.4–139.7 mm at an interval of 12.7mm and sizes 152.4–203 mm at 25.4mm intervals. The fleets were set parallel to the lake shoreline towards open water in the evening (17.00–18.00 h) and retrieved at dawn (05.00–06.00 h) the following morning. At each study site, geographical coordinates were recorded using a Global Positioning System (GPS). At the shallow inshore areas of each site, fish populations were sampled using a pulsed electro-fisher with an eight-watt generator and two anodes (Amisah & Cowx 2000). Two 30-minute runs were made at each site at an interval of 15 minutes to allow processing of the catch and recovery of conditions for fish re-occupancy. All the fish caught were measured for total and standard lengths (TL and SL) in centimeters, and identified to species level according to Greenwood (1966) guidelines. A total of 45 fish stomachs of Singidia Tilapia, Nile Tilapia, and *Coptodon zillii* indicating presence of any food were dissected out, contents evaluated and preserved in 5% formalin solution in separate numbered bottles for further analysis in the laboratory. The analysis of gut contents of preserved stomachs followed procedures reviewed by Elliott & Bagenal (1979). After rinsing the preserved stomachs with tap water and blotting off the excess water, the contents of each stomach to be analyzed were emptied into a petri-dish. Binocular (x10-80) and compound (x600) microscopes were used to identify the contents. At the lower magnification, large food items, such as, insects, fish or their remains were identified and quantification was based on the point's method (Hynes 1950). All the collected data were analyzed using excel spreadsheet to determine relative population abundance, percent composition of the diet. ArcGIS was used to generate distribution maps and critical habitats of Singidia Tilapia.

Mapping of critical habitats

A combination of scientific and indigenous knowledge was used to identify and map critical sites such as spawning and nursery grounds vital for the survival of Singidia Tilapia (Image 3) using the GPS. The criteria used to map these sites were based on known indicators such as presence of both mature (breeding) and young (immature/juvenile) Singidia fish, and characteristics of habitats such as shallow muddy bottom, presence

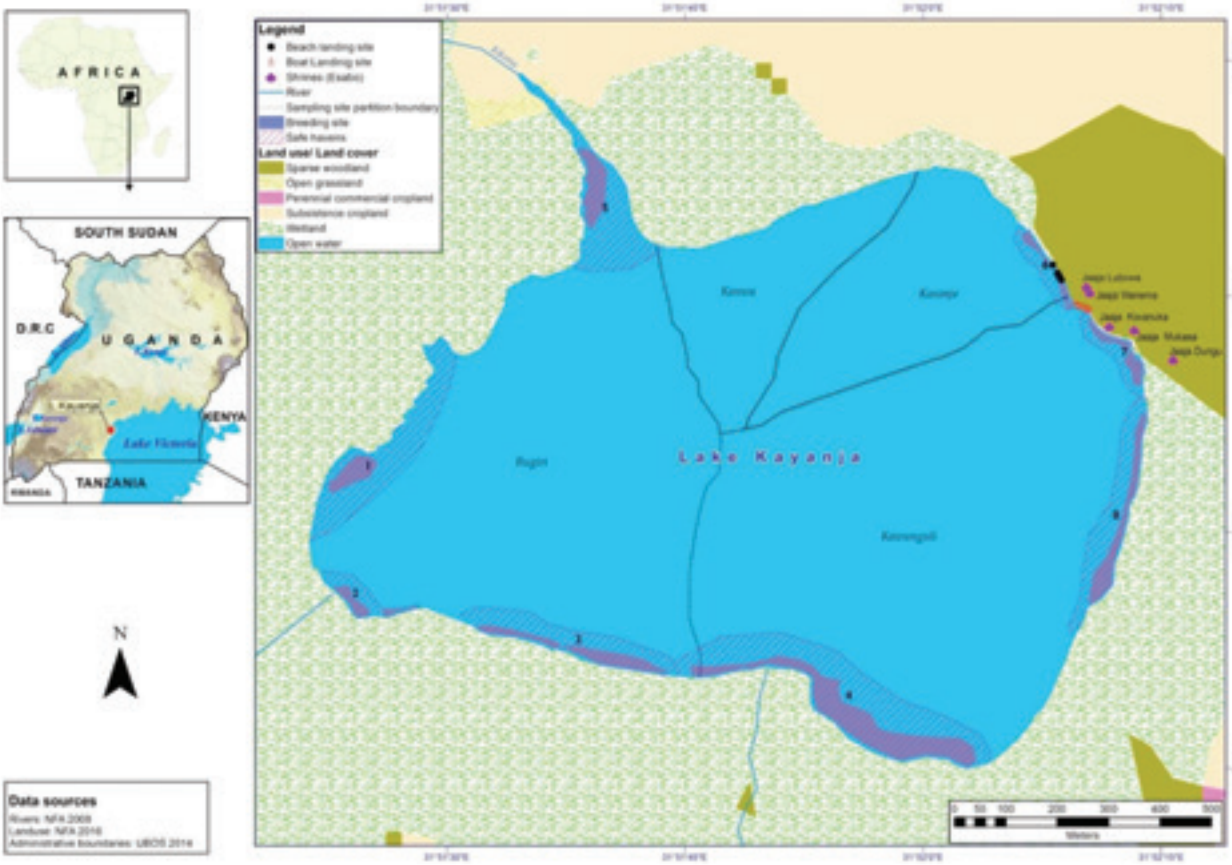


Figure 1. Breeding and nursery sites of Singidia Tilapia mapped on lake Kayanja.

Image 1. Experimental gill-netting in lake Kayanja.

Image 2. Electro-fisher being used to sample fish in lake Kayanja.

of breeding substrates like water lily, river inlets, and riverine forest preferred by of Singidia Tilapia

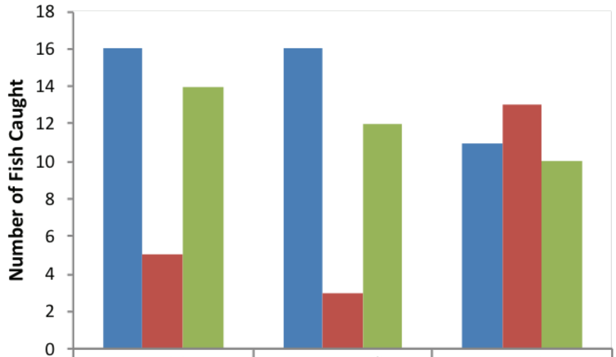
RESULTS AND DISCUSSION

Distribution and abundance of Singidia Tilapia

Singidia Tilapia was mostly found in areas identified and mapped as breeding and nursery areas (Figure 1; Image 4). A total of eight breeding sites of Singidia Tilapia were mapped in lake Kayanja (Figure 1). These critical sites are characterized by known indicators like shallow muddy bottoms, presence of waterweeds such as water lily, river inlets, and riverine forest. The surveys also revealed presence of introduced (exotic) tilapiines, i.e., Nile Tilapia *Oreochromis niloticus* and Redbelly Tilapia *Coptodon zillii*.

Population and abundance of Singidia tilapia

A total of 1,956 fish specimens representing 16 fish species were collected from the study area, of which 43 individuals were Singidia Tilapia, 21 were Nile Tilapia, and 36 were Redbelly Tilapia. Singidia Tilapia was the



	Bugiri	Kawunguli	Kasanje
Oreochromis esculentus	16	16	11
Oreochromis niloticus	5	3	13
Coptodon zillii	14	12	10

Figure 2. Population abundance of Singidia Tilapia and exotic fish species.

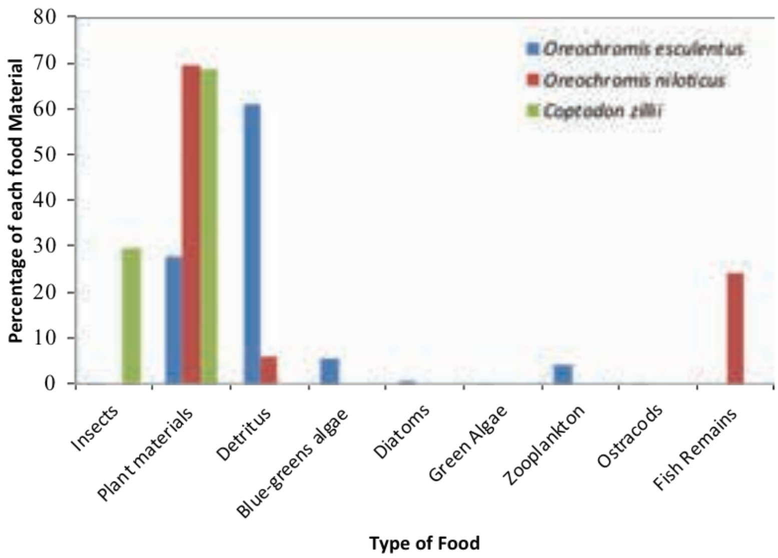


Figure 3. Prey of Singidia Tilapia and the introduced fish species.

most abundant (43%) relative to introduced (exotic) Nile Tilapia (21%) and Redbelly Tilapia (36%) in the study area. In terms of numbers, Singidia Tilapia was most abundant in Bugiri followed by Kawunguli sites, while Nile Tilapia was abundant in Kasanje (Figure 2). The variability in the distribution of Singidia Tilapia in lake Kayanja could be attributed mainly to habitat characteristics, for example, Kawunguli and Bugiri sites are dominated by shallow muddy bottom, breeding substrates like water lily, and river inlets which are preferred habitats for Singidia Tilapia. The high number of Nile Tilapia in Kasanje could be attributed to presence of the cage of Nile Tilapia in this area; we believed some of these Nile Tilapia fish must have escaped to the surrounding water from the cage.

Diet of Singidia Tilapia and the introduced fish species

A total of 45 fish stomachs of Singidia Tilapia, Nile Tilapia and Redbelly Tilapia were collected and analyzed to determine their feeding behaviors. The diet of Singidia Tilapia consisted of detritus (60.8%) followed by plant materials (27.7 %), blue-green algae (5.5 %), zooplanktons (4.5% and others (1.5%). The Nile Tilapia was feeding mainly on plant materials (69.5%) followed by fish remains (24.3%), and detritus (6.3%) (Figure 3). *Coptodon zillii* fed mainly on plant materials (68.7%) and insects (29.3%). Plant materials were the main diet for Nile Tilapia and *Coptodon zillii* while Singidia Tilapia fed mainly on detritus. *Coptodon zillii* fed more on insect remains than any of the targeted fish species. This finding complements on what other researchers have documented about the dietary requirement of native tilapias and introduced tilapias (Nagayi-Yawe et al. 2006; Mwanja et al. 2012; Ogutu-Ohwayo 1990; Lowe-McConnell 2009).

Image 3. Research team mapping breeding and nursery sites of Singidia Tilapias.

Image 4. Singidia Tilapia *Oreochromis esculentus*

Image 5. The cage for Nile Tilapia culture in lake Kayanja.

Image 6. Maize farm located at the shores of lake Kayanja.

The key threats to Singidia Tilapia fish species

This study revealed the transformation of lakeshore into farmlands and presence of introduced or exotic fish species were major threats that could jeopardize the ecological integrity of lake Kayanja and the conservation of endangered fishes in future. The following were some of the unwarranted activities being undertaken on lake Kayanja and its catchment areas

Cage fish farming of Nile tilapia in lake Kayanja (Image 5), which competes with Singidia Tilapia for food, spawning, and nursery ground.b)

Destruction of the buffer zones as result of cultivating crops up to the lake shores (Image 6), and increasing the chances of unused agro-chemicals such as fertilizers from farms to enter these lakes through surface runoffs, thus polluting the aquatic environment, in addition to burning of vegetation by fishermen.

Poor waste disposal and management due to the beach established for recreational, leisure, and special events and activities at the shores of lake Kayanja. Generally during and after such events, many contaminated polythene papers, non-biodegradable plastic bottles, and human wastes find their way into the lake, thus polluting the aquatic ecosystem.

CONCLUSIONS AND RECOMMENDATIONS

During the 19th and 20th centuries, Singidia Tilapia was one of the most abundant and important artisanal and commercial fish species in Uganda. It disappeared from the main lakes such as Victoria and Kyoga due to environmental degradation, predatory actions of the Nile Perch, and aggressive competition for food & space from introduced fishes particularly Nile Tilapia *Oreochromis niloticus*. Remnant populations of this fish species are now surviving in satellite lakes like Kayanja. This lake is, therefore, acting as functional refuge habitat for this

Critically Endangered fish and other aquatic resources that support the livelihoods of millions of people in Uganda. From this study, fish habitat modification, fragmentation and loss, and presence of introduced or exotic fish species were noted as the major threats that could jeopardize the ecological integrity of lake Kayanja to support the conservation of endangered fishes in future. The following recommendations need to be undertaken by all the relevant stakeholders to halt the risk of extinction of this fish species and other vital aquatic resources in lake Kayanja

Recommendations

a) Engagement of all stakeholders particularly government agencies and fishermen in best practices to abate, minimize, and mitigate threats to fish and their habitats in Uganda.

b) Proper management guidelines for satellite lakes to regulate and control development activities such as cage fish farming, agriculture within and around these lakes.

c) Development and implementation of strategic recovery plans to revive the population of Critically Endangered fishes including Singidia Tilapia in the wild.

d) Gazettement, monitoring, and protection of critical habitats for native tilapias not only in lake Kayanja, but also in other satellite lakes.

e) Promotion of fishing community involvement in the conservation and management of satellite lakes fisheries resources in Uganda.

f) Enhancement of public awareness about satellite lakes fisheries resources among all stakeholders to make them know the values and contribution of these resources to their wellbeing and livelihoods, as well as the actions they need to undertake to conserve and sustainably use these resources.

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Author contribution: RO, the principal investigator secured funds for this study, led the field team and participated in data collection, analysis and writing of this article. HN, EM and SB collected and analyzed data and wrote this article. WN provided technical advice, guidance and support to the field team to facilitate successful implementation of the study and writing of this manuscript. AT-M provided technical advice and reviewed this article.

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COMMUNICATION

Length-weight relationships of two conservation-concern mahseers (Teleostei: Cyprinidae: *Tor*) of the river Cauvery, Karnataka, India

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Abstract: Length-weight (LW) relationships are presented for two conservation-concern species of mahseer (*Tor* spp.) from southern India's river Cauvery. Constructed from angler catch data, these are the first available LW relationships for the Critically Endangered *Tor remadevii* and the non-native and locally invasive *Tor khudree*. For *T. remadevii*, the value of *b*, the allometric parameter, was 2.94 (95% CI: 2.75–3.14) and was not significantly different from 3.0, indicating isometric growth (t = 0.61, P = 0.54). For *T. khudree*, *b* was greater at 3.18 (95% CI: 3.01–3.38), but with this also not significantly different from 3.0 (t = 1.91, P = 0.06). Outputs are discussed with reference to species conservation and recreational catch-and-release fisheries.

Keywords: Angling, Critically Endangered, invasive fish, *Tor khudree*, *Tor remadevii*.

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Competing interests: The authors declare no competing interests.

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Author contribution: All authors contributed equally to the study design and data collection. ACP and JRB did the data analysis. ACP wrote the first draft. All authors contributed equally finalizing the manuscript

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Bournemouth University infinity MAHSEER TRUST

INTRODUCTION

Despite its global iconic status as a premier sport fish and the largest growing of all mahseers (*Tor* spp.) (Pinder et al. 2019), the formal taxonomic identity of the mega-faunal Hump-backed Mahseer has until recently eluded ichthyologists since first being brought to their attention in the 19th century (Jerdon 1849). Now known to be endemic to the Cauvery River catchment (Pinder et al. 2015a), recent research has confirmed this fish to be conspecific with *Tor remadevii* (Pinder et al. 2018a), a species for which the formal description was based on 19 juvenile specimens collected from the river Pambar, the southernmost tributary of the river Cauvery in Kerala, India (Kurup & Radhakrishnan 2007, 2010). Due to estimated population reductions in excess of 90% and an extremely limited distribution range, *T. remadevii* was recently assessed as Critically Endangered on the IUCN Red List of Threatened Species (Pinder et al. 2018b), making it the most imperilled of all *Tor* species.

Introductions of *T. khudree* into the river Cauvery from the 1970s has been implicated in the collapse of the endemic *T. remadevii* population (Pinder et al. 2015a; Pinder et al. in press). In recognition of the non-native and invasive status of *T. khudree* outside its native distribution range, India's current National Wildlife Action Plan 2017–2031, includes the action of actively removing *T. khudree* from Cauvery, through angling or other suitable means, to reduce the population of this undesirable species. This goes hand-in-hand with a further recommendation, that captive bred 'orange-finned' mahseer *T. remadevii* should be stocked to assist the recovery of this endemic species (Ministry of Environment, Forests and Climate Change, 2017). Furthermore, due to the establishment of *T. khudree* beyond its native range throughout much of southern India (see Pinder et al. in press), this species has recently been reassessed on the IUCN Red List from Endangered to Least Concern (de Alwis Goonatilake et al. 2020).

Here, the derivation of length-weight relationships from data collated from angling catches on the river Cauvery provides important biological parameters for both species for the first time. The results are discussed in relation to their indication of body allometry, their contributions to existing knowledge and persisting knowledge gaps which require urgent attention to better understand the biological and ecological mechanisms which may drive competitive interactions between these two species. Outputs are also discussed in the context of recreational catch-and-release fisheries and how stakeholders can utilise the data presented here to assist the urgent conservation of *T. remadevii*.

MATERIALS AND METHODS

Historic length-weight statistics for *T. remadevii* were recovered from the former angling camps and protected reaches of the middle River Cauvery that extend across 24km between Doddamakali Nature Camp (12.307^{0}N & 77.215^{0}E) and Mekedatu Gorge (12.259^{0}N & 77.447^{0}E), Karnataka, India (Fig. 1). Data used in the analysis date from 1976 to 1990 and were seasonally restricted between the months of December and May when river flows are suitably reduced to allow the recreational fishery to operate. These fish were captured by rod-and-line angling, with their fork lengths and weights recorded before release. Lengths were measured using non-rigid tape measures and weights from 'spring-balances'. For the latter, due to the combination of the size of some of the fishes (> 40kg) and their recording in field conditions, the weights were typically recorded to the nearest 250g.

For *T. khudree*, length-weight data of individual fish were collected from the upper river Cauvery (Ammangala Village, Valnur; 12.457^{0}N & 75.960^{0}E, in Kodagu District (Coorg), Karnataka, India (Fig. 1) during March 2014 and between February and April 2015. Captured using rod and line tactics, the data for each fish were recorded by trained fishery professionals. Fish lengths (FL) were recorded using a standard rigid measuring board (to 0.1cm) and weights recorded using a protective weigh sling and a spring balance appropriate to individual fish size (models: Salter Super Samson 20kg/100g and 5kg/25g). All fish were released following their processing.

To assess the length-weight relationships of each species, and to, thus, investigate allometry, their data were fitted to the linear form of the length-weight power function $W = aFL^b$, where a is the intercept parameter (shape coefficient) and b is the regression coefficient (allometric parameter), and where the linearised form of the equation is $\ln(W) = \ln(a)+b\ln(FL)$. In fishes, when the value of b is not significantly different from 3.0 (tested here via a 2-tailed t-test), it implies isometric growth, where there is a cubic increase in fish weight as length increases (Ali et al. 2013). If b is significantly lower than 3.0, it implies negative allometric growth and significantly higher than 3.0 implies positive allometric growth (Riedel et al. 2007). Should non-isometric growth be apparent then the factors driving this deviation can be explored (Ali et al. 2013).

Figure 1. River Cauvery showing the 24-km sampling reach of *Tor remadevii* between Doddamakali Nature Camp and Mekedatu Gorge (A–B) and *Tor khudree* at Valnur (C) in Kodagu District (Coorg), Karnataka, India.

RESULTS

The length-weight relationships were derived from a sample of 90 *T. remadevii* and 59 *T. khudree*. The subsequent values of *a* and *b*, and their associated statistical information, are provided in Table 1. For *T. remadevii*, the value of *b*, the allometric parameter, was 2.94 (95% CI: 2.75–3.14) and was not significantly different from 3.0, indicating isometric growth (t = 0.61, P = 0.54). For *T. khudree*, *b* was greater at 3.18 (95% CI: 3.01–3.38), but with this also not significantly different from 3.0 (t = 1.91, P = 0.06). Linearised relationship of fork length (cm) versus weight (g) for both species is provided in Figure 2.

DISCUSSION

The results suggest that the growth of both the *Tor* species analysed were isometric, i.e., there was a cubic increase in fish weight as length increased. These data are important in the context of biological information on these fishes that, to date, has been extremely limited.

Indeed, the substantial population decline of endemic *T. remadevii* that has occurred in the last 15 years now prevents the contemporary sampling of their populations to obtain new biometric data (Pinder et al. 2015a, 2018b). The high historical recreational and trophy value of this fish has, however, resulted in collection of data by anglers in previous years, enabling these data to be used here and highlighting the inherent value of angler log books to provide important biological data from catch data (Cooke et al. 2000; Pinder & Raghavan 2013; Pinder et al. 2015b). This did, however, result in the use of data collected by anglers in extreme field conditions (e.g., high air temperatures) using relatively crude equipment (spring-balances recording to an accuracy of 0.25kg). Nevertheless, some of the fish in the dataset were large, over 40kg, and thus would be inherently difficult to weigh to a greater level of accuracy

Table 1. Length (fork, cm) weight (g) relationship for *Tor remadevii* and *Tor khudree* from the river Cauvery, southern India, where $W=aL^b$, n = sample size; r^2 = coefficient of determination. All length-weight relationships were significant at $P < 0.001$. All data represent the first reporting of the length-weight relationship for the species.

Species	n	Length range (cm)	Mean length (cm)	Weight range (kg)	Mean weight (kg)	a	95% CI *a*	b	95% CI *b*	r^2
T. remadevii	90	40–175	111.83	1.5–45.3	19.7	0.016	0.006–0.040	2.94	2.75–3.14	0.91
T. khudree	59	15.5–83	34.92	0.06–8.8	0.87	0.007	0.003–0.012	3.18	3.01–3.38	0.95

Table 2. Summary of maximum length and weights reported from this study and previous studies (*Kurup & Radhakrishnan 2007; **http://www.fishbase.org/, version 12/2019)

Species	Previous maximum reported size		Data presented here	
	Max length (cm)	Max weight (kg)	Max length (cm)	Max weight (kg)
Tor remadevii	33.2 (TL)*	N/A	175 (FL)	45.3
Tor khudree	50 (TL)**	2.7**	83 (FL)	8.8

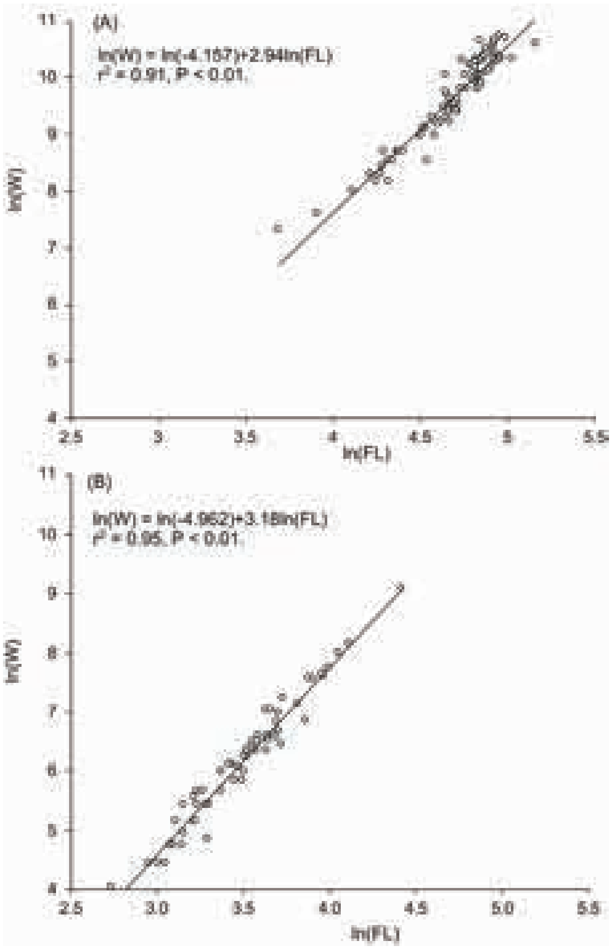

Figure 2. Linearised relationship of fork length (cm) versus weight (g) for (A) *Tor remadevii*, and (B) *Tor khudree*, according to ln(W) = ln(*a*)+*b*ln(FL). The straight lines are the relationship between the variables according to linear regression.

unless killed and also were unable to be captured by alternative methods to angling. Consequently, despite the method of data collection, it is argued these data have high value in the context of this conservation-dependent species that is currently close to extinction (Pinder et al. 2015a) and for which no adult length-weight data currently exist.

Due to the previous taxonomic confusion regarding the taxonomy of southern Indian *Tor* species (Pinder & Raghavan 2013; Pinder et al. 2018a, 2019) many previous studies have erroneously synonymised the 'nom de plume' *Tor* (or *Barbus*) *mussullah* (under the guise of the Hump-backed Mahseer (now known to be *T. remadevii*)) with *T. khudree*. As a consequence, much of the biometric data presented in the scientific literature, and open access resources (e.g., FishBase) for *T. khudree* need to be treated with appropriate caution. With reference to previous scientific studies where a high level of confidence can be applied to correct taxonomic use, the data reported here dramatically revise the maximum lengths and weights for both species (Table 2). Moreover, despite an absence of length records, other published data sources report weights of the Hump-backed Mahseer (*T. remadevii*) to 54.4kg (Wild Life 1977) and *T. khudree* to 27.9kg (Pinder et al. 2015a).

The results presented here provide the first biological data that can act as a base on which to build knowledge that is urgently required in a conservation context to both better understand the invasion consequences of *T. khudree* and to inform planning for the population restoration of *T. remadevii*, including understanding novel species interactions, and the range of biological parameters and ecological plasticity that may drive competitive advantages between these species (Pinder et al. in press).

Given the isometric growth of both species, these data can now be applied in a conservation context by enabling sport anglers using catch-and-release angling techniques to keep the fish in the water for unhooking, with weights then estimated from measured lengths. This would eliminate a high proportion of the manual handling and air exposure of the fish, minimising the stress that this is known to cause, along with the associated elevated risk of post-release mortality (Cooke & Suski 2005; Cook et al. 2015; Bower et al. 2016).

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PLATINUM OPEN ACCESS

COMMUNICATION

The identity and distribution of *Bhavania annandalei* Hora, 1920 (Cypriniformes: Balitoridae), a hillstream loach endemic to the Western Ghats of India

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Abstract: *Bhavania annandalei* Hora 1920, is resurrected from the synonymy of *B. australis* (Jerdon, 1849) based on examination of freshly collected topotypic specimens. The two species can be distinguished by a combination of morphological characters including low, dense, and sparsely distributed tubercles on dorsal surface of head and operculum, rostral barbels reaching anterior border of upper lip, rostral flaps between the rostral barbels fleshier, 11–12 scale rows above the lateral line, and caudal peduncle stout with its depth to width ratio less than 2.5. The two species formed significantly distinct clusters in multivariate space. Further, the two species have a raw genetic distance of 6.4% in the mitochondrial cytochrome oxidase subunit 1 gene. The distribution of *B. annandalei* is restricted to the river systems draining the Agasthyamalai Hills, below the Shencottah Gap in southern Western Ghats, while *B. australis* occurs in rivers north of the Shencottah Gap.

Keywords: Agasthyamalai, Cobitoidea, Kerala, mountain loach, synonymy.

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Competing interests: The authors declare no competing interests.

Author details: Remya L. Sundar, is interested in taxonomy, diversity and distribution of freshwater and estuarine fishes of Kerala. V.K. Anoop is interested in the systematics and biogeography of loaches of the Western Ghats. Arya Sidharthan is interested in molecular ecology and phylogeography of balitorid loaches of the Western Ghats. Neelesh Dahanukar is interested in molecular phylogenetics and biogeography of freshwater fishes of the Western Ghats. RAJEEV RAGHAVAN is interested in conservation of aquatic biodiversity of Western Ghats with special reference to freshwater fishes.

Author contribution: RR, ND and AS conceived the study; RLS, VKA and AS carried out the field surveys and laboratory studies; all authors equally contributed to the writing of the manuscript.

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INTRODUCTION

The hillstream loach *Bhavania annandalei* was described by Hora (1920; p203) from Tenmalai, erstwhile Travancore State (= current day southern Kerala), and suggested that the species occurs throughout the southern Western Ghats in the Nilgiris, Malabar, and Travancore. Hora (1920) diagnosed *B. annandalei* from its only known congener, *B. australis* (Jerdon, 1849) (type locality: Walliar Jungle = Walayar), by a combination of characters; the most prominent of which included a broad snout (vs. pointed), interrupted lower lip (vs. continuous), caudal-lobes equal (vs. lower lobe longer), and presence of a pair of papillae on the lower lip (vs. absence).

Hora's (1920) description of *B. annandalei* was however, based on a single adult female specimen collected by Dr. Annandale from Travancore, Kerala. Though, Hora (1920) seemed to have access to additional juvenile specimens collected by Captain Sewell from the Nilgiris (Cherambadi) and Wayanad (Nellimunda, Mananthavady, and near Vythiri), he did not examine them or provide other details. Subsequently, Hora (1937; p8) extended the distribution of the species to Mysore, based on four specimens collected by M.S. Bhimachar from a stream between Kottigehar and Balehonnur (erstwhile Mysore State = current day Tunga River System in Karnataka). No details of the specimens were provided.

In his review on 'Homalopterid fishes from Peninsular India', Hora (1941) synonymized *B. annandalei* with *B. australis*, after examining specimens from throughout its distribution range including Kallar/South Travancore (current day Vamanapuram River, Kerala); Pampadumpara/North Travancore (current day Periyar River, Kerala); Sethumadai Hills/ Mysore (current day Anamalai hills near Pollachi, Tamil Nadu); and Kottigehar/Mysore (current day Tunga River, Karnataka), and realizing that his description of *B. annandalei* was based mainly on immature specimens. This synonymy was subsequently adopted by Menon (1987) in his review of the homalopterid loaches of India, but without examining the type (or fresh topotypes) of *B. annandalei*, or the topotypes of *B. australis*. Later workers followed this synonymy and considered *Bhavania* to be monotypic (Talwar & Jhingran 1991; Menon 1999; Kottelat 2012). '*Bhavania arunachalensis*', described by Nath et al. (2007) from Naodhing drainage in Arunachal Pradesh, is considered to be a 'species inquirenda et incertae sedis' (i.e., doubtful identity and uncertain placement) (Kottelat 2012), and is most likely a species of the genus *Balitora* (see Fricke et al. 2020).

Given their hill-stream adaptations (widespread paired fins, flattened ventral surfaces with body suckers and rasping mouths on their ventral surface allowing them to firmly grasp rock or gravel surfaces necessary in the mountain torrents) (Chen 1980; Kottelat 2012), and the fact that the type locality of *B. annandalei* (Tenmalai) and *B. australis* (Walayar) are at least 300km apart and separated by two significant biogeographic barriers - the Palghat Gap and the Shencottah Gap (see Anoop et al. 2018), it is highly unlikely that the two are conspecific. Collection of fresh topotypic specimens of both *B. australis* and *B. annandalei* and detailed examination and comparison of their biometrics, and genetic distance analysis based on the mitochondrial cox1 gene, revealed that the two species are clearly distinct. We, therefore, resurrect *Bhavania annandalei* Hora, 1920, from the synonymy of *B. australis* (Jerdon, 1849) and provide notes on the distribution range of this species.

Six specimens of putative topotypic *Bhavania annandalei* were collected from Palaruvi falls at Tenmala (Kallada River), Kerala, and six specimens of putative topotypic *B. australis* were collected from near the Kavarakund falls, upstream of Malampuzha Reservoir, Kerala, India (Fig. 1). Samples were collected using a hand net/scoop net during early morning hours, fixed in 10% formalin and transferred to 70% ethanol for permanent voucher storage in the museum collections of the Kerala University of Fisheries and Ocean Studies (KUFOS), Kochi, India. Gill tissues were obtained from fresh specimens and preserved in absolute ethanol. Morphometric measurements were taken for 37 characters (measured to the nearest 0.1mm using digital calliper) and meristic values were determined for 10 characters using a stereo-zoom microscope. For meristic counts, values in parenthesis after the count respresent its frequency. For fin ray counts, unbranched fin rays are expressed as small roman numerals. For pectoral fin, fin rays are provided as padded fin rays + branched fin rays + unbranched fin rays. For statistical analysis of morphometric data, subunits of body were taken as percentage of standard length and subunits of head were taken as percentage of head length. Principal component analysis (PCA) was performed to check whether the two species formed distinct clusters in multivariate space using correlation matrix. Null hypothesis that the clusters are not significantly different from each other was tested using analysis of similarities (ANOSIM) employing Euclidian distances and 9999 permutations. Statistical analysis was performed in PAST 4.02 (Hammer et al. 2001). Genetic sequences

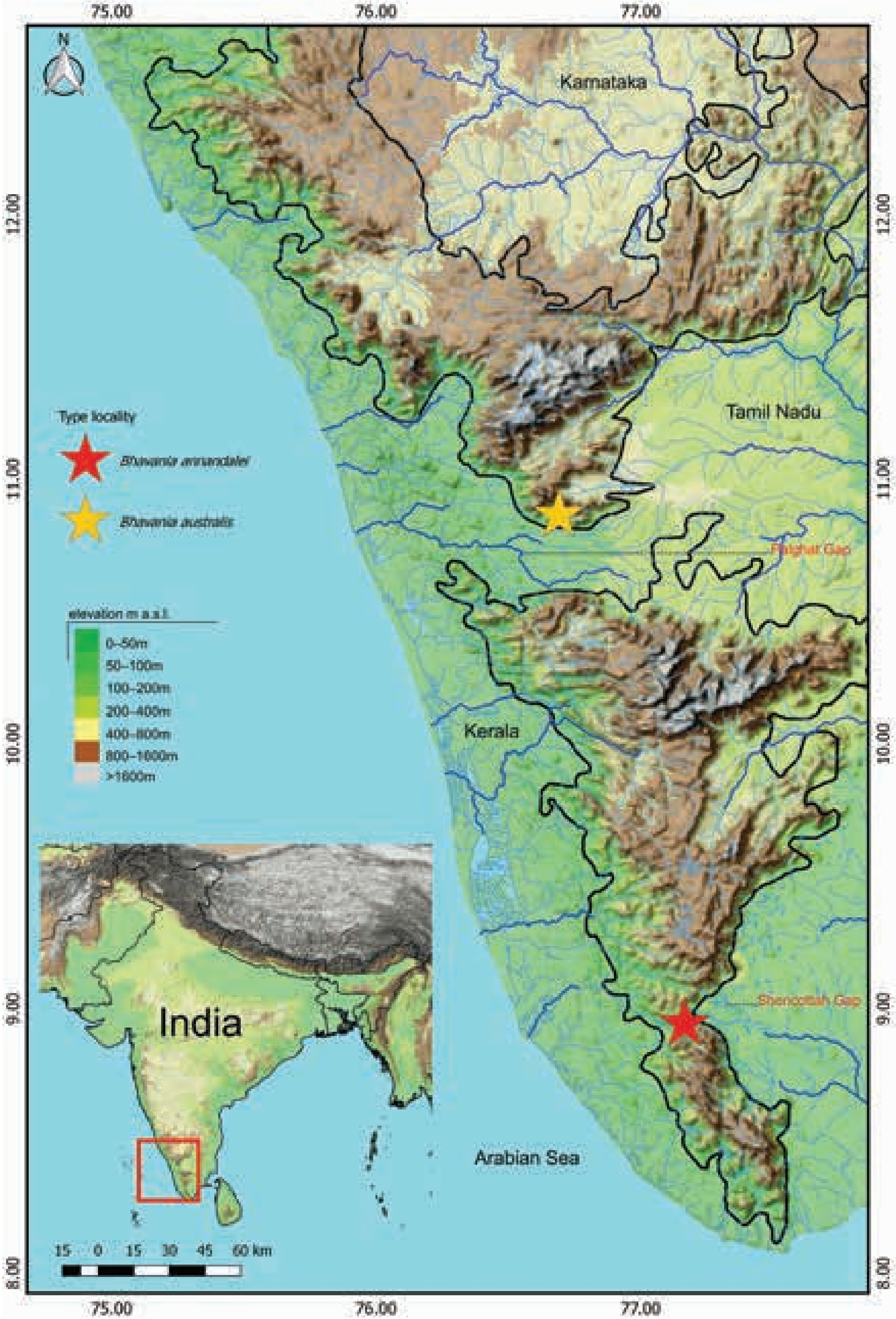

Figure 1. Collection localities of putative topotyes of *Bhavania annandalei* and *B. australis*.

of mitochondrial partial cytochrome oxidase subunit 1 (cox1) of topotypic *Bhavania annandalei* and *B. australis* were obtained from our ongoing study (Sidharthan et al. Unpublished). Additional sequences were downloaded from GenBank database. Gene sequences were aligned using MUSCLE (Edgar 2004) and raw genetic distance was estimated using MEGA 7 (Kumar et al. 2016). Data were partitioned into three codon positions of cox1 gene. Partition analysis (Chernomor et al. 2016) and ModelFinder (Kalyaanamoorthy et al. 2017) were used to find the right partitioning scheme and nucleotide substitution model for the partition scheme employing minimum Bayesian information criterion (BIC). Maximum likelihood (ML) analysis was performed in IQ Tree (Nguyen et al. 2015) with best partition scheme and ultrafast bootstrap support for 1,000 iterations (Hoang et al. 2018). Phylogenetic tree was edited in FigTree v1.4.2 (Rambaut 2009).

Bhavania annandalei Hora, 1920 (Images 1–3)

Materials examined: KUFOS.19.AS.BH.02.1–6, 6 ex., 07.ii.2019, 8.945N & 77.158E, 32.7–37.6 mm SL, Palaruvi falls, Tenmala, Kallada River, Kerala, India, coll. Arya Sidharthan, E.S. Abhijith, & George Joseph.

Diagnosis. *Bhavania annandalei* is distinguished from its only known congener *B. australis* by a combination of characters: low density and sparsely distributed tubercles on dorsal surface of head, especially on operculum, (vs. high density of tubercles on dorsal surface of head and operculum) (Image 3); gape of mouth comparatively farther from snout tip, as a result the rostral barbels reaching anterior border of upper lip, (vs. gape of mouth closer to snout tip, and rostral barbels reaching posterior border of upper lip) (Image 3); rostral flaps between the rostral barbels fleshier (vs. less fleshier) (Image 3); fewer post-dorsal scales (34–36 vs. 38–41); fewer scales above the lateral line (11–12 vs. 14–15); and caudal peduncle stout with its depth to width ratio 1.8–2.3 (vs. laterally compressed caudal peduncle with depth to width ratio 2.8–3.6). This species has a fin formula of D. ii+7+i; P. 6+10+i; V. ii+7–8; A. ii+5, and scale counts of Ll. 65–67 and L.tr. 11–12/9–10.

Description: Morphometric and meristic data of *Bhavania annandalei* are provided in Table 1 and Table 2, respectively. General body form as per Image 1a and Image 2a. Head details as in Image 3a, c.

Body elongate, dorso-ventrally depressed anteriorly, laterally compressed posteriorly; dorsal profile convex, deepest at dorsal-fin origin. Body wider than its depth at dorsal-fin origin, deeper than wide at anus. Head small, rounded, less than one-fourth of standard length; depressed, longer than broad, with minute sparsely distributed indistinct tubercles on dorsal surface of head. Eyes small, dorso-laterally positioned, not visible from underside of head. Snout pointed in lateral view, round in dorsal view. Nostrils positioned dorsally, closer to anterior border of eye than to snout tip, anterior nostril situated inside a skin flap covering the posterior nostrils. Mouth inferior. Lips fleshy. Gape of mouth less

Image 1. Putative topotypes: a—*Bhavania annandalei* | b—*B. australis* in life (specimens not preserved).

Table 1. Morphometric data of *Bhavania annandalei* (KUFOS.19.AS.BH.02.1-6, n=6) and *B. australis* (KUFOS.19.AS.BH.01.1-6, n=6) putative topotypes.

Characters	*Bhavania annandalei*		*Bhavania australis*	
	Mean (sd)	Range	Mean (sd)	Range
Total length (mm)	62.3 (18.2)	40.2–85.8	76.1 (10.6)	62.4–90.2
Standard length (SL, mm)	50.8 (14.5)	33.2–70.2	62.4 (8.8)	51.6–74.2
Head length (HL, mm)	11.1 (2.6)	8.2–14.7	13.0 (1.7)	11.3–15.2
% SL				
Head length	22.2 (1.6)	20.9–24.7	20.9 (0.9)	19.8–21.9
Pre-pectoral length	18.0 (0.9)	17.2–19.7	18.2 (0.9)	17.1–19.4
Pre-dorsal length	49.8 (1.9)	46.7–52.1	47.3 (1.8)	44.5–49.4
Pre-pelvic length	44.0 (1.1)	42.4–45.1	44.3 (1.5)	42.0–46.6
Pre-vent length	70.3 (2.5)	67.4–73.2	69.6 (1.6)	67.7–71.6
Pre-anal fin length	79.1 (1.8)	77.1–81.6	78.7 (1.6)	77.3–81.8
Origin of pelvic fin to anus distance	29.3 (1.5)	26.6–30.7	28.7 (3.1)	26.2–34.4
Anal fin to anus distance	9.2 (1.3)	7.6–11.0	9.9 (0.6)	9.1–10.4
Post dorsal length	44.3 (1.2)	42.9–46.1	44.7 (1.0)	43.6–46.2
Body depth at dorsal fin origin	14.3 (0.8)	12.9–15.2	13.2 (0.6)	12.0–13.8
Body width dorsal fin origin	17.7 (1.2)	15.5–18.8	18.5 (0.7)	17.4–19.3
Height of dorsal fin	19.2 (1.2)	16.9–20.0	20.1 (0.9)	19.1–21.7
Dorsal-fin base length	11.9 (0.7)	11.1–12.7	12.0 (0.4)	11.3–12.4
Body depth at anal fin origin	11.4 (0.5)	10.6–11.9	11.0 (0.5)	10.4–11.9
Body width at anal fin origin	7.0 (0.7)	6.2–7.9	6.9 (0.6)	5.9–7.6
Length of upper caudal lobe	20.7 (1.4)	18.4–22.0	20.6 (1.9)	19.0–24.1
Length of lower caudal lobe	24.3 (1.5)	22.3–26.1	22.2 (1.4)	20.8–24.7
Length of median caudal rays	17.6 (1.4)	15.2–19.2	16.2 (0.7)	15.3–16.7
Anal fin length	14.1 (0.9)	12.8–15.5	15.5 (0.5)	14.9–16.3
Anal fin base length	7.0 (0.7)	6.4–8.3	7.2 (0.5)	6.6–7.9
Pelvic fin length	22.5 (1.3)	21.3–24.8	22.8 (0.8)	21.6–23.9
Pectoral fin length	26.8 (1.7)	24.4–29.7	26.4 (1.2)	24.2–27.3
Length of caudal peduncle	13.3 (1.8)	11.7–15.9	14.2 (0.7)	13.1–15.1
Caudal peduncle depth	9.3 (0.3)	8.9–9.7	9.3 (0.8)	8.4–10.7
Caudal peduncle width	4.5 (0.5)	3.9–5.1	3.0 (0.1)	2.8–3.2
% HL				
Snout-supra-occipital distance	93.3 (5.6)	86.7–101.0	100.6 (5.4)	94.2–107.5
Gape of mouth	23.8 (3.3)	19.7–26.9	29.6 (3.2)	25.5–35.3
Head depth at eye	41.2 (2.1)	39.3–44.9	42.6 (3.2)	37.9–45.9
Head width at eye	75.3 (5.5)	68.3–80.9	83.4 (6.5)	75.7–93.0
Head depth at nape	52.9 (5.3)	47.3–60.3	41.8 (9.8)	30.7–51.6
Snout length	57.6 (5.3)	51.4–64.9	58.6 (2.8)	56.2–63.3
Maximum head width	83.0 (9.0)	71.1–95.8	88.9 (4.3)	84.1–94.3
Eye diameter	20.3 (2.8)	16.5–23.7	17.5 (1.2)	15.3–18.8
Interorbital width	35.7 (4.8)	30.6–42.9	39.0 (4.1)	33.2–45.0
Internarial width	27.3 (2.2)	24.2–30.3	29.9 (2.6)	26.1–33.7

Table 2. Meristic data of *Bhavania australis* (KUFOS.19.AS.BH.01.1-6, n=6), and *B. annandalei* (KUFOS.19.AS.BH.01.1-6, n=6) putative topotypes. Numbers in parenthesis indicate frequency of character state in the materials examined.

Characters	*Bhavania annandalei*	*Bhavania australis*
Dorsal-fin rays	ii+7+i (6)	ii+7 (3), ii+7+i (3)
Pectoral-fin rays	6+10+i (6)	6+9+i (1), 6+10 (1), 6+10+i (4)
Pelvic-fin rays	ii+7 (2), ii+8 (4)	ii+7 (4), ii+7+i (2)
Anal-fin rays	ii+5 (6)	ii+5 (4), ii+5+i (1); ii+6 (1)
Caudal-fin rays	19 (6)	19 (6)
Lateral line scales	65+4 (2), 66+3 (1), 67+3 (2), 67+3 (1)	65+3 (2), 65+4 (1), 66+3 (1), 68+3 (1), 69+3 (1)
Pre dorsal scales	29 (1), 30 (2), 31 (3)	28 (3), 29 (2), 30 (1)
Post dorsal scales	34 (3), 35 (2), 36 (1)	38 (1), 39 (2), 40 (2), 41 (1)
Scales above lateral line	11 (2), 12 (4)	14 (4), 15 (2)
Scales below lateral line	9 (2), 10 (4)	10 (3), 11 (3)

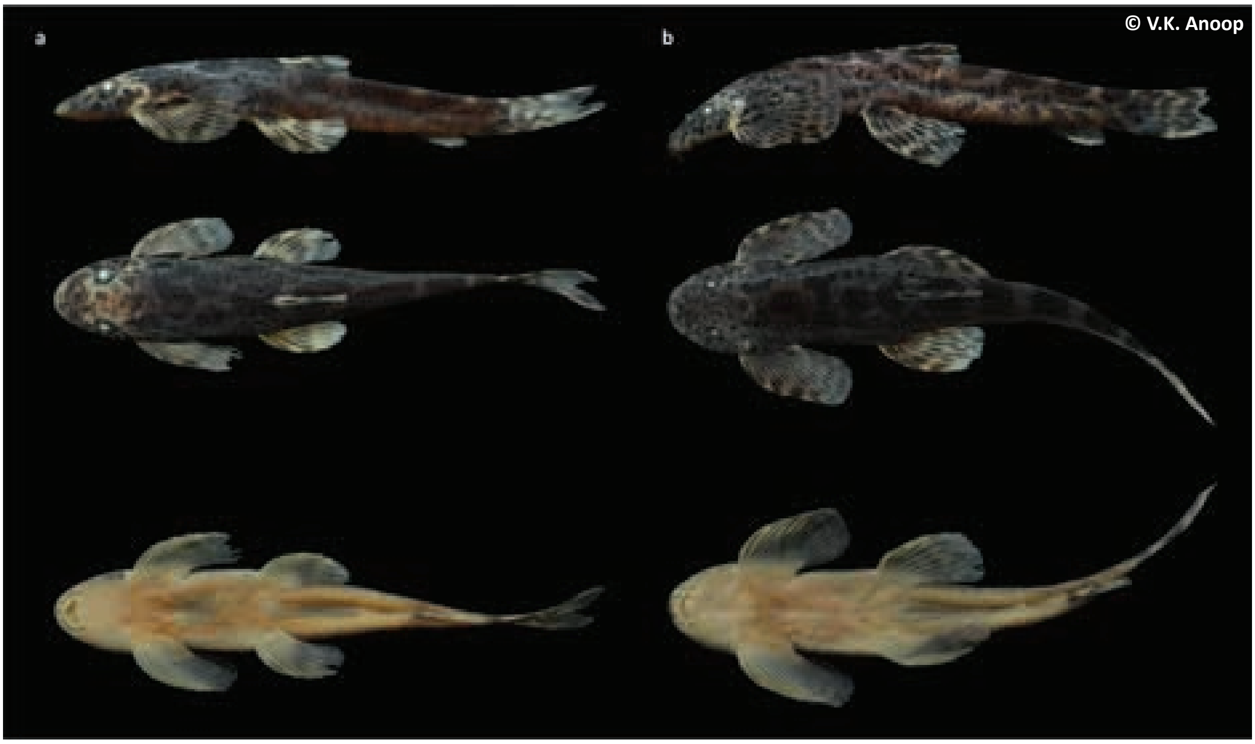

Image 2. Dorsal, lateral, and ventral images of putative topotypes: a—*Bhavania annandalei* | b—*B. australis*.

than three times maximum head width. Barbels three pairs, two rostral: outer rostral barbels shorter than inner ones; one pair of maxillary barbels, situated slightly anterior to the angle of mouth. Three fleshy rostral flaps interspaced between rostral barbels. Gill opening small, restricted above the base of the pectoral fin.

Body with scales except chest and belly. Lateral line complete, with 68–72 small scales. Caudal peduncle slender, its length almost three times its depth. Dorsal-fin originating slightly behind the pelvic-fin origin, closer to tip of snout than to caudal-fin base; with two unbranched, followed by seven branched and a simple ray. Pectoral fin elongated, longer than head, with six unbranched, followed by 10 branched and a simple ray. Pelvic-fin length almost equal to head length; fin origin closer to snout tip than to end of caudal peduncle, its posterior end not reaching anus, with two unbranched and eight branched rays. Anal fin with two unbranched and five branched rays. Caudal fin forked, with 19 principal rays.

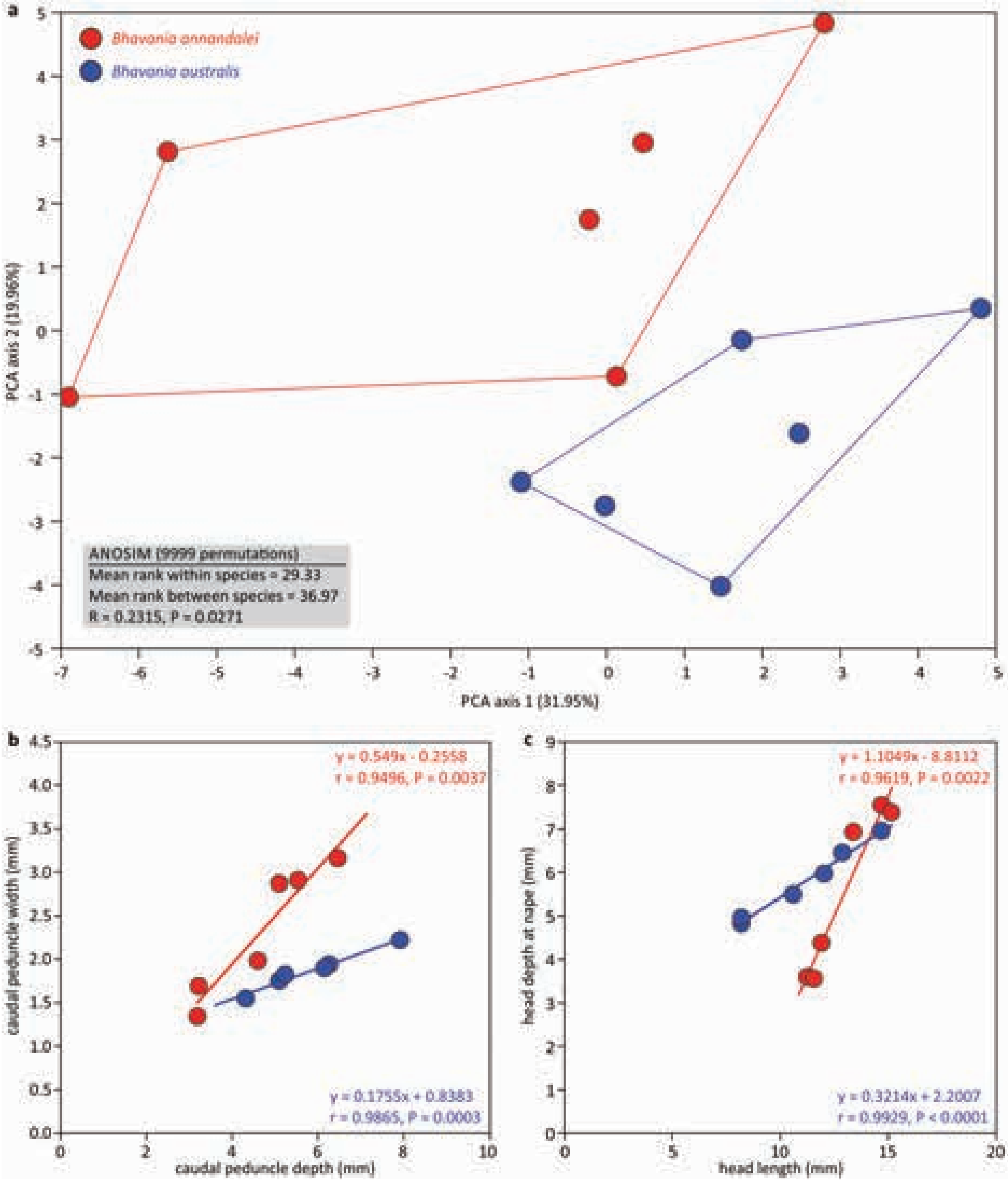

Figure 2. Morphometric analysis: a—Principal Component Analysis scatter plot of factor scores and ANOSIM statistics | b—Linear regression between caudal peduncle depth and width | c—Linear regression between head length and head depth at nape.

Colouration: In life (Image 1a), body is chestnut brown on dorsal and lateral sides, creamish-white on chest and belly; 3–4 prominent broad dark brown ventral bands; two broad ventral bands on the dorsal-fin base. There are three black-coloured bands on the dorsal fin, 6–7 bands on the pectoral, three bands on the pelvic, 1–2 bands on the anal, and four bands across the caudal fin.

Morphometric analysis: In the morphometric analysis, using all the size-adjusted characters (Table 1),

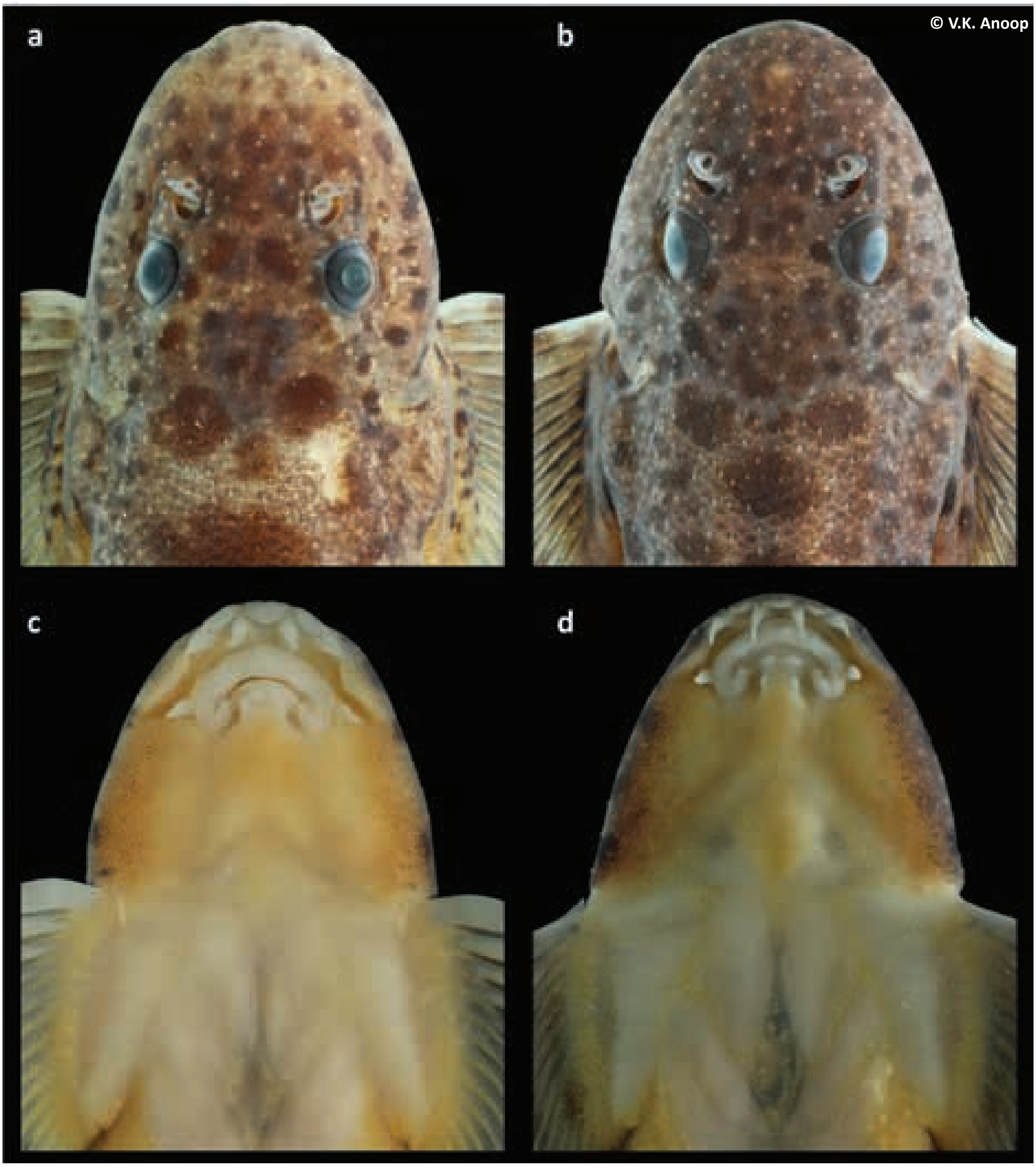

Image 3. Dorsal and ventral view of head: a, c—*Bhavania annandalei* | b, d—*B. australis*.

the two species clustered separately on the first two PCA axes (Fig. 2a). The clusters were significantly different from each other (ANOSIM, 9999 permutations, R = 0.2315, P = 0.0271) indicating that the species formed distinct clusters in multivariate space. While length-length relationships for most characters showed similar trends for both the species, there were two relationships that showed marked differences. Length-length relationship between caudal peduncle depth and width (Fig. 2b) suggested that width increased rapidly with increasing depth in the case of *B. annandalei* compared to *B. australis*. Similarly, length-length relationship between head length and head depth at nape (Fig. 2c) suggested that head depth increased rapidly with

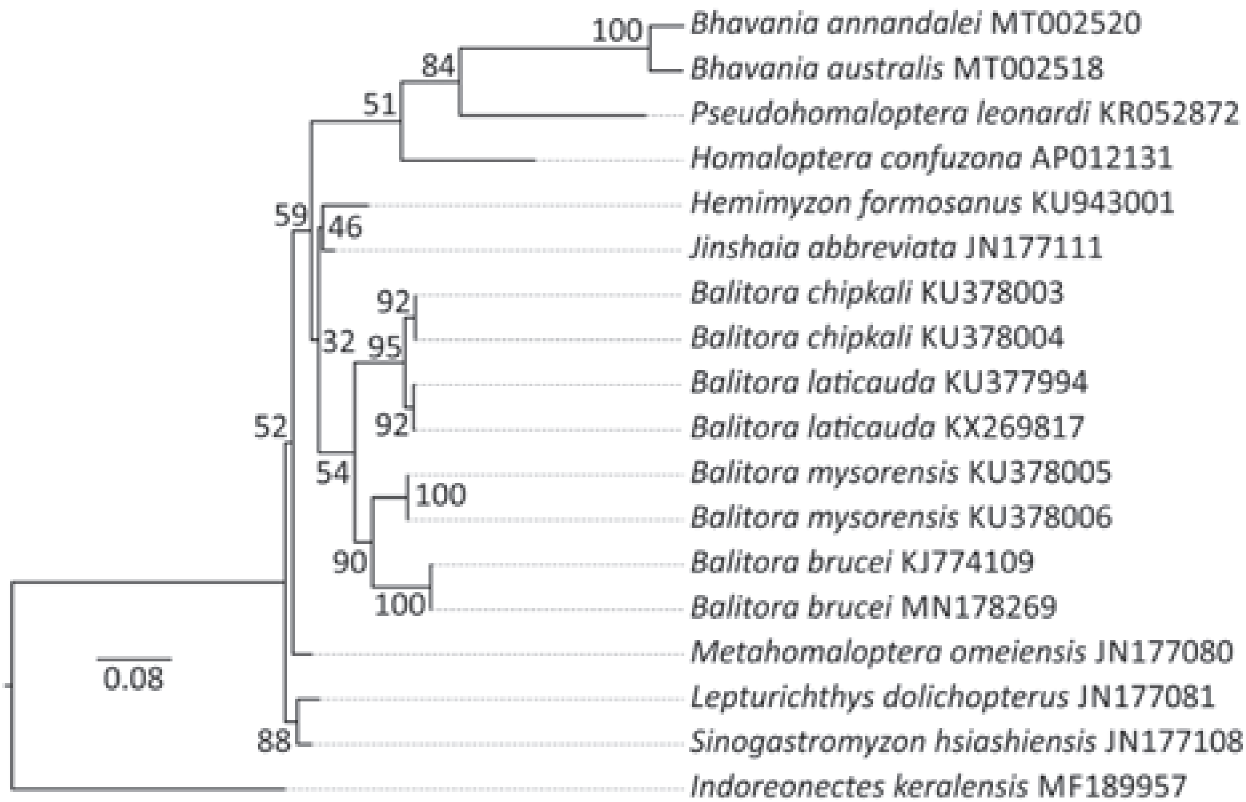

Figure 3. Maximum likelihood phylogenetic tree based on mitochondrial cytochrome oxidase subunit 1 gene using best partition scheme and model selection (lnL of consensus tree = -2631.97). *Indoreonectes keralensis* (Nemacheilidae) is used as an outgroup. Values along the nodes are percentage bootstraps based on 1,000 iterations.

increasing head length in the case of *B. annandalei* compared to *B. australis*.

Genetic analysis: Partition analysis and model selection identified separate nucleotide substitution models for all three codon positions, TNe+I for first codon, F81+F for second codon, TN+F+G4 for third codon position of *cox1* gene (BIC = 5570.419, lnL = -2633.96, df = 47). Maximum likelihood phylogenetic tree based on best partition scheme and model selection (Fig. 3) recovered *Bhavania annandalei* and *B. australis* as a clade sister to Southeast Asian congeners of Balitoridae. Topotypic *B. annandalei* (MT002520) differed from topotypic *B. australis* (MT002518) with a raw genetic distance of 6.4% in the *cox*1 gene.

Distribution: *Bhavania annandalei* is known with certainty from the Kallada, Vamanapuram, and Neyyar river systems in southern Kerala, India. These river systems drain the western slopes of the Agasthyamalai Hill ranges, south of the Shencottah Gap. It is highly likely that the species also occurs on the eastern slopes of the Agasthyamalai Hills particularly in the Tambaraparini River system in Tamil Nadu, but detailed surveys and voucher specimens are required to confirm this. In this context, we believe that previous records of *B. australis* from several tributaries of the Tambaraparini, Manimuthar, and Chittar draining the eastern slopes of the Agasthyamalai (Johnson & Arunachalam 2009), could most likely represent *B. annandalei*.

Remarks: The density of chromatophores in *Bhavania* is likely to be dependent on the micro-habitat as well as the colour and type of substratum it inhabits. Other ecological factors that may influence body colour are forest/canopy cover, intensity of light, turbidity, water flow and water temperature (V.K. Anoop pers. obs. 2018 and 2019). This is reflected in the different body colours shown by the two species in different habitats and locations (see Image 1), an observation which was also made by Hora (1941).

Comparative material: *Bhavania australis*, KUFOS.19.AS.BH.01.1–6, 6ex., 13.iv.2019, 10.8636N & 76.6904E, 46.4–58.8 mm SL, near Kavarakund falls, upstream of Malampuzha Reservoir, Kerala, India, coll. M.R. Ramprasanth.

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COMMUNICATION

Records of two toads *Duttaphrynus scaber* and *D. stomaticus* (Amphibia: Anura: Bufonidae) from southeastern India

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Abstract: We document two toad species *Duttaphrynus scaber* and *D. stomaticus* from southeastern India, in the Coromandel Coastal Plains. Owing to incorrect data presented in previous reports denoting the occurrence of these toad species, their occurrence in the said region has remained obscure. Our results, presented here, on both the species are based on morphological data from 15 preserved voucher specimens and direct field observations made by the authors in situ. In this work, we report *D. scaber* from Chengelpet and *D. stomaticus* from Thoothukudi. We revisited these places after studying the labeled specimens in Chennai Snake Park Trust Museum, to confirm their occurrences in the respective region and provide natural history notes based on our field observations.

Keywords: Chengelpet, Coromandel Coast, field sighting, India, morphology, toad, Thoothukudi (Tuticorin).

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For **Author details** see end of this article.

Author contribution: SRG and SKD conceived the work. SRG collected data for both the species dealt with; while MR, NAJ and AMJ collected data for one species. MR, NAJ and AMJ did most of the fieldwork, while SRG participated in some field tours. SRG studied the voucher materials, at least some of which were also perused by MR, NAJ and AMJ. SKD provided previous records from European and American museums and provided historical literature, besides advising this work overall. SRG and SKD led the writing in consultation with MR, NAJ and AMJ. All the authors equally participated in finalizing the write-up and read and approved the final version.

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INTRODUCTION

In amphibians, much of the diversity in the Indian peninsula is concentrated in the Western Ghats hill range (Biju 2001; Dinesh et al. 2009; Gururaja 2012), a global biodiversity hotspot covered with evergreen forests (Bossuyt et al. 2004). Other ecoregions in peninsular India are either under-surveyed or are depauperate in amphibian diversity (Dutta 1997; Daniels 2005; Gururaja 2012). Toads including species from the Indian peninsula were subjected to both morphological (Manamendra-Arachchi & Pethiyagoda 1998; Dubois & Ohler 1999) and molecular (Bocxlaer et al. 2009) reviews. But much of the above-mentioned studies better represent material from the Western Ghats and studies on toad species from southeastern India are largely lacking (Srinivasulu et al. 2013). Apart from the better-known, Common Indian Toad *D. melanostictus* (Schneider, 1799), two other species—the Dwarf Toad *D. scaber* (Schneider, 1799) and the Marbled Toad *D. stomaticus* (Lütken, 1864)—have been reported from the Coromandel Coastal Plains (Dutta 1997; Daniel 2002; Daniels 2005; Srinivasulu et al. 2013). Both morphological (Dubois & Ohler 1999) and molecular (Bocxlaer et al. 2009) studies revealed that *D. scaber*, *D. stomaticus*, and *D. melanostictus* all fall into different species groups of their own.

The type locality of *Duttaphrynus stomaticus* is Assam (Boulenger 1891; Dutta 1997). It is also known throughout the Indo-Gangetic floodplains from Aravallis up to Bengal, through the Terai belts of Nepal and Siwalik foothills and on to other places in northeastern India. South of this vast area, *D. stomaticus* is known from the Seoni Hills and Chota Nagpur Plateau and on to Salsette / Bombay in the Konkan Coast and eastwards in the Deccan Plateau (Dutta 1997; Daniel 2002; Deuti et al. 2014; Frost 2020). Further south, reports based on old museum collections (Dutta 1997) and a recent field sighting (Sondhi 2009) exist. Recently, Srinivasulu et al. (2013) recommended further studies on southern Indian *D. stomaticus* populations due to conflicting views about its presence there and some misidentified reports that were later falsified. They even mentioned the population referred to by Dutta (1997) from Tirunelveli Plains as *Duttaphrynus* cf. *stomaticus*.

Duttaphrynus scaber was first described from 'Orientali India' (= eastern India; Dutta 1997). It had, in fact, starting from the description of its synonym from Trivandrum (= *Bufo fergusoni*), has been better reported from western India, and not the eastern part of the peninsula (Frost 2020). In the adjacent island of Sri Lanka, *D. scaber* has remained relatively better-studied (Bogert & Senanayake 1966; Manamendra-Arachchi & Pethiyagoda 1998; Jayawardena et al. 2017), compared to India. Recently, Padhye et al. (2013) reported it from northern Western Ghats, based on both morphological and molecular data. But unfortunately, past reports of this species from Kadayam in southern Western Ghats foothills (Vijayakumar 2002), Chengelpet (Das & Martin 1998), and Mayiladuthurai (Ganesh & Chandramouli 2007; Nath et al. 2012) in Coromandel Coastal Plains were missed, although historical reports from nearby localities were mentioned (Boulenger 1892; Rao 1915). Puducherry was also added as another coastal plains site record for *D. scaber* (Seshadri et al. 2012 read with Srinivasulu et al. 2013).

Thus, reports from southeastern India of *D. scaber* fall short due to lack of voucher material (see Ganesh & Chandramouli 2007; Nath et al. 2012) while that of *D. stomaticus* falls short due to lack of recent field sightings with ample morphological descriptions (see Dutta 1997; Sondhi 2009). Adding on to this, some works have, sadly, confused the identities of *D. scaber* and *D. stomaticus*, again from the Coromandel Coastal Plains (Seshadri et al. 2012). All these factors, cumulatively, led Srinivasulu et al. (2013) to revisit such reports that were not based on collected voucher specimens accompanied with ample morphological description notes as well as recent field sightings in situ. The problem is further confounded by reports based on misidentifications (see Srinivasulu et al. 2013). In this paper, we present further records of *D. scaber* and *D. stomaticus* from southeastern India. Thus, though described in the 19th century, and often reported in many studies across the country (Dutta 1988, 1997), their occurrence in southeastern India, in the Coromandel Coastal Plains have remained murky. To fill up this lacuna, we describe the morphology and provide field observations for these two species based on both live and preserved materials originating from Coromandel Coastal Plains, in southeastern India.

METHODS

We conducted visual encounter surveys (Crump & Scott 1994) for collecting primary field data, both day and night. The sighted live individuals were gently restrained and examined, briefly measured and photographed in situ to enable unambiguous species identification, seen in light of publications dealt with by Srinivasulu et al. (2013). They were soon released after recording data and were not preserved and deposited in museums due to the want of permits. The preserved specimens already present in museum holdings were examined in detail. Measurements were recorded to the nearest mm using vernier calipers (least count 0.1mm). Morphological features were documented using a magnifying hand lens (X 5 optical zoom). Measurement protocols and morphometric nomenclature followed Dutta & Manamendra-Arachchi (1996). Colouration notes of live individuals were taken during field work and based on photographs taken there on. Photographs were taken using Canon Powershot SX-130IS model camera and some are reproduced here as photographic vouchers. Coromandel Coastal Plains Ecoregion definition follows Everard (2018). Habitat type classification follows Champion & Seth (1968). Museum abbreviation CSPT refers to Chennai Snake Park Trust, Chennnai, India. Geo-coordinates and elevation values were extracted from Google Earth software.

RESULTS

Taxonomy

***Duttaphrynus stomaticus* (Lütken, 1864)**
(Marbled Toad: Image 1)

Taxonomic history: This species was originally described as *Bufo stomaticus* by Lütken (1864). The type locality of this species is 'East India' (restricted to Assam, fide Boulenger 1891) and the type specimens are currently untraceable (Dutta 1997). There are currently three subjective junior synonyms (Dutta, 1997; Frost, 2020) namely: *Bufo pantherinus* (non Boie) Anderson, 1871, *Bufo andersoni* Boulenger, 1883 (type loc. Ajmere, Rajputana), *Bufo andersonii* Murray, 1884 (type loc. Thatta & Joongshai in Sind) and *Bufo stomaticus peninsularis* Rao, 1920 (type loc. Wattekole, Coorg, Mysore; status: incertae sedis). Bocxlaer et al. (2009) revised its generic allocation as *Duttaphrynus stomaticus*.

Material examined (n=7): CSPT/A-21, three adult males and four adult females, date and collector unknown, all collected from Tuticorin (8.764˚N & 78.136˚E; 5m), Coromandel Coastal Plains, peninsular India.

Description: Small to medium-sized toad; skin fairly smooth, often with blunt pustules; no ridges on top of head; tympanum ½ the size of eye, visible; parotid glands bean-shaped; fingers free; toes 35-45% webbed; relative finger lengths: 1=2<4<3; relative toe lengths: 1<2<5<3<4. Measurements (range in mm, juvenile's data in parenthesis): Snout to vent length: 35.0-43.0 (26.0), body width: 8.0–11.5 (5.0), axilla-groin distance: 20.0–24.5 (14.5), head length: 11.5–12.5 (8.5), head width: 7.0–8.0 (5.5), head depth: 4.0–8.5 (3.0), humeral length: 4.0–5.0 (2.5), radio-ulnar length: 4.0–5.0 (2.5), carpal length: 3.0–4.5 (2.0), femoral length: 7.0–8.5 (4.5), tibia length: 5.0–6.5 (3.5), metatarsal length: 4.5–6.0 (3.5), eye diameter: 2.0–3.0 (2.0), tympanum diameter: 0.5 (0.5), eye to nostril distance: 2.5–3.0 (2.0), eye to tympanum distance: 2.5–3.0 (2.0), eye to lip distance: 1.0 (0.5), internarial distance: 1.0–1.5 (0.5), interocular distance: 3.5–4.5 (2.5). Colouration: Dorsum dull ruddy brown, light yellow or dark brownish grey, with yellowish random wavy white spots and patterns; adult males with yellow, single, mid-gular vocal-sac; venter off-white with some dark markings; eyes yellow with a horizontally oval, black pupil.

Field observations: On 5 and 6 April 2015, we conducted night surveys (20.00–04.00 h) in Tuticorin for a total of 40 man hours (8hr x 5men). A total of five sightings, consisting of three adult males and two adult females were obtained. Individuals were sighted actively foraging on land, near paddy fields dotted with coastal scrub belts and grasslands. These short term observations require further field surveys to add more to our knowledge on the natural history of *D. stomaticus* in Tuticorin (also see Sondhi 2009).

***Duttaphrynus scaber* (Schneider, 1799)**
(Dwarf Toad: Image 2)

Taxonomic history: This species was first described as *Bufo scaber* Schneider, 1799 (type loc. ex orientali India). As this nomen was confused with *Bufo scaber* Daudin, 1803 (a synonym of *Bufo melanostictus* Schneider, 1799), it was also considered as a synonym of *D. melanostictus* till resurrection by Dubois & Ohler (1999). Again, Dubois & Ohler (1999) also synonymized the nominate taxon *Bufo fergusonii* Boulenger, 1892 (type locality - Trevandrum on the Cavalry Parade Ground) with *Bufo scaber* Schneider, 1799 (non Daudin, 1802). Bocxlaer et al. (2009) revised its generic allocation as *Duttaphrynus scaber* (also see Bogert & Senanayake 1966; Jayawardena et al. 2017).

Material examined (n=8): CSPT/A-19 four adult males, two subadult males and two adult females, date and collector unknown, all collected from Chengelpet (12.727˚N & 79.975˚E; 115m), Coromandel Costal Plains, peninsular India.

Description: Small-sized toad, with a rather depressed body, flat head, blunt snout and fairly slender limbs; skin very rough and warty with numerous pustules both dorsally and ventrally, larger pustules tipped with black keratinized point endings; distinct

Image 1. *Duttaphrynus stomaticus* CSPT/A-21 dorsal, ventral, lateral views. Live individuals and habitat. © S.R. Ganesh.

bony ridges on top of head; tympanum subequal to eye, visible; parotid glands rounded; fingers free; toes <25% webbed; relative finger lengths: 1=2<4<3; relative toe lengths: 1<2<3<5<4. Measurements (in mm): Snout to vent length: 40.0–47.0, body width: 8.0-11.5, axilla-groin distance: 19.0–26.0, head length: 12.5–14.0, head width: 8.0–9.0, head depth: 4.5–6.0, humeral length: 3.5–4.5, radio-ulnar length: 4.0–5.5, carpal length: 4.0–5.0, femoral length: 7.0–8.5, tibia length: 5.0–6.0, foot length: 5.0–6.5, eye diameter: 2.0–3.0, tympanum diameter: 1.0, eye to nostril distance: 3.0–3.5, eye to tympanum distance: 2.5–3.0, eye to lip distance: 1.5, internarial distance: 3.0–3.5, interocular distance: 3.5–4.0. Colouration: Dorsum dull ruddy brown, light

Image 2. *Duttaphrynus scaber* CSPT/A-19 dorsal, ventral, lateral views. Live individuals and habitat. © S.R. Ganesh.

yellow or dark brownish black; venter dirty white with some brownish minute specklings; adult males with yellow, single, mid-gular vocal sac; eyes yellow with a horizontally oval, black pupil.

Field observations: From diurnal (09.00–16.00 h) field surveys in Chengelpet by the first author during August 2013 and February 2014, for a period of 50 man hours, this species was sighted commonly. A total of 12 sightings consisting of six adult males (identified based on nuptial pads and gular sacs), four adult females and two juveniles (unsexed) were obtained. The toads were observed resting underneath rocks, debris and inside stone piles.

DISCUSSION

The current report of both the preserved voucher specimens and recent field observations attest to the fact that in deed both *D. scaber* and *D. stomaticus* are present in southeastern India. This means that three different species groups – *D. melanostictus* group, *D. scaber* group and *D. stomaticus* group are widely distributed in India (Dubois & Ohler 1999; Bocxlaer et al. 2009), with at least one species in each group. Recent records of *D. scaber* from northern Western Ghats by Padhye et al. (2013) stressed the fact that precise records are more from the Western Ghats, including historical record of Trevandrum (Boulenger 1892) and their report from Thrissur. As recent publications from southeastern India (Ganesh & Chandramouli 2007; Nath et al. 2012) are not based on voucher specimens, authors in general have not been unequivocal about the reports of *D. scaber* from southeastern India. The same holds true for *D. stomaticus* as well. In this case, despite it being absent in the adjacent and closely-affiliated Sri Lanka (Manamendra-Arachchi & Pethiyagoda 1998), previously this species has been reported from Tuticorin and Tirunelveli in the far south of India by Dutta (1997). Dutta (1997) in his compilation of exhaustive museum specimens of Indian frogs lodged worldwide reported *D. stomaticus* from Tuticorin and Tirunelveli based on Carnegie Museum specimens. But for this record, *D. stomaticus* has not been convincingly reported from anywhere in southern India (Srinivasulu et al. 2013). Our specimens studied here conformed to the topotypical *D. stomaticus* population (fide Choudhury et al. 2001; Jayaditya Purkayashta pers. comm.).

For a long while, only *D. melanostictus* has been thought to be the common species of toad widespread across India (Dutta 1997). Dutta (1988) provided scores of records of two more congeners–the same ones reported here–*D. scaber* and *D. stomaticus* from eastern peninsular India. Most records of *D. stomaticus* from peninsular India are scarce, e.g., in the Circar Coast (Dutta 1988; Mahapatro & Dash 1991), in the Konkan Coast (Daniel 2002), in the Deccan plateau (Srinivasulu & Das 2008) and in Western Ghats (Rao 1920). Most records are from the Northwestern Frontier (Sharma et al. 2011) and the Indo-Gangetic Plains (Grosjean & Dubois 2005), and eastwards to type locality–Assam and the northeast India in general (see Ahmed et al. 2009). Similarly, reports of *D. scaber* from India are from the Western Ghats (Boulenger 1892; Satyamurti 1967; Vijayakumar 2002; Ganesh & Asokan 2010; Padhye et al. 2013) and the Eastern Ghats (Thurston 1888; Satyamurti 1967; Srinivasulu & Das 2008; Ganesh & Asokan 2010; Ganesh et al. 2018), Deccan (Donahue & Daniel 1966), while a few reports exist from the Circar Coast (Dutta 1988) and Coromandel Coast (Rao 1915; Das & Martin 1998; Ganesh & Chandramouli 2007; Nath et al. 2012; Seshadri et al. 2012 read with Srinivasulu et al. 2013). A series of preserved specimens of both these species from southern India (Coimbatore, Srivilliputhur, Madurai near the Western Ghats foothills and Tuticorin near the coast) has been reported (Ganesh et al. 2020). But it has not been corroborated by field surveys that these toads exist in the regions mentioned. This work supplements existing records of *D. scaber* and *D. stomaticus* with voucher specimen descriptions and/or field observations made from under-reported areas in southeastern India.

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COMMUNICATION

Some rare damselflies and dragonflies (Odonata: Zygoptera and Anisoptera) in Ukraine: new records, notes on distribution, and habitat preferences

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Abstract: New records of 11 rare species of damselflies and dragonflies (*Calopteryx virgo*, *Lestes macrostigma*, *Nehalennia speciosa*, *Coenagrion scitulum*, *Ophiogomphus cecilia*, *Lindenia tetraphylla*, *Cordulegaster boltonii*, *Somatochlora arctica*, *Leucorrhinia albifrons*, *Leucorrhinia caudalis*, and *Selysiothemis nigra*) within Ukraine are given. Habitats and distribution of species within the country are briefly discussed. Breeding sites of *C. boltonii* within Ukraine is found for the first time and confirmed with larval material. *Somatochlora arctica* is recommended for inclusion in the next edition of the Red Data Book of Ukraine.

Keywords: Odonates, Red Data Book of Ukraine, stenobiotic species

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INTRODUCTION

Damselflies and dragonflies (Odonata: Zygoptera & Anisoptera) belong to a small order in the fauna of Ukraine; it comprises only 78 species (Gorb et al. 2000; Tytar 2007; Savchuk & Karolinskiy 2013; Bernard & Daraż 2015). Despite the rather scarce fauna, distribution of many species is poorly and unevenly studied. Some regions have a lot of information published on Odonata, while in other regions even the data on species compositions are fragmented. Consequently, the distribution and habitat preferences of rare species within Ukraine are still understudied and cannot be used for analysis of species' vulnerability.

This paper is aimed to publish new records of some rare Odonata in Ukraine; some of these species are included in the third edition of the Red Data Book of Ukraine (2009) or recommended to be included in the next edition of this book by other colleagues or by me.

MATERIAL AND METHODS

Collected material (imagoes, exuviae and larvae) is deposited in author's collection in the National Museum of Natural History of the National Academy of Sciences of Ukraine (further NMNH NASU). The larvae, exuviae, and imagoes are deposited in 85–95 % EtOH and pinned. Photographs of specimens were taken by author using Canon SX30SI (Images 1A, 1B, 6A, 7A, 10H) and Leica Z16 APO equipped with Leica DFC450 Digital Camera (Images 1C–E, 2A–D, 3A–C, 4A–C, 5A–F, 6B, 6C, 7B–F, 8A, 8B, 9A–D, 10A–D, I–K) in the I.I. Schmalhausen Institute of Zoology of the National Academy of Sciences of Ukraine, and subsequently processed with LAS Core 3.8 and Adobe Photoshop™ CS5 software. Photographs of some specimens and/or their distinguishing characters are given to confirm identification.

RESULTS AND DISCUSSION

Calopteryx virgo (Linnaeus, 1758)

This species is included in the Red Data Book of Ukraine (2009) and is relatively common in western regions of the country, but significantly rarer in Left-Bank Ukraine. Within Left-Bank Ukraine the species was registered only in a few locations in Kyiv, Chernihiv, Sumy, Luhansk, and Donetsk Regions (Zograf 1909; Sheshurak & Padalko 1996; Khrokalo 2000, 2004; Gorb et al. 2000; Matushkina 2006; Martynov 2010a). *Calopteryx virgo* is very rare in Donetsk and Luhansk Regions, and was previously known only by a few imagoes from two sites; stream in vicinity of Avdiivka town (48.136111N & 37.789722E) and Verhne Provallia River in vicinity of Provallia village (48.126389N & 39.809167E) (Zograf 1909; Martynov 2010a).

I registered new populations of the species within the highest part of Donetsk elevated area (Donetsk Ridge) (Image 1A–G) at the upper parts of Bulavina, Ol'hova and Khrustal'na Rivers. The rivers in these sections are covered with forest and represent rhithral or epipotamal zones with current velocity up to 0.7m/s (in some places absent, on rapids – up to 1.5m/s). The detailed description of the investigated section of Bulavina River, change of water temperature during the year and photos of habitats are given in previous articles (Martynov & Godunko 2013; Martynov 2013, 2014a).

Calopteryx virgo is relatively common only at Bulavina River. Imagoes were mainly recorded on small glades, up to 5–8 specimens at the same time; solitary specimens were regularly observed in shady forests and on water surface; larvae were registered at places with moderate current velocity, mainly near the banks on roots of black alder. Recorded population of *C. virgo* is the biggest known within southeastern Ukraine. Material from Ol'hova and Khrustal'na Rivers were sampled several times, and only some specimens of the species were registered. Moreover, many similar waterbodies of Donetsk Ridge can be considered as potential habitats for the species; they should be investigated in future.

Material and observations: Seven imagoes and one larva, Ukraine, Donetsk Region, vicinity of Debaltsevo urban settlement, border of Donetsk and Luhansk Regions, Bulavyna River in the forest, 48.315286N & 38.436253E, Martynov A.V., 18.vii.2010; more than 15 imagoes, ibid, Martynov A.V., 19.vii.2011; five imagoes and two larvae, ibid, Martynov A.V., 20.08.2010; four imagoes and one larva, ibid, Martynov A.V., 11.vi.2010; six imagoes and one larva, ibid, Martynov A.V., 1.viii.2010; one larva, ibid, Martynov A.V., 13.iii.2010; one larva, ibid, Martynov A.V., 17.iv.2010; one larva, ibid, Martynov A.V., 1.viii.2010; one larva, ibid, Martynov A.V., 19.ix.2010; one larva, ibid, Martynov A.V., 17.x.2010; two larvae, ibid, Martynov A.V., 13.xi.2010; one larva, ibid, Martynov A.V., 20.xi.2011.

Two larvae, Ukraine, Luhansk Region, vicinity of Ivanivka urban settlement, 2km toward NE from urban settlement, Ol'hova River, 48.252879N & 38.974304E, Martynov A.V., 30.iv.2012.

One larva, Ukraine, Luhansk Region, vicinity of Khrustalnyi village, Khrustal'na River, 48.183883 &

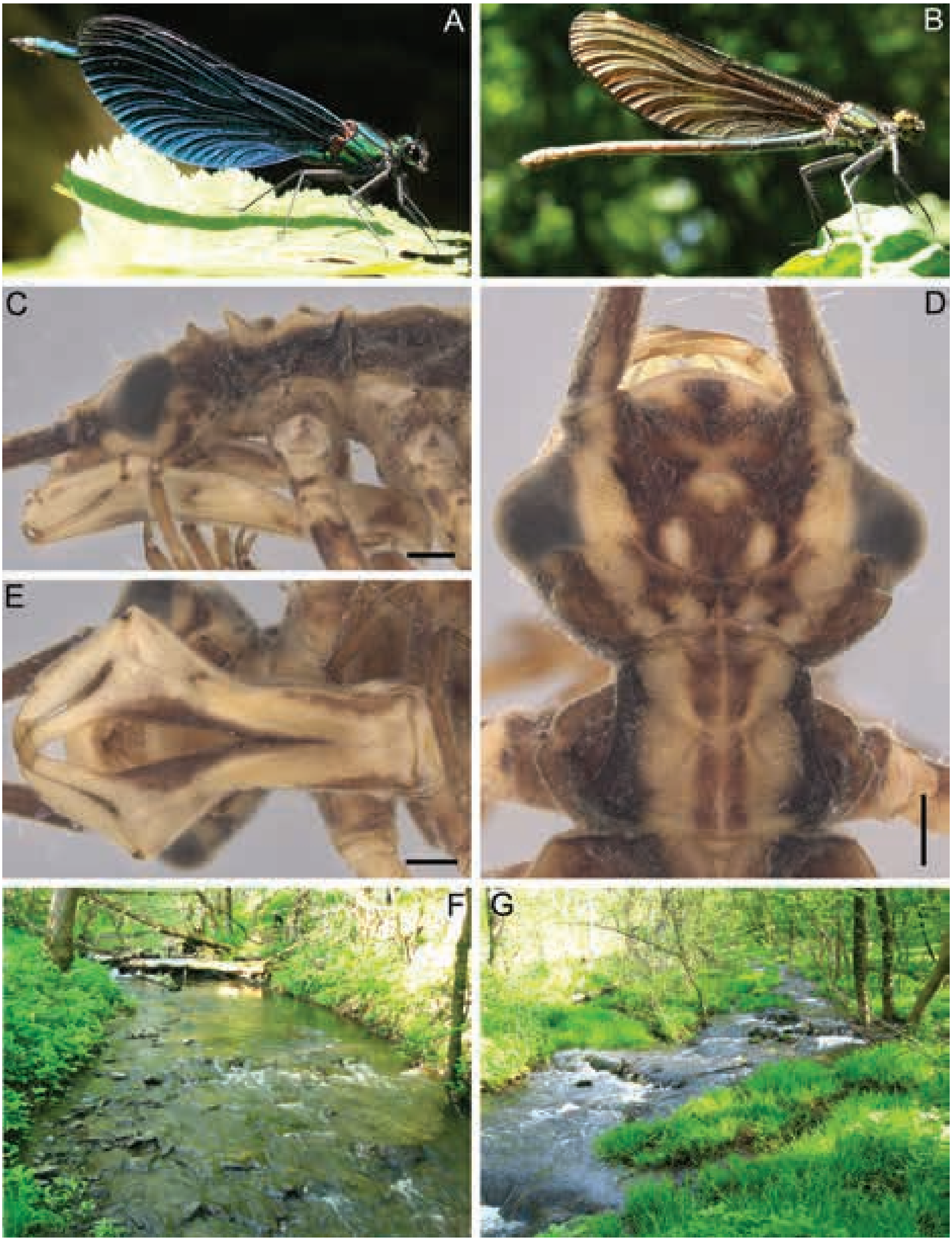

Image 1. *Calopteryx virgo* (Linnaeus, 1758), imago (A, B), larva (C–E), habitats (F, G): A—male | B—female | C—head and pronotum, lateral view, scale 0.5mm | D—head and pronotum, dorsal view, scale 0.5mm | E—mask, ventral view, scale 0.5mm | F—Ol'hova River, vicinity of Ivanivka urban settlement, Luhansk Region (30.iv.2012) | G—Khrustal'na River, vicinity of Khrustalnyi village, Luhansk Region (30.iv.2012). © Alexander V. Martynov.

38.878600, Martynov A.V., 30.iv.2012.

***Lestes macrostigma* (Eversmann, 1836)**

This locally distributed species inhabits mainly brackish continental and seaside waterbodies. Distribution of *L. macrostigma* is poorly studied in Ukraine; it is known from a few places in Odesa, Mykolaiv, Kherson, Vinnutsya, Kirovohrad, Khmelnytskyi, Chernihiv, Kharkiv, Donetsk Regions, and Crimea (Rodzyanko 1895; Gorb et al. 2000; Dyatlova 2006; Matushkina 2006; Martynov & Martynov 2007(2008); Martynov 2010a; Savchuk & Karolinskiy 2013; Smirnov & Tarasenko 2017). Presence of the species in some regions needs confirmation because of old and/or doubtful records. On the other hand, the southern regions of Ukraine have numerous waterbodies suitable for breeding of the species, therefore I am sure that *L. macrostigma* is more widely distributed in Ukraine than expected.

I recorded several new breeding locations of *L. macrostigma* in Zaporizhzhya, Dnipropetrovsk, and Kherson Regions (Image 2A–H) at Tashchenak River, Malyi Utluk River, Lyman Lake and unnamed pound near Syvash Lake. Most of these waterbodies are brackish. Species prefer dry riparian areas. At Taschenak River the species was most numerous, with thousands of specimens recorded; females oviposited eggs in trunks of *Bolboschoenus maritimus* (L.) Palla.

Material and observations: Six imagoes, Ukraine, Dnipropetrovsk Region, vicinity of Bulahovka village, dried part of salt Lyman Lake, 48.630584N & 35.657207E, Martynov A.V., 20.vi.2012.

Few imagoes, Ukraine, Zaporizhzhya Region, vicinity of Mala Ternivka village, pond on Malyi Utluk River, 46.582887N & 35.201294E, Martynov A.V., 24.vi.2019.

Hundreds of imagoes, Ukraine, Zaporizhzhya Region, vicinity of Radionivka village, temporary drying up area near the banks of Tashchenak River, 46.673468N & 35.239565E, Martynov A.V., 20.vi.2019.

Thousands of imagoes, Ukraine, Zaporizhzhya Region, vicinity of Radionivka village, temporary drying up area near the banks of Tashchenak River, 46.668631N & 35.25462E, Martynov A.V., 20.vi.2019.

Few imagoes, Ukraine, Zaporizhzhya Region, vicinity of Davydivka village, upper part of Utlyukskyi Estuary, temporary drying up areas near the bank, 46.511196N & 35.192460E, Martynov A.V., 26.vi.2019.

Few imagoes, Ukraine, Zaporizhzhya Region, vicinity of Kyrylivka village, channel and small temporary waterbody, 46.437174N & 35.441674E, Martynov A.V., 30.vi.2019.

Three imagoes, Ukraine, Kherson Region, vicinity of Strohanivka village, unnamed pound near Syvash Lake, 46.234207N & 33.874605E, Martynov A.V., 19.vii.2019.

***Coenagrion scitulum* (Rambur, 1842)**

This is a rare species in Ukraine; known from a few sites within Crimea, Odesa, Mykolaiv, Kherson, Chernihiv and Donetsk Regions (Polischuk 1964, 1974; Sheshurak & Padalko 1996; Dyatlova 2006; Khrokalo et al. 2009; Khrokalo & Prokopov 2009; Martynov & Martynov 2009; Stepoviy 2018). According to Pavlyuk (1973), the record of *C. scitulum* larvae from Kherson Region is doubtful; record of the species from Chernihiv Region should also be considered as doubtful. Here, I present a new record of the species within Donetsk Region; one imago was recorded on the bank of small lentic seasonal waterbody at Belosarayskaya spit (Image 3A–D). This record without information on concrete locality coordinates and data of collecting was mentioned in Martynov (2010b).

Material: One imago, Ukraine, Donetsk Region, vicinity of Yalta village, Belosarayskaya spit, small lentic periodically drying waterbody, 46.920647N & 37.312413E, Martynov A.V., 7.vii.2008.

***Nehalennia speciosa* (Charpentier, 1840)**

This species is the smallest odonate among European taxa. *Nehalennia speciosa* is locally distributed within all Europe and locally extirpated in many locations previously recorded as habitats (Bernard & Wildermuth 2005; Dijkstra 2006). Known few habitats of the species in Ukraine are situated within northern, western and eastern regions mainly; in most southern locations of the country (Crimea, Odesa, and Kherson Regions) the species is considered as locally extirpated (Polischuk 1974, Gorb et al. 2000; Khrokalo & Nazarov 2008; Khrokalo & Prokopov 2009; Tytar 2009, 2019; Dyatlova & Kalkman 2008; Karolinskiy 2013; etc.). *Nehalennia speciosa* was recommended for being included to the Red Data Book of Ukraine by Khrokalo (2005).

New breeding sites of *N. speciosa* were found in Rivne Region within Rivnenskyi Nature Reserve (Image 4A–E). The species inhabits waterbodies on sphagnum bogs (marshes) in all locations, except for two places where species inhabits deep lakes (Bile Lake and Black Lake) with banks overgrown with wide dense cushions of floating sphagnum. Depth of the lakes near the floating banks is about 2–3 m. Also, species was registered at small, relatively shallow natural waterbodies (area up to 20m^2; depth – about 0.5m) on sphagnum bog and at old artificial waterbodies (area – up to 150m^2; depth – up to 1.2m) on the same kind of bog. Moreover, the biggest number of specimens was recorded at the old

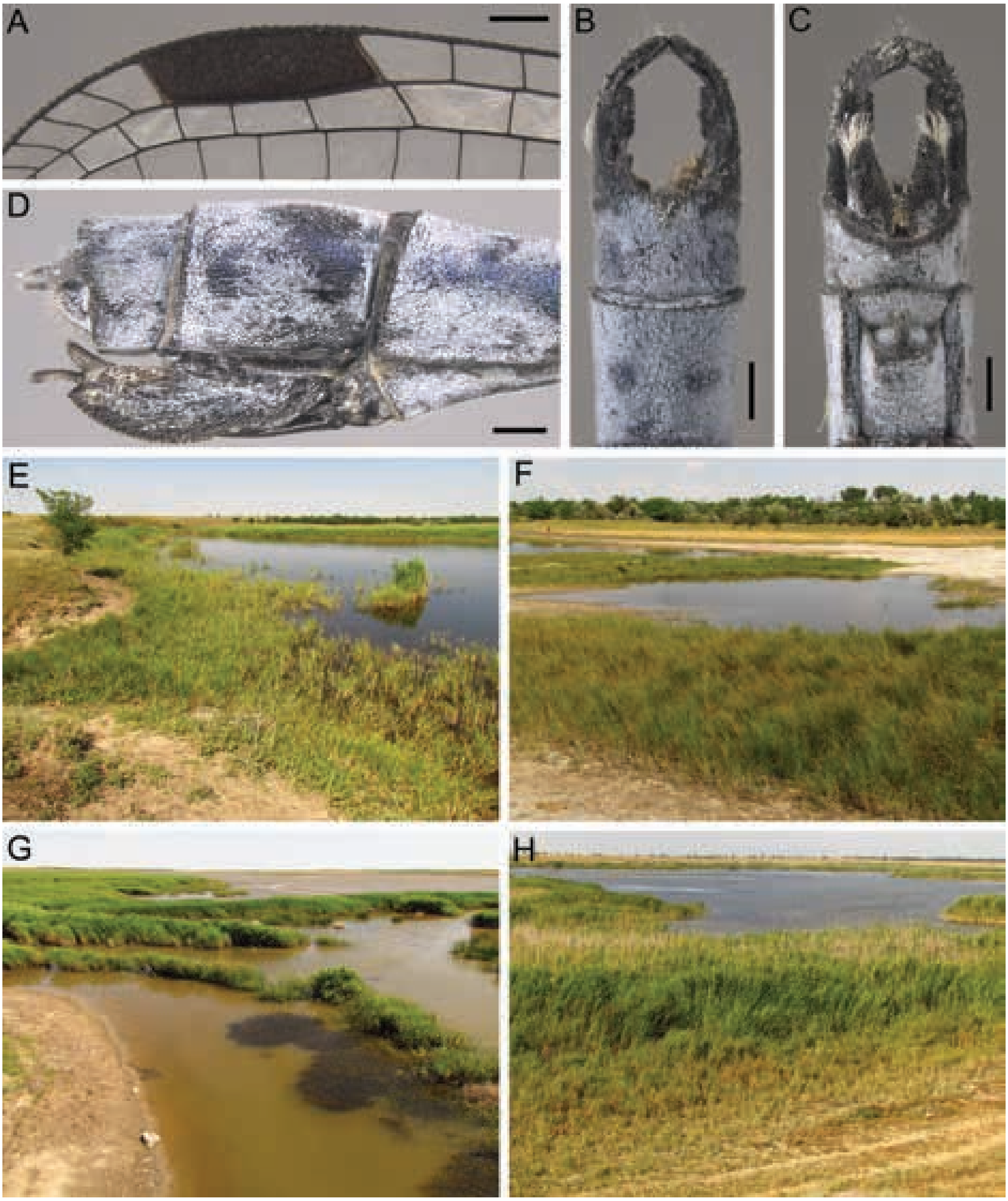

Image 2. *Lestes macrostigma* (Eversmann, 1836), imago (A–D) and habitats (E–H): A—pterostigma, scale 0.5mm | B—male, apex of abdomen, dorsal view, scale 0.5mm | C—male, apex of abdomen, ventral view, scale 0.5mm | D—female, apex of abdomen, lateral view, scale 0.5mm | E, F—Tashchenak River, vicinity of Radionivka village, Zaporizhzhya Region (20.vi.2019) | G—upper part of Utlyukskyi Estuary, vicinity of Davydivka village, Zaporizhzhya Region (26.vi.2019) | H—unnamed pound near Syvash Lake, vicinity of Strohanivka village, Kherson Region (19.vii.2019). © Alexander V. Martynov.

artificial waterbodies (up to 25–30 specimens at 10 m of a bank length); in all other points the number of specimens was much lower. It should be noted, that that due to significant age these artificial waterbodies didn't differ from the natural waterbodies in water parameters, vegetation, and appearance. Diapason of some parameters of waterbodies in collecting places was water hardness 9–16 ppm, pH 5.1–6.4.

Material and observations: 19 imagoes, Ukraine, Rivne Region, vicinity of Khmil' village, Bile Lake on sphagnum marsh, 51.479283N & 27.311233E, Martynov A.V., 3,6.vii.2017; 12 imagoes, emerging, copulation, ibid, Martynov A.V., 8.vi.2018; 8 imagoes, ibid, Martynov A.V., 12.vi.2019; five imagoes, emerging, ibid, Martynov A.V., 13.vi.2020.

Five imagoes, Ukraine, Rivne Region, vicinity of Khmil' village, Lysots'ke (Chorne) Lake on sphagnum marsh, 51.477505N & 27.306219E, Martynov A.V., 12.vi.2019; 3 imagoes, emerging, ibid, Martynov A.V., 13.vi.2020.

Several hundreds of imagoes, copulation, Ukraine, Rivne Region, vicinity of Khmil' village, artificial lentic waterbody on sphagnum marsh, near the forest road Bil's'k – Khmil', 51.492215N & 27.291293E, Martynov A.V., 4.vii.2017; about 50 imagoes, emerging, ibid, Martynov A.V., 13.vi.2020.

Eight imagoes, Ukraine, Rivne Region, vicinity of Hrabun' village, Rivne Nature Reserve, waterbodies on sphagnum marsh, 51.538117N & 27.189650E, Martynov A.V., 7.vi.2018.

Ophiogomphus cecilia (Fourcroy, 1785)

Rare species included to the Red Data Book of Ukraine (2009). It is locally distributed within Zakarpattya, Ivano-Frankivsk, Lviv, Volyn, Ternopil, Odesa, Vinnytsia, Kyiv, Chernihiv, Sumy, and Kharkiv Regions (Polischuk 1974; Sheshurak & Padalko 1996; Gorb et al. 2000; Khrokalo 2000; Ridei et al. 2007; Tytar 2009; Khrokalo & Verves 2009; Kolozsvári et al. 2015; Zamoroka et al. 2017; Kuzemko 2017; Smirnov 2017, 2018; Novosad 2018; Sheshurak et al. 2018; Shulga 2019, etc.). Some

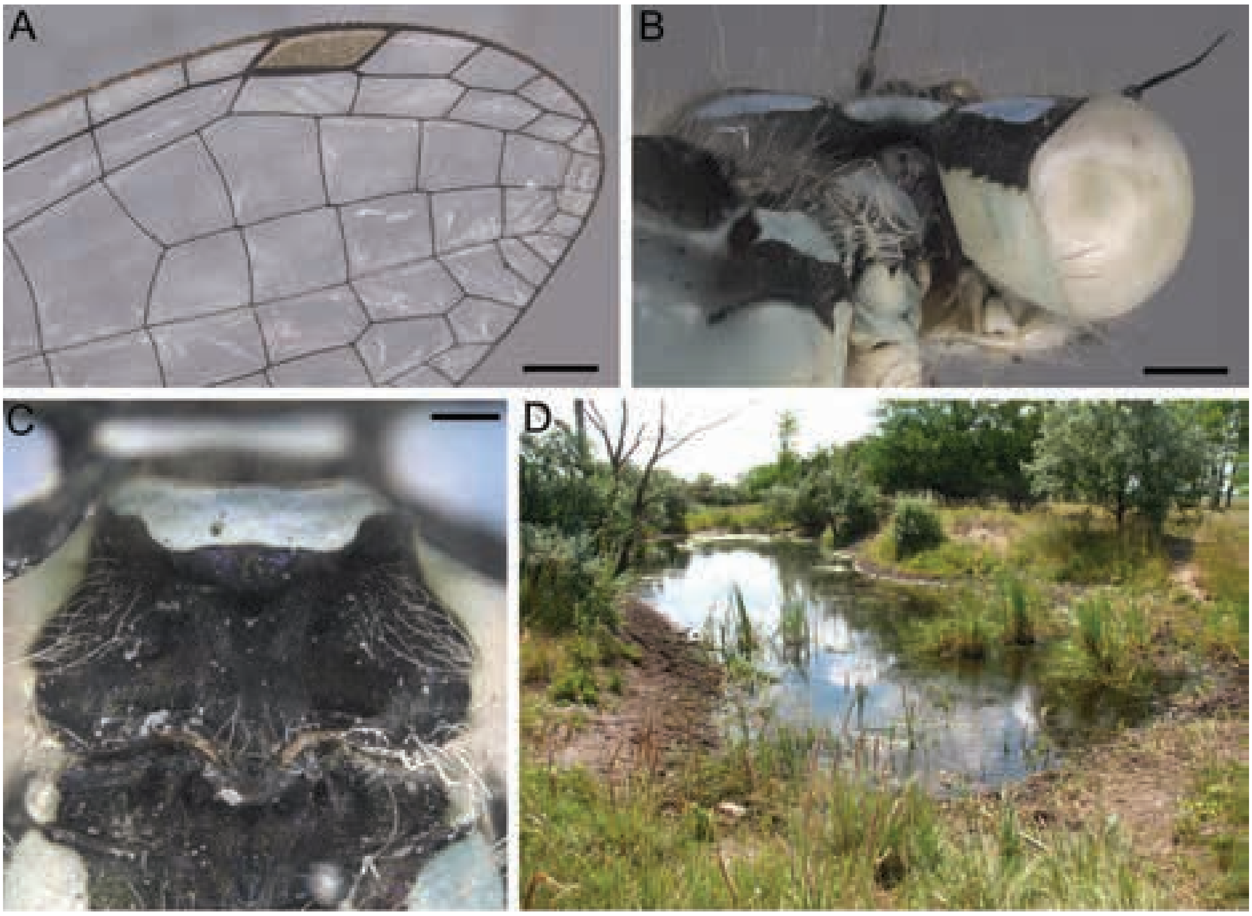

Image 3. *Coenagrion scitulum* (Rambur, 1842), female imago (A–C) and habitat (D): A—apex of wing, scale 0.5mm | B—head, back view, scale 0.5mm | C—pronotum, dorsal view, scale 0.5mm | D—small lentic periodically drying waterbody, vicinity of Yalta village, Donetsk Region (07.vii.2008). © Alexander V. Martynov.

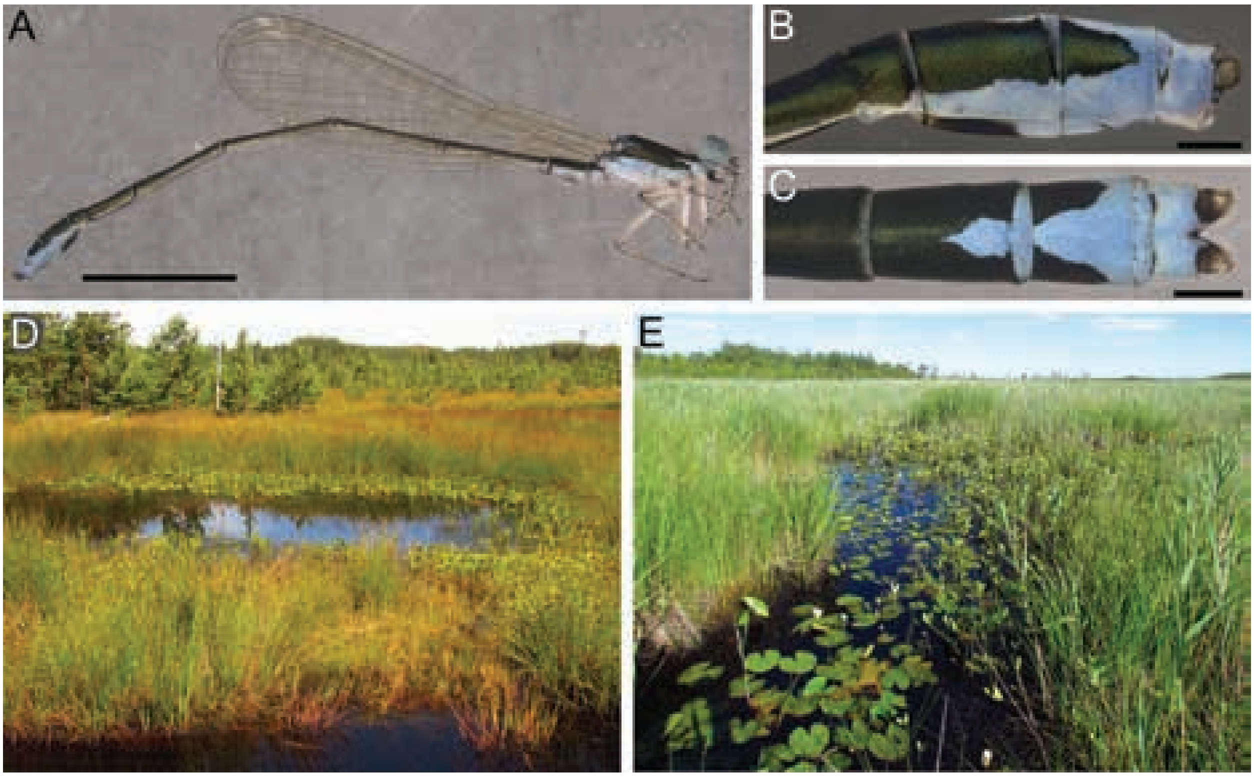

Image 4. *Nehalennia speciosa* (Charpentier, 1840), male imago (A–C) and habitats (D, E): A—total lateral view, scale 5mm | B—apex of abdomen, lateral view, scale 0.5mm | C—apex of abdomen, dorsal view, scale 0.5mm | D—artificial lentic waterbody on sphagnum marsh, vicinity of Khmil' village, Rivne Region (04.vii.2017) | E—waterbody on sphagnum marsh, vicinity of Hrabun' village, Rivne Region (07.vi.2018). © Alexander V. Martynov.

records on the species, however, are old, and need confirmation, as a result the adequate picture of species distribution within Ukraine could not be composed. All records of the species in Crimea refer to the larval stage only (Kiseleva & Vasyuta 1984), they are questionable and need confirmation (Khrokalo & Prokopov 2009).

I recorded the species in Horyn', Stvyga, Styr, and Sluch Rivers within Rivne Region, in the basin of Prypiat River (Image 5A–H). Larvae of the species were collected from bottom at microhabitats with sand in the rivers, sometimes with small stones or/and pieces of bog iron ore (in some cases bottom was just slightly silted), current velocity was about 0.2–0.3 m/s. These localities seem to be the most typical habitat for the species (Dijkstra 2006). The diapason of some parameters of waterbodies at collection sites were water hardness 43–210 ppm, pH 6.5–8.9. In my opinion, further investigations on similar rivers within northern Ukraine may reveal new habitats of *O. cecilia*.

Material and observations: One larva, Ukraine, Rivne Region, vicinity of Zbuzh village, Horyn' River, 50.990300N & 26.320683E, 154m , Martynov A.V., 07.vii.2017;

One larva, Ukraine, Rivne Region, vicinity of Poznan' village, Stvyga River, 51.591450N & 27.477868E, 139m, Martynov A.V., 05.vii.2017

One larva, Ukraine, Rivne Region, vicinity of Khmil' village, Stvyga River, 51.461417N & 27.387817E, 144m, Martynov A.V., 06.vi.2018.

One imago, Ukraine, Rivne Region, Stvyga River, between Glynne and Poznan' villages, 51.563133N & 27.428250E, 147m, Martynov A.V., 08.vi.2018; 1 imago, ibid, Martynov A.V., 12.vi.2019; 2 larvae, ibid, Martynov A.V., 15.viii.2019.

One imago, Ukraine, Rivne Region, vicinity of Poznan' village, Stvyga River, 51.60641N & 027.48431E, Martynov A.V., 12.vi.2019.

Two larvae, Ukraine, Rivne Region, vicinity of Sarny town, Sluch River, 51.317445N & 26.635826E, 148m, Martynov A.V., 02.viii.2017.

One exuvia, Ukraine, Rivne Region, vicinity of Mayunychi village, Styr River, 51.251447N & 25.946012E, Martynov A.V., 12.vi.2020.

Lindenia tetraphylla (Vander Linden, 1825)

The species was recorded at Crimea in 2009. It was the first record of the species from Ukraine (Savchuk & Karolinskiy 2013). Later, *L. tetraphylla* was found

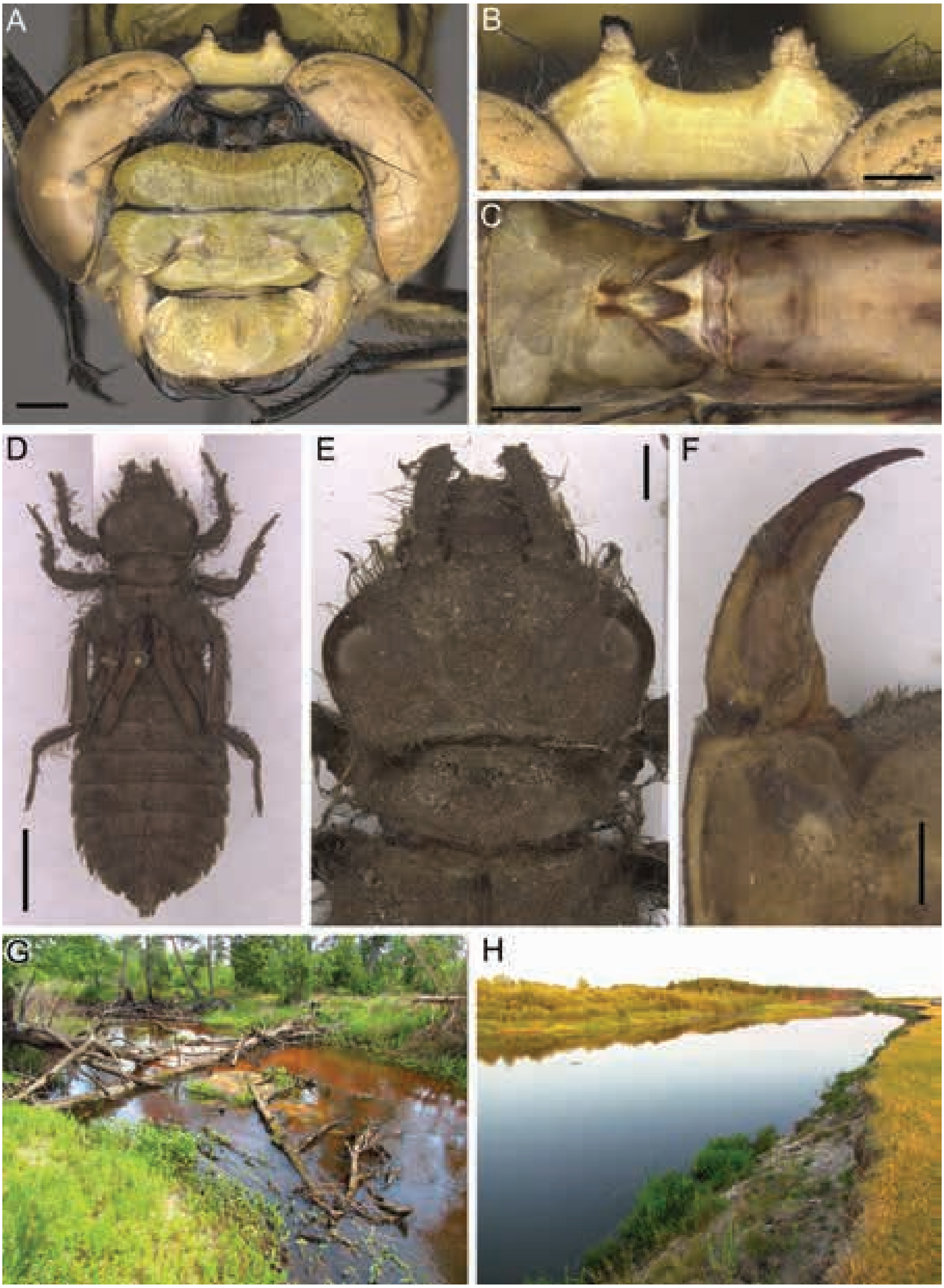

Image 5. *Ophiogomphus cecilia* (Fourcroy, 1785), female imago (A–C), larva (D–F), habitats (G, H): A—female, head, frontal view, scale 1mm | B—female, horns on head, frontal view, scale 0.5mm | C—female, valvular vulvae, scale 1mm | D—total dorsal view, scale 5mm | E—head and pronotum, dorsal view, scale 1mm | F—labial palp, dorsal view, scale 0.5mm | G—Stvyga River, between Glynne and Poznan' villages, Rivne Region (08.vi.2018) | H—Sluch River, vicinity of Sarny town, Rivne Region (02.viii.2017). © Alexander V. Martynov.

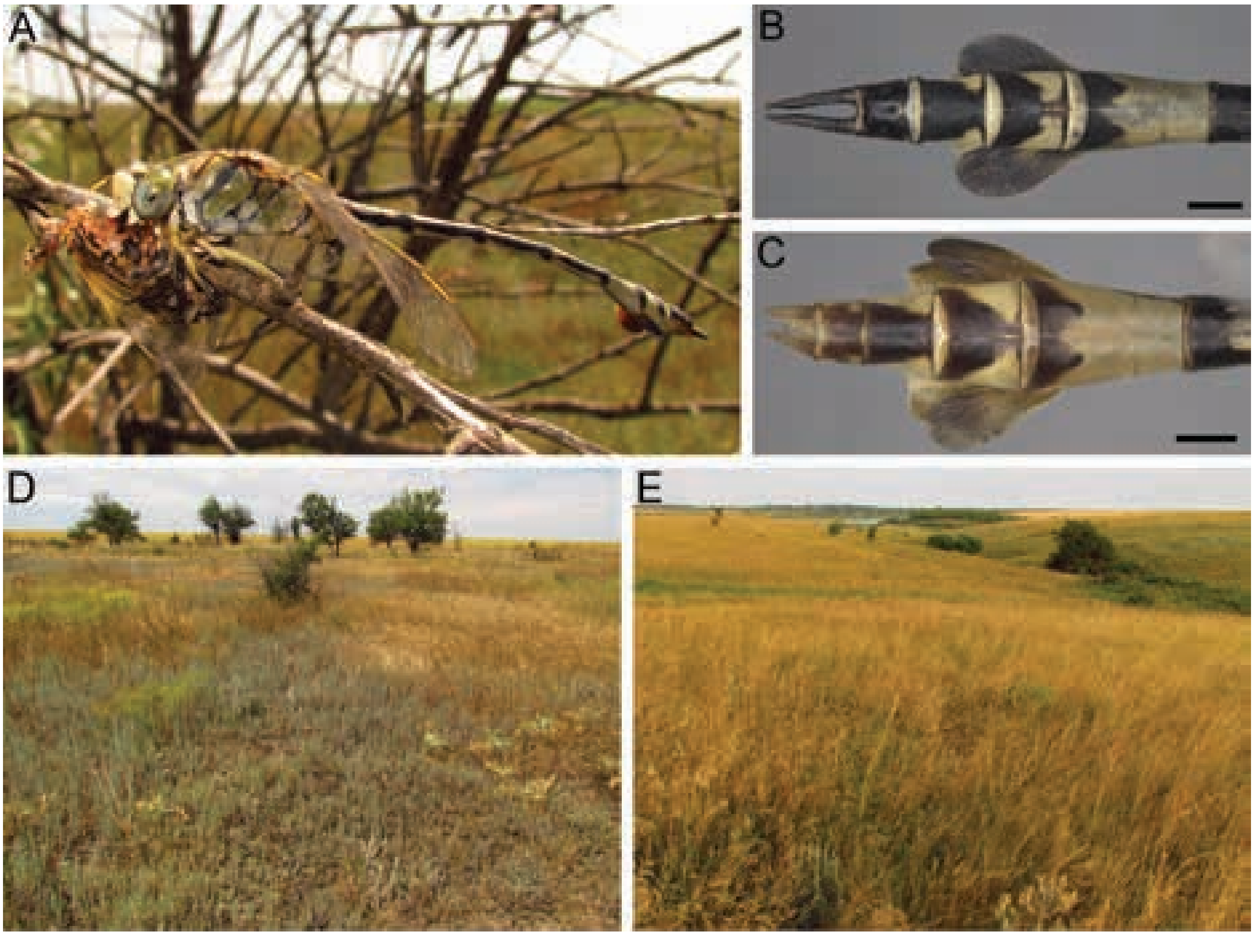

Image 6. *Lindenia tetraphylla* (Vander Linden, 1825), imago (A–C) and habitats (D, E): A—male with a prey | B—male, apex of abdomen, dorsal view, scale 2mm | C—female, apex of abdomen, dorsal view, scale 2mm | D—steppe area near upper part of Utlyukskyi Estuary, vicinity of Davydivka village, Zaporizhzhya Region (18.vi.2019) | E—steppe area near Malyi Utluk River, vicinity of Mala Ternivka village, Zaporizhzhya Region (19.vi.2019). © Alexander V. Martynov.

within Donetsk Region (Martynov 2014b). I registered imagoes of the species in a few places within southern Zaporizhzhia. Imagoes were recorded on steppe areas near Malyi Utluk River and Molochnyi Estuary, where they hunted for different insects (Image 6A–E). *Lindenia tetraphylla* was abundant in the region, up to seven specimens were registered on some areas. Larvae of the species are associated with lakes and slow-flowing rivers, therefore, the development of *L. tetraphylla* in regional waterbodies (e.g., Malyi Utluk River, Tashchenak River, Utlyukskyi Estuary) is quite possible. In my opinion the species possibly occurs in Odesa, Kherson, and Mykolaiv Regions.

Material and observations: Seven imagoes, Ukraine, Zaporizhzhya Region, vicinity of Davydivka village, steppe areas near upper part of Utlyukskyi Estuary, 46.517917N & 35.186437E and 46.506342N & 35.178574E, Martynov A.V., 18.vi.2019

Five imagoes, Ukraine, Zaporizhzhya Region, vicinity of Lymans'ke village, steppe area near Molochnyi Estuary, 46.427449N & 35.343673E, Martynov A.V., 21.vi.2019.

Four imagoes, Ukraine, Zaporizhzhya Region, vicinity of Mala Ternivka village, steppe area near Malyi Utluk River, 46.566884N & 35.197273E, Martynov A.V., 19.vi.2019.

Three imagoes, Ukraine, Zaporizhzhya Region, vicinity of Mala Ternivka village, steppe area near Malyi Utluk River, 46.583020N & 35.199763E, Martynov A.V., 24.vi.2019.

Six imagoes, Ukraine, Zaporizhzhya Region, vicinity of Shelyuhy village, steppe area near Malyi Utluk River, 46.546087N & 35.202348E, Martynov A.V., 24.vi.2019.

***Cordulegaster boltonii* (Donovan, 1807)**

The species is very rare in Ukraine and is included in the Red Data Book of Ukraine (2009). The species was previously known from Ukraine from several records (mainly imagoes) from Chernivtsi, Ivano-Frankivsk, Kyiv Chernihiv, Sumy, Donetsk and Volyn Regions (Brauner 1910; Gorb 1991; Sheshurak & Berest 2003; Sheshurak & Parkhomenko 2005; Red Data Book 2009; Kavurka et al. 2018; Sheshurak et al. 2018; Kyselyuk et al. 2018; Viter 2018). The distribution features of *Cordulegaster* within Ukraine suggest that any record of the genus within Donetsk Region (Viter 2018), whose Odonata fauna is well investigated, is doubtful and needs confirmation by the material. It should be noted that few years ago *Cordulegaster heros* Theischinger, 1979 was recorded from Ukraine (Chernivtsi Region) for the first time (Bernard & Daraż 2015). Furthermore, the correctness of Brauner's (1910) identification is doubtful, but can't be checked because the material was lost; the morphological proximity of *C. heros* and *C. boltonii* could cause misidentifications, especially considering the fact that *C. heros* was still undescribed in the early 20th century (Bernard & Daraż 2015). The record of *C. boltonii* from Ivano-Frankivsk Region given by Kyselyuk et al. (2018) is considered doubtful because of the similarity of two species mentioned above and available data on distribution of species within Ukraine. Unfortunately, the specimen mentioned in the article is absent in the collection of the authors (Slobodyan O.M., pers. comm. 2020). According to Gorb (1991), only known records of *C. boltonii* larvae from the territory of Ukraine (Tal' River, Kyiv Region) (Trylis 1988) are unreliable because the material was lost. The investigations carried out at Tal' River in the vicinity of Rudnya-Shpylivs'ka village in January 2020 did not reveal any larvae of *Cordulegaster*; further investigations of the river will be continued.

I recorded larvae of *C. boltonii* in Mohylivka River within Zhytomyr Region (Image 7A–G). This is the first confirmed record of the species' larvae within country. Investigated section of the river had riparian vegetation, and was shallow (depth up to 0.5m, but mainly about 0.2m), with numerous small bays; with current velocity up to 0.2–0.3 m/s, but mainly with standing water; sandy bottom was covered with detritus, leaf litter and branches; the bottom was presented with only sand in some sections of the main stream. Larvae were collected in bays, from a thick layer of detritus. The additional parameters of waterbodies in collecting places measured during the sampling were—water temperature 16°C, water hardness 47ppm, pH 8.5.

Material and observations: Three larvae, Ukraine, Zhytomyr Region, vicinity of Verbivka village, Mohylivka River, 50.706248N & 27.591347E, Martynov A.V., 21.ix.2018.

***Somatochlora arctica* (Zetterstedt, 1840)**

This species is very rare within Ukraine. For a long time, it was known only by almost 100-year old records from Zhytomyr Region (Gorb et al. 2000). Only in 2006 and 2007 this species was recorded within Poliskyi and Rivnenskyi Nature Reserves (Zhytomyr and Rivne Regions) (Khrokalo & Nazarov 2008; Martynov & Martynov 2009). *Somatochlora arctica* was known by a few imagoes only from both reserves, but the development of the species at the swamps of the protected areas is doubtless. Previously, the species was recorded from two sites within Rivnenskyi Nature Reserve in Bil's'k forestry in 2006 (Martynov & Martynov 2009) 51.491731N & 27.243597E and 51.477513N & 27.249568E (approximate coordinates). During further fieldworks within this reserve, I have got new records of the species from Bil's'k, Pivnichne, and Biloozers'ke forestries (Image 8A–E).

Material and observations: Two imagoes, Ukraine, Rivne Region, vicinity of Bil's'k village, small lake in the forest on the margin of *Sphagnum* bog, 51.493833N & 27.255117E, Martynov A.V., 23.v.2017.

Two imagoes, Ukraine, Rivne Region, vicinity of Bil's'k village, artificial lentic waterbodies (ditches) along forest road Bil's'k – Khmil', 51.472883N & 27.265267E and 51.484933N & 27.278117E, Martynov A.V., 23.v.2017.

Two imagoes, Ukraine, Rivne Region, vicinity of Khmil' village, Bile Lake on *Sphagnum* marsh, 51.479283N & 27.311233E, Martynov A.V., 23.v.2017.

One imago, Ukraine, Rivne Region, vicinity of Perebrody village, glade near drainage channel, 51.689947N & 27.086134E, Martynov A.V., 26.v.2017.

One imago, Ukraine, Rivne Region, vicinity of Rudka village, black-eared swamp, tributary of Berezyna River, 51.486267N & 25.709517E, Martynov A.V., 02.viii.2017.

For now, Rivnenskyi Nature Reserve is the territory with the highest number of records of *S. arctica* within Ukraine. The main reason of species' rarity and local distribution within Ukraine is the disappearance of waterbodies suitable for species' development, namely sphagnum and sphagnum-sedge bogs. The disappearance of these bogs is caused by—(i) ameliorative measures; (ii) decrease in the annual rainfall in Polissia, which leads to the drying up of bogs; and (iii) large volumes of illegal amber production in the region, which leads to the complete destruction of the necessary microhabitats and/or waterbodies suitable for the development of *S. arctica*. Therefore, I think that this species should be considered for inclusion in the

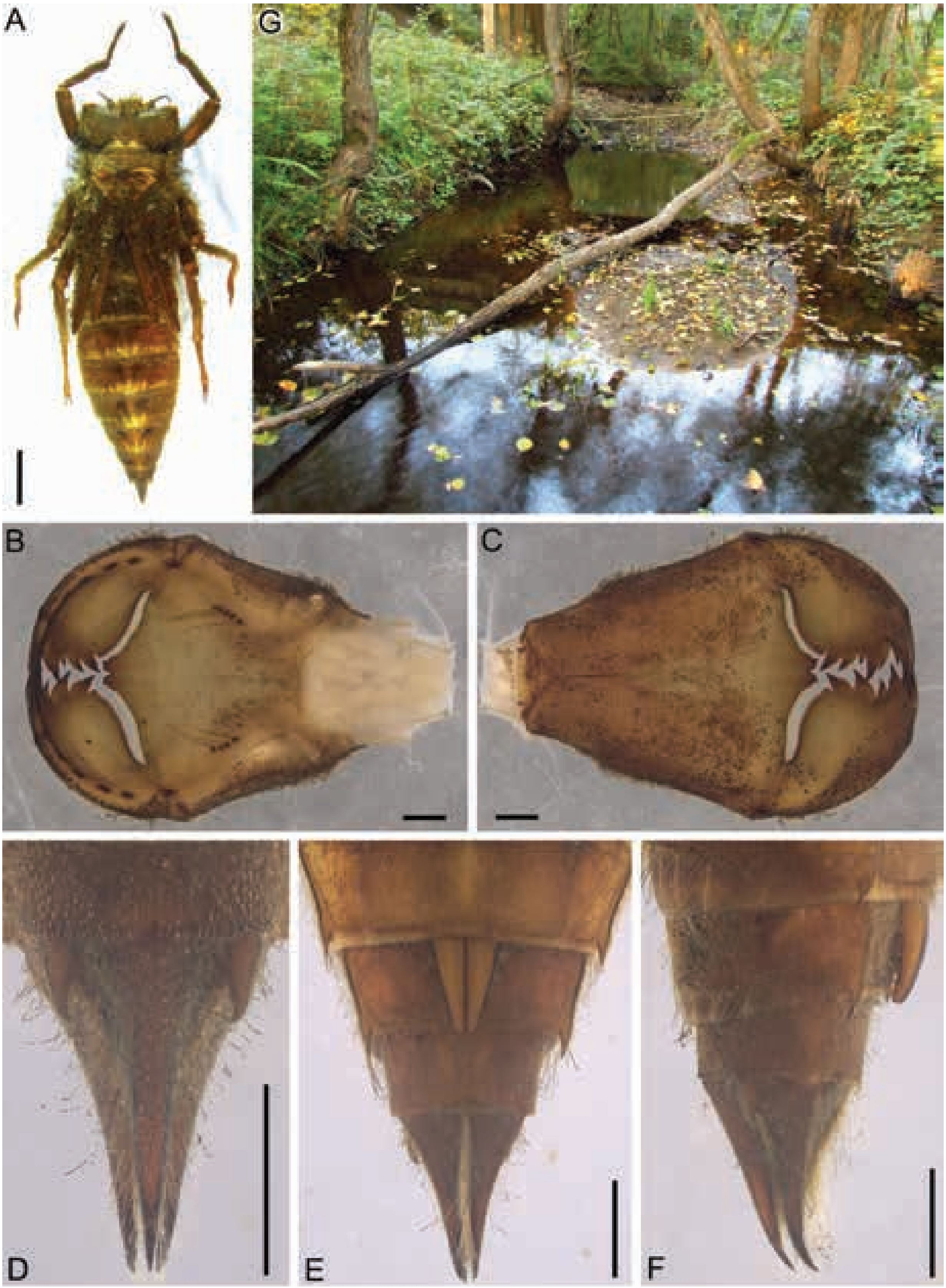

Image 7. *Cordulegaster boltonii* (Donovan, 1807), larva (A–F) and habitat (G): A—total dorsal view, scale 5mm | B—mask, dorsal view, scale 1mm | C—mask, ventral view, scale 1 mm | D—apex of abdomen, dorsal view, scale 2mm | E—the same, ventral view, scale 2mm | F—the same, lateral view, scale 2mm | G—Mohylivka River, vicinity of Verbivka village, Zhytomyr Region (21.09.2018). © Alexander V. Martynov.

Image 8. ***Somatochlora arctica*** **(Zetterstedt, 1840), male imago (A, B) and habitat (C–E): A—anal appendages, dorsal view, scale 0.5mm | B—the same, lateral view, scale 0.5mm | C—ditches along forest road, vicinity of Bil's'k village, Rivne Region | D—Bile Lake, vicinity of Khmil' village, Rivne Region (03.vii.2017) | E—black-eared swamp, vicinity of Rudka village, Rivne Region (02.viii.2017). © Alexander V. Martynov.**

next edition of the Red Data Book of Ukraine.

Leucorrhinia albifrons (Burmeister, 1839)

Species is included in the Red Data Book of Ukraine (2009), known from Zhytomyr, Volyn, and Kyiv Regions, and Crimea in Ukraine (Gorb et al. 2000; Matushkina 2006; Khrokalo & Nazarov 2008; Khrokalo 2016; Honchar et al. 2019). Doubtful records of *L. albifrons* are not mentioned here (e.g. larvae of the species from Odesa Region and Dnieper–Bug Estuary).

I had found imagoes (one of the records is a copulated pair) of the species at Bile Lake on sphagnum bog in vicinity of Rivnenskyi Nature Reserve (Image 9A–D). Most likely, the larvae of *L. albifrons* had been developing here. The detailed description of the lake is given above. The species was not registered at any other neighboring waterbody.

Material and observations: Two imagoes, copulation, Ukraine, Rivne Region, vicinity of Khmil' village, Bile Lake on sphagnum marsh, 51.479283N & 27.311233E, Martynov A.V., 03.vii.2017; 1 imago, ibid, Martynov A.V., 12.vi.2019; 5 imagoes, ibid, Martynov A.V., 13.vi.2020.

Thus, a lot of rare and/or red-listed in Ukraine Odonata species are registered at Bile Lake and neighboring Black Lake (e.g. *N. speciosa*, *A. imperator*, *S. arctica* and *L. albifrons*), therefore, these lakes are recommended to be included to the territory of Bil's'ke forestry of Rivnenskyi Nature Reserve.

Leucorrhinia caudalis Charpentier, 1840

This is a rare species within Ukraine, known mainly from northern and western Ukraine. Only solitary records from some other southern regions are known

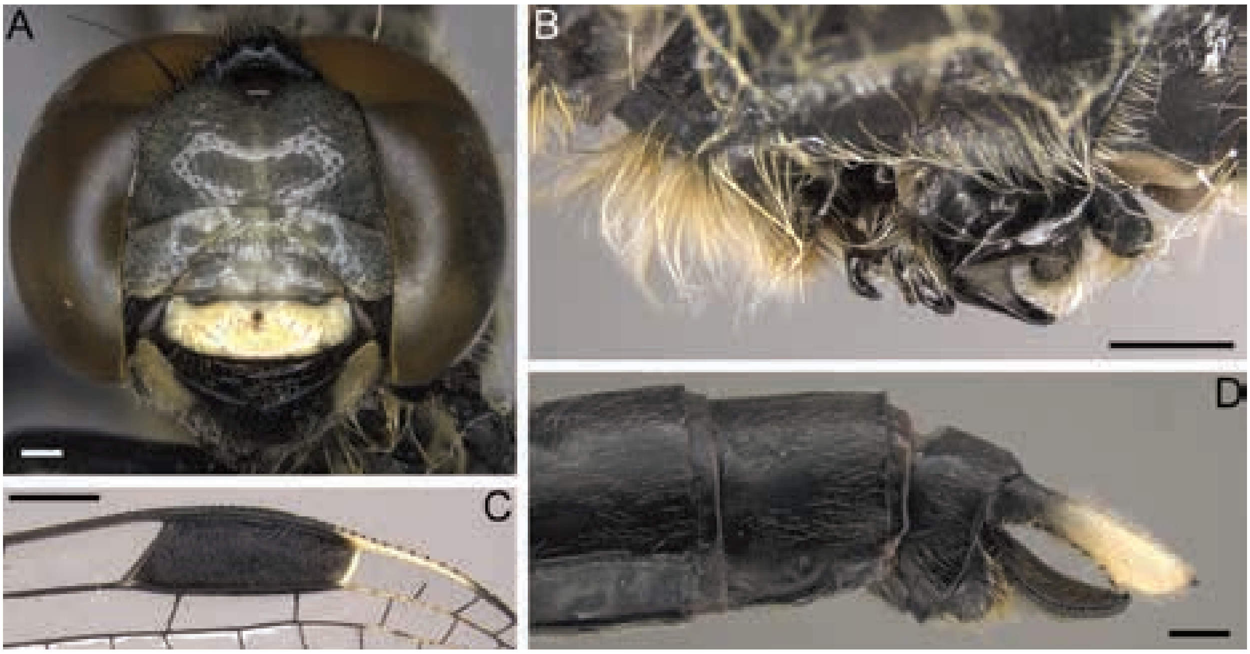

Image 9. *Leucorrhinia albifrons* (Burmeister, 1839), male imago: A—head, frontal view, scale 0.5mm | B—secondary genitalia, lateral view, scale 0.5mm | C—pterostigma, scale 1mm | D—apex of abdomen, lateral view, scale 0.5mm. © Alexander V. Martynov.

(Khrokalo & Matushkina 1999; Gorb et al. 2000; Sheshurak & Padalko 1996; Sheshurak & Khrokalo 2004; Khrokalo & Nazarov 2008; Khrokalo 2016; Raldugina 2019). Most southern records (e.g., Polischuk 1974) are doubtful, and this species had not been registered within southwestern Ukraine during the detailed investigation of Odonata carried out at the beginning of XXI century (Dyatlova 2006).

I had found one imago of the species within Rivnenskyi Nature Reserve on glade with seasonal lentic waterbody (Image 10A–F). Also, a large pound, drainage channel and bogs were located close to the collecting place.

Material: 1 imago, Ukraine, Rivne Region, vicinity of Perebrody village, near periodically drying up lentic waterbody, 51.690204N & 27.085416E, 141m, Martynov A.V., 11.vi.2019.

Selysiothemis nigra (Vander Linden, 1825)

In Ukraine, the species was registered for the first time in 2002 in Mykolaiv Region near Black Sea coast (Chirnine Lake) (Tytar 2007). Further, the species was recorded in Crimea, Kherson and Donetsk Regions (Matushkina 2007; Khrokalo et al. 2009; Savchuk & Karolinskiy 2013; Martynov et al. 2015).

I had recorded imagoes of *S. nigra* at few steppe areas near Malyi Utluk River and Molochnyi Estuary (Zaporizhzhia Region) (Image 10G–K). In some places I recorded up to eight specimens on 300m of a route. As in case of *L. tetraphylla*, larvae of *S. nigra* are perspective to be found in Malyi Utluk River, Tashchenak River, and Utlyukskyi Estuary. Also one male imago was registered at steppe area near Syvash Lake in Kherson Region.

In my opinion, the distribution of species in Ukraine is now wider and the places of development are denser than was previously known; distribution of *S. nigra* in Ukraine probably covers all coastal areas of Black and Azov Seas in Odesa, Mykolaiv, Kherson, Zaporizhzhia and Donetsk Regions, and Crimea.

Material and observations: Two imagoes, Ukraine, Zaporizhzhya Region, Yakymivka District, vicinity of Davydivka village, steppe areas near upper part of Utlyukskyi Estuary, 46.517917N & 35.186437E and 46.506342N & 35.178574E, Martynov A.V., 18.vi.2019.

One imago, Ukraine, Zaporizhzhya Region, Yakymivka District, vicinity of Lymans'ke village, steppe area near Molochnyi Estuary, 46.427449N & 35.343673E, Martynov A.V. 18.vi.2019.

Seven imagoes, Ukraine, Zaporizhzhya Region, Yakymivka District, vicinity of Mala Ternivka village, steppe area near Malyi Utluk River, 46.566884N & 35.197273E, Martynov A.V., 19.vi.2019.

One imago, Ukraine, Kherson Region, vicinity of Novomykolaivka village, steppe area near Syvash Lake, 46.204655N & 33.978565E, Martynov A.V., 13.vii.2020.

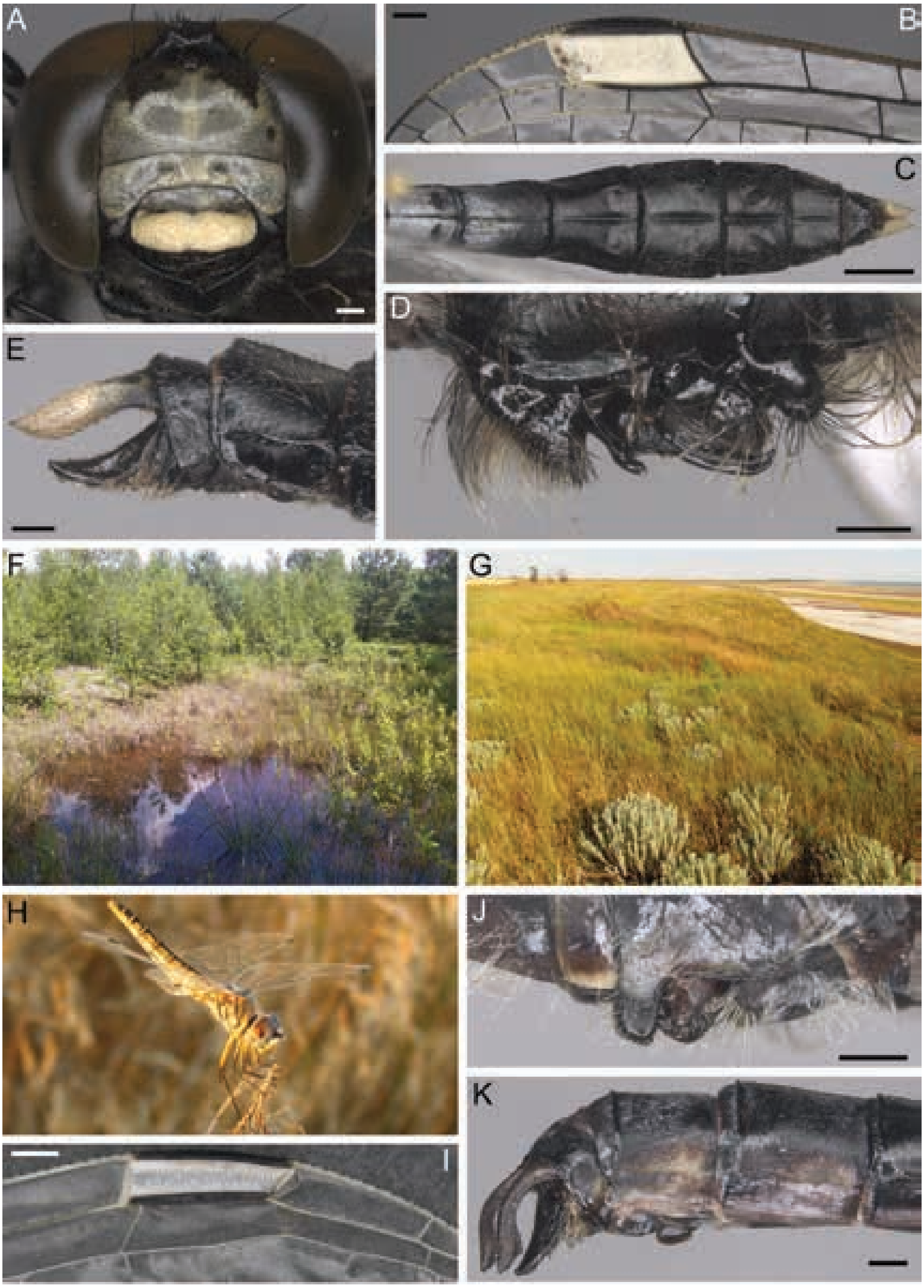

Image 10. *Leucorrhinia caudalis* Charpentier, 1840 (A–E) and *Selysiothemis nigra* (Vander Linden, 1825) (F–K), imagoes (A–E, H–K) and habitats (F, G): A—male, head, frontal view, scale 0.5mm | B—pterostigma, scale 0.5mm | C—male, abdomen, dorsal view, scale 2mm | D—male, apex of abdomen, lateral view, scale 0.5mm | E—male, secondary genitalia, lateral view, scale 0.5mm | F—periodically drying up lentic waterbody, vicinity of Perebrody village, Rivne Region (11.vi.2019) | G—steppe area near Molochnyi Estuary, vicinity of Lymans'ke village, Zaporizhzhya Region (18.vi.2019) | H—female on grass | I—pterostigma, scale 0.5mm | J—male, secondary genitalia, lateral view, scale 0.5mm | K—male, apex of abdomen, lateral view, scale 0.5mm. © Alexander V. Martynov.

Thus, the information presented in the paper shows which waterbodies of Ukraine supplement the list of habitats important for conservation of rare European Odonata species. The received data can be used for planning new protected areas, and most importantly this article shows that dragonflies and damselflies remain understudied within Ukraine.

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PLATINUM OPEN ACCESS

COMMUNICATION

Floristic diversity of Anjaneri Hills, Maharashtra, India

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Abstract: High altitude plateaux are found throughout northern Western Ghats. These plateaux harbor a great diversity of monsoon flora and endemism but are highly neglected due to the seasonality and harsh climatic conditions. Anjaneri Hill is an important rock outcrop in northern Western Ghats. It is the type locality of *Ceropegia anjanerica*. As an attempt to make a floristic inventory of an important area, a preliminary study was undertaken. A total of 385 flowering plants from 68 families have been reported from Anjaneri protected area in the present study, of these 114 are endemics. Out of these 114 species, 81 are endemic to India while 33 taxa are endemic to the Western Ghats. Anjaneri rock outcrop shows great floral diversity due to varied microhabitats. The observations on phenology and adaptive traits were recorded. The data on geology and geomorphology is presented in order to understand the geological nature of the rock outcrop. Intensive study on varied microhabitat is needed for the documentation of floral diversity existing on the Anjaneri Hill.

Keywords: *Ceropegia anjanerica*, endemic species, flowering plants, microhabitats, Nashik District, phenology, plateau, protected area, rock outcrop, Western Ghats.

Marathi Abstract: उत्तर-पश्चिम घाटामध्ये जास्त उंचीची पठारे खूप मोठ्या प्रमाणात आढळतात. पावसाळ्यात त्यांवर विपूल प्रमाणात वनस्पतींची विविधता आढळते. तेथे प्रदेशनिष्ठ वनस्पतींची संख्याही जास्त आहे. येथे वर्षाभरात ठराविक ऋतूंमध्ये वनस्पती आढळून येतात आणि येथील प्रतिकूल हवामानामुळे ही पठारे अभ्यासकांकडून तशी दुर्लक्षित झालेली आहेत. अंजनेरी पर्वत हा उत्तर-पश्चिम घाटातील एक महत्त्वाचे खडकाळ पठार आहे. सेरोपेजिया अंजनेरिका या प्रदेशनिष्ठ वनस्पतीची पहिली नोंद येथे झाली आहे. अशा महत्त्वपूर्ण पठारावरील सपुष्प वनस्पतींचा अभ्यास करून 68 कुळातील एकूण 385 वनस्पतींची नोंद प्रस्तूत अभ्यासात केलेली आहे त्यातील 114 प्रजाती या प्रदेशनिष्ठ असून 81 वनस्पती या भारतात आणि 33 प्रजाती या पश्चिम घाटापुरत्या प्रदेशनिष्ठ आहेत. येथील वनस्पतींच्या विविधितेचे कारण आहे, सूक्ष्म अधिवासांची विविधिता. या अभ्यासदरम्यान वनस्पतींना फुले येण्याचा कालावधी आणि अनुकूलन यावरील निरीक्षणे नोंदवली गेलेली आहेत. भूविज्ञान आणि भूगोलशास्त्र यांच्या आधारे अंजनेरी पर्वताचे भौगोलिक वैशिष्ट्य समजून घेऊन त्याची अभ्यासपूर्ण माहिती येथे सादर केलेली आहे. अंजनेरीवर असलेल्या सपुष्प वनस्पतींच्या विविधितेचे दस्तावेजीकरण करण्यासाठी येथील विविध सूक्ष्म अधिवासांचा अभ्यास करणे आवश्यक आहे

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INTRODUCTION

The Western Ghats are amongst well-known global hotspots recognized for its biodiversity and endemism (Daniels & Vencatesan 2008). Most conservation attention has been focused on the forests of the Western Ghats due to loss of plant species and intense habitat loss (Panigrahy et al. 2010). Southern Western Ghats shows great diversity of taxa especially trees and shrubs due to heavy rainfall, edaphic heterogeneities, and high mountain ranges, while the northern Western Ghats provides varieties of the unique habitats, e.g., forts, caves, cliffs, slopes, and plateaux which support diversity of herbaceous vegetation.

Northern Western Ghats also encompass higher plateaux or tablelands that have received less conservation attention (Porembski et al. 1994, 2000; Watve 2013), although studies suggest these ecological subsets of the Western Ghats mega-hotspot provide their own noteworthy and unique biological components. Many researchers have reported about the floral diversity of plateaux in northern Western Ghats. Report on two basaltic plateaux of northern Western Ghats has been provided by Rahangdale & Rahangdale (2014, 2018). Their documentation chiefly focuses on flowering plant diversity from Durgawadi Plateaux (600 taxa) and Naneghat Plateaux (249 taxa). Uncommon vegetation (Lekhak & Yadav 2012), a new species (Malpure et al. 2006; Malpure & Yadav 2009) and endemism (Joshi & Janarthanam 2004) were reported from lateritic plateaux.

Plateaux in Western Ghats lack proper substrate (soil) and exhibit extreme climatic conditions. Their environment usually shares a series of stressful characteristics, such as UV exposure, daily thermal variation, constant winds, high evapo-trasnspiration, low water retention, and impermeable soils (Porembski & Barthlott 2000). Plant communities of the plateaux are edaphically controlled and show adaptation for water accumulation, such as succulence *Cyanotis concanensis*, *Ceropegia lawii*, and poikilohydry, carnivory in response to the lack of nutrients (N, P, and S) in the soil and the presence of subterranean organs (bulbs, corms, tubers, and rhizomes) to overcome extreme temperature during summer. Despite the rich floral diversity and varied microhabitat, these plateaux are highly neglected, due to extreme conditions e.g., high temperature, altitude, and remote locations.

Watve (2007, 2010) reported that climatic and microclimatic (soil, rock, air, temperature, and humidity) conditions on rocky plateaux and their diurnal variation affected the vegetation on the plateaux. The microenvironment of the rocky plateaux tend to be extreme, from xeric to water logged, highly acidic (4.5–6.0), and rich in organic carbon.

Soil moisture has been recognized as the primary determinant of plant phenology in the Western Ghats (Joshi & Janarthanam 2004), and the plant diversity on the plateaux is only apparent while monsoon moisture persists.

The present study was carried out to document the diversity of flowering plants of the Anjaneri rock outcrop. The data generated in this study will help in planning for conservation of endemic and threatened plants.

MATERIALS AND METHODS

Study area

Anjaneri Hill (19.919^{0}N & 73.571^{0}E) (Fig. 1, 2) is a basalt mesa, a flat-topped hill with steep cliff edges. It is one of a cluster of five hills, together known as 'Tryambak Range' of the northern Western Ghats. Anjaneri Plateau is located 20km west of Nashik, towards Tryambakeshwar. Anjaneri Hills is an ancient mountain pass, from the period of Yadava, Satvahana Kings (approximately 700 CE). Historical references are also found from the regime of Peshava.

The elevations of the adjoining peaks are less than the highest point on the plateau (1,300m). Anjaneri Hill is a reserved forest (RF) area and has been given the status of medicinal plant conservation area (MPCA) in 2009–2010 and reserve area conservation committee has been constituted (April 2017) for the conservation of endemic plants from the plateau.

Data collection

Extensive and repeated field surveys were carried out during 2010 to 2016 to cover all the seasons of the year. A comprehensive checklist of plants was prepared altitude-wise in order to understand the range of distribution of species, ecological variations, and types of adaptation. Occurrence of the taxa was recorded based on the visual observations during field work. During the field surveys, types of vegetation, habit, habitat, morphological characters, associated species, adaptation, and phenology were documented.

Plant specimens were collected and identified using Flora of Nashik (Lakshminarasimhan & Sharma 1991) and regional floras (Sharma et al. 1996; Singh & Karthikeyan 2000; Singh et al. 2001). The data on endemism has been taken from Singh et al. (2015). The species documented

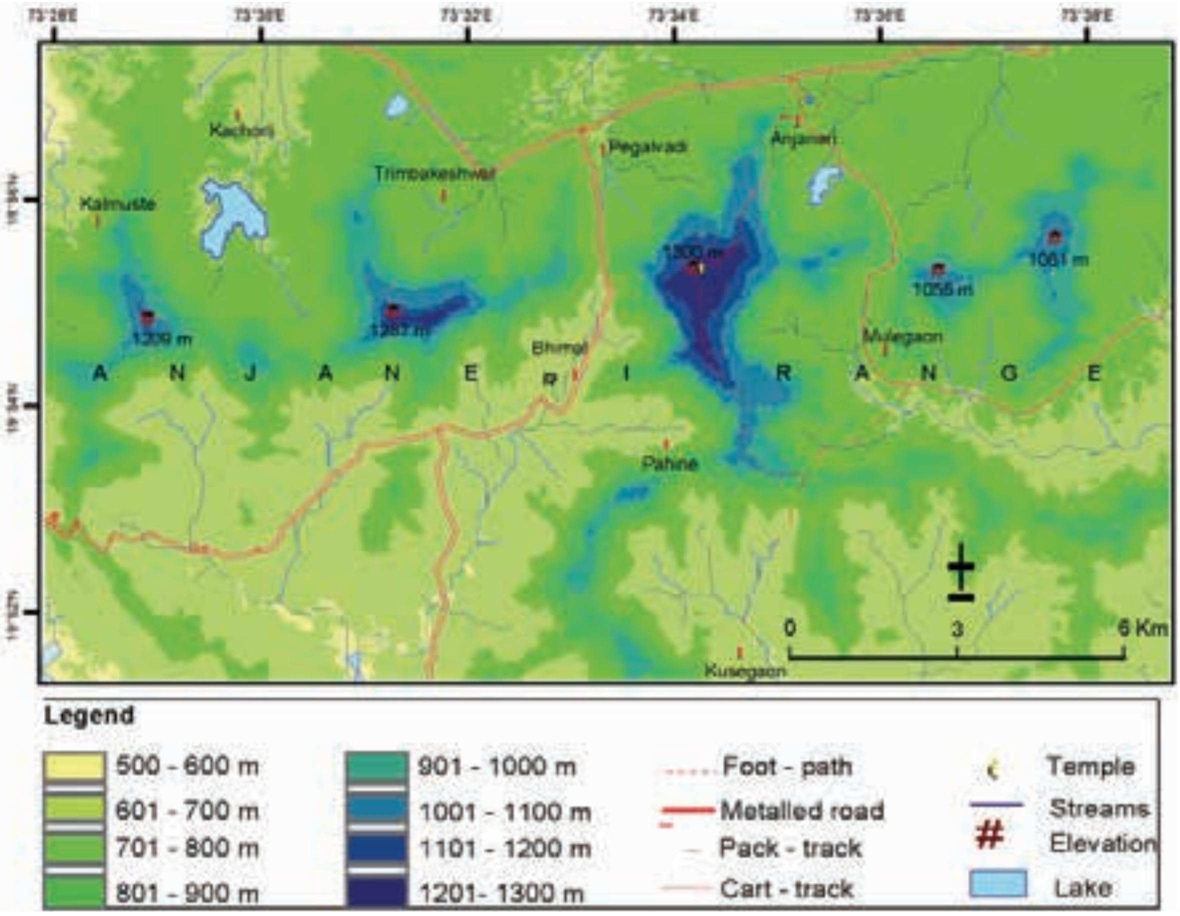

Figure 1. The Anjaneri range and its surroundings.

are listed in Table 1 as per APG IV (2016).

Geology and geomorphological studies

The present study is based on the data collected from primary and secondary sources. Primary data was procured by visiting the study area. Secondary data were obtained through Survey of India topographical maps. In addition to these, quantification of a number of geographical features for the area under study were made possible by means of the analyses of digital elevation model (DEM) of ca. 30m resolution advance space borne thermal emission and reflection radiometer (ASTER) data. The digital elevation data was used to extract information with the help of standard procedures in ArcGIS 9.3 (Kale & Shejwalkar 2008; Dehbozorgi et al. 2010).

Geology

Geologically, the study area is underlain by horizontally bedded Cretaceous-Eocene Deccan volcanic basalts. It is a part of the Deccan Volcanic Province (DVP) covering 5×10^5 km^2 area of central and western India, ranks as one of the largest flood basalt provinces on Earth (Brown et al. 2011). The lava flows of the Anjaneri Plateaux belong to Kalsubai subgroup of DVP, although the details of the lava flows at Anjaneri Plateaux is not known. The Bramhgiri Hill (1,287m), located close to Anjaneri Plateaux, exposes a 620.5m thick pile of a few compound pahoehoe flows, varying 40–96 m in thickness and one 9m thick flow, which occurs at 716m level. The area under study is characterized by two prominent dykes, through which basaltic lava was intruded. The dykes appear in the form of lineaments that are zones of weakness.

Geomorphology

Geomorphologically, the highest point of Anjaneri Plateaux is 1,300m with an area of 5.7km^2. The maximum local relief of the plateaux is 660m to the south-west. The plateaux are bordered by high cliffs from almost all the sides. The lower slopes of Anjaneri Plateaux are concave in nature with semi-evergreen vegetative growth particularly in the form of trees. The profiles reveal that the Anjaneri area maintains the classical characteristics of the plateaux.

Climate: The Anjaneri Plateaux do not have any official or unofficial weather station. Therefore, it is not possible to describe the climate of the study area, however, some information is available for Tryambakeshwar, which is located close to the study area. The region experiences extreme weather, i.e., very hot summers and very cold winters. Summer and monsoon is a feature of the area. Therefore, the climate of the area is divided into three distinct seasons, namely, (a) summer season (March to May) are hot with a maximum average temperature reaching up to 40°C, (b) monsoon season (June to October) is likely to offer average annual rainfall around 2,000mm particularly on Anjaneri Plateaux, and (c) winter season (November to February) is mostly pleasant with a minimum and maximum temperature between 7°C and 34°C, respectively. It is likely to have higher temperatures on the top of the plateaux than the surrounding region particularly in the summer season. It is evident by occurrence of succulents like *Ceropegia anjanerica*, *Drimia polyantha*, *Euphorbia khandallensis* and the spinescent *Lepidagathis cuspidata.*

Ecosystem services

The steep hill slopes give rise to many cascades and streams that supply water to major dams like Vaitarana Dam and three minor reservoirs. At the end of monsoon, the plateaux have grass cover providing stuff for local cattle. Natural and man-made ponds are also present on the plateaux. The area has medicinal plant species and local people regularly collect these species. It has been declared as a medicinal plant conservation area (MPCA) by the forest department and special protection has been provided against exploitation.

Floristic composition

A total of 385 species are recorded from the Anjaneri Hills. These plants are distributed in 68 families: Poaceae (59), Leguminosae (48), Asteraceae (40), Acanthaceae (21), and Lamiaceae (15) are dominant families. These five families represent 183 species of the total flora. In comparison with lateritic plateaux like Kaas, Satara (41 endemics) (3.26km^2) and Barki, Kolhapur (six endemics) (3.75km^2) (Lekhak & Yadav 2012 and Shenai et al. 2013), and basaltic rock outcrops Durgawadi, Pune (150 endemics) (2.8793km^2) (Rahangdale & Rahangdale 2018) and Naneghat, Junnar (seven endemics) (0.7524km^2) (Rahangdale & Rahangdale 2014) Anjaneri outcrop (5. 6963km^2) harbors 385 flowering plants of which 114 are endemic species. Endemism given for Kaas and Barki are restricted to the plateaux and not the whole area, while the endemics from Durgawadi, Naneghat, and Anjaneri are from entire area.

Anjaneri outcrop shows high endemism and commonly shared taxa are relatively low (31.21%) indicating that the Anjaneri outcrop is floristically and in terms of habitats is very diverse. It is the type locality of *Ceropegeia anjanerica* (Malpure et al., 2006) and supports varied habitats for many endemic plants (Table 1). The reason for the species richness and high endemism of Anjaneri outcrop might be in its geographical location, climatic conditions, specific basaltic nature, and high altitude. A few species which occur on Kaas, Barki, Dugarwadi, and Naneghat plateau, e.g., *Dipcadi ursulae*, *Aponogeton satarensis*, *Ceropegia jainii*, and *Eriocaulon epedunculatum* were not found in the present study area may be due to lack of required specific habitats.

Anjaneri rock outcrop shows three levels (flat areas) at 800–850 m, 1,150–1,200 m and 1,300m and large slopes. Each level and slope is unique in terms of soil deposition and water content. Basal level (800–850 m) has a good amount of soil and water, supported species from Lamiaceae (*Colebrookea oppositifolia*, *Pogostemon deccanensis*), Solanaceae (*Solanum anguivi*), and Asteraceae (*Senecio bombayensis*) and trees like *Mangifera indica*, *Terminalia tomentosa*, *Bridelia retusa*, *Syzygium cumini*, *Sterculia guttata*, *Schleichera oleosa*, and *Falconeria insignis*. Good populations of *Gloriosa superba* and *Paracalyx scariosus* were recorded.

Middle level (1,150–1,200 m) contains 1–1.5 cm of soil dominated by grasses like *Chrysopogon fulvus*, *Cymbopogon martini*, and *Dichanthium assimile*. A number of shallow water bodies are formed during the monsoon season which provide habitat for *Lindernia parviflora*, *Rotala rosea*, *Ammannia baccifera*, and *Hygrophila serpyllum*. At 1,100–1,150 m small tree cover occurs on the soil-rich areas of the plateaux. This cover includes plants like *Elaeagnus conferta*, *Ziziphus rugosa*, *Terminalia chebula*, *Trema orientalis*, *Acacia pennata*, and *Kydia calycina*. Little above the middle plateau (1,200m), a small natural pond exists. It supports hydrophytes like *Persicaria glabra*.

Uppermost level (1,250–1,300 m) shows large number of herbaceous, ephemeral flush and grasses. In some areas of this level little soil deposition occur, this area shows a large population of *Strobilanthes reticulata* and *Curcuma neilgherrensis*. Various taxa like *Polygala arvensis*, *Habenaria brachyphylla*, and *Haplanthodes verticellata* were associated with *Strobilanthes* population. The species like *Impatiens dalzellii* (Image 3H) (above 1,150m), *Drosera indica* (1,250m), *Crinum*

Image 1. Major habitat of Anjaneri Hill: A—Top elevation plateau | B—Middle elevation plateau | C—Slope | D—Steep and hanging rocks | E—Black boulders with seasonal stream | F—Seasonal pond at top plateau. © Dr. K.V.C. Gosavi.

latifolium (1,300m), *Ceropegia anjanerica* (1,300m), *Euphorbia khandallensis* (1,275m), *Sonerila scapigera* (Image 4G) (1,175m), *Cyathocline lutea* (1,300m) were reported. During monsoon a large number of small shallow puddles are formed, supporting herbaceous plants like *Pogostemon deccanensis*, *Eriocaulon tuberiferum*, *Exacum lawii*, and *Utricularia praeterita*. Apart from above habitats, rocky outcrops provide various habitats like boulders, exposed rock surfaces, small ephemeral pool, and soil covered areas.

Slopes of all three levels show variation in their species composition. Slope from middle to upper level were covered with a huge population of *Strobilanthes callosa*, *Chlorophytum glaucum*, *Pimpinella wallichiana*, *Lepidagathis cuspidata*, *Gynura bicolor*, *Alysicarpus bupleurifolius*, *Desmodiastrum racemosum* var. *rotundifolium*, *Smithia* species and middle slope with various herbaceous plants like *Commelina* species, *Neanotis foetida*, *Neanotis montholonii*, *Cynarospermum*, and *Canscora diffusa*.

Study area shows dominance of lithophytes due to their greater ability to survive under disadvantageous environmental conditions (Porembski & Barthlott 2000). Due to their short life-cycle and high reproduction rate, they are well-adapted to extreme environments and high levels of disturbances. Most of the plants survive

Image 2. Seasonal changes of top plateau: A—Dried plants in the month of May | B—Dominated *Curcuma neilgherrensis* after first shower in the first week of June | C—Dominant *Habenaria grandifloriformis* in the first week of July | D—*Pinda concanensis*, *Senecio bombaiensis* appear in August | E—Mix population of many outcrops species appears in September | F—Outcrops species are drying from October to November. © Dr. K.V.C. Gosavi.

the dry spell as dormant seeds or tuber.

Due to the absence of large accumulations of soil over the plateaux little rainwater is stored, but most of the water is lost as runoff. The loss of water due to run-off is due to steep slopes.

Seasonal succession and phenology

Plant communities on the Anjaneri outcrop are gradually changing temporally with specific interval (approximately 10 days) due to changing environmental conditions. The growing season starts with the dominance of ephemerals and this is later replaced by perennials. Both the number of species and the number of individuals declined after a peak at the beginning of the growing season. Such seasonal or phenological phenomena with respect to basaltic plateaux in northern Western Ghats have been studied by Rahangdale & Rahangdale (2014, 2018) and lateritic plateaux by Joshi & Janarthanam (2004), Bhattarai et al. (2012) and Lekhak & Yadav (2012). Similar pattern to the one seen on the Anjaneri outcrop was observed by Lekhak & Yadav (2012) and Rahangdale & Rahangdale (2014). Based on the phenology of the plants four phases can be recognized: 1. The pre-monsoon phase (June–July) is characterized by the growth of grasses and ground orchids on the plateaux. The grass species which are quite common are *Eragrostis unioloides*, *Isachne elegans*, and *Paspalum canarae* var. *fimbriatum* along with *Curculigo orchioides*, *Ceropegia lawii*, *Habenaria grandifloriformis*, *Arisaema murrayi*, *Crinum latifolium*, and *Curcuma neilgherrensis*; 2. The monsoon phase (August–September) mainly geophytes such as *Ceropegia anjanerica*, *C. media*, *Eriocaulon tuberiferum*, *Habenaria suaveolens*, *H. grandifloriformis*, *Hypoxis aurea*, and members of the ephemeral vegetation such as *Glyphochloa maharashtraensis*, *Fimbristylis lawiana*, *Utricularia* spp., *Murdannia nimmoniana*, *Eriocaulon* spp., and *Smithia hirsuta* come in flowering. This is

Image 3. Endemic plants: A—*Strobilanthes callosa* Nees | B—*Pancratium nairii* Sasikala & Reema Kumari | C—*Pinda concanensis* (Dalzell) P.K. Mukh. & Constance | D—*Ceropegia anjanerica* Malpure, M.Y.Kamble & S.R.Yadav | E—*Ceropegia media* (Huber) Ansari | F—*Frerea indica* Dalzell | G—*Arisaema murrayi* (J.Graham) Hook. | H—*Impatiens dalzellii* Hook.f. & Thomson | I—*Cyathocline lutea* Law ex Wight. © Dr. K.V.C. Gosavi.

Image 4. Endemic plants: A—*Adelocaryum malabaricum* (C.B.Clarke) Brand | B—*Cyanotis concanensis* Hassk. | C—*Pogostemon deccanensis* (Panigrahi) Press | D—*Desmodiastrum racemosum* var. *rotundifolium* (Baker) A.Pramanik & Thoth. | E—*Indigofera santapaui* Sanjappa | F—*Smithia purpurea* Hook. | G—*Sonerila scapigera* Dalzell | H—*Habenaria heyneana* Lindl. | I—*Dichanthium armatum* (Hook.f.) Blatt. & McCann. © Dr. K.V.C. Gosavi.

Table 1. Plants of Anjaneri Hill.

	Plant species	Family	Location
1*	*Amorphophallus commutatus* (Schott) Engl.	Araceae	MP, UP
2	*Ariopsis peltata* Nimmo	Araceae	UP
3$	*Arisaema murrayi* (J.Graham) Hook.	Araceae	MP,UP
4	*Arisaema tortuosum* (Wall.) Schott	Araceae	MP,UP
5	*Remusatia vivipara* (Roxb.) Schott	Araceae	Slope between MP and UP
6	*Sauromatum venosum* (Dryand. ex Aiton) Kunth	Araceae	UP
7	*Dioscorea bulbifera* L.	Dioscoreaceae	Slope UP
8	*Dioscorea pentaphylla* L.	Dioscoreaceae	Slope UP
9	*Gloriosa superba* L.	Colchicaceae	BP
10*	*Dendrobium barbatulum* Lindl.	Orchidaceae	MP
11	*Dendrobium herbaceum* Lindl.	Orchidaceae	MP
12$	*Dendrobium microbulbon* A.Rich.	Orchidaceae	MP
13$	*Habenaria brachyphylla* (Lindl.) Aitch.	Orchidaceae	UP
14$	*Habenaria foetida* (Geyer ex Hook.) S.Watson	Orchidaceae	UP
15$	*Habenaria foliosa* A.Rich.	Orchidaceae	MP,UP
16$	*Habenaria grandifloriformis* Blatt. & McCann	Orchidaceae	UP, MP
17$	*Habenaria heyneana* Lindl.	Orchidaceae	BP, UP
18$	*Habenaria suaveolens* Dalzell	Orchidaceae	UP
19	*Curculigo orchioides* Gaertn.	Hypoxidaceae	MP
20	*Hypoxis aurea* Lour.	Hypoxidaceae	MP
21	*Crinum latifolium* L.	Amaryllidaceae	UP
22*	*Pancratium nairii* Sasikala & Reema Kumari	Amaryllidaceae	UP
23	*Agave americana* L.	Asparagaceae	MP
24$	*Chlorophytum borivilianum* Santapau & R.R.Fern.	Asparagaceae	Slopes of foot hills
25$	*Chlorophytum glaucum* Dalzell	Asparagaceae	UP
26*	*Drimia polyantha* (Blatt. & McCann) Stearn	Asparagaceae	UP
27	*Phoenix sylvestris* (L.) Roxb.	Arecaceae	BP
28	*Commelina benghalensis* L.	Commelinaceae	MP,UP, Slope MP,UP
29*	*Commelina paleata* Hassk.	Commelinaceae	In shady places along slopes
30*	*Cyanotis concanensis* Hassk.	Commelinaceae	Slope MP,UP
31	*Cyanotis fasciculata* (B.Heyne ex Roth) Schult. & Schult.f.	Comelinaceae	Slope MP,UP
32	*Murdannia nimmoniana* (J.Graham) Bole & M.R.Almeida	Commelinaceae	UP
33*	*Murdannia nimmoniana* var. *sahyadrica* (Ancy & Nampy) Nandikar	Commelinaceae	In shady places along slopes
34$	*Ensete superbum* (Roxb.) Cheesman	Musaceae	MP
35$	*Curcuma neilgherrensis* Wight	Zingiberaceae	UP
36	*Eriocaulon heterolepis* Steud.	Eriocaulaceae	UP
37$	*Eriocaulon sedgwickii* Fyson	Eriocaulaceae	UP
38*	*Eriocaulon tuberiferum* A.R.Kulk. & Desai	Eriocaulaceae	UP
39	*Cyperus difformis* L.	Cyperaceae	MP,UP
40	*Eleocharis atropurpurea* (Retz.) J.Presl & C.Presl	Cyperaceae	MP,UP
41$	*Fimbristylis lawiana* (Boeckeler) J.Kern	Cyperaceae	MP,UP
42	*Kyllinga bulbosa* P.Beauv.	Cyperaceae	MP,UP
43	*Pycreus flavidus* (Retz.) T.Koyama	Cyperaceae	MP,UP
44	*Apluda mutica* L.	Poaceae	Slopes

	Plant species	Family	Location
45	*Arthraxon hispidus var. hispidus* (Thunb.) Makino	Poaceae	MP
46*	*Arthraxon jubatus* Hack.	Poaceae	MP
47	*Arthraxon lanceolatus* var. *lanceolatus* (Roxb.) Hochst.	Poaceae	UP,MP
48*	*Arthraxon lanceolatus* var. *meeboldii* (Stapf) Welzen	Poaceae	MP
49	*Arthraxon lancifolius* (Trin.) Hochst.	Poaceae	MP
50$	*Arundinella ciliata* (Roxb.) Nees ex Miq.	Poaceae	UP
51	*Arundinella pumila* (Hochst. ex A. Rich.) Steud.	Poaceae	UP, MP
52	*Chloris virgata* Swartz	Poaceae	UP, MP
53	*Chrysopogon fulvus* (Spreng.) Chiov.	Poaceae	UP,MP
54	*Coix gigantea* Koen. ex Roxb.	Poaceae	MP
55	*Cymbopogon martini* (Roxb.) Wats.	Poaceae	MP, UP
56	*Cynodon dactylon* (L.) Pers.	Poaceae	MP,UP
57	*Dendrocalamus strictus* (Roxb.) Nees	Poaceae	MP
58	*Dactyloctenium aegyptium* (L) P. Beauv.	Poaceae	MP, UP
59*	*Dicanthium paranjapyeanum* (Bhide) Clayton	Poaceae	UP
60	*Dichanthium annulatum* (Forssk.) Stapf	Poaceae	MP, UP
61*	*Dichanthium armatum* (Hook.f.) Blatt. & McCann	Poaceae	MP
62	*Dichanthium assimile* (Steud.) Deshpande	Poaceae	MP,UP
63	*Dichanthium caricosum* (L.) A.Camus	Poaceae	MP, UP
64	*Dichanthium odoratum* Jain & Deshpande	Poaceae	UP
65*	*Dichanthium oliganthum* (Hochst. ex Steud.) T.A.Cope	Poaceae	UP
66	*Digitaria ciliaris* (Retz.) Koel.	Poaceae	UP
67	*Echinochloa colonum* (L.) Link	Poaceae	MP
68	*Eragrostiella bifaria* (Vahl) Bor	Poaceae	MP
69	*Eragrostis unioloides* (Retz.) Nees ex Steud	Poaceae	MP
70	*Eragrostis viscosa* (Retz.) Trin.	Poaceae	MP
71	*Euclasta clarkei* (Hack.) T.A.Cope	Poaceae	MP
72	*Eulalia trispicata* (Schult.) Henr.	Poaceae	MP,UP
73$	*Garnotia arborum* Stapf ex T.Cooke	Poaceae	MP, UP
74	*Garnotia tenella* (Arn. ex Miq.) Jan.	Poaceae	UP
75*	*Glyphochloa maharashtraensis* Potdar & S.R.Yadav	Poaceae	UP
76$	*Glyphochloa forficulata* (C.E.C.Fischer) W.D.Clayton	Poaceae	UP
77	*Heteropogon contortus* (L.) P.Beauv. ex Roem. & Schult.	Poaceae	UP
78$	*Indopoa paupercula* (Stapf) Bor	Poaceae	UP
79$	*Isachne elegans* Dalzell	Poaceae	UP
80$	*Isachne gracilis* C.E.Hubb.	Poaceae	UP
81	*Ischaemum impressum* Hack.	Poaceae	UP
82	*Ischaemum indicum* (Houtt.) Merr.	Poaceae	MP
83$	*Ischaemum raizadae* Hemadri & Billore	Poaceae	UP, MP
84	*Jansenella griffithiana* (C.Muell.) Bor	Poaceae	MP,UP
85*	*Jansenella neglecta* S.R.Yadav, Chivalkar & Gosavi	Poaceae	MP,UP
86	*Oplismenus burmannii* f. *cristata* (J.Presl) Hier. ex Peter	Poaceae	MP
87	*Oplismenus compositus* (L.) P.Beauv.	Poaceae	MP
88$	*Paspalum canarae* var. *fimbriatum* (Bor) Veldk.	Poaceae	UP
89	*Pennisetum pedicellatum* Trin.	Poaceae	MP

	Plant species	Family	Location
90*	*Pogonachne racemosa* Bor	Poaceae	UP
91$	*Pseudanthistiria heteroclita* (Roxb.) Hook.f.	Poaceae	UP
92*	*Pseudodichanthium serrafalcoides* (T.Cooke & Stapf) Bor	Poaceae	UP
93	*Sehima nervosum* (Rottl.) Stapf	Poaceae	UP
94	*Setaria pumila* Roem. & Schult.	Poaceae	UP, MP
95$	*Spodiopogon rhizophorus* (Steud.) Pilger	Poaceae	MP, UP
96	*Sporobolus indicus* (Buse) Baaijens	Poaceae	MP
97	*Themeda quadrivalvis* (L.) O.Ktze.	Poaceae	MP, UP
98$	*Triplopogon ramosissimus* (Hack.) Bor	Poaceae	MP,UP
99	*Tripogon bromoides* Roth	Poaceae	UP
100	*Tripogon capillatus* Jaub. & Spach.	Poaceae	MP
101$	*Tripogon jacquemontii* Stapf	Poaceae	MP
102$	*Tripogon lisboae* Stapf	Poaceae	MP, UP
103	*Cocculus hirsutus* (L.) W.Theob.	Menispermaceae	MP, UP
104	*Cyclea peltata* (Lam.) Hook.f. & Thomson	Menispermaceae	UP
105	*Clematis gouriana* Roxb. ex DC.	Ranunculaceae	UP
106$	*Clematis hedysarifolia* DC.	Ranunculaceae	UP
107	*Acacia auriculiformis* Benth.	Leguminosae	MP
108	*Acacia pennata* (L.) Willd.	Leguminosae	MP
109	*Acacia nilotica* ssp. *indica* (Benth.) Brenan	Leguminosae	MP
110	*Aeschynomene indica* L.	Leguminosae	UP
111	*Albizia lebbek* (L.) Benth.	Leguminosae	BP
112	*Albizia odoratissima* (L.f.) Benth.	Leguminosae	BP
113	*Alysicarpus bupleurifolius* (L.) DC.	Leguminosae	Slope UP
114	*Alysicarpus vaginalis* (L.) DC.	Leguminosae	Slope UP
115	*Bauhinia racemosa* Lam.	Leguminosae	BP
116	*Butea monosperma* (Lam.) Taub.	Leguminosae	BP
117$	*Cajanus sericeus* (Benth. ex Baker) Maesen	Leguminosae	Slope MP
118	*Canavalia gladiata* (Jacq.) DC.	Leguminosae	Slope MP
119	*Cassia fistula* L.	Leguminosae	Slope MP
120	*Chamaecrista mimosoides* (L.) Greene	Leguminosae	MP
121$	*Clitoria annua* J.Graham	Leguminosae	MP
122$	*Crotalaria filipes* Benth.	Leguminosae	Slope UP, UP
123	*Crotalaria hebecarpa* (DC.) Rudd	Leguminosae	Slope UP
124	*Crotalaria medicangea* Lam.	Leguminosae	Slope UP
125	*Crotalaria mysorensis* Roth	Leguminosae	Slope UP
126	*Crotalaria nana* Burm.f.	Leguminosae	Slope UP
127	*Crotalaria pallida* Aiton	Leguminosae	Slope UP
128	*Crotalaria retuse* L.	Leguminosae	Slope UP
129	*Crotalaria triquetra* Dalzell	Leguminosae	Slope UP
130	*Crotalaria vestita* Baker	Leguminosae	Slope UP
131$	*Desmodiastrum belgaumense* (Wight) A.Pramanik & Thoth.	Leguminosae	Slope UP
132$	*Desmodiastrum racemosum* var. *rotundifolium* (Baker) A.Pramanik & Thoth.	Leguminosae	Slope MP
133	*Desmodium laxiflorum* DC.	Leguminosae	Slope UP
134	*Dolichos robustus* Bolus	Leguminosae	MP

	Plant species	Family	Location
135	*Dolichos trilobus* L.	Leguminosae	Slope UP
136	*Erythrina stricta* Roxb.	Leguminosae	MP
137	*Flemingia strobilifera* (L.) W.T.Aiton	Leguminosae	MP
138	*Geisaspis cristata* Wight & Arn.	Leguminosae	Slope UP
139*	*Geissaspis tenella* Benth.	Leguminosae	Slope UP
140	*Indigofera cordifolia* B.Heyne ex Roth	Leguminosae	Slope MP
141	*Indigofera linifolia* L.f. Retz.	Leguminosae	Slope MP
142*	*Indigofera santapaui* Sanjappa	Leguminosae	MP
143	*Indigofera trifoliata* L.	Leguminosae	Slope MP
144	*Mucuna pruriens* (L.) DC.	Leguminosae	Slope MP
145	*Paracalyx scariosus* (Roxb.) Ali (as 'scariosa')	Leguminosae	Slope MP
146	*Smithia bigemina* Dalzell	Leguminosae	MP, UP
147$	*Smithia hirsuta* Dalzell	Leguminosae	MP, UP
148$	*Smithia purpurea* Hook.	Leguminosae	UP
149	*Smithia sensitiva* Aiton	Leguminosae	MP, UP
150*	*Smithia setulosa* Dalzell	Leguminosae	MP, UP
151	*Teramnus labialis* (L.f.) Spreng.	Leguminosae	Slope UP
152	*Vigna dalzelliana* (Kuntze) Verdc.	Leguminosae	Slope UP
153$	*Vigna khandalensis* (Santapau) Sundararagh. & Wadhwa	Leguminosae	Slope UP
154*	*Vigna sahyadriana* Aitwade, K.V. Bhat & S.R.Yadav	Leguminosae	Slopes MP
155	*Polygala arvensis* Willd.	Polygalaceae	Slopes
156	*Polygala persicariifolia* DC.	Polygalaceae	Slopes
157	*Elaeagnus conferta* Roxb.	Elaeagnaceae	MP
158	*Ziziphus rugosa* Lam.	Rhamnaceae	MP
159	*Ziziphus mauritiana* Lam.	Rhamnaceae	MP
160	*Trema orientalis* (L.) Blume	Ulmaceae	MP
161	*Ficus arnottiana* (Miq.) Miq.	Moraceae	MP
162	*Ficus exasperata* Vahl	Moraceae	MP
163	*Ficus racemosa* L.	Moraceae	MP
164	*Ficus tinctoria ssp. gibbosa* (Blume) Corner	Moraceae	MP
165	*Boehmeria macrophylla* Hornem.	Urticaceae	Slope MP
166	*Girardinia diversifolia* (Link) Friis	Urticaceae	Slope MP
167	*Laportea interrupta* (L.) Chew	Urticaceae	MP
168	*Lecanthus peduncularis* (Wall. ex Royle) Wedd.	Urticaceae	UP
169	*Pouzolzia zeylanica* (L.) Benn.	Urticaceae	MP
170$	*Cucumis setosus* Cogn.	Cucurbitaceae	MP
171	*Diplocyclos palmatus* (L.) C.Jeffrey	Cucurbitaceae	Slope MP,UP
172	*Momordica cymbalaria* Fenzl ex Naudin	Cucurbitaceae	Slope UP
173	*Momordica dioica* Roxb. ex Willd.	Cucurbitaceae	Slope UP
174$	*Solena amplexicaulis* (Lam.) Gandhi	Cucurbitaceae	Slope UP
175	*Trichosanthes tricuspidata* Lour.	Cucurbitaceae	MP
176	*Zehneria perpusilla* (Blume) Bole & M.R.Almeida	Cucurbitaceae	MP
177	*Begonia crenata* Dryand.	Begoniaceae	BP,MP
178	*Celastrus paniculatus* Willd.	Celastraceae	Slope MP
179	*Maytenus rothiana* Lobr.-Callen	Celastraceae	MP, Slope UP

	Plant species	Family	Location
180	*Oxalis corniculata* L.	Oxalidaceae	MP
181$	*Euphorbia khandallensis* Blatt. & Hallb.	Euphorbiaceae	MP, UP
182	*Euphorbia ligularia* Roxb.	Euphorbiaceae	UP
183*	*Euphorbia pycnostegia* Boiss.	Euphorbiaceae	Slope UP
184	*Falconeria insignis* Royle	Euphorbiaceae	Along slopes of BP
185	*Jatropha curcas* L.	Euphorbiaceae	MP
186	*Mallotus philippensis* (Lam.) Müll.Arg.	Euphorbiaceae	MP, Slope UP
187	*Securinega leucopyrus* (Willd.) Muell.-Arg.	Euphorbiaceae	MP
188	*Bridelia retusa* (L.) A.Juss.	Phyllanthaceae	BP, MP
189$	*Glochidion hohenackeri* (Müll.Arg.) Bedd.	Phyllanthaceae	MP
190	*Phyllanthus urinaria* L.	Phyllanthaceae	MP
191	*Linum mysorense* B.Heyne ex Wall.	Linaceae	Slope MP
192	*Terminalia chebula* Retz.	Combretaceae	BP , MP
193	*Terminalia tomentosa* Wight & Arn.	Combretaceae	BP
194	*Ammannia baccifera* L.	Lythraceae	UP
195$	*Lagerstroemia microcarpa* Wight	Lythraceae	Foothills
196*	*Rotala malampuzhensis* R.V.Nair ex C.D.K.Cook	Lythraceae	UP,MP
197	*Rotala rosea* (Poir.) C.D.K.Cook	Lythraceae	UP, MP
198	*Rotala serpyllifolia* (Roth) Bremek.	Lythraceae	UP
199	*Woodfordia fruticosa* (L.) Kurz	Lythraceae	BP
200	*Ludwigia octovalvis* (Jacq.) P.H.Raven	Onagraceae	UP
201	*Syzygium cumini* (L.) Skeels	Myrtaceae	BP
202*	*Sonerila scapigera* Dalzell	Melastomataceae	UP
203	*Lannea coromandelica* (Houtt.) Merr.	Anacardiaceae	UP
204	*Mangifera indica* L.	Anacardiaceae -	BP , MP
205	*Schleichera oleosa* (Lour.) Oken	Sapindaceae	MP
206	*Abelmoschus manihot* (L.) Medik.	Malvaceae	MP
207	*Abutilon persicum* (Burm.f.) Merr.	Malvaceae	MP
208$	*Eriolaena quinquelocularis* (Wight & Arn.) Wight	Malvaceae	MP
209	*Helicteres isora* L.	Malvaceae	BP
210	*Kydia calycina* Roxb.	Malvaceae	MP
211	*Sida acuta* Burm.f.	Malvaceae	BP
212	*Sida cordata* (Burm.f.) Borss.Waalk.	Malvaceae	BP
213	*Sida rhomboidea* Roxb. ex Fleming	Malvaceae	BP
214	*Sterculia guttata* Roxb. ex G.Don	Malvaceae	Slope MP
215	*Thespesia lampas* (Cav.) Dalzell	Malvaceae	MP
216	*Thespesia populnea* (L.) Sol. ex Correa	Malvaceae	Foothills
217	*Triumfetta annua* L.	Malvaceae	MP
218	*Triumfetta rhomboidea* Jacq.	Malvaceae	MP
219$	*Cleome simplicifolia* Hook.f. & Thomson	Cleomaceae	Slope UP
220	*Cardamine trichocarpa* Hochst. ex A.Rich.	Brassicaceae	Slope MP
221	*Roripa indica* (L.) Hiern	Brassicaceae	MP
222	*Dendrophthoe falcata* (L.f.) Ettingsh.	Loranthaceae	MP
223	*Persicaria glabra* (Willd.) M.Gomez	Polygonaceae	MP
224	*Polygonum plebeium* R.Br.	Polygonaceae	MP

	Plant species	Family	Location
225	*Drosera indica* L.	Droserceae	UP
226	*Achyranthes aspera* L.	Amaranthaceae	MP
227	*Alternanthera ficoidea* (L.) Sm.	Amaranthaceae	BP
228	*Alternanthera sessilis* (L.) R.Br. ex DC.	Amaranthaceae	Bp
229	*Celosia argentea* L.	Amaranthaceae	BP
230	*Gomphrena celosioides* Mart.	Amaranthaceae	MP
231	*Nothosaerva brachiata* (L.) Wight	Amaranthaceae-	Slope between MP and UP
232	*Glinus lotoides* L.	Aizoaceae	MP
233	*Impatiens balsamina* L.	Balsaminaceae	Slopes
234*	*Impatiens dalzellii* Hook.f. & Thomson	Balsaminaceae	Slopes along UP
235	*Impatiens minor* (DC.) Bennet	Balsaminaceae	MP
236	*Impatiens oppositifolia* L.	Balsaminaceae	MP
237	*Careya arborea* Roxb.	Lecythidaceae	MP
238	*Diospyros montana* Roxb.	Ebenaceae	MP
239	*Anagallis arvensis* L.	Primulaceae	MP
240	*Anagallis pumila* Sw.	Primulaceae	MP
241	*Embelia tsjeriam-cottam* (Roem. & Schult.) A.DC.	Primulaceae	MP
242	*Catunaregam spinosa* (Thunb.) Tirveng.	Rubiaceae	MP
243	*Meyna laxiflora* Robyns	Rubiaceae	MP
244$	*Neanotis foetida* (Dalzell) W.H.Lewis	Rubiaceae	Slope, UP, UP
245	*Neanotis montholonii* (Hook.f.) W.H.Lewis	Rubiaceae	MP
246	*Oldenlandia corymbosa* L.	Rubiaceae	UP
247	*Pavetta indica* L.	Rubiaceae	MP
248	*Spermadictyon suaveolens* Roxb.	Rubiaceae	MP
249	*Canscora diffusa* (Vahl) R.Br. ex Roem. & Schult.	Gentianaceae	Slopes MP
250	*Canscora pauciflora* Dalzell	Gentianaceae	Slope UP
251$	*Centaurium meyeri* (Bunge) Druce	Gentianaceae	MP
252$	*Exacum lawii* C.B.Clarke	Gentianaceae	Slope UP, UP
253	*Exacum petiolare* Griseb.	Gentianaceae	Slope UP, UP
254$	*Swertia minor* T.Cooke	Gentianaceae	Slope UP, UP
255	*Calotropis procera (*Aiton) Dryand.	Apocynaceae	BP
256	*Carissa congesta* Wight	Apocynaceae	MP
257*	*Ceropegia anjanerica* Malpure, M.Y.Kamble & S.R.Yadav	Apocynaceae	UP
258	*Ceropegia bulbosa* var. *bulbosa* Roxb.	Apocynaceae	UP
259*	*Ceropegia lawii* Hook.f.	Apocynaceae	MP, UP
260*	*Ceropegia media* (Huber) Ansari	Apocynaceae	Slopes
261	*Cryptolepis buchananii* Roem. & Schult.	Apocynaceae	UP
262	*Cynanchum callialatum* Buch.-Ham. ex Wight	Apocynaceae	Slope between MP and UP
263$	*Frerea indica* Dalzell	Apocynaceae	Along steep boulders
264	*Hemidesmus indicus* (L.) R. Br. ex Schult.	Apocynaceae	BP
265$	*Heterostemma alatum* Wight & Arn.	Apocynaceae	UP
266	*Nerium oleander* L.	Apocynaceae	MP
267	*Rauvolfia serpentina* (L.) Benth. ex Kurz	Apocynaceae	BP
268$	*Tylophora dalzellii* Hook.f.	Apocynaceae	MP
269$	*Adelocaryum coelestinum* (Lindl.) Brand	Boraginaceae	Slope of UP

	Plant species	Family	Location
270$	*Adelocaryum malabaricum* (C.B.Clarke) Brand	Boraginaceae	Slope of UP
271	*Cordia dichotoma* G.Forst.	Boraginaceae	BP
272	*Cynoglossum wallichii* G.Don	Boraginaceae	UP
273	*Heliotropium indicum* L.	Boraginaceae	MP
274	*Heliotropium supinum* L.	Boraginaceae	Slope of MP
275	*Trichodesma inaequale* Edgew.	Boraginaceae	MP
276*	*Argyreia involucrata* C.B.Clarke	Convolvulaceae	BP
277	*Dinetus racemosus* (Roxb.) Buch.-Ham. ex Sweet	Convolvulaceae	MP
278	*Ipomoea hederifolia* L.	Convolvulaceae	MP
279	*Ipomoea illustris* (C.B.Clarke) Prain	Convolvulaceae	MP
280	*Ipomoea nil* (L.) Roth	Convolvulaceae	BP
281	*Ipomoea obscura* (L.) Ker Gawl.	Convolvulaceae	MP
282	*Ipomoea triloba* L.	Convolvulaceae	BP
283	*Rivea hypocrateriformis* Choisy	Convolvulaceae	MP
284	*Rivea ornata* Choisy	Convolvulaceae	MP
285	*Solanum anguivi* Lam.	Solanaceae	MP
286	*Jasminum arborescens* Roxb.	Oleaceae	MP
287	*Olea dioica* Roxb.	Oleaceae	MP
288	*Lindenbergia muraria* (Roxburgh ex D. Don) Brühl	Plantaginaceae	MP, UP
289	*Mecardonia procumbens* (Mill.) Small	Plantaginaceae	MP
290	*Lindernia ciliata* (Colsm.) Pennell	Linderniaceae	UP
291	*Lindernia nummulariifolia (*D.Don) Wettst.	Linderniaceae	UP
292	*Lindernia parviflora* (Roxb.) Haines	Linderniaceae	UP
293	*Torenia indica* C.J.Saldanha	Linderniaceae	UP
294$	*Nepeta hundostana* var. *woodrowii* (T.Cooke) Santapau	Lamiaceae	Slope UP
295	*Anisochilus carnosus* (L.f.) Wall.	Lamiaceae	MP
296$	*Anisomeles heyneana* Benth.	Lamiaceae	Slope UP
297	*Colebrookea oppositifolia* Sm.	Lamiaceae	BP
298	*Lantana camara* L.	Lamiaceae	BP
299$	*Lavandula bipinnata* (Roth) Kuntze	Lamiaceae	Slope MP
300	*Leucas lavandulaefolia* Rees	Lamiaceae	MP, UP
301	*Leucas martinicensis* (Jacq.) R.Br.	Lamiaceae	UP, MP Slope
302	*Leucas stelligera* Wall. ex Benth.	Lamiaceae	MP,UP
303	*Plectranthus mollis* (Aiton) Spreng.	Lamiaceae	MP
304	*Pogostemon benghalensis* (Burm.f.) Kuntze	Lamiaceae	BP
305$	*Pogostemon deccanensis* (Panigrahi) Press	Lamiaceae	UP
306	*Rotheca serrata* (L.) Steane & Mabb.	Lamiaceae	Slope UP
307	*Tectona grandis* L.f.	Lamiaceae	BP
308	*Vitex negundo* L.	Lamiaceae	MP
309	*Parasopubia delphiniifolia* (L.) H.-P. Hofm. & Eb. Fisch.	Orobanchaceae	MP
310*	*Rhamphicarpa longiflora* Benth.	Orobanchaceae	MP
311	*Striga gesnerioides* (Willd.) Vatke	Orobanchaceae	UP
312$	*Utricularia janarthanamii* S.R.Yadav, Sardesai & S.P.Gaikwad	Lentibulariaceae	UP
313 $	*Utricularia praeterita* P.Taylor	Lentibulariaceae	UP
314	*Utricularia striatula* Sm.	Lentibulariaceae	MP and UP

	Plant species	Family	Location
315	*Asystasia dalzeliana* Santapau	Acanthaceae	MP
316$	*Barleria lawii* T.Anderson	Acanthaceae	Slope between BP and MP
317*	*Cynarospermum asperrimum* (Nees) Vollesen	Acanthaceae	Slope between UP and MP
318	*Dicliptera leonotis* Dalzell ex C.B.Clarke	Acanthaceae	MP
319$	*Eranthemum roseum* (Vahl.) R.Br.	Acanthaceae	Slopes
320$	*Haplanthodes verticellata* (Roxb.) R.B.Majumdar	Acanthaceae	UP
321$	*Hemigraphis crenata* (Benth.) Bremek.	Acanthaceae	Slope between MP and UP
322$	*Hemigraphis latebrosa* (Roth) Nees	Acanthaceae	Slope between MP and UP
323	*Hygrophila auriculata* (Schumach.) Heine	Acanthaceae	MP
324$	*Hygrophila serpyllum* (Nees) T.Anderson	Acanthaceae	MP
325	*Justicia betonica* L.	Acanthaceae	Slope between MP and UP
326	*Justicia japonica* Thunb.	Acanthaceae	Slope between MP and UP
327	*Justicia procumbens* L.	Acanthaceae	Slope between MP and UP
328$	*Lepidagathis cuspidata* Nees	Acanthaceae	MP and Slope between MP and UP
329$	*Lepidagathis trinervis* Nees	Acanthaceae	UP
330$	*Neuracanthus sphaerostachys* Dalzell	Acanthaceae	MP
331	*Peristrophe bicalyculata* (Retz.) Nees	Acanthaceae	Slope between MP and UP
332$	*Rungia elegans* Dalzell & A.Gibson	Acanthaceae	Slope between MP and UP
333	*Rungia pectinata* (L.) Nees	Acanthaceae	Slope between MP and UP
334$	*Strobilanthes callosa* Nees	Acanthaceae	Slope between MP and UP , UP
335$	*Strobilanthes reticulata* Stapf	Acanthaceae	UP
336$	*Heterophragma quadriloculare* (Roxb.) K.Schum.	Bignoniaceae	BP
337	*Lantana camara* L.	Verbenaceae	BP
338	*Martynia annua* L.	Martyniaceae	MP
339	*Lobelia heyneana* Schult.	Campanulaceae	Slope UP, UP
340	*Lobelia nicotianifolia* Roth ex Schult.	Campanulaceae	Slope UP,UP
341	*Acmella paniculata* (Wall. ex DC.) R.K.Jansen	Asteraceae	MP
342	*Ageratum conyzoides* L.	Asteraceae	MP
343	*Bidens biternata* (Lour.) Merr. & Sherff	Asteraceae	MP, BP
344$	*Blumea eriantha* DC.	Asteraceae	Slope between BP & UP
345$	*Blumea malcolmii* Hook.f.	Asteraceae	Slope between BP & UP
346	*Blumea mollis* (D.Don) Merr.	Asteraceae	MP
347$	*Caesulia axillaris* Roxb.	Asteraceae	Slope between BP & UP
348	*Chromolaena odorata* (L.) R.M.King & H.Rob.	Asteraceae	Slope between MP & UP
349	*Cosmos caudatus* Kunth	Asteraceae	Slope between BP & UP
350	*Cyanthillium cinereum* (L.) H.Rob.	Asteraceae	BP
351$	*Cyathocline lutea* Law ex Wight	Asteraceae	UP
352	*Cyathocline purpurea* (Buch.-Ham. ex D.Don) Kuntze	Asteraceae	MP
353	*Eclipta prostrata* (L.) L.	Asteraceae	BP
354	*Elephantopus scaber* L.	Asteraceae	MP, UP
355	*Emilia sonchifolia* (L.) DC. ex DC.	Asteraceae	Slope between MP & UP
356	*Erigeron trilobus* (Decne.) Boiss.	Asteraceae	Slope between BP & UP
357	*Galinsoga parviflora* Cav.	Asteraceae	Slope between MP & UP
358	*Gnaphalium pulvinatum* Delile	Asteraceae	Slope between MP & UP

	Plant species	Family	Location
359	*Grangea maderaspatana* (L.) Poir.	Asteraceae	Slope between MP & UP
360	*Gynura bicolor* (Roxb. Ex Willd.) DC.	Asteraceae	Slope between MP & UP
361	*Kleinia grandiflora* (Wallich ex DC.) N.Rani	Asteraceae	Slope between MP & UP
362	*Lagascea mollis* Cav.	Asteraceae	BP
363	*Laphangium luteoalbum* (L.) Tzvelev	Asteraceae	Slope between MP & UP
364	*Launaea procumbens* (Roxb.) Ramayya & Rajagopal	Asteraceae	BP
365*	*Nanothamnus sericeus* Thomson	Asteraceae	Slope between MP & UP
366	*Pentanema cernuum* (Dalzell) Ling	Asteraceae	MP, UP
367	*Pentanema indicum* (L.) Ling	Asteraceae	MP,UP
368$	*Phyllocephalum scabridum* (DC.) K.Kirkman	Asteraceae	Slope between MP & UP
369	*Pluchea senecioides* (DC.) W.Theob.	Asteraceae	UP
370$	*Senecio bombayensis* N.P.Balakr.	Asteraceae	MP, UP
371*	*Senecio dalzellii* C.B.Clarke	Asteraceae	MP,UP
372	*Sigesbeckia orientalis* L.	Asteraceae	UP
373	*Sonchus oleraceus* (L.) L.	Asteraceae	UP
374	*Sphaeranthus indicus* L.	Asteraceae	BP
375	*Synedrella nodiflora* (L.) Gaertn.	Asteraceae	MP
376$	*Tricholepis amplexicaulis* C.B.Clarke	Asteraceae	MP
377	*Tridax procumbens* L.	Asteraceae	BP
378	*Vernonia anthelmintica* (L.) Willd.	Asteraceae	BP
379	*Vernonia divergens* (DC.) Edgew.	Asteraceae	BP
380	*Xanthium strumarium* L.	Asteraceae	BP
381*	*Heracleum grande* (Dalzell & A. Gibson) Mukhop.	Apiaceae	UP
382$	*Pimpinella adscendens* Dalzell	Apiaceae	UP
383$	*Pimpinella wallichiana* (Miq.) Gandhi	Apiaceae	Slopes
384*	*Pinda concanensis* (Dalzell) P.K. Mukh. & Constance	Apiaceae	UP and Slopes
385	*Trachyspermum roxburghianum* (DC.) H.Wolff	Apiaceae	UP

$—Endemic to India | *—Endemic to Western Ghats | MP—Middle plateau | BP—Basal plateau | UP—Upper plateau.

the peak flowering period on the plateau; 3. In the post monsoon phase (October–December) *Arundinella ciliata*, *Indopoa paupercula*, *Dimeria* spp., and *Striga gesnerioides* come in flowering; 4. The fourth phase (January–May) is the dry period during which only a few species such as *Blumea eriantha*, *Blumea malcolmii*, *Lepidgathis cuspidata* flower in January–February. *Drimia polyantha*, *Euphorbia khandallensis*, and *Pancratium nairii* flowers in March. Observations on the phenology of the plants revealed that maximum number of species complete their reproductive cycle between July and December.

Middle slopes of Anjaneri Hill exhibit small patch of evergreen trees, shrubs, and herbaceous flora due to retention of some amount of soil. Surrounding plants also affected the climatic condition of the plateaux, which favors the herbaceous flora, e.g., the forest undergrowth.

Threats

Anjaneri Hill is utilized for grazing, resource extraction, and tourism. Relatively easy road access, trampling, trails, and tourist services, could have direct or indirect impacts on floristic diversity. We have reported the shifting of few plant species and decrease in population from middle level e.g., *Pinda concanensis*, *Pancratium nairii*, *Drimia polyantha*, *Polygala arvensis*, and few species of *Smithia* to upper plateaux due to drastic seasonal changes in moisture content, amount and time of rainfall. Heavy rainfall for longer duration causes vegetative growth and delay in initiation of flowering in *Pogostemon deccanensis*.

Adaptive traits

Plants on this plateau experience harsh environmental conditions, e.g., drought, high temperature and light intensities and nutrient deficiency, which cause development of certain traits in plants of plateaux, which allow them to overcome environmental adversities. A detailed account on the adaptation/eco-physiology of vascular plants of rock outcrops is provided by Kluge & Brulfert (2000). Some well-known adaptive traits that have been observed in the vascular plants on the plateaux are mentioned below (modified after Biedinger et al. 2000).

1. Carnivory: It is a means to overcome the scarcity of Nitrogen, Phosphorous and Sulphur in the soil. Carnivorous plants are extremely calcifuge and need acidic and wet soils (Kluge & Brulfert 2000). *Drosera indica*, *Utricularia prateirata* are the common carnivores on the plateaux. These species comprise ephemeral vegetation where soil deposition is negligible.

2. Succulence: Succulence is a 'desiccation avoidance strategy' in xeric habitats. Typical leaf succulents of the plateau are *Cyanotis concanensis* Hassk. and *Euphorbia khandallensis*.

3. Poikilohydry: These are plants in which water content varies with the varying humidity in the environment. Desiccation tolerance is mainly a protoplasmic property, e.g., *Tripogon lisboae.*

4. Subterranean perennating organs: This is yet another adaptive strategy of the plants of the

plateau in the form of underground perennation organs like corms, rhizomes, bulbs, and tubers, e.g., geophytes like *Ceropegia anjanerica*, *C. lawii*, *Curcuma neilgherrensis*, *Cyanotis fasciculata*, *C. concanensis*, *Eriocaulon tuberiferum*, *Euphorbia khandallensis*, *Habenaria* spp., and *Hypoxis aurea*.

5. Vegetative propagation: Vegetative propagules such as bulbs and bulbils formed at the leaf tips are an adaptation of some plants of the plateaux, e.g., *Curculigo orchioides*

CONCLUSIONS

Anjaneri a basaltic outcrop is unique due to great diversity (385 species), high endemism (114 taxa) and as type locality of *Ceropegia anjanerica*. Outcrop exhibited different habitats due to its distinct geographical location, climatic condition and edaphic nature. Due to adverse climatic conditions and extreme micro-environments, plants have developed unique morphological, physiological and life cycle adaptations.

The environmental uniqueness, high diversity, IUCN assessment studies, high anthropogenic activities and rapid destruction of these ecosystems make Anjaneri outcrop a "hotspeck". Systematic approaches are required to conserve various unique habitats, which supported great diversity of existing plant species and for the conservation of *Ceropegia anjanerica.*

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Author contribution: SAG done the preliminary survey of the area, planned the field tours and documented the Plants through Video Camera, wrote the first raw draft of the MS. SSK analyzed the data, identified the dicotyledonous plants and confirmed their identity. KVCG worked on the monocotyledonous plants especially on the grasses and photographed the plants. ANC documented and confirmed the identities of the monocotyledonous plants especially Cyperaceae.

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COMMUNICATION

A checklist of macrofungi (mushroom) diversity and distribution in the forests of Tripura, India

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Abstract: The tropical region, which has the highest macrofungi diversity, has not been fully exploited instead of this is an important component of the global diversity. However, no work has been carried out to assess such diversity in Tripura. Since tropical forests are diverse in plant composition and structure, hence the objective of this study was to explore the mushroom species richness in Tripura, Northeast India with the aim of producing a checklist along with their present geographical distributions, key identification characters and valid photographs. Field surveys and collection of mushrooms were carried out in Tripura covering different sites during 2015–2018. Data on macrofungal diversity, distribution patterns and taxonomic identification were analyzed. A total of 217 wild mushrooms were documented from eight districts of Tripura, northeastern India. Out of 217 samples, 202 samples were identified up to the genus level, 125 samples were identified up to the species level. A total of 76 genera belonging to 60 families and 25 orders were classified in this ecological study. The majority of macrofungi belong to the family Polyporaceae (30 nos), and order Agaricales (103 specimens). The wild macrofungi were collected from 56 sites of eight districts of this state and the maximum macrofungal diversity was recorded from Sepahijala District. Present findings also observed that the maximum wild fungi of this state grow on different plant parts. This is the preliminary study on documentation of wild macrofungi from eight districts of Tripura, northeastern India and it will be used as a reference database of wild mushrooms of this state, which will also help in future research work in different fields.

Keywords: Geographical distribution, fungi, habitats, mycoflora, northeastern India.

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Author contribution: SD has done the different data collections, fieldwork and photography, micro-morphology work of this study and writing part of this manuscript. RCU has done the confirmation of this taxonomical work and correction part of the manuscript. RS has helped in fieldwork and photography of the studied macrofungi. KM has prepared the maps with the help of GPS data. PD helped in writing part of the manuscript. AKS has done the correction part of the manuscript and supervised this work. All authors reviewed the research article.

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INTRODUCTION

Fungi have been known from (the fossil records) the Silurian period according to archaeological evidence (408–438 million years ago) in the Paleozoic era and the diversity of fungi had improved by the Pennsylvanian period 286–320 million years ago (Alexopoulos et al. 1996). Fungi are one of the diverse kingdoms of eukaryotes and important major biological constituents of forest ecosystems. It is important to understand their existence on plant communities, their ecological functions and their impact on nature (Martin et al. 2011). Mushrooms can be defined as macrofungi having unique fruiting bodies which are either epigeic or hypogeic, visualized by the naked eye and are easily handpicked (Chang & Miles 2004). Hence, Hawksworth (2001) has anticipated that 0.14 million species created fruiting bodies of adequate shape, size, and appropriate structure to be considered as macrofungi i.e., mushrooms out of the 1.5 million studied fungi based on Chang & Miles (2004). These studies have stressed the importance of macrofungi in nature preservation and forestry organization different from agroecosystems (Straatsma et al. 2001). Ecologically, fungi can be classified into three groups—saprophytes, the parasites, symbiotic or mycorrhizal and endophytic species. Most of the terrestrial macrofungi are saprobic, mycorrhizal symbionts, but some of them are pathogens of plants or other fungi.

According to Manoharachary et al. (2005) India is enriched with mushroom flora as one-third of the fungal diversity of the globe exists in India and only 50% of these have been characterized till date. Northeastern India is also very richin macrofungal diversity (Verma et al. 1995) and very few reports on macrofungal diversity have been carried out in the northeastern region of India (Das 2009 and 2010; Tanti et al. 2011; Tapwal et al. 2013). This study to collect, document, and classify the macrofungi was undertaken to fill this data gap. Tripura is one of the seven states in the northeastern part and the third smallest state of India with a geographical area of 10,491km^2, of which 6,292km^2 (59.98%) is forest area as per legal classification in the state. Tripura situated between 23.840^{0}N and 91.280^{0}E. The fruiting bodies of mushroom species grow only under precise conditions, including geographic location, elevation, temperature, humidity, light, pH, nutritional sources (carbon and nitrogen sources) and surrounding flora (Swapna et al. 2008).

The existence or nonexistence of mushrooms species is a potential indicator to assess the deterioration or the development of an ecosystem and they also play an important role in nutrient reprocessing, growth and establishment of plants in forests (Tapwal et al. 2013). Literature survey concerning the documentation of macrofungi revealed that there are meager reports available from northeastern India. The field documentation of macrofungi from Tripura remains unexplored till today. Therefore, the main intention of the current study was to identify wild macrofungi up to species level and to document their distribution in natural habitats. Thus, the specific goal of this study was to prepare a checklist of macrofungi in different districts of Tripura, northeastern India and also to raise awareness among people to conserve macrofungi for future generations and to maintain the ecosystem's diversity.

MATERIALS AND METHODS

Study area

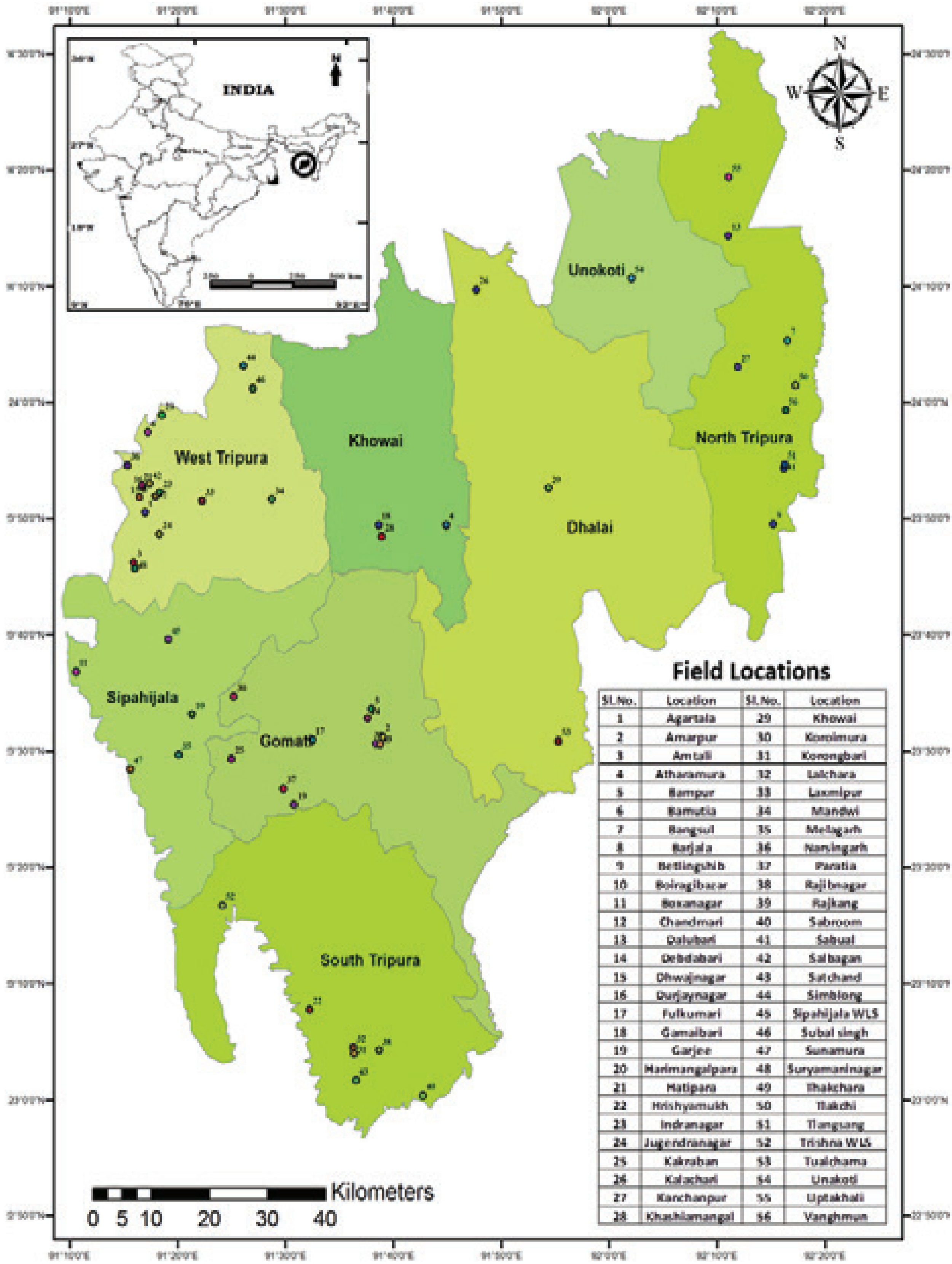
The current study was conducted in eight districts of Tripura namely, Dhalai, Sipahijala, Khowai, Gomati, Unakoti, North Tripura, South Tripura, and West Tripura (Figure 1).

Collecting sites

Included undisturbed forest, secondary forests, roadside, plantations, crop fields, jhum fallow and agriculture lands. The samples were collected through simple random sampling method from different sites, which is an unbiased surveying technique and each specimen was chosen randomly and entirely by chance during the rainy season of 2015–2018.

Mushroom collection

Macrofungi were collected carefully by using forceps or trowel from their natural habitats. Photographs were taken and information such as date of collection, locality, habitat, colour, odour, test, size and shape of the specimen in their natural condition were also recorded as field notes (Table 1). Each sample was given specific laboratory accession number—Mushroom Culture Collection Tube (MCCT) for future reference and identification. After collection, all specimens were wrapped in a paper envelope and cautiously taken to the newspaper sheet and labelled systematically as per given MCCT #. Specimens were dried in a hot air oven at 45–55^{o}C for 48hr and then samples were preserved in sealed polyethylene bags by adding 1, 4-dichlorobenzene (Debnath et al. 2017). All dry mushroom samples were



Sl.No.	Location	Sl.No.	Location
1	Agartala	29	Khowai
2	Amarpur	30	Korolmura
3	Amtali	31	Korongbari
4	Atharamura	32	Lalchara
5	Bampur	33	Laxmipur
6	Bamutia	34	Mandwi
7	Bangsul	35	Melagarh
8	Barjala	36	Narsingarh
9	Bettingshib	37	Paratia
10	Boiragibazar	38	Rajibnagar
11	Boxanagar	39	Rajkang
12	Chandmari	40	Sabroom
13	Dalubari	41	Sabual
14	Debdabari	42	Salbagan
15	Dhwajnagar	43	Satchand
16	Durjaynagar	44	Simblong
17	Fulkumari	45	Sipahijala WLS
18	Gamaibari	46	Subal singh
19	Garjee	47	Sunamura
20	Harimangalpara	48	Suryamaninagar
21	Hatipara	49	Thakchara
22	Hrishyamukh	50	Thakchi
23	Indranagar	51	Tlangsang
24	Jugendranagar	52	Trishna WLS
25	Kakraban	53	Tualchama
26	Kalachari	54	Unakoti
27	Kanchanpur	55	Uptakhali
28	Khashiamangal	56	Vanghmun

Figure 1. Tripura and 56 sites surveyed for collection of 217 macrofungi from eight districts of Tripura, northeastern India.

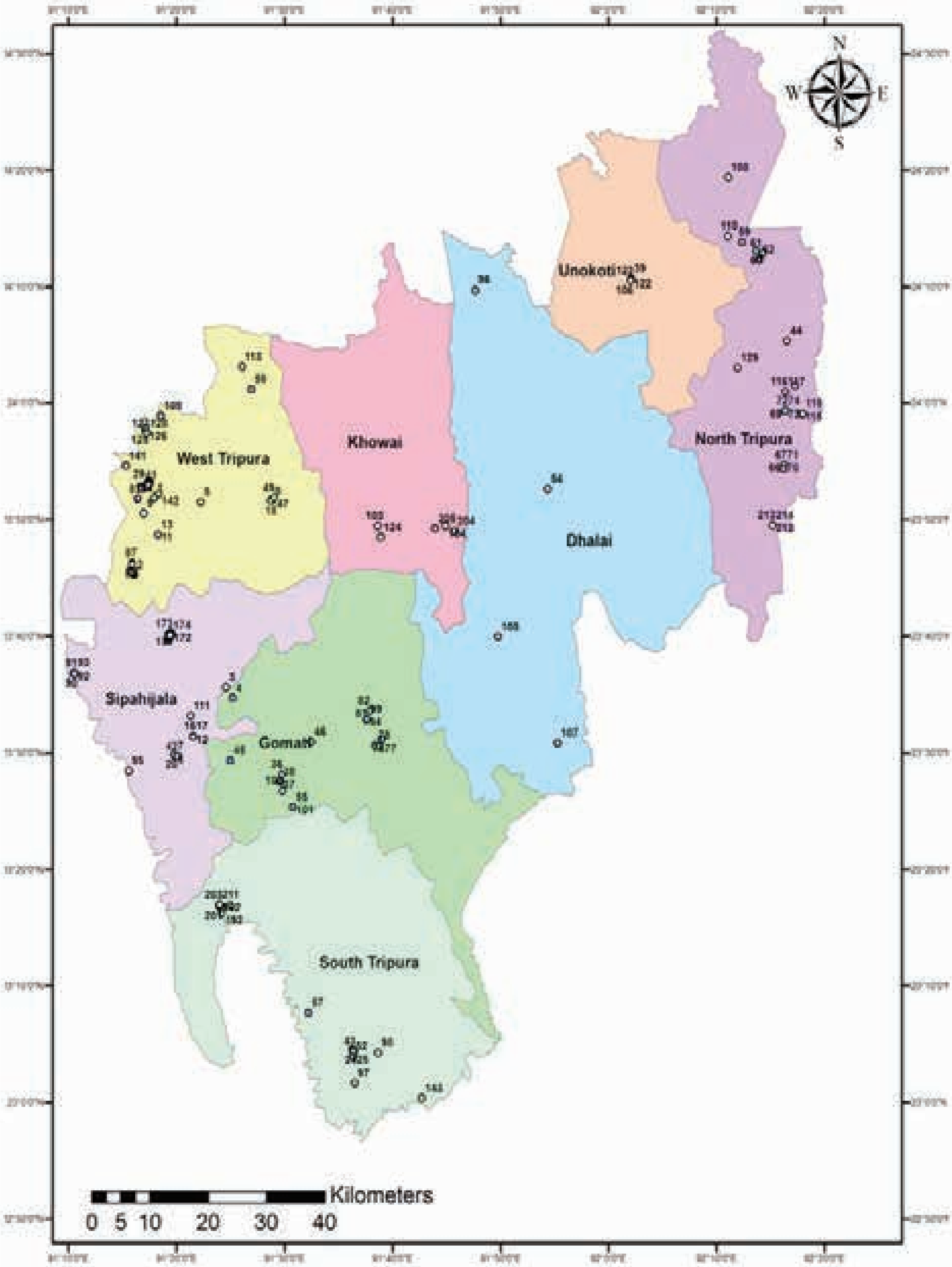


Figure 2. Geographical distribution of 217 macrofungi collected from different habitats of Tripura.

deposited in the Mycology & Plant Pathology Laboratory, Department of Botany, Tripura University for future reference.

Identification of wild mushrooms

Wild mushrooms were identified morphologically based on the available literature, viz., Pegler (1977); Purkaystha & Chandra (1985); Weinstein et al. (2002); Castellano et al. (2003); Hall et al. (2003); Rogers et al. (2005); Antonín & Buyck (2006); Desjardin & Ovrebo (2006); Wei & Yao Tang (2009); Senthilarasu (2013a,b); Karun & Sridhar (2013); Moore & O'Sullivan (2014); Semwal et al. (2014). We also considered available webresources (http://www.mushroomexpert.com/major_groups.html; http://www.mycokey.com/newMycoKeySite/MycoKeyIdentQuick.html; http://qldfungi.org.au/ etc.) for identification and confirmation of wild mushrooms.

RESULTS

Morphological identification and processing

In this study, macrofungi were randomly collected from 56 different sites under eight different districts of Tripura. Among these eight districts,the maximum number of mushroom specimens, i.e., 62 different mushrooms were collected from Sepahijala District followed by West Tripura (55), South Tripura (39), North Tripura (18), Gomati (14), Khowai (9), Dhalai (4), and Unakoti (4) (Figure 1). Sepahijala District ishighly diverse sincethis area contains two wildlife sanctuaries (Sepahijala and Trishna) which were protected and undisturbed areas. Mushroom specimens were identified on the basis of their morphometric characteristics. All information about wild mushrooms such as scientific name, location, habitat, district name and distinguishing characters are presented in Table 1 and the photographs are presented in Image 1–11.

This study revealed that these mushrooms were recorded for the first time from this region. A total number of 217 macrofungal species were documented of which 202 were identified at genus level and 15 macrofungal specimens remain unidentified (Table 1). The geographic distribution of all 217 macrofungal species (as per serial number mentioned in Table 1) throughout the study area was shown in Figure 2. Most of the wild mushrooms recorded inthis study were found to grow on dead wood.

In this study, a total of 77 genera belonging to 42 families and 16 orders were considered for ecological studies. Among the collected samples, majority of macrofungi belong to the family Polyporaceae, which contained 30 species and nine genera (Figure 3). The dominant genus was *Lentinus* which contain 12 morphotypes and *Marasmiellus, Pleurotus* were the second and third dominant genus which contained 11 and nine morphotypes, respectively (Figure 4). Agaricaceae and Marasmiaceae were found to be second dominant families because both families contained 21 species each belonging to eight and four genera, respectively. On the other hand, order Agaricales contained the maximum

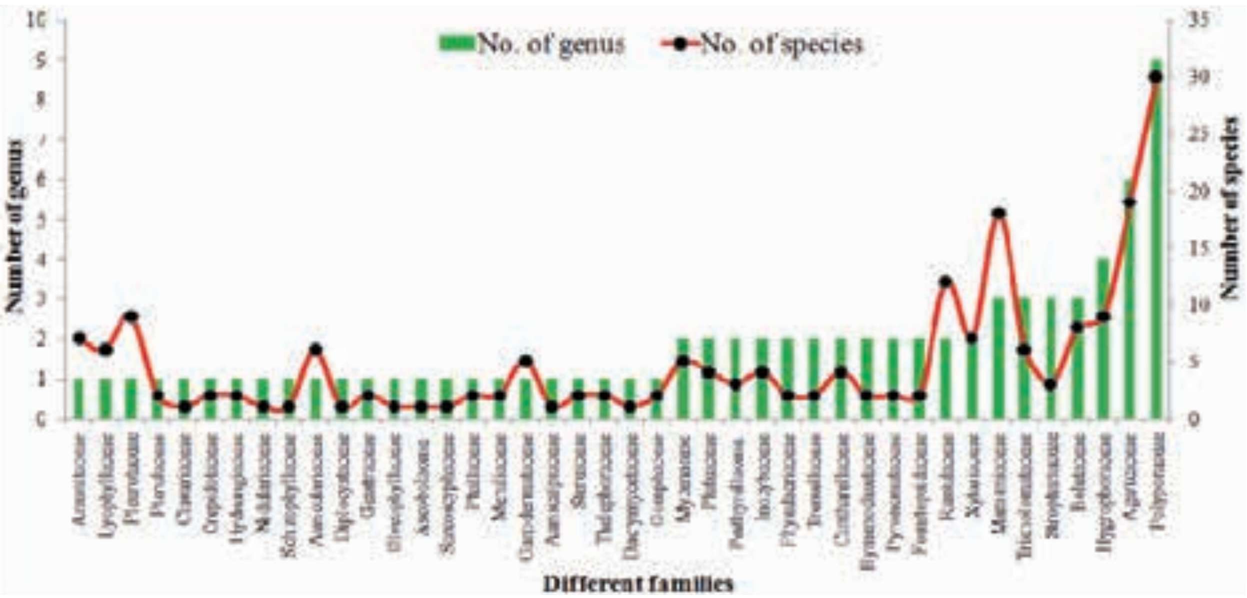


Figure 3. Distribution of macrofungal genus and species into different families.

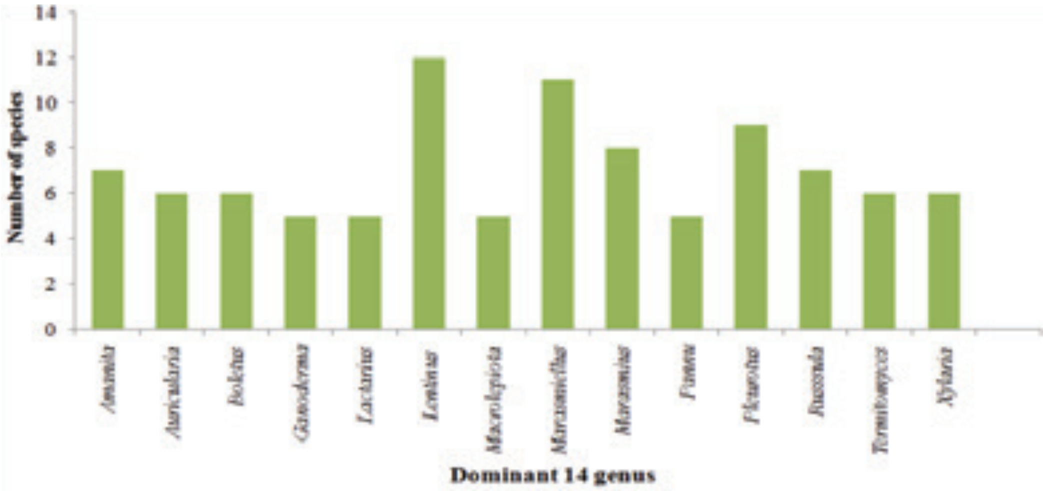


Figure 4. Total number of macrofungal species distributed into different genera.

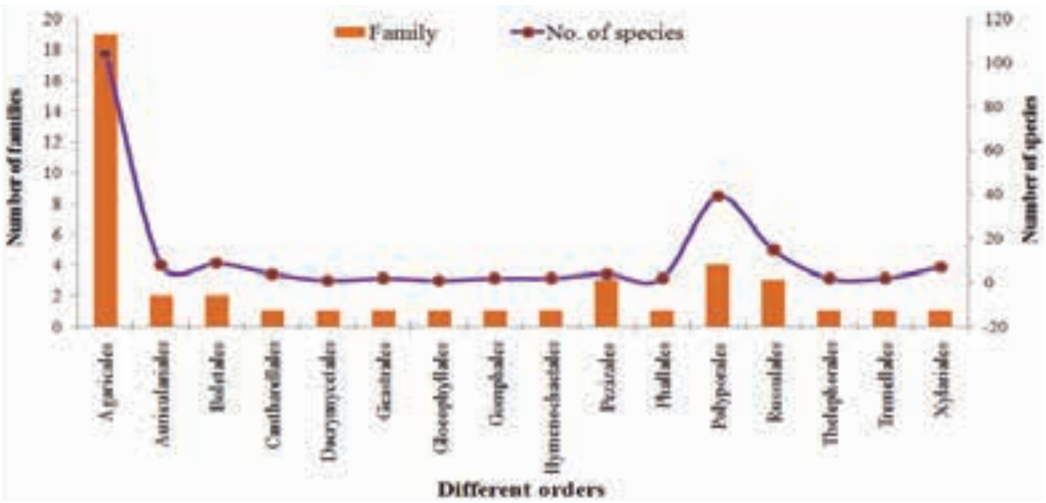


Figure 5. Taxonomic richness of macrofungal species in Tripura.

number of macrofungal species, whereas Polyporales and Russulales are the second and third dominant orders (Figure 5).

Present observations showed that fungal diversity also depends on their substrates. The maximum numbers of wild mushrooms of this state easily grow on dead wood during the monsoon, winter, spring and summer seasons. In this study 31 types of habitats were observed and these were catagorised into four groups namely, different plant parts (bark of living plant, dead wood, dead root, decaying paddy straw, decaying rice bran, decomposed wooden dust, bamboo rhizome, dead decaying wood, dead leaf, dead wooden bark, decaying bamboo, decaying plant, sawdust, living plant, decaying leaf, dead plant, decaying wood, dead wood), decomposed soil (decaying wood with soil, decomposed grass, soil with decaying paddy straw, soil with

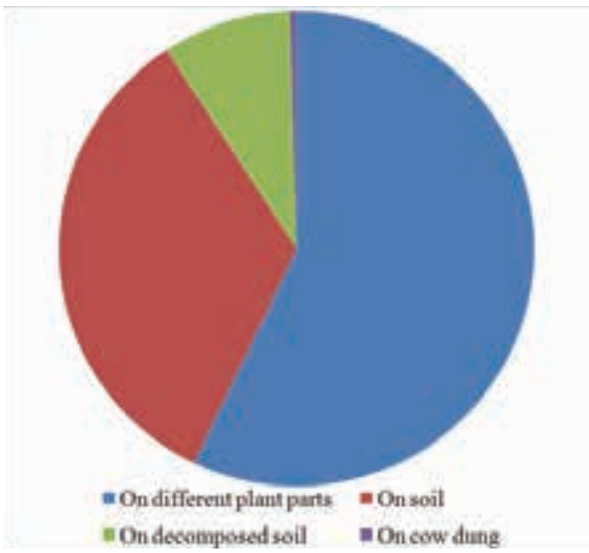


Figure 6. Different habitats used by 217 macrofungi species of Tripura.

Table 1. Checklist of wild mushroom diversity of Tripura with their collection number (*MCCT-Mushroom Culture Collection Tube), valid scientific name, their natural distribution in Tripura, habitat ecology, distinguishing features for identification

	LCN	Scientific name	Location	Districts	Habitat	Distinguishing features
1	MCCT010	*Agaricus campestris* L.	Chandmari	West Tripura	On ground in open grassy field soil	Solitary, gregariously. Pileus 5–6 cm, convex to broadly convex, whitish to brown, smooth and fibrous, scaly; gills free from the stipe, deep pink becoming brown and dark brown in maturity, crowded. Stipe 4–5×1–2 cm, white, more or less equal, ring present at premature stage.
2	MCCT011	*Macrolepiota procera* (Scop.) Singer.	Suryamaninagar	West Tripura	On soil with grass field	Solitary, scattered or gregarious. Pileus 10–15 cm, white but at mature stage centre are brown, brown scales are present; gills free, crowded, white. Stipe 12–16×1.5–2.0 cm, white to light brownish and long straight, scale and ring present.
3	MCCT017	*Chlorophyllum molybdites* (G. Mey.) Massee	Koroimura	South Tripura	On woods of dead plants	Solitary or scattered or sometimes gregarious. Pileus 10–11 cm, white, convex to spherical in young stage but almost flat in mature stage, surface scaly, top part light brown; gills free, crowded, white to brownish. Stipe 10–15×1.5–2.5 cm, white to light brownish, enlarged toward base, white ring present, after touching it changes its colour of light bluish.
4	MCCT018	*Amanita* sp. Pers.	Koroimura	South Tripura	On soil	Mycorrhizal, basidiocarp small, conical. Pileus 2–3 cm, white with white scales; lamellae white, thin, mostly crowded. Stipe 3–4 cm, well developed, central, white with white scles, seperable from pileus; volva very small and white.
5	MCCT021	*Marasmius* sp. Fr.	Laxmipur	West Tripura	On decaying leaf of Rubber	Saprobic, solitary or scattered. Pileus 2–3 cm, cyathiform, dark brown, convex to becoming flat, faintly lined at the margin, dry. Stipe 7–8×0.3–0.7 cm, light brown, equal, dry, white mycelium present at the base.
6	MCCT022	*Macrolepiota* sp. Singer	Melagarh	Sepahijala	On soil with decomposed leaf	Lepiotoid, solitary, large. Pileus 4.5–9.5 cm, white, soft, fleshy, expanding, squamulose; lamellae free, soft, white broad, crowded. Stipe 7–15×0.4–1.2 cm, white, central, elongate, little bulbose base, fleshy, surface fibrillose; annulus present and mobile.
7	MCCT023	*Leucocoprinus cretaceous* (Bull.) Locq.	Melagarh	Sepahijala	On root of bamboo	Saprobic, gregarious. Pileus 6cm, milky white, dusted with white powder, egg shaped when young but at maturity it becomes convex to bell shaped, white and powdery; gills free from the stem, crowded. Stipe 6–7×1.5–2.5 cm, white and powdery, non-straight; ring present at premature stage.
8	MCCT024	*Tricholoma* sp. Fries.	Mandwi	West Tripura	On soil	Solitary. Pileus 10–11 cm, depressed, creamish white, distant, crowded. Stipe 16–17 cm, creamish white, equal, solid, rough surface.
9	MCCT027	*Lentinus* sp. Fr.	Agartala	West Tripura	On living plant	Saprobic, solitary. Pileus 1–2 cm, infundibuliform, white to cream; lamellae decurrent, crowded. Stipe 10–12 cm, brownish, central or ecentric, cylindrical, equal or expended at upper and lower portion, solid.
10	MCCT028	*Lentinus* sp. Fr.	Melagarh	Sepahijala	On dead wood	Saprobic, solitary or caespitose. Pileus 7–11×6–7.5 cm, medium to large, depressed, surface dry, cream white off white; margin thin and inrolled; lamellae decurrent, crowded, entire. Stipe 7–12.5×0.5–1.3 cm, cream white, lateral, elongate, solid, firm.
11	MCCT030	*Parasola auricoma* (Pat.) Redhead, Vilgalys & Hopple	Jugendranagar	West Tripura	On soil or bamboo rhizome	Gregarious, fruit body milky white, dusted with white powder. Pileus 6cm, egg shaped when young but at maturity it becomes convex to bell shaped, white and powdery; gills free from the stipe, crowded. Stipe 6–7×1.5–2.5 cm, white and powdery, non-straight; ring present at premature stage.
12	MCCT031	*Panus* sp. Fr.	Melagarh	Sepahijala	On dead plant	Saprobic, solitary or caespitose, tough. Pileus 4–6.5×4–6 cm, coriaceous, deeply infundibuliform to expanding to cyathiform, pale purplish to reddish brown, dense squamules, more towards the centre; lamellae arcuate, short to deeply decurrent, reddish brown. Stipe 2–3.5×0.1–0.4 cm, brown, cylindric, equal, expanding slightly at the apex, solid, surface concolorous with the pileus.
13	MCCT032	*Polyporus* sp.P.Micheli ex Adans.	Jugendranagar	West Tripura	On living plant of Rubber	Saprobic, caespitose. Pileus 8–10×4–5.8 cm, irregularly flabelliform, cracked, pore present at lower surface, circular shaped pore, edge yellowish, white to cream. Stipe 0.5–1×0.3–0.5 cm, white to cream, solid.
14	MCCT033	*Marasmiellus* sp.Murrill	Melagarh	Sepahijala	On dead plant	Saprobic, marasmioid, small to medium. Pileus 5–6.5 cm, white, soft to membranous, slight translucent; lamellae adnexed to decurrent, thin. Stipe 4–5.5× 0.2–0.4 cm, short, white, slightly lateral, solid.
15	MCCT035	*Marasmiellus* sp.Murrill	Melagarh	Sepahijala	On dead plant	Saprobic, marasmioid, small to medium in size. Pileus 1.2–3.0 cm, white, convex to applanate, smooth, glabrous slightly translucent; lamellae adnate, narrow, distant, white. Stipe 1.0–1.7×0.1–0.3 cm, white, excentric or lateral, equal, solid, translucent.

	LCN	Scientific name	Location	Districts	Habitat	Distinguishing features
16	MCCT036	*Lentinus crinitus* (L.) Fr.	Melagarh	Sepahijala	On soil with shaded area	Solitary. Pileus 1–5.5 cm, infundibuliform to cyathiform, white to purplish; lamella decurrent, crowded, edge serrate to denticulate. Stipe 4–7 cm, central, cylindrical, equal or expended at upper and lower portion, solid or almost woody, brownish, scales present in pileus and stipe.
17	MCCT037	*Marasmiellus corticum*Singer	Melagarh	Sepahijala	On dead wood	Saprobic, solitary or joined two or more. Pileus 4–5×3.5–4.7 cm, convex to applanate, white but at maturity centre yellowish; lamella wavy, adnate, close. Stipe 1.5–2×0.2–0.4 cm, excentric, white but lower portion light black, solid, radicating,
18	MCCT038	*Schizophyllum commune*Fr.	Mandwi	West Tripura	On dead wood	Saprobic, solitary or gregarious. Fruitbody 0.5–1.5×0.6–0.9 cm, thin, flabelliform, laterally attached by a small base, surface dark grayish brown; margin lobed, deeply incised. Stipe absent.
19	MCCT039	*Pleurotus opuntiae* (Durieu & Lév.) Sacc.	Melagarh	Sepahijala	On living plant of mango	Saprobic, solitary or cluster. Pileus 4–9×2–5.5 cm, flabelliform or spathulate, creamy whitish but at maturity yellowish, smooth, maturity margin lobed or splitting, lamellae decurrent, yellowish. Stipe absent or very short, 0.1–0.3×0.2–0.3 cm, lateral, central, cylindric, solid, surface creamy whitish.
20	MCCT040	*Pleurotus pulmonarius* (Fr.) Quél.	Melagarh	Sepahijala	On dead root	Saprobic, solitary or gregarious. Pileus 13–14×6–6.9 cm, flabelliform, whitish creamy, crowded, decurrent, cracked. Stipe 2–2.5×0.3–0.4 cm, white, solid, equal.
21	MCCT041	*Xerulina* sp.Singer	Salbagan	West Tripura	On living plant	Saprobic, gregarious or cluster. Pileus 1–1.5 cm, whitish brown, depressed, free, close, lanceolate. Stipe 2.5–3×0.3–0.8 cm, whitish brown, fibrous, hard, slightly unequal.
22	MCCT042	*Marasmiellus* sp.Murrill	Lalchara	Khowai District	On dead plant	Saprobic, gregarious. Pileus 0.5–1.5×0.3–1.1 cm, dark cream to light brown, convex; lamellae distant. Stipe absent or rarely present and not measurable, excentric.
23	MCCT044	*Lentinus* sp. Fr.	Lalchara	Khowai District	On dead plant of *Mengifera* sp	Saprobic, cluster. Pileus 1–2.5 cm, whitish creamy, spathulate to infundibuliform, glabrous, incised, raised scales, lamellae thin, crowded. Stipe 2–3.5×0.2–0.6 cm, white to creamy, central, cylindric, solid, scaly.
24	MCCT045	*Lentinus prolifer*(Pat. & Har.)	Lalchara	Khowai District	On dead plant	Saprobic, solitary or cluster. Pileus 2.5–3 cm, infundibuliform,white to creamy to light yellowish, margin thin, entire or lobed; lamellae decurrent, concolorous, crowded, thin, raised scaly. Stipe 1.5–2.0×0.2–0.5 cm, lateral, solid, cylindrical, whitish creamy.
25	MCCT047	*Auricularia* sp. Bull. ex Juss.	Lalchara	Khowai District	On dead wood	Saprobic, solitary or scattered. Fruitbody 3–11×2–8 cm, wavy and vain like apeearence at maturity, ear like fruitbody at immature stage, fruitbody ear to shell shaped or forming narrow, flabby elastic.
26	MCCT048	*Hygrocybe reidii*Kühner	Salbagan	West Tripura	On soil with decomposed leaf in shaded area	Solitary or scattered or sometimes gregarious. Pileus 2–2.5 cm, convex or broadly convex to bell-shaped, fibrillose, bright orange, gills attached, distant. Stipe 3–3.5×0.2–0.4 cm, more or less equal, pale orange to yellowish, dry.
27	MCCT049	*Hygrocybe conica*(Schaeff.) P.Kumm.	Salbagan	West Tripura	On soil with shaded area	Solitary or gregariously. Pileus 1–1.5 cm, broadly conical or broadly convex, pointed tip, sticky, bright orange, distant. Stipe 2.5–3.5×0.3–0.5 cm, equal, yellow to orangish yellow, with white base, dry, hollow.
28	MCCT050	*Panus fasciatus* (Berk.) Singer	Salbagan	West Tripura	On decaying wood	Saprobic, solitary or scattered. Pileus 5–10 cm, deeply infundibuliform to cyathiform, tough, surface cinnamon brown, concolorous hair, margin thin. Stipe 5–11 cm, chestnut brown, central, cylindric, solid, tough surface and covered with erect hairs.
29	MCCT051	*Marasmius* sp. Fr.	Salbagan	West Tripura	On soil with decomposed leaf	Saprobic, solitary or scattered. Pileus 1–1.5 cm, convex to becoming flat, light yellow, upper surface white dotted; gills attached. Stipe 4.5–5×0.3–0.7 cm, equal, dry, hairy, white mycelium present at the base.
30	MCCT052	*Marasmius sullivantii* Mont.	Salbagan	West Tripura	On decaying leaf of Sal	Saprobic, solitary or scattered. Pileus 1–1.5 cm, convex to becoming flat, faintly lined at the margin, dry, light yellow or rust-colored; gills attached. Stipe 4.5–5×0.3–0.7 cm, equal, dry, hairy, white mycelium present at the base, white at the apex, reddish brown to black at lower portion.
31	MCCT053	*Geastrum triplex* Jungh.	Salbagan	West Tripura	On decaying leaf of Sal	Saprobic, solitary or gregariously. At immaturity star shaped and then smooth, egg-shaped with a pointed beak, point base, at maturity the outer skin break down to form 5–7 more or less triangular shaped arms, buff or light ash colored, arms thick that develop fissures and cracks, spore case more or less round, smooth, brownish, 5–8.5 cm arms are opened and spores are black.
32	MCCT054	*Aleuria aurantia* (Pers.) Fuckel,	Salbagan	West Tripura	On decaying leaf	Saprobic, cup-shaped, often becoming flattened or irregularly shaped semicircular, 3×4 cm wide.
33	MCCT055	*Thelephora* sp.Ehrh. ex Willd.	Salbagan	West Tripura	On soil	Mycorrhizal, cluster. Hymenophore commonly rosette i.e., finger like, several erect, and in central base, finger like structures 4–7×0.2–0.6 cm.

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34	MCCT056	*Lentinus cladopus*Lév.	Salbagan	West Tripura	On dead decaying plant	Saprobic, caespitose, many basidiocarps arising from single base. Pileus 3-5 cm, white to cream white, membranous, convex, depressed to subinfundibuliform, glabrous, smooth, amrgin straight, entire; lamellae short, decurrent, cream, crowded. Stipe 4–8.5×0.3–0.7 cm, white to cream white, central, equal, solid, glabrous.
35	MCCT057	*Termitomyces umkowaan*(Cooke & Massee) D.A.Reid	Suryamaninagar	West Tripura	On termite mounds or on soil	Pseudorhizoid, scattered to gregarious. Pileus 7.5–13.5 cm, at first campanulate becoming expanded to convex and at maturity broadly conical umbo, greyish yellowto yellowish brown, radially wrinkled, smooth, viscid or slimy; lamellae white, broad, free, regular, crowded. Stipe 8.5–10.7×0.5–1.5 cm, cylindrical, central, swollen or bulbous.
36	MCCT058	*Tremella fuciformis* Berk.	Paratia	South Tripura	On dead wood	Saprobic, cluster, fruitbody white, translucent, frond like, white jelly, 4–5 cm or more long, pliable, gelatinous.
37	MCCT059	*Cyathus intermedius* (Mont.) Tul. & C. Tul.	Paratia	South Tripura	On dead wood	Saprobic, solitary or gregariously. Fruitbody (peridium) 1–1.3 cm across, ball or glob but at maturity it exposes a pile of eggs, outer surface shaggy, powdery and brownish.
38	MCCT060	*Lentinus sajor-caju*(Fr.) Fr.	Paratia	South Tripura	On decaying wooden log	Saprobic, caespitose. Pileus 3–7.5 cm, upper surface dark brown to light blackish but lower surface creamish white, cyathiform to infundibuliform, minutely squamulose towards the centre, margin curved downwards, glabrous; lamellae deeply decurrent, extending down to the annulus, crowded. Stipe 1.5–3.5×0.5–1.3 cm, creamish white, central at immaturity but at maturity excentric, short, solid, equal, glabrous; annulus present but on maturity it disappears, tough, fleshy.
39	MCCT061	*Macrolepiota* sp. Singer	Unakoti	Unakoti	On soil	Basiodiocarp large, lepiotoid. Pileus 7–10.5 cm, campanulate to expanded with a solid central umbo, light or sometimes dark brown, entire surface squamules; lamellae free, white, crowded. Stipe 9–14.5×1.2–1.5 cm, light brown, central, cylindric with bulbous base, hollow or semi solid, fibrous; annulus present at immature stage.
40	MCCT063	*Inocybe rimosa* (Bull.: Fr.) P. Kumm.	Durjaynagar	West Tripura	On soil	Mycorrhizal or saprobic, solitary. Pileus 5–8 cm, conical to bell-shaped to broadly bell-shaped, with a sharp central bump, margin splitting and the surface becoming radially separated,dry, hairy, gills attached, crowded. Stipe 5–9×0.5–1.4 cm, more or less equal, unequal, dry, rough surface, silky, whitish or pale yellowish.
41	MCCT066	*Leucocoprinus fragilissimus* (Berk. & M.A.Curtis) Pat.	Salbagan	West Tripura	On decaying leaf rubber	Saprobic, solitary or scattered. Pileus 2–3.5 cm, plano-convex, becoming flat, with a small central bump, Gills were free from the stem, distant, light yellow. Stipe 4–8×0.05–0.2 cm, equal with a small basal bulb at the tip portion.
42	MCCT067	*Lycoperdon utriforme* (Bull.)	Melagarh	Sepahijala	On soil with decaying leaf	Saprobic and mycorrhizal, solitary. Fruitbody 4–7× 3–5.5 cm, more or less round, light yellowish, dry and rough surface.
43	MCCT068	*Ganoderma tsugae* Murrill	Lalchara	Khowai District	On decaying wooden log	Basidiocarp parasitic, solitary. Fruitbody 5–10 cm, elongated, at maturity more or less fan- or kidney-shaped, hard and shiny surface, dark red to reddish brown when mature but margin white.
44	MCCT069	*Funalia polyzona*(Pers.) Niemelä	Bangsul	North Tripura	On dead wood	Basidiocarp shelf-shaped, semicircular, with broadly attached base, hard. Pileus 0.5–1.5×0.4–0.9×0.3–0.6 cm, usually a few caps growing side by side or overlapping. Upper surface hairy, usually distincly zonate, at first brownish cream, older bright orange-brown, edge sharp, pore semicircular; 0.2–0.4×0.3–0.5 cm; sessile.
45	MCCT070	*Ganoderma applanatum* (Pers.) Pat.	Kakraban	Gomoti	On dead wooden log	Basidiocarp (10–35×7–25)×(1–4.5) cm, applanate, woody, shelf like; upper surface pale grey to dark brown, with concentric zonation, covered with layer of brown spore appearing dusty; margin 0.1–1cm, thick, rounded, sterile; pore surface whitish to coffee, rough, spherical to ovoid, 0.3–0.5 cm; sessile.
46	MCCT073	*Lentinus* sp. Fr.	Fulkumari	Gomoti	On decaying wooden log	Saprobic, solitary or caespitose. Pileus 4–6.5 cm, dark brown or light blackish, medium, infundibuliform to cyathiform, upper surface dotted and umbo present at the centre, dry, fleshy; margin thin, inrroled; lamellae thin crowded, decurrent, tough. Stipe 2–4.5×0.5–1.3 cm, dark brown, central but sometimes lateral, short, solid, firm, squamoles present at earlier stage.
47	MCCT074	*Podoscypha petalodes* (Berk.) Pat.	Mandwi	West Tripura	On dead wood	Saprobic, basidiocarps small to medium. Pileus 2–6.5×0.5–2.5 cm, thin, spathulate to funnel shaped, pseudoinfundibuliform, margin entirely wavy, frequently curl inward and often forming rosette-like fruit bodies. Stipe 0.5–1.5×0.1–0.2 cm, solid, relatively short, surface brownish todark brown.

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48	MCCT076	*Macrolepiota* sp. Singer	Suryamaninagar	West Tripura	On soil with decomposed plants	Basidiocarps large, lepiotoid. Pileus 4.5–8.5 cm, white, at first globose to expanding, dry, smooth, plate like squamulose at centre; lamellae free, white, broad, very crowded. Stipe 7–15×1.2–1.5 cm, white, cylindric, central, equal but bulbose at the base, fleshy, surface fibrilose; annulus present, white, comples, mobile.
49	MCCT078	*Termitomyces* sp. R.Heim	Mandwi	West Tripura	On termites soil	Basidiocarp large and long. Pileus 6.5–13.8 cm, white, large, black umbo at the centre, at first sub-globose then expending, centre squamules like a plate or disk, dry, solid; margin straight, broken at maturity; lamellae white, free to adnexed, crowded. Stipe 13–29×1.1–2.1 cm, white, semi-solid or sometimes solid, unequal, cylindric, swollen at the base, surface fibrous with squamules; annulus present at immature stage, soft, white, mobile.
50	MCCT080	*Chlorophyllum* sp. Massee	Durjaynagar	West Tripura	On dead decaying plant	Saprobic, large, lepiotoid. Pileus 7–10.5 cm, upper surface white to light cream but lower surface dark cream to light yellow, convex to expanded, soft, fleshy, squamules at whole area of upper surface; margin soft, entire; lamellae soft, free, broad, crowded, light cream but after touching its colour change to light brown in colour. Stipe 7.5–14.5×1.1–1.8 cm, light brown to brown, soft, semi-soilid, hollow, central, elongate, bulbose at the base, uneual; annulus present, brown, mobile, soft.
51	MCCT081	*Marasmius praecox*Singer	Suryamaninagar	West Tripura	On soil with grasses	Saprobic, gregarious. Pileus 1.5–2 cm, hemispheric to convex, sulcate from disk to edge, depressed at the centre, fulvous-reddish brown, occasionally bumpy, glabrous, centre lightest; context thin. Stipe 3–5×0.1–0.2 cm, thin, off-white, glabrous.
52	MCCT082	*Mycena haematopus* (Pers.) P.Kumm.	Korongbari	Khowai District	On decomposed soil	Saprobic, gregarious. Pileus 1–4.5 cm, oval to broadly conic, convex, broadly bell-shaped, margin with a tiny sterile portion, becoming tattered with age. Stipe 3–6.5×0.1–0.2 cm, smooth, equal, hollow, pale reddish hairs, reddish brown or nearly purple.
53	MCCT084	*Auricularia auricula* Hooker	Hatipara	West Tripura	On dead wood	Saprobic, gregarious or cluster. Basidiocarp 10–12×6–8 cm, cup shaped, gelatinous, elastic and attached to the substrata by the back surface of the cup, occurs in group, upper and lower surface dark brown. Stipe absent.
54	MCCT085	*Cantharellus* sp.Adans. ex Fr.	Harimangalpara	Dhalai District	On decomposed soil	Basidiocarps small to medium. Pileus 3–5.5 cm, convex or planoconvex with depressed centre, bright to deep yellow, covered with purplish squamules; margin wavy, serrate, smooth. Stipe 2–3.7×0.5–1.3, light yellow, unequal, fibrous, solid or semi-solid, sometimes hollow.
55	MCCT086	Unidentified	Garjee	South Tripura	On decaying wooden log	Saprobic, solitary. Pileus 3.0–3.7 cm, upper surface ash and lower surface white or light ash, soft, squamules at upper surface; gilles absent, lower surface also fleshy, spongy. Stipe absent.
56	MCCT089	*Termitomyces heimi*Natarajan	Durjaynagar	West Tripura	On termite mounds or on soil	Pseudorhizoid, solitary or gregarious. Pileus 10.5–14.7 cm, white or creamy white, first subglobose to subumbonate with incurved margin, at maturity convex, split margin, smooth, fibrillose and viscidor, silky, slimy when moist or other than dry; lamellae white, free, crowded, broad, regular. Stipe 12.0–15.7×2.3–3.5 cm, central, long and thick base, cylindrical, stuffed, whitish and smooth.
57	MCCT090	*Clitocybe* sp.(Fr.) Staude	Hrishyamukh	South Tripura	On soil	Basidiocarps solitary or gregarious, clitocyboid. Pileus 2–3.8 cm, dark cream to light brown, plano-convex to umbilicate, smooth, moist; margin thin, smooth, uplifted at maturity, entire; lamellae adnate decurrent, crowded. Stipe 2.7–4×0.3–0.8 cm, cream, flexuous, cylindric, equal but some times unequal.
58	MCCT091	*Termitomyces eurrhizus* (Berk.) R. Heim	Subal singh	West Tripura	On soil	Basidiocarps solitary or scattered. Pileus 10–18 cm, convex at first, applanate to concave when mature with pointed perforatorium, surface brown, dark brown to almost black at centre, usually paling toward margin, smooth and glabrous,margin straight. Stipe 5.0–17.0×0.5–3.0 cm, central, cylindrical, surface white, smooth, solid, fibrous.
59	MCCT094	*Phallus duplicatus* Bosc	Bangsul	North Tripura	On soil	Basidiocarp bell-shaped to oval. Pileus 1.5–2 cm, green-brown, the stalk is white. Stipe 4–5×1.5–2 cm, cylindrical; universal veil was present, 4–5 cm long.
60	MCCT095	*Lentinus squarrosulus*Mont. Singer	Bangsul	North Tripura	On dead wood	Saprobic, caespitos. Pileus 1.0×0.2–0.3 cm, white cream, depressed at the centre, deeply infundibuliform, fleshy when fresh but after drying hard; margin thin, regular or sometimes lobed; lamellae deeply decurrent, crowded, thin, 0.15–0.3 cm wide. Stipe 1.2–5×0.3–0.6 cm, central or sometimes excentric, cylindric, solid, squamulose; annulus absent or sometimes present at very young stage.
61	MCCT096	*Stereum ostrea*(Blume & T. Nees) Fr.	Bangsul	North Tripura	On dead wood	Saprobic,gregariously. Fruiting body 3.0–5.5 cm, tough, funnel shaped that has been break down one side but at young stage fan-shaped or kidney-shaped, semicircular, hairy at first but often smoother at maturity, concentric zones of red to orange or yellowish, undersurface smooth, grayish to reddish brown. Stipe absent.

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62	MCCT097	*Marasmiellus troyanus*(Murrill) Dennis	Bangsul	North Tripura	On dead wooded plant	Saprobic, marasmioid, small, gregarious. Pileus 3–5.2 cm, white, slightly translucent; lamellae adnexed, tough, thin. Stipe 0.8-1.4 cm, white, short, solid, cylindric, slightly curved.
63	MCCT099	*Panellus serotinus*(Pers.) Kühner	Tlangsang	North Tripura	On soil	Basidiocarp fan shaped. Pileus 2×1.5 cm, dark brown, semicircular to shell-shaped or kidney shaped. Stipe is very short or absent.
64	MCCT100	*Termitomyces microcarpus* (Berk. & Broome) R.Heim	Tlangsang	North Tripura	On termites nest or soil	Basidiocarp solitary or gregarious, small in size. Pileus 1– 1.8 cm, greyish to brown, conical with spiniform perforatorium; lamellae white, broad, free to adnexed, regular and crowded. Stipe 3–4.5×0.2–0.3 cm, whitish, small to long, central, equal, smooth, solid or sometimes hollow, cylindrical, fibrillose.
65	MCCT102	*Marasmiellus stenophyllus* (Mont.) Singer	Tlangsang	North Tripura	On dead wooden log	Saprobic, marasmioid, small, gregarious. Pileus 3–4×2–2.5 cm, convex at young stage but at maturity expanding to plano-convex, white to creamy white, margin entire to lightly translucent-striate, surface moist to dry, dull, glabrous; lamellae narrowly adnate to arcuate, crowded. Stipe 1–1.5×0.1–0.2 cm, parallel, thin to thick walled, cylindrical, incrusted, inamyloid..
66	MCCT103	*Marasmiellus enodis*Singer	Tlangsang	North Tripura	On dead plant	Saprobic, marasmioid, gregarious. Pileus 4–5.5 cm, upper portion is yellowish brown but lower portion is light yellow. Stipe 4–4.5×0.5–0.6 cm, white.
67	MCCT104	*Marasmiellus dendroegrus* Singer	Tlangsang	North Tripura	On decaying leaf	Saprobic, marasmioid. Pileus 3–3.5 cm, creamy white; margin striate; gills adnate, smooth. Stipe 3–4.5×0.2 cm, dark brown, long.
68	MCCT106	*Marasmius siccus* Schwein. ex Fr.	Vanghmun	North Tripura	On dead plant	Saprobic, basidiocarp medium. Pileus 3–3.5 cm, upper surface brown and lower surface white, wide, circular, and convex to umbrella shaped; lamellae adnate, distante, white or cream. Stipe 4.5–5.5×0.1– 0.2 cm, central, well developed, basal mycelium present, context dextrinoid, dark brown to black.
69	MCCT107	*Polyporus tenuiculus* (P. Beauv.) Fr.	Vanghmun	North Tripura	On decaying wooden log	Saprobic, solitary, polyporoid. Pileus 3–5.7 cm, white, kidney or semi-circular shaped, fleshy, solid, porous, reniform to convex, surface glabrous, radially striate; margin acute, entire. Stipe 1.2–2.3×0.2–0.5 cm, white, solid, cylindric, equal, smooth.
70	MCCT108	*Polyporus alveolaris* (DC.) Bondartsev & Singer	Tlangsang	North Tripura	On decaying plant	Saprobic, polyporoid. Pileus 3–6.5×2.5–5.2 cm, upper surface orange and lower surface white, semi-circular or kidney shaped, radially fibrillose to scaly, dry, bald; typically featuring; margin wavy, smooth. Stipe 0.2–0.5×0.2–0.4 cm, excentric, solid, white, squamulues.
71	MCCT109	*Pleurotus* sp. (Fr.) P. Kumm.	Tlangsang	North Tripura	On decaying wooden log	Saprobic, solitary or gregarious. Pileus 2–5.6 cm, light yellow or dark cream, soft; lamellae decurrent or tooth like, moderately spaced; margin smooth, wavy. Stipe absent.
72	MCCT110	*Podoscypha multizonata* (Berk. & Broome) Pat.	Vanghmun	North Tripura	On decaying plant	Saprobic, solitary. Pileus 1.5–2.5×1.2–2.1 cm, fan-shaped or spathulate, thin, leathery, upper surface pale pinkish brown to pale brown, porous, with paler and darker zones; margin wavy, thin, initially white, ridged. Stipe 1.0–1.5×0.2–0.4 cm, solid, cylindric, rough surface, white, slightly unequal.
73	MCCT111	*Crepidotus alabamensis*Murrill	Vanghmun	North Tripura	On dead wooden log	Saprobic, gregarious. Pileus 1–1.5×1 cm, kidney- or clamshell shaped, creamy white, soft; lamellae decurrent when stipe present, narrow or broad. Stipe absent.
74	MCCT112	*Pycnoporus sanguineus* (L.) Murrill	Vanghmun	North Tripura	On dead wooden log	Saprobic, gregarious.Pileus 4–5×3–4 cm, sessile, semicircular, flabelliforme, bright orange red when young but at maturity reddish orange, glabrous, zoned, margin acute, smooth to wavy thin. Hymenophore poroide, reddish orange; pores 0.3–0.4 cm.
75	MCCT114	*Amanita farinose* (Schwein.)	Amarpur	Gomoti	On soil	Basidiocarps solitary, amailoid. Pileus 2–4.5 cm, brownish gray to brown, striate margin; gills adnate, close to subcrowded, white. Stipe 2–3.5×0.2–0.4 cm, straignt, white; universal veil present.
76	MCCT115	*Chlorophyllum* sp. Massee	Amarpur	Gomoti	On soil	Basidiocarps mediun, lepiotoid. Pileus 3–6.8 cm, white to cream, fleshy, convex to expanding, squamules entire surface and centre plate like brown; margin at first inflexed, entire; lamellae free, white, edge minutely serrated, touching change the colour to reddish brown. Stipe 3.5–7.2×0.4–1.3 cm, white central, elongete, equal but bulbose at the base, cylindric, smooth, fleshy, hollow; annulus present at upper portion, light brown, soft, mobile.
77	MCCT116	Unidentified	Amarpur	Gomoti	On decomposed leaf	Saprobic, solitary or gregarious, mycelioid. Pileus 1.2–1.6 cm, upper surface dark brown and lower surface white, umbrella shaped, smooth, spft, slightly umbo at the centre; margin soft, inrolled; lamellae dense, white, distant. Stipe 3.5–6.5×0.2–0.3 cm, central, brown, equal, hollow, fleshy, fibrous.
78	MCCT117	*Polyporus* sp.P.Micheli ex Adans.	Rajkang	Gomoti	On dead wood	Saprobic, solitary or gregarious, polypoloid. Pileus 3.5–5.5×2.5–4.0 cm, white, porous, soft or slightly solid, spanthanulate, fleshy or leathery; margin unequal, light yellow, fleshy. Stipe 2.3–3.5×0.2–0.4 cm, white, excentric or lateral, cylindric, unequal.

	LCN	Scientific name	Location	Districts	Habitat	Distinguishing features
79	MCCT118	*Humaria hemisphaerica* (F.H. Wigg.) Fuckel	Bampur	Gomoti	On termites soil	Fruit body 5.5–6×–5–6 cm, cup shaped, sessile, outer surface fringed with stiff with brownish hairs, distinctly hair on the margin, inner surface grayish.
80	MCCT121	Unidentified	Bampur	Gomoti	On dead wooden log	Saprobic, solitary or gregarious. Pileus 1.5–3.4×1.2–2.5 cm, white, soft, spanthanulate, smooth, fleshy; margin smooth, light orange; lamellae soft, inrolled, dense, unequal size. Stipe 0.5–0.9×0.1–0.3 cm, absent or sometimes present, white soft, solid, equal, lateral.
81	MCCT122	Unidentified	Bampur	Gomoti	On soil	Basidiocarps gregarious. Pileus 1.3–4.5 cm, white, applanate to umbilicate, smooth, soft; margin soft, inrolled, sometimes serrate. Stipe 1.4–3.5×0.2–0.5 cm, central or excentric, white, cylindrical, solid, unequal at upper and lower part.
82	MCCT123	*Marasmiellus* sp.Murrill	Bampur	Gomoti	On decaying plant	Saprobic, marasmioid, small, gregarious. Pileus 1.5–3.2 cm, white, convex to expanded or umbonate, thin; margin smooth, striate; lamellae adnate, white, soft, edge entire. Stipe 2.5–3.7×0.1–0.3 cm, white, excentric, equal, hollow, smooth, soft.
83	MCCT132	*Crepidotus applanatus* (Pers.) P. Kumm.	Barjala	West Tripura	On dead wooden log	Saprobic. Pileus 1.4–2.0 cm, petaloid, flabelliform, semi-orbicular, spathulate, glabrous, villose or fibrillose at the base, white was becoming brownish or cinnamon as the spores mature; margin striatulate, hygrophanous. Stipe absent.
84	MCCT138	*Volvariella volvacea*(Bull.: Fr.) Singer	Barjala	West Tripura	On sawdust	Saprobic, solitary or scattered. Pileus 5–12 cm, egg-shaped when immature, expanding to convex or broadly conic and at maturity broadly convex or nearly flat, hairs, gray or grayish brown. Stipe 8–12×0.6–1.4 cm, tapering gradually to apex, swollen base, whitish or brownish, universal volva present.
85	MCCT142	*Pluteus americanus* (P. Banerjee &Sundb.) Justo, E.F. Malysheva & Minnis	Amtali	West Tripura	On decaying wooden log and sawdust	Saprobic, solitary or scattered. Pileus 4–7 cm, broadly convex at first, expanding to planoconvex or flat, moist when fresh, very finely scaly over the center, but bald elsewhere, dark grayish brown when young and fresh, fading markedly as it dries out and eventually becoming very pale grayish brown or gray, with a darker center, the margin becoming finely lined for 1.0–1.5 cm; gills free from the stipe or close, short-gills frequent, white at first, becoming pink and, eventually, brownish pink, bruising grayish blue. Stipe 4–6×0.3–0.5 cm, equal above a slightly swollen base, bald or finely hairy, dry, whitish, becoming brownish with age, bruising slowly grayish blue, basal mycelium white; flesh very thin, white, unchanging when sliced.
86	MCCT149	*Amanita phalloides*(Vaill. ex Fr.) Link	Boxonagar	Sepahijala	On soil	Basidiocarp small to large. Pileus 5–13 cm, fleshy, convex to applanate but at maturity expanding, viscid at immaturity but soon dry and silky; lamella free, white, thin, mostly crowded, mostly entire. Stipe 5.5–9×0.5–0.8 cm, whitish, smooth, cylindric, expanding towards the base, solid, central; annulus present, membranous, white, lobed; volva saccate, fleshy, white, lobed.
87	MCCT151	*Inocybe* sp. (Fr.) Quél.	Amtali	West Tripura	On soil	Basidiocarp small to very large and fleshy, pholiotoid, rarely crepidotoid. Pileus 3–6 cm, convex to expanded flat, center depressed, yellowish, non-striate margin, fibrillose, disc subglabrous, towards margin radially appressed; lamellae adnexed to decurrent, rarely fleshy. Stipe 5–6.5×0.3–0.8 cm, central, solid, equal, cylindrical, bright yellow, glabrous or fibrous.
88	MCCT154	*Boletus* sp. L.	Boxonagar	Sepahijala	On soil	Basidiocarp centrally stipitate. Pileus 3–5.5 cm, glabrous to squamose; hymenophore tubulate, free, adnate, yellowish, at times bruising blue. Stipe 2–5×0.3–0.7 cm, central, smooth, glandular.
89	MCCT158	*Clavulinopsis fusiformis* (Sowerby) Corner	Boxonagar	Sepahijala	On soil	Basidiocarp cylindric, with rounded to sharpened tips, occasionally shallowly forked near the tip, 2–3×0.4–0.7cm, smooth and slick; orangish yellow, spore print yellowish.
90	MCCT159	*Pleurotus ferulaginis*Zervakis, Venturella & Cattar.	Boxanagar	Sepahijala	On wooden log	Basidiocarp casepitos. Pileus 5–7×4–6 cm, depressed, umbilicate or infundibuliform, upper surface dry, margin thin or often inrolled; lamella decurrent, crowded. Stipe 1.5–2.0×0.3–0.7 cm, lateral, solid, short.
91	MCCT160	*Auricularia auricula-judae* (Bull.) Quél.	Boxanagar	Sepahijala	On dead wooden log	Saprobic, gregarious. Pileus 6–13×5–7 cm, cup shaped, cluster, elastic, gelatinous, attached to the substrata, outer surface bright reddish to purple but lower surface smooth and light with irregular vein. Stipe absent.
92	MCCT161	*Auricularia* sp.Bull. ex Juss.	Boxanagar	Sepahijala	On dead wooden log	Lignicolous, gregarious. Basidiocarp 3–3.5 cm, thick fleshy, cupulate, hymenium geneva blue, abhymenial surface leather brown, no veins, attached on one side of the pileus.
93	MCCT165	*Clitocybe brunneocaperata*J.A. Cooper	Boxanagar	Sepahijala	On soil	Basidiocarp large, growing in soil, solitary with a pungent smell. Pileus 15–20 cm, margin creamish, centre light brown, irregular with striation, slightly hygrophanous and scales squarrose. Stipe 10–12×1.5–2 cm, long, solid, tough, creamish; lamella 8–9 sets of lamelluae, creamish, shortly decurrent, smooth; annulus, veil and volva absent.

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94	MCCT166	*Gymnopus fagiphilus* (Velen.) Antonín, Halling & Noordel	Debdabari	Gomoti District	On soil with decaying leaf	Saprobic or mycorrhizal, solitary or gregarious. Pileus 1.2–1.7 cm, convex with expanded and centrally depressed, inflexed margin; margin, smooth when very young, then smooth or rugulose; lamellae pinkish brown or pinkish cream, glabrous, upwards, distant, broadly adnate, sometimes to adpressed falsecollarium, whitish to pale cream when young, at maturity yellowish grey or orange-grey, concolorous. Stipe 0.7–1.5×0.05–0.2 cm, long, finely hairy, filiform, smooth, glabrous, rarely slightly pruinose, dark brown, smooth.
95	MCCT169	*Lentinus* sp.Fr.	Sunamura	Sepahijala	On dead wooden log	Lignicolous, caespitose. Pileus 2.5–3.5 cm, regular, non striate; margin inflexed, dry, nonhygrophanous, fbrillose, scales orange cover the entire surface, cuticle fully peeling, pileus trama white, 0.2cm thick, confluent; lamellae unequal, orange, coricaeous, crowded, shortly decurrent, non separable, 0.2cm broad, sigmoid and smooth. Stipe 2.5–3×0.1–0.3 cm, central, light orange, thick, terete, smooth, tough, stuffed stipe trama creamish; ring and volva absent.
96	MCCT172	*Panus* sp. Fr.	Kalachari	Dhalai District	On dead wooden log	Saprobic, growing gregarious to cluster. Pileus 4–8 cm, broadly convex at immaturity but developing a central depression or becoming deeply vase-shaped at maturity, hairy, often radially wrinkled, purplish to purplish brown in young stage and brown margin at maturity. Stipe 2–4.5×0.8–1.2 cm, lateral, tough, equal, slightly enlarged toward the base, hairy especially toward the base.
97	MCCT175	*Auricularia polytricha* (Mont.) Sacc.	Satchand	South Tripura	On dead mango plant	Lignicolous, gregarious. Basidiocarp 6–7 cm, thin, fleshy, cupulate, pepper red, veined, attached on one side of dead log. Spore hyaline, bean shaped, apiculate, germ pore absent, oil globule present, cyanophillic and non amyloid.
98	MCCT176	*Stropharia stercoraria* (Schumach.) Quél.	Rajibnagar	South Tripura	On decaying rice bran	Saprobic or mycorrhizal. Pileus 1–3 cm, hemispheric to convex, umbonate, olive yellow, dark yellow in the centre, viscid, nonhygrophanous, smooth, regular, thin, little striate, firm, whitish. Stipe 7–9.5×0.2–0.3 cm, central, cylindrical but expanded base, yellow, viscid, striate and basal mycelium white.
99	MCCT178	*Agrocybe splendida* Clémençon	Debbari	Gomoti District	On soil with decaying paddy straw	Saprobic. Pileus 1.5–2.5 cm, subglobose to convex, brownish yellow to yellowish brown, moist, smooth, glabrous, non–striate. Stipe 3–5.5×0.3–0.5 cm, central, cylindrical, solid, bulbous at both ends, brownish yellow.
100	MCCT202	*Pleurotus* sp. (Fr.) P. Kumm.	Paratia	Gomati District	On dead wooden log	Saprobic, solitary or gregarious. Pileus 4.5–7.5×2.5–6.5 cm, infundibuliform, whitish cream, smooth; margin smooth but sometimes lobed; lamella decurrent, edge smooth. Stipe 1.7–3.5×0.3–0.6 cm, eccentric, smooth, cream.
101	MCCT206	*Crepidotus mollis* (Schaeff.) Staude	Garjee	South Tripura	On dead wooden log	Saprobic. Pileus 2-4.5 cm, reniform to obovate, plane, flaccid, brownish, hygrophanous, shining, margin faintly striatulate. Stipe absent.
102	MCCT209	*Panus* sp. Fr.	Thakchara	Gomoti District	On dead wooden log	Saprobic, pleurotoid, solitary. Pileus 3.0–5.7 cm, subinfudibuliform to deeply umbilicate at center, dark brown, squamules present at entire surface; margin entire, involute, solid; lamellae decurrent, thin, moderately distant, without lamellulae. Stipe 3.7–3.4×1.0–1.6 cm, dark brown squamules whole surface, central to slightly excentric, cylindric, tapering upward, swollen at the base, surface strigose, solid.
103	MCCT212	*Flamulina velutipes* (Curtis) Singer	Gamaibari	Khowai District	On dead wooden log	Saprobic, gregarious. Pileus 1.5–2.7 cm, convex to broadly convex, smooth, yellow to butter yellow and center light orange, subviscid to viscid; margin striate, translucently; lamellae adnexed, crowded to slightly distant, cream to light yellow, edge even. Stipe 3–5.5×0.3–0.6 cm, central, subcylindrical, subequal to slightly attenuate, upper part cream to yellowish and lower part darker, surface pruinose to pubescent, viscid.
104	MCCT225	*Cookeina tricholoma* (Mont.) Kuntze	Atharomura	South Tripura	On decaying wooden log	Saprobic, solitary or gregarious. Apothecia 4–7.5×2.5–3.5 cm, singly, cupulate, stipitate, margin enrolled. Receptacle concave, orange colour, glabrous. Stipe 1–1.5×0.2–0.4 cm, broad, glabrous. Spines 0.2–0.5×0.05–0.1 cm, tips narrowed, cylindrical, aseptate. Hairs cylindrical, straight, septate, thin-walled, hyaline.
105	MCCT226	*Lactarius piperatus* (L.) Roussel	Barabari	Dhalai District	On soil	Scattered to gregarious. Pileus 2–6 cm, convex, center depressed, infundibuliform, smooth and dry, cracked, wrinkled towards margin, white or cream; margin incurved; lamellae crowded, white, repeatedly forked. Stipe 2–6.5×0.4–1.2 cm, central to eccentric, equal, solid, white, dry, smooth and latex white.
106	MCCT230	*Pterula indica*G. Senthilarasu	Unakoti	Unakoti District	On soil	Basidiomes terrestrial, gregarious or cluster. Pileus 6.5–18.7×6–8.5 cm, branched, erect, dichotomous, tubular. Stipe 1.2×2.4 cm, reddish brown to dark brown and at maturity it become dark, brittle, subulatus, glabrous, acute.

	LCN	Scientific name	Location	Districts	Habitat	Distinguishing features
107	MCCT234	*Auricularia delicate* (Mont. ex Fr.) Henn.	Tuichama	Dhalai District	On wooden log	Saprobic, solitary or gregarious. Basidiocarps 5–7.5×2–6.5 cm, gelatinous, flabelliform, orbicular, upper surface dark brown and lower surface light brown, reticulate, circular or semicircular, fleshy and solid; abhymenium yellowish hairs, gregarious but not dense; margin smooth in young stage, lobad when adult and medulla absent.
108	MCCT236	*Heterotextus miltinus* (Berk.) McNabb	Uptakhali	North Tripura	On dead wooden log	Saprobic, gregarious or scattered, orange-yellow or orange-red when fresh. Pileus 0.4–1.3 cm, cupulate or flattened-discoid, margin irregularly undulate, rough and faintly ribbed. Stipe 0.3–0.6 cm, short, stout, entire, consistency gelatinous.
109	MCCT237	*Inocybe parvibulbosa* E. Horak	Vanghmun	North Tripura	On soil	Solitary or scattered. Pileus 1.5–2.5 cm, smooth or minutely scaly in upper surface, splitting or rimose towards the margin. Stipe 1.5–3.5×0.1–0.4 cm, slender, entirely pruinose, distinct marginate bulb, cortina absent.
110	MCCT239	*Macrolepiota mastoidea*(Fr. : Fr.) Singer	Dalubari	North Tripura	On soil	Basidiomata large. Pileus 7–13 cm, fleshy, white to off-white, ovoid at immaturity, convex to plano-convex at maturity, umbo disc, covered gray-brownish furfuraceous squamules and it first smooth and continuous, irregular patches; margin appendiculate; lamellae crowded, free, white to grayish white. Stipe 7–14×0.5–1.3 cm, subcylindrical, whitish, upwards, covered with tiny furfuraceous brownish squamules, base slightly enlarged; annulus whitish, ascending, simple, membranous.
111	MCCT241	*Pholiota* sp.(Fr.) P.Kumm.	Boiragibazar	Sepahijala	On dead wooden log	Lignocolous, pholiotoid. Pileus 7.0–7.6 cm, when young purple at centre and light purple yellowish at the margin but after maturity yellowish, appalanate or depressed to infundibuliform; margin irregular, non-striate, surface squamullose. Stipe 6–8.2×0.6–0.8 cm, central, concolourous with pileus, consistency fleshy, context stuffed; ring, veil and volva absent.
112	MCCT242	*Mycena* sp. (Pers.) Roussel	Tlakchi	Sepahijala	On soil	Scattered. Pileus 1.1–1.2 cm, ash to grayish black, shape convex with short umblicate; margin grayish white but at maturity white and ash at the centre, regular and appendiculate. Stipe 2.0–2.5×0.1 cm, central, white at the top and black at the base, shape equal, texture smooth; ring, veil and volva absent.
113	MCCT243	*Lacterius* sp. Pers.	Simblong	Sepahijala	On soil	Scattered. Pileus 4–4.5 cm, upper surface red and lower surface white, conical at initial stagebut at maturity depressed to infundubuliform; margin irregular and non striate, roll straight or reflexed, surface dry, non hygrophanous, surface glabrous, cuticle not peeling, consistency fleshy. Stipe 3–4×0.6–0.8 cm, central but sometimes ecentric, light camel brown at the top and darker at the base, equal, base blunt, consistency fibrous, surface powdery, context solid; ring, veil and volva absent.
114	MCCT244	*Amanita* sp. Pers.	Tlakchi	Sepahijala	On soil	Amanitoid, solitary. Pileus 2.5–2.6 cm, grayish brown at the centre and light gray brown; margin shape umbonate to convex, irregular, half translucent. Stipe 1.6–1.9×0.2–0.3 cm, central, white, shape clavate, terete or round, texture smooth; volva present, 0.2cm, light brown; ring and veil absent.
115	MCCT245	*Trametes versicolor* (L.) Lloyd	Vanghmun	North Tripura	On dead wooden log	Lignicolous, gregarious. Fruitbody 5–10×4–7 cm, white when young but at maturity margin white and light grayish at the centre, it contains several colour in its upper surface, wide, shape petalloid to flabelliform, margin irregular; margin roll inflexed, surface dry or leathery, surface glabrous, consistency fleshy; ring, veil and volva absent. Stipe absent.
116	MCCT246	*Boletus* sp. L.	Tlakchi	North Tripura	On decaying wood	Boletoid, solitary, light ash to white. Pileus 2.5×3.0 cm, grayish brown; margin regular, margin roll straight, bigger pore size. Stipe 3.0–3.3×0.5–0.7 cm, central, light ash, shape equal, round, base blunt, texture smooth, fleshy, surface glabrous, context solid; ring, veil and volva absent.
117	MCCT247	*Laccaria proxima* (Boud.) Pat.	Tlakchi	North Tripura	On sandy soil	Caespitose or connate. Pileus 1.5×2.0 cm, orange brown, infundibulate, surface dry, non hygrophanous, glabrous, not peeling; margin regular, translucent, roll inflexed. Stipe 3.5–4.0×0.3–0.4 cm, central, orange brown, equal, base bulbose, texture smooth, consistency cartilaginous, context hollow; ring, veil and volva absent.
118	MCCT250	*Russula brevipes*Peck	Vanghmun	North Tripura	On soil	Mycorrhizal, basidiocarp white to light cream white, solitary and scattered. Pileus 5.5×6.7 cm, white, cyathiform, margin irregular, non striate, surface dry, non hygrophanous, glabrous, cuticle half peeling; margin roll inflexed to uplifted. Stipe 2.5–3.0×1.2–1.7 cm, central to lateral, obclavate, base blunt, texture smooth, context stuffed; ring, veil and volva absent.
119	MCCT251	*Coltricia cinnamomea* (Jacq.) Murrill	Sabual	North Tripura	On soil	Solitary or connate, epigeous. Pileus 1.5–2.0×1.5–2.0 cm, cinnamon brown and margin yellowish brown, conical to depressed, surface dry, hygrophanous, cuticle non peeling; margin regular, straight to sulcate. Stipe 1.5–1.7×0.1–0.2 cm, central, base bulbous, texture smooth, context hollow; ring, veil and volva absent.

	LCN	Scientific name	Location	Districts	Habitat	Distinguishing features
120	MCCT252	*Boletus*sp. L.	Sabual	North Tripura	On soil	Solitary. Pileus 5×5.2 cm, orange to yellow, conical, surface reticulate or strobiliform, fully peeling, fleshy; margin irregular, non striate, straight, glutinous, non hygrophanous. Stipe 2.5–2.7×0.3–0.5 cm, central, brownish yellow, fleshy, striate, stuffed or solid, trama yellow; ring, veil and volva absent.
121	MCCT253	*Boletus strobilaceus*Scop.	Sabual	North Tripura	On soil	Boletoid, solitary or scattered. Pileus 4.5×5.0 cm, upper surface white with black dotted and lower surface light whitish cream, conical or hemispherical to applanate; margin irregular, surface strobiliform, underside pores are hexagonal. Stipe 3.5–4.0×0.5–0.7 cm, central, equal, base bulbous, texture lacunose, surface slimy, context stuffed; ring, veil and volva absent.
122	MCCT256	*Lycoperdon* sp. Pers.	Unakoti	Unakoti	On decomposed wooden dust.	Saprobic, solitary, mycorrhizal. At immaturity more or less round but maturity like an inverted pear, 2–4.0×2.5–4.3 cm, dry; covered with tiny white spines when young but at maturity its disappear, typically with a pinched-off base, central perforation through which spores are liberated by creaked at maturity, spore disperse through rain or wind.
123	MCCT260	*Pleurotus* sp. (Fr.) P.Kumm.	Unakoti	Unakoti	On dead wooden log	Saprobic, solitary, pleurotoid. Pileus 2.5–5.4×2.0–3.8 cm, light brown but centre whitish, spathulate, sessile with a short basal attachment, i.e., short stipe; margin dry, smooth, glaborous, thin, inrolled, entire or lobed; lamellae white, thin, crowded. Stipe 0.5–1.2×0.3–0.6 cm, lateral, white, solid, cylindric.
124	MCCT263	*Dacryopinax spathularia* (Schwein.) G.W.Martin	Khashiamangal	Khowai District	On decaying wood	Saprobic. Basidiomata scattered or gregarious.Fruitbody 0.5–1.8×0.05–0.2 cm, spathulate, stipitate, orange, softcartilaginous.
125	MCCT270	*Lactocollybia* sp.Singer	Bamutia	West Tripura	On decaying wood	Saprobic. Pileus1.3–2.8 cm, convex to plano-convex, smooth, subumbonate, surface dull white to light brown, glabrous; margin striate, crisped, eroded; lamellae adnate, white, crowded. Stipe 0.5–1.6×0.1–0.2 cm, thin, excentric, equal, tubular, slightly tapering towards apex, subbulbous at the base, surface smooth, shiny.
126	MCCT275	*Pleurotus ostreatus* (Jacq. ex Fr.)P. Kumm.	Bamutia	West Tripura	On decaying wood	Saprobic, solitary or scattered. Pileus 4.0–5.9×2.0–6.8 cm, infundibuliform, white to cream, some times dark gray at young stage, smooth; margin smooth or slightly lobate; lamella decurrent but sometimes with tooth, edge smooth. Stipe 2.0–2.9×0.5–0.9 cm, cylindric, solid, lateral-eccentric, cream, smooth.
127	MCCT278	*Panus* sp. Fr.	Bamutia	West Tripura	On dead wooden log	Saprobic, solitary or gregarious. Pileus 1.5–4.5 cm, deeply infundibuliform to cyathiform, tough, surface cinnamon brown, hair present abundantly; margin thin. Stipe 1.0–2.0 cm, chesnut brown, central, cylindric, solid, covered with erect hairs.
128	MCCT282	*Ramaria* sp.Fr. ex Bonord.	Bamutia	West Tripura	On decomposed soil	Scattered or gregariously. Fruit body 4–11×4–8.5 cm, base well developed, branching repeatedly; branches vertically oriented, elongated to flattened, smooth, light pink.
129	MCCT301	*Coprinus* sp. Pers.	Kanchanpur	North Tripura	On decaying wood	Saprobic. Pileus 1.0–2.5 cm, convex, upper surface white but centre light brown, lower surface whitish brownish, smooth; margin Irregular. Stipe 1.5–3.5 cm, equal, white, central and glabrous.
130	MCCT302	*Lactarius hygrophoroides* (Berk. & M.A. Curtis) Kuntze	Salbagan	West Tripura	On soil with decaying sal leaf	Mycorrhizal, solitary or scattered. Pileus 5.5–1.0 cm, convex at young and plane at maturity, dry, centrally depressed, azonate, golden yellow to yellowish brown, smooth; margin inrolled at young stage and plane at maturity; lamellae adnate to decurrent, narrow to moderately broad, distant, whitish to pale, juice present. Stipe 4.3–7.0×8.0–2.5 cm, solid, short, firm, glabrous or with an unpolished velvety sheen.
131	MCCT303	*Lepiota cristata* (Bolton) P. Kumm.	Salbagan	West Tripura	On dead wooden log	Saprobic. Pileus 2.5×2.1 cm, conical, white with brown spotted, surface rough and dry; margin regular; gills free, crowded, white. Stipe 3–5.5×0.3–0.6 cm, center, equal or clavate, white; annulus present.
132	MCCT304	*Russula cyanoxantha* (Schaeff.) Fr.	Salbagan	West Tripura	On soil with decaying leaf	Basidiocarp solitary. Pileus 5–10 cm, globose at immaturity and convex to flat at maturity, central depression present, slimy, grayish purple to dark violet; gills subdecurrent to adnexed, flexible, white. Stipe 4.5–7.5×0.7–1.5 cm, thick, cylindrical or slightly bulbous at the base, white, smooth.
133	MCCT305	*Psathyrella candolleana* (Fr.) Maire	Salbagan	West Tripura	On decaying bamboo ehizome with ant nest soil	Saprobic, solitary or gregarious. Pileus 9.5–14.0×6.3–10 cm, elongated, orange ocher to pale orange; context of 1.0–1.4 cm, tough, fibrous. Hymenophore with pores, coral to red, angular pores. Stipe absent.
134	MCCT306	*Russula* sp. Pers.	Salbagan	West Tripura	On soil	Mycorrhizal, solitary or scattered. Pileus 5–16 cm, convex with a central depression, white to whitish or creamy, margin inrolled at immaturity but broadly convex at maturity; margin inrolled, dry, cracked at maturity; gills attached crowded, white at first and creamy at maturity. Stipe 2.5–4×1.5–3 cm, solid, more or less equal, dry, whitish, bruising brown to brownish.
135	MCCT307	*Marasmius jasminodorus*Wannathes, Desjardin & Lumyong	Salbagan	West Tripura	On decaying leaf	Saprobic, solitary or scattered. Pileus 1.2–3.8 cm, convexus to campanulatus, umbone, pruinosus, margine rugoloso-striato, laete brunneo usque brunneo-aurantiaco. Stipe 1.7–5.5×0.1–0.3 cm, dark brown to light brown, hollow, central, cylindrical, cavus.

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136	MCCT308	*Marasmiellus tenuissimus* (Jungh.) Singer	Salbagan	West Tripura	On bark of living plant	Lignicolous, densely gregarious. Pileus 1.6–2.7×1.0–1.7 cm, orange white or pale orange, with white or concolorous margin, glabrous, slightly striate; lamellae adnexed to almost free, distant to subdistant, with series of lamellulae, intervenose, narrow. Stipe 0.07–0.4×0.03–0.1 cm, eccentric to sublateral, cylindrical to tapering, pubescent to velutinous, hollow, insititious, dark brown.
137	MCCT309	*Agaricus moelleri* Wasser	Salbagan	West Tripura	On soil	Basidiocarp pluteoid, small to large size. Pileus 5–13 cm, convex to expanding, sometime umbonate, surface silky and squamulose; lamellae free, dark brown, thin, crowded. Stipe 4–8.5×1–2.5 cm, central, cylindric with bulbose base, fibrous; annulus present, white.
138	MCCT310	*Marasmius* sp. Fr.	Salbagan	West Tripura	On decaying wood	Saprobic, solitary. Pileus 3.5–6.8 cm, dark pink at the centre to becoming light pink, expanding, smooth, and wavy; lamellae joined, distant. Stipe 2.8–4.3×0.4–0.7 cm, light pink, solid, centric or some times excentric, rough, cylindric, equal.
139	MCCT311	*Laccaria fraterna* (Sacc.) Pegler	Salbagan	West Tripura	On dead wooden log	Mycorrhizal. Pileus 2.5–6.5 cm, convex to flat, depressed, faintly lined, red-brown to orangish buff; gills attached distant, pinkish. Stipe 2.5–7.5×1.5–3.5 cm, equal, pinkish, hairy and white basal mycelium present.
140	MCCT312	*Leucocoprinus cepistipes* (Sowerby) Pat.	Salbagan	West Tripura	On decaying wood	Saprobic. Pileus 2.5–10 cm, egg-shaped at immaturity but nearly round to convex when mature with a sharp or shallow central hump, whitish to pale brownish, grayish brown center, dry, powdery, whitish granules, margin distinctly lined; gills free, crowded, white to slightly brownish. Stipe 5.5–10×0.5–1.0 cm, mostly equal but swollen slightly near the bottom, white, discoloring pinkish to brownish.
141	MCCT313	*Cantharellula* sp. Singer	Narsingarh	West Tripura	On decaying wood	Saprobic, solitary or scattered. Pileus 1.5–3.0 cm, flattened then broadly depressed at centre, surface greasy, entirely white-pruinos; margin enrolled, thin, dark brown to reddish brown, striate only with age; lamellae adnexed, arcuate, then shortly decurrent when expanded, ash-grey; edge smooth, concolorous. Stipe 2.5–3.8×0.455–0.8 cm, hollow, cylindrical, often compressed, entirely covered by a dense white fibrillum.
142	MCCT314	*Cantharellula* sp. Singer	Indranagar	West Tripura	On decaying wood with soil	Saprobic, solitary or scattered. Pileus 1.5–2.5 cm, brown to reddish brown, umrella shaped, centre slightly depressed; margin surface greasy, enrolled, white, pruinose; lamellae, adnexed, arcuate, then shortly decurrent, smooth, concolorous. Stipe 2.0–3.5×0.2–0.5 cm, hollow, cylindrical, compressed, entirely covered by a dense white fibrillum.
143	MCCT315	*Ganoderma sessile* Murrill	Sabroom	South Tripura	On dead wooden log	Basidiome sessile, solitary or scattered. Pileus 4–7.5×3–6 cm, surface glabrous, rugose, laccate, concentrically sulcate, yellowish to reddish brown and dark brown at maturity, wrinkled, woody, dimidiate, conchate to flabelliform; margin acute and thin., ochraceous zones present. Pores 0.2–0.4 cm, brown, grayish brown, circular or angular, dissepiments entire.
144	MCCT316	*Ischnoderma resinosum* (Schrad.) P.Karst.	Sipahijala WS	Sepahijala	On dead tree	Saprobic, solitary or gregariously. Fruitbody size (5–15×4–6)×(1–1.6) cm, semicircular, whitish at immature stage but at maturity upper surface brown to black and lower surface white; margin white, smooth and fibrous.
145	MCCT317	*Daedaleopsis confragosa* (Bolton) J.Schröt.	Sipahijala WS	Sepahijala	On dead tree	Saprobic, solitary or gregariously. Fruitbody size (3–9×3–5)×(0.5–1.5) cm, brown, semicircular, rough and fibrous, pore white to brownish and elongated.
146	MCCT318	*Trametes elegans*(Spreng) Fr.	Sipahijala WS	Sepahijala	On leaving tree	Saprobic, solitary or gregariously. Fruit body 8–20×1.5–3 cm, semicircular or kidney shaped with bracket zones, white to light creamy, rough and fibrous, white thin margin.
147	MCCT319	*Hygrocybe spadicea* (Fr.) P. Karst.	Sipahijala WS	Sepahijala	On soil with bryophyte association	Basidiocarps solitary. Pileus 2–4 cm, dark brown, at immature stage conical but at maturity lobed and margin split, gill adnex. Stipe 3–2×1–2 cm, smooth surface white or light yellow, hollow, fibrous; ring absent.
148	MCCT320	*Phellinus igniarius* (L.) Quél.	Sipahijala WS	Sepahijala	On dead log	Saprobic, solitary. Fruitbody 17–25×10–16×3–6 cm, hemispherical or semicircular with bracket zones, black brown, hard or woody; margin sharp with serrate.
149	MCCT321	*Microporus* sp. P.Beauv.	Sipahijala WS	Sepahijala	On dead plant	Saprobic, solitary. Fruit body 3.5–5.5 cm, broadly funnel, tough, leathery, upper surface dry, shiny, strongly banded in shades of buff and rich brown with the outer edge of the cap cream to white, lower surface cream to white; pores decurrent, white. Stipe 1.2–3.8×0.2–0.6 cm, central to slightly eccentric, cylindrical, base tough, attached to the substrate by a disc.
150	MCCT323	*Microporus xanthopus* (Fr.) Kuntze	Sipahijala WS	Sepahijala	On dead detached branch	Saprobic or mycorrhizal, solitary or gregariously. Fruitbody 3–7×2–4 cm, cinnamon brown; margin white straight thin; pore angular or circular. Stipe 1–3.5×0.5–0.8 cm, thick, white or creamy white.

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151	MCCT324	*Hygrocybe acutoconica* (Clem.) Singer	Sipahijala WS	Sepahijala	On soil	Basidiocarp solitary or scattered. Pileus 2–4 cm long, yellow but gill portion white, broadly conical with a central nipple, lined with uplifted margin; lamella free from stipe. Stipe 3–5×1–2 cm, whitish to light yellowish, equal or slightly unequal, hollow, fibrous; ring absent.
152	MCCT325	*Artomyces* sp.Jülich	Sipahijala WS	Sepahijala	On soil	Mycelial, cluster. Fruitbody 15–37×0.2–0.5 cm, white or creamy, gregariously, multiple branching, pointed ends.
153	MCCT326	Unidentified	Sipahijala WS	Sepahijala	On soil	Basidiocarps solitary. Pileus: 3–4 cm, yellow whiish. Stipe: 4–5×2–1 cm, convex to brodlly convex, smooth; ring present
154	MCCT327	*Amanita constricta*Thiers & Ammirati	Sipahijala WS	Sepahijala	On soil	Mycorrhizal, solitary. Pileus 3–10 cm, flate, whitish and tip portion grayish brown; gills whitish, free, crowded; lamella white, 2–3 lamellates. Stipe 7–8×1–2.2 cm, whitish, slightly hard, hairy; ring present at immature stage but at maturity ring absent; volva present.
155	MCCT328	Unidentified	Sipahijala WS	Sepahijala	On dead leaf	Solitary. Pileus 3–4 cm, brown. Stipe 9–10×1–2 cm, convex to broadly convex, smooth; ring absent.
156	MCCT329	*Russula virescens* (Schaeff.) Fr.	Sipahijala WS	Sepahijala	On soil	Mycorrhizal and solitary. Pileus 4–7 cm, convex to broadly convex and centrally depressed, light yellowish green or light ash, dry; gills attached, white, crowded. Stipe 6–7×1–2 cm, central, umbonate, smooth fibrous; ring absent.
157	MCCT330	*Amanita jacksonii* Pomerl	Sipahijala WS	Sepahijala	On soil	Mycorrhizal, solitary. Pileus 5–10 cm, orange but margin yellow, oval shaped to convex; gills free from stem, crowded. Stipe 5–13×1.5–2.0 cm, yellow, scally, ring present; volva present bell shaped and white.
158	MCCT331	*Clitocybe ditopa* (Fr.) Gillet	Sipahijala WS	Sepahijala	On soil	Basidiocarp clitocybiod, solitary. Pileus 4–7 cm, convex to depressed or cyathiform, grayish brown, surface hygrophanous, striate, dry smooth; margin inrolled; lamella crowded, short and lamellulae 3. Stipe 5–8×0.5–1 cm, cylindric, solid, pale grayish, glabrous; ring absent.
159	MCCT332	Unidentified	Sipahijala WS	Sepahijala	On soil	Basidiocarp solitary. Pileus 6–7 cm, yellow whitish. Stipe 7–8×3–4 cm, depressed, yellow whitish; ring absent
160	MCCT333	*Agaricus placomyces* Peck	Sipahijala WS	Sepahijala	On soil with decaying leaf	Saprobic or mycorrhizal, scattered or gregariously. Pileus 4–8 cm, whitish with brown spot especially in the centre, scally, convex to straight at maturity; margin straight and smooth; lamella brownish, free from stem, crowded. Stipe 7–10×0.5–1.3 cm, whitish brown, straight, fibrous, hollow, base bulbose; ring present.
161	MCCT334	*Russula emetica* (Schaeff.) Pers.	Sipahijala WS	Sepahijala	On soil with decaying leaf	Mycorrhizal, solitary or scattered. Pileus 4–5 cm, pink but centre dark pink, convex to depressed, non-circulate; gill free from stem, crowded. Stipe 4.0–7.0×1.0–1.6 cm, white, hard.
162	MCCT335	*Astraeus hygrometricus* (Pers.) Morgan	Sipahijala WS	Sepahijala	On soil	Basidiocarp solitary. Fruitbody redish white, Majority of them are unopened or partially opened at apex with irregular 7 petal-like lobes, the lobes recurves, remain flat on crack of 4–12 lobes, further undergoes division about 7 incurves towards centre, incurving enclosing the spore sac, centre of leathery incurved or flat lobes.
163	MCCT336	*Termitomyces* sp. R.Heim	Sipahijala WS	Sepahijala	On soil	Solitary. Pileus 6–10 cm, white to creamy brown, campanulate to umbo, umbonate portion brown, smooth; margin split at maturity; lamellae white creamy, crowded, regular. Stipe 8–10×1–1.5 cm, white, central, equal, fibrous, hard; ring absent.
164	MCCT337	Unidentified	Sipahijala WS	Sepahijala	On dead leaf	Solitary. Pileus 4–5 cm, brown. Stipe 4–5×1–2 cm, depressed shape; ring absent.
165	MCCT338	*Psathyrella* sp. (Fr.) Quél.	Sipahijala WS	Sepahijala	On soil	Saprobic, scattered or cluster. Pileus 2.5–7 cm, light brownish, scaly margin smooth; gills free distant, brownish. Stipe 7–11×0.5–0.8 cm, fibrous, brownish; ring present.
166	MCCT339	*Thelephora terrestris*Ehrh.	Sipahijala WS	Sepahijala	On dead tree	Solitary. Fruitbody 4–5 ×2–4 cm, centrally depressed, fan-shaped to semicircular, radially wrinkled and grooved, dry, brown, fibrillose to velvety; ring absent.
167	MCCT340	*Strobilomyces confusus* Singer	Sipahijala WS	Sepahijala	On soil	Solitary. Pileus 4–5 cm, brown, convex, becoming broadly convex, dry, covered with small, erect, fibrillose. Stipe 4–5×1–2 cm, more or less equal, depressed shape, solid, base covered with dense; ring absent.
168	MCCT341	Unidentified	Sipahijala WS	Sepahijala	On soil	Mycorrhizal, solitary or scattered. Pileus 4–5 cm, light brown, fleshy; lamellae white, attached, decurrent. Stipe 4–5×1–1.2 cm, white, smooth, hard.
169	MCCT342	*Stereum* sp. Hill ex Pers.	Sipahijala WS	Sepahijala	On soil	Solitary, ring absent, brown. Pileus: 4–5 cm. Stipe 4–5×1–2 cm, depressed shape.
170	MCCT343	*Marasmiellus candidus* (Fr.) Singer	Sipahijala WS	Sepahijala	On dead plant	Saprobic, solitary. Pileus 1–2.5 cm, white, convex with a central depression, thin fragile, dry; gills vein like, decurrent. Stipe 0.5–1.7×0.1–0.3 cm, white to brownish or blackish, equal, dry.

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171	MCCT344	*Ganoderma* sp.P.Karst	Sipahijala WS	Sepahijala	On hard dead wood	Saprobic, solitary. Fruitbody broadly fan shaped or semicircular, upper surface brown with ring shape, margin white, lower surface white.
172	MCCT345	*Gloeophyllum* sp.P.Karst	Sipahijala WS	Sepahijala	On dead wooden log	Saprobic, solitary or gregariously. Fruitbody 7–12×5–8 cm, yellowish brown to dark brown, semicircular or kidney shaped and sessile.
173	MCCT346	*Mycena* sp. (Pers.) Roussel	Sipahijala WS	Sepahijala	On decaying leaf	Saprobic, solitary or scattered or gregariously, mycelloid. Pileus 1–1.8cm, dark brown to black, conical or bell shaped, dry; gill light yellowish, attached to stem, distant. Stipe 5–9×0.1–0.2 cm, light yellow, smooth, hollow.
174	MCCT347	*Cantharellus cibarius* Fr.	Sipahijala WS	Sepahijala	On soil	Scattered to gregarious or caespitose clusters. Pileus 5–13 cm, yellow to whitish, convex with yellow margin, wavy, sticky, crack; gills fold, thick decurrent. Stipe 2–4×0.5–2.0 cm, solid, centre, yellow to whitish, thick smooth.
175	MCCT348	Unidentified	Trishna WS	South Tripura	On soil	Saprobic, gregariously joined. Fruitbody 15–26×1–2.5 cm, semicircular or kidney shaped, reddish brown to dark brown; ring like collar present.
176	MCCT349	*Ramaria stricta* (Pers.) Quél.	Trishna WS	South Tripura	On soil	Mycorrhizal. Fruit body 3–15×3–7 cm, cream whitish, branching 6–12, base rarely absent.
177	MCCT350	*Pterula* sp. Fr.	Trishna WS	South Tripura	On soil with decaying leaf	Saprobic, solitary or scattered. Basidiomes 5–11×0.4–0.6 cm, white to creamy white, branching arise from tip portion, branches 7 –12 in number, tip portion sharp.
178	MCCT351	Unidentified	Trishna WS	South Tripura	On dead wooden log	Saprobic, solitary to scattered. Pileus 3–6.5 cm, light yellow to brown, dark brown at the centre, gills distant, light yellow, margin serrate. Stipe 4–7×0.3–0.7 cm, central, dark brown, fibrous solid, equal.
179	MCCT352	*Russula natarajanii* K. Das, J.R. Sharma & Atri	Trishna WS	South Tripura	On soil	Mycorrhizal, solitary. Pileus 5–8 cm, white to creamy white, fibrous; margin serrate; gills adnex, white to creamy white, close. Stipe 4–6×0.8–1.7 cm, whitish, central, unequal, solid, base blunt.
180	MCCT353	*Russula* sp. Pers.	Trishna WS	South Tripura	On soil	Mycorrhizal, solitary to scattered. Pileus 8–14 cm, convex with central depression, white; margin inrolled; gills crowded, decurrent and white. Stipe 3–4×0.7–1.8 cm, white, thick, equal, dry, base blunt, mycelium present.
181	MCCT354	*Daldinia concentrica* (Bolton) Cesati & de Notaris	Trishna WS	South Tripura	On dead wooden log	Saprobic, solitary to scattered. Stromata up to 4–6 cm, hemispherical, across, reddish-brown, perithecia small.
182	MCCT355	*Fomitopsis* sp.P.Karst	Trishna WS	South Tripura	On dead wood	Saprobic, solitary or gregariously. Fruitbody 25–36×13–24×8–12 cm, yellowish to dark brown, semicircular or kidney shaped; ring like collar present.
183	MCCT356	Unidentified	Trishna WS	South Tripura	On soil with degrading leaf	Saprobic and mycorrhizal, solitary. Pileus 3–4.6 cm, white and light yellow at the centre, fibrous, soft, adnex; gills white, lanceolate, wavy; 3–4 lamellae. Stipe 3–5×0.3–0.6 cm, hollow, brown, central, straight.
184	MCCT357	*Ganoderma* sp.P.Karst	Trishna WS	South Tripura	On decaying wood	Saprobic, solitary. Fruitbody 5–8×3–4.5 cm, 2–3.5 cm thick, kidney shaped, whitish-dark brown-black, surface smooth, hard; margin whitish. Stipe absent.
185	MCCT358	*Cantharellus cinereus* (Pers.) Fr.	Trishna WS	South Tripura	On soil with decaying leaf	Solitary. Pileus 4–6×5–6 cm, ash or brown to light black, funnel shaped and crossed and attached, slight decurrent; gills distant, lanceolate; margin serrate. Stipe 3–4×0.2–0.6 cm, centric or ecentric, noncircular, brown, equal.
186	MCCT359	*Marasmius oreades* (Bolton) Fr.	Trishna WS	South Tripura	On soil with decaying leaf	Saprobic or mycorrhizal, solitary. Pileus 4–5 cm, brown, convex with central depression, soft, serrate; gills lanceolate, adnex, soft; 5 lamellae. Stipe 4–6×0.5–1.3 cm, white to light yellow, central, solid, scally, base blunt.
187	MCCT361	*Lentinus velutinus* Fr.	Trishna WS	South Tripura	On dead wood	Saprobic, solitary. Pileus 5–9 cm, infundibuliform to cyathiform, brown, erect, hairy; lamellae decurrent, crowded, thin. Stipe 6–10.3×0.4–0.7 cm, brown, central, cylindric, solid hairy.
188	MCCT362	*Geastrum saccatum* Fr.	Trishna WS	South Tripura	On decaying bamboo	Saprobic, gregarious. Basidioma smooth, at immaturity egg shaped but at maturity flower shaped with pointed beak, beak 2–3cm, brown; 7 pointed triangular shaped skil.
189	MCCT363	Unidentified	Trishna WS	South Tripura	On soil	Solitary. Pileus 6–9 cm, yellow, creanate to appendiculate, margin serrate; gills crowded, yellow and lanceolate. Stipe 5–7×0.5–1.5 cm, whitish-yellow, central, fibrous, solid, equal.
190	MCCT364	*Chalciporus piperatus* (Bull.) Bataille	Trishna WS	South Tripura	On soil	Solitary or scattered. Pileus 4–6 cm, hemispherical, fruit body yellow brown to orange, smooth; pore reddish brown. Stipe 4–7×1–2 cm, yellow to reddish, equal to taperate light.

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191	MCCT365	*Lactarius glaucescens* Crossl.	Trishna WS	South Tripura	On soil	Mycorrhizal, solitary or scattered. Pileus 5–10 cm, convex with a central depression, white to creamy white; gills decurrent, crowded, thin creamy, juice secretion present. Stipe 4–7×1–1.6 cm, thich, white, smooth, blunt base.
192	MCCT366	*Hygrophorus marzuolus* (Fr.) Bres.	Trishna WS	South Tripura	On soil	Solitary. Pileus 5–8 cm, light yellow at young stage but dark brown to light black at maturity, central portion depressed; margim serrate; gills brown to black, lanceolate, closely adnate. Stipe 3–6×2–4 cm, brown, central, equal, fibrous.
193	MCCT367	*Funalia* sp. Pat.	Trishna WS	South Tripura	On decaying Wood	Saprobic, solitary. Fruitbody 4–7 cm, blackish-brown, pore large, rough surface. Stipe absent.
194	MCCT368	*Lactarius corrugis* (Peck) Kuntze	Trishna WS	South Tripura	On soil	Mycorrhizal, solitary to scattered. Pileus 3–7.6 cm, convex with a central depression, red brick; gills brownish, crowded, secreting juice, thin. Stipe 5–8×1–1.6 cm, central or some times ecentric, solid, red brick, non straight, blunt base.
195	MCCT369	*Boletus reticulates* Schaeff.	Trishna WS	South Tripura	On soil	Mycorrhizal, solitary or scattered. Pileus 6–12 cm, convex, whitish to light brown, pore surface whitish to gray. Stipe 5–8×1–1.5 cm long, white to creamy white, more or less equal.
196	MCCT370	*Amanita* sp. Pers.	Trishna WS	South Tripura	On soil	Mycorhizal, solitary. Pileus 4–6 cm, white to light bluish, convex, scaly, soft; gills distant, white, separable. Stipe 5–8×0.6–1.4 cm, white, scaly, unequal, solid or hollow, fibrous; ring present; volva present, volva 1–1.8 cm long, white soft.
197	MCCT371	*Chromosera cyanophylla*(Fr.) Redhead, Ammirati & Norvell	Trishna WS	South Tripura	On soil	Solitary or gregarious. Pileus 1–3.5 cm, brown to light yellow, at first hemispherical with flattened and depressed centre, inflexed margin but reflexed margin becoming lobed to lacerated, surface glutinous to sticky, smooth. Stipe 2–4.3×0.2–0.0.4 cm, cylindrical with broadened base, curved, shiny-glassy, sticky and waxy, dry, smooth.
198	MCCT372	Unidentified	Trishna WS	South Tripura	On soil	Solitary. Pileus 3–6 cm, brownish, straight with slight central depression, smooth, dry; gills adnex, lanceolate; 4–5 lamellae, brownish. Stipe 4–6.5×0.3–1.3 cm, brownish, central, unequal, top and lower portion blunt.
199	MCCT373	*Lentinus* sp. Fr.	Trishna WS	South Tripura	On dead wood	Saprobic, caespitose. Pileus 3.5–7.5 cm, medium to large, white to cream white, centrally depressed, infundibuliform, fleshy, squamose at immature stage; margin thin fleshy, inrolled, serrate at maturity; lamellae decurrent, crowded, tough, short. Stipe 3.5–7.5×0.4–0.9 cm, white, central or sometimes excentric, solid, cylindric, elongated.
200	MCCT374	Unidentified	Trishna WS	South Tripura	On dead wood	Saprobic, gregarious or solitary. Pileus 4.5–7.7 cm, broadly convex at immaturity but at maturity occur a central depression or becoming deeply vase-shaped at maturity, squeamules at upper side, purplish to brown in young stage and dark brown at maturity. Stipe 2–3.8×0.7–1.2 cm, central or slightly lateral, solid, equal, slightly enlarged toward the base, squamules present.
201	MCCT375	*Pluteus* sp. Fr.	Sipahijala WS	Sepahijala	On sawdust	Saprobic, solitary or cluster. Pileus 2.5–3.9 cm, conic to convex or slightly umbonate, upper surface light ash and slightly darker at the centre but lower surface white; margin thin, soft, finely sulcate; lamellae white, free, unequal, crowded. Stipe 3.5–6.5×0.2–.6 cm, white to whitish grey, subequal, central, flexuous, hollow, basal mycelium.
202	MCCT376	*Pleurotus* sp. (Fr.) P. Kumm.	Sipahijala WS	Sepahijala	On dead wood	Saprobic, solitary or scattered. Pileus 2.2–4.5×1.6–3.6 cm, white, flabeliform, small, attached to the substrate, fleshy, soft; lamellae decurrent, crowded. Stipe absent or very little, excentric.
203	MCCT378	*Chromosera* sp. Redhead, Ammirati & Norvell	Sipahijala WS	Sepahijala	On dead wood	Saprobic, solitary. Pileus 1.5–3.5 cm, light yellow, convex to plano-convex, disc broadly flattened, central portion depressed; margin translucent-striate, incurved, surface glabrous; context thin; lamellae decurrent, lavender, subdistant, cream-colored in age. Stipe 1.5–3.5×1.0–2.0 cm, yellowish, fragile, more or less equal, hollow, base and upper part sub-bulbous, surface glabrous, viscid, lavender.
204	MCCT383	*Agaricus trisulphuratus*Berk.	Atharamura	Khowai District	On soil	Solitary. Pileus 3–5 cm, convex to applanate with a subumbonate, orange to salmon orange, imbricate squamules; margin involute; lamellae free pale pinkish to dark brown, thin, crowded. Stipe 2.5–5×0.3–0.5 cm, equal, cylindric; annulus present.
205	MCCT384	*Tyromyces lacteus* (Fr.) Murrill.	Atharamura	Khowai District	On dead wooden log	Saprobic. Fruitbody 5.2×3.5 cm, white, white micropores were present under side, surface moist, texture solid and tough.
206	MCCT385	*Ascobolus* sp. Pers.	Salbagan	West Tripura	On cow dung	Saprobic, solitary or gregarious. Ascomata apothecioid, yellow, semi-immersed, receptacle at first closed then irregularly opening at the top, cupulate, disc flat to convex, yellow.

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207	MCCT386	*Boletus* sp. L.	Salbagan	West Tripura	On decomposed grass	Mycorrhizal, solitary or gregarious. Pileus 10–45 cm; convex to broadly convex, tacky, bald light brown to reddish brown or yellow-brown; pore surface yellowish, not bruising, pores stuffed, angular to circular. Stem 10–30×3–15 cm, thick, club-shaped, cylindric, and more or less equal.
208	MCCT387	*Volvariella* sp. Speg.	Amtali	West Tripura	On decomposed soil	Basidiocarps solitary. Pileus 3–5.8 cm, grayish-brown to brownish-gray, convex to broadly convex, dry, and finely radially hairy; margin not lined, splitting; lamellae free, crowded, pink to brownish pink. Stipe 3.5–6.0×0.7–1.3 cm, grayish brown to brownish, thick, slightly swollen base, dry, slightly hairy at the apex; sack-like volva with squamules.
209	MCCT388	*Coprinus* sp. Pers.	Salbagan	West Tripura	On decaying paddy straw	Saprobic, solitary or scattered. Pileus 0.2–3.2 cm, upper surface grayish white and lower surface ash to black, long, long acorn-shaped, campanulate to revolute, pileus veil breaks up into loose. Stipe 3.5–12.5×0.05–0.4 cm, white, hollow, base often slightly enlarged, a faint annular or volvate zone near the base, mostly smooth and glabrous.
210	MCCT389	*Phallus indusiatus* Vent.	Amtali	West Tripura	On soil	Saprobic, solitary. Pileus 20–25 cm, spike-like, smooth at first but pitted and ridged by maturity, covered with a slimy, olive-brown substance which is carried away by flies, whitish to light brown, developing a perforation at the top. Stipe 11–18.5×1.2–4.0 cm, white; sack like volva present, white to slightly pinkish, hanging up to 15cm from the bottom edge.
211	MCCT390	*Pleurotus* sp. (Fr.) P. Kumm.	Trishna WS	South Tripura	On dead wooden log	Saprobic, solitary or gregarious. Pileus 3.5–5.5×1.5–3.5 cm, sessile, infundibuliform, whitish to light brown, smooth; margin smooth and lobed.
212	MCCT391	*Xylaria obovata* (Berk.) Berk	Betlingshib	North District	On decaying logs	Saprophytic, solitary. Stromata 1.6–2.6×0.7–1.9 cm, blackishbrown with sub-globose to obovate, round fertile head, narrowing below into a black, short and stout sterile stipe, flesh whitish, hard, ostiole papillate or semi-papillate. Perithecia 1.4–1.9×0.5– 1.6 cm and stout sterile stem was 0.3– 0.4×0.2 cm, black, sub-spherical with fertile head.
213	MCCT392	*Xylaria nigripes*(Klotzsch) Cooke	Betlingshib	North District	On dead wooden log	Saprophytic, solitary. Stromata 4–8×0.2–0.5 cm, ash to blackish, cylindrical, long, hard, branched or unbranched to gregarious, extended fertile apex which is curved and ash. It turns to dark black with maturity and also becomes hard with age. Surface smooth and becomes wrinkled when fully grown. Perithecia black, sub-spherical to spherical, fertile head. The size of the head was 0.009–0.029 cm.
214	MCCT393	*Xylaria polymorpha* (Pers.) Grev	Betlingshib	North District	On dead wooden bark (crack tissue)	Saprophytic, grow in unbranched or sparingly branched. Stromata 0.8–2.2×0.2–0.62 cm, dark brown to black, lower and upper part is sharp, apex round fertile head and narrowing below into a brownish-black, short, stout sterile stem. Stromata tough, more or less club shape, stem often proportionally long, but also frequently short or nearly absent. Perithecia black, sub-spherical, fully embedded in fertile head and size measured as 0.052–0.13 cm.
215	MCCT394	*Xylaria schreuderiana* [Van der Byl.]	Tlangsang	North District	On dead wooden bark (crack tissue)	Saprophytic, grew in solitary. Stromata gregarious, occasionally fasciculate to solitary and scattered, slender, upright, stipate, often unbranched, fertile portion subglobose with upper part consist of 0.1–0.2 cm of an apiculus, only a few perithecia or less fertile portion with more perithecia and then subcylindrical. Stromata 0.4–0.7×0.05–0.2 cm, surface rough, dark black, with raised lines, dense, black stipe and absence of hairs.
216	MCCT395	*Xylaria multiplex*(Kunze) Fr.	Tlangsang	North District	On dead wooden log	Saprophytic, united or solitary. Stromata 1.76–4.86×0.32–0.64 cm, blackish to blackish-brown, elongated, cylindric, undulated, clavate, apex fertile head and narrowing below into a brownish-black, short sterile stem. Perithecia 0.03–0.04 cm, black, subspherical, embedded in fertile head, arranged in a single dense layer.
217	MCCT396	*Xylaria hypoxylon* (L.: Fr.) Grev	Sabual	North District	On decaying wooden log	Saprophytic, single or groups. Stromata 4.5–9.6×0.24–0.58 cm, irregular, single or attached habitually originating from common base, surface roughened, branched apex, with short or long concolorous horns, stipe first white towards becoming dull black, interior white, woody to carbonaceous. Perithecia 0.02×0.05 cm, black, sub-spherical, embedded, arranged in a single dense layer just below the surface.

LCN—Laboratory Collection Number

decomposed plants, soil with decaying leaf), soil (ground in open grassy field soil, sandy soil, soil with bryophyte association, soil with grass field, termite mounds) and cow dung (Figure 6). Some interesting substrates were noticed, which were specific to certain genera. These interesting habitats of macrofungal genera were living plant for *Lentinus, Polyporus, Pleurotus, Xerulina, Marasmiellus*, soil with bryophyte association for *Hygrocybe*, bamboo rhizome for *Parasola*, *Psathyrella*, dead wooden bark (crack tissue) for *Xylaria* and termite mounds for *Termitomyces* and *Humaria*. This divergence of habitats may be due to their nutritional needs and the need for a suitableenvironment to survive.

DISCUSSION

The present study revealed that a total of 217 different morphotypes were collected from eight different districts of Tripura and 55 mushrooms were collected from West Tripura District, whereas previous findings (Debnath et al. 2017) showed that West Tripura contained 22 morphotypes. There are few reports on mushrooms in Tripura (Debnath et al. 2017, 2019, 2020a,b) but a study on mushroom diversity of the state of Tripua has not been conducted earlier. Baptista et al. (2010) recorded a total of 2677 carpophores belonging to 73 species across 16 families and 23 genera in the Tra´s-os-Montes region of Northeast Portugal, which also showed more or less dissimilarity with our finding. According to Cho et al. (2019), they documented 95 macrofungi that belong to 57 species, 47 genera, 24 families, and 8 orders in Ascomycota and Basidiomycota from the Inner Tian Shan in Kyrgyzstan located in China and the dominant species belonged to the families Polyporaceae (8 species) and Agaricaceae (6 species), respectively. A large number of fungi was reported from moist deciduous and wet evergreen forest of Andaman &Nicobar Islands based on existing literature; a total of 446 fungal species was reported which belong to 216 genera, 96 families, 44 orders 10 classes and seven phyla (Niranjan & Sarma 2018). Tapwal et al. (2013) also recorded 30 macrofungal species representing 26 genera belonging to 17 families which were collected from six different sites in wet ever green tropical forest of Assam, India. A total of 71 species of 41 genera belonging to 24 families were recorded including 32 edible, 39 inedible and altogether 19 medicinally potential mushrooms were collected from tropical evergreen and deciduous mixed type of forest in Gurguripal Eco-forest, Paschim Medinipur, West Bengal, India (Singha et al. 2017). The present study showed that the Polyporaceae family was dominant which also showed resemblance with other findings (Tapwal et al. 2013). Priyamvada et al. (2017) documented a total of 113 macrofungal species belonging to 54 genera and 23 families and the highest species were recorded in the family Agaricaceae followed by Polyporaceae and Marasmiaceae. Present findings revealed that maximum numbers of macrofungi were growing on different plant parts in comparison to soil habitat (Debnath et al. 2017).

The distribution and abundance of wild macrofungi are influenced by natural factors (Swapna et al. 2008), like rains and accessibility of decomposed organic matters (Debnath et al. 2017). The occurrences of mushrooms in forest bed and plantation site suggest a close association between the macrofungal population and physical condition of forest (Debnath et al. 2017). Most of the fleshy and gilled macrofungi were recorded in the rainy seasons as this period is favorable for their production since there is adequate moisture, favorable temperature, relative humidity and sunshine, which also aids the macrofungi in the decomposition of dead organic matter. While polypores can grow in all the seasons because they require less rainfall, i.e., moisture and relative humidity, high temperature and sunshine are also favorable but most of the macrofungi cannot survive these exceptional conditions. According to Payton (1993) the high macrofungal diversity was found in high altitude because of low temperature, soil moisture and high relative humidity which directly affected the forest ecosystem found on the mountains. Present documentation reports that the total 217 macrofungi were collected from 56 sites under eight districts of Tripura. Most wild mushrooms of this state grow on dead wood. Maximum mushroom specimens were collected from Sepahijala District of Tripura but collection was highest in West Tripura.Occurrence and diversity of wood inhabiting macrofungi (some of them listed in Table 1) was studied along with details of host ranges in central India. In the study, *Phellinus*was recorded as the most diverse genus with 18 species followed by *Trametes* and *Ganoderma* 17 species each, *Polyporus* seven species, *Microporus* five species, *Daedelea, Hexagonia* and *Hymenochaete*four species each. *Schizophyllum commune, Tremates cingulata* and *Flavodon flavus* were common to all places and showed the maximum frequencies of occurrence (Tiwari et al. 2013). Diversity of two groups of mushrooms belonging to Amanitaceae and Russulaceae were studied. Mushrooms belonging to Amanitaceae (80 species) were reported from different parts of India including four genera—*Amanita*(73), *Catatrama*(1), *Limacella*(4), and *Saproamanita*(2). Maximum diversity of Amanitaceae were recored from Uttarakhand followed by Himachal Pradesh, Kerala, Odisha, Jammu & Kashmir, Meghalaya, Madhya Pradesh and West Bengal (Verma & Pandro 2018).

CONCLUSIONS

This is the earliest ever organized study on documentation of wild macrofungi from Tripura, northeastern India and this study also provides the baseline information for the researchers to do various studies on these mushrooms in future. The findings of this study will be a reference database of wild mushroom of the state and will help in future research work in different fields. The significance of macrofungal diversity is not only for the ecosystem but also for human diet and health, which are also necessary reasons for conservation, however, the different biological activities, cultivation techniques and economic importance of some selected mushrooms are yet not known to us, therefore further research is needed to develop various cultivation techniques and also to isolate the functionally active components of these wild mushrooms.

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Image 1. Macrofungi species of Tripura. MCCT 10—*A. campestris* | MCCT 11—*M. procera* | MCCT 17—*C. molybdites* | MCCT 18—*Amanita* sp. | MCCT 21—*Marasmius* sp. | MCCT 22—*Macrolepiota* sp. | MCCT 23—*L. cretaceous* | MCCT 24—*Tricholoma* sp. | MCCT 27—*Lentinus* sp. | MCCT 28—*Lentinus* sp. | MCCT 30—*P.auricoma*| MCCT 31—*Panus* sp. | MCCT 32—*P. alveolaris* | MCCT 33—*Marasmiellus* sp. | MCCT 35—*Marasmiellus* sp.| MCCT 36—*L. crinitus* | MCCT 37—*M. corticum* | MCCT 38—*S. commune* | MCCT 39—*P. opuntiae* | MCCT40—*P. pulmonarius.*

Image 2. Macrofungi species of Tripura. MCCT 41—*Xerulina* sp. | MCCT 42—*Marasmiellus* sp., | MCCT 44—*Lentinus* sp. | MCCT 45—*L. prolifer* | MCCT 47—*Auricularia* sp. | MCCT48—*Hygrocybe reidii* | MCCT 49—*H. conica* | MCCT 50—*P. fasciatus* | MCCT51—*Marasmius* sp. | MCCT 52—*M. sullivantii* | MCCT 53—*Geastrum triplex* | MCCT 54—*Aleuria aurantia* | MCCT55—*Thelephora* sp. | MCCT 56—*L. tuber-regium* | MCCT 57—*Termitomyces umkowaan* | MCCT 58—*Tremella fuciformis* | MCCT 59—*Cyathus intermedius* | MCCT 60—*L. sajor-caju* | MCCT 61—*Macrolepiota* sp. | MCCT 63—*I. rimosa*

Image 3. Macrofungi species of Tripura. MCCT 66—*L. fragilissimus* | MCCT 67—*L. utriforme* | MCCT 68—*G. tsugae* | MCCT69—*Funalia polyzona* | MCCT 70—*G. applanatum* | MCCT 73—*Lentinus* sp. | MCCT 74—*Podoscypha petalodes* | MCCT 76—*Macrolepiota* sp. | MCCT 78—*Termitomyces* sp. | MCCT 80—*Chlorophyllum* sp. | MCCT 81—*Marasmius praecox* | MCCT 82—*Mycena haematopus* | MCCT84—*Auricularia auricula* | MCCT85—*Cantharellus* sp. | MCCT86—Unidentified | MCCT 89—*T. heimi* | MCCT 90—*C. brunneocaperata* | MCCT 91—*T. eurrhizus* | MCCT 94—*Phallus duplicates* | MCCT 95—*L. squarrosulus*.

Image 4. Macrofungi species of Tripura. MCCT 96—*Stereum ostrea* | MCCT 97—*Marasmiellus troyanus* | MCCT 99—*Panellus serotinus* | MCCT 100—*T. microcarpus* | MCCT 102—*M.stenophyllus* | MCCT103—*M. enodis* | MCCT 104—*M. dendroegrus* | MCCT 106—*M. siccus* | MCCT 107—*Polyporus tenuiculus* | MCCT 108—*P. alveolaris* | MCCT 109—*Pleurotus* sp. | MCCT110—*Podoscypha multizonata* | MCCT111—*Crepidotus alabamensis* | MCCT112—*Pycnoporus sanguineus* | MCCT 114—*Amanita farinose* | MCCT115—*Chlorophyllum* sp. | MCCT116—Unidentified | MCCT117—*Polyporus* sp. | MCCT118—*Humaria hemisphaerica* | MCCT121—Unidentified.

Image 5. Macrofungi species of Tripura. MCCT122—Unidentified | MCCT123—*Marasmiellus* sp. | MCCT132—*Crepidotus applanatus* | MCCT138—*V. volvacea* | MCCT142—*Pluteus americanus* | MCCT 149—*Amanita phalloides* | MCCT 151—*Inocybe* sp. | MCCT 154—*Boletus* sp. | MCCT 158—*Clavulinopsis fusiformis* | MCCT 159—*P. ferulaginis* | MCCT160—*A. auricula-judae* | MCCT 161—*Auricularia* sp. | MCCT 165—*Clitocybe brunneocaperata* | MCCT 166—*Gymnopus fagiphilus* | MCCT 169—*Lentinus* sp. | MCCT 172—*Panus* sp. | MCCT 175—*Auricularia polytricha* | MCCT176—*Stropharia semiglobata* | MCCT178—*Agrocybe splendida* | MCCT202—*Pleurotus* sp.

Image 6. Macrofungi species of Tripura. MCCT206—*Crepidotus mollis* | MCCT 209—*Panus* sp. | MCCT 212—*Flammulina velutipes* | MCCT225—*Cookeina tricholoma* | MCCT 226—*Lactarius piperatus* | MCCT230—*Pterula indica* | MCCT234—*A. delicate* | MCCT236—*Heterotextus miltinus* | MCCT237—*Inocybe parvibulbosa* | MCCT 239—*Macrolepiota mastoidea* | MCCT 241—*Pholiota* sp. | MCCT 242—*Mycena* sp. | MCCT 243—*Lacterius* sp. | MCCT 244—*Amanita* sp. | MCCT 245—*Trametes versicolor* | MCCT246—*Boletus* sp. | MCCT 247—*Laccaria proxima* | MCCT 250—*Russula brevipes* | MCCT 251—*Coltricia cinnamomea* | MCCT 252—*Boletus* sp.

Image 7. Macrofungi species of Tripura. MCCT 253—*Boletus strobilaceus* | MCCT 263—*Dacryopinax spathularia* | MCCT 270—*Lactocollybia* sp. | MCCT 275—*P. ostreatus* | MCCT 278—*Pannu* sp. | MCCT 301—*Coprinus* sp. | MCCT 302—*Lactarius hygrophoroides* | MCCT 303—*Pycnoporus cinnabarinus* | MCCT 304—*R. cyanoxantha* | MCCT 305—*Psathyrella candolleana* | MCCT 306—*Russula* sp. | MCCT 307—*Marasmius jasminodorus* | MCCT 308—*M. tenuissimus* | MCCT 309—*Agaricus moelleri* | MCCT 310—*Marasmius* sp. | MCCT311—*L. fraterna* | MCCT 312—*Leucocoprinus cepistipes* | MCCT 313—*Cantharellula* sp. | MCCT 314—*Cantharellula* sp. | MCCT 315—*Ganoderma sessile*.

Image 8. Macrofungi species of Tripura. MCCT 316—*Ischnoderma resinosum* | MCCT 317—*Daedaleopsis confragosa* | MCCT 318—*Trametes elegans* | MCCT 319—*Hygrocybe spadicea* | MCCT320—*Phellinus igniarius* | MCCT321—*Microporus* sp. | MCCT323—*Microporus xanthopus* | MCCT 324—*Hygrocybe acutaconica* | MCCT325—*Artomyces* sp. | MCCT326—Unidentified | MCCT 327—*Amanita constricta* | MCCT328—Unidentified | MCCT329—*Russula virescens* | MCCT330—*Amanita jacksonii* | MCCT331—*Citocybe ditopa* | MCCT332— Unidentified | MCCT333—*Agaricus placomyces* | MCCT334—*Russula emetic* | MCCT335—*Astraeus hygrometricus* | MCCT336—*Termitomyces* sp.

Image 9. Macrofungi species of Tripura. MCCT337—Unidentified | MCCT338—*Psathyrella* sp. | MCCT339—*Thelephora terrestris* | MCCT340—*Strobilomyces confuses* | MCCT341—Unidentified | MCCT342—*Stereum* sp. | MCCT343—*Marasmiellus candidus* | MCCT344—*Ganoderma applanatum* | MCCT345—*Gloeophyllum* sp. | MCCT346—*Mycena* sp. | MCCT347—*Cantharellus cibarius* | MCCT348—Unidentified | MCCT349—*Ramaria stricta* | MCCT350—*Pterula* sp. | MCCT351—Unidentified | MCCT352—*Russula natarajanii* | MCCT353—*Russula brevipes* | MCCT354—*Daldinia concentrica* | MCCT355—*Fomitopsis* sp. | MCCT356—Unidentified.

Image 10. Macrofungi species of Tripura. MCCT357—*Ganoderma* sp. | MCCT358—*Cantharellus cinereus* | MCCT359—*Marasmius oreades* | MCCT361—*Lentinus velutinus* | MCCT362—*Geastrum saccatum* | MCCT363— Unidentified | MCCT364—*Chalciporus piperatus* | MCCT365—*Lactarius glaucescens* | MCCT366—*Hygrophorus marzuolus* | MCCT367—*Funalia polyzona* | MCCT368—*Lactarius corrugis* | MCCT369—*Boletus reticulates* | MCCT370— *Amanita* sp. | MCCT371—*Chromosera cyanophylla* | MCCT372—Unidentified | MCCT 373—*Lentinus* sp. | MCCT 374—Unidentified | MCCT 375—*Pluteus* sp. | MCCT 376—*Pleurotus* sp. | MCCT 378—*Chromosera* sp.

Image 11. Macrofungi species of Tripura. MCCT282—*Ramaria* sp. | MCCT 383—*Agaricus trisulpharatus* | MCCT 384—*Tyromyces lacteus* | MCCT 385—*Ascobolus* sp. | MCCT 386—*Boletus* sp. | MCCT 387—*Volvariella* sp. | MCCT 388—*Coprinus* sp. | MCCT 389—*Phallus indusiatus* | MCCT 390—*Pleurotus*sp. | MCCT 256—*Lycoperdon* sp. | MCCT 260—*Pleurotus* sp. | MCCT391—*Xylaria obovata* | MCCT 392—*X. nigripes* | MCCT 393—*X. Polymorpha* | MCCT 394—*Xylaria schreuderiana* | MCCT 395—*X. multiplex* | MCCT 396—*X. hypoxylon.*

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SHORT COMMUNICATION

A threat assessment of Three-striped Palm Squirrel *Funambulus palmarum* (Mammalia: Rodentia: Sciuridae) from roadkills in Sigur Plateau, Mudumalai Tiger Reserve, Tamil Nadu, India

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Abstract: This study was undertaken to assess the threat from road kills for three-striped palm squirrels in the tropical forest of Sigur plateau, Mudumalai Tiger Reserve, Tamil Nadu, and Southern India from January 2014 to December 2016. Road kills were recorded along the Udhagamandalam to Masinagudi state highway passing through Mudumalai Tiger Reserve (40 km). Four visits per month were carried out mostly on weekends (Saturday or Sunday). A total of 497 three-striped palm squirrel kills were recorded, with an overall rate of 0.09/km of the roadway. Habitat wise 387 kills were observed in the thorn forest and 110 in dry deciduous forest habitats. Season wise 176 kills were recorded in winter, 156 in summer, 83 post-monsoon, and 82 during the monsoon. The study distinguished the ongoing major threat on the three-striped palm squirrel in the present scenario.

Keywords: Deciduous forest, ecology, habitat loss, mortality, vehicle movements.

The Three-striped Palm Squirrel *Funambulus palmarum* is a small rodent of the Sciuridae family, with four subspecies native to India and Sri Lanka. *F. palmarum* is endemic to southern India and Sri Lanka (Thorington & Hoffmann 2005; Nameer & Molur 2008), where it is widely distributed from sea level to 2,000m (Nameer & Molur 2014). Squirrels can reach head-body length of 12–15 cm and tail length of 14–15 cm (Menon 2014), and they have short fur that is yellowish-brown or brown on the back and creamy white on the belly (Menon 2014). Three white stripes on the back stretch from the head to tail. *F. palmarum* has dark round eyes, small triangular ears, long front teeth, and a bushy tail (Figure 1a; Prater 1971; Menon 2014; Pradhan & Talmale 2012). It is an omnivore with a diet based largely on fruit and nuts that also includes

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eggs, small birds, larvae, and insects (Prasad et al. 1966; Malhi & Kaur 1994; Malhi & Khushrupinder 1995). Squirrels mate throughout the year and build nests in treetops using grass and branches. Pregnancy lasts 34 to 45 days and produces 1–5 offspring; young are fully weaned at 10 weeks and reach sexual maturity at nine months. Animals can survive up to four years in the wild and >5 years in captivity (Weigl 2005). This study was undertaken to assess the threat to Three-striped Palm Squirrels from roadkills in the tropical forest of Sigur Plateau, Tamil Nadu in southern India.

Study Area

Sigur Plateau is located in Mudumalai Tiger Reserve. It is a connective junction of Western and Eastern Ghats and harbors a diverse range of wildlife that includes Asian Elephant *Elephas maximus*, Tiger *Panthera tigris*, Leopard *Panthera pardus*, Gaur *Bos gaurus*, Chital *Axis axis*, Sambar *Rusa unicolor*, and other mammals (Ramakrishnan & Saravanamuthu 2012), as well as birds such as Endangered and Critically Endangered vultures including the Long-billed Vulture *Gyps indicus*, White-rumped Vulture *Gyps bengalensis*, Red-headed Vulture *Sacrogyps calvus*, and Egyptian Vulture *Neophran percnopterus* (Ramakrishnan et al. 2014; Samson et al. 2014, 2015). The corridor between the Western and Eastern Ghats is used by elephants, tiger, gaur, and other herbivores for seasonal migrations influenced by the southwest and northeast monsoons. The major streams of Sigur Plateau are the Moyar River, the Sigur River, the Avarahalla River, the Kedarhalla River, and the Gundattihalla River, which crisscross the Moyar Valley and drain into the Bhavanisagar Reservoir. Villages located within the Sigur Plateau are home to local communities and more recently to several tourist facilities that subsist mainly on the attractions of the diverse wildlife in the area surrounding Mudumalai Tiger Reserve.

Methods

Roadkills were recorded along the Udhagamandalam–Masinagudi state highway passing through Mudumalai Tiger Reserve (40km) (Figure 1). The local habitats are classified as dry thorn forest and dry deciduous forest (Gokula & Vijayan 1996; Ramakrishnan & Saravanamuthu 2012). Four visits per month were carried out between January 2014 and December 2016, mostly on weekends (Saturday or Sunday) by an observer and driver on a motorbike traveling at 10–15 km/h; observation times alternated between morning (06.00–08.00 h) and evening (16.00–18.00 h). Intermittent roadkills were also observed by forest officials and drivers, which when verified were included in the totals. For each kill the information recorded included the location, surrounding area (forest, human habitation, plantation), habitat type,

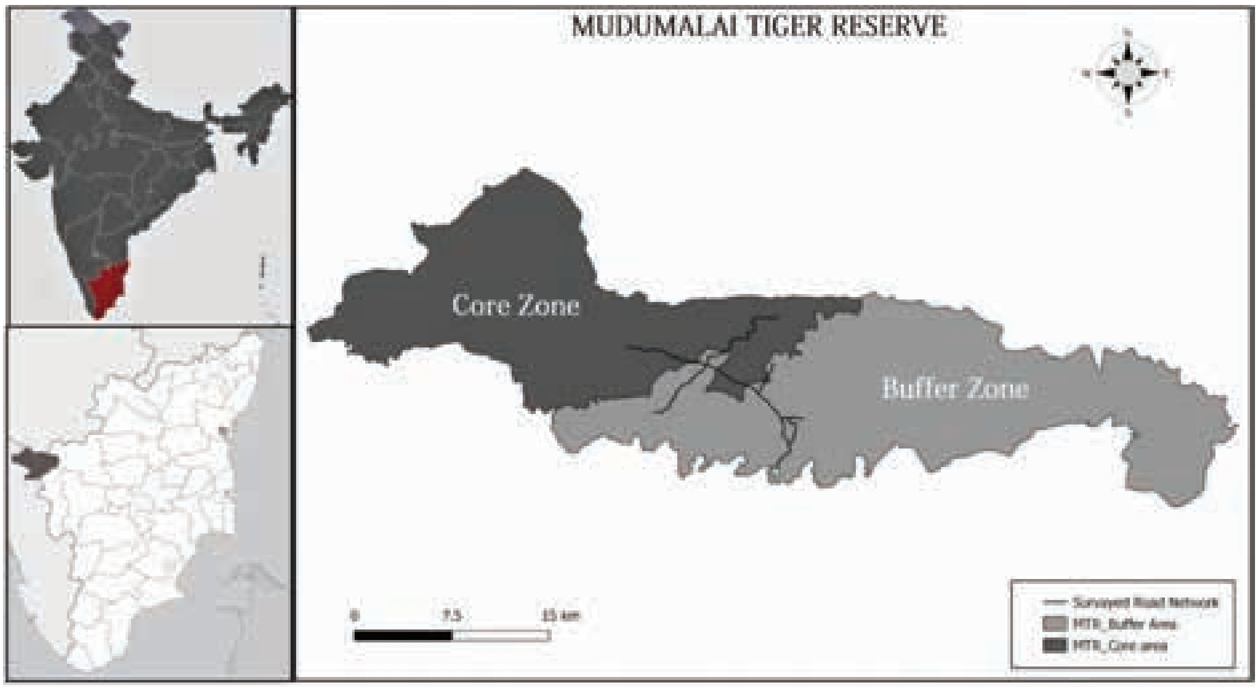

Figure 1. The location of the road networks in the Sigur plateau in Mudumalai Tiger Reserve.

and state & sex of dead animals, which when possible were removed from the road to avoid recounting.

Results

A total of 497 individual Three-striped Palm Squirrels (Figure 1; Image 1) were recorded as roadkill victims in 144 visits covering 5,760km, for an encounter rate (ER) of 0.09 individuals/km/month. Most kills were recorded as fresh (n=307). Males (n=220) were more frequently observed than females (n=145), although many were unidentified (n=132; Figure 1). Three-hundred-and-eighty-seven kills were observed over 33km of road in thorn forest habitats (ER=0.08 individuals/km/month), and 110 in dry deciduous forest (7km; ER=0.11 individuals/km/month) (Table 2). More roadkills were recorded in forest habitats (n=354; ER=0.078 individuals/km/month) followed by human habitation (n=89; ER=0.08 individuals/km/month), and plantations (n=54; ER=0.57 individuals/km/month). The roadkill results show significant variation R^2=0.995 year by year 2014 (n=148; 12.33±1.25; ER=0.08 individuals /km/month), 2015 (n=165; 13.75±1.55; ER=0.08 individuals/km/month), and 2016 (n=184; 15.33±1.58; ER=0.10 individuals/km/month) (Figure 2). Month-wise analyses of the roadkills show that May (n=75; 25±1.15) had more number of roadkills followed by December (n=61; 20.33±1.76), April (n=48; 16±1.15), November (n=47; 15.66±1.45) March (n=42; 14±1.15), and January (n=41; 13.66±1.45) (Figure 2); and significant variations were observed between month-wise data and the year-wise data (F=11.12 p= 0.005). The season-wise data revealed

Table 1. Season-wise roadkills of Three-striped Palm Squirrel in Sigur Plateau in Mudumalai Tiger Reserve.

Seasons	Totals	M±SE	ER
Winter (December–March)	176	14.66±1.19	0.10
Summer (April–June)	156	17.33±2.12	0.11
Monsoon (July–September)	82	9.11±0.78	0.06
Post Monsoon (October–November)	83	13.83±1.07	0.09

Table 2. Habitat-wise roadkills of Three-striped Palm Squirrel in Sigur Plateau in Mudumalai Tiger Reserve.

Vegetation	Km	Total km	Totals	M±SE	ER
Thorn Forest	33	4752	387	32.25±3.28	0.08
Dry Deciduous Forest	7	1008	110	9.16±1.09	0.11

Image 1. Male and female roadkill of Three-Striped Palm Squirrel.

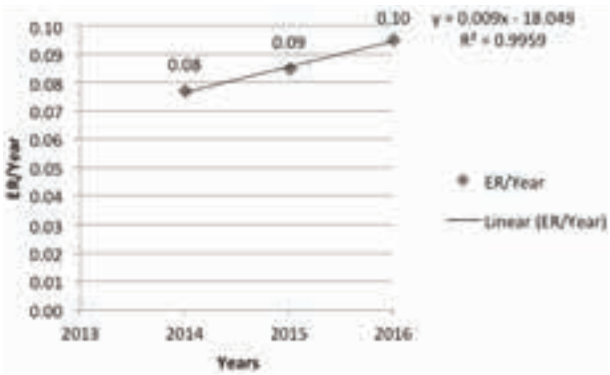

Figure 2. Year-wise encounter rate of roadkills of Three-striped Palm Squirrel in Sigur Plateau, Mudumalai Tiger Reserve.

that winter (December–March) (n=176; 14.66±1.19; ER= 0.09 individuals/km/month) and summer (pre-monsoon) (April–June) (n=156; 17.33±2.12; ER= 0.11 individuals/km/month) seasons recorded more kills compared to post-monsoon (October–November) (n=83; 9.11 ± 0.78; ER= 0.09 individuals/km/month) and monsoon seasons (July–September) (n=82; 13.83±1.07; ER= 0.06 individuals/km/month) (Figure 3; Table 1).

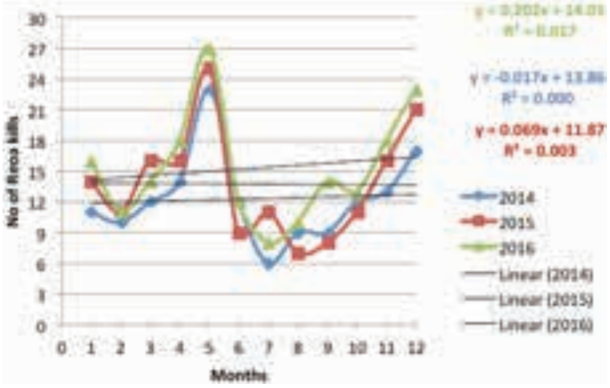

Figure 3. Year-wise and month-wise number roadkills of Three-striped Palm Squirrel in Sigur Plateau, Mudumalai Tiger Reserve.

Discussion

This study targeted a single species affected by linear construction like road networks. In fragmented habitats, linking route ways enhance the movements of small mammals (Coffman et al. 2001). Medium and large-sized mammals are particularly at risk, especially when the emergence of young coincides with high traffic volumes (Oxley et al. 1974). The present study shows that males are frequently killed rather than females. Linear construction appears to affect the movement of males and females (Davis-Born & Wolff 2000). Various species show seasonal peaks in accident rates often with a higher percentage of males being killed (Davies et al. 1987; Rotar & Adamic 19975; van Langevelde & Jaarsma 1997; Mead 1997; Reeve & Huijser 1999). This suggests that breeding or dispersal behavior may be partly responsible (Moshe & Mayer 1998). Three-striped Palm Squirrel live in diverse habitats but mainly occur in tropical forests and around human habitation (Molur et al. 2005). The present study was carried out in two different vegetation structures in Sigur Plateau. Thorn forest had more roadkills compared to dry deciduous forest which indicated that Three-striped Palm Squirrels utilized thorn forest vegetation more. A considerable amount of roadkills was observed in human habitation as well as plantations. Three-striped Palm Squirrels are easily tamed by humans and easily adapt to human habitation, plantations , and gardens (Molur et al. 2005).

Sunbathing is one of the key activities for striped squirrel at dawn and dusk (Mendez-Carvajal et al. 2016). Samson et al. (2016) recorded that most fresh roadkills of Three-striped Palm Squirrel are observed at dawn and dusk in the present study also corroborate the previous study indicating that Three-striped Palm Squirrel use the road surface for sunbathing, it seemed to be the reason for the high death rate. Some incidences may have occurred related to eating the insect on the roads. The road and road allowances attract prey populations, in particular, small mammals and carrion, but also insects and worms that are washed out of the soil onto roads (Tabor 1974). According to the literature, individuals from this genus prefer insects as protein sources more than fruits and nuts when fruits and vegetation are in the same proportions (Prater 1971; Barnett & Prakash 1975; Tiwari 1990; Balasubramanian 1995; Parasara et al. 1997).

Winter and summer seasons recorded Three-striped Palm Squirrel roadkills because of very high traffic on the state highway passing through the Nilgiri North Forest Division at one end connected to the Interstate highway NH 67 at Theppakadu and Ooty on other end. Generally, winter and summer are the best seasons to visit Udhagamandalam and that is a reason for high vehicular traffic intensity resulting in the high number of roadkills. Similarly, significant number of roadkills were also found in Mudumalai Tiger Reserve due to local vehicular movement as well as wildlife safaris (Samson et al. 2016)

According to the literature, habitat loss and degradation due to agro-industry farming, small-scale logging, human encroachments, invasive alien species, and hunting for local consumption purposes are minor threats to the Three-striped Palm Squirrel population (IUCN Red List Data 2016). The present study explored the current major threat in the present scenario. An urgent long-term study is needed to better understand the impact of roads on the ecology of the Three-striped Palm Squirrel.

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PLATINUM OPEN ACCESS

SHORT COMMUNICATION

Impact of vehicular traffic on birds in Tiruchirappalli District, Tamil Nadu, India

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Abstract: Roads have numerous direct and indirect ecological impacts on wildlife. Roads constitute an extensive and integral part of our environment. Collisions with vehicles kill a large number of birds every year. The present study was carried out from January 2016 to December 2016. The data was collected from Nehru Memorial College to Pavithram Lake of Thuraiyur to Namakkal road of Musiri Taluk, Tiruchchirappalli District. During this study, we recorded a total of 64 birds belonging to 12 species killed due to vehicular traffic. A maximum of 11 birds were killed in the months of January and October, and a minimum of two bird kills were observed in the months of September and December. Of the 64 birds, the roadside mortality was observed to the tune of 25%, 20.3%, 14%, 12.5%, 10.9%, 4.6%, and 4.6% for Southern Coucal *Centropus parroti*, Common Myna *Acridotheres tristis*, House Crow *Corvus splendens*, Spotted Owlet *Athene brama*, Indian Jungle Crow *Corvus culminatus*, Yellow-billed Babbler *Turdoides affinis*, and Large Grey Babbler *Turdoides malcolmi*. Other birds such as Asian Koel *Eudynamys scolopaceus*, Indian Roller *Coracias benghalensis*, Shikra *Accipiter badius*, White-breasted Waterhen *Amaurornis phoenicurus*, and White-browed Bulbul *Pycnonotus luteolus* accounted for 1.5% mortality. Suggestive measures to prevent wildlife loss due to vehicular traffic are presented in this communication.

Keywords: Bird mortality, Common Myna, ecological factors, roadkill, vehicle collision.

Roads are important part of human life for moving from one place to another with the help of vehicles. They restrict animal movement within the landscape and they cause roadside animal mortality due to vehicles (Van der Zande et al. 1980; Forman & Alexander 1998). Roads affect the surrounding environment in many ways to harm their neighboring floral and faunal diversity (Forman & Alexander 1998). Roads can alter animal behavior, with many animals being attracted to them (Santos et al. 2011). For example, ectothermic animals like reptiles visit roads to bask, and birds consume fallen grains from roadside and gravel to aid digestion (Noss 2002). Scavenging birds like corvids and raptors are attracted to the carcasses of other roadkill animals and are often killed themselves (Dean & Milton 2003; Antworth et al. 2005; Collinson 2013).

Road accidents with vehicles lead to death or injury of several groups of animals from small insects to large mammals all over the world. They affect the populations of both common and threatened animal species. Birds utilize roads for foraging, hunting, scavenging, shelter and this can increase their vulnerability to vehicle collisions (Orlowski 2005; Boves 2007; Huijser et al. 2007). Insectivorous and nocturnal birds follow insects that are attracted to headlights of vehicles during the night making them more vulnerable to collisions.

Most of the roadkill studies on wildlife have been taken up in protected areas and particularly on large mammals.

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In India, roadkill mortality studies outside protected areas are scarce, a few have been reported by Kumara et al. (2000), Vijayakumar et al. (2001), Sunder (2004), Pragatheesh (2011), Seshadri & Ganesh (2011), and Gubbi et al. (2012). According to Sundar (2004), during wet monsoon season, more number of bird mortality is recorded on the roads compared to the other seasons. These studies underline the importance of understanding how road characteristics and road surroundings influence roadkill numbers and hence the present investigation.

Materials and Methods

Study Area

The study area was selected between Nehru Memorial College and Pavithram Lake of Musiri Taluk (State Highway numbers 62 and 161 between Thuraiyur and Namakkal) (Figure 1). This is one of the busiest routes of this area and it is used commonly by two-wheelers, cars, public transport buses, and goods carriers of various sizes. The length of the road was 41km. The altitude of the chosen study area ranged 110–225 m. On the 41-km road stretch on either side, the following habitats of mostly rainfed crop lands, barren lands, human habitations, and a few forest areas were observed.

Methods

The present study was carried from January 2016 to December 2016. Roadkill surveys were conducted using a two-wheeler. Only birds killed due to vehicular traffic were observed and recorded approximately 10 to 15 days every month. Data on the roadkill species, number of individuals and the place of the kill was noted, and the latitude and longitude recorded using a hand-held Garmin etrax20 device; however, roadkill specimens were not collected from the encountered sites and only photographs were taken to aid in identification. The killed birds were identified up to species level using the field guide by Grimmett et al. (2011).

Results and Discussion

In total, 64 birds were encountered and recorded during the entire study period (Table 1; Image 1–8). There were 12 species of birds which belonged to six orders (Cuculiformes, Passeriformes, Coraciiformes, Accipitriformes, Strigiformes, and Gruiformes) and nine families (Cuculidae, Sturnidae, Corvidae, Coraciidae, Leiothrichidae, Accipitridae, Strigidae, Rallidae, and Pycnonotidae). In the months of January and October, a maximum of 11 dead birds were observed. On the other

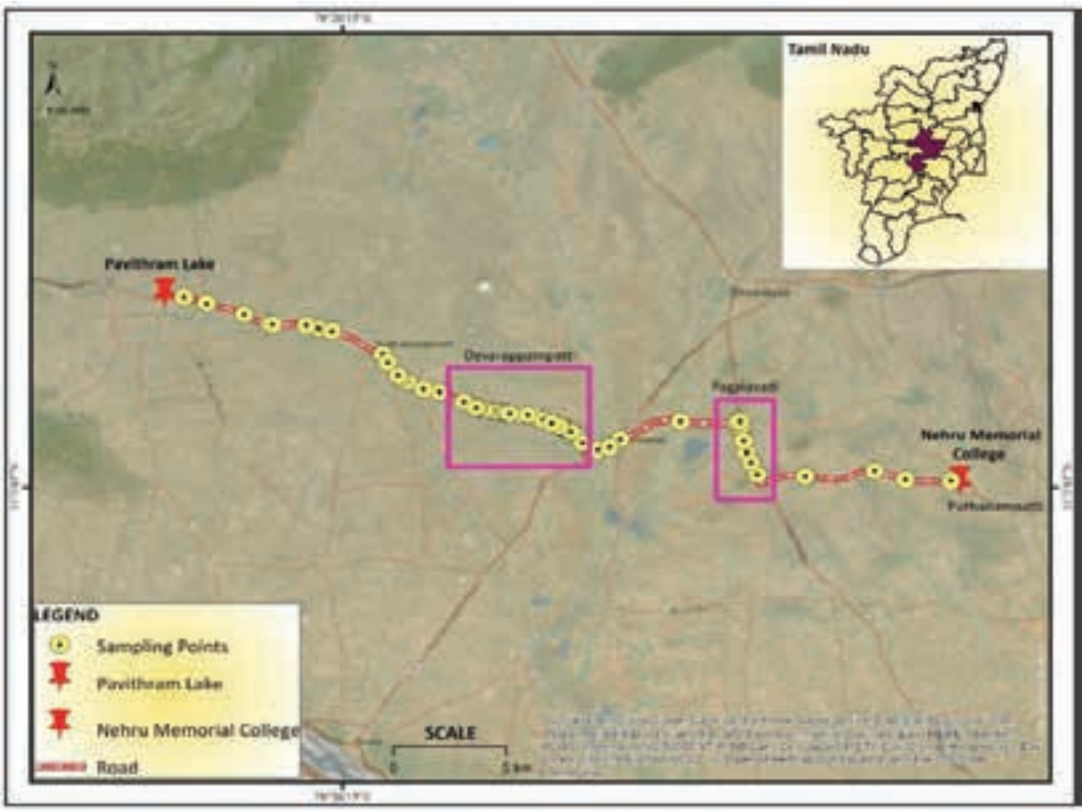

Figure 1. The chosen study area where bird roadkills due to vehicular traffic were encountered.

hand, a minimum of two birds were seen in the months of September and December 2016 (Figure 2). Highest mortality in terms of numbers, i.e., 16 were found for Southern Coucal *Centropus parroti* followed by 13 for Common Myna *Acridotheres tristis*, nine for House Crow *Corvus splendens*, eight for Spotted Owlet *Athene brama*, seven for Indian Jungle Crow *Corvus culminatus*, three for Yellow-billed Babbler *Turdoides affinis* and Large Grey Babbler *Turdoides malcolmi*, and one each for Asian Koel *Eudynamys scolopaceus*, Indian Roller *Coracias benghalensis*, Shikra *Accipiter badius*, White-breasted Waterhen *Amaurornis phoenicurus*, & White-browed Bulbul *Pycnonotus luteolus*.

Maximum mortality (30) was recorded close to Devarappampatti and the adjacent forest areas (Devarappampatti Reserved Forest). As there are only three speed breakers in the stretch between Kannanurpalayam and Thathaiyangarpettai, vehicles cross this distance at high speeds. The commuters traveling on two and four-wheelers near the forest areas throw food including food grains on either side of the road, which attract birds and eventually lead to the mortality of birds. More number of bird mortality in the months of January and October might be correlated with the movement of general public in their own and public vehicles before and after local festivals such as 'Pongal' and 'Diwali'. During these months the vehicular traffic density would be more when compared to all other months in the year and this would have caused a higher number of bird roadkills. Among the recorded birds, there were nine omnivorous, two carnivorous, and one insectivorous bird. Scavengers or omnivorous birds were attracted to carcasses on the roads, and while feeding on them, were hit by vehicles resulting in their death. All the 12 species of recorded birds are common and are listed in the Least Concern category of IUCN but their role in the environment is essential.

The highest mortality of Southern Coucals in the present investigation is due to their habit of low height flight (1–2 m above the road; pers. obs. of first author) when crossing the road. Similarly, babblers also took low height flight while crossing the road. Common Myna has the habit of searching scattered grains and other

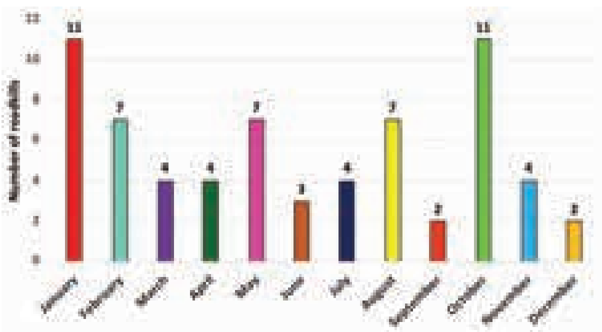

Figure 2. Month-wise bird mortality observed and recorded in the study area.

Table 1. Birds that were killed due to vehicular traffic in the chosen study area during the study period.

	Order	Family	Name of the bird	Scientific name	Food habit	Number of bird roadkills
1	Accipitriformes	Accipitridae	Shikra	*Accipiter badius*	Carnivorous	1
2	Gruiformes	Rallidae	White-breasted Waterhen	*Amaurornis phoenicurus*	Omnivorous	1
3	Cuculiformes	Cuculidae	Asian Koel	*Eudynamys scolopaceus*	Omnivorous	1
4			Southern Coucal	*Centropus* (*sinensis*) *parroti*	Omnivorous	16
5	Strigiformes	Strigidae	Spotted Owlet	*Athene brama*	Carnivorous	8
6	Coraciiformes	Coraciidae	Indian Roller	*Coracias benghalensis*	Insectivores	1
7	Passeriformes	Corvidae	House Crow	*Corvus splendens*	Omnivorous	9
8			Indian Jungle Crow	*Corvus* (*macrorhynchos*) *culminatus*	Omnivorous	7
9		Leiothrichidae	Yellow-billed Babbler	*Turdoides affinis*	Omnivorous	3
10			Large Grey Babbler	*Turdoides malcolmi*	Omnivorous	3
11		Pycnonotidae	White-browed Bulbul	*Pycnonotus luteolus*	Omnivorous	1
12		Sturnidae	Common Myna	*Acridotheres tristis*	Omnivorous	13
					Total	**64**

Image 1–8. Birds killed due to vehicle collisions during the study period. 1—House Crow | 2—White-breasted Waterhen | 3—Southern Coucal | 4—Common Myna | 5—Large Grey Babbler | 6—Yellow-billed Babbler | 7—Spotted Owlet | 8—Shikra. © T. Siva.

food particles on and alongside the road. Thus, it can be suggested that the common factors for the mortality of birds is the movement from one side to another side at low height, and getting attracted towards food on the road or along the road sides.

Roadkill studies in India has mainly focused on vertebrates with a few studies on invertebrates. Earlier, in Anamalai Hills, Vijayakumar et al. (2001) reported roadkill of vertebrate fauna such as amphibians, reptiles, birds, and mammals while Jeganathan et al. (2018) reported both invertebrate and vertebrate animals' mortality. Wildlife mortality due to vehicular traffic in Mudumalai Wildlife Sanctuary and Tiger Reserve has been published by Gokula (1997) and Baskaran & Boominathan (2010). Roadkill of amphibians was earlier recorded by Seshadri et al. (2009) from the Sharavathi River basin in central Western Ghats. Roadkill mortality of snakes in the Malnad region, central Western Ghats, was given by Jagadeesh et al. (2014). Earlier researchers reported the following factors to affect bird mortality on roads such as the volume of traffic, speed of vehicles, scavenging behaviour, individual configuration of roads, road density, foraging opportunities (Clevenger et al. 2003; Erritzoe et al. 2003; Holm & Laursen 2011; Kociolek & Clevenger 2011). All these factors corroborate the results of the present investigation. This study presents observations made in non-protected areas.

Conclusions and Recommendations

It is evident from the results that the chosen study area is prone to bird roadkills due to vehicular traffic. Movement of birds from one side to the other side of the road at low height and feeding on food grains/carcasses found on or near the road could be the major reasons for the roadkill. Awareness about the importance of birds needs to be created among the drivers of vehicles who frequently/regularly use the road.

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SHORT COMMUNICATION

Ichthyofaunal diversity of Manjeera Reservoir, Manjeera Wildlife Sanctuary, Telangana, India

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Abstract: The ichthyofaunal diversity of Manjeera Wildlife Sanctuary in Telangana State was studied between October 2015 and November 2016. A total of 57 species of fish belonging to 42 genera, within 20 families and 11 orders were recorded. The present communication provides an updated ichthyofaunal checklist of Manjeera Reservoir and discusses the threats to fish in Manjeera Wildlife Sanctuary.

Keywords: Checklist, freshwater fish, Godavari river basin, Manjeera river.

Fish are an essential source of protein in human diets and significantly to food security and livelihoods. India contributes to about 7.7% of global fish diversity, of which, 1,668 species are marine, and 994 are freshwater (Froese & Pauly 2019). Freshwater fish diversity of India is distributed in large number of ponds, tanks, lakes, reservoirs, seasonal streams, rivers, and other man-made water bodies, which together comprise an area of 111,690km^2 (Bassi et al. 2014).

Telangana State in peninsular India has rich freshwater resources including tanks, reservoirs, and is drained by major rivers such as Godavari and Krishna, and their numerous tributaries. Many ichthyofaunal studies have been carried out in the rivers of Telangana (Day 1878; Rahimullah 1943a; Rahimullah 1944; Mahmood & Rahimullah 1947; Chacko 1949; David 1963; Jayaram 1981, 1995, 1999, 2010; Barman 1993; Talwar & Jhingran 1991; Menon 1999; Devi & Indra 2003). The most comprehensive study among these is by Barman (1993) (of combined Andhra Pradesh State), who reported 158 freshwater fish species belonging to 68 genera, 27 families, and 10 orders. Compared to river systems, only a few studies are available on the ichthyodiversity of man-made reservoirs and tanks in Telangana (Rahimullah 1943b, 1944; Mahmood & Rahimullah 1947; Chandrasekhar 2004; Rao et al. 2011; Shyamsundar et al. 2017).

Manjeera is one of the important reservoirs in Telangana State, created by the construction of a barrage on Manjeera River near Kalabgur Village, Sangareddy District. The barrage was constructed to ensure water sotage, and supply drinking water to the twin cities of Hyderabad and Secunderabad located about 50km south-east. The reservoir covers an area of 32km^2 between Singur and Manjeera dams (Prasad et

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al. 2018). The reservoir has nine islands with extensive marshy fringes, which also supports submerged and emergent vegetation that is used by both crocodiles and birds. Manjeera Wildlife Sanctuary was declared as a protected area in 1978, to provide a safe haven to the wild population of the vulnerable marsh crocodiles, along with numerous avian, mammalian, and floral diversity (Prasad et al. 2018). The first and the senior author have been documenting the biodiversity of Manjeera Wildlife Sanctuary since 2010 (Prasad et al. 2014, 2018). Through this contribution, we provide baseline information on the ichthyofauna of the Manjeera Wildlife Sanctuary.

Materials and methods

Study Area: Manjeera Wildlife Sanctuary (17.62–17.75^{0}N & 77.92–78.08^{0}E) is located in Sangareddy District, Telangana State, India (Fig. 1). The sanctuary encompasses the reservoir, and the area on either bank of the Manjeera River course, running 26km between Singur and Manjeera dams. The reservoir also supports submerged and emergent vegetation including species of *Nymphaea*, *Nelumbo*, *Polygonum*, *Hydrilla*, *Pistia* (Prasad et al. 2018). The soil type is red loamy, sandy and fertile black, and the major crops grown include cotton, rice, jowar, maize, and sugarcane. Ambient temperature ranges between 15°C (in winters) and 42°C (in summers), and the rainfall is approximately 1,000–1,100 mm per year (Prasad et al. 2014).

Methods: The study was carried out from October 2015 to November 2016, and the voucher samples were collected from October 2015 to November 2015. We selected four locations (Fig. 1) along the river course, and samples were collected using cast nets (mesh size of 6–12 mm for small size fish, depth of operation 1–2 m), gill nets (mesh size of 40–90 mm for large size fish, depth of operation 3–8 m), and other traditional methods (square-shaped bamboo cage traps) with the help of local fishermen. Specimens were collected, photographed, labelled, and preserved in 4–10 % formalin solution relative to the fish size (Jayaram

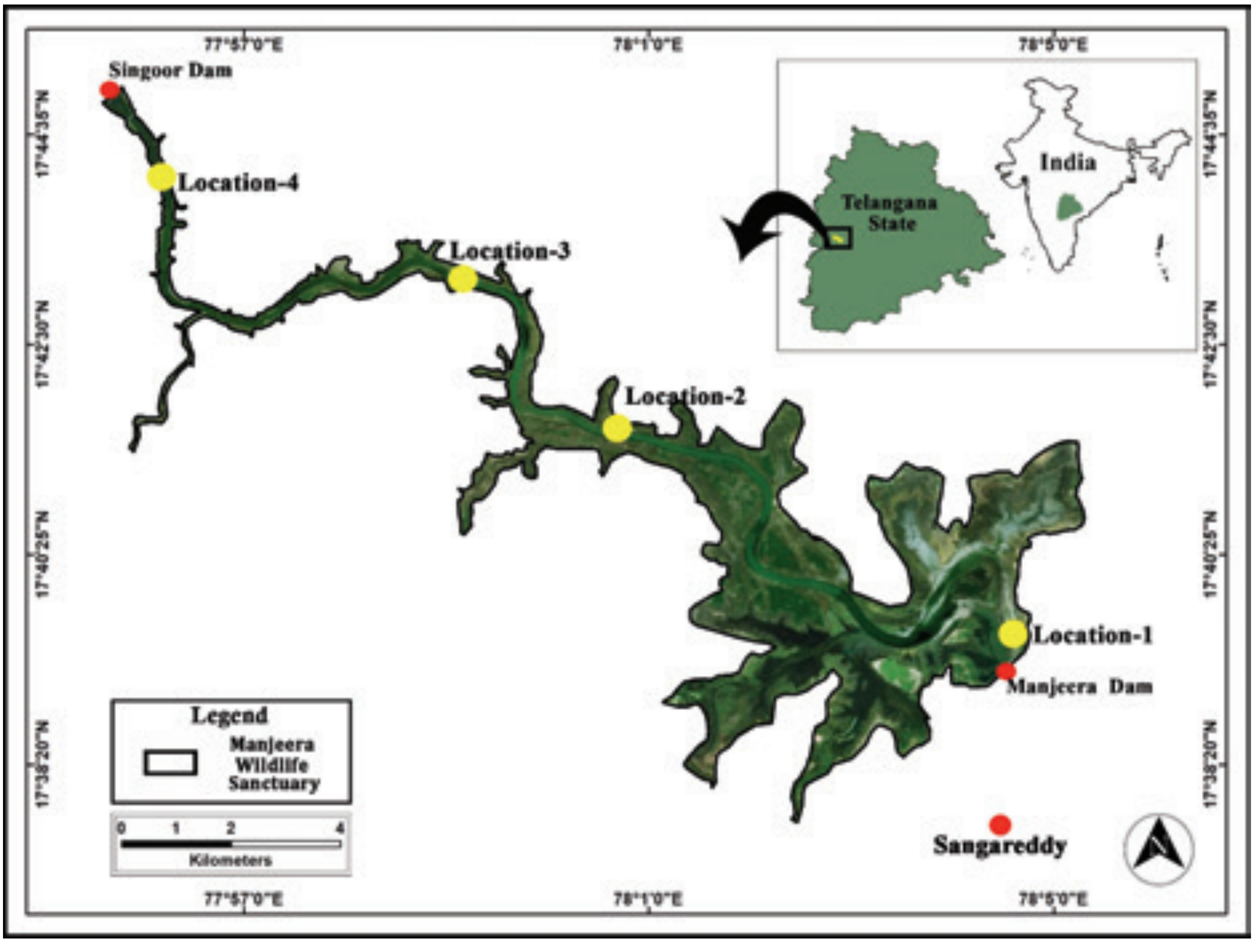

Figure 1. Sampling locations in Manjeera Wildlife Sanctuary, Sangareddy District, Telangana State, India (India and Telangana State are shown for indicative purposes and are not to scale).

2010). Fish were identified up to the species level followed Talwar & Jhingran (1991), Jayaram (1991), Jayaram & Dhas (2000), Jayaram & Sanyal (2003), and Jayaram (2010). Nomenclature of fishes followed Fricke et al. (2019). Voucher specimens and photo vouchers (of those species whose voucher specimens were not collected) are deposited in the Natural History Museum of Osmania University, Department of Zoology, Osmania University, Hyderabad, Telangana State, India (Table 1). Conservation status of the fish species is based on the IUCN Red List of Threatened Specie (IUCN 2019).

Results and Discussion

Manjeera Reservoir (MR) and the Manjeera Wildlife Sanctuary (MWS) harbour a total of 57 species of fish belonging to 42 genera within 20 families and 11 orders (Table 1). During the present study, we collected 51 species of fishes and have included an additional six species that were reported earlier (Barman 1993; Chandrashekar 2004), but not recorded during the present study. Of these, Cyprinidae (33.3%) was the most dominant family followed by Danionidae (14.0%), Bagridae (7.0%), Channidae (5.2%), Cichlidae (5.2%), Ambassidae (5.2%), Cobitidae (3.5%), Siluridae (3.5%), and Mastacembelidae (3.5%).

Most fish species in the MWS are native, and only 8.8% of the fish diversity was represented by exotic species including *Ctenopharyngodon idella*, *Cyprinus carpio*, *Oreochromis mossambicus*, *O. niloticus*, and *Gambusia affinis*. As per the IUCN threat categories, most (S=46) native species were of Least Concern category (80.7% the diversity), and only two species were assessed as Endangered (3.5%). Four species (7.0%) were assessed as Near Threatened (IUCN 2019). Species assessed as threatened included *Tor khudree* and *Clarias magur*, while those assessed as Near Threatened included *Anguilla bengalensis*, *Ompok bimaculatus*, *Wallago attu*, and *Parambasis lala*.

The MR also harbored native aquarium fish species including *Aplocheilus panchax*, *Chanda nama*, *Danio rerio*, *Devario aequipinnatus*, *Esomus danrica*, *Hyporhamphus limbatus*, *Oryzias dancena*, *Parambassis ranga*, *Parambasis lala*, *Pseudetroplus maculatus*, and *Puntius vittatus*. The present study revealed the presence of Blue Perch *Badis badis*, which was for the first time reported from Telangana recently (Prasad & Srinivasulu 2019). The abundance of fish species could not be quantitatively assessed due to restriction of the fishing within the sanctuary limits.

Rahimullah (1944) reported 52 valid species of fishes from Manjeera River and its perennial tributaries of Haldi and Aleru from Medak District of erstwhile Hyderabad State. In the present study from MR, we recorded 28 of the 52 species reported by Rahimullah (1944). Rahimullah (1944) reported the presence of *Silonia childreni*, *Tor khudree,* and *Hypselobarbus mussullah* from Manjeera river, which we failed to detect during the present study. Chandrasekhar (2004) reported only eight species of fish from MR, of which we were unable to detect *Cyprinus carpio*, *Labeo fimbriatus*, *Lepidocephalichthys guntea*, *Salmostoma untrahi*, *Sperata aor,* and *Tor khudree*.

Rao et al. (2011) reported 25 species from Pocharam Reservoir, which is fed by the Aleru River (one of the tributaries of Manjeera River). Both the Pocharam and Manjeera reservoirs are dominated by the species belonging to the order Cypriniformes followed by Siluriformes, though the present study indicated that MR harbours more fish species compared to Pocharam Reservoir.

As part of our study, we also observed some threats to the fish fauna of the sanctuary. Habitat loss due to encroachments such as alteration of riverbanks, construction of canals, expansion of adjacent paddy fields into the sanctuary, and also loss of riparian vegetation for local firewood collection has been noticed as a significant threat to the habitat. Fishing within the sanctuary has been banned by the Telangana State Forest Department, however, illegal fishing activity is still a threat to fish diversity within the sanctuary limits. It is suspected that the excessive use of pesticides and inorganic fertilizers in agricultural fields adjacent to the sanctuary may also lead to water pollution (Prasad et al. 2014). Mitigating such causes that lead to decline in water quality will go a long way and help sustain and improve the ichthyofaunal diversity of MR and MWS, which is home to one of the healthiest population of marsh crocodiles in Telangana State.

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Table 1. List of fishes of the Manjeera Reservoir and Manjeera Wildlife Sanctuary, Telangana, India

	Scientific name	English name	IUCN status	Voucher number
Order Anguilliformes				
Family Anguillidae				
1	*Anguilla bengalensis* (Gray, 1831)	Indian Mottled Eel	NT	NHMOU.F.PV.92
Order Osteoglossiformes				
Family Notopteridae				
2	*Notopterus notopterus* (Pallas, 1769)	Bronze Featherback	LC	NHMOU.F.56
Order Cypriniformes				
Family Cobitidae				
3	*Lepidocephalichthys guntea* (Hamilton, 1822)	Guntea Loach	LC	*vide* Chandrasekhar (2004)
4	*Lepidocephalichthys thermalis* (Valenciennes, 1846)	Common Spiny Loach	LC	NHMOU.F.32
Family Cyprinidae				
5	*Cirrhinus mrigala* (Hamilton, 1822)	Mrigala	LC	NHMOU.F.48
6	*Cirrhinus reba* (Hamilton, 1807)	Reba Carp	LC	NHMOU.F.47, and 186
7	*Ctenopharyngodon idella* (Valenciennes, 1844)	Grass Carp	*	NHMOU.F.PV.75
8	*Cyprinus carpio* Linnaeus, 1758	Common Carp	*	*vide* Barman (1993)
9	*Garra mullya* (Sykes, 1839)	Sucker Fish	LC	NHMOU.F.174
10	*Gymnostomus ariza* (Hamilton, 1807)	Reba	LC	NHMOU.F.PV.90
11	*Labeo calbasu* (Hamilton, 1822)	Orangefin Labeo	LC	NHMOU.F.PV.94
12	*Labeo catla* (Hamilton, 1822)	Catla	LC	NHMOU.F.PV.41
13	*Labeo fimbriatus* (Bloch, 1795)	Fringed-lipped Peninsula Carp	LC	*vide* Barman (1993)
14	*Labeo porcellus* (Heckel, 1844)	Bombay Labeo	LC	NHMOU.F.49 to 52
15	*Labeo rohita* (Hamilton, 1822)	Roho Labeo	LC	NHMOU.F.PV.77
16	*Osteobrama cotio* (Hamilton, 1822)	Cotio	LC	NHMOU.F.30, and 31
17	*Pethia conchonius* (Hamilton, 1822)	Rosy Barb	LC	NHMOU.F.252
18	*Pethia ticto* (Hamilton, 1822)	Ticto Barb	LC	NHMOU.F.303 to 305
19	*Puntius chola* (Hamilton, 1822)	Swamp Barb	LC	NHMOU.F.42
20	*Puntius sophore* (Hamilton, 1822)	Pool Barb	LC	NHMOU.F.250, and 251
21	*Puntius vittatus* Day, 1865	Greenstripe Barb	LC	NHMOU.F.239 to 244
22	*Systomus sarana* (Hamilton, 1822)	Olive Barb	LC	NHMOU.F.46
23	*Tor khudree* (Sykes, 1839)	Deccan Mahseer	EN	*vide* Barman (1993)
Family Danionidae				
24	*Amblypharyngodon mola* (Hamilton, 1822)	Mola Carplet	LC	NHMOU.F.189, and 190
25	*Danio rerio* (Hamilton, 1822)	Zebra Danio	LC	NHMOU.F.249
26	*Devario aequipinnatus* (McClelland, 1839)	Giant Danio	LC	NHMOU.F.172
27	*Esomus danrica* (Hamilton, 1822)	Flying Barb	LC	NHMOU.F.299
28	*Laubuka laubuca* (Hamilton, 1822)	Indian Glass Barb	LC	NHMOU.F.288
29	*Salmostoma bacaila* (Hamilton, 1822)	Large Razorbelly Minnow	LC	NHMOU.F.35
30	*Salmostoma untrahi* (Day, 1869)	Mahanadi Razorbelly Minnow	LC	*vide* Chandrashaker (2004)
31	*Rasbora daniconius* (Hamilton, 1822)	Slender Rasbora	LC	NHMOU.F.286, and 287
Order Siluriformes				
Family Bagridae				
32	*Mystus* cf. *bleekeri* (Day, 1877)	Day's Mystus	LC	NHMOU.F.62, 178, and 180
33	*Mystus vittatus* (Bloch, 1794)	Striped Dwarf Catfish	LC	NHMOU.F.61
34	*Sperata aor* (Hamilton, 1822)	Long-whiskered Catfish	LC	*vide* Chandrashaker (2004)

	Scientific name	English name	IUCN status	Voucher number
35	*Sperata seenghala* (Sykes, 1839)	Giant River-Catfish	LC	NHMOU.F.176
Family Siluridae				
36	*Ompok bimaculatus* (Bloch, 1794)	Butter Catfish	NT	NHMOU.F.57, and 175
37	*Wallago attu* (Bloch & Schneider, 1801)	Wallago	NT	NHMOU.F.PV.71
Family Heteropneustidae				
38	*Heteropneustes fossilis* (Bloch, 1794)	Stinging Catfish	LC	NHMOU.F.PV.91
Family Clariidae				
39	*Clarias magur* (Hamilton, 1822)	Magur	EN	NHMOU.F.PV.95
Family Schilbeidae				
40	*Proeutropiichthys taakree* (Sykes, 1839)	Indian Taakree	LC	NHMOU.F.33, and 34
Order Gobiiformes				
Family Gobiidae				
41	*Glossogobius giuris* (Hamilton, 1822)	Tank Goby	LC	NHMOU.F.58, and 216 to 218
Order Synbranchiformes				
Family Mastacembelidae				
42	*Macrognathus pancalus* Hamilton, 1822	Barred Spiny Eel	LC	NHMOU.F.236
43	*Mastacembelus armatus* (Lacepède, 1800)	Zig-zag Eel	LC	NHMOU.F.60
Order Anabantiformes				
Family Channidae				
44	*Channa marulius* (Hamilton, 1822)	Great Snakehead	LC	NHMOU.F.54
45	*Channa punctata* (Bloch, 1793)	Spotted Snakehead	LC	NHMOU.F.55
46	*Channa striata* (Bloch, 1793)	Striped Snakehead	LC	NHMOU.F.PV.40
Family Badidae				
47	*Badis badis* (Hamilton, 1822)	Badis	LC	NHMOU.F.43
Order Cichliformes				
Family Cichlidae				
48	*Pseudetroplus maculatus* (Bloch, 1795)	Orange Chromide	LC	NHMOU.F.173
49	*Oreochromis mossambicus* (Peters, 1852)	Mozambique Tilapia	*	NHMOU.F.59
50	*Oreochromis niloticus* (Linnaeus, 1758)	Nile Tilapia	*	NHMOU.F.171
Order Cyprinodontiformes				
Family Aplocheilidae				
51	*Aplocheilus panchax* (Hamilton, 1822)	Blue Panchax	LC	NHMOU.F.237
Family Poecilidae				
52	*Gambusia affinis* (Baird & Girard, 1853)	Mosquitofish	*	NHMOU.F.225 to 229
Order Beloniformes				
Family Hemiramphidae				
53	*Hyporhamphus limbatus* (Valenciennes, 1847)	Congaturi Halfbeak	LC	NHMOU.F.273 to 276
Family Adrianichthyidae				
54	*Oryzias dancena* (Hamilton, 1822)	Rice Fish	LC	NHMOU.F.238
Order Perciformes				
Family Ambassidae				
55	*Chanda nama* Hamilton, 1822	Elongate Glass-Perchlet	LC	NHMOU.F.221 to 224
56	*Parambassis ranga* (Hamilton, 1822)	Indian Glassy Fish	LC	NHMOU.F.29
57	*Parambasis lala* (Hamilton, 1822)	Highfin Glassy Perchlet	NT	NHMOU.F.219, and 220

LC–Least Concern | NT–Near Threatened | EN–Endangered | *–Exotic Species | NHMOU.F.–Natural History Museum, Osmania University, Fishes | NHMOU.F.PV–Natural History Museum, Osmania University, Fishes, Photo Voucher.

Image 1. *Anguilla bengalensis* (Gray, 1831)

Image 2. *Notopterus notopterus* (Pallas, 1769)

Image 3. *Lepidocephalichthys thermalis* (Valenciennes, 1846)

Image 4. *Cirrhinus reba* (Hamilton, 1807)

Image 5. *Ctenopharyngodon idella* (Valenciennes, 1844)

Image 6. *Garra mullya* (Sykes, 1839)

Image 7. *Gymnostomus ariza* (Hamilton, 1807)

Image 8. *Labeo calbasu* (Hamilton, 1822)

Image 9. *Labeo catla* (Hamilton, 1822)

Image 10. *Labeo porcellus* (Heckel, 1844)

Image 11. *Labeo rohita* (Hamilton, 1822)

Image 12. *Osteobrama cotio* (Hamilton, 1822)

Image 13. *Pethia conchonius* (Hamilton, 1822)

Image 14. *Pethia ticto* (Hamilton, 1822)

Image 15. *Puntius chola* (Hamilton, 1822)

Image 16. *Puntius sophore* (Hamilton, 1822)

Image 17. *Puntius vittatus* Day, 1865

Image 18. *Systomus sarana* (Hamilton, 1822)

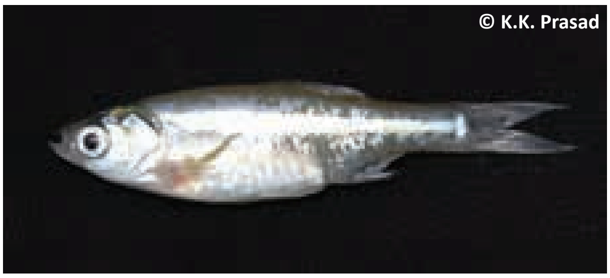

Image 19. *Amblypharyngodon mola* (Hamilton, 1822)

Image 20. *Danio rerio* (Hamilton, 1822)

Image 21. *Devario aequipinnatus* (McClelland, 1839)

Image 22. *Esomus danrica* (Hamilton, 1822)

Image 23. *Laubuka laubuca* (Hamilton, 1822)

Image 24. *Salmostoma bacaila* (Hamilton, 1822)

Image 25. *Rasbora daniconius* (Hamilton, 1822)

Image 26. *Mystus* cf. *bleekeri* (Day, 1877)

Image 27. *Mystus vittatus* (Bloch, 1794)

Image 28. *Sperata seenghala* (Sykes, 1839)

Image 29. *Ompok bimaculatus* (Bloch, 1794)

Image 30. *Wallago attu* (Bloch & Schneider, 1801)

Image 31. *Heteropneustes fossilis* (Bloch, 1794)

Image 32. *Clarias magur* (Hamilton, 1822)

Image 33. *Proeutropiichthys taakree* (Sykes, 1839)

Image 34. *Glossogobius giuris* (Hamilton, 1822)

Image 35. *Macrognathus pancalus* Hamilton, 1822

Image 36. *Mastacembelus armatus* (Lacepède, 1800)

Image 37. *Channa marulius* (Hamilton, 1822)

Image 38. *Channa punctata* (Bloch, 1793)

Image 39. *Channa striata* (Bloch, 1793)

Image 40. *Badis badis* (Hamilton, 1822)

Image 41. *Pseudetroplus maculatus* (Bloch, 1795)

Image 42. *Oreochromis mossambicus* (Peters, 1852)

Image 43. *Oreochromis niloticus* (Linnaeus, 1758)

Image 44. *Aplocheilus panchax* (Hamilton, 1822)

Image 45. *Gambusia affinis* (Baird & Girard, 1853)

Image 46. *Hyporhamphus limbatus* (Valenciennes, 1847)

Image 47. *Oryzias dancena* (Hamilton, 1822)

Image 48. *Chanda nama* Hamilton, 1822

Image 49. *Parambassis ranga* (Hamilton, 1822)

Image 50. *Parambasis lala* (Hamilton, 1822)

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SHORT COMMUNICATION

New distribution record of the endemic and critically endangered Giant Staghorn Fern *Platycerium grande* (Fee) Kunze (Polypodiaceae) in central Mindanao

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Abstract: *Platycerium grande* (Fee) Kunze is an endemic, Critically Endangered species of fern in the Philippines. The known distribution of this species remains limited at present and its population is threatened by various anthropogenic threats especially for ornamental collection. In our recent survey, we found high abundance of this species in Central Mindanao, southern Philippines. It can be distinguished from other species belonging to the genus *Platycerium* through its frond's vegetative leaf which is symmetrical with two equally long main lobe. Based on literatures, the known distribution range extend from Zambaonga, Lanao, and Davao (Mt. Apo); and our recent records extends the known distribution of this species in Kalamansig, Sultan Kudarat and South Upi, Maguindanao suggesting this species may still be around in other areas within the known range, however, the species may remain narrowly distributed as multiple threats to this species continue to persist.

Keywords: Conservation, fern, Maguindanao, phorophyte, Sultan Kudarat.

Platycerium Desv is a distinct genus under Polypodiaceae, and is distinguished by the morphological structure of its frond. The species under this genus is distinguishable by its frond dimorphism, formation of a basket of base fronds and the vegetative frond that is divided dichotomously (Hennipman & Roos 1998). This taxa mainly grow in a more or less open canopy and are among the most frequent vascular plant epiphytes in subtropical to tropical lowland forests with 15 to 18 known species. There are two known species in the Philippines, viz.: *Platycerium coronarium* (König ex Müller) Desv and *Platycerium grande* (Fèe) Kunze (Copeland 1958; Hennipman & Roos 1998). The previously mentioned species can be identified from the latter by its foliage frond which is asymmetrical and its soral patch that completely covers the fertile lobe. Of these two species, *P. grande* is endemic to the Philippines (Amoroso & Amoroso 2003) and is closely related to *P. holttumii* distributed in Indochina (Kreier & Schneider 2006).

Platycerium grande also known as the Giant Staghorn Fern was recorded in Mindanao specifically in Zamboanga, Lanao, and Davao (Mt. Apo), however, Copeland's (1958) report from Mt. Cristobal in Luzon could be possibly in error (Pelser et al. 2019). Hennipman et al. (1979) stated that the specimen used to complete the description of this species was taken from the wild of Davao and traced in Cebu then brought to Leiden and Kew.

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Its unique and peculiar structure makes this species valuable as an ornamental and attractive plant for collectors and poachers (Darnaedi & Praptosuwiryo 2003). As a matter of fact, *P. grande* and other species in the genus are highly-prized ornamental species. Consequently, coupled with habitat changes in its native range, continuous over exploitation, and its poor propagation success (Amoroso & Amoroso 2003) this species is currently assessed as critically endangered (Fernando et al. 2008). In this paper, we report the new distribution records of *P. grande* in localities in Mindanao Island, Philippines.

Methods

The study was conducted in the two provinces of Central Mindanao: Sultan Kudarat and Maguindanao, southern Philippines. The province of Sultan Kudarat is situated in the Soccsksargen region in the southwestern part of Mindanao. Kalamansig is one of its municipalities which is situated at approximately 6.554^{0}N, 124.052^{0}E. On the other hand, area in Maguindanao where *P. grande* exist is the municipality of South Upi which lies at about 7.017^{0}N, 124.176^{0}E (Fig. 1).

Purposive sampling was done. Survey was conducted from the months of April 2018–April 2019 in various areas of Kalamansig and South Upi. Three barangays in Kalamansig, Sultan Kudarat were identified – Barangays Paril, Limulan and Poblacion and two in South Upi, Maguindanao – Barangays Kuya and Poblacion. The actual number of individuals were counted and recorded. To confirm the identity of the species, morphological characteristics of the species were examined such the base and vegetative fronds and the soral patch. These are the morphological characteristics by which the two species of *Platycerium* in the Philippines can be distinguished. Identification is further supported by the work of Copeland (1958), Hovenkamp et al. (1998) and Philippine plant list website. Furthermore, a map was generated using QGIS application.

Results and Discussion

Platycerium grande was found thriving along national road for both areas in Kalamansig, Sultan Kudarat and South Upi, Maguindanao, however, individuals of this

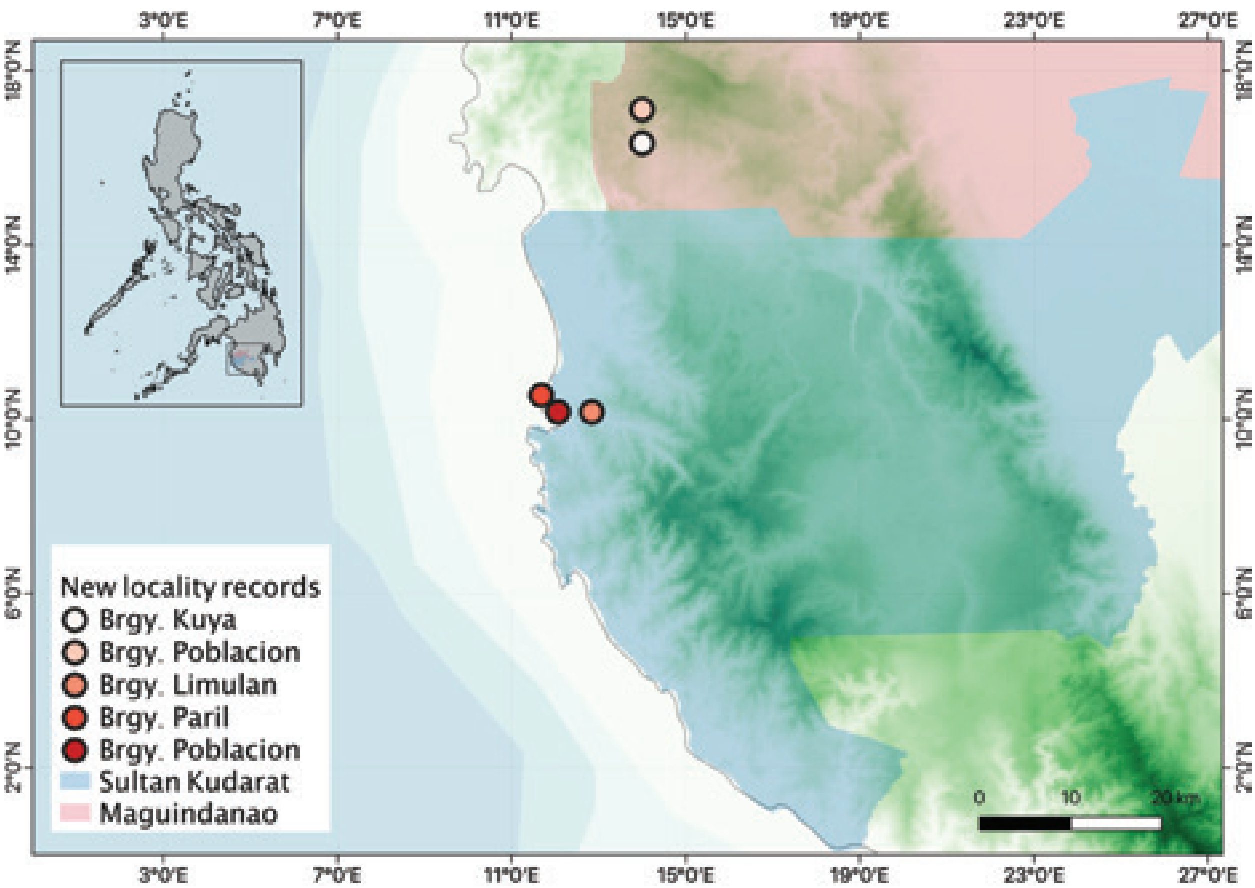

Figure 1. The updated distribution of *Platycerium grande* in Mindanao.

Image 1. Habit and morphological structure of *Platycerium grande*: A—Habit showing upper part of the base frond | B—Lower part of the base | C—Foliage fronds symmetrical | D—One of the main long lobe of the foliage frond with sori. © Authors.

Image 2. Individuals of *Platycerium grande* attaching on its phorophytes: A–Coconut *Cocos nucifera* | B—Acacia Tree *Albizia saman*. © Authors.

species in Kalamansig, Sultan Kudarat were seen in an agricultural area planted with coconut. The species was identified based on its morphological characterization in which the lower part of the base frond is strongly wavy on the margin (sinouse margin), upper part spreading and forked equally, and foliage fronds are symmetrical, with two equally long main lobes, each with a wide, horizontal soral patch and two lateral pendulous forked lobes. Soral patch of *P. grande* is semicircular and occupies the undersurface of the foliage fronds (Image 1). These are the diagnostic characteristics to identify the species as *Platycerium grande* (Copeland 1958; Hennipman & Roos 1998; Aspiras 2010). The species was found to be thriving in an open area at an elevation of 6.69–662.71 m and observed to be commonly attached on coconut and huge trees along national roads. The wild population of *Platycerium grande* is presently scarcely known. It can, however, be seen in home gardens or botanical gardens. But recently it was found out to be abundantly thriving in areas of Sultan Kudarat and Maguindanao.

A total of 212 individuals were recorded from the three barangays of Kalamansig, Sultan Kudarat and 30 individuals from South Upi, Maguindanao (Table 1).

Table 1. The number of individuals of *P. grande* in the two sites.

Location of *P. grande*	Latitude (N)	Longitude (E)	Number of Individuals
Kalamansig, Sultan Kudarat			
Brgy. Paril	124.033	6.567	96
Brgy. Limulan	124.083	6.550	76
Brgy. Poblacion	124.050	6.550	40
South Upi, Maguindanao			
Brgy. Kuya	124.133	6.817	3
Brgy. Poblacion	124.133	6.850	27

Coconut served as the phorophyte of most recorded individuals of *P. grande* in Kalamansig, however, many individuals were noticed to be thriving on an individual tree of *Albizia saman*. This might be due to fact that areas where the species was seen is an agricultural landscape which is almost planted with coconut. Its point of attachment on a coconut tree starts from 2m from the ground up to the point almost reaching the top of the tree where the fruit are located. It was also documented that individuals growing on trees coexist with a *Drynaria* sp.

It was previously mentioned that most individuals recorded were on coconut trees, however, fewer in number compared with those on huge trees (Image 2). *P. grande* attached on coconut ranges from 1–5 individuals wherein huge trees harbors up to 30 individuals per tree. This might be due to the absence of branches on coconut trees which gives mechanical support to this plant being an epiphyte.

Result of this study will help to substantiate the distribution of *Platycerium grande* in this part of the country given that very little literature is available on its distribution in the Philippines (Pelser et al. 2019). It is presumed that more individuals can be found in the two areas and neighboring places if comprehensive surveys are conducted. Moreover, findings of this study will also be of use in reassessing its status and in the implementation of appropriate conservation strategies. Furthermore, discovering new locations of *P. grande* is an avenue for more in-depth studies of this endemic and critically endangered species of fern.

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NOTE

First photographic record of the Dhole *Cuon alpinus* (Mammalia: Carnivora: Canidae) from the Sirumalai Hills in Tamil Nadu, India

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The Asiatic Wild Dog or Dhole has a wide global range covering central, southern and southeastern Asia (Kamler et al. 2015). It has been recorded over most of the Indian subcontinent except for the deserts of western India and Eastern Ghats of Tamil Nadu. Though it has been observed in the Western Ghats of Karnataka (Johnsingh 1983; Karanth & Sunquist 1995; Kumara et al. 2012), Kerala (Nair et al. 1985; Rice 1986; Jayson & Ramachandran 1996; Jayson 1998; Vishnu 2012; Narasimen et al. 2013; Shahid & Jamal 2016;), Tamil Nadu (Johnsingh 2001; Kumaraguru et al. 2011; Naresh 2012; Ramesh et al. 2012; Srinivas et al. 2013; Varsha 2018), and both Eastern Ghats of Andhra Pradesh (Behera & Borah 2010; Jhala et al. 2015) and Telangana (Sudhakar Reddy et al. 2019) (Figure 1), it has not been reported from Eastern Ghats of Tamil Nadu. In fact, extant numbers of individuals vary from report to report. The Canid Specialist Group (www.wildcanids.net) report that 2,500 mature individuals remain in the wild on the global scale and the declining trend is expected to continue. Kamler et al. (2015) estimate a total population of 4,500–10,500 animals of which 949–2,215 are mature individuals and most, if not all current subpopulations of Dholes are relatively small and isolated, and often exhibit extreme fluctuation in numbers.

Among the sub-populations of Dhole in southern Asia, Johnsingh (1985) reported that it is frequently seen in many of the protected areas south of the Ganga River, with the central Indian highland forests having the largest population of Dhole, followed by the Western Ghats of southern India. In Western Ghats, Bandipur National Park was presumed to have had the largest subpopulations of Dhole four decades back, a total population of 207–304 individuals and estimated 44–64 mature individuals (20–29 alpha males and 20–29 alpha females with 4–6 sub-dominant breeders (Johnsingh 1982). Dhole density in southern India over the last four decades vary between 14–100 /km^2; e.g., 31/100 km^2 (Venkataraman et. al. 1995) to 43/100 km^2 at Mudumalai (Ramesh 2010), 35–90/100 km^2 at Bandipur (Johnsingh 1983), and 14/100 km^2 at Nagarhole (Karanth 1993). Nevertheless, any new sight records from the lesser explored sites, contribute in understanding their occurrence and possible further exploration of its population status. We report one such sight record from Sirumalai Hills in Tamil Nadu.

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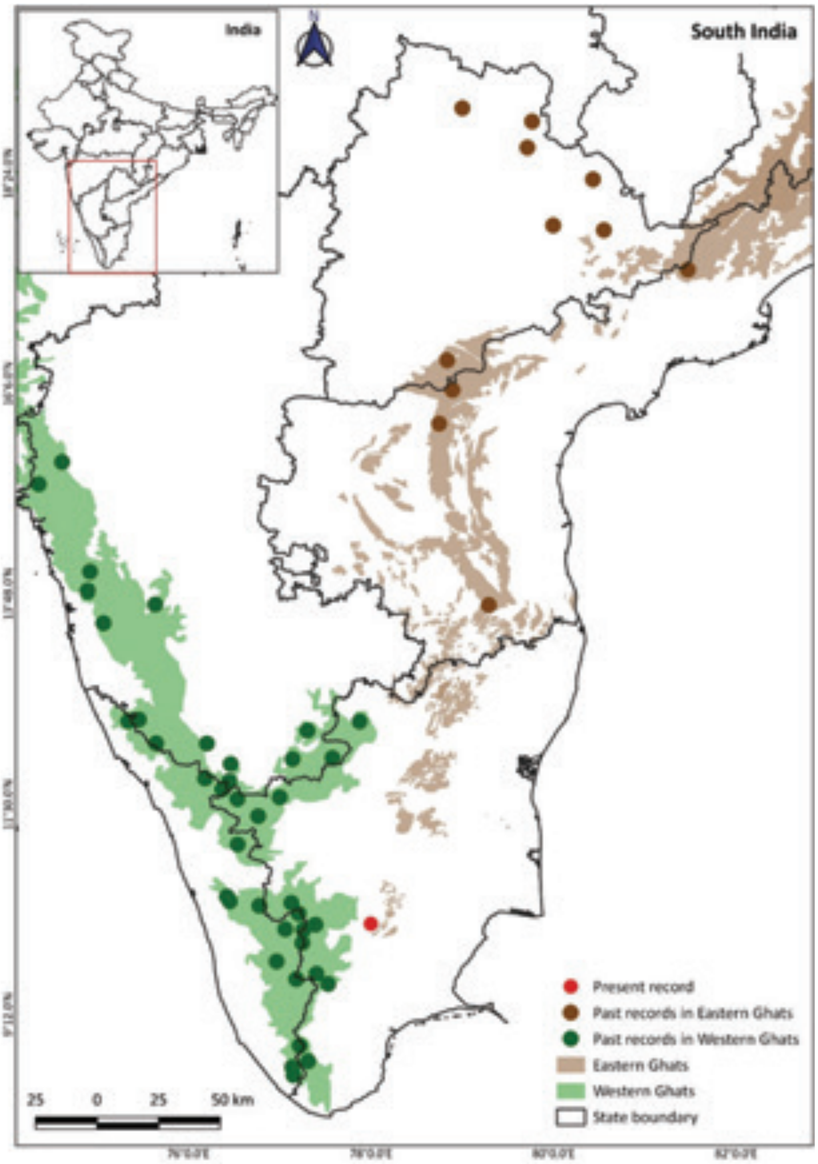

Figure 1. Records of Dhole *Cuon alpinus* in southern peninsular India along with present record from Khandige Estate in Sirumalai Hills, Tamil Nadu.

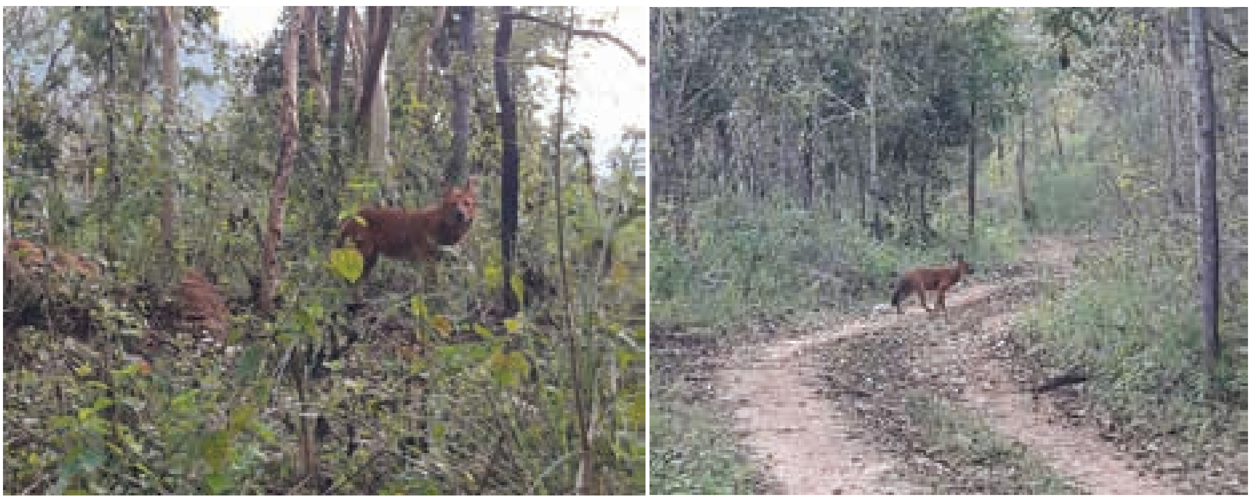

Image 1. Dhole *Cuon alpinus* sighted from Khandige Estate in Sirumalai Hills, Tamil Nadu. © A. Ramesh.

The Sirumalai Hills (10.194^{0}N & 77.996^{0}E) are a low range of hills situated 25km from Dindigul and 96.8km from Kodaikanal in Tamil Nadu and has an altitude of 1,600m. Khandige Estate or Namaste Estate is spread over 4.04km^2 in the Sirumalai Hills with two perennial streams flowing through it before reaching the plains. The estate is surrounded by reserve forest on three sides without any fences. Except for approximately 0.20 km^2 of cultivated area (Chayote *Sechium edule*, Lemon *Citrus limon*, and Banana *Musa* sp.), the rest is almost forest.

We, hereby, provide photographic evidence of the Dhole *Cuon alpinus* from Khandige Estate in Sirumalai (photographs were taken on 09 December 2017 & 05 January 2019; Image 1). Since the establishment of the estate, plantation workers and staff have been sighting these canids on and off and they are under the impression that not more than four individuals exist. The photographs were taken at the open areas of the Khandige Estate. The nearest area to the Sirumalai Hills with Dholes is Upper Palani plateau which lies c. 68km away from Sirumalai's west side. Davidar (1975) had recorded six Dholes feeding on Sambar *Rusa unicolor* and Indian Muntjac *Muntiacus muntjac* from upper Palani plateau*,* while Varsha (2018) has reported the presence of Dhole from Kodaikanal Wildlife Sanctuary.

Sirumalai Hills have been considered a broken chain of Palani Hills, separated from the latter by anthropogenically modified plains (Vijayakumar et al. 2002). But it is on record that "at their southern end, the Eastern Ghats form several ranges of low hills. The southernmost of the Eastern Ghats are the low Sirumalai and Karanthamalai hills of southern Tamil Nadu (Jayakumar et al. 2008; Sankar et al. 2009). Another anomaly is that the Sirumalai receives most of its rainfall (1,200–1,320 mm) in the months of October–December (North-east or Winter Monsoon) which is very similar to coastal Tamil Nadu (Blasco & Legris 1972; Mehr-Homji 1974). Uniquely, Kodaikanal which is only 96.8km from Sirumalai receives the bulk of its rainfall during the south-west or summer monsoon in July.

If established literature and climate are to be taken as essential parameters for the occurrence *of Cuon alpinus* then it is definitely first photographic evidence of the species in the Eastern Ghats of Tamil Nadu.

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Threatened Taxa

Corrigendum

Patwardhan, A. & R. Khot (2020). Description of a new species of the genus *Lampropsephus* Fleutiaux, 1928 (Coleoptera: Elateridae: Elaterinae: Dicrepidiini) from Konkan, Maharashtra, India. *Journal of Threatened Taxa* 12(1): 15181–15185. https://doi.org/10.11609/jott.1878.12.1.15181-15185

In the original publication of this short communication, published on 26 January 2020 (*Journal of Threatened Taxa* 12(1): 15181–15185) <https://doi.org/10.11609/jott.187812115181-15185>, the authors had proposed a transfer of *Propsephus assamensis* (Schwarz, 1905) to *Sephilus assamensis* (Schwarz, 1905) followed by the suffix 'syn. nov.' However, the correct suffix usage for the 'change of generic assignment' should be 'comb. nov.' as per the ICZN article 48. Additionally, this transfer doesn't require any change in the spelling of specific name (ICZN article 34.2.1). Thus, the corrected proposed name is ***Sephilus assamensis* (Schwarz, 1905) comb. nov.**

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NOTE

Tracing heavy metals in urban ecosystems through the study of bat guano - a preliminary study from Kerala, India

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Heavy metal pollution has greatly increased the mobilisation of metals in the air, water, and soil. Metals such as arsenic, cadmium, chromium, copper, mercury, manganese, nickel, lead, and tin are toxic at elevated levels and some even at low concentrations. As these elements do not decay with time, their emission to the environment is a serious problem. Bio-indicator organisms like small mammals, particularly bats allow detection of biological responses and provide a tool in assessing the state of ecosystem health (Clark 1981). Insectivorous bats are considered to be the best bio-indicators as they are exposed to contaminants more directly through invertebrates that may consume soil (Ma & Talmage 2001). Being the only flying mammal, bats are sensitive to a wide range of environmental stresses to which they respond in predictable ways (Zukal et al. 2015) and thus, are important keystone species in the ecosystem, having enormous potential as biodiversity, ecological, and environmental indicators (Jones et al. 2009). Their widespread distribution and proximity to humans make them susceptible to contamination through anthropogenic activities. The potential of bats as bio-indicators of pollution is two-fold: Firstly, exposure to contaminants, including heavy metals, contributes to the decrease in bat populations. Secondly, levels of the contaminants in bat guano serve as an indicator of the prevalent pollution levels in the surrounding environment. This study aims to evaluate the pollution levels in two different environments using bats as indicator organisms and it is hypothesized that urban areas would reveal comparatively greater amounts of contaminants than rural areas.

Sampling was carried out in different sites from Ernakulam (Mangalavanam Bird Sanctuary and Tripunithura) and Thrissur (Irinjalakuda) districts of Kerala. Fresh (whenever possible) and few-days-old guano deposits of bats like *Pteropus medius* Temminck, 1825, *Megaderma spasma* (Linnaeus, 1758) and *Taphozous melanopogon* Temminck, 1841 were collected by placing nets fitted onto PVC frame of size 0.8 × 0.8 m on the floor of the bat's roosting site and left undisturbed for 4–6 days to allow for sufficient guano deposition. For sample digestion, a mixture of concentrated nitric acid and perchloric acid (5:1 ratio) was added to 0.5g of dry guano in a Borosil glass beaker; the beaker kept in a heating mantle at 90^{o}C for 1–2 h or until digestion was complete. After cooling, the sample was diluted to 20ml using distilled water, the contents filtered and transferred

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to clean Borosil glass vials and then stored at room temperature prior to analysis. Analysis of the metals was done using the Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES) facility at the Kerala University of Fisheries and Ocean Studies, Panangad. Mercury (Hg) analysis was performed using direct Hg analyser at the Sophisticated Test and Instrumentation Centre, Cochin University of Science and Technology (CUSAT). Elemental compositions of dry homogenised samples were determined by X-ray fluorescence (XRF) analyser at the CSIR-Central Electrochemical Research Institute, Karaikudi. Statistical analyses was done using the software package PAST v 3.18 and graphs were made using MS Excel.

It has been known that the composition of elements in bat guano normally equals that in the undigested portion of the ingested food, and as such may provide some clues to the location of contaminants in the environment (Martin 1992). Factors such as the bats' diet, roosting location, foraging habitat, and metabolism may significantly influence accumulation. It seems likely, therefore, that heavy metal exposure pathways differ between frugivorous and insectivorous bat species.

Contamination in fruit bats is likely to be through atmospheric pollution, contact with contaminated foliage whilst searching for and eating food, which may be later ingested directly while grooming. Insectivorous bat species become contaminated mainly through bio-accumulation through the food-chain, i.e., from water/soil/sediments/plants or other sources to insects and finally to the bats themselves. The additional routes of exposure to heavy metals may include contact with skin and inhalation (Allinson et al. 2006). Usually, upon oral ingestion, about 5–10% of the metal gets absorbed and about 99.5% of total ingested metal is excreted through faeces/guano thus leaving only 0.5% to be deposited in various body tissues (Klaassen 1976). Table 1 represents the general composition of elements detected by the XRF analyser in the bat guano used for the study.

Guano analysis indicated the presence of heavy metals such as mercury (Hg) and various other metals in varying concentrations. The concentration of metals like lead, cadmium and zinc, however, were below detection limits. Figure 1 represents the concentration of Hg obtained from the direct Hg analyser and Table 2 represent the concentrations of the metals (Chromium, Copper, Manganese and Nickel) obtained using the ICP-AES analyser.

In our study, the concentration of mercury varied between the bats from the urban areas of Ernakulam and the rural areas of Irinjalakuda (Thrissur), with higher contamination levels in the Ernakulam District. The composition of guano also varied between the insectivorous and frugivorous bats and this was indicated by the presence of the elements Aluminium (Al) and Titanium (Ti) in insectivorous bat guano. It was also noted that the levels of Copper (Cu), Chromium (Cr), Manganese (Mn), and Nickel (Ni) were significantly

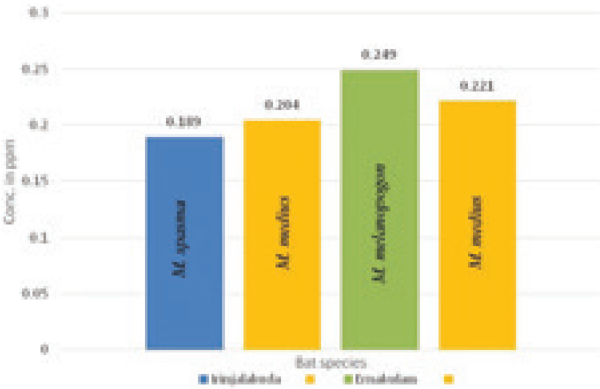

Figure 1. Average mercury levels (n=4) in bat guano (in ppm)

Table 1. Elemental composition of guano from different bats.

Element	Avg. mass (%) (n=4)			
	T. melanopogon	*M. spasma*	*P. medius (1)*	*P. medius (2)*
Aluminium (Al)	4.6105	5.5846	BDL	BDL
Calcium (Ca)	10.7272	17.0122	21.221	21.1739
Copper (Cu)	BDL	0.4237	1.3149	0.1164
Iron (Fe)	42.8869	15.2537	4.1669	6.8953
Potassium (K)	BDL	3.1887	35.3471	36.4112
Molybdenum (Mo)	0.0001	0.0002	0.0003	0.0002
Oxygen (O)	34.7198	39.3272	27.7743	27.3338
Silicon (Si)	6.7776	16.8635	8.335	7.2244
Titanium (Ti)	0.278	1.1079	BDL	BDL
Zinc (Zn)	BDL	1.2382	1.8369	0.5562
BDL →Below detection limit ≈ 0				
(1)→ Irinjalakuda, Thrissur; (2) → Ernakulam				

Table 2. Comparison of metal concentrations (mg/kg wet weight) in the guano of insectivorous bats from Ernakulam and Thrissur (mean ± standard deviation [n=12]).

Metals	Cr	Cu	Mn	Ni
Ernakulam	79.69 ± 35.56	3973.68 ± 418.38	820.12 ± 464.26	60.03 ± 22.23
Thrissur	24.93 ± 10.56	2869.22 ± 503.13	76.92 ± 38.62	24.61 ± 16.68
p-value	0.016	0.057	0.016	0.033
p-values were calculated at 95% confidence using Mann-Whitney U test				

different between the insectivores from Ernakulam and those from Irinjalakuda. This may be probably due to the elevated pollution levels in Ernakulam. Further studies are needed to determine if these values are representative of the bat colonies from Kerala, to pinpoint the sources of contamination, and to determine if these levels of contamination adversely affect bats.

Variability in the levels of metals found in bat bodies is influenced by their background environmental levels, which in turn reflects the amounts accumulated. Metals may interfere with the normal functioning of the immune system, cause physiological and histological distress and thus, increase the prevalence of parasites or wildlife infectious diseases (Hernout et al. 2016). Environmental pollution and contamination, in turn, can cause population declines in bats. Assessments of these contaminants thus, help us to understand the levels that would harm humans.

As far as we are aware, there are no other time-trend data for heavy metals in bats in Kerala, and so it is impossible to assess whether the trend in the studied bats is typical for other bat species. Ecotoxicological data are essential for risk assessment and decision-making in bat conservation. Data from this study provides information on baseline levels of interest to monitor status and trends in the heavy metal residue in the bats of the study areas, and therefore, they represent a tool to evaluate potential wildlife, ecological, and human health exposure. Such an evaluation of the contaminant load through guano analysis sheds light on the potential use of guano as a simple, relatively inexpensive and non-invasive bio-indicator tool to assess the prevalent pollution levels and thus, the environmental quality. The relationship between levels of heavy metals in bat guano, prey analysis, and the various components of the environment in which the insects develop, should also prove to be a fruitful area for future research.

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NOTE

Population dynamics and management strategies for the invasive African Catfish *Clarias gariepinus* (Burchell, 1822) in the Western Ghats hotspot

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Freshwater biodiversity is in peril, threatened by a range of (often interacting) stressors including flow-regulation, pollution, invasive alien species, climate change, and overexploitation (Dudgeon et al. 2006; Strayer & Dudgeon 2010). Of these, biological invasion is one of the most widespread and damaging stressors on freshwater ecosystems (Strayer & Dudgeon 2010), responsible for the extinction of over 17 fish species, and the imperilment of over 450 threatened fish species worldwide (IUCN 2019).

The freshwater ecosystems of India's Western Ghats (WG) Hotspot harbour more than 300 fish species, of which 65% are endemic (Dahanukar et al. 2011). Though much of this endemism is concentrated in the southern region of the WG Hotspot, inside terrestrial protected areas, no management or monitoring plans are in place for freshwater taxa (Raghavan et al. 2016). For example, a threatened species of mountain catfish *Glyptothorax madraspatanus* was extirpated from Eravikulam National Park, a protected area in the WG due to the invasion by the Rainbow Trout *Oncorhynchus mykiss* (Thomas et al. 1999). In a similar situation, four alien species compete for resources with eight point-endemics in the watershed of the Periyar National Park, one of WG's intensively-managed protected areas (Molur & Raghavan 2014).

The African Sharp-tooth Catfish, *Clarias gariepinus* (Burchell 1822) is one of the world's most successful aquatic invader (Booth et al. 2010), in view of its spread and impacts to native fauna in close to 30 countries (GISD 2020). Diverse life history traits including eurytopic nature, pseudo-lungs, trophic flexibility, predatory & piscivorous feeding habits, fast growth, and high mobility (Kadye & Booth 2012; Weyl et al. 2016) has facilitated their invasion across tropics; unmanaged aquaculture, and stock enhancement being the major reasons (Weyl et al. 2016). Although extensive information is available on the occurrence and distribution of invasive *C. gariepinus*, there has been very little focus on understanding the population dynamics of invasive populations (Booth et

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al. 2010). In the present paper, the demographics of invasive *C. gariepinus* in the watershed of the Periyar National Park, an Alliance for Zero Extinction (AZE) site, and one of the most critical habitats for freshwater fish conservation in southern Asia (Molur & Raghavan 2014) is determined, to inform management and conservation action.

The Periyar Lake-Stream system inside the Periyar National Park (9.160^{0}N & 76.553^{0}E) (an IUCN Category II protected area) is an AZE site known to harbour the only global population of three endangered cyprinids (*Hypselobarbus periyarensis*, *Tariqilabeo periyarensis* & *Lepidopygopsis typus*) (Molur & Raghavan 2014). This critical habitat is, however, threatened by four alien species, *Oreochromis mossambicus* (Peters, 1852), *Cyprinus carpio* (Linnaeus, 1758), *Poecilia reticulata* (Peters, 1859), and *Clarias gariepinus*. An organized small-scale fishery primarily focused on gillnets (32–110 mm) is carried out in the lake by local tribal fishers, and the resultant catch is sold at a nearby landing centre organized by the Kerala State Forest and Wildlife Department.

Clarias gariepinus samples (n=344) exploited using gill nets (40–110 mm mesh size) and sold at the local landing centre, were collected at monthly intervals from December 2018 to November 2019, measured for standard lengths ($L_{TS,}$ to the nearest mm) and body weight (M_B, to the nearest g). A large share of the sample comprised of dead fish, and only a small number of individuals were alive at the time of collection. These were euthanized immediately by immersing in ice-slurry. The length data were grouped into 5cm class intervals with the smallest mid-length of 2.5cm. The length-mass relationship ($M_B = aL_T^b$) was determined following Pauly (1984) and the parameters (a, b) were estimated by least squares regression of log-log plot (Zar 1999). The null hypothesis that n=3 (i.e., individuals show isometric growth pattern; Froese 2006) was tested using two-tailed t-tests. The statistical analysis was performed in PAST 3.20 (Hammer et al. 2001).

The von Bertalanffy growth parameters, asymptotic length (L_∞) and growth coefficient (K) were estimated from length-frequency data using the electronic length frequency analysis I (ELEFAN I) incorporated in FAO-ICLARM Stock Assessment Tools II (FiSAT II) software (Gayanilo et al. 2005). Based on L_∞ and K values, growth performance index (Ø) and potential longevity (3/K) were estimated (Pauly & Munro 1984). Instantaneous total mortality (Z) was estimated using length-converted catch curve (Pauly 1984); natural mortality (M) was determined by Pauly's empirical formula (Pauly 1980). In (M) = -0.0152-0.279, In (L_∞) + 0.6543 In (K)+0.4634 In (T), where T is the annual mean temperature of the water in which the fish occurs (26°C for the study area); instantaneous rate of fishing mortality (F) was computed as $F=Z–M$ and exploitation rate (E) was as $E=F/Z$ (Gulland 1970). The E_{max} (maximum yield per recruit) and E_{50} (exploitation that retains 50% of the biomass) were predicted using relative yield per recruit (Y/R) and relative biomass per recruit (B/R) analysis using knife-edge selection method (Pauly 1984). From length-converted catch curve, the length at first capture (L_c) was analysed. Growth parameters were used to determine the reproductive pulses per year, and the relative strength of each pulse using recruitment analysis (Moreau & Cuende 1991). Growth and mortality parameters were used to perform virtual population analysis (VPA) (Hilborn & Walters 1992). Fishing mortality was considered as the terminal fishing mortality *Ft*. To understand how the population in different size classes might be affected by an increase in the fishing mortality, VPA was performed with different values of *Ft*. To develop an effective eradication plan for the local *C. gariepinus* population, the threshold value of E_{max} above which the population would be overexploited in Y/R analysis was plotted against L_c. To understand whether a change in the fishing regime, especially with respect to the length of first capture, can facilitate eradication of *C. gariepinus*, we performed Y/R analysis and plotted threshold value of E_{max}, above which the population will collapse, against varying length at first capture (L_c).

Table 1. Growth, mortality and exploitation parameters of *Clarias gariepinus* from Periyar Lake.

Demographics and exploitation parameters	Value
Asymptotic length (L_∞; cm)	91.88
Growth coefficient (K: year^{-1})	0.54
Growth performance index (Ø)	3.66
Longevity (3/K; years)	5.56
Total mortality (Z: year^{-1})	1.34
Natural mortality (M; year^{-1}) at 26°C)	0.84
Fishing mortality (F; year^{-1})	0.50
Current exploitation rate (E)	0.37
Length at first capture (L_c; cm)	29.90
$E_{0.1}$	0.46
$E_{0.5}$ (Optimum)	0.31
Exploitation rate producing maximum yield (E_{max})	0.54

Length and weight measurements of *C. gariepinus* collected from the Periyar Lake ranged 17.9–86.7 cm L_{Ts} and 80–6,300 g. The LWRs was defined by the equation

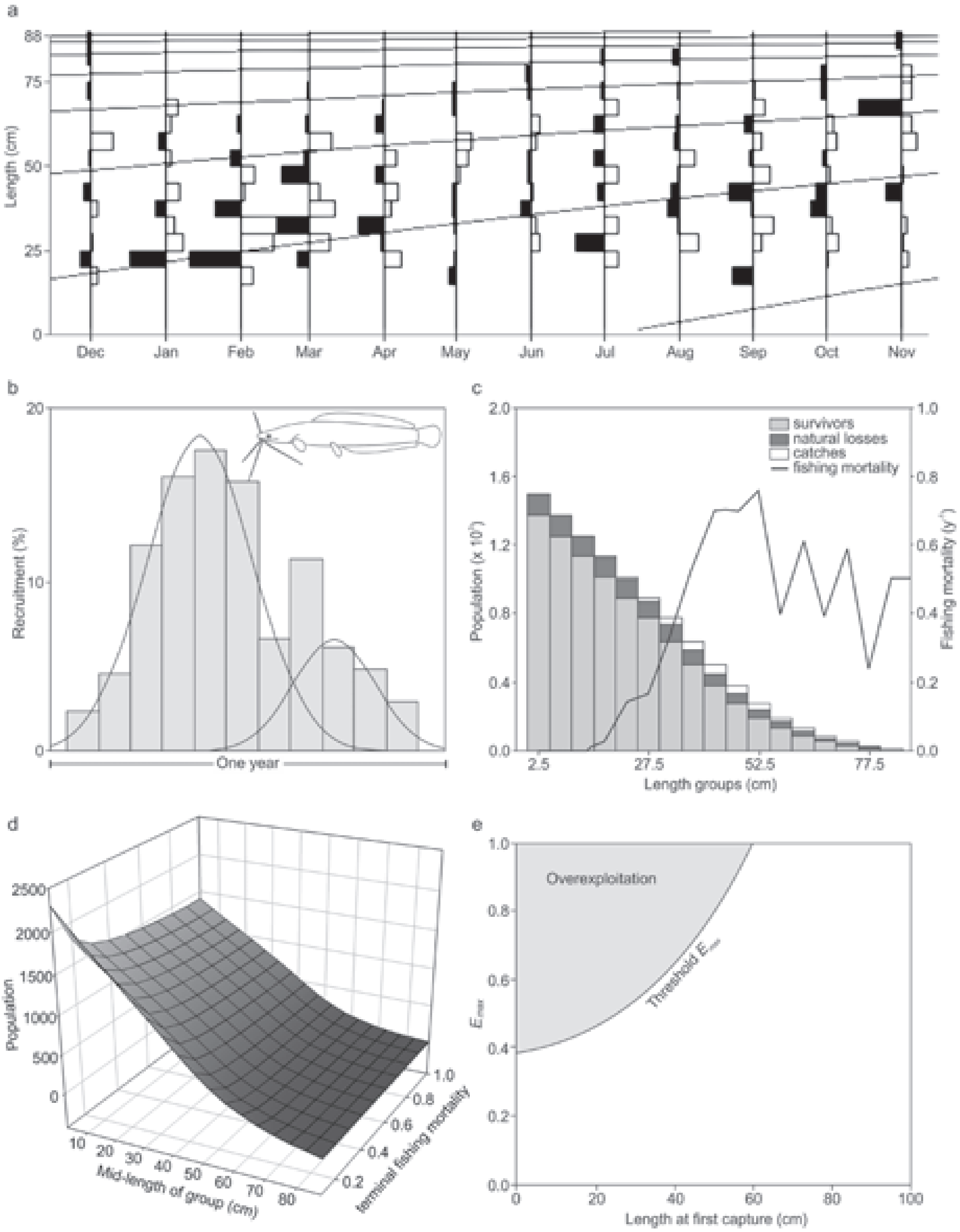

Figure 1. Growth and mortality modelling of *C. gariepinus* from Periyar Lake: a—von Bertalanffy growth curve drawn on a restricted length-frequency sample, where peaks or the positive points (black bars) and troughs or the negative points (white bars) are shown. The points were computed and used to plot the growth curve that passes through largest number of positive points by avoiding negative points | b—computed recruitment pattern suggests that the species has two spawning peaks in a year | c—length structure virtual population analysis suggests current fishing mortality can reduce population of larger individuals but not the smaller individuals | d—effect of terminal fishing mortality on the population in different size classes | e—effect of length at first capture on the maximum sustainable exploitation above which the population will be overexploited and subsequently collapse.

W=0.0132 $L^{2.8719}$, and the b value 2.8719 was significantly lower than the cubic value (t=5.0092, P<0.0001) expected under isometry, indicating that *C. gariepinus* shows a negative allometric growth pattern (A^-) in the Periyar Lake. The b value obtained in our study is similar to native *C. gariepinus* populations in Kenya (2.81; Macharia et al. 2017) and introduced populations in a reservoir in the WG (2.9; Pillai et al. 2016).

The occurrence of juveniles (17.9cm) as well as mature females (31.5cm) suggests that the species has successfully established and colonized the lake. The von Bertalanffy growth curve shows an asymptotic length of 91.88cm and a growth coefficient of 0.54 year^{-1} (Figure 1a; Table 1) which was greater than those observed for various native populations of *C. gariepinus*, i.e., L_∞: 80–124 cm, K=0.06–0.49 year^{-1} and $Ø$=2.96–3.36 (Clay 1984; Wudneh 1998; Okogwu 2011; Tesfaye & Wolff 2015; Macharia et al. 2017). The estimated growth performance index of 3.66 (Table 1) is also higher than that reported for *C. gariepinus* in its native range (Clay 1984; Wudneh 1998; Abdulkarim et al. 2009; Tesfaye & Wolf 2015). No estimates of growth parameters are available from any invasive populations of *C. gariepinus*.

The total mortality (Z) of *C. gariepinus* in Periyar Lake was estimated as 1.34 year^{-1} (Table 1). The natural mortality rate of 0.84 year^{-1} (Table 1) is comparable to an invasive population in South Africa (Booth et al. 2010), but lower than native populations in Nigeria (Abdulkarim et al. 2009), suggesting that *C. gariepinus* has no natural fish predators in its invasive habitat in the WG. The low fishing mortality and exploitation rate (Table 1), which is much below the optimum exploitation rate (E_{max}=0.68) indicate minimal fishing pressure favouring population expansion. In addition, recruitment analysis suggested continuous recruitment throughout the year with two peaks (Figure 1b) similar to populations in Western Africa (Kwarfo-Apegyah & Ofori-Danson 2010).

The VPA (Figure 1c) suggests a high survival rate due to low natural mortality and fishing pressure. A simulation of VPA for increasing fishing mortality (Figure 1d) revealed that greater fishing pressure could exponentially reduce the juvenile population but will not result in population eradication. Further, adult individuals may not be significantly affected, probably because of high survival rate due to low fishing mortality and predation. Our analysis further suggests that using this experimental fishing regime will not result in eradication of the local *C. gariepinus* population. Analysis to understand the changes in the fishing regime suggests that the threshold value of E_{max} required to overexploit the species decreases exponentially with decrease in L_c (Figure 1e). The length at first capture in our experimental fishing was 29.90cm (Figure 1c), i.e. 32.54% of the asymptotic length. Reducing this value to below 10cm, comprising mainly of immature individuals (see Hossain et al. 2016 for size at first maturity values), will no doubt be the best management strategy for eradication. This may be achieved through mesh size selectivity, and specifically targeting spawning grounds to capture young, immature individuals.

Understanding the population biology of an invasive species is important for its long-term management (Booth et al. 2010). Rapid growth, high growth performance index, low fishing mortality and year-round recruitment significantly contribute to the successful invasion of *C. gariepinus* in Periyar Lake, and possibly throughout its invasive range. Though it might be difficult to eradicate *C. gariepinus* from the lake, where they have already established a strong population, effective management and control can be achieved by targeting fish smaller than 10cm. Further studies to understand the reproductive biology and ecology, and its links to the demographics of *C. gariepinus* will help inform improved management measures for this invasive species in a critical freshwater AZE Site.

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NOTE

First records of the black widow spider *Latrodectus elegans* Thorell, 1898 (Araneae: Theridiidae) from Nepal

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The black widow spiders of the genus *Latrodectus* Walckenaer, 1805 (32 species) have a nearly worldwide distribution and are among the medically most significant spiders, with the bites of some species (particularly *L. mactans* (Fabricius, 1775), *L. hasselti* Thorell, 1870 and *L. tredecimguttatus* (Rossi, 1790)) causing significant morbidity and mortality in their distribution range (Jelinek 1997; Garb et al. 2004; Ryan et al. 2017). This exceptionally successful genus has settled on almost all continents (except Antarctica) and some species now (likely due to anthropogenic dissemination) have an almost cosmopolitan distribution (e.g., *L. geometricus* C.L. Koch, 1848) (Gonzalez et al. 2004). While the majority of species are found in Africa/Middle East (~13 species) and North/South Americas (11 species) (World Spider Catalog 2020), southern and southeastern Asia exhibit a relatively low *Latrodectus* species diversity (three species). Among the Asian species, *L. erythromelas* Schmidt & Klaas, 1991 has an uncharacteristically narrow distribution range (Sri Lanka and southern India: Schmidt & Klaas 1991; Srinivasulu et al. 2013), while *L. hasselti* appears in southern Asia at the western edge of its vast distribution area (Srinivasulu et al. 2013), which also includes Australia and New Zealand (Garb et al. 2004). The third species native to southern Asia, *L elegans,* ranges from India, Burma and China to Japan (Yoshida 2009). This species has only been recorded from southern Asia (India) relatively recently (Kananbala et al. 2012), perhaps reflecting historical undersurveying of arachnids in this region. This is particularly true for Nepal, with the most recent summary publication listing only 175 species of spiders (Thapa 1995), undoubtedly an underestimate. Contributions to the diversity of the Nepali spider fauna thus fill an important knowledge gap in biodiversity estimates. Nepal shares borders with both India (in the south, east and west) and China (in the north) and is a biodiversity hotspot due to its variety of altitudes that create a diversity of microclimate and vegetation zones across the country. During a trip to Nepal in April 2016, we observed several apparent members of the genus *Latrodectus*, one of which was clearly identifiable as *L. elegans*. These observations are described herein and contextualized with a previous (historical) record for the genus in Nepal.

Observed specimens: Two adult females, 28°19'35.6"N & 84°54'29.9"E, Kerauja, Yaruphant (Manaslu), Nepal, 1,250m, 24.ii.2012, under stones in dry riverbed (Buri Gandaki), observed by Henning Rose and Alexander Rose, not collected. Two adult females, 27°56'14.1"N & 84°24'15.2"E, Bandipur, Nepal, 900m,

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Figure 1. Known records of *Latrodectus* in Nepal. Lm, *L. mactans* sensu Levi 1959, Le, *L. elegans.* The map was created through modification of a template obtained from Naapi Bibhag (www.dos.gov.np).

16.iv.2016, in webs at night at upper edge of roadside embankment, observed by Binu Shrestha and Tobias Dörr, not collected.

Historical record: *L. mactans* (mentioned in (Levi 1959): Nepal: 28^{0}24'N & 83^{0}23'E, Mayangdi Khola nr. Darban, 3,000ft , collected by K.H. Hyatt.

While conducting night-time searches (20.00–21.00 h) in Bandipur (roughly halfway between Kathmandu and Pokhara) in April 2016, we encountered two large individuals of a *Latrodectus* sp. in their webs at the top of a roadside embankment (at a height of ~3m) close to Bandipur main street (Image 1A–C). Based on coloration, these spiders were identified as *Latrodectus elegans*, a species which is widely distributed in southern and southeastern Asia (Japan, Myanmar, and India) (Yoshida 2009; Kananbala et al. 2012; World Spider Catalog 2020). The dorsal coloration matches that described for *L. elegans* (Image 1A,D); however, the red ventral hourglass marking typical of many *Latrodectus* species, though present, was not clearly visible due to a somewhat subdued red coloration (Image 1B). The distinctness of this hourglass shape appears to exhibit high inter-individual variation in other *Latrodectus* as well (Kaston 1970).

An exhaustive internet search revealed an additional photographic record from the Gorkha area, around 60km distance from Bandipur area. Two females were found during a trekking expedition under stones in a dry river bed (Image 1D) (Henning & Alexander Rose pers. comm. May 2016).

The nearest confirmed record for *L. elegans* lies in Manipur, India (Kananbala et al. 2012), a distance of ~1,000km to the southeast, and its occurrence in Nepal, and thus represents a significant extension of the known range of this species. Importantly, to the best of our knowledge, this is only the second record of the genus *Latrodectus* from Nepal and the first more recent one – a historical record of *L. mactans* is mentioned in (Levi 1959) without a date (but must stem prior to 1959, when the citing article was published), however, what was considered by Levi as "*L. mactans*" comprises a group that other authors have considered distinct species (while presently, *L. mactans* refers to a species with a North American center of distribution). Importantly, the Nepali "*L. mactans"* was collected in west-central Nepal only ~100km from where we found *L. elegans* (Figure 1). We consider it highly likely that this record actually refers to *L. elegans,* or an as yet undescribed *Latrodectus* species.

The occurrence of *L. elegans* in Nepal raises a number of interesting questions. Firstly, *Latrodectus* spp. are medically significant spiders, and the degree to which

Image 1. *Latrodectus elegans* from two localities in Nepal: A—dorsal view of adult female from Bandipur | B—ventral view of same individual | C—adult female in situ in its web in Bandipur | D—adult female from Manaslu. © 1A–C—Tobias Dörr; 1D—Henning and Alexander Rose.

the Nepali species cause envenomation is unknown. Nepal is listed among countries in which "Latrodectism" (Black Widow spider envenomation) is endemic (Maretic 2013) (albeit without clear source attribution), suggesting that indeed *Latrodectus* might be of medical significance in Nepal. Secondly, the apparently immense distribution area of *L. elegans* (from Japan, Burma, China, and India to Nepal) raises the question of origin. Are the Nepali specimens autochthonous populations or were they established in Nepal by accidental human activity? *Latrodectus* spp. are often found near human habitations and could have traveled to Nepal via, for example, firewood. Future studies should be directed at phylogenetic comparisons of specimens collected in Nepal with those from the type locality in Myanmar. If *L. elegans* turns out to be autochthonous, this likely means that the species is widely distributed within Nepal. Alternatively, *L. elegans* might actually represent a morphologically extensively homogeneous species complex. Unfortunately, a recent phylogenetic study of global *Latrodectus* distribution omitted *L. elegans* (Garb et al. 2004). Future work is needed to address this issue.

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Corrigenda

Daniel, J.A. & K. Ramaraju (2020). Collecting parasitic Aculeata (Hymenoptera) from rice ecosystems of Tamil Nadu, India. *Journal of Threatened Taxa* 12(8): 15828–15834. https://doi.org/10.11609/jott.4724.12.8.15828-15834

(i) Page No. 15831 Image no. 9 written as “*Zavatilla* sp.” should be read as “*Spilomutilla* sp.”

(ii) “*Zavatilla* sp.” should be read as “*Spilomutilla* sp.” throughout the article.

(iii) Page No. 15833, Table 3, Rows 9 & 10, column 2 (host), written as “Coleoptera, Diptera, & Hymenoptera” should be read as “Hymenoptera (Aculeata), rarely Diptera or even Coleoptera”

(iv) Page No. 15833, Table 3, Rows 9 & 10, column 3 written as “Lelej et al. 2007” should be read as “Lelej & Schmid-Egger 2005”.

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NOTE

First report of the assassin bug *Epidaus wangi* (Heteroptera: Reduviidae: Harpactorinae) from India

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A single female assassin bug, collected in Arunachal Pradesh, was identified as belonging to the genus *Epidaus* Stål, 1859, based on the key given by Distant (1904), but it did not match with any species described by him. The family Reduviidae that includes predatory bugs, is one of the largest and most diverse group among Heteroptera (Schuh & Slater 1995). The genus *Epidaus* Stål, 1859 occurs mainly in the Oriental region and has more than 25 described species (Maldonado-Capriles 1990; Chen et al. 2016). In the checklist of Reduviidae of India, Ambrose (2006) included five species under *Epidaus*, namely: *E. alternus* Bergroth, 1915, *E. conspersus* Stål, 1863, *E. atrispinus* Distant, 1904, *E. bicolor* Distant, 1903, and *E. famulus* (Stål, 1863). Most of these species are, however, distributed in northeastern India, except *E. bicolor,* which is from Malabar region. A brief diagnosis of four of the above, except *E. alternus,* was given by Distant (1904); *Epidaus parvus* Distant, 1904, described from Burma (=Myanmar) was excluded. Later, a search of the literature revealed that the species collected in Arunachal Pradesh is, in fact, *Epidaus wangi* Chen et al., 2016 described recently from Tibet, China (Chen et al. 2016).

Since this is a recently described species, we are giving only diagnostic characters of the genus and the species, along with many illustrations.

A single collected female (Arunachal Pradesh, leg. Gaurang Gowande, July 2019) was preserved in 70% ethanol, subsequently dried and mounted for study. It was studied under Leica stereozoom MZ6 microscope and photographed with attached Canon PowerShot S50 camera. Several photographs were stacked using CombineZP software and stacked images were processed using Adobe Photoshop CS5. Measurements were done with Erma stage and ocular micrometer and an accurate scale. All measurements are in millimeters (mm).

Heteroptera, Reduviidae, Harpactorinae
Genus *Epidaus* Stål, 1859

Diagnostic characters (mainly following Distant 1904): Body elongate; head slightly shorter than pronotum, with a distinct spine at base of antennal insertion; postocular region longer than anteocular; first visible labial segment shorter or subequal to second

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and third segments combined; posterior pronotal lobe with a pair of discal erect spines or tubercles; lateral or humeral angles of pronotum with a sharp spine and a smaller tooth-like spine or a tubercle just behind; fore femora slightly incrassate than mid and hind femora.

Epidaus wangi Chen, Zhu, Wang & Cai, 2016. (Images 1 A–E)

Diagnostic characters: Coloration—Body yellow brown, subshining, with a pattern of black stripes and spots. Eyes black; ocelli brownish; first antennal segment with three broad black annulations, second antennal segment with basal and apical black annulations, third and fourth segments entirely yellow brown, without annulations. Pronotum dorsally with following black markings or portions: anterior angles, base of discal tubercles, and laterally on each side just behind transverse sulcus; lateral and discal spines. Black markings of legs include complete and incomplete black annulations on femora and tibia. As shown in images 1A–B, fore femora have one complete annulation beyond middle or in distal half while mid- and hind-femora possess one complete annulation beyond middle and an incomplete annulation before middle; all tibia possess three black annulations – one basal, one before middle, and one apical. Extreme margin of some connexival segments indistinctly brownish. On ventral side, the black markings are at lateral (pleural) margin of prosternum and a spot near base of meso and metacoxae on outer side (Image 1B).

General structural characters—Head: a prominent spine at the base of antennae; eyes globular; ocelli distinct situated on a tubercle (Image 1C); labium as shown in Image 1D; pronotum with lateral and discal spines (Image 1C); female terminalia as shown in Image 1E.

Chen et al. (2016) have provided several colour illustrations and also line drawings of male and female genitalia of *E. wangi*. The abdomen is broadened at some segments in our specimen, as originally described for female of this species; the female terminalia, the size, and other body measurements of our specimen are also matching with the original description. Chen et al. (2016) have also discussed the similarity/dissimilarity of this species with other Oriental species. The other species of *Epidaus* in India are distinctly different in coloration and so are unlikely to be confused with this species. *Epidaus bachmaensis* Truong, Zhao & Cai, 2006 and *Epidaus insularis* Zhang, Zhao, Cao & Cai, 2010, described recently from Vietnam and China, respectively, are very different species.

Thus the specimen examined here matches perfectly with figures and the detailed description given by Chen et al. (2016). As it is not so far recorded from India, we are reporting it for the first time from the Indian territory taking the total of *Epidaus* species known from India to six. It is true that the occurrence of this species in India is not surprising as the type locality of the species is in the adjacent region and we do share many other species with that region in China.

Measurements (in mm): Total length 25.0, Head length including neck 4.2; head breadth between eyes 1.0; head breadth at eyes 1.87, eye diameter 0.75; anteocular 1.70, postocular including neck 1.75; antenna: first segment 9.0, second segment 3.75, third segment 5.75, fourth segment 2.60; labium: first segment 2.50, second segment 1.75, third segment 0.75; pronotum length along midline 5.0; width at humeral angle spine 8.1; width at anterior angles of pronotum 2.0; distance between discal spines 2.0; scutellum length 1.75; scutellum breadth at base 2.0; legs: forefemur 8.5, foretibia 8.0, foretarsus with claw 1.5; mid femur 7.0, mid tibia 6.5, tarsus with claw 1.5; hind femur 9.0, hind tibia 11.0, hind tarsus with claw 1.50; hemelytra 16.00; hemelytra passing abdomen by 3.0; maximum width of abdomen 8.3.

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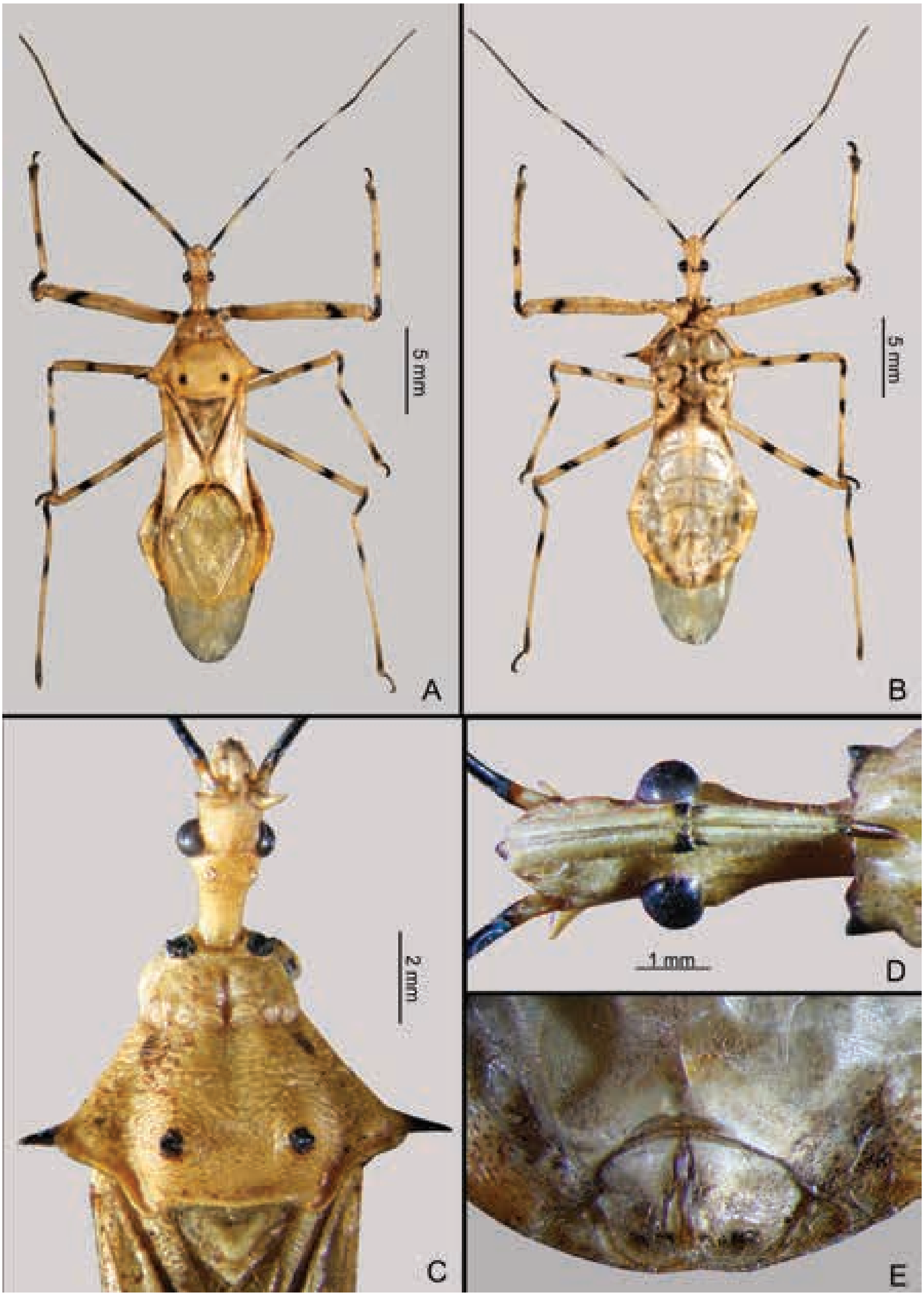

Image 1. *Epidaus wangi* Chen et al., 2016: A—dorsal view | B—ventral view | C—head and pronotum, dorsal view | D—head, ventral view, including labium | E—female terminalia, ventral view. © Hemant V. Ghate.

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NOTE

Observations of the damselfly *Platylestes* cf. *platystylus* Rambur, 1842 (Insecta: Odonata: Zygoptera: Lestidae) from peninsular India

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Lestidae is a rather small family of cosmopolitan, relatively large-sized, slender damselflies (Insecta: Odonata: Zygoptera) commonly known as spreadwings. One-hundred-and-fifty-three species of Lestidae from nine genera are known from around the world and India has 25 species belonging to five genera (Subramanian 2018). *Platylestes platystylus* was described by Jule Pierre Rambur in 1842. Earlier collections of the species are from Bengal and Myanmar (Fraser 1933). The extant range of *Platylestes platystylus* is depicted by the IUCN Red List as India (West Bengal), Lao People's Democratic Republic, Myanmar, Thailand, and Iraq. Though it is listed as a Least Concern species, there is an urgent need for research regarding its taxonomy, population size, population trends, distribution, life history, ecology, and threats (Sharma 2010).

Multiple individuals of unidentified female damselflies were observed and photographed by RKJ from Thommana region (10.342^{0}N & 76.250^{0}E) of the Kole wetlands and Thumboor (10.297^{0}N & 76.256^{0}E), a nearby village during the period 2015–2017. Close observations of the insect's general body structures, wing postures, and wing positioning habits helped us confirm that the damselflies belonged to the family Lestidae. However, the observed individuals could not be assigned to any species as they did not match the description, illustration or photographs of any *Lestes* species known from the region. A male individual was photographed from Thumboor Village in September 2018 by RKJ. A female was observed and photographed from Uppungal region (10.692^{0}N & 75.997^{0}E) of the Kole wetlands by a volunteer, Renjith R.V. during the first Kole Odonata survey organized jointly by the Society for Odonate Studies, Kerala Agricultural University and Kerala Forest and Wildlife Department in October 2018. Both male and female individuals were observed from Thommana and Thumboor during August 2019 to December 2019 by RKJ and VCA. The species was confirmed as *Platylestes* cf. *platystylus* after referring to Fraser (1933) and discussing with Noppadon Makbun (10 April 2018). Since the species was observed from one of the southernmost (Thommana) and northernmost (Uppungal) points of the Kole wetlands, it is reasonable to assume that the species occurs in various locations in and around Kole wetlands.

Description of adult male: *Platylestes platystylus* is a small, dull-coloured damselfly of the size of *Lestes* species. Like other members of Lestidae family, it holds

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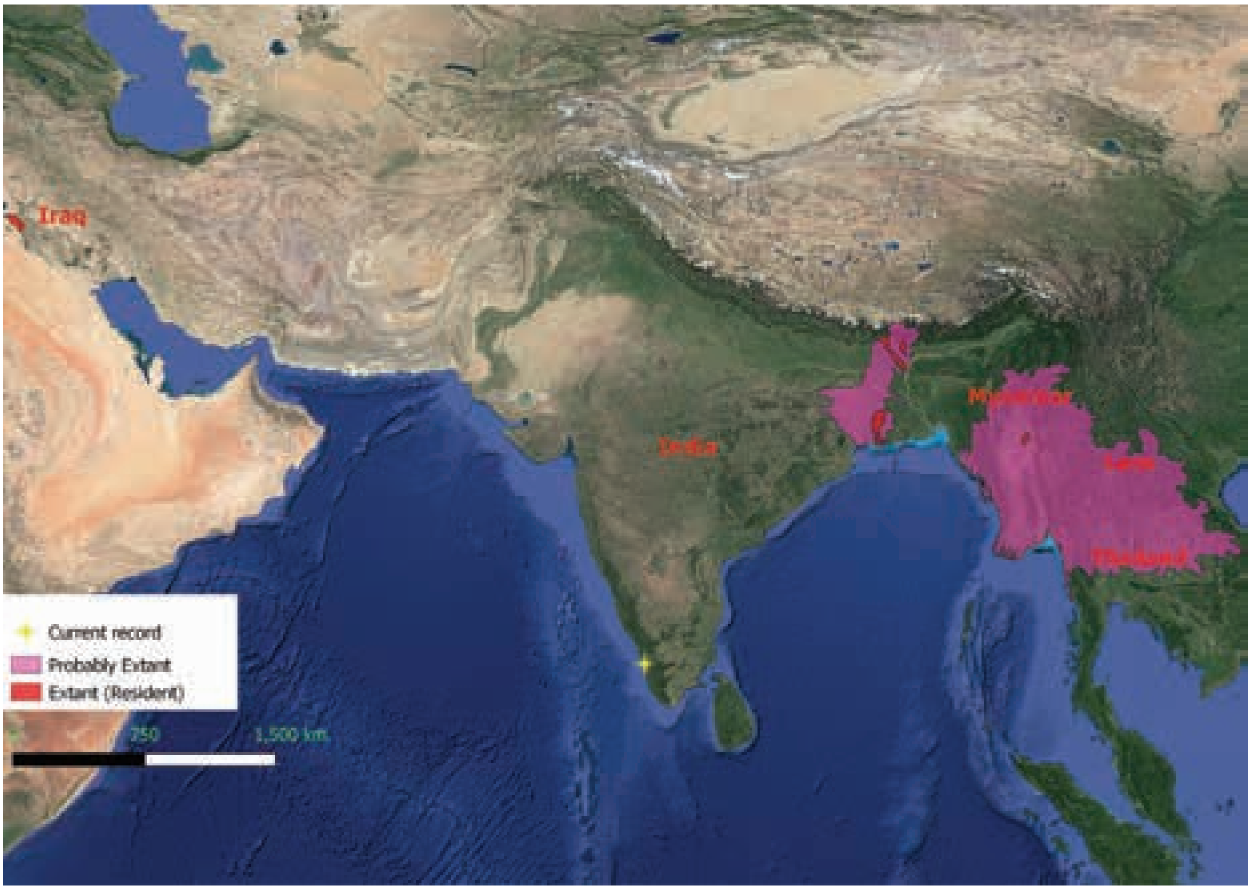

Image 1. Distribution of *Platylestes platystylus*

its stalked, clear wings spread out at rest. Eyes are of bright green colour. The labium is dirty yellow and the labrum, bases of mandibles and cheeks are olivaceous in colour. Its prothorax and thorax are light green, paler at the sides and pruinosed white beneath. The thorax has several black spots. Its wings are palely enfumed. The quadrate pterostigma (wing spots) of *Platylestes platystylus* with pale or white inner and outer ends help distinguish it from *Lestes* species for which the more elongate pterostigma are of uniform colouration (Table 1). Its abdomen is olivaceous to warm reddish-brown in colour with black apical rings on each segment. Anal appendages are whitish with the superiors black at base, curling in at apices to meet each other. Inferior appendages are about half the length and thick at base.

Description of adult female: Female closely resembles the male in most aspects. Anal appendages are yellow, blackish-brown at the base, and as long as segment 10 of the abdomen.

Immature individuals have pale khaki brown thorax and eyes, but the black spots on thorax are distinctive.

Odonatological studies in the Western Ghats have not recorded *Platylestes platystylus* till date (Emiliyamma 2014; Subramanian 2018). We made 20 observations of the species during the period 2015–2020, all from submerged paddy fields. We made field visits twice every month, but could observe the adults only during the period of June–December. Mating and egg-laying were observed in the months of October and November. The females after mating laid their eggs in grasses emerging from water, unguarded by the males. Teneral individuals (newly emerged adults) were also observed, highlighting the importance of this wetland as their breeding habitat. The species is highly seasonal and no adult could be observed during the period from January to June. Fraser (1933) has stated that it is possible that more than one species exists among the four specimens he examined, emphasizing the need for further taxonomic study of the species.

The Kole wetlands is a low-lying area that remains submerged under floodwater for about six months in a year. Wetland agriculture, mainly paddy cultivation is the most important activity undertaken here (Johnkutty & Venugopal 1993). Kole is a globally important

Table 1. Differences between *Platylestes platystylus* and other members of Family Lestidae found in the region.

Species	*Platylestes platystylus*	*Lestes* species	*Indolestes davenporti*
Position of wings at rest	Spread out	Spread out	Held close to the body
Thoracic markings	Large number of black spots	Metallic/non-metallic stripes, few spots in some	Striped thorax, no spots
Pterostigma	Quadrate with pale or white inner and outer ends	At least twice as long as broad, uniform dark colours	Bicolorous, three times as long as broad

Image 2. *Platylestes* cf. *platystylus* adult male from Kole wetlands.

Image 4. Anal appendages of adult male (dorsal view) *Platylestes* cf. *platystylus.*

Image 3. Anal appendages of adult male (ventral view) *Platylestes* cf. *platystylus*.

Image 5. Ovipositing *Platylestes* cf. *platystylus* adult female.

Image 6. *Platylestes* cf. *platystylus* teneral female.

Image 7. Wings of *Platylestes* cf. *platystylus* showing distinctive quadrate pterostigma with pale inner and outer ends.

Image 8. *Platylestes* cf. *platystylus* female photographed at Uppungal

wetland designated as a Ramsar site since 2002 (Islam & Rahmani 2008), but it faces multiple threats in the form of encroachments, waste dumping and excessive use of pesticides. The observation of the rare *Platylestes* cf. *platystylus* adds to the conservation value of this wetland.

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NOTE

Herminium longilobatum (Orchidaceae), a new record for Bhutan

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Herminium L. is a genus of terrestrial or rarely epiphytic orchids belonging to the family Orchidaceae (subfamily Orchidoideae, tribe Orchideae and sub-tribe Orchidinae) (Chase et al. 2015). It is represented by 49 species in the world, distributed in the northern hemisphere with a clear center of diversity in the Himalaya (Pearce & Cribb 2002; Raskoti et al. 2017). Species are characterized by small greenish, whitish or yellowish flowers on the raceme, a (sub) globose tuber, a lip with a concave or spurred base, and column with the stigma-lobes not adnate to the base of the lip (Raskoti et al. 2017).

Bhutan harbors 19 species of *Herminium* (Pearce & Cribb 2002; Gurung 2006; Dalstrom 2017; National Biodiversity Centre 2017; Raskoti et al. 2017) namely, *H. albomarginatum* (King) X.H. Jin, *H. albosanguineum* Renz, *H. albovirens* (Renz) X.H. Jin, *H. clavigerum* Lindl, *H. elisabethae* Duthie, *H. fallax* (Lindl.) Hook.*f*, *H. gracile* King & Pantl., *H. handelii* X.H. Jin, *H. himalayanum* (Renz) X.H. Jin, *H. josephi* Rchb.f., *H. lanceum* (Thunb. ex Sw.) Vuijk., *H. latilabre* Lindl, *H. macrophyllum* (D.Don) Dandy, *H. monophyllum* (D.Don) P.F. Hunt & Summerh., *H. monorchis* (L.) R.Br., *H. orbiculare* Hook.f., *H. pugioniforme* Lindl. ex Hook.*f*., *H. pygmaeum* Renz, and *H. quinquelobum* King & Pantl.

During a recent field exploration, we found an interesting epiphytic orchid growing on the dead trunk of an oak tree *Quercus oxyodon* embedded with thick mosses and epiphytic fern at an elevation of 2,746m (27.618^0N & 91.531^0E) inside the cool broad-leaved forest on 24 September 2018, in the Serkhang-chuu catchment area of Trashi Yangtse District. Ferns, shrubs, *Symplocus* species, bamboos, and *Quercus semicarpifolia* were other associated vegetation in the area. Photographs of the orchid were sent to the orchid expert, Dr. Dhan Bahadur Gurung, for identification and subsequently it was confirmed as *Herminium longilobatum* S.N. Hedge & A.N. Rao. The specimen was collected on 17 October 2019, and preserved at the Forest Range Office, Doksum under the Trashigang Forest Division. This constitutes the 20^{th} representative of the genus from Bhutan. The same is being presented here with a short description, phenology, ecology and color plates.

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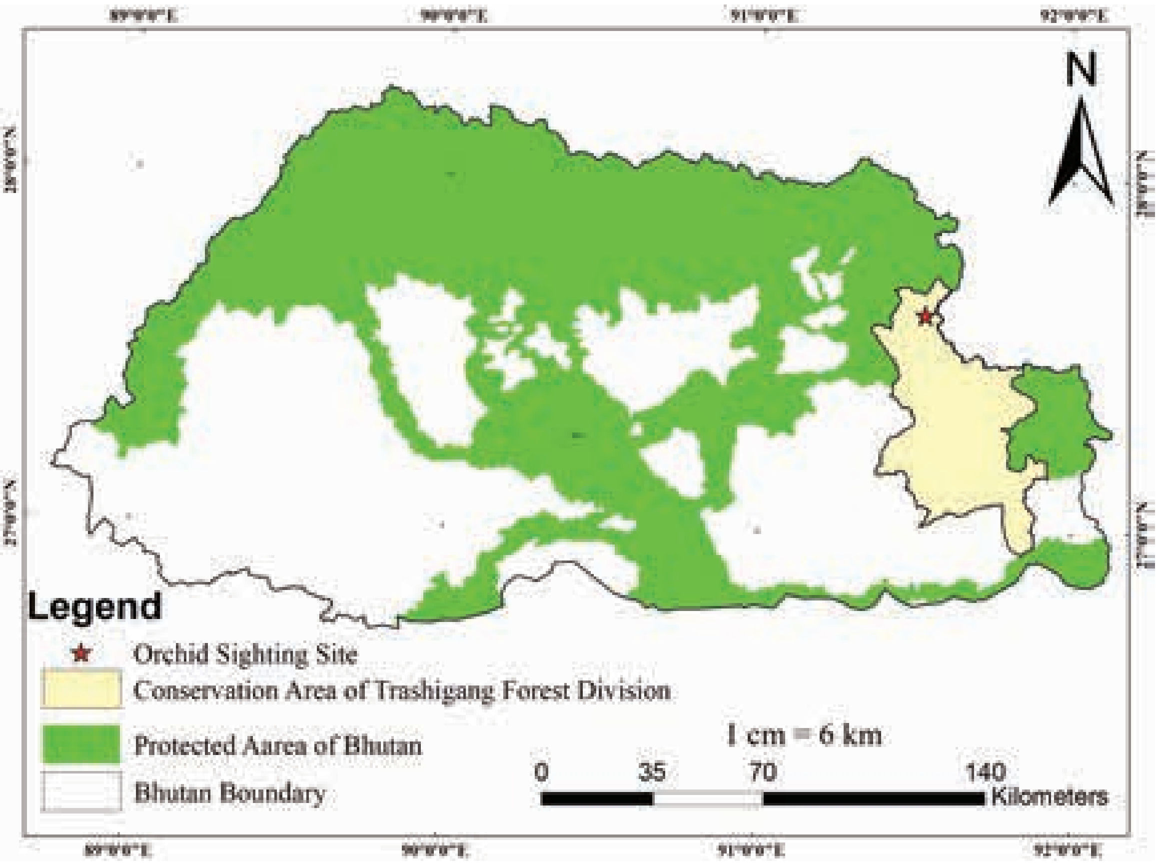

Figure 1. Location of *Herminium longilobatum* in Bhutan.

Image 1. *Herminium longilobatum* S.N. Hegde & A.N. Rao from Bhutan: A—plant in its natural habitat | B—close up of the inflorescence. © Tandin Wangchuk.

Herminium longilobatum **S.N. Hegde & A.N. Rao Himalayan Pl. J. 1(2): 47 (1982).**

Type: Yarlung Zangbo–Brahmaputra Region, Towang, 2,800 m, Hegde 3208-A (TIPI).

Plant epiphytic herbs, up to 30–50 cm tall, including inflorescence. Tubers 1 or 2, ovoid, globose to oblong. Pseudostem up to 8–10 cm, long, slender, covered with two tubular sheaths of which the basal is much shorter and few well-spaced leaves near the middle. Leaves linear to oblong-lanceolate, 8–20 × 0.5–1.5 cm, acuminate, narrow at base into a long tubular sheath clasping the pseudo stem. Scape with inflorescence 12–20 cm tall; inflorescence terminal raceme, peduncle terete, with peduncle-scales 0.5–2.4 cm; rachis 5–18 cm, many flowered, flowers laxly arranged. Floral bracts ovate-lanceolate, 1.5–5.0 mm, slightly shorter than the ovary and apex acuminate. Flowers about 5x5 mm, opening widely, greenish-white. Sepals subequal, ovate, 2.0 × 1.5 mm, subacute, concave. Petals lanceolate, 2.0 × 1.5 mm, apex subacute. Lip much longer than the other perianth lobes, oblong, 3-lobed, widened at base, with a callus at base of attachment to the column, midlobe short, lanceolate, obtuse; lateral lobes 10mm long, more than 10 times longer than the midlobe, filiform, uncoiled. Column 1mm, short; anther cells 2, parallel; staminodes 2, lateral; rostellum two-lobed; stigmas 2, transversely oblong, divergent. The fruit oblong, 7mm long. Ovary sessile, resupinate, beaked.

Flowering and Fruiting: August–September

Habitat and Ecology: Orchids were found growing on the dead trunk of Oak species *Quercus oxyodon* (five clumps) covered with mosses at an elevation of 2,746m inside the cool broad-leaved forest.

Distribution: Bhutan, China, India, Nepal.

Specimens examined: Bhutan: Trashi Yangtse District, Serkangchu catchment, 2,746m, 24.ix.2018., Tandin W., Ugyen D., and Lam N., (Haplotype: Doksum Forest Range). Yarlung Zangbo-Brahmaputra Region: Kameng District, Towang Hegde, 3208 A-C (Orchid Herbarium, Tipi); Phudong-Dirang, Hajra 54808 (Assam). Nepal: Sagarmatha, Solukhumbu District, below Sete, 2,500m, Raskoti B.B., 01299 (KATH).

Image 2. *Herminium longilobatum*—voucher specimen preserved at Doksum Forest Range, Trashigang Forest Division.

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Recent record of a threatened holoparasitic plant *Sapria himalayana* Griff. in Mehao Wildlife Sanctuary, Arunachal Pradesh, India

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In India, a variety of the climatic, edaphic, and topographic variations have resulted in a great range of habitats. Northeastern India, particularly, is extremely diverse and rich in biodiversity (Singh 2003). Lying between 22–30^{0}N & 89–97^{0}E and spread over 262,379km^2, this region represents the transition zone between the Indian, Indo-Malayan, and Indo-Chinese biogeographic regions and a meeting place of the Himalayan mountains and peninsular India (Ramakantha et al. 2003). Northeastern India is, thus, the biogeographical 'gateway' for much of India's flora and fauna, as a result, the region is one of the richest in biological values. Despite being rich and diverse in terms of biological diversity, the vegetation of the northeastern India is fairly less known. With about 167,000km^2 area under forest, this region accounts for approximately 7,500 species of angiosperms (Ramakantha et al. 2003).

Arunachal Pradesh, the largest state in northeastern India among the seven sisters (a term used for the northeastern states collectively) is situated between 26.500^{0}N–91.500^{0}E and 29.500^{0}N–97.500^{0}E. It covers a geographical area of 83,743km^2. The state is predominantly hilly with deep valleys, accompanied by a wide variation of climate and soils that have resulted in the formation of varied ecological diversity (Baishya et al. 2001). Mehao Wildlife Sanctuary (WS) is rich in floral and faunal diversity and it harbours an interesting and endangered plant species, *Sapria himalayana* Griff., (Nayar & Sastry, 1987), which was recorded for the first time from the sanctuary (28.083^{0}N–93.500^{0}E and 28.250^{0}N–95.750^{0}E), Lower Dibang Valley, Arunachal Pradesh and later in 2014 (Andreas & Jis 2014). This species is the largest root parasite having a host specific relationship with the plant genus *Tetrastigma* of Vitaceae family (Hajra et.al. 2008) and *T. bracteolatum* (Wallich) Planchon and *T. serrulatum* (Roxb.) Planchon are reported as the host plants of *Sapria* in Namdapha National Park (Arunachalam et al. 2004).

Sapria needs special attention due to its botanical characteristics and a very restricted distribution around the world (Borah & Ghosh 2018). Globally, it is distributed in southeastern Tibet, northeastern India, Myanmar (Burma), Thailand, and Vietnam. In India, it was first reported from the tropical wet evergreen forests of Mishmi Hills in Lohit District by William Griffith in 1847 and later from Aka Hills in Kameng

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Image 1. Flower of *Sapria himalayana* Griff. in Mehao Wildlife Sanctuary.

Image 2. A globose bud of *Sapria* in the forest floor of Mehao Wildlife Sanctuary.

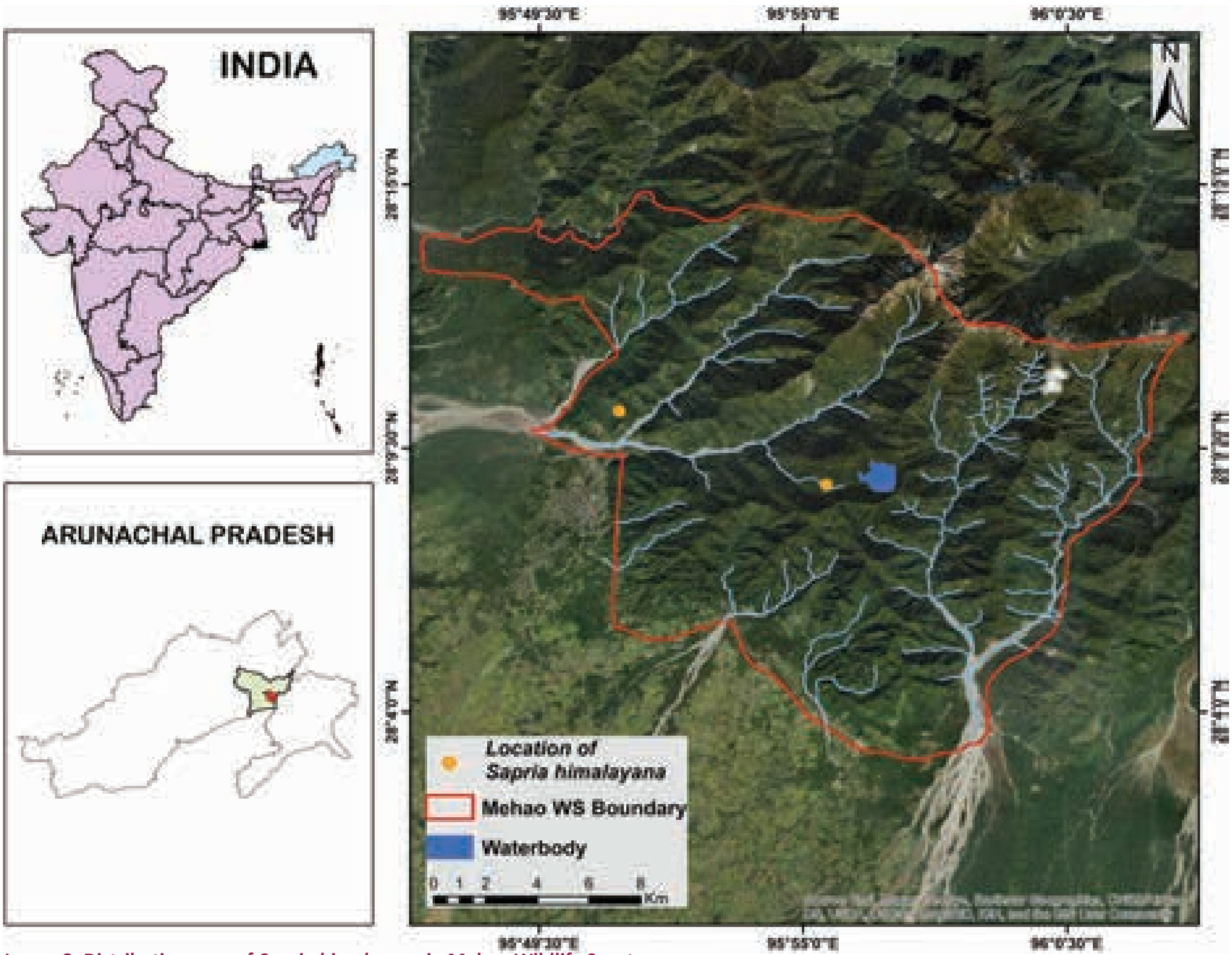

Image 3. Distribution map of *Sapria himalayana* in Mehao Wildlife Sanctuary.

District by Norman Loftus Bor in 1938 (Borah & Ghosh 2018). Recently, it was reported by Jayom Karlo in the Perlek Modi Hills of West Siang and in Namdapha Tiger Reserve in Changlang District (Borah & Ghosh 2018). Earlier, *Sapria* was also distributed in Assam, Manipur, and Meghalaya, however, all current locations of this plant are in Arunachal Pradesh in the eastern Himalaya. According to Elliot (1992), S. *himalayana* is also known as a 'Hermit's Spittoon' which has been reported from the evergreen forest of Thailand which is similar in its habitat to the Mehao WS. Thailand acts as a geographical bridge that connects communities from the northern parts of the Himalayan mountain range and southern China to the Malay Peninsula and Cambodia to Laos.

Sapria himalayana belongs to the Rafflesiaceae family, recognized as large-flowered genera. The sister clades *Rafflesia*, *Rhizanthes*, and *Sapria* have reduced vegetative body among all angiosperms. The members of Rafflesiaceae family produce the world's largest flowers (*Rafflesia arnoldii*), which is an iconic symbol of the southeastern Asian rainforests. *Rafflesia* and *Sapria*, however, share a very similar conspicuous floral chamber. Thus, despite their superficial similarities, the floral chambers are constructed differently in these two cousin genera (Nikolov et al. 2014).

Sapria himalayana is a rare holoparasitic (or obligate parasitic) flowering plant which is completely dependent on its host plant for water, nutrients, and products of photosynthesis. It sucks food through a specialised root system called haustoria, which are attached to both xylem and phloem of the host plant. The visible body is globose, flowers are dioecious and unisexual. Flowers bloom in winter have 10 bracts each which are bright red in colour covered with sulphur-yellow spots. Flowers are fleshy with imbricate inflorescence while perianth being campanulate. It flowers in between August and September followed by fruiting during winters. Fruits are swollen and crowned with perianth. The seeds are of the size of grapefruit and are blackish-brown in colour (Elliot 1992; Borah & Ghosh 2018).

The forests of Mehao WS have been facing disturbances due to anthropogenic sources such as shifting cultivation and non-timber forest produce extraction that are now visible in several parts of the sanctuary. During the early process of developing a forest, the ground is lopped off followed by burning of forest remains, which has severely damaged the host plants of *Sapria*. *Sapria* favours shady, gentle slope, nutrient-rich humus soil with plenty of leaf litter on forest floor, humid habitats with great canopy cover throughout. *Sapria* generally grow in patches. We found three flowers in one patch and five flowers in another patch. The patch which is found near Mehao Lake had three globose buds of *Sapria*. The parasitic plant is lesser-known and a poorly understood taxon. The plant has no known commodity value in terms of food, drug or other natural products for the local inhabitants (Borah & Ghosh 2018). Identification of their peculiar morphology is problematic and thus has contributed greatly towards the confusion surrounding the plants evolutionary affinities and development of their body plan. Due to its restricted distribution, little knowledge about its host range and host-parasite interaction exist. Increased human interference and habitat shrinkage impose the risk of extirpation. Further studies focusing on population dynamics and vegetation ecology of *Sapria* and its host species is suggested for its conservation.

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Threatened Taxa

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N O T E

Eleven new records of lichens to the state of Kerala, India

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In the present state of knowledge, Kerala comprises ca. 782 species of lichens which were made through various publications and contributions (Vohra et al. 1982; Patwardhan 1983; Kumar 2000; Easa 2003; Sequiera 2003, 2007; Singh & Sinha 2010; Biju et al. 2010, 2014a, b; Pandit et al. 2012; Joshi et al. 2016, 2018; Bajpai et al. 2018; Zachariah et al. 2018, 2019). The Pathanamthitta District of Kerala State consists of three different natural geographical regions; the highlands—part of Western Ghats that cover thick forests and tall hills with an average elevation of 800m; the midland—that covers areas with small hills with an elevation ranging from 20–100 m; and the lowlands with less than 20m elevation and wetlands that remain closer to the western coastal boundaries. The highland comprises of reserve and plantation forests while the midland and lowlands include human-inhabited and cultivated lands. The reserve forest area of the district is 1385.27km^2 that comprises 50% of the total area of the district and is completely devoted for the conservation of biodiversity. The area experiences a tropical climate with temperature ranging from 20–39 °C and the south-west and north-east monsoons provide good rain. About 75% of the annual rainfall is received during the south-west monsoon. A total of 83 species of lichens were reported from Pathanamthitta District till date (Kumar 2000; Easa 2003; Zachariah et al. 2018, 2019). During the ongoing studies on the lichen mycota of Pathanamthitta District, we came across eleven lichen species which are new to the state of Kerala.

Specimens were collected from various cropland areas of Pathanamthitta District and identification was conducted at the Lichenology laboratory, CSIR-National Botanical Research Institute (CSIR-NBRI), Lucknow. Morphological characters were studied using a stereo zoom Leica S8APO microscope whereas the anatomical details were examined with Leica DM2500 compound

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microscope attached with camera and image analysis software. Chemical studies were carried out by spot tests and TLC using solvent system C following Orange et al. (2001). Awasthi (2007) and Lendemer (2013) were followed for identification of the species, and new records were confirmed by comparing with the checklists and other relevant literature (Easa 2003; Singh & Sinha 2010). Identified specimens were deposited at the Regional Herbarium of Kerala (RHK), Department of Botany, SB College, Changanacherry, Kerala and one set of voucher specimens at herbarium LWG of CSIR-NBRI.

1. *Cladonia praetermissa* A.W. Archer

Muelleria 5: 273. 1984. (Cladoniaceae) (Image 1)

Specimens examined: RHK L0613, L0614, L0615, L0616; LWG 35848, 22.ii.2019, Kerala, Pathanamthitta District, Pachakkanam, on soil, 9.487°N & 77.144°E, 895m, coll. S.A. Zachariah.

Distribution: In India, the species was earlier known from Himachal Pradesh, Jammu & Kashmir, Madhya Pradesh, Sikkim, and Uttarakhand (Rai & Upreti 2014).

Image 1. *Cladonia praetermissa* A.W. Archer

2. *Collema japonicum* (Müll. Arg.) Hue

Nouv. Arch. Mus. Hist. Nat., ser. 3, 10: 220. 1898. (Collemataceae) (Image 2)

Specimens examined: RHK L0573, LWG 35833, 30.i.2019, Kerala, Pathanamthitta District, Upper Moozhiyaar, on bark, 9.308°N & 77.127°E, 912m, coll. S.A. Zachariah.

Distribution: In India, the species is widely distributed in Sikkim, Uttarakhand, and West Bengal (Rai & Upreti 2014).

Image 2. *Collema japonicum* (Müll. Arg.) Hue

3. *Heterodermia hypochraea* (Vain.) Swinscow & Krog

Lichenologist 8: 119. 1976. (Physciaceae) (Image 3)

Specimens examined: RHK L0078, 28.x.2017, Kerala, Pathanamthitta District, Ranni forest division, Goodrickal range, Anathode, on bark, 9.342°N & 77.153°E, 974m, coll. S.A. Zachariah; RHK L0121, 24.v.2018, Kerala, Pathanamthitta District, Ranni forest division, Goodrickal range, Kakki, Attappara, on bark, 9.348°N & 77.157°E, 1108m, coll. S.A. Zachariah; RHK L0603, 22.ii.2019, Kerala, Pathanamthitta District, Ranni forest division, Goodrickal range, Pachakkanam, on bark, 9.458°N & 77.141°E, 964m, coll. S.A. Zachariah.

Distribution: In India, this species was earlier known from Karnataka and Nagaland (Singh, 2018).

Image 3. *Heterodermia hypochraea* (Vain.) Swinscow & Krog

4. *Leptogium coralloideum* (Meyen & Flot.) Vain.

Suomal. Tiedeakat. Toim., ser. A, 6(7): 110. 1915. (Collemataceae) (Image 4)

Specimens examined: RHK L0221, 9.x.2018, Kerala, Pathanamthitta District, Tiruvalla, Niranam, on bark of *Garcinia mangostana*, 9.347°N & 76.523°E, 8m, coll. S.A. Zachariah; RHK L0247, 10.x.2018, Kerala, Pathanamthitta District, Tiruvalla, Kaviyoor, on bark of *Swietenia macrophylla*, 9.384°N & 76.615°E, 11m, coll. S.A. Zachariah; RHK L0409, 12.xi.2018, Kerala, Pathanamthitta District, Malayalappuzha-Puthukkulam, on bark of *Artocarpus heterophyllus*, 9.301°N & 76.841°E, 128m, coll. S.A. Zachariah; RHK L0410, 12.xi.2018, Kerala, Pathanamthitta District, Kumblampoika-Thalachira, on bark of *Hevea brasiliensis*, 9.302°N & 76.816°E, 141m, coll. S.A. Zachariah; RHK L0411, LWG 35844, 12.xi.2018, Kerala, Pathanamthitta District, Puthukkulam, Thekkummala, on bark of *Areca catechu*, 9.306°N & 76.848°E, 245m, coll. S.A. Zachariah.

Distribution: In India it was earlier reported from the subtropical areas including Andaman & Nicobar Islands, Tamil Nadu, and Uttarakhand (Singh & Sinha 2010).

Image 4. *Leptogium coralloideum* (Meyen & Flot.) Vain.

5. *Pannaria emodii* P.M. Jørg.

Lichenologist 33: 298. 2001. (Pannariaceae) (Image 5)

Specimens examined: RHK L0501, LWG 35837, 5.i.2019, Kerala, Pathanamthitta District, Ranni, Gurunathanmannu, on bark, 9.288°N & 77.017°E, 579m, coll. S.A. Zachariah.

Distribution: In India, earlier reported from Tamil Nadu and Uttarakhand (Singh & Sinha 2010).

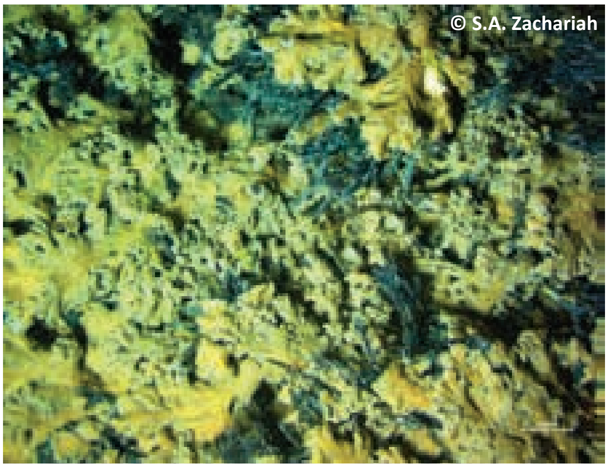

Image 5. *Pannaria emodii* P.M. Jørg.

6. *Phyllopsora chlorophaea* (Müll. Arg.) Zahlbr.

Denkschr. Kaiserl. Akad. Wiss., Math.-Naturwiss. Kl. 83: 133. 1909. (Ramalinaceae) (Image 6)

Specimens examined: RHK L0572, LWG 35846, 30.i.2019, Kerala, Pathanamthitta District, Upper Moozhiyaar, on bark, 9.298°N & 77.125°E, 885m, coll. S.A. Zachariah.

Distribution: In India, the species was earlier recorded from tropical to sub temperate areas of Karnataka and Odisha (Mishra et al. 2011).

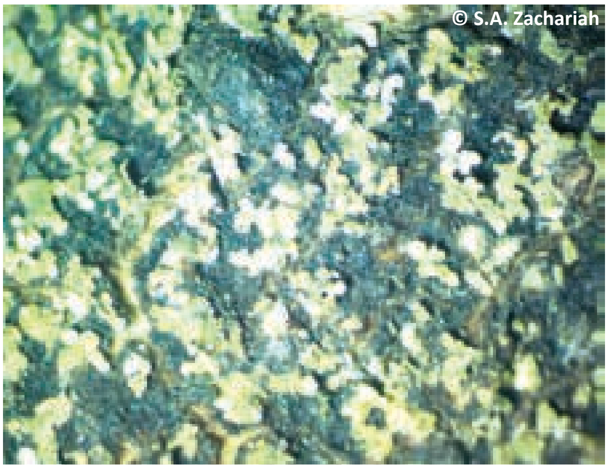

Image 6. *Phyllopsora chlorophaea* (Müll. Arg.) Zahlbr.

7. *Phyllopsora parvifolia* var. *subgranulosa* (Tuck.) Müll. Arg.

Bot. Jharb. Syst. 20: 264. 1894. (Ramalinaceae) (Image 7)

Specimens examined: RHK L0518, 5.i.2019, Kerala, Pathanamthitta District, Ranni, Gurunathanmannu, on bark, 9.293°N & 77.014°E, 545m, coll. S.A. Zachariah; RHK L0546, LWG 35836, 30.i.2019, Kerala, Pathanamthitta District, Upper Moozhiyaar, on bark, 9.301°N & 77.125°E, 896m, coll. S.A. Zachariah; RHK L0593, 20.ii.2019, Kerala, Pathanamthitta District, Konni- Mannarappara, on bark, 9.090°N & 77.022°E, 239m, coll. S.A. Zachariah; RHK L0607, Kerala, Pathanamthitta District, Pachakkanam, on bark, 9.459°N & 77.142°E, 936m, coll. S.A. Zachariah.

Distribution: In India, this species was earlier reported from Manipur (Singh & Sinha 2010).

8. *Physcia dilatata* Nyl.

Syn. Lich. 1(2): 423. 1860. (Physciaceae) (Image 8)

Specimens examined: RHK L0223, LWG 35840, 9.x.2018, Kerala, Pathanamthitta District, Tiruvalla, Niranam, on bark of *Areca catechu*, 9.346°N & 76.522°E, 8m, coll. S.A. Zachariah.

Distribution: It was earlier reported from Himachal Pradesh, Madhya Pradesh, Manipur, Sikkim and Uttarakhand states of India (Singh & Sinha 2010).

9. *Physcia dubia* (Hoffm.) Lettau

Hedwigia 52: 254. 1912. (Physciaceae) (Image 9)

Specimen examined: RHK L0290, 18.x.2018, Kerala, Pathanamthitta District, Adoor, on bark of *Areca catechu*, 9.160°N & 76.726°E, 62m, coll. S.A. Zachariah.

Distribution: It was earlier reported from Jammu & Kashmir and Uttarakhand states of India (Singh & Sinha 2010).

10. *Physcia sorediosa* (Vain.) Lynge

Vid. -Slesk. Skrift. I. Mat. -Naturv. Kl. No. 16: 27. 1924. (Physciaceae) (Image 10)

Specimens examined: RHK L0212, 28.vii.2018, Kerala, Pathanamthitta District, Adoor, on bark of *Moringa oleifera*, 9.162°N & 76.726°E, 60m, coll. S.A. Zachariah; RHK L0265, 12.x.2018, Kerala, Pathanamthitta District, Vennikkulam, on bark of *Alstonia scholaris*, 9.408°N & 76.675°E, 63m, coll. S.A. Zachariah; RHK L0266, 12.x.2018, Kerala, Pathanamthitta District, Vennikkulam, on rock, 9.408°N & 76.676°E, 63m, coll. S. A. Zachariah; RHK L0298, 18.x.2018, Kerala, Pathanamthitta District, Adoor, on bark of *Artocarpus heterophyllus*, 9.166°N & 76.720°E, 54m, coll. S.A. Zachariah; RHK L0359, 26.x.2018, Kerala, Pathanamthitta District, Mylapra, on bark of *Hevea brasiliensis*, 9.292°N & 76.807°E, 220m, coll. S.A. Zachariah; RHK L0385, 7.xi.2018, Kerala, Pathanamthitta District, Koodal-Rajagiri, on bark of *Hevea brasiliensis*, 9.151°N & 76.881°E, 98m, coll. S.A. Zachariah; RHK L0417, 12.xi.2018, Kerala, Pathanamthitta District, Malayalappuzha-Puthukkulam, on bark of *Cocos nucifera*, 9.301°N & 76.841°E, 128m, coll. S.A. Zachariah; RHK L0418, L0419, LWG 35841, 12.xi.2018, Kerala, Pathanamthitta District, Puthukkulam-Thekkummala, on bark of *Alstonia scholaris*, 9.303°N & 76.839°E, 133m, coll. S.A. Zachariah.

Image 7. *Phyllopsora parvifolia* var. *subgranulosa* (Tuck.) Müll. Arg.

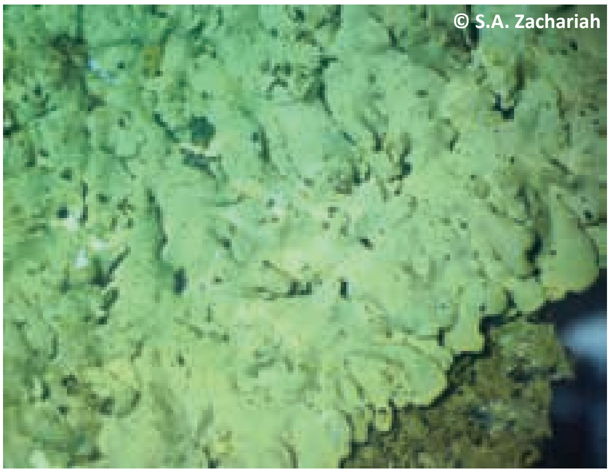

Image 8. *Physcia dilatata* Nyl.

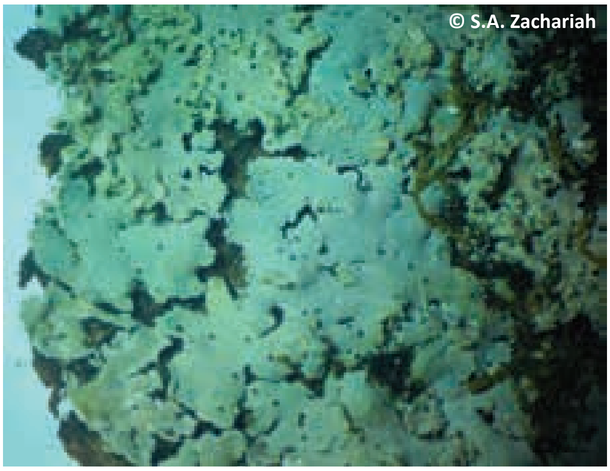

Image 9. *Physcia dubia* (Hoffm.) Lettau

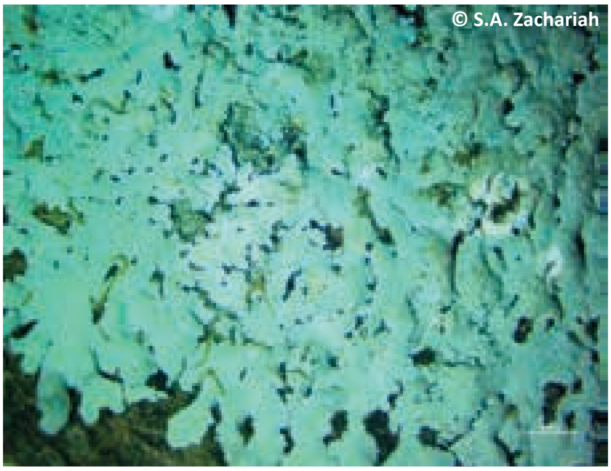

Image 10. *Physcia sorediosa* (Vain.) Lynge

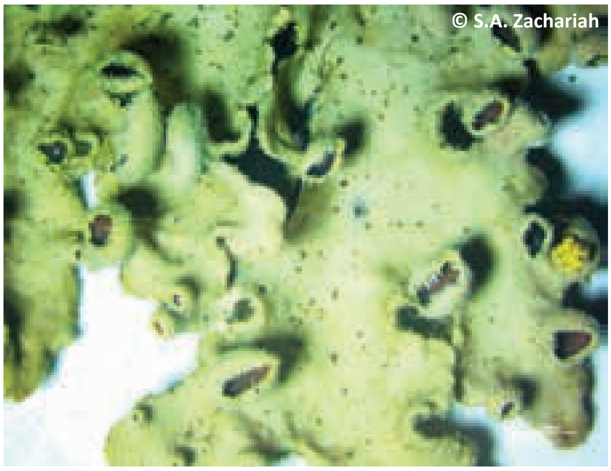

Image 11. *Pseudocyphellaria clathrata* (De Not.) Malme

Distribution: In India, this species was earlier reported from Nagaland and Tamil Nadu (Singh & Sinha 2010).

11. *Pseudocyphellaria clathrata* (De Not.) Malme

Ark. Bot. 26A (14): 9. 1935. (Lobariaceae) (Image 11)

Specimens examined: RHK L0617, LWG 35847, 22.ii.2019, Kerala, Pathanamthitta District, Pachakkanam, on bark, 9.458°N & 77.141°E, 964m, coll. S.A. Zachariah.

Notes: Earlier reports in India are from Sikkim and Nagaland (Singh & Sinha 2010).

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