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Coimbatore, Tamil Nadu 641035, India
Ph: +91 9385339863 | www.threatenedtaxa.org
Email: sanjay@threatenedtaxa.org

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Caption: Stripe-backed Weasel *Mustela strigidorsa*. Medium—digital, Software—procreate, Device—iPad + Apple pencil © Dhanush Shetty.

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ARTICLE

Roosting habits and habitats of the Indian Flying Fox *Pteropus medius* Temminck, 1825 in the northern districts of Tamil Nadu, India

M. Pandian [1] & **S. Suresh** [2]

[1] No. F1901, Taisha, Natesan Nagar West, Virugambakkam, Chennai, Tamil Nadu 600092, India.
[2] Department of Statistics, University of Madras, Chepauk, Chennai, Tamil Nadu 600005, India.
[1] pandian.m14@gmail.com (corresponding author), [2] sureshstat22@gmail.com

Abstract: This paper pertains to the study on roosting habits and habitats of the Indian Flying Fox *Pteropus medius* Temminck, 1825 in 12 villages of four northern districts—Vellore, Krishnagiri, Tiruvannamalai, and Viluppuram—of Tamil Nadu. Studies targeted roosting tree species, population status, diurnal-roosting behaviour, interactions with other animals, and probable threats to the species. A total of 22,365 individuals of the species were observed in 72 roosting colonies in 72 trees belonging to nine families, 11 genera, and 13 species. The tree species that harbored the greatest population of *P. medius* (n= 12,465) were those of *Tamarindus indica* L. (Fabaceae) (n= 39), followed by *Ficus religiosa* L. (Moraceae) (n= 3,960), *Madhuca latifolia* J.F. Macbr. (Sapotaceae) (n= 2,760), and *Ficus benghalensis* L. (Moraceae) (n= 1,620). One-Way ANOVA revealed that a significant relationship exists between colony size and tree diameter at breast height (dbh), and their canopy size ($p < 0.05$). However, no significant difference occurred between the colony size and tree height. The time taken for emergence of individuals of the colony from the canopy for foraging varied between 20 and 40 min after 1750 h in the evening. The species mostly roosted on trees proximal to human settlements, electrical power lines, and water bodies. Individuals of *P. medius* used various tree species in different areas in different geographical regions and did not maintain any consistency in roosting tree species selection. A majority of individuals (88.7 %; n= 887) were found roosting using both legs and a minority of *P. medius* (11.3 %; n= 113) were clinging to tree branches using one. Individuals of *P. medius* flew to nearby water bodies to quench thirst and cool their bodies. Mating was observed during day roost in 146 pairs including male-female fellatio in seven pairs. Smoke from shrines in sacred groves, pruning of branches for various cultural reasons, populations of House Crow *Corvus splendens* (Vieillot, 1817) (Corvidae), Black-winged Kite *Elanus caeruleus* (Desfontaines, 1789) and Black Kite *Milvus migrans* (Boddaert, 1783) (both Accipitridae) were key disturbances to roosting populations of *P. medius*.

Keywords: Diurnal behaviours fellatio, mating, *Pteropus giganteus*, roosting trees, threats.

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Author details: M. Pandian has completed MSc, PhD, in Botany and BLIS from University of Madras and Bachelor of Education (BEd) from Annamalai University, Chidambaram and now serves in Tamil Nadu Police Department. His area of interest is ecology and nesting biology of birds and has published a few papers on house sparrows, weaver birds, munias and ring-necked parakeets. S. Suresh has completed MSc, and PhD, in Manonmaniam Sundaranar University, Tirunelveli and a recipient of INSPIRE Fellow under Department of Science and Technology. He has published few articles in the field of time series analysis and data mining in reputed journals. He is a life member of statistics forums IISA and ISPS. He has rich knowledge in R programming languages.

Author contributions: MP has conceptualized, designed the research, performed survey, wrote paper, reviewed and edited the paper for final approval. SS has analysed the data and gave interpretations.

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INTRODUCTION

The order Chiroptera consists of over 1,400 species of bats worldwide, of which 148 species occur in southern Asia (Simmons & Cirranello 2020; Srinivasulu et al. 2021a). Pteropodidae, the Old-World fruit-eating bats, are well adapted to live in the tropics, particularly in India, Bangladesh, Bhutan, Nepal, China, the Maldives, Myanmar, Pakistan, and Sri Lanka (Helgen et al. 2009; Jnawali et al. 2011). India harbors 12 species of fruit bats and among them three occur commonly; they include *Pteropus medius*, *P. leschenaultii*, and *Cynopterus sphinx* (Srinivasulu et al. 2021b). The Indian Flying Fox *Pteropus medius* Temminck, 1825 (earlier treated as *P. giganteus*) is one of the largest bats and is widely distributed in southern and south eastern Asia (Marimuthu 1996). This species is a gregarious, colonial mammal that roosts in large trees that possibly protect them from strong winds and offer an easy updrift access for flight. The number of individuals of *P. medius* per colony was found to be varied. Between 260 and 1,550 individuals were recorded during different months (January–October) in a single colony in the Kathmandu valley, Nepal (Manandhar et al. 2018), whereas a colony of 2,844 individuals was recorded in the Lower Dir district, Pakistan (Khan et al. 2021). A total of 11,000 individuals were counted on 182 trees in Jambughoda Wildlife Sanctuary, Gujarat (Vyas & Upadhyay 2014). An average of 43 to 6,141 individuals was counted in the colonies on 19 tree species in Odisha (Rao & Poyyamoli 2017). In Tamil Nadu, over 600 individuals in Nallur near Chennai (Smith 1998), 16,000 individuals in Srivaikundam (Sudhakaran et al. 2010), and 431 individuals in Pudukottai district were enumerated. They usually prefer to roost on tall trees in urban areas of Lahore, Pakistan (Gulraiz 2014). In Tamil Nadu, they preferred *Terminalia arjuna* trees in Srivaikundam (Sudhakaran et al. 2010) whereas *Vachellia leucophloea* (= *Acacia leucophloea*) and *Pongamia pinnata* in Pudukottai district (Tangavelou et al. 2013)

Generally, bat roosting sites are found adjacent to water bodies (Fenton & Barclay 1980; Kunz 1982; Thomas 1988). The colonies of *P. medius* mostly preferred to choose trees for roosting near human settlements in India and Nepal (Bates & Harrison 1997; Katuwal et al. 2019). They exhibit various diurnal behaviour during day roost and belly-soaking behaviour is very common among this species during summer in Purulia district of West Bengal probably to regulate body temperatures (Dey et al. 2015). This species utilizes rain water droplets to quench its thirst by licking rain droplets from its patagium (Baskaran et al. 2016). The majority of individuals cling to the branches using either both legs or with single leg (Rao & Poyyamozhi 2017). Mating in the day roost and fellatio behaviour in hetero-sexual pairs was common among bats (Wilkinson 1986; Kerth et al. 2003; Tan et al. 2009), and so in *P. medius* individuals (Maruthupandian & Marimuthu 2013). The emergence time of *P. medius* individuals from the roosting trees varied: early emergence occurred during winter (1720–1837 h) and delayed emergence during summer (1838–1946 h) in Mohanlal Ganj, Uttar Pradesh (Ramkumar et al. 2019).

Populations of flying foxes are declining worldwide (Mildenstein et al. 2005; Stier & Mildenstein 2005) due to growing human population, destruction of habitats by felling of trees (Chakravarthy & Yeshwanth 2008), hunting by humans (Marimuthu 1996), shortage of their food resources, and urbanization (Fujita & Tuttle 1991; Mickleburgh et al. 2002). Deforestation, electrocution, expansion of highways, construction of buildings, and hunting reduces populations of *P. medius* (Molur et al. 2008; Ali 2010). A variety of birds of prey and various reptiles including snakes and lizards prey upon bats (Pierson & Rainey 1992). Ethnic communities usually hunt the Indian Flying Fox for meat as they believe it to have medicinal value (Acharya 2008; Thapa 2008). Various conservation attempts have been made for tree roosting *P. medius* (Katuwal et al. 2019). The IUCN Red List of Threatened Species categorises conservation status of this species as 'Least Concern' (Tsang 2020). No detailed studies were carried out on the habits and habitats of *P. medius* in the northern parts of Tamil Nadu. Hence to fill up this gap the present study was carried out.

This study, focussing on how habitat disturbances will affect the populations of *P. medius*, will contribute to future studies on the role of habitat disturbances on species in southern India. In this study, we aimed to document the diurnal roosting behaviour of *P. medius* with special reference to trees utilized in northern Tamil Nadu. The following objectives were targeted: (1) to assess the population status of *P.* medius and roosting tree species in the study area; (2) to understand the relationship between the roosting sites of *P. medius* and distances from human settlements, electric power lines, water bodies, and mobile-phone towers; (3) to document diurnal behaviours including mating and pre-emergence patterns; (4) to know interaction with other animals; and (5) to access the probable threats to their populations.

MATERIALS AND METHODS

Study Area

The study was carried out in 12 villages (listed in the legend of Figure 1) located in Krishnagiri, Vellore, Tiruvannamalai, and Viluppuram districts of northern Tamil Nadu (c. 17,000 km^2, c. 80,40,000 human population). Agriculture is the principal occupation of the residents. The maximum and minimum annual temperatures in these districts are 36 °C and 20 °C, respectively. The average annual rainfall is 1,060 mm (www.tn.gov.in).

Methods

We selected 72 active roosting colonies of *P. medius* distributed on 72 trees belonging to 13 species in 12 villages where *P. medius* populations were known to be locally present through nomadic gypsies. The number of *P. medius* observed on each tree was considered a single roost/colony. The roosting colonies and trees were surveyed between 0600 and 1900 h from June 2020 to January 2021.

Questionnaire study: Eighty respondents, all above 60 years old, residing adjacent to the roosting sites were interviewed as they have information from the past, in

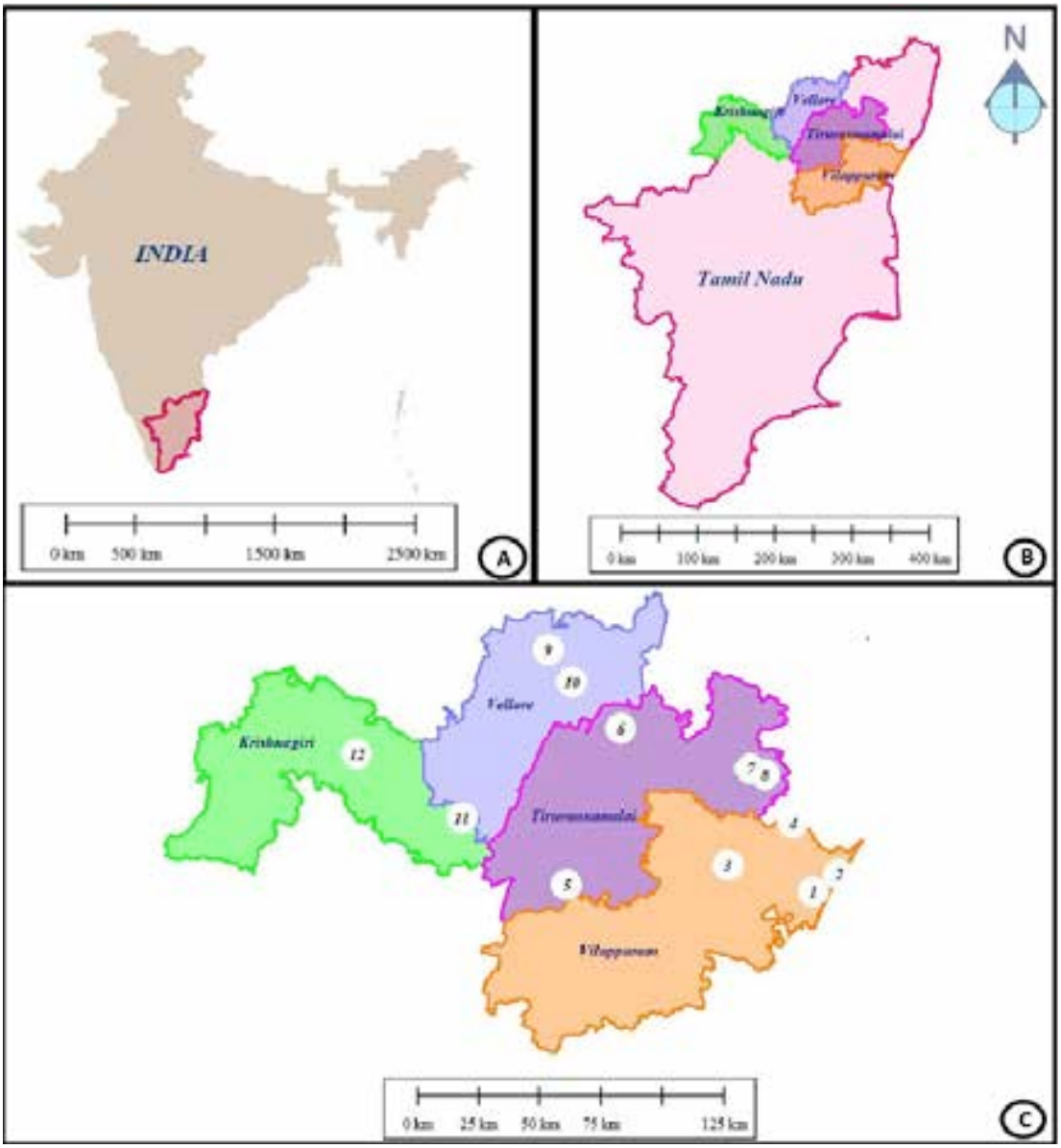

Figure 1. Study area: A—India map showing Tamil Nadu | B—Tamil Nadu indicating four study districts | C—Names of the 12 villages: 1. Kazhuperumbakkam, 2. Anumandai, 3. Maruvur, 4. Padhiri, 5. Rayandapuram, 6. Kesavapuram, 7. Vandavasi, 8. Marudhadu, 9. Gudiyatham, 10. Ongapadi, 11. Chenur, and 12. Junjupalli.

the selected 12 villages using a questionnaire survey form (in the Tamil language). The questionnaire form included questions on time periods of existence of the local *P. medius* colonies, population trends, details on roosting trees and tree selection, persecution and hunting of the flying fox, and perception of the local community about the animal as a nuisance, and the probable threats to the populations of local *P. medius* colonies.

Population count: A population count of the selected *P. medius* colonies was carried out visually and by using a pair of Super Zenith field binoculars (Model No. 20 x 50 Field 3^{O}, Jack Berg, El Paso, Texas, USA) following Barlow's (1999) direct roost-count method. The count was conducted fortnightly during June–July 2020 and the numbers were arithmetically averaged.

Behavioural study: Some behaviours of the species in the colonies such as grooming, mating, and interactions with other animals were also observed. Anthropogenic impacts such as smoke from cooking, hunting, and pruning of trees chosen for roosting were observed and the level of impact was categorized. The height was measured using Silva Clinometer (Gulraiz 2014), dbh (diameter at breast height), canopy width and distance between roosting trees were measured using 100 m measuring tape. The nearest human settlements, power lines, water bodies, and mobile-phone towers were measured using a 100 m measuring tape. The canopy width was obtained by cross method (Blozan 2006) by measuring the edge of the canopy shadow on the ground. The pre-emergence and emergence activities were observed between 1700 and 1900 h for 20 days in January 2021. Locations of the colonies and mobile-phone towers were determined using a standard GPS (Garmin Etrex 20x, 2017, Garmin Corporation, Taiwan). Photographs and videography were made using a digital camera (Nikon Coolpix P1000 Super-telephoto, Nikon).

Data Analysis

One-way analysis of variance (ANOVA) was used to test the difference in means between the numbers of *P. medius* counted and the types of roosting tree species by using Statistical Package for Social Science (SPSS version 25.0 software). Roosting tree species having more than two individuals were considered for analysis. Those tree species with less than two individuals were ignored. One-way ANOVA was used to test the significance between the numbers of individuals of *P. medius* counted and the height, dbh, and canopy size of roosting trees. Test of significance between the variables was assessed at $p < 0.05$.

RESULTS

Tree species selection for roosting

A total of 22,365 individuals of *P. medius* were counted from 72 colonies (Table 1). The roosting sites occurred in and around 11 human settlements, 11 sites in farmlands, and five sites near shrines within sacred groves. Out of the 12 villages, the maximum individuals that is 32.64 % (n= 7,298) occurred in Ongapadi (Vellore district) and the least 1.77 % (n= 398) in Junjupalli (Krishnagiri district). Among four districts, the highest population of *P. medius* (n= 9,268; 41.45 %) occurred at Vellore district on 10 trees, followed by 23.68 % (n= 5,298) on 47 trees in Tiruvannamalai district, and 20.91 % (n= 4,678) on seven trees in Krishnagiri district. The least populations of 13.95 % (n= 3,121) were counted on eight trees in Viluppuram district. On an average, 310 individuals of *P. medius* /tree existed in the study area. (Table 1, Image 1).

Altogether, 13 species belonging to 11 genera and nine families of 72 trees were roosted upon by *P. medius*. *Bambusa arundinacea* (L.) Voss (Poaceae), a large, arborescent herb, was one among the 13 species. A total of 12,465 individuals (55.73 %) of *P. medius* lived on 49 trees of the family Fabaceae. Most of the colonies (53.9 % of their total population, n= 12,055) were on *Tamarindus indica* L. (n= 39) and a minimum population (0.12%, n= 28) on a single *Lannea coromandelica* (Houtt.) Merr. (Table 2).

The tree species used for roosting, such as *Delonix regia* (Boj. ex Hook.) Raf.*, Azadirachta indica* A. Juss.*, Ceiba speciosa* (A.St.Hil.) Ravenna*, Lannea coromandelica* (Houtt.) Merr.*, Madhuca longifolia* J.F.Macbr.*, Syzygium cumini* (L.) Skeels., and *Terminalia arjuna* L. were represented only by either one or two trees which were excluded from the analysis. Statistical testing (ANOVA) revealed a significant relationship between the means of *P. medius* individuals and the tree species chosen by *P. medius* for roosting ($F_{5,56}$= 5.35, $p < 0.05$).

One-way ANOVA shows the relationship between the height, dbh, and canopy size of the roosting trees. However, no significant relationship occurred between the average number of *P. medius* and heights of the trees ($F_{2,69}$= 1.42, $p > 0.05$). Nevertheless, there was a significant difference between the average number of *P. medius* and the dbh of trees used by *P. medius* for roosting ($F_{2,69}$= 8.25, $p < 0.05$). In addition, significant differences occurred between the number of *P. medius* and the canopy size of roosting trees ($F_{2,69}$= 10.34, $p < 0.05$).

Table 1. District-wise details of villages, GPS co-ordinates, number of roosting trees and total number of Pteropus medius counted in the study area.

	District	Name of the village	GPS	Total no. of trees have roosting colony	Total no. of *P. medius* counted on these trees	Percentage (%) of *P. medius*
1	Vellore	Gudiyatham	12.938438°N, 78.861062°E	4	1970	8.8
2		Ongapadi	12.822734°N, 78.946628°E	6	7298	32.63
3	Krishnagiri	Junjupalli	12.564656°N, 78.164119°E	4	398	1.64
4		Chenur	12.360311°N, 78.583989°E	3	4280	19.13
5	Tiruvannamalai	Rayandapuram	12.092188°N, 78.928710°E	13	2723	12.17
6		Kesavapuram	12.655683°N, 79.126282°E	18	1417	6.33
7		Vandavasi	12.510984°N, 79.597503°E	10	700	3.12
8		Marudhadu	12.490742°N, 79.653357°E	6	458	2.94
9	Viluppuram	Kazhuperumpakkam	12.067317°N, 79.829502°E	1	780	3.48
10		Anumandhai	12.131800°N, 79.911418°E	4	1251	5.59
11		Maruvur	12.164664°N, 79.515650°E	1	410	1.83
12		Padhiri	12.314802°N, 79.755639°E	2	680	3.04
Total	4	12		72	22365	100

Table 2. Details on the diversity of roosting trees and total *Pteropus medius* counted in the study area.

	Type of roosting trees	Family	Total no. of trees have *P. medius* roosting	Total no. of *P. medius* individuals counted
1	*Albizia lebbeck* (L.) Benth.	Fabaceae	5	219
2	*Dellonix regia* (Boj. ex Hook.) Raf.	Fabaceae	1	120
3	*Pongamia pinnata* (L.) Panigrahi	Fabaceae	4	71
4	*Tamarindus indica* L.	Fabaceae	39	12055
5	*Azadirachta indica* A.Juss.	Meliaceae	1	46
6	*Bambusa arundinacea* (L.) Voss	Poaceae	7	468
7	*Ceiba speciosa* (A.St.Hil.) Ravenna	Malvaceae	2	175
8	*Ficus benghalensis* L.	Moraceae	4	1620
9	*Ficus religiosa* L.	Moraceae	3	3960
10	*Lannea coromandelica* (Houtt.) Merr.	Anacardiaceae	1	28
11	*Madhuca longifolia* J.F.Macbr.	Sapotaceae	1	2760
12	*Syzygium cumini* (L.) Skeels.	Myrtaceae	2	56
13	*Terminalia arjuna* (Roxb.) Wight & Arn.	Combretaceae	2	787
Total		**9**	**72**	**22365**

Apparent preference of trees close to human settlements

Sixty per cent of the trees used for roosting (n= 43) and 80 % individuals of total population of *P. medius* (n= 17,880) occurred within 100 m radius from human settlements. No roosting trees were located between 100 and 250 m. Only 40 % trees used for roosting (n= 29) and 20 % individuals (n= 4,485) of *P. medius* were found beyond 250 m (Figure 2).

Forty-three per cent of trees used for roosting (n= 31) and 64.75 % of *P. medius* (n= 14,482) occurred within a 25-m radius from electric power lines. A maximum of 84.72 % of trees used for roosting and 92.1 % *P. medius* (n= 20,600) occurred within a 100-m radius from power lines. Only 15.28 % of trees used for roosting (n= 61) and 7.9 % of *P. medius* (n= 1,765) occurred beyond 100 m. No mortality of *P. medius* due to electrocution was noticed during the study period (Figure 3).

Ninety-six per cent of trees used for roosting (n= 69) and 80.86 % of *P. medius* (n= 18,085) occurred within 1,000-m radius from water bodies such as lakes, ponds, rivers, and canals (Figure 4). Thirty-two per-cent of trees used for roosting (n= 23) and 50.4 % *P. medius* individuals (n= 11,272) occurred within a 500-m radius from mobile-phone towers and 62.5 % trees (n= 45) and 28.62 % *P. medius* (n= 6,403) were observed within a 501–2000 m radius from mobile-phone towers. The remaining 5.55 % trees (n= 4) and 20.97 % *P. medius* (n= 4,690) occurred beyond 2001 m from mobile-phone towers (Figure 5).

Perception of local people

Of the 80 local respondents interviewed, 87 % residents (n= 66) were concerned over the declining populations of *P. medius* and the numbers of trees

Image 1. Roosting habitats of *Pteropus medius*: a & b—Roosting habitats in sacred groves | c & d—Roosting in *Tamarindus indica* tree | e—Male in *Ficus benghalensis* tree | f—Female in *Ficus benghalensis* tree | g—Power cables passing adjacent to roosting tree *Tamarindus indica* | h—Roosting *Bambusa arundinacea* bush near water body. © M. Pandian

used for roosting. That the residents of these villages consider roosting populations of flying foxes important in their culture and life is notable. For example, if they considered it a bad omen, they would have either cut those trees that accommodate roosting populations of *P. medius* or chased the roosting colonies away from the trees. However, in Junjupalli village, we observed that soon after a marriage ceremony, the married couple worshipped the tree (*Ficus benghalesnsis*) supporting a roosting population of *P. medius*. Residents from the villages reported that the numbers of *P. medius* had reduced, compared to six decades ago. Thirty-five residents (44 %) indicated either occasional or clandestine hunting of *P. medius* for folk-medicinal reasons. Seventy-four residents (92 %) considered the presence of a roosting colony as a sign of prosperity to their village. Sixty residents (75 %) indicated that cracker bursting was always done only after sunset when *P. medius* population was away from the trees for foraging. To protect roosting colonies of *P. medius* residents of Ongapadi village avoided bursting crackers during festive times. Seventy-four residents (92 %) considered *P. medius* populations within the village were never a nuisance; despite the fact that these animals desecrate houses, walls, and other common public areas under the roosting trees, and the foul odour emanating from the droppings. Sacredness and an environmental value addition because of culture, offer 'protection' to populations of *P. medius* contributing to their conservation.

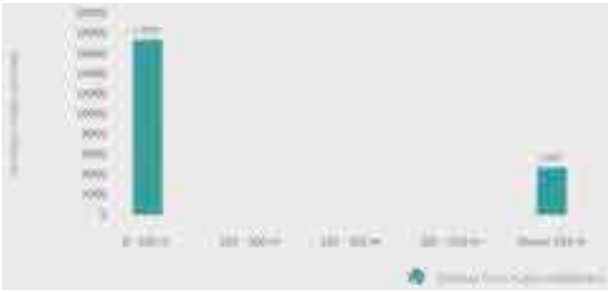

Figure 2. Bar-chart showing the distance between roosting of *Pteropus medius* and human dwellings in the study area.

Figure 3. Bar-chart showing the distance between roosting of *Pteropus medius* and power cables in the study area.

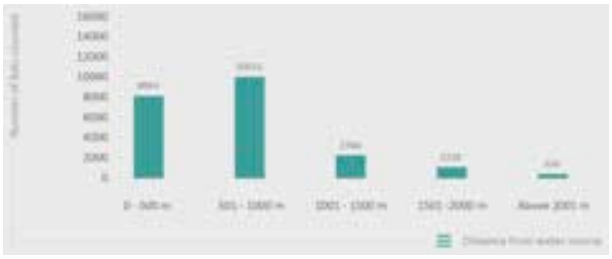

Figure 4. Bar-chart showing the distance between roosting of *Pteropus medius* and waterbodies in the study area.

Figure 5. Bar-chart showing the distance between roosting of *Pteropus medius* andmobile-phone towers in the study area.

Behaviour of *P. medius*

During the north-east monsoon rains (October—November 2020), individuals of *P. medius* were observed clinging to tree branches with their heads and ventral parts of their body wrapped with their membranous wings. Immediately after the rain, they flap their wings speedily and move from one branch to another. After the rain, they groom, scratch, and lick water droplets from their body (Image 2).

During hot summer days (June—July), individuals of *P. medius* moved from the top of the canopy downwards, i.e., midparts of the tree and roosted on large tree trunks, probably to avoid direct exposure to sunlight. In June–July 2020 in Marudhadu village, five incidents of *P. medius* individuals flying to a nearby lake and soaking the ventral part of their body were observed.

Mating

One-hundred-and-forty-six incidents of mating were observed in the studied villages between 0700 h and 1645 h during October—December 2020. A maximum of 26 pairs engaged in courtship and copulation was observed in Kesavapuram village, and two mating pairs in Anumandhai village. Before copulation, seven incidents of males licking the genitalia of the females

Image 2. Roosting habits of *Pteropus medius*: a—Individuals hanging with one and two legs | b—Fighting individuals | c—Roosting tree close to residence | d—Covering the body with patagium-ventral view | e—Covering the body with patagium-dorsal view | f—Covering the body with patagium-during rain. © M. Pandian

were observed, which occurred for 2—4.5 min. After copulation, both pairs moved away from each other and female–male fellatio stopped. Two instances of males licking their own penises before copulation were observed in Padhiri village (Table 3; Image 3).

Emergence from trees

A total of 20 pre-emergence and emergence activities were observed for 20 days continuously from 1700 to 1900 h in Kazhuperumbakkam and Maruvur (Viluppuram district). Frequent and irregular migrations of individuals from one branch to another either in the same tree or between different trees occurred between 1710 and 1750 h. From a minimum of one to a maximum of 11 were found flying, encircling the canopy for a few minutes and returning to the tree used for roosting.

Image 3. Roosting habits of *Pteropus medius*: a & b—*Pteropus medius* individuals migrate to tree trunk to avoid exposure to direct sunlight | c—Individual with punctured patagium | d—Female-male fellatio | e—Copulation | f—Desecration of residence due to excreta of roosting individuals | g & h—Pruned roosting trees. © M. Pandian

Image 4. Pictures showing threats to *Pteropus medius*: a—Monkey chases roosting *P. medius* individuals | b—Monkey slaps a *P. medius* | c—House Crow disturbs roosting colony | d—Black-winged Kite near roosting colony. © M. Pandian

Wing flapping and grooming activities were high and almost all individuals of *P. medius* concurrently made vocal communications, resulting in a loud, collective noise around the roost. The emergence of the first batch of individuals (10–50) from the colony occurred between 1750 and 1810 h. The emergence time of the last batch of the colony was between 1820 and 1840 h. The time taken for emergence of individuals (80–100) of the colony from the canopy varied between 20 and 40 min.

Interactions with other animals

Twelve incidents of *Macaca radiata* (E. Geoffroy, 1812) (Cercopithecidae) living on *T. indica* trees in Gudiyatham and Rayandapuramwere observed. When a troop of *M. radiata* climbed over *T. indica* trees to feed on flowers and raw fruits, *P. medius* individuals from the nearby branches flew away from these trees to nearby trees. In one instance, one *M. radiata* was found slapping a roosting *P. medius* when the latter hindered it while plucking fruits of *T. indica*. *Corvus splendens* frequently visited the trees used by *P. medius* for roosting, disturbing them. When the *P. medius* started to fly, *C. splendens* selectively chased the juveniles of *P. medius* away. A total of 36 incidents of *C. splendens* chasing *P. medius* individuals from roosting colonies were observed. But no incidents of *C. splendens* predating on the juveniles of *P. medius* were found during the study (Fig 10).

Threats

Smoke disturbance to roosting colonies of *P. medius* was common around shrines located within sacred groves. Local residents cook porridge on firewood stoves to offer to deities in the sacred groves in Marudhadu, Kazhuperumpakkam, Padhiri, Maruvur, and Chenur during July–August and January–February. The emerging smoke disturbed *P. medius* individuals, driving them away from the trees to migrate to other trees (e.g., *T. indica* and *F. religiosa*) situated outside the villages for roosting.

Trees chosen for roosting by *P. medius* adjacent to residential areas and farm lands are frequently pruned because the village administrators see them as obstructions to electric power lines and villagers who see

Table 3. Details of mating pairs and female-male fellatio observed during day roost in October and December 2020 in the study area.

	District	Name of the village	Total no. of mating individuals observed	Female-male fellatio observed
1	Vellore	Gudiyatham	12	2
2		Ongapadi	08	0
3	Krishnagiri	Junjupalli	14	0
4		Chenur	04	1
5	Tiruvannamalai	Rayandapuram	22	0
6		Kesavapuram	26	2
7		Vandavasi	08	0
8		Marudhadu	14	0
9	Viluppuram	Kazhuperumpakkam	20	1
10		Anumandhai	02	0
11		Maruvur	06	0
12		Padhiri	12	1
Total	4	12	146	7

them preventing sunlight to crop plants. One *P. medius* individual was noticed with a damage on its patagium. Although the exact cause for the damage was unknown. One Black-winged Kite *Elanus caeruleus* (Desfontaines, 1789) was seen hovering and roosting on power lines in the vicinity of trees used by *P. medius* for day roost at Maruvur village, although no incident of attack by *E. caeruleus* on *P. medius* was observed. Villagers remarked that Black Kites, Black-winged Kites, and House Crows occasionally predate on the juveniles of *P. medius*.

DISCUSSION

Tree species selection for roosting

The Indian Flying Fox has been known to use nine tree species in avenues in Delhi (Mishra 2010) and 18 tree species in Uttar Pradesh (Kumar et al. 2017). In the present study conducted in Vellore, Krishnagiri, Tiruvannamalai, and Viluppuram districts in northern Tamil Nadu, *P. medius* populations used 13 tree species belonging to nine families and 11 genera for roosting. Among the 13 species of roosting trees, *T. indica* and *L. coromandelica* are the most preferred by the flying fox in Tamil Nadu. The same taxa also commonly occur in Vellore, Krishnagiri, Tiruvannamalai, and Viluppuram districts, except *H. brasiliensis* (Vijayasankar et al. 2012) but these tree species were not selected by *P. medius* populations for roosting. Tree species such as *P. longifolia*, *Neolamarckia cadamba* (Roxb.) Bosser. (Rubiaceae), *Eucalyptus citriodora* (Hook.) K.D.Hill & L.A.S. Johnson (Myrtaceae), *Mimusops elengi* L. (Sapotaceae), *Samaneae saman* (Jacq.) Merr. (Fabaceae), *Tectona grandis* L.f. (Lamiaceae), *Peltophorum pterocarpum* (DC.) K.Heyne, and *Lagerstroemia speciosa* (L.) Pers. (Lythraceae) (Rao & Poyyamoli 2017) were not used by *P. medius* in Vellore, Krishnagiri, Tiruvannamalai, and Viluppuram disricts. In Pudukkottai district, central Tamil Nadu, *P. pinnata* and *V. leucophloea*, especially in the sacred groves, were the trees used maximally for roosting (Tangavelou et al. 2013). In the present study, *P. pinnata* was the tree that housed maximum roosting populations of *P. medius* (n= 71). Different species of *Eucalyptus* (Myratceae) were the most used trees for roosting in Kathmandu (Nepal) (Manandhar et al. 2018). But in the present study area no *Eucalyptus* tree species was used by *P. medius* for roosting, although various species of *Eucalyptus* occur abundantly in the studied districts. The reason may be due to the felling of *Eucalyptus* trees periodically by the social forestry department because these trees were not allowed grow for long periods and hence, *P. medius* might have avoided selecting this tree species. These findings indicate that *P. medius* use various tree species in different geographical regions and do not maintain any consistency in tree selection for roosting.

No positive relationship occurred between the numbers of *P. medius* and heights of the trees used for roosting ($F_{2,69}$= 1.42, p >0.05). Significant relationship existed between the dbh and canopy size of trees selected for roosting and the number of *P. medius* individuals in urban and semi-urban areas in Uttar Pradesh (Kumar & Elangovan 2019). In the present study, a significant, positive relationship occurred between the means of *P. medius* individuals and numbers of *A. lebbeck*, *P. pinnata*, *T. indica*, *B. arundinacea*, *F. benghalensis*, and *F. religiosa* chosen by *P. medius* for roosting ($F_{5,56}$= 5.35, p <0.05). There was a significant difference between the average number of *P. medius* and the dbh ($F_{2,69}$= 8.25, p <0.05) and the canopy size of trees used by *P. medius* for roosting ($F_{2,69}$= 10.34, p <0.05). It indicates that individuals of *P. medius* preferred trees with larger dbh and larger canopy size for roosting in the study area.

Apparent preference of trees close to human dwellings

In the Indian subcontinent, populations of *P. medius* mostly preferred to choose trees for roosting near human settlements (Bates & Harrison 1997). In lower Nepal, most of the colonies of *P.* medius were recorded close to human settlements and in farmlands (Katuwal et al. 2019). This species roosts on trees that occur close to human settlements in Tirunelveli district, viz., sacred

groves, and agricultural lands (Jayapraba 2016). In the present study, 60 % of trees (n= 43) chosen for roosting and 80 % *P. medius* individuals (n= 17,880) were found within 100 m radius from human settlements and hence it is in accordance with the observations of Bates & Harrison (1997), and Katuwal et al. (2019).

Behaviours observed

In New South Wales, Australia, flying foxes were observed to visit nearby water bodies in peak summers to soak their fur and wings to cool their bodies (Welbergen et al. 2008). Belly-soaking behaviour is very common among the Indian Flying Fox during summer in Purulia district of West Bengal (Dey et al. 2015). In the present study, the observations of partial dipping of its ventral body surfaces in water might have been to quench its thirst and to reduce its body temperatures during hot summer and hence it matches with the views of Dey et al. (2015) and Welbergen et al. (2008).

Populations of *P. medius* usually roost on trees for 12–14 h daily hanging from branches. A majority of individuals (88.7 %) were found roosting using both legs and a minority of *P. medius* (11.3 %) were clinging to tree branches using one. They probably relax their leg muscles by alternately using both or a single leg and it requires further studies. The majority of individuals clinging to the branches used both legs during day roost as stated by Rao & Poyyamozhi (2017).

After rainfall the individuals of *P. medius*, groom, scratch, and lick their body to remove the water droplets (Maruthapandian & Marimuthu 2013). This species utilizes rain water droplets to quench their thirst by licking rain droplets from the wing membrane (Baskaran et al. 2016). As stated by the above authors, in the present study also we observed similar behaviours of *P. medius* individuals scratching and licking its body and removing water droplets. The droppings of *P. medius* desecrate human residences, common usage areas, and cause foul odour, but the residents tolerate it and allow roosting colonies on trees in their villages.

The occurrence of mating in the day roost and fellatio behaviour in hetero-sexual pairs was common among *P. medius* individuals (Wilkinson 1986; Kerth et al. 2003; Maruthupandian & Marimuthu 2013; Tan et al. 2009). Similar behaviours while mating during day and female-male fellatio were observed in the current study as stated by the above authors.

Emergence from trees

The emergence time of *P. medius* individuals from the trees varied: early emergence occurred during winter (1720–1837 h) and delayed emergence during summer (1838–1946 h) in Mohanlal Ganj, Uttar Pradesh (Ramkumar et al. 2019). In the present study the emergence period during the winter season was between 1750–1840 h and it nearly corroborates with the observations of Ramkumar et al. (2019). The time taken for emergence of all the individuals of the colony was found to vary: 21 min to 39 min. The variations of emergence time during summer have not been studied.

Interactions with other animals

A variety of birds of prey, both Falconiformes and Strigiformes, various reptiles including snakes and lizards prey upon them (Pierson & Rainey 1992). Though monkeys and house crows caused disturbance to *P. medius* individuals, no incidents of predation was reported in the present study area. Villagers remarked that individuals of Black Kites and Black-winged Kites had frequented roosting colonies and predate of juveniles of *P. medius* and hence it corroborates with the findings of and Pierson & Rainey (1992). However, no predation by Black Kites, Black-winged Kites, and reptiles were noticed in the study sites.

Threats

This species roost on trees that occur close to human settlements, farmlands and sacred groves. Because of human habitation, electrical power lines usually occur close to those roosting trees. Ali (2010) reported small numbers of *P. medius* were found electrocuted and died in Dhubri district, Assam. The present survey revealed that no mortality of *P. medius* individuals was found in the surveyed four districts. Although 84.72 % trees chosen for roosting and 92.1 % *P. medius* individuals (n= 20,600) occurred within a 100-m radius from electrical power lines, no mortality due to electrocution was observed.

Hunting of bats for meat is still prevalent in some parts of Nepal (Katuwal et al. 2019). The meat of flying foxes ('valguli mamsa' in local language) is believed to be of some therapeutic value and its consumption is recommended locally. Meat of this species is consumed for treating rheumatism in India (Nowak 1999) and the people of Attapadi region (Kerala) believe that the meat of *P. medius* treats asthma and chest pain (Padmanaban & Sujana 2008). During the survey, 44 % of residents (n= 35) indicated either occasional or clandestine hunting of *P. medius* for folk-medicinal reasons.

Electromagnetic radiations exert an abnormal behaviour and affect the foraging activities of bats in Aberdeen, Scotland. Their activity was more rigorous in

the control sites than the sites exposed to a high level (>2v/m) of electromagnetic radiation (Nicholls & Racey 2007). In Mumbai, the number of flying foxes was found to have decreased when mobile-phone towers occurred within 80 m from a roosting colony (Kumar 2010). In the present study the minimum distance between a tree used for roosting and a mobile-phone tower was 40 m at Ongapadi (Vellore district) and the maximum 6,000 m in Maruvur (Viluppuram district). The trees used for roosting and *P. medius* populations revealed that a large number of trees chosen for roosting (31.94 %; n= 23) and *P. medius* individuals (50.4 %; n= 11,272) occurred within 500 m radius from the mobile-phone towers. However, in the event of the existence of mobile-phone towers in almost all villages, the situation of a tree 40 m distance from the mobile-phone tower, the exact impact of the mobile-phone tower on the roosting colonies of *P. medius* needs further study.

CONCLUSION

The populations of *P. medius* used 13 tree species belonging to 11 genera and nine families for roosting at various habitats, such as human dwellings, farmlands, and water bodies. No positive relationship occurred between the numbers of *P. medius* and heights of the trees used for roosting. There was a significant difference between the average number of *P. medius* and the dbh and the canopy size of trees used by *P. medius* for roosting. The individuals of *P. medius* were found soaking themselves in water during summer probably to reduce body temperatures. While roosting, they mostly cling on to tree branches using both legs, rarely using one. Mating and fellatio behaviour in hetero-sexual pairs were observed during the day roost. The time taken for emergence of individuals of the colony from the canopy varied between 20 and 40 min. No mortality due to electrocution was observed. The impact of mobile-phone towers on roosting colony needs further study. The roosting populations were disturbed by individuals of Bonnet Macaque, House Crow, Black Kite, and Black-winged Kite. Anthropogenic impacts like hunting, pruning trees used for roosting and smokes emanated from sacred groves during festivals pose a threat to the populations of *P. medius.*

In spite of rapid urbanization, industrialization, population increase, habitat destruction, hunting by villagers and decreasing areas of cultivation including orchards, considerable *P. medius* populations exist in the study area. A special management plan could be devised for the area, considering the anthropogenic and natural stresses to which the habitat is currently subjected. The present roosting sites should be declared as protected areas and further organisations (NGOs) have to play a major role in creating awareness among the general public to protect this species. This study clearly demonstrates the presence of 22,365 Indian Flying Fox individuals in their natural habitats and identifies current and emerging challenges in conservation of habitats of such key species in the natural ecosystems.

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ARTICLE

Diversity and distribution of avifauna at Warathenna-Hakkinda Environmental Protection Area in Kandy, Sri Lanka

Dinelka Thilakarathne [1], Tithira Lakkana [2], Gayan Hirimuthugoda [3], Chaminda Wijesundara [4] & Shalika Kumburegama [5]

[1,3,4,5] Department of Zoology, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka.
[1] Postgraduate Institute of Science, University of Peradeniya, Peradeniya, Sri Lanka.
[2] Faculty of Science and Technology, Uva Wellassa University, Passara Road, Badulla, Sri Lanka.
[1] dinelkat@yahoo.com, [2] tithiralakkana@gmail.com, [3] nadeela@lankamail.com, [4] chamindaw@sci.pdn.ac.lk,
[5] skumburegama@yahoo.com (corresponding author)

Abstract: The present study was carried out in the recently established Warathenna-Hakkinda EPA in the Kandy District, Sri Lanka to investigate the avifaunal diversity and conservation threats. Sampling was conducted in two main habitat types: river islands and riverine forests. Both point count (10 m radius) and line transect (200 m long) methods were utilized and maximum of 30 minutes was used to sample the birds in each point. Food habit, niche type, endemism, abundance, and diversity indices (Shannon & Margalef) were calculated to compare the two habitats in this area. A total of 74 bird species belonging to 61 genera and 35 families were encountered from the study site. Among these, seven species are endemic: Sri Lanka Grey Hornbill, Sri Lanka Green Pigeon, Sri Lanka Wood Pigeon, Sri Lanka Hanging Parrot, Crimson-fronted Barbet, Yellow-fronted Barbet, and Sri Lanka Hill Mynah; while six were migratory: Green Sandpiper, Common Sandpiper, Indian Pitta, Asian Brown Flycatcher, Yellow Wagtail, and Grey Wagtail and the rest were non-endemic natives. Most of them were canopy and sub canopy dwellers associated with riverine forests and islands. According to the National Red List of Sri Lanka, three species, the Sri Lanka Wood Pigeon, Sri Lanka Hill Mynah, and Alpine Swift, are listed as threatened. Ardeidae, Alcedinidae, Columbidae, Accipitridae, and Apodidae were the most species rich families in this habitat. Out of the sampled species, 31% and 25% of the birds were carnivores and insectivores, respectively, while 5% were nectarivores. According to the avifauna, the riverine forests are more diverse (Shannon index H'= 2.55; Margalef's index M= 10.92) than the river islands (H'= 2.29; M= 5.07) in this landscape. The variety of habitats along the Mahaweli River at Warathenna appears to aid in sustaining a rich bird community and this Environmental Protection Area will help create a safe haven for the birds.

Keywords: Birds, conservation threats, endemic species, riverine forests, Kandy District, river islands, Warathenna-Hakkinda.

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Author details: Dinelka Thilakarathne (B.Sc. and M.Phil.) is a Lecturer (Probationary) in the Department of Zoology, Faculty of Science, University of Ruhuna. Animal ecology and wildlife conservation are her main research interests and she is currently conducting biodiversity and animal ecology related research in Sri Lanka. Tithira Lakkana is a Research Assistant attached to the China-Sri Lanka Joint Center for Research and Education (CSL-CER), University of Ruhuna. He completed his M.Phil. (Forestry) in 2020 and is currently involved in the mangrove conservation project in Sri Lanka. His research interests are in plant regeneration and forest ecology. Gayan Hirimuthugoda is a Technical Officer at the Department of Zoology, University of Peradeniya. In reltation to his interests in biodiversity, he is currntly engaged in research work related to fish breeding, embryology and rearing, especially of endemic, Endangered species. Chaminda Wijesundara is a Senior Lecturer in the Department of Zoology, University of Peradeniya, Sri Lanka. He is currently engaged in research on waterbirds and songbirds. Shalika Kumburegama is a developmental biologist with a Ph.D. in Zoology from University of Hawaii at Manoa, USA. She is a Senior Lecturer in the Department of Zoology, University of Peradeniya, Sri Lanka and is involved in studies in embryology and developmental biology, and biodiversity and conservation.

Authors contributions: DK—research design, data collection, species identification, data analysis and manuscript writing. TL—research design, data collection, species identification, data analysis and manuscript reviewing. GH—research design, data collection, species identification and manuscript writing and reviewing. CW—species Identification, data analysis, manuscript reviewing. SK—research planning and designing, data collection, manuscript writing and reviewing. Principal Investigator of the research.

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INTRODUCTION

Sri Lanka and the Western Ghats of India is considered a global biodiversity hotspot due to the high diversity and species endemicity (Bossuyt et al. 2004). Sri Lanka, which is a tropical island located in the Indian Ocean between longitudes 79.65E and 81.88E and latitudes 5.90N and 9.86N experiences a year round tropical climate with average temperatures of 27–28 °C and a relatively constant day length (Wijesundara & de Silva 2005). The precipitation in the island is largely governed by the south-west and north-east monsoons (Ashton et al. 1997; Gunatilleke et al. 2008). Sri Lanka is renowned for the diversity and endemicity of its vertebrate fauna, including its diverse avifauna (de Silva Wijeyeratne 2014; Weerakoon 2015).

Sri Lanka is home to 240 breeding resident species, 216 purely migrant species, and 72 vagrant species of birds. Of the total 453 species, 27 are endemic, and six are proposed as endemics (Gunawardena & Weerakoon 2012), while 43 species, including five winter migrants are considered endemic to the southern Asian region (Kotagama & Wijeyasinghe 1998; Kotagama 2000; Santiapillai & Wijesundara 2002; Rasmussen & Anderson 2005; Wijesundara & de Silva 2005; Chandrasiri et al. 2018). According to the National Red List (MOE 2012), 46 of the breeding species on the island are nationally threatened, including 10 Critically Endangered, 15 Endangered, and 21 Vulnerable bird species. The country is divided into six avifaunal zones and two sub zones by considering the distribution patterns of the resident birds. The six major avifaunal zones are Highlands Avifaunal Zone, Wet Forest Avifaunal Zone, Uva Avifaunal Zone, Marine Avifaunal Zone, Palk Bay Coastal Avifaunal Zone, and Rakwana Hill Avifaunal Zone. The two sub zones are Wet Lowland Avifaunal Sub-Zone, and Wet Mid-Hill Avifaunal Sub-Zone (Kotagama 1993; MoMD&E 2019). This study was conducted to investigate the avifaunal diversity in the Warathenna-Hakkinda Environmental Protection Area (EPA) in the Kandy district located in the Wet Forest Avian Zone (Harrison & Worfolk 1999; MoMD&E 2019).

Warathenna-Hakkinda EPA was declared in 2017 after the findings of rare, endemic flora and fauna from this area. This EPA has an extent of 0.61 km^2 extending from the Halloluwa suspension bridge in the north to the Gatambe Bridge in the south, and bordered by the Peradeniya-Halloluwa-Katugastota Road on one side and the "Srimath Kuda Rathwaththe Mawatha", "Deveni Rajasinghe Mawatha", and the Colombo-Kandy Road on the other side of the river (Sri Lanka 2017: 4/81.VI). This EPA encompasses an approximately 2 km stretch of the Mahaweli River, all its river islands in this stretch referred to as the Hakkinda river islands, as well as the surrounding riverine forests and Kandyan home gardens. Only a handful of studies thus far have looked at the biodiversity in this area including the diversity of dragonflies and fish (Samarawickrama et al. 2012; Kumara & Samarawickrama 2017; Thilakarathne et al. 2019). The present study aimed to evaluate the species composition of the bird community in this EPA.

MATERIALS AND METHODS

Description of the study site

Mahaweli river is the longest river in Sri Lanka. It originates from the central highlands and flows through the wet, intermediate and dry zones of the country (Fernando 1990). The study was conducted along a 2 km stretch of the Mahaweli River in the Kandy District starting from the Gatambe main bridge (7.45N, 80.10E) to the Dodangwela Suspension Bridge (7.46N, 80.10E), from June 2016 to May 2017. This area falls within the Warathenna-Hakkinda Environmental Protection Area (EPA). The banks of the Mahaweli River along this stretch of the study site consists of riverine forests patches and river islands that were distinguished according to the geomorphological features and the vegetation characteristics.

Vegetation of the riverine forests and river islands consists of both native endemic and non-endemic plant species as well as higher number of exotic species due to the high influence of anthropogenic activities. In the riverine forests, plant species such as, *Terminalia arjuna, Neolitsea cassia*, *Mesua thwaitesii*, *Dillenia indica*, *Barringtonia racemosa*, *Horsfieldia iryaghedhi*, *Glochidion zeylanicum*, *Ficus tsjahela*, *Ficus benghalensis, Ficus racemosa, Symplocos cochinchinensis, Spathodea campanulata, Alstonia macrophylla, Michelia champaca, Caryota urens*, and *Bambusa vulgaris* were frequently encountered. In the approximately 20 river islands in the EPA (the largest of which has an extent of about 3.2 ha), plant species such as *Leea indica, Schefflera stellata*, *Ficus hispida, Ficus tinctoria*, *Ficus exasperata, Pandanus kaida*, *Syzygium jambos, Mimosa pigra*, *Clusia rosea*, *T. arjuna*, *D. indica*, *M. thwaitesii*, *N. cassia, Terminalia catappa*, and *Macaranga peltata* were recorded. Members of the genera *Lagenandra* (*L. praetermissa*) and *Cryptocoryne* (*C. undulata, C. beckettii, C. walkeri*, and *C. parva*) were seen in the shallow waters around the river islands. Furthermore, the exotic free floating

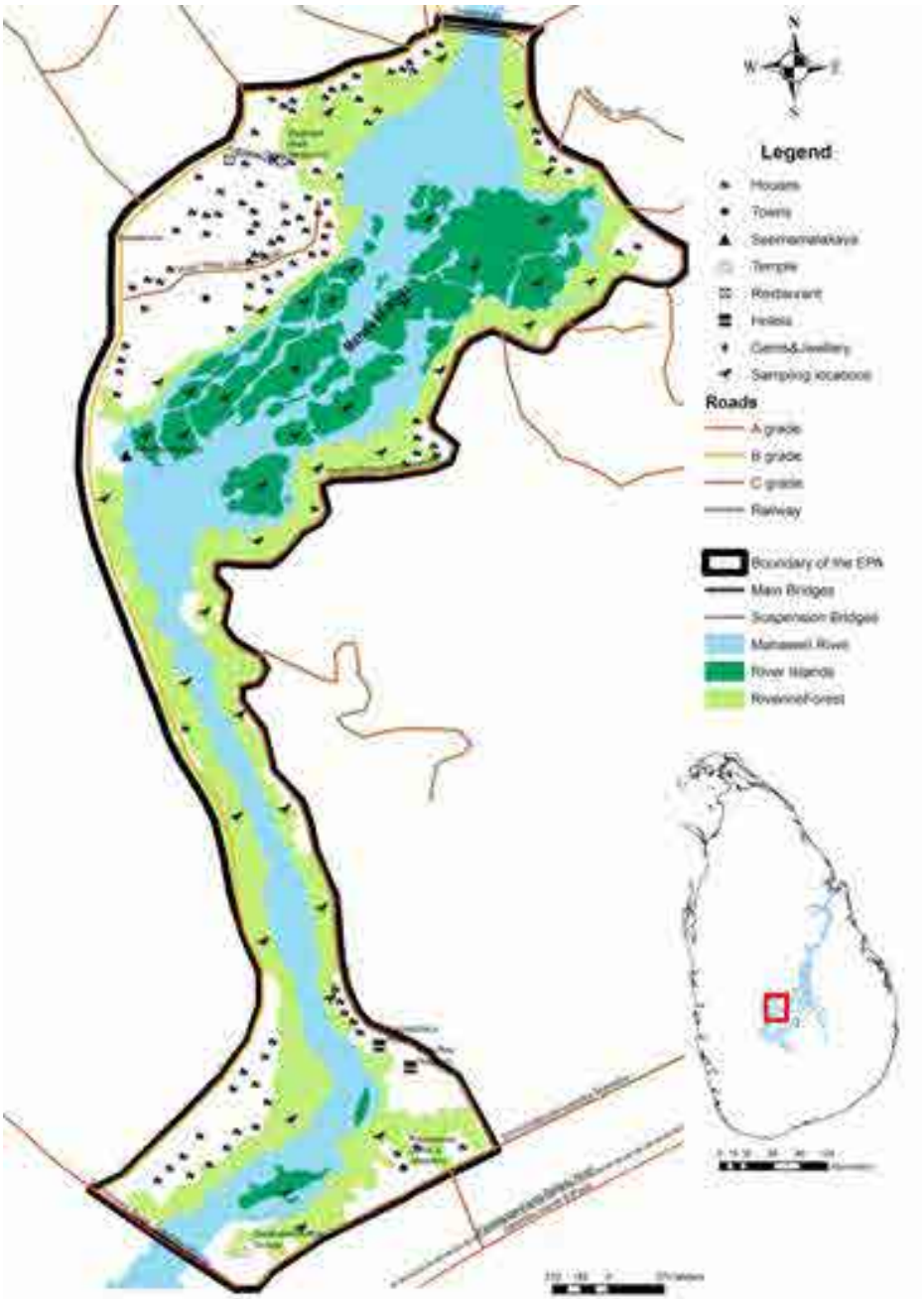

Figure 1. Map of Warathenna-Hakkinda EPA starting from the Gatambe main bridge (7.45N, 80.10E) to the Dodangwela Suspension Bridge (7.46N, 80.10E).

Eichhornia crassipes was seen in areas with slow moving water.

The sampling of avifauna was carried out in 17 river islands and 24 riverine forest patches. Sampling locations were marked using a portable global positioning system (GPS) (Magellan eXplorist 110) and sampling points were separated by a minimum distance of 150 m (Figure 1).

Survey of avian fauna along the declared EPA

Field sampling was carried out twice a week during the study period. Systematic random sampling method was used to record the birds from this EPA, and sampling was conducted along two main roads on either side of the Mahaweli River, the Peradeniya-Halloluwa-Katugastota Road (2.5 km) on the west and the "Srimath Kuda Rathwaththe Mawatha" and "Deveni Rajasinghe Mawatha" (3 km) on the east. Eighteen 200 m line

transacts were sampled along the two main roads within the EPA. Two 10 m radius points along each 200 m line transect were established to record the birds along the riverine forest. A point count method (5 m radius) was carried out in the river islands and along river banks to record bird species. A maximum of 30 minutes was spent in each site during both point count and line transect methods. Birds were observed using direct observations with the aid of 10 × 42 binoculars (Nikon, Monarch) and identified using available field guides (e.g., Harrison, 2011; Warakagoda et al. 2012) as well as through vocalizations. Opportunistic and incidental observations were also recorded during the survey. With the aid of previously published records (Henry 1971; Ali & Ripley 2001), the recorded birds were categorized according to their dietary habits. The conservation status of identified bird species was classified according to the National Red List 2012 of Sri Lanka (MOE 2012). The counting was conducted at 0630–0930 h and 1530–1830 h when most of the birds are active. The bird species, their abundance, and forest strata where they were observed were recorded in the field.

Data analysis

Data on avifauna were analyzed for riverine forests and the river islands. The species richness, family richness, endemism, migratory percentages, relative abundance, and the diversity were calculated using R version 3.6.1 (R Core Team 2014). Pooled t-test was carried out to determine the significance of the two habitats under 95% confidant intervals using R version 3.6.1 (R Core Team 2014). The difference among different micro-habitats/strata was evaluated using one-way ANOVA using tukey comparison under 95% confidant limits in R studio version 3.6.1 (R Core Team 2014). The relative abundance was calculated as follows.

$$\text{Relative abundance } (p_i) = \frac{\text{Number of individuals in a particular species}}{\text{Total Number of sampled individuals in all species}}$$

The rarefaction curve, endemism, family representation and national conservation status were plotted using SigmaPlot-10. Chao 2 and second order Jacknife 2 richness estimators were calculated in EstimateS software (Version 9.1.0) (Chao et al. 2005) to estimate the predicted species richness in the EPA. Species diversity was measured using Shannon diversity index. The proportional abundance of species was used to determine the Shannon diversity index (H') and the species richness was used to determine Margalef's diversity index using R version 3.6.1 (R Core Team 2014) for comparison of avifaunal diversity between riverine forests and river islands. Jaccard similarity index was calculated using R version 3.6.1 (R Core Team 2014) to estimate the degree of similarity between the two habitat types.

$$\text{Shannon} - \text{Weiner index } (H') = -\sum p_i \ln p_i$$

$$\text{Margaleaf index } (M) = \frac{S-1}{\ln N}$$

Where, p_i= Relative abundance of a species, S= Number of species (species richness), and N= Total number of individuals

$$\text{Jaccard Index } (C_j) = \frac{j}{(a+b-j)}$$

Where, j= Number of species found in both sites, a= Number of species in site A, and b= Number of species in site B

RESULTS

A total of 666 individuals belonging to 74 bird species, 61 genera and 35 families were encountered during the study (Table 1, Image 1,2). The species based rarefaction curve, with lower and upper limits, did not reach the asymptote, which implied that more sampling effort was needed. According to the Chao 2 and Jackknife 2 estimates, the species richness could be 88 and 104, respectively (Figure 2A,B). Seven species: Yellow-fronted Barbet *Psilopogon flavifrons*, Crimson-fronted Barbet *Psilopogon rubricapillus*, Sri Lanka Green Pigeon *Treron pompadora*, Sri Lanka Wood Pigeon *Columba torringtoniae*, Sri Lanka Hill Mynah *Gracula ptilogenys*, Sri Lanka Hanging Parrot *Loriculus beryllinus*, and Sri Lanka Grey Hornbill *Ocyceros gingalensis* (Image 2A) encountered during the study are endemic, while six: Grey Wagtail *Motacilla cinerea*, Yellow Wagtail *Motacilla flava*, Asian Brown Flycatcher *Muscicapa dauurica*, Indian Pitta *Pitta brachyura* (Image 2I), Common Sandpiper *Actitis hypoleucos*, and Green Sandpiper *Tringa ochropus*) are migratory (Figure 3). However, majority of the sampled birds were non-endemic native resident birds. Since this is a riverine system, 24% of the encountered species were water associated birds while 76% were terrestrial birds. The most species-rich family was Ardeidae (herons and egrets; Image 1C,E,F) with seven species. Other than that, Alcedinidae (kingfishers – four species; Image 1A, B), Columbidae (pigeons – five species), Accipitridae (raptors – four species), and Apodidae (swifts – four species) were the most common families represented in the EPA. Of the recorded families, 43% were represented by only a single species. Although the species richness

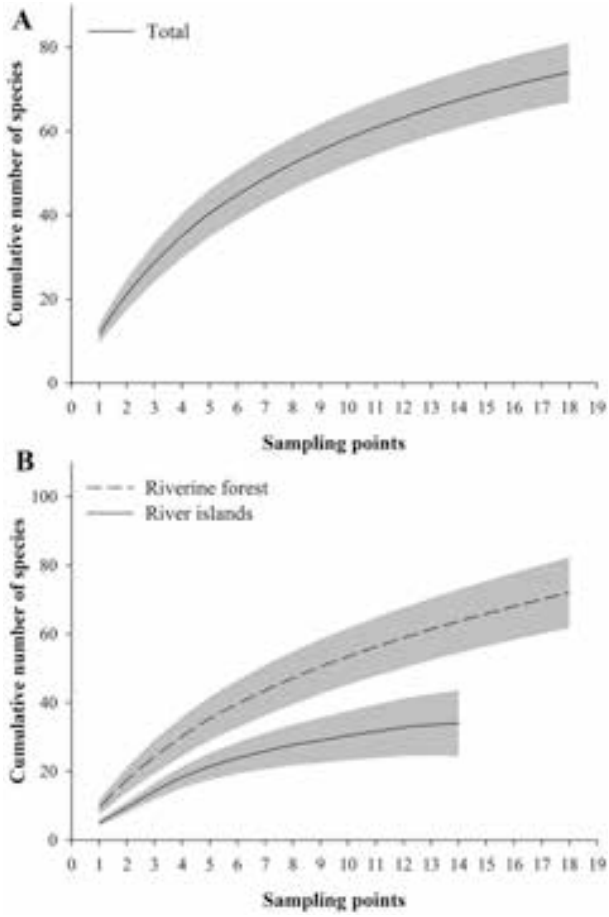

Figure 2. Species based rarefaction representation of the birds recorded from Warathenna-Hakkinda EPA from 2016 to 2017 with 95% lower and upper boundaries: A—Total species richness | B—Species richness between riverine forests and river islands.

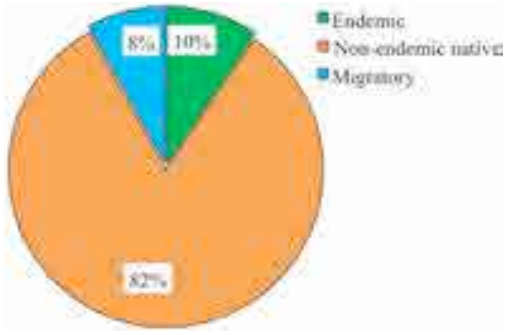

Figure 3. Endemism of the birds recorded from Warathenna-Hakkinda EPA

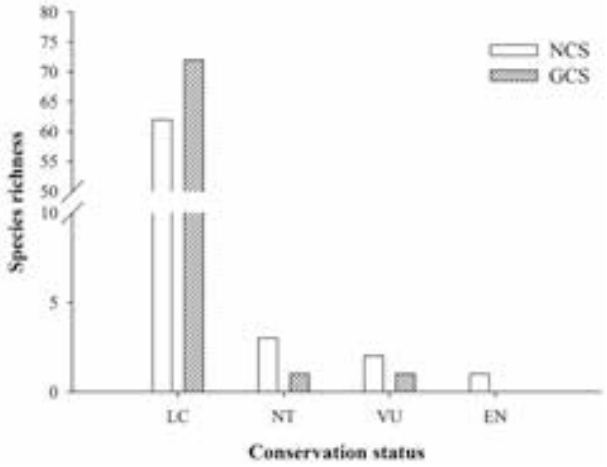

Figure 4. National conservation status (NCS) and Global conservation status (GCS) of the bird species recorded from Warathenna-Hakkinda EPA: LC—Least Concern | NT—Near Threatened | VU—Vulnerable | EN—Endangered.

was highest in Ardeidae, Columbidae, Alcedinidae, Accipitridae, and Apodiade families, the highest number of individuals in this ecosystem and hence the dominant families were Aredeidae (15% of relative abundance), Phalacrocoracidae (12% of relative abundance), and Sturnidae (11% of relative abundance; Table 1).

Out of the total number of species encountered, three species are listed under the categories of Vulnerable (VU) and Endangered (EN) according to the National Red List (MOE 2012). Of the remaining species, three are listed as Near Threatened (NT) and the rest of the 63 species are listed as Least Concern (LC). Of the recorded species, Alpine Swift is in the EN category while the Sri Lanka Wood Pigeon and Sri Lanka Mynah are listed as VU (MOE 2012). However, according to the global conservation status, the Sri Lanka Wood Pigeon is considered to be VU, Sri Lanka Hill Mynah as NT while the rest of the 72 species are considered to be LC. The LC category species were the most abundant (99% of relative abundance) in this ecosystem while VU species were the least abundant (0.3% of relative abundance; Table 1 and Figure 4).

According to the food habits, the encountered birds in the EPA included carnivores, omnivores, insectivores, piscivores, frugivores, nectarivores, and granivores. The species richness of the birds among the food habit categories was significantly different ($F= 1.45$; $p <0.05$). Of these, most species were categorized as carnivores (31%) and insectivores (25%) while nectarivores (5%) were the lowest in this riverine system. In addition, the highest numbers of individuals were recorded from carnivores and omnivores (35% and 26% of relative abundance, respectively) while the least number of individuals were recorded from nectarivores (Figure 5).

Forests can be defined by four vertical forest strata namely, canopy, sub canopy, understory and the ground layer. Some of the bird species in the EPA were encountered from a single layer while others were

Table 1. Recorded bird species, their conservation status, forest strata, food habit and relative abundance in riverine forests and river islands in Warathenna-Hakkinda EPA, Kandy.

Family	Scientific Name	Common Name	NCS/ GCS	Stratum	Food habit	RA/%	Rarity	Abundance		
								RI	RF	*p* Value
Accipitridae	*Accipiter badius*	Shikra	LC/LC	Canopy	Carnivores	0.3	R	1	1	-
Accipitridae	*Haliaeetus leucogaster*	White-bellied Sea Eagle	LC/LC	Canopy	Carnivores	0.6	C	2	2	-
Accipitridae	*Haliastur indus*	Brahminy Kite	LC/LC	Canopy	Carnivores	0.9	C	2	4	-
Accipitridae	*Spilornis cheela*	Crested Serpent Eagle	LC/LC	Canopy	Carnivores	0.6	C	1	3	-
Alcedinidae	*Alcedo atthis*	Common Kingfisher	LC/LC	Sub canopy, Canopy	Carnivores	0.3	R	0	2	-
Alcedinidae	*Ceyx erithaca*	Oriental Dwarf Kingfisher	NT/LC	Sub canopy, Canopy	Carnivores	0.3	R	1	1	-
Alcedinidae	*Halcyon smyrnensis*	White-throated Kingfisher	LC/LC	Sub canopy, Canopy	Carnivores	1.2	C	1	7	-
Alcedinidae	*Pelargopsis capensis*	Stork-billed Kingfisher	LC/LC	Sub canopy, Canopy	Carnivores	1.95	C	4	9	0.54
Apodidae	*Aerodramus unicolor*	Indian Swiftlet	LC/LC	Canopy, Sub canopy	Insectivores	0.75	C	3	2	-
Apodidae	*Apus melba*	Alpine Swift	EN/LC	Canopy, Sub canopy	Insectivores	0.6	C	0	4	-
Apodidae	*Apus nipalensis*	House Swift	LC/LC	Canopy, Sub canopy	Insectivores	1.5	C	0	10	-
Apodidae	*Cypsiurus balasiensis*	Asian Palm-Swift	LC/LC	Canopy, Sub canopy	Insectivores	0.45	C	0	3	-
Ardeidae	*Ardea alba*	Great Egret	LC/LC	Sub canopy, Ground	Carnivores	0.15	R	0	1	-
Ardeidae	*Ardea intermedia*	Intermediate Egret	LC/LC	Sub canopy, Ground	Carnivores	5.26	VC	5	30	0.27
Ardeidae	*Ardeola grayii*	Indian Pond Heron	LC/LC	Sub canopy, Ground	Carnivores	0.6	C	0	4	-
Ardeidae	*Bubulcus ibis*	Cattle Egret	LC/LC	Sub canopy, Ground	Carnivores	3	C	10	10	0.61
Ardeidae	*Egretta garzetta*	Little Egret	LC/LC	Sub canopy, Ground	Carnivores	5.41	VC	11	25	0.34
Ardeidae	*Ixobrychus cinnamomeus*	Cinnamon Bittern	NT/LC	Sub canopy, Ground	Carnivores	0.15	R	0	1	-
Ardeidae	*Nycticorax nycticorax*	Black-crowned Night Heron	NT/LC	Ground	Carnivores	0.3	R	1	1	-
Bucerotidae	*Ocyceros gingalensis*[E]	Sri Lanka Grey Hornbill	LC/LC	Sub canopy, Canopy	Frugivores	0.3	R	1	1	-
Campephagidae	*Pericrocotus cinnamomeus*	Small Minivet	LC/LC	Sub canopy, Understory	Insectivores	0.6	C	0	4	-
Campephagidae	*Pericrocotus speciosus*	Scarlet Minivet	LC/LC	Sub canopy, Understory	Insectivores	1.65	C	5	6	0.52
Charadriidae	*Vanellus indicus*	Red-wattled Lapwing	LC/LC	Ground	Omnivores	0.6	C	0	4	-
Chloropseidae	*Chloropsis aurifrons*	Golden-fronted Leafbird	LC/LC	Sub canopy, Understory	Frugivores	0.6	C	2	2	-
Chloropseidae	*Chloropsis jerdoni*	Jerdon'sLeafbird	LC/LC	Sub canopy, Understory	Frugivores	0.75	C	2	3	-
Cisticolidae	*Prinia inornata*	Plain Prinia	LC/LC	Sub canopy, Understory	Insectivores	0.3	R	0	2	-
Cisticolidae	*Prinia socialis*	Ashy Prinia	LC/LC	Sub canopy, Understory	Insectivores	0.45	C	0	3	-
Columbidae	*Chalcophaps indica*	Emerald Dove	LC/LC	Sub canopy, Understory	Frugivores	0.3	R	0	2	-
Columbidae	*Columba livia*	Feral Pigeon	-/LC	Sub canopy, Understory	Granivores	1.5	C	0	10	-
Columbidae	*Columba torringtoniae*[E]	Sri Lanka Wood Pigeon	VU/VU	Sub canopy, Understory	Frugivores	0.3	R	0	2	-
Columbidae	*Streptopelia chinensis*	Spotted Dove	LC/LC	Sub canopy, Understory	Granivores	1.05	C	0	7	-
Columbidae	*Treron pompadora*[E]	Sri Lanka Green Pigeon	LC/LC	Sub canopy, Understory	Frugivores	0.3	R	0	2	-

Family	Scientific Name	Common Name	NCS/ GCS	Stratum	Food habit	RA/%	Rarity	Abundance		
								RI	RF	*p* Value
Corvidae	*Corvus splendens*	House Crow	LC/LC	Sub canopy, Understory	Omnivores	7.81	VC	5	47	0.09
Cuculidae	*Centropus sinensis*	Greater Coucal	LC/LC	Understory, Ground	Carnivores	0.45	C	2	1	-
Cuculidae	*Eudynamys scolopaceus*	Asian Koel	LC/LC	Sub canopy, Understory	Frugivores	1.05	C	1	6	-
Dicaeidae	*Dicaeum erythrorhynchos*	Pale-billed Flowerpecker	LC/LC	Sub canopy, Understory	Nectarivores	2.25	C	2	13	-
Dicruridae	*Dicrurus caerulescens*	White-bellied Drongo	LC/LC	Sub canopy, Understory	Insectivores	0.9	C	0	6	-
Estrildidae	*Lonchura malacca*	Black-headed Munia	LC/LC	Sub canopy, Understory	Granivores	0.75	C	0	5	-
Estrildidae	*Lonchura punctulata*	Scaly-breasted Munia	LC/LC	Sub canopy, Understory	Granivores	2.4	C	0	16	-
Estrildidae	*Lonchura striata*	White-rumpedMunia	LC/LC	Sub canopy, Understory	Granivores	2.1	C	0	14	-
Hirundinidae	*Cecropis hyperythra*	Sri Lanka Swallow	LC/LC	Canopy, Sub canopy	Insectivores	0.45	C	0	3	-
Motacillidae	*Motacilla cinerea*[M]	Grey Wagtail	-/LC	Ground	Carnivores	0.3	R	0	2	-
Motacillidae	*Motacilla flava*[M]	Yellow Wagtail	-/LC	Ground	Carnivores	0.15	R	0	1	-
Muscicapidae	*Copsychus saularis*	Oriental Magpie-Robin	LC/LC	Sub canopy, Understory	Insectivores	0.9	C	0	6	-
Muscicapidae	*Cyornis tickelliae*	Tickell's Blue Flycatcher	LC/LC	Sub canopy, Ground	Insectivores	0.15	R	0	1	-
Muscicapidae	*Muscicapa dauurica*[M]	Asian Brown Flycatcher	-/LC	Sub canopy	Insectivores	0.15	R	0	1	-
Nectariniidae	*Cinnyris asiaticus*	Purple Sunbird	LC/LC	Sub canopy, Understory	Nectarivores	1.5	C	4	6	0.48
Nectariniidae	*Cinnyris lotenius*	Loten's Sunbird	LC/LC	Sub canopy, Understory	Nectarivores	0.3	R	0	2	-
Nectariniidae	*Leptocoma zeylonica*	Purple-rumped Sunbird	LC/LC	Sub canopy, Understory	Nectarivores	1.95	C	3	10	0.42
Oriolidae	*Oriolus xanthornus*	Black-hooded Oriole	LC/LC	Sub canopy, Understory	Frugivores	1.2	C	1	7	-
Paridae	*Parus major*	Great Tit	LC/LC	Sub canopy, Understory	Omnivores	0.75	C	0	5	-
Passeridae	*Passer domesticus*	House Sparrow	LC/LC	Sub canopy, Understory	Granivores	0.6	C	0	4	-
Phalacrocoracidae	*Microcarbo niger*	Little Cormorant	LC/LC	Sub canopy, Ground	Carnivores	11.11	VC	37	37	0.51
Phalacrocoracidae	*Phalacrocorax fuscicollis*	Indian Cormorant	LC/LC	Sub canopy, Ground	Carnivores	0.45	C	0	3	-
Picidae	*Chrysocolaptes stricklandi*	Crimson-backed Goldenback	-/LC	Sub canopy, Understory	Insectivores	0.15	R	0	1	-
Picidae	*Dinopium benghalense*	Lesser Goldenback	LC/LC	Sub canopy, Understory	Insectivores	0.15	R	0	1	-
Pittidae	*Pitta brachyura*[M]	Indian Pitta	LC/LC	Understory	Insectivores	0.15	R	0	1	-
Psittacidae	*Loriculus beryllinus*[E]	Sri Lanka Hanging Parrot	LC/LC	Sub canopy, Understory	Frugivores	0.15	R	0	1	-
Psittacidae	*Psitta culakrameri*	Rose-ringed Parakeet	LC/LC	Sub canopy, Understory	Frugivores	1.2	C	5	3	0.71
Pycnonotidae	*Iole indica*	Yellow-browed Bulbul	LC/LC	Sub canopy, Understory	Omnivores	1.2	C	0	8	-
Pycnonotidae	*Pycnonotus cafer*	Red-vented bulbul	LC/LC	Sub canopy, Understory	Omnivores	3.15	C	7	14	0.19
Rallidae	*Amaurornis phoenicurus*	White-breasted Waterhen	LC/LC	Ground	Carnivores	0.3	R	0	2	-
Ramphastidae	*Psilopogon flavifrons*[E]	Yellow-fronted Barbet	LC/LC	Canopy, Understory	Frugivores	1.2	C	2	6	-
Ramphastidae	*Psilopogon rubricapillus*[E]	Crimson-fronted Barbet	LC /LC	Canopy, Understory	Frugivores	0.6	C	0	4	-
Ramphastidae	*Psilopogon zeylanicus*	Brown-headed Barbet	LC/LC	Canopy, Understory	Frugivores	1.35	C	2	7	-

Family	Scientific Name	Common Name	NCS/ GCS	Stratum	Food habit	RA/%	Rarity	Abundance		
								RI	RF	*p* Value
Scolopacidae	*Actitis hypoleucos*[M]	Common Sandpiper	LC/LC	Ground	Carnivores	1.35	C	2	7	-
Scolopacidae	*Tringa ochropus*[M]	Green Sandpiper	- /LC	Ground	Carnivores	0.3	R	2	0	-
Sittidae	*Sitta frontalis*	Velvet-fronted Nuthatch	LC/LC	Sub canopy	Insectivores	0.15	R	1	0	-
Sturnidae	*Acridotheres tristis*	Common Mynah	LC/LC	Sub canopy, Understory	Omnivores	5.71	VC	0	38	-
Sturnidae	*Gracula ptilogenys*[E]	Sri Lanka Hill Mynah	VU/NT	Canopy, Sub canopy	Omnivores	0.45	C	2	1	-
Sturnidae	*Gracula religiosa*	Lesser Hill Mynah	LC/LC	Canopy, Sub canopy	Omnivores	5.26	VC	24	11	0.21
Sylviidae	*Orthotomus sutorius*	Common Tailorbird	LC/LC	Sub canopy, Understory	Insectivores	1.95	C	2	11	-
Timaliidae	*Turdoides affinis*	Yellow-billed Babbler	LC/LC	Sub canopy, Understory	Insectivores	3.9	C	0	26	-
Zosteropidae	*Zosterops palpebrosus*	Oriental White-Eye	LC/LC	Sub canopy, Understory	Omnivores	0.6	C	0	4	-

[M]—Migratory birds | [E]—Endemic birds and rest of the birds were non-endemic native birds | NCS—National conservation status | GCS—Global conservation status | LC—Least Concern | NT—Near Threatened | EN—Endangered | VU—Vulnerable | RA—Relative abundance | R—Rare | C—Common | VC—Very common | RI—River islands | RF—Riverine forests.

Image 1. Some of the water associated birds recorded from the Warathenna-Hakkinda EPA: A—White-throated Kingfisher | B—Stork-billed Kingfisher | C—Indian Pond Heron | D—Little Cormorant and Indian Cormorant | E—Little Egret | F—Intermediate Egret. © Tithira Lakkana.

encountered from multiple layers such as canopy-sub canopy, canopy-understory, sub canopy-understory, sub canopy-ground and understory-ground. Most of the bird species were encountered from the canopy and sub canopy layers in the forest. According to the forest strata analysis, most of the birds were recorded from the sub canopy-understory layer (47% of total sampled species) while understory and understory-ground dwellers (15% of sampled species in each strata) were the least species rich forest strata in this ecosystem. The species richness among the nine combinations of the four main strata of the forest layer was significantly different (F= 2.97; p <0.05) (Figure 6). The abundance of species was highest in sub canopy-understory (50%) and sub canopy-ground (26% relative abundance) while the least abundance was recorded from the understory (0.15% relative abundance).

During sampling of the river islands, 136 individuals belonging to 34 species in 20 families were recorded while riverine forest patches recorded 510 individuals belonging to 72 species in 34 families (Image 2B). All seven endemic species recorded during the study were observed in the riverine forests as well as six migratory species except Green Sandpiper and 60 non-endemic natives. On the other hand, three endemics (Sri Lanka Grey Hornbill, Yellow-fronted Barbet, and Sri Lanka Hill Mynah) and two migratory species (Common Sandpiper and Green Sandpiper) and 29 non-endemic natives were recorded from the river islands (Table 1). However, the species richness was not significantly different between the two habitats (t= -2.13, p >0.05). Green Sandpiper and Velvet-fronted Nuthatch *Sitta frontalis* were the only two species not recorded from riverine forest although they were present in river islands. Swift, Munia, Wagtail, and woodpecker species were absent in the river islands in the EPA (Table 1). However, the species abundance between the two habitats were significantly different (t= -3.89, p <0.05). Yet, the relative abundance of the individual species between two habitats were not significantly different. The highly abundant species in riverine forests were the House Crow *Corvus splendens*, Common Mynah *Acridotheres tristis*, Little Cormorant *Microcarbo niger* (Image 1D), Intermediate Egret *Ardea intermedia* (Image 1F), Yellow-billed Babbler *Turdoides affinis* (Image 2G), and Little Egret *Egretta garzetta* (Image 1E) (47, 38, 37, 30, 26, and 25 individuals, respectively) while Little Cormorant and Southern Hill Mynah *Gracula religiosa* (37 and 24 individuals, respectively) were highly abundant in river islands. The least common species in riverine forest were Greater Coucal *Centropus sinensis*, Sri Lanka Hill Mynah, Great Egret *Ardea alba*, Cinnamon

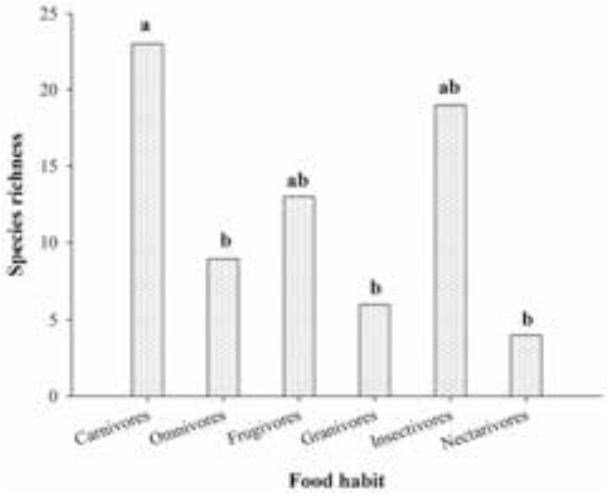

Figure 5. The food habits of sampled bird communities in Warathenna-Hakkinda EPA (a and b letters denote the significance level of the data).

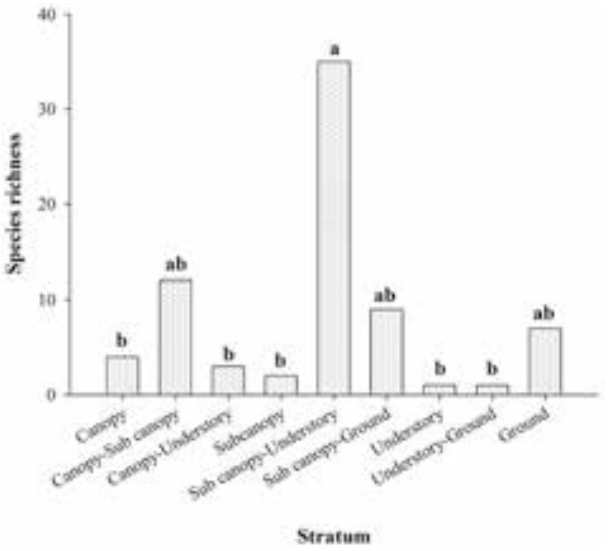

Figure 6. Distribution of encountered bird species along the forest strata in Warathenna-Hakkinda EPA; a and b denote the significance of the values. (a and b letters denote the significance level of the data).

Bittern *Ixobrychus cinnamomeus*, Yellow Wagtail, Asian Brown Flycatcher, Tickell's Blue Flycatcher *Cyornis tickelliae*, Crimson-backed Goldenback *Chrysocolaptes stricklandi*, Lesser Goldenback *Dinopium benghalense*, Indian Pitta, and Sri Lanka Hanging Parrot while Velvet-fronted Nuthatch, Crested Serpent Eagle *Spilornis cheela*, Asian Koel *Eudynamys scolopaceus* (Image 2D), White-throated Kingfisher *Halcyon smyrnensis* (Image 1A), and Black-hooded Oriole *Oriolus xanthornus* were the least abundant species in river islands. Shikra *Accipiter badius*

(Image 2C), Oriental Dwarf Kingfisher *Ceyx erithaca*, Black-crowned Night Heron *Nycticorax nycticorax*, and Sri Lanka Grey Hornbill showed low abundance in both habitats in the EPA (Table 1).

Both Shannon-Wiener and Margalef's diversity indices were highest in riverine forests (H′= 2.55; M= 10.92) compared to the river islands (H′= 2.29; M= 5.07). According to the Jaccard index the two habitats showed 43% similarity. According to the food habits of the sampled species, the highest species richness and abundance was recorded from carnivores in both river island and riverine forest habitats (82 individuals 15 species and 154 individuals 22 species, respectively; Table 1), whereas the lowest species richness and abundance was recorded from nectarivores in both these habitats (9 individuals 3 species and 31 individuals 4 species, respectively).

DISCUSSION

Riverine forest habitats along the Mahaweli River provide shelter for diverse animal communities (Sinha et al. 2019). Due to the high heterogeneity of the habitats in riverine ecosystem, it is home to a variety of mammals, birds, reptiles, amphibians, and many invertebrate communities. However, the bird diversity in the Warathenna-Hakkinda EPA has not been investigated to date. Data on avifauna in this EPA may be useful for future conservation efforts and ecotourism.

Rarefaction graphical representations are used to determine the sampling effort. The statistical significance of this curve is revealed using 95% upper and lower confidence limits (Colwell & Coddington 1994). This curve for the present study is close to leveling off (i.e., not completely leveled off); hence, it indicates the requirement of more sampling effort. However, according to the published literature this graphical representation does not directly reveal the total species richness (Magurran 2004). Therefore, more commonly used and statistically powerful Chao 2 and Jackknife 2 methods are used to estimate the predicted species richness in the EPA (Colwell & Coddington 1994; Colwell et al. 2012). Since this study was conducted during the daytime, the study possibly missed the nocturnal species and may account for the lower number of species in relation to the estimated numbers of 88 and 104 species in Chao 2 and Jackknife 2.

The 74 species of birds recorded from the EPA represents about 16% of the island's total bird species. This indicate that the species richness in this EPA is higher than those reported in many other areas around Kandy city limits (Karunaratna 1986; Wijesundara & Santiapillai 2001; Ellepola 2014; Weerakoon 2015; Hettiarachchi & Wijesundara 2017). However, the bird species richness in Warathenna-Hakkinda EPA is lower than what is recorded in the Gannoruwa Forest Reserve (84 species) which is located adjacent to the EPA with an extent of 2.1 km^2 (Rathnayake et al. 2016). The Warathenna-Hakkinda EPA is a mere 0.61 km^2 area with not only riverine forest and river islands but also Kandyan home gardens surrounding human habitation. Hence, this area is highly affected by anthropogenic influences compared to the Gannoruwa Forest Reserve.

This EPA harbors about 28% of the islands breeding residents (out of the 240 breeding residents in Sri Lanka) and 3% of the 213 migratory bird species in Sri Lanka. In addition, it represents 26% of endemic bird species of the island (MOE 2012; Gabadage et al. 2015), while only 11 endemic species have been recorded from the Gannoruwa forest (Rathnayake et al. 2016). The number of endemic species is a measure that can predict the amount of human influence (Linder 1995; BirdLife International 2008; Hettiarachchi & Wijesundara 2017). Typically, undisturbed natural forests in the wet zone harbor many endemic species. For example, 16 species in the forests of the Knuckles mountain range, 12 species in the Horton Plains National Park, 23 species in the Sinharaja forest reserve, and 33 species in the Samanala Nature Reserve (Bambaradeniya et al. 2003; Karunarathna et al. 2011; Subasinghe & Sumanapala 2014; Chandrasiri et al. 2018).

Ardeidae, Alcedinidae, some Accipitridae, and some Apodidaeare considered as water-bird families (Abie et al. 2019; Sinha et al. 2019), while Sturnidae, Estrildidae, and Columbidae families are highly associated with human habitations (Silva et al. 2017; Bellanthudawa et al. 2019). The abundance of both these two groups in the EPA hence can be correlated to its positioning along the Mahaweli River and the surrounding human settlements. Similar results have been obtained from a previous study carried out in Hantana forest, where the most abundant species was the Common Mynah, followed by Black Crow, and Yellow-billed Babbler (Wijesundara & Santiapillai 2001). On the other hand, most of the other wet zone forest as well as the forest located within the Kandy city limits (Udawattakele Forest Reserve) has more forest dwelling individuals and species such as Swallows, Swifts, Barbets, forest Babblers, Bulbuls, and Hill Mynahs (Bambaradeniya et al. 2003; Wijesundara & Silva 2005; Karunarathna et al. 2011; Subasinghe & Sumanapala 2014; Rathnayake et al.

Image 2. Some of the terrestrial endemic, non-endemic native and migratory birds recorded from the Warathenna-Hakkinda EPA: A—Sri Lanka Grey Hornbill | B—Yellow-browed Bulbul | C—Shikra | D—Asian Koel | E—House Sparrow | F—Feral Pigeon | G—Yellow-billed Babbler | H—Pale-billed Flowerpecker | I—Indian Pitta. © Tithira Lakkana.

2016; Hettiarachchi & Wijesundara 2017; Chandrasiri et al. 2018).

The forest strata the birds inhabit correlate with their food habits. Most of the frugivores (leaf birds, barbets and hill mynahs) and insectivores are observed in the canopy and sub canopy forest layers while most of the piscivores are found on the ground layer and omnivores are encountered from sub canopy, understory and ground layers during the present survey. A large number of carnivores, are recorded from the EPA because this is a water associated habitat. But our findings were contrary to the study carried out in Udawatta-kele, which is a secondary forest in Kandy (Ellepola 2014; Weerakoon 2015) and the Knuckles range (Subasinghe & Sumanapala 2014), where they record a large number of insectivores and frugivores. A previous study carried out in the hill country of Sri Lanka documented that the insectivores (Sri Lanka Bush Warbler, Common Tailorbird), frugivores (Yellow-fronted Barbet), and nectarivores (Purple Sunbird) showed a marked

preference for primary montane forests while carnivores preferred primary montane forests and grassland-forest interface where they can easily spot their prey species (Wijesundara & Silva 2005).

Although there is a difference in both the diversity and distribution of birds between the two habitats studied in the EPA, a large number of common bird species (43% of sampled birds) are recorded from both the habitats. This is possibly because there is very little distinction between these two habitats in terms of floristic characteristics. Several studies have shown that the bird distribution and diversities highly depend on the heterogeneity of the habitats (Bambaradeniya et al. 2003; Wijesundara & Silva 2005; Karunarathna et al. 2011; Subasinghe & Sumanapala 2014; Weerakoon 2015; Rathnayake et al. 2016; Hettiarachchi & Wijesundara 2017; Chandrasiri et al. 2018). The higher bird diversity in the riverine forests in the EPA may be attributed to the availability of relatively more distinct habitats.

Since the Warathenna-Hakkinda EPA is surrounded by human habitation, a number of anthropogenic activities have a direct impact on the EPA. Construction and expansion of human habitation, logging, garbage, and sewage dumping can lead to the deterioration and loss of biodiversity in this EPA. Given the high diversity of flora and fauna, including birds, as indicated in this study, this area requires effective conservation planning, including proper landscape management strategies, strengthening of existing national environmental rules and policies, continuous monitoring programs, public education and awareness programs for safeguarding the biodiversity in this EPA.

CONCLUSIONS

A total of 74 bird species belonging to 61 genera and 35 families were encountered from the Warathenna-hakkinda EPA, which represent 16% of the island total bird species, 28% of the islands breeding residents, 3% of the migratory bird species and 26% of endemic birds of Sri Lanka. The variety of habitats provided by the riverine forests and river islands along the Mahaweli River of the EPA appears to aid in sustaining a rich bird community. However, since this EPA is located within the densely populated city of Kandy, it faces immense population pressures. Therefore, effective conservation planning including continuous monitoring programs, proper landscape managing strategies, strengthening of existing environmental policies, as well as educational and awareness programs are essential to minimize threats and safeguard the biodiversity in the EPA.

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ARTICLE

Grass species composition in tropical forest of southern India

M. Ashokkumar [1], S. Swaminathan [2] & R. Nagarajan [3]

[1] Bombay Natural History Society, Hornbill House, S.B. Singh Road, Mumbai, Maharastra 400001, India.
[1] Centre for Wildlife Studies, Kerala Veterinary and Animal Sciences University, Pookode, Kerala 673576, India.
[2] Wildlife SOS, Bannerghatta National Park, Bengaluru, Karnataka 560083, India.
[3] PG and Research Department of Zoology and Wildlife Biology, A.V.C. College, Mannampandal, Mayiladuthurai, Tamil Nadu 609305, India.
[1] vimalashok7@gmail.com (corresponding author), [2] swaminathan@wildlifesos.org, [3] r.nagarajan@ex.ac.uk

Abstract: Grass composition was assessed by plot method (1 m^2; n= 1,749) in three habitats (dry deciduous-DDF, moist deciduous-MDF, and thorn forest-TF) at Mudumalai Tiger Reserve, southern India across different seasons from Jan 2004 to Dec 2007. The grass species richness and availability (per cent composition) varied significantly with habitats. Seventy-four species of grasses and sedges were recorded in all three habitats, with a few species common in all habitats. Grass availability varied significantly in different habitats across seasons and was positively influenced by precipitation. Among biotic factors, regeneration and shrub density had a primary influence on grass availability, followed by herb, sedge and weed density. The principal coordinate analysis revealed seven major associations in the tropical forest. There were considerable changes in the composition and association of grasses when compared to the past. Fire resistant species such as *Themeda triandra*, *Heteropogan contortus* and *T. cymbaria* dominated in the DDF. Grass species *Aristida*/*Eragorstis* were recorded in the TF, which were considered as indicators of heavy grazing pressure. Grass species that were reported rare and sporadic in the earlier study were not recorded, which emphasizes better pasture management in the tropical forest. Grass species composition and availability was threatened by invasion of weeds.

Keywords: Graminae, Mudumalai Tiger Reserve, influence of fire on grass, *Themeda triandra*, *Heteropogon contortus*, *Themeda cymbaria*.

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Author details: Ashokkumar Mohanarangan (MA) is a wildlife biologist, completed his master's and PhD in Wildlife biology, from AVC College. He has been associated with organizations such as WWF-India, BNHS and AVC college providing technical support. He is passionate about wild animal ecology and conservation. Presently he is working as Teaching Assistant at KVASU-CWS. Shanmugavelu Swaminathan (SS) is a wildlife biologist, who has been working on large mammal populations, carnivore ecology and wildlife management for more than 30 years in the Western Ghats. Presently he is working as a senior wildlife biologist at Wildlife SOS. Rajaratinavelu Nagarajan (RN) is the Principal and professor and head of the Zoology Dept. A.V.C College and Honorary Associate Professor of Envt. Sc., University of Exeter, UK. He has more than 30 years of research and teaching experience. He is an eminent scholar and excellent mentor, who has always been a source of inspiration.

Author contributions: MA developed the concept, formulated a hypothesis, and carried out data analysis. SS supported in receiving funds, field data collection and preliminary analysis. Dr. RN provided technical support and supervised the work. All the authors contributed to the preparation of the final manuscript.

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INTRODUCTION

Grasslands are highly dynamic ecosystems encompassing natural and semi-natural pastures, woodlands and scrubs dominated by grasses (Blair et al. 2014). Grasses are one of the important sources of biodiversity and the primary food source for many herbivores that support ecosystem function, agricultural sustainability, and livelihood for many pastoral communities (Sala & Paruelo 1997; White et al. 2000). In India, 1,506 species of grass belonging to 266 genera were reported (Kellogg et al. 2020). Peninsular India has maximum diversity and endemism (Karthikeyan 1989). The study of grass species is important since they are sensitive to global warming and altered precipitation patterns, and exhibit immediate response to climate change (Knapp & Smith 2001).

Grass species in the Western Ghats are threatened by domestic livestock, mining, wind-farms, plantations, canals and dams have led to degradation and loss of grassland habitats (Vanak 2013). The invasion of exotic species into tropical forest threatens grasslands (Srinivasan 2011; Ashokkumar et al. 2012). Invasions not only affect grass composition but also the foraging efficiency of herbivores (Wilson et al. 2013). Pasture management is essential in protected area management strategies to reduce the human-animal interactions. Although grasses have wide ecological amplitude and several adaptations to withstand trampling, grazing, fire, flood, and drought, they face severe competition for light and nutrients from aggressive wood species and invasive plants in tropical forests.

Mudumalai Tiger Reserve (MTR) is located in the Western Ghats, one of 34 global biodiversity hotspots (Myers et al. 2000). There were no earlier studies on the dynamics of grass species composition and diversity in similar tropical forest in Southern India. Though tree, herb and shrub species were studied in detail (Robert et al. 2002; Nath et al. 2006) information on grass species is lacking in the tropical ecosystem. In addition, the study area also has baseline data on grass species composition studied a decade before (Sivaganesan 1991), which enabled comparison with the present study. Sivaganesan (1991) studied grass composition in the study area in the year 1985, and he has studied grass species composition using strip transects of one kilometer length (n= 20) and laid 1 m^2 plots at every 250 m interval, resulting in sampling of five plots per transect and a total of 100 plots across different vegetation types.

Seasonal changes in the phenology of grass species influence herbivore movement, distribution and abundance (Sivaganesan 1991; Baskaran 1998). Cattle grazing and fire have major impacts on species composition of woody plants (Kodandapani et al. 2008) and grasses. The present study investigated the effect of environmental factors on grass availability (grass abundance) and grass association in tropical forests of Southern India. Studies on the grass association help to understand the grass communities in tropical forest and their dynamics due to climatic and anthropogenic factors.

STUDY AREA

Mudumalai Tiger Reserve (MTR) is located in the Nilgiris District of Tamil Nadu (11º 32´ and 11º 42´ N and 76º 20´ and 76º 45´ E). It extends over an area of 321 km^2 and forms a part of the Nilgiris Biosphere Reserve (Figure 1). It is part of a contiguous stretch of forest with Bandipur Tiger Reserve to the north, Segur Reserve forest to the east, Wayanad Wildlife Sanctuary to the west, and Gudalur forest division to the South. Altitude varies from 485 to 1,226 m with a general elevation of about 900 to 1,000 m. The annual rainfall varies from 1,001 mm to 1,648 mm. The sanctuary receives rain from both south-west (May to August) and north-east (September to December) monsoons. Based on climate seasons can be classified into dry season (January to April), first wet season (south-west monsoon) and second wet season (north-east monsoon). The three major forest types in the study area are tropical moist deciduous forest (MDF), dry deciduous forest (DDF) and tropical thorn forest (TF) (Champion & Seth 1968).

The major tree species association in MDF is *Lagerstoroemia-Terminalia-Tectona.* The ground flora mainly composed of *Helicteres isora*, *Desmodium* sp., and *Curcuma* sp. The dominant grass species are *Cyrtococcum accrescens*, *C. oxyphyllum*, *Bothriochloa pertusa*, *Oplismensus compositus* and *Oryza meyeriana* occur. Bamboo *Bambusa arundinacea* is very common along the perennial water sources. Swamp vegetation mainly consists of tall grass *Cenchrus hohenackeri*. Tree species in DDF is dominated by *Anogesis latifolia*, *Terminalia crenulata*, *Tectona grandis*, *Diospyros montana*, and *Gmelina arborea*. Shrubs include *Helicteres isora*, *Antidesma diandram*, and *Pavetta indica*. Grasses species is dominated by tall perennial rhizomatous grasses such as *Themeda cymbaria*, *Cymbopogon flexuosus*, and *Apluda mutica* in dry deciduous tall grass area. *T. triandra*, *Setaria intermedia*, and *Dicanthium caricosum* are common in short grass

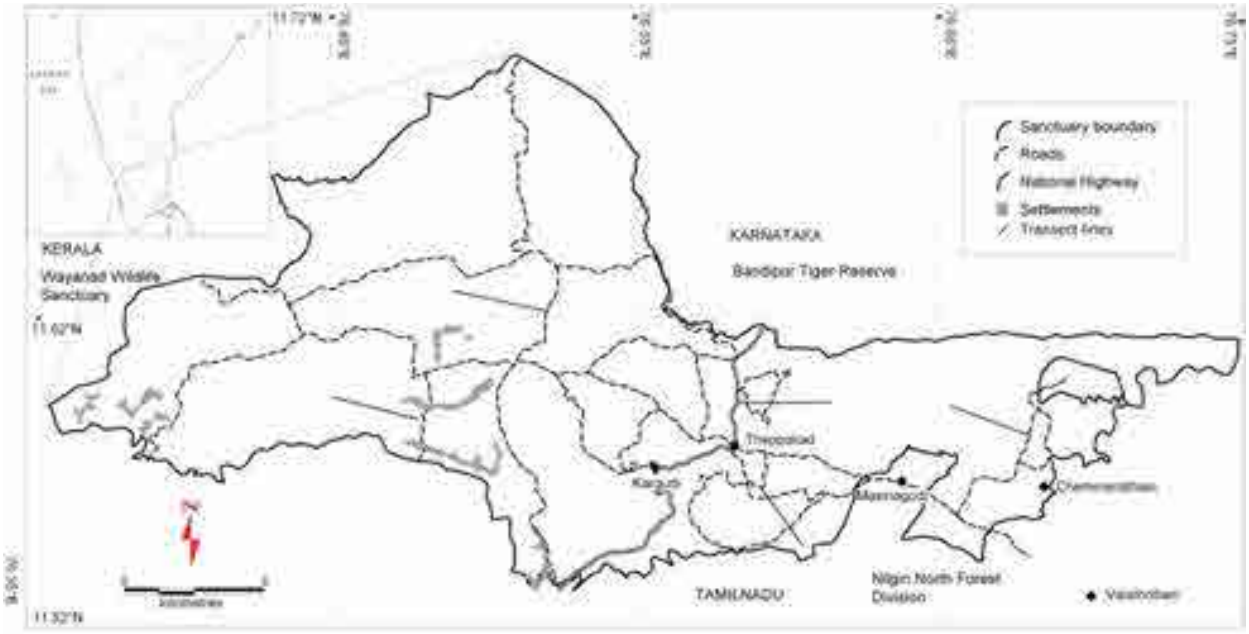

Figure 1. Map showing the location of transect lines used for vegetation sampling at Mudumalai Tiger Reserve.

area. TF is dominated tree species such as *Acacia* sp., *Albizia* sp., *Premna tomentosa*, *Dalbergia lanceolaria*, and *Ziziphus* sp. The shrub species includes *Acacia pinnata*, *Canthium parviflorum*, *Rhus mysorensis*, and *Mytenus emarginatus*. Grass species in TF includes *Aristida adscencsionis*, *Heteropogon contortus*, and *Tragus mongolorum*. The study area is threatened by habitat degradation from overgrazing and human disturbance.

METHODS

Five transects each of three-kilometre length were marked in three habitats (DDF 3; MDF 1, and TF 1; Figure 1). Two transects in Mudumalai range, two transects in Theppakad range and one in Masinagudi range were marked and sampled. The locations of transects were given in the georeferenced study area map (Figure 1). A total of 30 plots (1 m^2) were laid at an interval of 100m in each transect. Transects were sampled two times per season in alternate months. A total of 825 plots were laid in all three vegetation types (DDF 493, MDF 169, TF 103) in different seasons. In addition to this data, grass species composition, which was collected as part of Gaur *Bos gaurus* foraging ecology study was used. A total of 924 plots (DDF 669, MDF 110, TF 145) of 1 m^2 were laid in the Gaur foraged areas in different habitats, to assess the forage plant species including grass species and their consumption.

A herbarium of grass species that include both grass and sedges was made for confirmation of the species identity. All specimen vouchers were deposited in the Center for Ecological Sciences, Indian Institute of Sciences, Bangalore. Plant species were identified using Gamble (1935), Saldanha & Nicolson (1976), Saldanha (1984, 1996), Sharma et al. (1977), and Kellogg et al. (2020). Grass cover in each quadrat was visually estimated by giving a percent cover. Percent cover was given according to the proportion of area (within the quadrat) covered by grass (Giles 1971; Sivaganesan 1991). The other variables such as grass height, percent green grass, grass texture, and phenology were recorded (Jarman & Sinclair, 1979; Menaut and Cesar 1979; Sivaganesan 1991; Baskaran 1998).

Precipitation data was collected on monthly basis from weather stations located at the different habitats of the study area maintained by Center for Ecological Science, Indian Institute of Science. The information on extant and frequency of fire was collected from forest management plan and studies on fire in the study area (Kodandapani et al. 2008). Grass species richness, mean percent availability and grass height were tested using ANOVA.

The effect of environmental and biotic variable on grass availability was tested using multiple regressions. The relationship between the percent grass availability and environmental factors (habitat, season, precipitation

and fire) and biotic factors (shrub, regeneration, herb, sedges, and weed) were investigated using multiple regression. The variations among the habitats, seasons and fire were controlled by entering these predictors as a dichotomous variable.

Grass species association was determined by principal co-ordinate analysis and species association was plotted in Euclidean space. The variables used in the analysis are percent composition of grass, height, habitat, elevation, fire, and spatial locations in the study area. Statistical analyses were performed by using Windows based statistical package *viz.* SPSS 21.0 (SPSS Inc., Chicago, IL, USA) and Past software 3.17 (Hammer et al. 2001).

RESULTS

A total of 74 species of grasses and sedges were recorded in the MTR with a maximum of species in DDF followed by TF and MDF (Table 1). MDF had lower grass species diversity (0.6) than other habitats. Though, species richness was high in TF (3.4), the mean percent availability of grass was less in TF (12.7%) than DDF (19%) and MDF (17%). The species richness and mean percent availability of grass varied significantly among habitats. The equitability of species was equal in all the habitats. While grass species diversity was higher in TF, the abundance of grass was higher in deciduous forests (MDF and DDF).

Species composition and availability

Grass species composition varied among different habitats. Altogether, 66 grasses and eight species of sedges were recorded in three habitats. There were 21 species were common in all habitats, viz., *Themeda triandra, Oplismenus undulatifolius, Setaria intermedia, S. flavidum*, and *S. pumila* (Table 2). Among different grass species *Perotis indica, Cymbopogon* sp., *Cappillipedium assimile, E. spicatus*, and *Kyllinga* sp. were recorded only in DDF. Likewise, species such as *Cyrtococcum oxyphyllum, Paspalum conjugatum*, and *Cenchrus polystachios* in MDF and *Bothriochloa* sp. *Eragrostis atrovirens*, *Pseudanthistiria umbellata*, *P. tripheron*, and *Leersia hexandra* were recorded only in TF.

In DDF dominant grass species included both tall and short grass species. Tall grass species include *T. cymbaria* (30%), *I. cylindrica* (13%) and *S. fertilis* (13%) and short grasses were *T. triandra* (27%), *O. undulatifolius* (25%) and *S. intermedia* (22%). In MDF, the dominant species were *C. oxyphyllum, E. indica, C. patens, P. polystachion* and *A. compressus*. Swamp areas of both DDF and MDF were dominated by grass species such as *C. polystachyios*, *A. compressus, I. cylindrica*, and *E. indica*. Dominant grass species in TF were *D. bicornis, P. umbellata, D. caricosum*, and *A. mutica* (Table 2).

The percent grass composition varied significantly across season ($F= 11.6$; $p <0.001$) in different habitats ($F= 13.92$; $p <0.001$). Fire was not recorded in the TF area during the study period. Grass availability was higher in the MDF during dry season (27.7%). The mean percent available grass was highest in first wet season in the DDF (46 %) in the fire burnt areas (Figure 2). Grass availability was low in second wet season in TF. The three-way interaction among fire, habitats and seasons in ANOVA on grass availability was significant. The abundance of grass was higher in the DDF and MDF in wet seasons in the unburnt areas.

The influence of environmental variables on grass availability

The grass availability had a linear relationship with predictors. The model was highly significant and explained 23% variations in grass availability (%). Previous month precipitation positively influenced grass availability. All the other variables negatively influenced grass availability. From the Standardized Partial Regression Coefficients (SPRC), it was inferred that the shrubs had the primary influence on growth of grasses followed by sedges, regeneration, herbs, and weed (Table 3; Figure 3). Furthermore, the co-efficient of habitat and season indicated that the percent availability of grass reduced significantly among three habitats and seasons. Though, fire negatively influenced grass availability, it was not statistically significant in the model.

Grass species association

Principal coordinate analysis (multidimensional scaling) summarizes inter grass species association based on dissimilarity in a Euclidean space. There were seven distinct clusters formed. Among different variables elevation, height and percent composition collectively contributed 87% of the variance. There were four distinct clusters identified based on elevation and further separation was based on habitat and microhabitat (Figure 4). The first cluster consisted of grass species such as *Themeda triandra*, *Setaria intermedia*, *Enteropogon dolichostachyus* and *Oplismenus undulatifolius* in DDF. The second cluster consisted of *Axonopus* sp. (Image 1e) and *Bothriochloa bladhii* in riverine forest. The third cluster consisted of thorn forest species such as *Arthraxon, Chrysopogon, Psudanthistiria*, and *Cynodon*

Table 1. Mean percent grass available (±SD), species richness per plot, diversity and equitability of grass (and sedges) in different habitats of Mudumalai Tiger Reserve.

Habitat[a]		Total number of species	Species richness (S) / plot (±SD)	Mean percent (%) ± SD	Index value	
					Shannon Weiner Diversity (H')	Equitability (J')
DDF (n= 1,162)		61	2.9 ± 1.30	18.8 ± 22.45	0.65 ± 0.40	0.68 ± 0.22
MDF (n= 279)		33	2.7 ± 1.34	17.5 ± 21.67	0.60 ± 0.42	0.69 ± 0.21
TF (n= 248)		53	3.4 ± 1.79	12.7 ± 16.79	0.80 ± 0.45	0.72 ± 0.21
Overall (n= 1,749)		74	3.0 ± 1.42	17.3 ± 21.40	0.67 ± 0.42	0.69 ± 0.22
ANOVA	F		F_{1645}= 20.3	$F_{2,821}$= 14.04	F_{1645}= 20.5	F_{1432}= 5.18
	P		p <0.001	p <0.001	p <0.001	p <0.001

[a]-DDF—Dry Deciduous Forest | MDF—Moist Deciduous Forest | TF—Thorn forest.

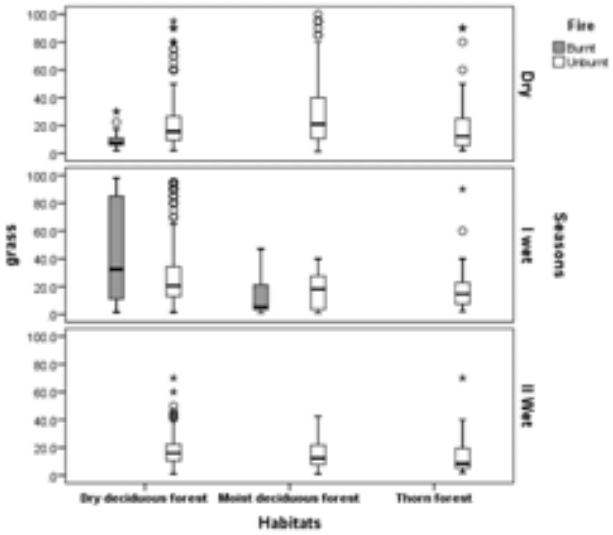

Figure 2. Grass composition (%) in different habitats, seasons, and fire (burnt/unburnt) in Mudumalai Tiger Reserve.

sp. Forth cluster consisted of *Cenchrus*, *Sporobolus, Centotheca*, and *Eragrostis* sp. in dry deciduous tall grass at 1,000 m elevation. Fifth cluster composed of *T. cymbaria, Ischaemum, Cyrtococcum*, and *Kyllinga* species in the moist deciduous forest. The sixth cluster composed of *Imperata*, *Echinochloa*, and *Cenchrus hohenackeri* in swamp areas of MDF. Dry deciduous higher elevation regions composed of *Arthraxon, Cappillipedium*, and *Setaria* species.

DISCUSSION

A total of 66 species of grasses and eight sedges were recorded in the Mudumalai Tiger Reserve. The number of species recorded was lower than earlier report (75 species) in the study area (Sivaganesan 1991). The marginal variation in the species composition could be

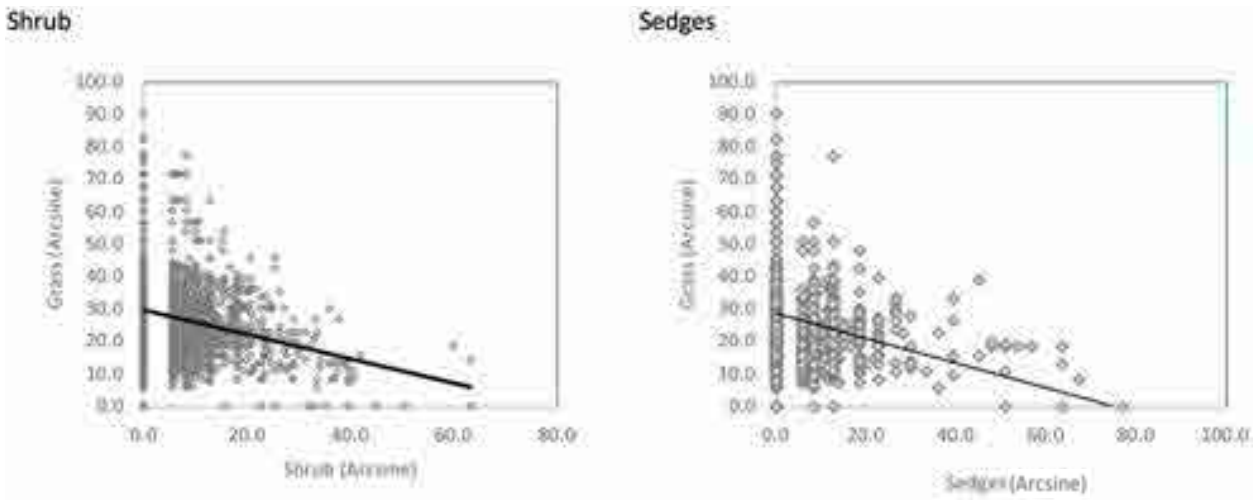

Figure 3. Relation between biotic factors and grass composition at Mudumalai Tiger Reserve.

Table 2. Percent grass (grass and sedges) available in different habitats of Mudumalai Tiger Reserve during the study period (Data sorted in descending order based on total percent).

		Habitats			
	Species	DDF	MDF	TF	Total
	Grass				
1	*Axonopus compressus*	45.7 ± 39	28.2 ± 31.67	-	33.4 ± 34.34
2	*Cyrtococcum oxyphyllum*	-	33.4 ± 22.19	-	33.1 ± 22.3
3	*Cenchrus hohenackeri*	27.4 ± 24.17	36.3 ± 33.65	-	33.1 ± 30.6
4	*Themeda cymbaria*	30.4 ± 22.45	25 ± 17.32	-	30.1 ± 22.15
5	*Themeda triandra*	27.2 ± 21.53	20.2 ± 20.17	23 ± 26.08	26.7 ± 21.68
6	*Oplismenus undulatifolius*	25.1 ± 24.99	4.3 ± 4.27	26.7 ± 24.9	25.3 ± 24.9
7	*Axonopus* sp.	28.4 ± 31.12		6.5 ± 5.58	23.9 ± 29.19
8	*Setaria intermedia*	22.3 ± 22.06	25 ± 7.07	31.4 ± 26.1	23.6 ± 22.78
9	*Pseudanthistiria umbellata*	-	-	23.4 ± 20.47	23.4 ± 20.47
10	*Centotheca lappacea*	-	-	40 ± 0.01	20.5 ± 27.58
11	*Setraria flavidum*	17.5 ± 18.03	2 ± 0.01	25.9 ± 16.92	18.9 ± 18.06
12	*Setaria pumila*	18.5 ± 21.39	28 ± 0.01	17.3 ± 16.38	18.5 ± 21
13	*Enteropogon dolichostachyus*	16.2 ± 18.84	14.1 ± 14.95	20.7 ± 24.35	16.6 ± 19.42
14	*Eleusine indica*	22.4 ± 31.09	14 ± 13.86	7.4 ± 7.16	16.3 ± 22.74
15	*Cenchrus polystachios*	-	15.6 ± 13.53	-	15.6 ± 13.53
16	*Heteropogon contortus*	19.2 ± 20.03	-	10 ± 13	15.3 ± 17.93
17	*Cyrtococcum accrescens*	8.7 ± 13.06	20.1 ± 21.69	-	15.1 ± 19.3
18	*Setaria verticillata*	-		15 ± 0.1	15 ± 0.1
19	*Imperata cylindrica*	13 ± 13.9	16.2 ± 28.06	-	13.9 ± 18.92
20	*Digitaria* sp.	11.6 ± 12.51	12.3 ± 15.37	16.9 ± 12.8	13.6 ± 12.82
21	*Bothriochloa* sp.	-	-	13.6 ± 7.47	13.6 ± 7.47
22	*Panicum* sp.	14.4 ± 8.46	-	1 ± 0.01	13.1 ± 9.04
23	*Digitaria bicornis*	13.8 ± 21.91	4 ± 1.73	9.8 ± 15.84	12.2 ± 19.82
24	*Digitaria griffithii*	11.9 ± 13.2	5 ± 0.01	12 ± 6.35	11.9 ± 12.65
25	*Perotis indica*	11.9 ± 17.94	-	-	11.9 ± 17.94
26	*Panicum tripheron*	7.8 ± 11.67	-	15.2 ± 14.85	11.8 ± 13.87
27	*Urochloa distachya*	12.2 ± 11.92	12.5 ± 10.61	10.6 ± 9.93	11.8 ± 11.23
28	*Apluda mutica*	9.4 ± 11.32	9.2 ± 13.09	18 ± 18.37	11.8 ± 14.16
29	*Dichanthium caricosum*	10 ± 0.01	5 ± 0.01	13 ± 9.08	11.4 ± 8.02
30	*Eragrostis tenuifolia*	15.8 ± 23.01	-	3.1 ± 2.77	11.4 ± 19.53
31	*Sporobolus fertilis*	13 ± 12.75	-	1 ± 0	11.4 ± 12.54
32	*Ischaemum ciliare*	10.2 ± 10.98	11 ± 15.25	-	10.9 ± 14.7
33	*Setaria palmifolia*	10.8 ± 12.59	1 ± 0.01	10 ± 0.01	10.5 ± 12.33
34	*Eragrosteilla* sp.	11.8 ± 8.67	-	8.2 ± 13.66	10.1 ± 11.39
35	*Eragrosits atrovirens*	-	-	10 ± 7.07	10 ± 7.07
36	*Oplismenus compositus*	6.3 ± 10.4	13.2 ± 13.87	-	9.9 ± 12.79
37	*Paspalum conjugatum*	-	9 ± 9.64	-	9 ± 9.64
38	*Aristida adscensionis*	8.4 ± 7.6	-	8.8 ± 10.18	8.7 ± 9.89
39	*Cynodon radiatus*	15 ± 0.1	-	2 ± 0.01	8.5 ± 9.19
40	*Echinochloa colona*	6.3 ± 7.51	15 ± 0.1	-	8.5 ± 7.51
41	*Themeda tremula*	7.2 ± 3.13	5 ± 0.1	20 ± 0.1	8.5 ± 5.4

	Species	Habitats			Total
		DDF	MDF	TF	
42	*Dactyloctenium aegyptium*	13.9 ± 16.5	-	5.3 ± 7.09	8.5 ± 11.8
43	*Sehima sp.*	7.3 ± 15.34	-	11.5 ± 15.73	8.2 ± 15.23
44	*Tragus mongolorum*	1 ± 0.01	-	8.1 ± 7.74	8 ± 7.73
45	*Sporobolus* sp.	7.8 ± 9.15	7.5 ± 11.22	4.2 ± 3.49	7.5 ± 9.01
46	*Alloteropsis cimicina*	5.4 ± 8.93		24.9 ± 25.6	7.5 ± 13.38
47	*Chrysopogon sp.*	-	-	7.5 ± 9.46	7.5 ± 9.46
48	*Cymbopogon sp.*	7.2 ± 5.18	-	-	7.2 ± 5.18
49	*Cappillipedium assimile*	6.8 ± 3.95	-	-	6.8 ± 3.95
50	*Cynodon dactylon*	7.1 ± 5.73	1 ± 0.01	3.3 ± 2.08	6.4 ± 5.54
51	*Eragrostis* sp.	1 ± 0.01	-	6.6 ± 12.56	6.3 ± 12.22
52	*Oryza meyeriana*	7.3 ± 10.01	4.7 ± 9.64	10 ± 0.1	5.8 ± 9.74
53	*Sporobolus diandrus*	4.8 ± 3.77	10 ± 0.1	-	5.8 ± 4.02
54	*Digitaria abludens*	20 ± 0.1	-	4.5 ± 4.96	5.1 ± 5.65
55	*Elytrophorus spicatus*	5 ± 0.1	-	-	5 ± 0.1
56	*Eragrosits abludens*	-	-	5 ± 0.1	5 ± 0.1
57	*Cenchrus purpureus*	5 ± 0.1		-	5 ± 0.1
58	*Bambusa arundinacea*	5.4 ± 2.88	4.5 ± 4.37	1.7 ± 0.58	4.3 ± 3.74
59	*Arthraxon* sp.	7.3 ± 8.62	-	2.5 ± 1.9	3.1 ± 3.58
60	*Panicum notatum*	-	-	3 ± 0.1	3 ± 0.1
61	*Bothriochloa bladhii*	2 ± 0.1	-	-	2 ± 0.1
62	*Isachne elegance*	2 ± 0	-	-	2 ± 0
63	*Leersia hexandra*	-	-	2 ± 0.1	2 ± 0.1
64	*Arthraxon lancifolia*	-	-	1.5 ± 0.58	1.5 ± 0.58
65	*Mnesithea granularis*	1 ± 0.1	-	1.5 ± 0.55	1.4 ± 0.53
66	*Chrysopogon lawsonii*	1 ± 0.1	-	-	1 ± 0.1
	Sedges				
67	*Kyllinga melanosperma*	15.2 ± 22.46	7.1 ± 7.22	6.2 ± 7.95	12 ± 18.59
68	*Mariscus madraspatanus*	6 ± 8.37	17.4 ± 26.83	2.5 ± 1.22	9.8 ± 17.98
69	*Fimbristylis aestivallis*	7.4 ± 5.87	-	6.2 ± 6.02	7 ± 5.73
70	*Cyperus distans*	4.2 ± 4.91	8.1 ± 13.59	5 ± 0	4.9 ± 7.42
71	*Cyperus rubicundus*	6.2 ± 5	-	3.2 ± 3.75	4.2 ± 4.41
72	*Fimbristylis* sp.	3.7 ± 2.36	-	2.6 ± 2.4	3 ± 2.41
73	*Kyllinga* sp.	2.6 ± 2.78	-	-	2.6 ± 2.78
74	*Kyllinga tenuifolia*	2 ± 0.1	-	1 ± 0	1.3 ± 0.58

DDF—Dry deciduous forest | MDF—Moist deciduous forest | TF—Thorn forest | ––Species were not recorded.

due to difference in the area of sampling, earlier study covered greater area of sampling. Sivaganesan (1991) divided the tiger reserve into five zones and did sampling in five transects with 30 plots in each transects with 250 m interval. The number of transect in Moist deciduous forest is less than earlier study. Further, there were invasion of exotic weed species such as *Lantana camera* and *Chromolena odorata* in the study area (Ashokkumar et al. 2012; Wilson et al. 2013), which were less and restricted to tourism zone in the study area. Whereas the growth of weeds was extensive and occupied all the grassland patches of DDF and MDF.

Grass species richness, composition varied among habitats, with maximum number of species recorded in DDF followed by TF. *Cymbopogon* sp. found in hill slopes of DDF in the elevation range of 2,000–3,000 m,

Table 3. Multiple regression equation to investigate the effect of environmental (habitat, fire and precipitation) and vegetation factors on the grass availability (%) in Mudumalai Tiger Reserve.

Independent variable	Predictor	Coefficients ± SE	SPRC*	t	p	Model (r^2)	Model (p)
Grass (%)	(Constant)	38.17 ± 2.535		15.059	<0.001	23.1	p<0.001
	Fire	-0.76 ± 1.100	-0.015	-.694	0.488		
	Habitat	-3.59 ± 0.414	-0.191	-8.653	<0.001		
	Season	-2.60 ± 0.598	-0.138	-4.353	<0.001		
	Previous month precipitation (mm)	2.82 ± 0.403	0.229	6.998	<0.001		
	Herb (%)	-0.31 ± 0.042	-0.161	-7.286	<0.001		
	Regeneration (%)	-0.52 ± 0.063	-0.179	-8.206	<0.001		
	Sedges (%)	-0.37 ± 0.039	-0.200	-9.341	<0.001		
	Shrub (%)	-0.46 ± 0.038	-0.268	-12.096	<0.001		
	Weed (%)	-0.23 ± 0.043	-0.112	-5.254	<0.001		

*—Standardized partial regression coefficient.

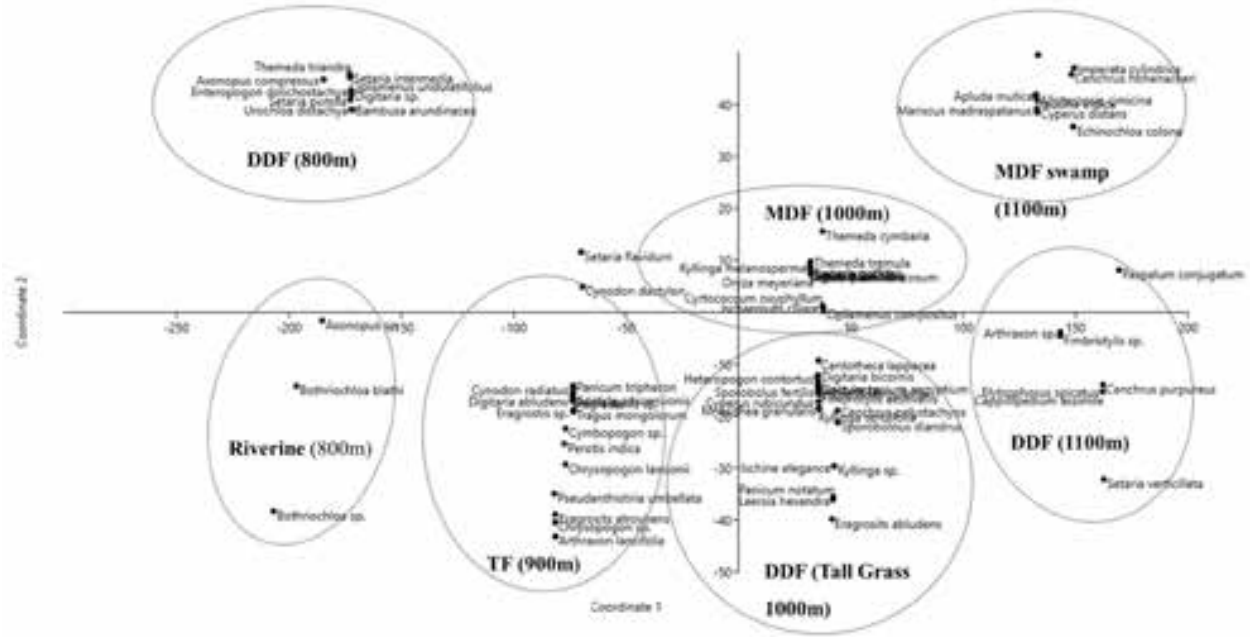

Figure 4. Principal coordinate (PCoA) analysis of grass species association based on dissimilarity in Mudumalai Tiger Reserve (Circles indicate distinct clusters).

P. polystachyon recorded in swamp areas of MDF in the elevation of above 1,000 m, and *A. adscensionis* found in TF in the elevation less than 600 m. Grass species such as *C. polystachios, L. hexandra*, and *I. cylindrica* were observed in the swamps of MDF and DDF in MTR. This might have been influenced by high moisture content and nutrients of the soil (Skerman & Riveros 1990). Amarasinghe & Pemadasa (1982) have also concluded that the complex interaction of edaphic factors, altitude, precipitation and human disturbance were responsible for a variation on Montane grasslands in Sri Lanka. Thus, the grass composition varied depending on altitudes and moisture content of the soil.

Factors influencing grass composition

Shrubs had the primary influence on the grass growth followed by sedges, regeneration, herbs and weeds. Studies done in Prairie grasslands in Canada indicated that shrubs strongly reduced available soil nitrogen and the secondary growth of shrubs allowed them to accumulate more biomass and height that eventually displaced the grass species (Kochy & Wilson 2000).

Image 1. Grass species composition in the selected habitats of Mudumalai Tiger Reserve: a—Dry deciduous tall grass (*Cymbopogon* sp.) | b—Dry deciduous tall grass (*Themeda- Cymbopogon-Imperata*) | c—MDF swamp areas with (*Cenchrus-Themeda-Imperata*) | d—*Setaria palmifolia* | e—*Axonopus compressus* | f—*Cyrtococcum oxyphyllum.* © M. Ashokkumar

The grass species *Axonopus* sp. was recorded only in *L. camara* invaded areas. This grass species was originated in United States and this species itself considered as weed (Skerman & Riveros 1990). Therefore, it competes well with weed species. In addition, both *L. camara* and *Axonopus* sp. grow well in humid areas and thus, they do have similar microhabitat preference. The microhabitat preference and weed resistance properties of *Axonopus* sp. enabled successful survival in *L. camara* invaded areas. Grass species that were recorded in *C. odorata*

invaded areas (*Cenchrus*, *Setaria*, and *Chrysopogon*) seem to have high alkaline tolerance (Skerman & Riveros 1990). Thus, grass species had species-specific interaction with weed species. The percent availability of grass varied significantly among three habitats and seasons. The seasonal variation in grass availability was due to phenological changes of grass species due to senescence. The phenology of tropical grasses are moisture driven, with germination occurring shortly after the rains of first wet season. Grass senescence occurs in the end of the second wet season or in the early dry season. Both the reproduction and senescence have been influenced by multiple factors such as temperature, rainfall and photoperiod (Blair et al. 2014). Hence the availability of grass was higher in the wet seasons.

The percent grass available was significantly positively correlated with precipitation. Rainfall varied spatiotemporally across vegetation types in the study area. Such a rainfall pattern is ecologically significant and perhaps a boon to the dynamics of the study area. Elephant habitat preference was related to the rainfall in the study area (Sivaganesan 1991). In Africa, several ecologists (Leuthold & Sale 1973; Caughley & Goddard 1975; Leuthold 1976; Eltringham 1979; McNaughton 1985) documented the significance of the rainfall on the habitats and distribution pattern of the larger herbivores. The western part of the study area with MDF receives rainfall during south-west monsoon and eastern part (TF) during north-east monsoon. The grass growth and phenological changes can be seen depending on the precipitation.

Variation in grass composition in the study area

Comparison of grass species composition with earlier study Sivaganesan (1991) revealed that though, there were no changes in the dominant grass species there were considerable changes in the minor grass species composition. The principal coordinate analysis revealed seven distinct clusters of grass species association. Sivaganesan (1991) reported four distinct clusters of grass association in the study area: *Themeda-Cymbopogon-Imperata* in the dry deciduous tall grass area (Image 1a), *Cenchrus-Themeda-Imperata* in the swamp area (Image 1c), *Cyrtococcum-Apluda-Arthraxon* in MDF, and *Themeda-Heteropogon-Digitaria-Apluda* in the TF area. Changes occurred in the grass species composition in all habitats. The percent availability of grass was reduced when compared to past, possibly due to greater extent of invasion of exotic species.

Sivaganesan (1991) indicated that annual fire seems to influence the species association and succession of species at Mudumalai. He reported that fire-resistant species such as *T. triandra*, *H. contortus*, and *T. cymbaria* have survived and dominated the dry deciduous forest. This is unison with his finding that the above species also dominated in DDF based on the present study. The fire frequency was also high (22 incidences per annum), and more area was burnt in DDF (56%) than other habitats (Ashokkumar 2011). Grass species which were reported rare and sporadic in the earlier study were not reported in the present survey, for example *Chionachne koenigii* in DDF and *Oryza meyeriana* in MDF were not recorded. Similarly, percent composition of *Apluda* sp. and *Arthraxon* sp. were less in MDF. Fewer species were recorded in MDF, but the mean percent available grass was more in MDF. The dominant grasses in MDF were tall grass species in the swamp areas which grow up to 3 m, and thus their percent composition was higher. Earlier TF was dominated by *T. triandra* and *H. contortus* (Sivaganesan 1991) and these species were poorly represented during the present survey and TF is dominated by *Digitaria* sp., *Pseudanthistiria umbellata.* TFs facing severe pressure due to cattle grazing and removal of cattle dung from the forest floor had severely affected the forest regeneration and nutrient cycle. Earlier studies on livestock populations reported 7,248 cattle in the fringe areas (Silori & Mishra 2001) allowed to free graze in the reserve. Continued grazing affects grass availability and species composition.

Protection from cattle grazing

Grass species *Aristida-Eragrostis* were recorded in the TF which were considered as an indicator species of deteriorated grassland (Skerman & Riveros 1990). Grass species such as *Themeda-Heteropogon-Digitaria-Apluda* were dominant species in thorn forest reported in the past. At present, the quality of grass pastures was too poor to provide any grazing. Severe cattle grazing should be stopped for four or five years to allow the succession to progress towards fair condition represented by *Cynodon dactylon* as the first step toward improvement. Thus grasslands of TF required protection of pasture from cattle grazing or at least reduction of cattle pressure for at least four to five years to recover. Species reduced by overgrazing can recover if there were no change in the physical environment.

Influence of fire on grass availability

In the study area during the peak of dry season wildfire was common. These, wildfires were set by the villagers to get fresh fodder for their cattle and easy to move around in burnt areas. Fire in grass patches

last only for a short time and high temperatures were maintained for only a few seconds. Temperatures at soil level rise steeply to 175–200 °C depending on wind, height and density, and usually return to ambient temperature within a few minutes (Mondal & Sukumar 2014). The soil temperature at a depth of about two centimeters changes little, varying at most by 14 C. The effect of subterranean portions of grasses is thus slight.

The study area as a whole had a fire-return interval of 3.3 years (Ashokkumar 2011). The vegetation type with the highest mean area burnt was at DDF (*Shorea* sp. dominant) with 56.6%, whereas, TF had the lowest mean area burnt with 14.6%. Forest fires burnt an average of 30% (98 km^2/year) of the forests in each year. Grass biomass was significantly low in burnt areas. Distance from the park boundary was reported as an important factor that predicts the fire-return interval in the study area (Kodandapani et al. 2008). Grass biomass was significantly low in the fire burnt areas of DDF and MDF. Sivaganesan (1991) indicated that the effect of annual fire seems to influence the grass species association and succession of species. On other hand, the annual fire plays an important role in the maintenance of forest stands at deciduous forest and seedling growth. The forest fire scorches the tree seeds of *Tectona grandis* and facilitates the growth by removing a portion of the seed coat (Seth & Kaul 1978). But overall tree species diversity, structure and regeneration were reduced by fire in tropical forest (Kodandapani et al. 2008), further, the results suggest both grass availability and composition altered by fire.

CONCLUSIONS

The present study provides baseline information on grass species composition in the tropical forest of southern India. There were considerable changes occurred in the grass species composition when compared to past. Grass association revealed seven major types of association in the tropical deciduous forest. Grasslands of TF were dominated by *Aristida-Eragrostis* indicators of heavy gazing and require protection of pasture from cattle grazing or at least reduction of cattle pressure to recover. Grass composition and availability was positively influenced by rainfall and reduced by fire in the tropical deciduous forest. Further grass availability and composition is threatened by invasion of weeds.

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COMMUNICATION

Habitat use and conservation threats to Wild Water Buffalo *Bubalus arnee* (Mammalia: Artiodactyla: Bovidae) in Koshi Tappu Wildlife Reserve, Nepal

Reeta Khulal [1], Bijaya Neupane [2], Bijaya Dhami [3], Siddhartha Regmi [4], Ganesh Prasad Tiwari [5] & Manita Parajuli [6]

[1] Tribhuvan University, Institute of Forestry, Office of Dean, Kirtipur, Kathmandu, 44600, Nepal.
[2,3,6] Tribhuvan University, Institute of Forestry, Pokhara Campus, Pokhara, 33700, Nepal.
[4] Tribhuvan University, Institute of Forestry, Hetauda Campus, Hetauda, 44107, Nepal.
[5] Agriculture and Forestry University, Faculty of Forestry, Hetauda, 44107, Nepal.
[1] reetkc9336@gmail.com, [2] bijneu@gmail.com (corresponding author), [3] bijaysinghdhami@gmail.com, [4] iregmisid@gmail.com, [5] tiwari.ganesh24@gmail.com, [6] manitaparajuli11@gmail.com

Abstract: Wild Water Buffalo (WWB) *Bubalus arnee* is an endangered species and a protected animal in Nepal. The remaining WWB population is located in Koshi Tappu Wildlife Reserve (KTWR), and it appears to have low viability under prevailing conditions. We assessed the habitat use and conservation threats to wild water buffalo in KTWR. For habitat analysis the quadrant method was used. Eighty-four quadrants of 25 m^2 for trees, 168 quadrants of 10m^2 for shrubs and 336 quadrants of 1 m^2 for herbs were laid out in the study area. Ivlev's electivity index (IV) was calculated to assess the use of different habitat components. The important Value Index (IVI) was used for vegetation assessment. A relative threat ranking method was used to assess conservation threats for wild buffalo and their habitats. Wild buffalo mostly preferred habitats with distance to water resources less than 500 m (IV= 0.4), less than 25 % crown coverage (IV= 0.39) and more than 75 % ground coverage (IV= 0.42). The trees species *Phyllanthus emblica*, *Acacia catechu*, shrub species *Mimosa pudica* and the herb species *Brachiaria distachya*, *Vetiveria zizanioides*, *Imperata cylindrica*, and *Saccharum spontaneum* were preferred by WWB in the study area. Among the different plant categories, we found that *Acacia catechu* was the most preferred tree species (IVI= 156.95), *Mimosa pudica* the most preferred shrub species (IVI= 58.68), and *Imperata cylindrica* the most preferred herb species (IVI= 64.73). Major conservation threats perceived by local stakeholders for wild buffaloes were overgrazing by cattle and genetic swamping through crossbreeding with domestic buffalo. Therefore, conservation of grass species through control of grazing, and prevention of cross breeding are measures supported by this study. Additionally, site-specific conservation strategies should be adopted, based on identified threats in the study area.

Keywords: Crossbreeding, endangered, genetic swamping, important value index, Ivlev's electivity index, quadrats.

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Author details: Reeta Khulal is a MSc graduate in wildlife, protected area management, and biodiversity conservation. Bijaya Neupane is an assistant professor in wildlife and protected area management working with the Department of Park Recreation and Wildlife Management at his institution since December 2016. He possesses more than 5 years of research and teaching experiences in ecology and wildlife conservation in Nepal as well as some field and lab experiences in Norway and Sweden. Bijaya Dhami is a BSc Forestry final year student and is actively involved in several conservation activities and is a president of his NGO, one of the green organization of Pokhara. Siddhartha Regmi is a BSc Forestry graduate and now he is working as a research technician in conservation NGO, Care for Nature, Nepal and is directly involved in numerous wildlife related projects. Ganesh Prasad Tiwari is a MSc Forestry student. Manita Parajuli is a BSc final year student.

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INTRODUCTION

Nepal has two zoogeographic regions: Palearctic and Oriental, and is known for faunal diversity including 212 species of mammals (Baral & Shah 2008; Jnawali et al. 2011; Amin et al. 2018), including 49 threatened species. The Wild Water Buffalo *Bubalus arnee* (WWB), also called Wild Asian Buffalo (Image 1) is a large bovine native to southern and southeastern Asia (Dahmer 1978), which primarily occurs in tropical, subtropical forest, and swampy grasslands (Thapa et al. 2020). It is legally protected in India, Nepal, Cambodia, Myanmar, Thailand, and Bhutan (Groves 1981). This species is categorized as 'Endangered' mammal species on the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (Kaul et al. 2019) and in Appendix III of the Convention on International Trade in Endangered Species of wild fauna and flora (CITES) (CITES 2017). It is one of the protected mammals included in Nepal's National Parks and Wildlife Conservation Act, 1973 (GoN 1973).

WWB is a large powerful animal that weighs between 800–1,200 kg, with horn span of around 2 m (Aryal et al. 2011). Home ranges are 1.7–10 km^2 (Nowak 1999). Generally, males are able to breed after 18 months while females are able after 3 years. The pregnant female undergoes a gestation period of 12 months and gives birth to a single calf at a time, with a minimum birth interval of about 2 years (Shrestha 1997). In the wild, WWB can live up to 25 years, and in captivity up to 29 years (Roth 2004). They are social animals and typically form herds of 10–20 individuals, with herds of up to 100 having been witnessed (Heinen 1993). Being intensely reliant on water and investing significant time wallowing in puddles or rivers, they are frequently sighted in swamps and marshes, grasslands, and riverine forests (Roth 2004). WWB usually prefer marshy floodplains with towering elephant grass (e.g., *Saccharum* and *Phragmites*) and scrubby wooded forests of *Bombax, Dalbergia*, and *Acacia* (Sah 1997). Additionally, open short grasslands, forests and agriculture fields provide good shelter (Adhikari 1999).

In Nepal, Koshi Tappu Wildlife Reserve (KTWR), established in 1976, shelters the last enduring population of WWB, consisting of 498 individuals (DNPWC 2021). With the aim to establish a second sub-population of WWB, 15 individuals were translocated and kept in an enclosure in Chitwan National Park in January 2017, but their viability is not yet ensured (Shah et al. 2017). Thus conserving WWB in KTWR is a serious issue that is getting more critical every year. The species and their habitat have been mainly threatened by human interference, including illegal hunting, habitat fragmentation, and degradation (Heinen & Kandel 2006; Kafle et al. 2020). Besides, there is also the severe problem of crossbreeding with domestic buffalo (Khatri et al. 2012), consequently losing the genetic diversity of the species (Kaul et al. 2019). There is only about 0.8 km^2 area per individual WWB in the reserve, which is inadequate to sustain a thriving buffalo population (Aryal et al. 2011).

Apart from habitat-use information, it is essential for conservationists to find out the threat status of an ecological community (Nicholson et al. 2009; Joshi et al. 2020) to plan and implement conservation activities effectively. The threat ranking method used by WWF in the Standards of Project and Program Management shows the degree to which each direct threat affects the biodiversity target at a given site (WWF 2007). In this study, a similar technique was employed, which consisted of recognizing a set of standards and applying them to direct risks in order to develop a conservation action plan by focusing on the areas where they are most needed. To our knowledge, very limited studies have been conducted particularly on the habitat use and threats of WWB in the study area, so this study attempts to fulfill such information gap that can help the conservationists, planners, and reserve managers to implement the required conservation measures for such threatened and isolated species.

MATERIALS AND METHODS

Study area

The KTWR extends from 86.916–87.0830 E to 26.566–26.7510 N and is located in Eastern Nepal's Saptari, Sunsari, and Udaypur districts, on the alluvial flood plains of the Sapta Koshi River (Figure 1). It covers a total core area of 175 km^2 with an additional buffer zone of about 173 km^2 surrounding the reserve, declared in 2004. Recognizing the reserve's significance, it was assigned as a wetland of global significance and included in the Ramsar list on 17 December 1987 (IUCN 1990). The reserve is mostly comprised of riverine grasslands (56%), sand & gravel deposits (22%), agricultural field (5%), forest land (1%), river & stream (10%), marshes & swamps (6%), and lake & pond (0.01%) (Chettri et al. 2013). It is listed as an important bird area where 490 species of birds have been recorded (Shrestha & Pantha 2018). Natural predators of WWB such as Leopard *Panthera pardus*, Dhole *Cuon alpinus*, Tiger *Panthera tigris*, were wiped out from KTWR for at the last 40 years

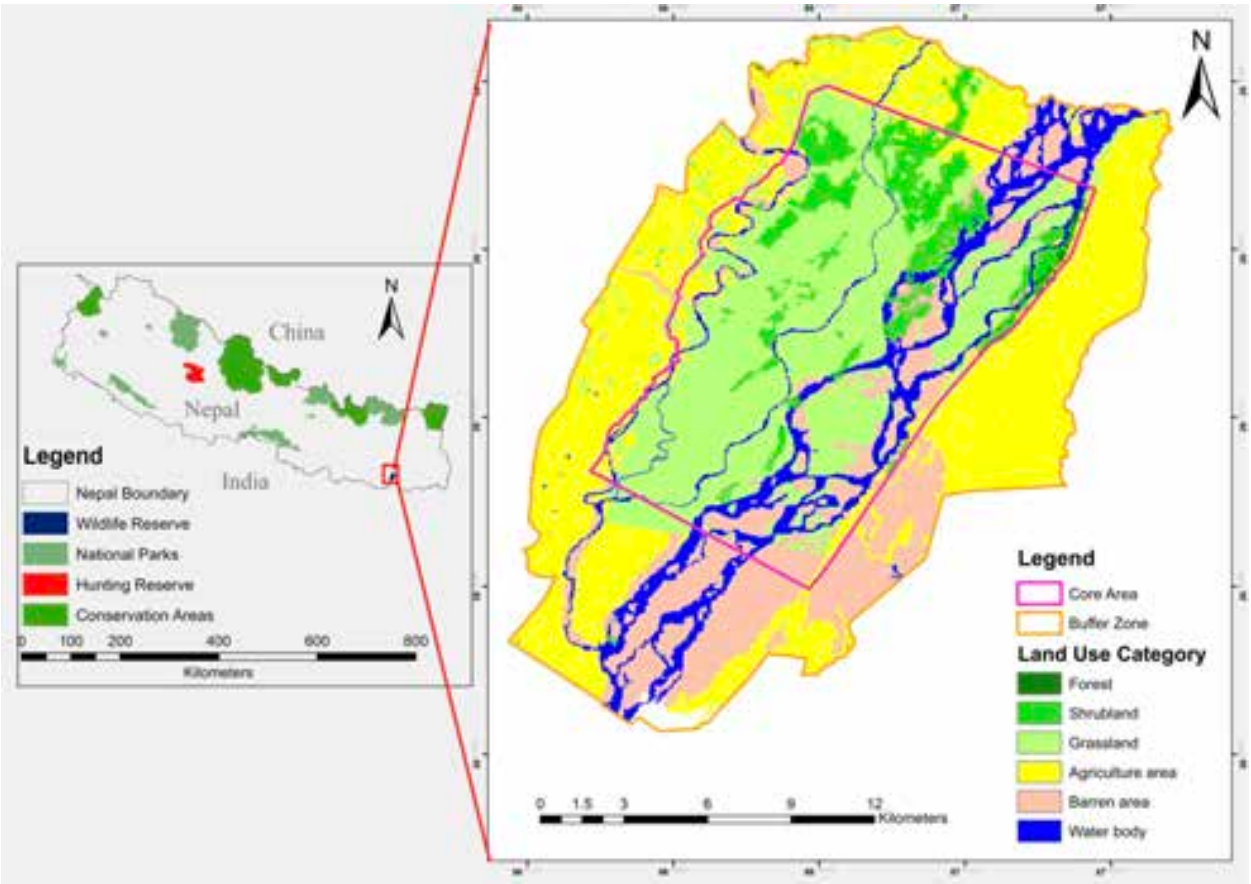

Figure 1. Map of the study area (Koshi Tappu Wildlife Reserve, Nepal).

Image 1. Wild Water Buffalo *Bubalus arnee* sighted in KTWR. © Reeta Khulal.

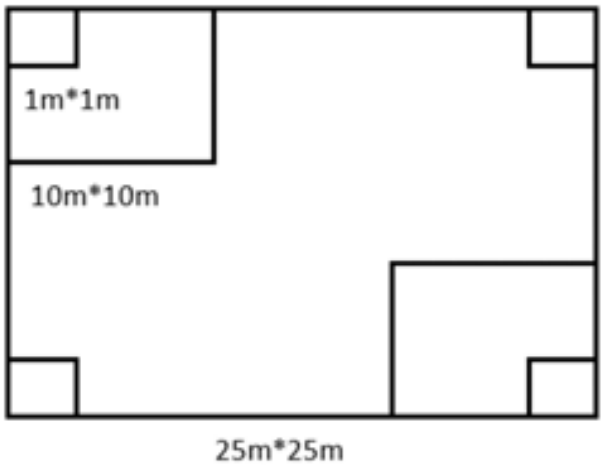

Figure 2. Layout of quadrant in the study area.

(Heinen & Paudel 2015). The climate of the reserve is the tropical monsoonal type and the monsoon season, which runs from mid-June to late September, accounts for 80–85 percentage of total rainfall. The average monthly temperature ranges between 15.7 ^{0}C and 29.2 ^{0}C and the average annual rainfall range from 1,300 mm to 2,050 mm with higher humidity that remains throughout the year.

Data collection

We conducted the field study between December 2019 and January 2020. In the initial phase, all the potential sites of WWB, in consultation with the experienced park staff and warden, were surveyed for evidence such as droppings, exudation of sap, crushed tissues, fresh clipping, and direct sighting during the active periods of dawn and dusk (Heinen & Singh 2001). Then, a random sampling method was adopted to identify different attributes of habitat associated with WWB. Both Habitat Use plots "U" and Availability plots "A" were established on those sites. In each location where the indirect evidence (droppings, hair, pugmarks, bedding sites, and horns) of the WWB were observed; the habitat use plot was established within a distance of 50 m (Neupane et al. 2021). Different habitat attributes from each plot such as ground cover, crown cover, and distance to water source were noted. Further, Availability plots were established within 100 m distance from the Use plots in random direction (Neupane et al. 2021). Similar habitat attributes were noted in each availability plot as noted in use plots. If any signs of the WWB were observed in availability plots, the availability plots were renamed as use plots. Vegetation analysis was conducted on both the availability and use plots. Eighty-four quadrants each of size 25 x 25 m for trees; 168 nested quadrants of 10 x 10 m for shrubs and 336 nested quadrants of 1x 1 m for herbs were laid out randomly on those selected sites (Figure 2). Within each quadrant, all the trees were counted and their diameter at breast height (DBH), and heights were assessed using diameter tape and clinometers respectively. Similarly, the species composition and percentage cover of shrubs and herbs and their respective frequencies were noted.

Threat assessment was done by direct field observation and through interviews with the local people, local experts, and reserve authorities in the study area. These interviewees were conducted with different local stakeholders who have been residing there for more than 20 years and are familiar with the WWB and their habitats, following a similar method used in the previous studies (Chhetri et al. 2020; Neupane et al. 2020). Literature reviews were also conducted to gather information on various facets of each threat. Interviews were taken with conservation officers, political pioneers, and heads of the metropolitan wards to investigate their insight and perspectives on the existing threats to WWB and their habitats. We assigned the scope, severity, urgency, and irreversibility ratings of each threat component, and based on the information gained from these methods, we ranked the threats using the relative threat ranking method.

Data analysis

The habitat utilization of WWB was analyzed using Ivlev's electivity index (IV), whose value ranges in between +1 to -1. The positive value of IV indicates habitat utilization and negative value indicates habitat avoidance and finally, zero value indicate random utilization of the habitat (Ivlev 1961). The (IV) value was calculated using following formula.

IV= (U % − A %) / (U % + A %) (Ivlev 1961; Yonzon & Hunter 1989; Neupane et al. 2021).

Percentage of crown cover as well as ground cover was divided into four categories that include 0–25 %, 26–50 %, 51–75 %, and 76–100 %. Vegetation analysis and calculations was done according to the methods suggested by Zobel et al. (1987) with the formula mentioned below.

$$\text{Density of species A} = \frac{\text{Number of individual of A species in all quadrates x 100\%}}{\text{Total number of quadrates studied x Size of quadrate taken}}$$

$$\text{Relative density of species A} = \frac{\text{Density of species A occurred x 100\%}}{\text{Sum of all density}}$$

Table 1. Interpretations of criteria and associated rankings used to prioritize each threat (adapted from TNC 2007; WWF 2007; NHWAP 2015).

Criteria and rankings	Definition
Scope	**The geographical extent of impact on the biological target that can be fairly foreseen within 10 years under existing conditions**
Very high	The threat is expected to be pervasive in its scope, influencing the target over all or most (71–100%) of its occurrence/population.
High	The threat is expected to be widespread in its scope, influencing the target over (31–70%) of its occurrence/population
Medium	The threat is expected to be restricted in its scope, influencing the target over (11–30%) of its occurrence/population
Low	The threat is expected to be very narrow in its scope, influencing the target over a less part (1–10%) of its occurrence/population
Severity	**The degree of damage to biological target that may be realistically predicted within 50 years under existing conditions.**
Very high	The threat is expected to eliminate or degrade the target or minimize its population by 71–100% within 10 years or 3 generations, within the scope
High	The threat is expected to seriously degrade the target or minimize its population by 31–70% within 10 years or 3 generations, within the scope
Medium	The threat is expected to moderately degrade the target or minimize its population by 11–30% within 10 years or 3 generations, within the scope
Low	The threat is expected to slightly degrade the target or minimize its population by 1–10% within 10 years or 3 generations, within the scope
Urgency	**This attribute is used to measure the certainty and time frame over which the threat's effects will be seen.**
Very high	The impacts of the threat are noticeable already and there is an urgency to take action to cope with the issue within a year.
High	The impacts of the threat are likely to emerge and the issue are predicted during the upcoming 1–10 years.
Medium	The impacts of the threat are likely to emerge and the issue are predicted within the upcoming 10–25 years.
Low	The impacts of the threat are unlikely to occur and the issue are predicted in about 25 years from now
Irreversibility	**The extent to which the impacts of a stressor can be reversed**
Very high	The threat's impact cannot be reverted and it is doubtful that the target can be recovered, and/or it would take 100 years to attain this
High	The threat's impact can technically be reverted and the target is likely to be recovered, but it is not feasible practically and/or it may take long period i.e., 21–100 years to achieve this
Medium	The threat's impact can be reverted and the target is likely to be recovered with a sensible commitment of resources and/or within 6–20 years
Low	The threat's impact is quickly reversible and the target may be easily recovered at a reasonable cost and/or within 0–5 years

$$\text{Frequency of species A} = \frac{\text{No of quadrates in which species A occurred x 100 \%}}{\text{Total number of quadrates studied}}$$

$$\text{Relative frequency of species A} = \frac{\text{Frequency of species A occurred x 100\%}}{\text{Sum of total frequences}}$$

$$\text{Basal area} = \frac{\pi d2}{4}$$

$$\text{Relative coverage (RC)} = \frac{\text{Coverage of a species x 100\%}}{\text{Total coverage of all species}}$$

$$\text{Relative basal area of species A (RBA)} = \frac{\text{Basal area of species x 100\%}}{\text{Total basal area of all species}}$$

In the community structure, importance value index (IVI) provides the general significance of every species and calculated as mentioned in equations (I) and (II).

IVI= RF+RD+ RC (for herbs and shrubs) ..... (I)
IVI= RF+RD+ RBA (for trees) .....(II)

Threat assessment

A relative threat ranking method was followed in order to assess the conservation threats (TNC 2007; WWF 2007) and four scales of classification - scope, severity, urgency, and irreversibility (permanence) (Table 1) (NHWAP 2015) were used to identify and prioritize the major existing issues based on the collected data. Those four threat criteria were assigned to each of the identified issues and ranked with the highest rank equal to the number of total threats.

From these different fields, 10 types of major threats were identified and ranked as threats with the value of rank ranging from 1 to 10, where the value 10 implies very high with serious effect, and value 1 implies very low with least effect, respectively. These values are categorized under a 4-point scale for analysis and categorized as Very High (VH), High (H), Medium (M), and Low (L).

RESULTS

Habitat utilization

Distance from water sources: WWB mostly utilized the distance less than 500 m (IV= 0.40), and randomly used distance more than 2000 m (IV= 0) from the water source. It is observed that as distance from water source increases, WWB avoided the use of the area (Figure 3).

Crown cover: WWB highly preferred the area with crown cover of 0–25% (IV= 0.39) followed by 26–50% (IV= 0.13) and avoided 51–75 % (IV= -0.1), and closed crown cover of 76–100% (IV= -0.25) (Figure 4).

Ground cover: WWB highly utilized the area with 76-100% (IV= 0.42) ground cover followed by 0–25% (IV= 0.36), and 51–75% (IV= 0.17), and randomly used the area with 25–50% ground cover (IV= 0) (Figure 5).

Vegetation Analysis

In total, we recorded nine major species of trees, nine shrub species, and 50 species of herbs in our study area. Out of nine major tree species, *Acacia catechu* possessed the highest IVI. Besides, six of them were preferred by WWB whereas two of them were randomly used and one species was completely avoided. Among the nine major species of shrub, *Mimosa pudica* possessed the highest IVI among them, which was also the only preferred shrub species of WWB. Similarly, *Ziziphus mauritiana* and *Cascabela thevetia* were randomly used while other shrub species were avoided by WWB. Six of the 50 herb species commonly documented in the research region were preferred by WWB where *Imperata cylindrica* shared the highest IVI followed by *Saccharum spontaneum*, *Phragmites karka* and *Cynodon dactylon* as shown in Table 2.

Threats assessment

Among the 10 identified threats to WWB, overgrazing by domestic cattle and crossbreeding between domestic and WWB were ranked as the most severe threats in the study area. Similarly, invasion by weeds, disease and parasites, flooding and intensive utilization of forest resources were ranked as the high threats. Other threats with their ranked results are mentioned in Table 3.

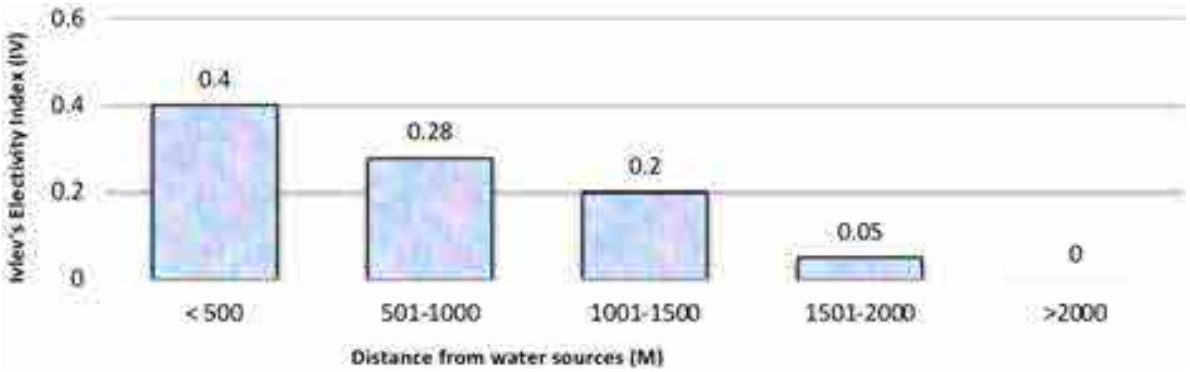

Figure 3. IV values with respect to distance from water sources.

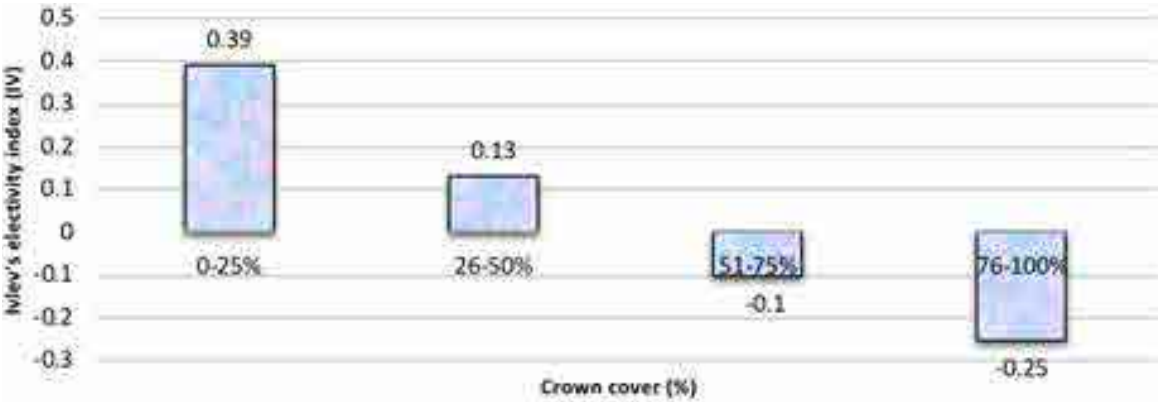

Figure 4. IV values with respect to percentage of crown cover

Table 2. Most abundant tree, shrub, and herb species with IV and IVI values.

	Species	Local Name	Family	Life form	IV	IVI	Preference
1	*Acacia catechu*	Khair	Fabaceae	Tree	0.34	94.85	Preferred
2	*Dalbergia sissoo*	Sissoo	Fabaceae	Tree	0	36.02	Random use
3	*Trewia nudiflora*	Gutel	Euphorbiaceae	Tree	-0.25	26.32	Avoided
4	*Bombax ceiba*	Simal	Malvaceae	Tree	0.18	21.97	Preferred
5	*Streblus asper*	Bedula	Moraceae	Tree	0.25	9.91	Preferred
6	*Phyllanthus emblica*	Amala	Phyllanthaceae	Tree	0.42	8.81	Preferred
7	*Albizia chinensis*	Kalo siris	Fabaceae	Tree	0.17	5.35	Preferred
8	*Mangifera indica*	Aanp	Anacardiaceae	Tree	0	2.89	Random use
9	*Syzygium cumini*	Jamun	Myrtaceae	Tree	0.29	2.88	Preferred
10	Others	-	-	Tree		91	-
11	*Mimosa pudica*	Shy plant	Fabaceae	Shrub	0.43	58.68	Preferred
12	*Chromoleana odorata*	Ban Masha	Asteraceae	Shrub	-0.95	42.25	Avoided
13	*Lantana camara*	Banmara	Verbenaceae	Shrub	-1.0	24.36	Avoided
14	*Calotropis procera*	Aank	Apocynaceae	Shrub	-1.0	19.35	Avoided
15	*Ziziphus mauritiana*	Bayer	Rhamnaceae	Shrub	0	18.18	Random used
16	*Xanthium strumarium*	-	Asteraceae	Shrub	-0.17	15.64	Avoided
17	*Jatropha curcas*	Sajiwan	Euphorbiaceae	Shrub	-0.31	13.58	Avoided
18	*Datura metel*	Dhaturo	Solanaceae	Shrub	-0.42	12.89	Avoided
19	*Cascabela thevetia*	Yellow oleander	Apocynaceae	Shrub	0	8.1895	Random used
20	Others	-	-	Shrub		86.873	Preferred
21	*Imperata cylindrica*	Siru	Poaceae	Herb	0.56	64.73	Preferred
22	*Saccharum spontaneum*	Kash	Poaceae	Herb	0.49	61.47	Preferred
23	*Phragmites karka*	Narkat	Poaceae	Herb	0.31	44.55	Preferred
24	*Cynodon dactylon*	Dubo	Poaceae	Herb	0.65	34.46	Preferred
25	*Brachiaria distachya*	Bansho ghas	Poaceae	Herb	0.90	21.97	Preferred
26	*Vetiveria zizanioides*	Kus	Poaceae	Herb	0.82	16.31	Preferred
27	Others	-	-	Herb		56.50	-

Table 3. Relative ranking of the most severe threats.

	Threats	Scope	Severity	Urgency	Irreversibility	Total	Threat Classification
1	Overgrazing	10	9	10	8	37	Very high
2	Crossbreeding between domestic and Wild Water Buffalo	9	8	9	9	35	Very high
3	Flooding	8	7	7	8	30	High
4	Invasion by weeds	7	8	7	6	28	High
5	Intensive utilization of the forest resources	6	6	7	6	25	High
6	Disease and parasite	5	5	4	7	21	High
7	Road traffic accident	4	4	4	5	17	Medium
8	Hunting and poaching	2	3	3	3	11	Medium
9	Poisoning	2	2	2	1	7	Low
10	Electrocution	1	2	1	1	5	Low
	Total	54	54	54	54	216	

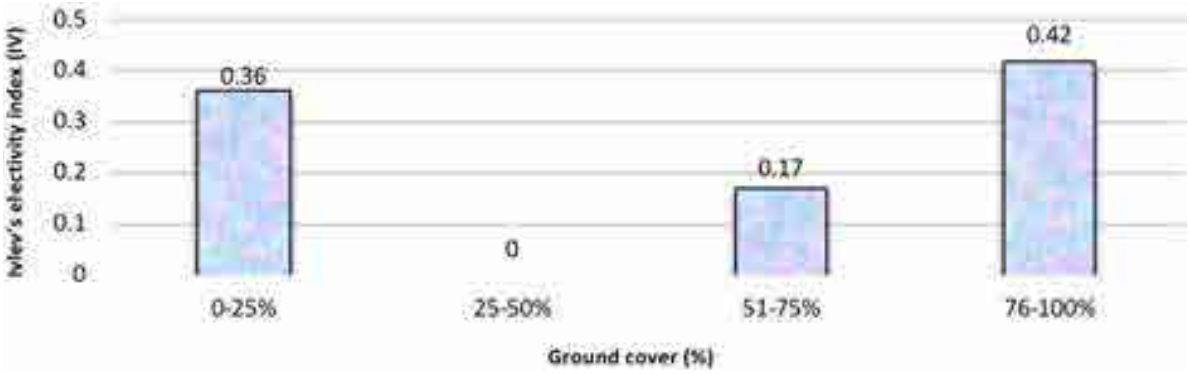

Figure 5. IV values with respect to percentage of ground cover.

DISCUSSION

Our study showed that WWB preferred the area within the distance of 500 m from the river and the habitat use got decreased with increasing distance from those sources. This might be because WWB require continuous supply of water for wallowing. Supporting this fact, Singh (2015) have reported that WWB home range size extends up to 3.9 miles^2 that mainly consist of water bodies, grazing area and resting sheds. Similarly, the study carried out by Dahmer (1978) indicated that the visibility of WWB is seen less frequent in the dense vegetation. Our study also showed that WWB mostly used the area with crown cover of only 0–25 % and avoided the area with crown cover more than 50 %. This might be because the dense crown cover does not permit the entry of light that is necessary for the growth of ground cover and necessitates greater alertness to the predators. Likewise, we observed that WWB mostly preferred the ground cover of 76–100%. This preference is obvious because WWB is a chief grazer (Ram & Sharma 2011) and selects area with dense ground cover to fulfill the dietary requirements.

With regard to types of vegetation, a study conducted in Thailand revealed that *Saccharum arundinaceum* and *S. spontaneum* were preferred by WWB (Bolton 1975). Likewise, a study carried out by Lama (2013) in KTWR showed that *Imperata cylindrica, Cynodon dactylon*, and *Saccharum spontaneum* were preferred by WWB, similar to the findings of our study. This might be because the KTWR is dominated by the above-mentioned species as shown by their IVI values. Parihar et al. (1986) showed that *Dalbergia sissoo, Acacia catechu* and *Bombax ceiba* were the preferred tree species in Kanha National Park and Lama (2013) mentioned that WWB preferred *Acacia-Dalbergia* associated forest in KTWR. However, our study shows that *Phyllanthus emblica* and *Acacia catechu* were the most preferred tree species while *Dalbergia sissoo* was randomly used. Majority of the shrub species were avoided by WWB in our study. Siwakoti (2009) identified these species as invasive species in KTWR, which are regarded as problematic species by Aryal et al. (2011).

WWB face serious threats in KTWR (Heinen & Kandel 2006). Our study demonstrated that open grazing and crossbreeding with domestic buffalo are the critical threats to WWB survival in KTWR. To settle the problem of over grazing, conservation managers had adopted a few strategies in the past like culling buffaloes of domestic origin with the permission from DNPWC in 2001, evacuation of domestic cattle from the park between 2004–2005 and 2010 through a sweeping method (DNPWC 2020). However, these strategies were ineffective. Livestock farming is a traditional mode of subsistence for many people in buffer zone. There are few public lands left outside for grazing, so there is no alternative to use of the reserve as a land for grazing and bringing their livestock into the reserve for sharing food with the wild animals. Hence, providing incentives to the local farmer to initiate stall-feeding might help to control over grazing inside the park.

The small size of the reserve and higher number of livestock inside it is leading to problems of both in-breeding of WWB and cross-breeding with domestic buffalo. Low genetic variation among WWB groups is linked to the practices of local farmers, who crossbreed domestic females with wild males (Heinen 2001). Flamand et al. (2003) conducted genetic analysis to validate that the reserve consists of pure wild stock, and found that three genetically identifiable populations of buffalo were present in the KTWR: wild, domestic and backcrossed. A study carried by Aryal et al. (2011) supports our findings in that they identified livestock grazing inside the KTWR as serious threat to WWB and their foraging plant species. Adhikari (2006) also

reported overgrazing as major threat, as extensive grazing retards plant regeneration. Similarly, Khatri et al. (2012) and (KTWR 2018) reported crossbreeding as the major threat in KTWR similar to our study. Further, our study shows that existing threats like flooding, invasion by weeds, intensive forest resource extraction, disease and parasite are of high level, which is supported by several studies. Aryal et al. (2011) stated flooding as the significant threat in KTWR, which is similar to our finding. Flash floods during monsoons also have a high chance of impacting WWB, especially calves.

Similar to our findings, Khatri et al. (2012) reported invasive weeds as serious threat to native vegetation, including species preferred by WWB. Weeds like *Lantana camera, Chromolaena odorta* cover most of the study area and are invading forest areas and grasslands of the reserve, which is leading to loss of food and destruction of habitat. Similar to our study, Aryal et al. (2011) noted that over-harvesting and uncontrolled use of reserve resources are the major threats, where the local community enter the reserve in unauthorized manner and accumulate grass and other forest product (Heinen & Kandel 2006). Food preferred by WWB, such as *Imperata cylindrica, Saccharum spontaneum, Typha elephentina*, and *Cynodon dactylon,* are used by local people for fodder, firewood and making mats, brooms and baskets. Similar to our study, transfer of disease and parasite from domestic cattle to WWB is also regarded among the major threats (Aryal et al. 2011; Heinen & Paudel 2015) since there is close overlap of WWB and domestic livestock, the high density particularly of latter, and the small and localized nature of WWB population.

Several strategies have been developed to conserve the endangered population of the WWB of KTWR in joint efforts by the Government of Nepal with other stakeholders using the habitat. In order to minimize conflicts between local people and the reserve, an area of 173.5 km^2 adjoining to KTWR was set up in 2004 as a buffer zone which is the innovational strategy for participatory conservation (Khatri et al. 2012). Further, the management plan of KTWR approved in 2010 is now revised as the management plan (2018–2022) with the vision to manage ecological integrity and to conserve biological diversity of the reserve (KTWR 2018). Likewise, with the assistance of Conservation and Sustainable Use of Wetlands in Nepal (CSUWN) project, various livelihood and conservation interventions have been adopted particularly to prevent movement of domestic buffalo population into KTWR (Khatri et al. 2012). In addition, there is legal provision by KTWR office over the gathering of forest products like; fuelwood, fodder and grass in seasonal basis with the aim to reduce illegal collection (Khatri et al. 2010). Further, to provide sufficient forage and wallowing locations to guarantee the vitality and ecological integrity of WWB population, the WWB Conservation Action Plan for Nepal has emphasized to expand the habitat of KTWR (DNPWC 2020). Likewise, in every two years, KTWR undertakes a census of wild buffalo to analyze their population dynamics (Khadka 2018).

CONCLUSION

This study concluded that WWB mostly preferred the habitats within the distance of 500 m from the water sources, crown cover less than 25 % and ground cover more than 75 %. *Imperata cylindrica*, *Cynodon dactylon*, and *Sacharrum spontaneum* were the most preferred grass species whereas *Phyllanthus emblica* and *Acacia catechu* were the most preferred tree species. However, majority of the shrub species, which have weed characteristics, were avoided. Overgrazing and cross breeding with domestic buffalo were the critical surviving threats to WWB in KTWR. As the last remaining population of WWB is experiencing several threats, different conservation interventions are required to secure the wild population. Our study recommends for strict prohibition of the livestock grazing inside the park, conservation of grass species such as *Imperata cylindrica, Saccharum spontaneum*, and *Typha elephentina* should be encouraged and effective management plan for controlling the spread of invasive plant species such as *Chromoleana odorata, Eupatorium adenophorum, Lantana camara*, and *Mikania micrantha* should be carried out immediately. Additionally, there is an urgent need to establish veterinary clinic, animal orphanages and proper service of rescue to control vulnerability of wild animals by flood and spreading of communicable diseases.

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COMMUNICATION

Get my head around owls: people perception and knowledge about owls of Andaman Islands

Shanmugavel Sureshmarimuthu [1], Santhanakrishnan Babu [2], Nagaraj Rajeshkumar [3] & Honnavalli Nagaraj Kumara [4]

[1–4] Sálim Ali Centre for Ornithology and Natural History, Anaikatty (PO), Coimbatore, Tamil Nadu 641108, India.
[1] Manipal Academy of Higher Education, Tiger Circle Road, Madhav Nagar, Manipal, Karnataka 576104, India.
[3] Present address: Office of the Wildlife Warden, Idukki Wildlife Division, Kerala Forests & Wildlife Department, Vellappara, Painavu P.O, Idukki, Kerala 685603, India.
[1] mailme.sureshmarimuthu@gmail.com, [2] sanbabs@gmail.com (corresponding author), [3] rajesh.kumar221991@gmail.com, [4] honnavallik@gmail.com

Abstract: Understanding people's perceptions and knowledge about birds in an endemic bird area is a prerequisite for bird conservation. This is more so in the case of non-charismatic birds such as owls. In this context, we conducted a questionnaire survey about owls in the North Andaman Island between January 2016 and 2018. We interviewed 203 respondents from six market places in North Andaman tehsil, and collected data on their socio-economic status as well as their knowledge on owls. Although all the respondents were familiar with owls, only 9% of them identified all species of owls in the Andaman Islands. Around 98% of respondents were aware of owl diets, either partly or wholly. We found several superstitious beliefs revolving around owls. Two species, *Otus sunia* and *Ninox obscura* were associated with negative beliefs while *Tyto deroepstorffi* was associated with positive beliefs. Generalized linear model with the demographical predictors showed that positive attitudes towards owls is associated with age (older), education (literacy), revenue villages and temporary houses. We conclude that *Tyto deroepstorffi* had the highest positive values among islanders and hence, may be considered as a focal species to create awareness about owls and to protect other endemic owls of the Andaman Islands. Awareness programmes targeting younger, illiterate people, and land encroachers may help in conservation of cryptic owl species of Andaman.

Keywords: Awareness, bad omen, beliefs, culture, diet, education, endemic owls, questionnaire survey.

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Author details: S. Sureshmarimuthu is currently pursuing PhD on owls of Andaman and his research revolves around the distribution pattern of owls in Andaman Archipelago. Santhanakrishnan Babu is a senior scientist at SACON, Tamil Nadu and his research focuses on the conservation of birds, landscape ecology and remote sensing & GIS. Honnavalli N. Kumara is a principal scientist in SACON. His research focuses on various aspects of conservation. N. Rajeshkumar was a research fellow in the project and now he is associated with the Kerala Forest Department.

Author contributions: SS, SB & HNK designed the study; SS & NR collected data; SS analyzed and wrote the article with inputs from SB and HNK.

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INTRODUCTION

Involving local communities in conservation programmes is crucial, especially in areas where people share resources with wildlife. Without understanding the local community's perceptions and knowledge about wildlife, conservation efforts may not produce expected results (Kellert & Westervelt 1984; Kaiser 1999). Among birds, owls have a special place in local culture—either positively or negatively—as they are associated with many cultural and spiritual narratives that lead to positive or negative encounters with owls that result in worship or retaliation (such as through the destruction of nests, hunting and poisoning of adults). Even though owls do have human-like forward facing eyes, they are often portrayed negatively in many societies and cultures across the world, possibly due to their nocturnal activity patterns, loud vocalisations and silent flights. However, communities across the world often have different perspectives on different owl species. It is, therefore, important to understand local knowledge about owls and peoples' perceptions about the birds.

Throughout India, owls are considered as birds of ill omen, messengers of bad luck or servants of death (Santhanakrishnan et al. 2012). In some parts of India, pale-coloured owls are considered the vehicle of goddess Laxmi and hence, people welcome owls into their homes in the belief that these birds will bring wealth and prosperity (Srivastava 1987). The same believers tend to kill owls within their homes to force goddess Laxmi to remain. On full moon nights and night of the festival Diwali, believers would sacrifice owls under the assumption that it will improve the family's wealth (Padhy 2016).

India has 36 species of owls belonging to two families namely, Tytonidae (five species) and Strigidae (31 species) (Praveen et al. 2021). Owls are persecuted and also traded. Commonly traded species are the Common Barn Owl *Tyto alba*, Indian Eagle Owl *Bubo bengalensis*, Jungle Owlet *Glaucidium radiatum*, Indian Scops Owl *Otus bakkamoena*, Brown Fish Owl *Ketupa zeylonensis*, and Mottled Wood Owl *Strix ocellate* (Ahmed 2010).

The Andaman Islands have been recognised as an endemic bird area (EBA) for a high concentration of endemic birds (nearly 32%) (Birdlife International 2021; Praveen et al. 2021), most of which require immediate conservation attention. Five species of owls—the Andaman Barn Owl *Tyto deroepstorffi,* Andaman Scops Owl *Otus balli,* Andaman Hawk Owl *Ninox affinis*, Hume's Hawk Owl *Ninox obscura*, and Oriental Scops owl *Otus sunia*—are known from the Andaman archipelago (Image 1–5). The first four are endemic to the Islands. Despite this high diversity and endemicity of owl species, information on people's perceptions of these magnificent nocturnal birds is anecdotal.

Except for a few indigenous tribal communities (i.e., Andamanese, Onge, Jarawa, and Sentinelese) and a few settlers from Burma, most of the human population in the Andaman Islands migrated from mainland India particularly from Jharkhand, West Bengal, Tamil Nadu, Kerala, and Andhra Pradesh (Vidyarthi 1971). The Andaman Islands are culturally and biologically rich. So, the interaction of residents here with forests and local wildlife is often unavoidable and complex. Considering the diverse cultural beliefs among people in the area and the high degree of endemism in owls, understanding the knowledge and perceptions of local communities is a prerequisite for the future conservation of owl species in the Andaman Islands. In this context, this study was developed to document the knowledge and perceptions of North Andaman islanders on owls.

METHODS

Study area

The study was conducted in the North Andaman Island, which comes under Diglipur tehsil of North and Middle Andaman district, Andaman & Nicobar Islands, India. The North Andaman Island lies between 13.708^{0}N, 92.607^{0}E & 13.657^{0}N, 93.173^{0}E over 1,400.85km^2. The North and Middle Andaman district comprises of 63 wildlife sanctuaries and one national park (Prasad et al. 2010). Diglipur tehsil consists of 72 villages. According to Census 2011, a total of 10,714 persons are residing in these villages. We conducted questionnaire surveys in and around six market places (Aerial Bay, Pachimsagar, Ram Nagar, Kalighat, Kishori Nagar, and Radha Nagar; Figure 1). We selected these market places because people gather here from both revenue and encroached settlements and all five species of owls were reported in these villages during our earlier survey (Babu et al. 2019). Irrespective of the settlement type, rain-fed agriculture and fisheries were the primary occupations of these islanders (Anon 2011).

Data collection and analysis

We conducted open-ended questionnaire surveys with same set of questions but without any specific order because our objective was to create baseline information on what people know about owls and to record the beliefs surrounding these birds. On selecting

Image 1. Andaman Barn Owl

Image 2. Oriental Scops Owl

Image 3. Andaman Scops Owl - rufous morph

Image 4. Hume's Hawk Owl

Image 5. Andaman Hawk Owl

a participant for the survey, we described the nature of our work and inquired about his/her willingness to participate in the interview. Then, we considered them as our respondents and asked their socio-economic background (gender, age, occupation, village type, house type, and literacy level) followed by questions related to owls. We asked questions such as respondents' familiarity with owls (yes or no), knowledge of owl species in the area (one to five), identification technique used (e.g., morphology, calls, behaviour), diet of owls (prey items – descriptive) and their beliefs about owls (positive and negative beliefs; descriptive). We showed them pictures of owls and mimicked or played the calls of owls to confirm species identity. Since most of the respondents knew Hindi, all questions were asked in this language. Occupations of respondents were classified into three categories: regular workers (people

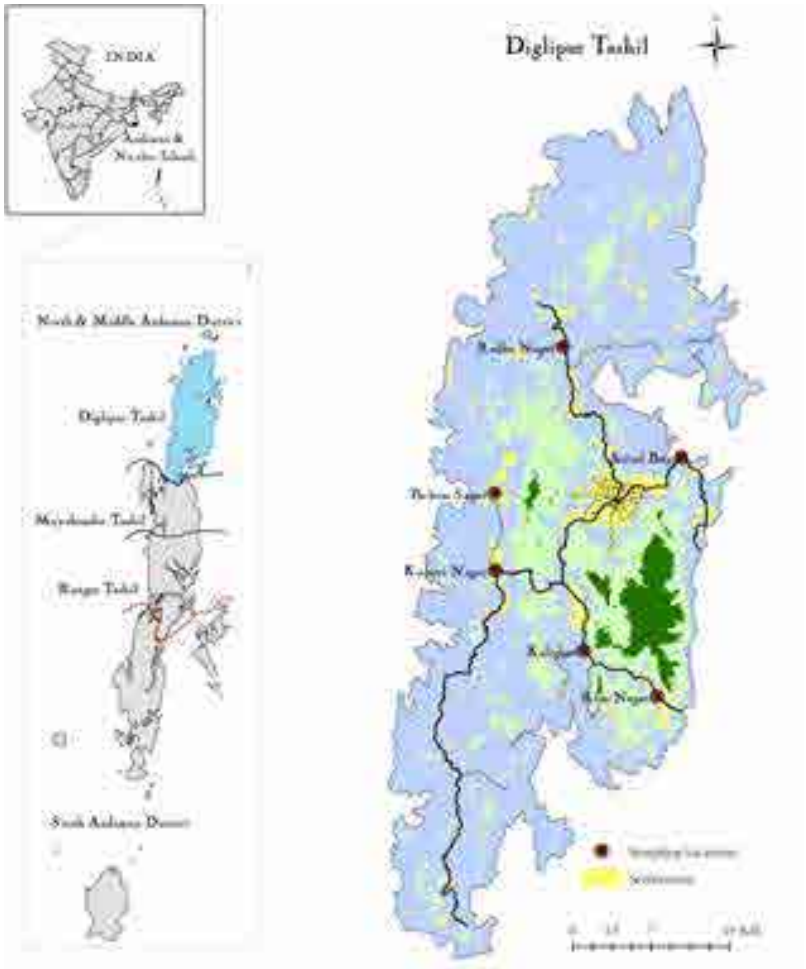

Figure 1. Map showing the study locations in the Andaman Islands

with employment opportunities for the entire year), irregular workers (people who work for half the year), and unemployed (people without a job). Housewives were considered unemployed for this study. The literacy level of respondents was grouped into two categories: literate (if the person could either read or write) and illiterate (if the person could neither read nor write). Settlements were categorised into two namely revenue land and forest encroachment land. Finally, the houses of respondents were categorised as permanent (concrete house), semi-permanent (walls are concrete and roof as thatched), temporary house (thatched and mud construction) and rented house. To identify the demographic factors that influence the perception of people, we ran generalized linear model with logit link for three species of owls (*O. sunia*, *N. obscura*, and *T. deroepstorffi*) using R programme (RStudio Team, 2015).

RESULTS

Socio-demographic details of respondents

Altogether, we interviewed 203 respondents, 57% of whom were men and 43% women, across six survey sites: Kalighat (26 people), Kishorinagar (42 people), Pachimsagar (27 people), Radhanagar (30 people), Aerial Bay (37 people), and Ramnagar (41 people). The average age of female and male respondents were 36 years (ranging 21–57) and 46 years (ranging between 21–65) respectively. Out of 203 people, 54% and 46% were considered literate and illiterate, respectively. Nearly 22% of the respondents were regular workers, 45% were irregular workers, and 33% were unemployed. Twenty-two per cent of respondents had permanent houses while 50% had semi-permanent houses. Around 20% and 8% of the respondents lived in temporary and rented houses respectively. Nearly 61% of people lived in revenue villages and 39% lived on encroached forest land.

Knowledge about owl richness & identification

All respondents said that they have encountered the owls and have known about these birds. The respondents also confirmed the presence of owls around their houses. Amongst respondents, about 74% of them know owls as 'ullu' (Hindi: owls) and 17% of knew them as 'pecha' (Bengali: owls). Interestingly, only 9% of the people could distinguish between 'ullu' (vernacular name for owls) and 'pecha' (refers to the barn owl). However, their knowledge on owl richness was meagre. Only 9% of people could differentiate between the five species of owls and their calls. Nearly 44% (90 people) said that they have seen or heard four different species, 34% (70 people) of people recognized three species, 11% (22 people) knew only two species and only two respondents said they can recognize only one species in Andaman. People often got confused between two species of Hawk Owls (*Ninox* genus) and scops-owls (*Otus* genus) and this lead to wrong identification of owls. Interestingly, 7% of people identified Andaman Scops owl calls as "*jungli murgi*" (Watercock *Gallicrex cinerea*) and one respondent identified Oriental Scops Owl calls as that of a frog. A large proportion of people could identify the Andaman Barn Owl (Figure 2).

Respondents correctly differentiated owl species using three common characters—owl size, colour, and vocalization—and sometimes, a combination of these characters. *T. deroepstorffi* and *O.sunia* were largely identified based on their size difference. To differentiate *N. obscura* from other species, respondents used all three characters (Figure 3).

Knowledge of locals about owl's prey

Figure 4 illustrates the major food items of owls, as listed by respondents of the survey. A large proportion of respondents (44% people) reported that rats are the preliminary food source followed by frogs (26%), insects (15%), and snakes & lizards (8%). Interestingly, 11 people reported that bats are the major prey of owls in the Andaman Islands. Three people said fruits are food for owls. None of the respondents mentioned birds as owl prey.

Perception about owls

Nearly 80, 77, and 55 per cent people reported negative beliefs about *O. sunia*, *N.obscura* and *N. affinis*, respectively. Seventy-one per cent of respondents mentioned that *T. deroepstorffi* would bring good luck (positive beliefs) and nearly 59% of people were neutral about *O. balli* (Table 1). Illiterate and young persons had more negative attitudes about *O.sunia*, whereas those resides in temporary houses in revenue villages were more positive about *N.obscura*, and *T. deroepstorffi* (Table 2).

DISCUSSION

Residents of North Andaman are familiar with owls but most of them could not identify all species in the area. This may be due to the nocturnal habits and skulking nature of owls. Owls common in and around human habitation were correctly identified by most respondents using size and calls of these owls, in

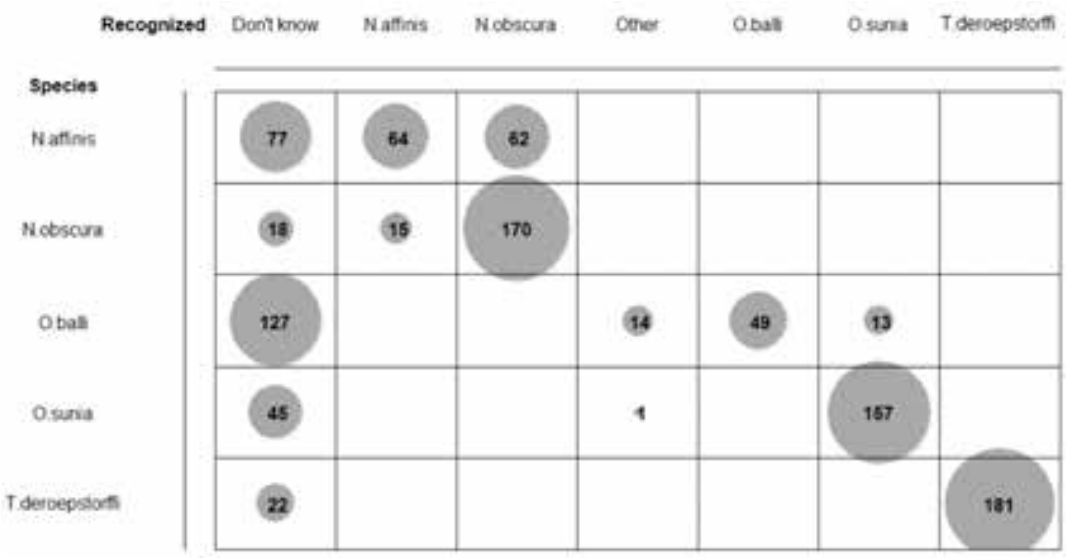

Figure 2. Familiarity of respondents in the identification of different owl species. Larger the size of circle indicates more responses.

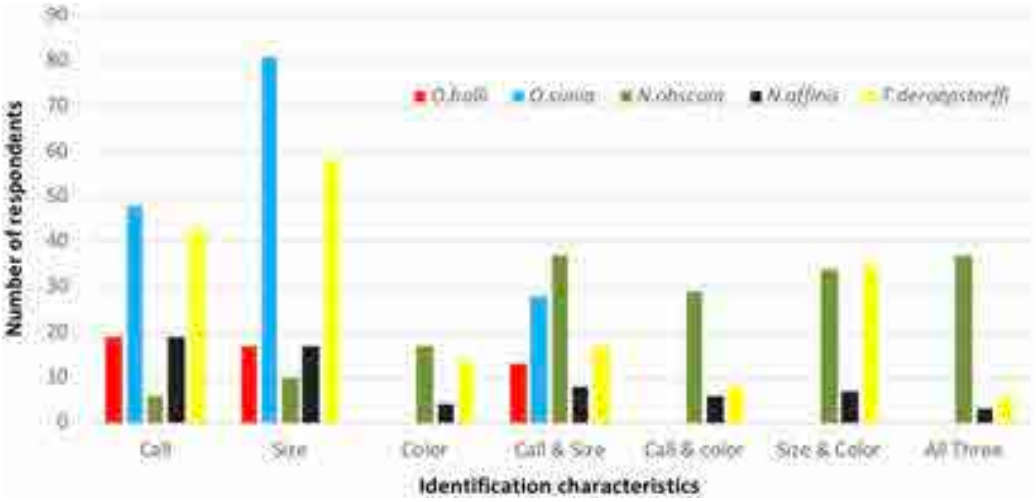

Figure 3. Morphological and behavioural characteristics being used to identify owl species by the respondents in North Andaman Islands.

Table 1. Summary of respondent's beliefs about different species of owls in the Andaman Islands.

Beliefs of respondents	Number of responses (%)				
	O. balli **(N= 49)**	***O. sunia*** **(N= 157)**	***N. affinis*** **(N= 64)**	***N. obscura*** **(N= 170)**	***T. deroepstorffi*** **(N= 181)**
Positive beliefs					
Brings luck	1 (2%)	0 (0%)	3 (5%)	1 (1%)	128 (71%)
Beneficial	8 (16%)	2 (1%)	6 (9%)	12 (7%)	7 (4%)
Negative beliefs					
Loud vocalisations	0 (0%)	83 (53%)	6 (9%)	27 (16%)	2 (1%)
Brings bad luck	9 (18%)	36 (23%)	21 (33%)	32 (19%)	3 (2%)
Weird and threatening	2 (5%)	6 (4%)	8 (13%)	71 (42%)	26 (14%)
Neutral beliefs					
Does not disturb me	12 (24%)	20 (13%)	2 (3%)	11 (6%)	6 (3%)
Not aware of folklore	17 (35%)	10 (6%)	18 (28%)	16 (9%)	9 (5%)

Table 2. Demographic factors influencing the perception of people about owls in Andaman Islands.

Genus	Predictors	Estimate	SE	z-Value	p
Otus sunia (N= 175)	Intercept	-24.360	13.33000	-0.018	0.98
	Literate	1.7360	0.50450	3.442	0.00
	Age	0.1257	0.06074	2.069	0.03
Ninox obscura (N= 153)	Intercept	0.8148	1.60346	0.508	0.61
	Temporary houses	1.5730	0.7569	2.078	0.03
Tyto deroepstorffi (N= 181)	Intercept	1.4623	2.18893	0.668	0.50
	Revenue village	1.9042	0.498304	3.821	0.00

particular the Andaman Barn Owl (Figure 2). Most of them are aware of the ecological role played by owls, i.e., control of rodents and insects in agriculture fields (Figure 4). A majority of respondents worship the Andaman Barn Owl, in the belief that it brings wealth to the family. However, owls in other genus (*Otus* and *Ninox*) are being killed or chased away by locals under the superstition that they bring illness/bad luck.

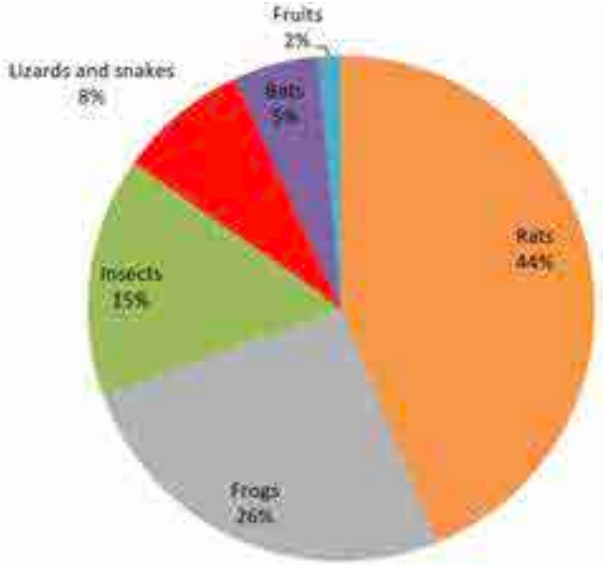

Figure 4. Diet of owls as listed by the respondents in the Andaman Islands.

In general, people show more interest towards a bird species that has high aesthetic values (colourful plumage), large body size and unique behaviours (including calls) and hence, they give more attention to those species and show keener interest to classify them using specific local names (Berlin 1992; Johannes 1993). Although all respondents knew of the presence of owls on their lands by referring to them using the common name 'ullu', they were not able to correctly distinguish all the five species. It is well known that the local community may use a single name to refer a group of animals if they are not attractive to them (Fleck et al. 2002). However, a majority of people could identify at least three genera present on the Andaman Islands (Figure 2) by their sizes. Since there are more than one species in two genera (*Otus* and *Ninox*), islanders found it difficult to distinguish species of similar size. This is because most respondents are from mainland India and Burma. Hence, they could better identify widespread species such as the Barn Owl, Oriental Scops Owl, and Brown Hawk Owl (whose call resembles that of the Hume's Hawk Owl) than endemic species such as the Andaman Scops Owl and Andaman Hawk Owl.

In the Andamans, there was a programme to introduce Barn Owls from the mainland to the Island to control rodents in oil palm plantations (Sundaramoorthy 2010). However, protests by locals against this has created an awareness among residents regarding the ecological role that owls play. This could be the reason for a higher percentage of respondents reporting rats as a major component of owl diets. Even though many respondents considered bats as one of the prey items of owls, none considered birds to be prey. This result indicates that residents of Andaman Islands do not see owls as raptors.

Birds are better appreciated than reptiles and amphibians (Czech & Krausman 2001) but our results indicate that this statement cannot used as a thumb rule for owls. The perceptions of people regarding the importance and conservation of owls in the Andaman Islands are likely to depend on their cultural beliefs. People rank species based on the cultural knowledge about the species (Moral & Camacaro 2011). This could be the reason for the higher appreciation of the Andaman Barn Owl by locals when compared to other species in the vicinity, because Andaman Barn Owls are culturally believed to be the vehicle of goddess Laxmi, as per Hindu mythology (Srivastava 1987). Studies suggest that unpopular and wild species receive negative attitudes from people (Bjerke et al. 2003; Røskaft et al. 2003; Lindemann-Matthies 2005; Ceriaco 2012; Almeida 2014; Alves et al. 2014). Our study on population assessment of owls in Andaman (Babu et al. 2019) revealed that *O. sunia* and *N. obscura* are highly abundant and found in wide array of habitats whereas *N. affinis* and *O. balli* were uncommon and found in specific habitats. Even though the people had higher exposure to two generalist and abundant species, they were more negative towards them. This is clear that whether the species is either popular or wild, folklore and superstitious belief play a major role in their acceptance. Andaman Barn Owls are celebrated in the 'Laxmi Puja' festival while other species are considered as bad omen, and have lower conservation values. By contrast, a study in mainland India (Santhanakrishnan et al. 2012) found that 69% of respondents have negative beliefs about Barn Owls *Tyto alba*. Higher neutral values for *O. balli* and *N. affinis* are due to their fewer interactions with humans since both species are found to be habitat specialists and forest dwellers (Babu et al. 2019).

Though differential responses were received from the people of North Andaman Island about different species of owls, three predictors were found to contribute more to their perception. Literate and older people living in temporary houses showed positive response towards these species. It is not surprising that literacy level influenced the perception positively (Heinen 1993; Fiallo & Jacobson 1995; Infield 1988). The people who have the ability to read and write are exposed to the species profiles from media and other sources so they could understand better than those that are illiterate. Older people due their higher level

of experience, knowledge and exposure to owls tend to have less belief in the folklore about species (Ceríaco 2012). Highly appreciated *T. deroepstorffi* have positive perception from the residents of revenue villages.

We summarize that *Tyto deroepstorffi* have the highest positive values among islanders and hence, it may be used as a surrogate species to create awareness about less-appreciated owls. The inherited traditional and cultural knowledge on Barn Owl would help ecologists and conservation biologists to convince locals about the similarity among the species and to reduce the negative attitudes towards other owl species. Further, both positive and negative attitudes vary with education, age, and residency. So, it is evident that lack of knowledge is the primary factor for the negative attitudes and therefore regular awareness program targeting this group may change their attitude towards owls.

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COMMUNICATION

Abundance and diversity of threatened birds in Nangal Wetland, Punjab, India

Rajwinder Kaur [1] & Onkar Singh Brraich [2]

[1,2] Department of Zoology and Environmental Sciences, Punjabi University, Patiala, Punjab 147002, India.
[1] rajwinderhansi888@gmail.com (corresponding author), [2] singhonkar@yahoo.com

Abstract: Anthropogenic threats to wetland ecosystems, including discharge of industrial effluents, municipal sewerage, land reclamation, erosion and deforestation, have contributed to the rapid declines in populations of many bird species. The present study aimed to document avian diversity, including birds on the IUCN Red List, at Nangal Wetland, Punjab from February 2013 to January 2015. A total of 155 species belonging to 48 families (resident and migratory) under 17 orders were recorded, of which 13 come under various IUCN Red List categories: one 'Endangered'—Egyptian Vulture *Neophron percnopterus*; five 'Vulnerable'—Common Pochard *Aythya ferina*, Greater-Spotted Eagle *Aquila clanga*, Sarus Crane *Grus antigone*, Lesser White-Fronted Goose *Anser erythropus*, and Woolly-necked Stork *Ciconia episcopus*; and seven 'Near Threatened'—Ferruginous Duck *Aythya nyroca*, River Lapwing *Vanellus duvaucelii*, Indian River Tern *Sterna aurantia*, Painted Stork *Mycteria leucocephala*, Oriental Darter *Anhinga melanogaster*, Blossom-headed Parakeet *Psittacula roseata*, and Alexandrine Parakeet *Psittacula eupatria*. The Shannon-Weaver index of diversity was highest during winter (H'= 1.9) followed by autumn (H'= 1.9) then spring (H'= 1.5), and was lowest during summer (H'= 1.4). Though this wetland is highly productive and provides homes to many threatened species, untreated industrial effluents from adjoining areas sometimes create problems. The discharge of pollutants should be stopped through strict enforcement of environmental laws and policies.

Keywords: Avifauna, conservation, IUCN Red List.

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Author details: Rajwinder Kaur has completed doctorate degree and is working as an assistant professor in the Zoology Department at Govt Ranbir College Sangrur. Onkar Singh is working as an assistant professor in the Zoology Department at Punjabi University Patiala.

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INTRODUCTION

Wetlands are important bird habitats (Mitsch & Gosselink 1986; Guadagnin et al. 2005) that provide suitable breeding, staging, and wintering grounds for a wide array of migratory birds (Kristen & Brander 1991). Wetland with multiple sub-habitats or micro habitats attract diverse species of waterbirds. Being ecologically important with high nutritional value and productivity, wetlands support a good diversity of birds (Gibbs 1993; Paracuellos 2006).

It might be predicted that migratory species are more likely to be threatened because they are dependent on different sites and habitats during breeding and non-breeding seasons. A threat operating in just one of these areas could have a severe impact (Salathe 1991). Several studies suggest that habitat destruction is one of the prime reasons for the decline of birds. For instance, it was reported that over 90 % of globally threatened birds and 86 % of other bird species are facing a serious threat mainly due to habitat degradation (Kauzeni & Kiwasila 1994; Kideghesho et al. 2006). Information on status and distribution of threatened and endemic birds, therefore, aids in prediction of disturbance level and execution of conservation measures at all potential sites where they occur (Stattersfield et al. 1998; Riley 2002; Robin & Sukumar 2002). In 2000, the 'Threatened Birds of the World', which listed 1,186 species worldwide and 123 species in India (BirdLife International 2000).

Restricted range and threatened bird species require special attention from ecologists and conservationists. These species are more sensitive to disturbance and invite immediate conservation concern (BirdLife International 2001; Lei et al. 2003, 2007; Wijesinghe & Brooke 2005; Pandit et al. 2007). The present article documented the threatened and near-threatened bird species recorded at Nangal wetland to provide information about the current distribution and status of bird species as baseline data where future population trends can be compared.

MATERIAL AND METHODS

Study Area

Nangal Wetland is (Figure 1) (31.404°N & 76.368°E) located in Ropar District over the Sutlej River at 357m (1172ft). It spreads over an area of 700 acres and is enriched with diverse flora, fauna and hydrology. This wetland was created in the downstream of Bhakhra Reservoir for its strategic importance as balancing reservoir to adjust the extra water during the rainy season. The water of Nangal wetland is used for drinking and irrigation purposes. This wetland is important for socio-economic, ecological, hydrological and recreational values. This unique wetland ecosystem attracts thousands of migratory birds during winter season every year for feeding and also provides suitable feeding and breeding grounds for resident birds. However, it is very important to document its various components of biodiversity and its conservation needs and management measures due to its strategic importance (PSCST 1994). It was announced as a wetland of national importance by the Ministry of Environment, Forests & Climate Change, Government of India in January, 2008 and included it under the National Lake Conservation Program. It was also declared as a wildlife sanctuary on 10 August 2009. In 2020, Nangal wetland was declared as a Ramsar site. The study area experiences various seasons and broadly divided into spring (March, April, May), summer (June, July, August), autumn (September, October, November), and winter (December, January, February) seasons.

The study on avifaunal diversity at Nangal Wetland was conducted from February 2013 to January 2015. The point count method (Sutherland 1999) was used for the census of birds at the study sites. The study was undertaken by establishing 15 counting stations of 50 m radius each in the study area with 100 m intervals between two counting stations to cover the whole wetland area. Data were collected every month during winter season for five days per month and twice a day from 0700 h to 1000 h and 1600 h to 1800 h and during the summer season from 0600 h to 0900 h and 1700 h to 1900 h. The observer waited for a few minutes after arrival at each station before beginning the count. The bird count was carried out for ten minutes at each station. Each bird was counted once either seen or heard within the radius. Average count of birds at each station for five days was calculated. Identification has been done with the help of various field guides (Ali & Ripley 1987; Grewal et al. 1995; Ali 1996; Grimmett et al. 2001; Kazmierczak 2002). Shannon diversity index (*H'*) (Shannon & Weaver 1949) was calculated by using PAST (PAST: Paleontological Statistics) Software.

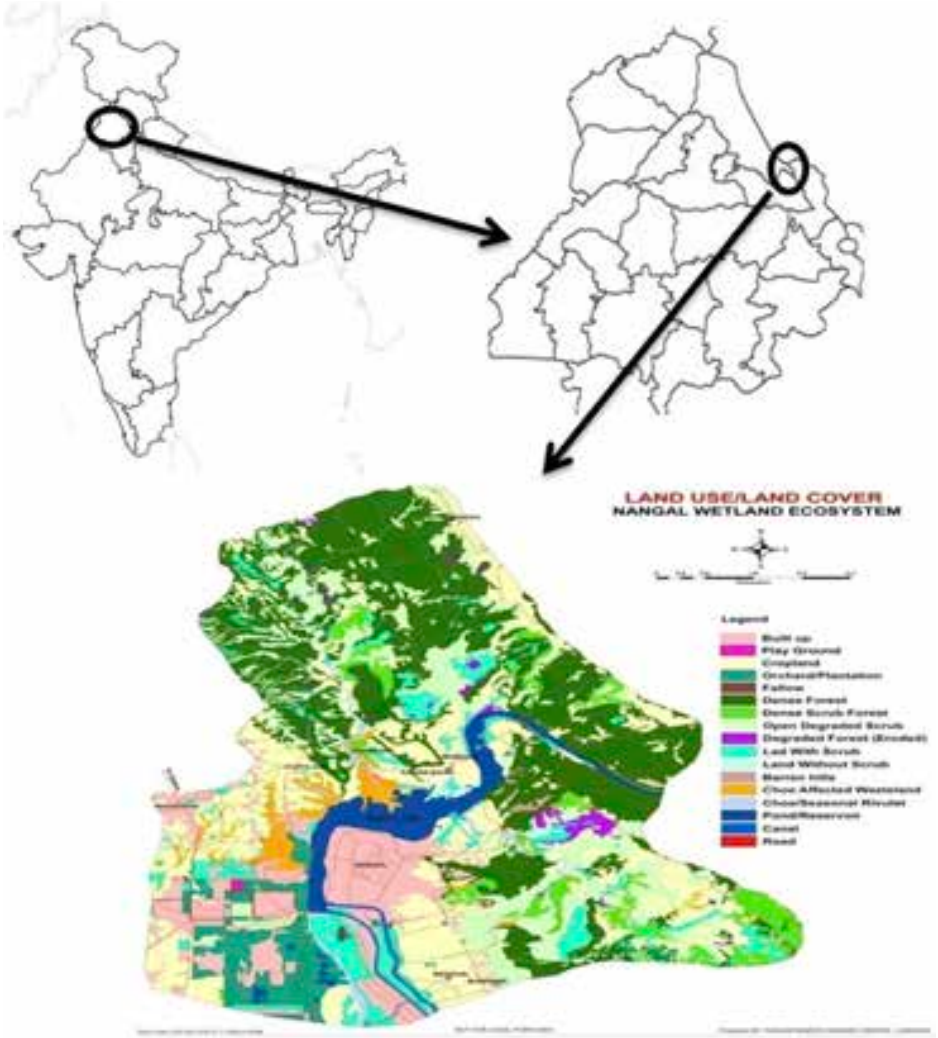

Figure 1. Map showing the Nangal Wetland.

RESULTS AND DISCUSSION

Nangal wetland harbours a significant number of threatened bird species, belonging to different categories of the IUCN Red List. During this study, a total of 155 bird species were recorded (Table 1). Of these, 13 species belonging to seven orders and eight families were in the globally threatened category of IUCN (Table 2). According to the IUCN Red List of birds (IUCN 2018), 7.7 % were EN (n= 1), 39 % were VU (n= 5) and 54 % were NT (n= 7) (Figure 2). The 'Endangered' species recorded from this wetland was Egyptian Vulture *Neophron percnopterus*; 'Vulnerable' species included Common Pochard *Aythya ferina*, Greater-Spotted Eagle *Aquila clanga*, Sarus Crane *Grus antigone*, Lesser White-Fronted Goose *Anser erythropus*, and Woolly-necked Stork *Ciconia episcopus*. The 'Near Threatened' species included Ferruginous Duck *Aythya nyroca*, River Lapwing *Vanellus duvaucelii*, Indian River Tern *Sterna aurantia*, Painted Stork *Mycteria leucocephala*, Oriental Darter *Anhinga melanogaster*, Blossom-headed Parakeet *Psittacula roseata*, and Alexandrine Parakeet *Psittacula eupatria*.

Narayanan et al. (2011) recorded a total of 225 species of birds from Kuttanad wetlands inclusive of 10 Red Listed species, namely, Greater Spotted Eagle *Clanga clanga*, Ferruginous Pochard *Aythya nyroca*, Painted Stork *Mycteria leucocephala*, Oriental White Ibis *Threskiornis melanocephalus*, Spot-billed Pelican *Pelecanus philippensis*, Oriental Darter *Anhinga melanogaster*, Greater-headed Fish Eagle *Haliaeetus ichthyaetus*, Black-tailed Godwit *Limosa limosa*, Eurasian Curlew *Numenius arquata*, and European Roller *Coracias*

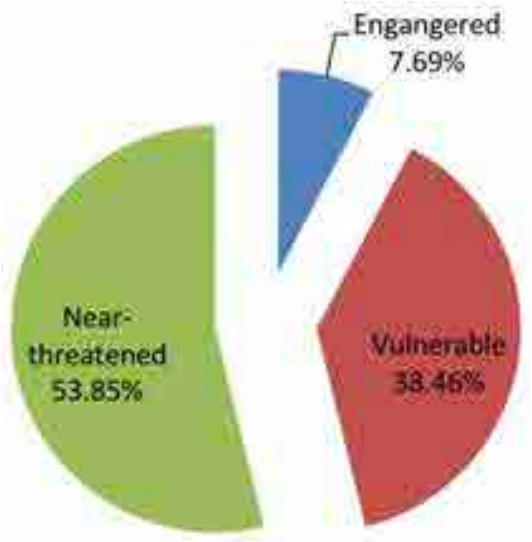

Figure 2. Percentage contribution of different groups of birds.

garrulous.

Some wetlands in Punjab are highly infested with unwanted weeds mostly *Eichhornia crassipes* which covers the entire surface area. But Nangal wetland does not support these weeds and provide plenty of space for migratory birds during winter season. Presence of 155 bird species in the Nangal wetland indicates that the area is able to give ecological security to the wetland dependent birds by providing sufficient quantity of food in the form of microflora (aquatic planktonic species, e.g., *Fragillaria* spp., *Spirogyra* spp., *Oedogonium* spp., *Tabellaria* spp., *Cymbella* spp., *Gomphnema* spp.), mesoflora (aquatic vegetations, e.g., *Lemna* spp., *Valisneria* spp., *Azolla* spp., *Pistia* spp.), microfauna (small microscopic animals), and mesofauna (fish, insects, and small animals) in the wetland. Besides these, resident birds were observed throughout the year due to the availability of favorable conditions for breeding, feeding, roosting, and nesting sites. This wetland not only attracts water birds, but is also favorable and rewarding spot for terrestrial birds. The occurrence of high number of terrestrial birds could be due to strong influence of vegetation cover and presence of varieties of microhabitats which provide niche to large numbers of terrestrial birds.

In the present investigations, birds were classified on the basis of their occurrence at the study area, of the 13 Red Listed species, three were migratory, eight were local migratory and two were residents. Similarly, birds were also classified on the basis of their feeding habits, it was observed that three species were herbivorous, four were omnivorous and six were carnivorous. Chaudhry et al. (2012) study on threatened and near-threatened avifauna of Pakistan recorded 16 species inclusive of resident and migratory species. Of the total recorded species, nine were 'Near Threatened', one 'Endangered', and one 'Critically Endangered'.

The mean value and standard deviation of occurrence of monthly birds count were calculated. A well-marked seasonal variation in bird populations was recorded (Table 3). Generally the population of waterbirds started increasing from August to January, with a peak in month of December and January and thereafter started decreasing. During the present study, a sharp decline in the waterbirds count was observed after the month of February due to the partial departure of migratory species. Almost complete absence of migratory waterbirds was noticed from April to July during both years, only local resident birds reside during the remaining months. Highest diversity in winter months was attributed to the influx of migratory waterbirds during this season. Least diversity in the summer months was due to the absence of migratory waterbirds species. Similar observations of seasonal variations were also made by Saxena (1975) on avifauna of Keoladeo National Park, Bharatpur and Bhat et al. (2009) on avifauna of Anekere wetland, Karnataka. Giri & Chalise (2008) also recorded a greater diversity in winter months due to the addition of migratory birds in this season. Kershaw & Cranswick (2003) studied waterbirds become highly mobile in winter season as living conditions rendered unfavorable during this cold weather. The waterbirds start moving to other areas in response to hostile weather conditions such as changes in water levels and diminishing availability of food.

In order to investigate the variations in diversity of bird species and ecological groups during different seasons of the study period, the species diversity was calculated using Shannon-wiener index. The Shannon-Weaver index of diversity was highest during winter (H'= 1.915) followed by autumn (H'= 1.868) then spring (H'= 1.534) and was lowest during summer season (H'= 1.436). Value of index during autumn and winter seasons had revealed the greatest diversity in terms of both species richness and evenness. Gerritsen et al. (1998) revealed that the increase in the value of H' is directly associated with the increase in the number and distribution of species during favorable periods (biotic diversity) within the community, thereby confirming the present observations.

Table 1. Check list of birds recorded from Nangal Wetland.

	Zoological name	Common name
	Order: Anseriformes	
	Family: Anatidae	
1.	*Anas poecilorhyncha* J.R. Forester, 1781	Indian Spot-billed Duck
2.	*Anas strepera* Linnaeus, 1758	Gadwall
3.	*Aythya ferina* (Linnaeus, 1758)	Common Pochard
4.	*Netta rufina* (*Pallas* 1773)	Red-crested Pochard
5.	*Aythya nyroca* (Guldenstadt, 1770)	Ferruginous Duck
6.	*Anas platyrhynchos* Linnaeus, 1758	Mallard
7.	*Tadorna ferruginea* (Pallas, 1764)	Ruddy Shelduck
8.	*Tadorna tadorna* (Linnaeus, 1758)	Common Shelduck
9.	*Anser indicus* (Latham, 1790)	Bar-headed Goose
10.	*Anser anser* (Linnaeus, 1758)	Graylag Goose
11.	*Anser erythropus* (Linnaeus, 1758)	Lesser White-Fronted Goose
12.	*Anas acuta* (Linnaeus, 1758)	Northern Pintail
13.	*Anas clypeata* Linnaeus, 1758	Northern Shoveller
14.	*Anas crecca* Linnaeus, 1758	Common Teal
15.	*Anas querquedula* Linnaeus, 1758	Garganey
16.	*Aythya fuligula* (Linnaeus, 1758)	Tufted Duck
17.	*Anas penelope* Linnaeus, 1758	Eurasian Wigeon
18.	*Sarkidiornis melanotos* (Pennant, 1769)	Knob-billed Duck
	Order: Accipitriformes	
	Family: Accipitridae	
19.	*Accipiter badius* (Gmelin, 1788)	Shikra
20.	*Milvus migrans* (Boddaert, 1783)	Black Kite
21.	*Elanus caeruleus* (Desfontaines, 1789)	Black-winged Kite
22.	*Aquila rapax* (Temminck, 1828)	Tawny Eagle
23.	*Aquila pomarina* (Brehm CL, 1831)	Lesser-spotted Eagle
24.	*Aquila clanga* Pallas, 1811	Greater-spotted Eagle
25.	*Aquila nipalensis* Hodgson, 1833	Steppe Eagle
26.	*Pandion haliaetus* (Linnaeus, 1758)	Osprey
27.	*Circus aeruginosus* (Linnaeus, 1758)	Western Marsh Harrier
28.	*Accipiter nisus* (Linnaeus, 1758)	Asiatic Sparrowhawk
29.	*Haliastur indus* (Boddaert, 1783)	Brahminy Kite
30.	*Neophron percnopterus*	Egyptian Vulture
	Order: Apodiformes	
	Family: Apodidae	
31.	*Apus affinis* (J.E. Gray, 1830)	Indian House Swift
	Order: Bucerotiformes	
	Family: Bucerotidae	
32.	*Ocyceros birostris* (Scopoli, 1786)	Indian Grey Hornbill
	Order: Charadriiformes	
	Family: Charadriidae	
33.	*Vanellus indicus* (Boddaert, 1783)	Red-wattled Lapwing
34.	*Vanellus duvaucelii* (Lesson, 1826)	River Lapwing
35.	*Vanellus leucurus* (Lichtenstein, 1823)	White-tailed Lapwing
36.	*Himantopus himantopus* (Linnaeus, 1758)	Black Winged Stilt
37.	*Actitis hypoleucos* Linnaeus, 1758	Common Sandpiper
38.	*Charadrius dubius* Scopoli, 1786	Little Ringed Plover
39.	*Charadrius hiaticula* Linnaeus, 1758	Common Ringed Plover
40.	*Sterna aurantia* J.E. Gray, 1831	Indian River Tern
	Order: Ciconiformes	
	Family: Ardeidae	
41.	*Bubulcus ibis* (Linnaeus, 1758)	Cattle Egret
42.	*Ardea alba* Linnaeus, 1758	Eastern Large Egret
43.	*Egretta garzetta* (Linnaeus, 1766)	Little Egret
44.	*Ardea intermedia* Wagler, 1829	Intermediate Egret
45.	*Ardeola grayii* (Sykes, 1832)	Indian Pond Heron
46.	*Nycticorax nycticorax* (Linnaeus, 1758)	Black-crowned Night Heron
47.	*Ardea purpurea* Linnaeus, 1766	Purple Heron
48.	*Ardea cinerea* Linnaeus, 1758	Grey Heron
	Ciconiidae	
49.	*Mycteria leucocephala* (Pennant, 1769)	Painted Stork
50.	*Ciconia episcopus* (Boddaert, 1783)	Woolly-necked Stork
	Laridae	
51.	*Larus brunnicephalus* (Jerdon, 1840)	Brown-headed Gull
52.	*Ichthyaetus ichthyaetus* (Pallas, 1773)	Palla's Gull/ Great Black-headed Gull
	Phalacrocoracidae	
53.	*Phalacrocorax niger* (Vieillot, 1817)	Little Cormorant
54.	*Phalacrocorax carbo* (Linnaeus, 1758)	Great Cormorant
55.	*Anhinga melanogaster* Pennant, 1769	Oriental Darter
	Podicipedidae	
56.	*Podiceps cristatus* (Linnaeus, 1758)	Great Crested Grebe
57.	*Tachybaptus ruficollis* (Pallas, 1764)	Little Grebe
58.	*Podiceps nigricollis* Brehm, CL, 1831	Black Necked Grebe
	Order: Columbiformes	
	Family: Columbidae	
59.	*Streptopelia decaocto* (Frivaldszky, 1838)	Eurasian Collared Dove
60.	*Streptopelia senegalensis* (Linnaeus, 1766)	Laughing Dove
61.	*Streptopelia chinensis* (Scopoli, 1786)	Spotted Dove
62.	*Columba livia* Gmelin, 1789	Blue Rock Pigeon
63.	*Treron phoenicoptera* (Latham, 1790)	Yellow Footed Pigeon

	Zoological name	Common name
	Order: Coraciiformes	
	Family: Alcedinidae	
64.	*Halcyon smyrnensis* (Linnaeus, 1758)	White Breasted Kingfisher
65.	*Alcedo atthis* (Linnaeus, 1758)	Small Blue Kingfisher
66.	*Ceryle rudis* (Linnaeus, 1758)	Lesser Pied Kingfisher
	Meropidae	
67.	*Coracias benghalensis* (Linnaeus, 1758)	Indian Roller
68.	*Merops orientalis* Latham, 1801	Little Green Bee-Eater
69.	*Merops leschenaulti* Vieillot, 1817	Chestnut Headed Bee-Eater
	Order: Cuculiformes	
	Family: Cuculidae	
70.	*Centropus sinensis* (Stephens, 1815)	Greater Coucal
71.	*Eudynamys scolopacea* (Linnaeus, 1758)	Asian Koel
72.	*Hierococcyx varius* (Vahl, 1797)	Common Hawk Cuckoo
73.	*Clamator jacobinus* (Boddaert, 1783)	Jacobin Cuckoo
	Order: Galliformes	
	Family: Phasianidae	
74.	*Coturnix coturnix* (Linnaeus, 1758)	Grey Or Common Quail
75.	*Perdicula asiatica* Latham, 1790	Jungle Bush Quail
76.	*Gallus gallus* (Linnaeus, 1758)	Red Jungle Fowl
77.	*Francolinus pondicerianus* (Gmelin, 1789)	Grey Francolin
78.	*Melanoperdix niger* (Vigors, 1829)	Black Partridge
79.	*Pavo cristatus* Linnaeus, 1758	Indian Peafowl
	Order: Gruiformes	
	Family: Gruidae	
80.	*Grus antigone* (Linnaeus, 1758)	Sarus Crane
	Rallidae	
81.	*Gallinula chloropus* (Linnaeus, 1758)	Common Swamphen
82.	*Porphyrio porphyrio* (Linnaeus, 1758)	Indian Purple Moorhen
83.	*Amaurornis phoenicurus* (Pennant, 1769)	White-breasted Water Hen
84.	*Fulica atra* Linnaeus, 1758	Common Coot
	Order: Passeriformes	
	Family: Acrocephalidae	
85.	*Acrocephalus dumetorum* (Vieillot, 1817)	Blyth's Reed Warbler
	Alaudidae	
86.	*Alauda gulgula* Franklin, 1831	Oriental Or Small Skylark
87.	*Galerida cristata* (Linnaeus, 1758)	Indian Crested Lark
88.	*Mirafra cantillans* Blyth, 1845	Singing Bush Lark
	Campephagidae	
89.	*Pericrocotus cinnamomeus* (Linnaeus, 1766)	Small Minivit
90.	*Pericrocotus ethologus* Bangs & Phillips, 1914	Long Tailed Minivet

	Zoological name	Common name
	Certhiidae	
91.	*Certhia nipalensis* Blyth, 1845	Rusky-flanked Treecreeper
	Cisticolidae	
92.	*Prinia socialis* Sykes, 1832	Ashy Prinia Or Ashy Wren Warbler
93.	*Prinia gracilis* (Lichtenstein, MHC, 1823)	Streaked Wren Warbler
	Corvidae	
94.	*Corvus splendens* Vieillot, 1817	House Crow
95.	*Corvus macrorhynchos* Wagler, 1827	Indian Jungle Crow
96.	*Dendrocitta vagabunda* (Latham, 1790)	Rufous Treepie
97.	*Dicrurus macrocercus* Vieillot, 1817	Black Drongo
	Emberizidae	
98.	*Emberiza melanocephala* Scopoli, 1769	Black-headed Bunting
99.	*Emberiza buchanani* Blyth, 1845	Grey-necked Bunting
	Estrildidae	
100.	*Lonchura malabarica* (Linnaeus, 1758)	White-throated Munia
101.	*Lonchura punctulata* (Linnaeus, 1758)	Scaly-breasted Munia
102.	*Amandava amandava* (Linnaeus, 1758)	Red Avadavat
	Hirundinidae	
103.	*Hirundo smithii* Leach, 1818	Indian Wire-tailed Swallow
104.	*Hirundo rustica* Linnaeus, 1758	Barn Swallow
	Laniidae	
105.	*Lanius excubitor* Linnaeus, 1758	Great Grey Shrike
106.	*Lanius vittatus* Valenciennes, 1826	Bay-backed Shrike
107.	*Lanius schach* Linnaeus, 1758	Long Tailed Shrike
	Locustellidae	
108.	*Megalurus palustris* Horsfield, 1821	Striated Marsh Warbler
	Motacilladae	
109.	*Motacilla alba* Linnaeus, 1758	White Wagtail
110.	*Motacilla cinerea* Tunstall, 1771	Grey Wagtail
111.	*Motacilla maderaspatensis* Gmelin, JF, 1789	White-browed Wagtail
112.	*Motacilla citreola* Pallas, 1776	Citrine Wagtail
	Muscicapidae	
113.	*Saxicoloides fulicata* (Linnaeus, 1776)	Indian Robin
114.	*Copsychus saularis* (Linnaeus, 1758)	Oriental Magpie Robin
115.	*Phoenicurus ochruros* (Gmelin, 1774)	Black Redstart
116.	*Orthotomus sutorius* (Pennant, 1769)	Indian Tailor Bird
117.	*Cercomela fusca* (Blyth, 1851)	Indian Chat
118.	*Saxicola torquata* (Linnaeus, 1766)	Common Stone Chat
119.	*Luscinia svecica* (Linnaeus, 1758)	Blue Throat
120.	*Myiophonus caeruleus* (Scopoli, 1786)	Himalayan Whistling Thrush

	Zoological name	Common name
121.	*Terpsiphone paradisi*	Asian Paradise Flycather
122.	*Ficedula westermanni* (Sharpe, 1888)	Little Pied Flycather
123.	*Eumyias thalassinus* (Swainson, 1838)	Verditer Flycather
	Oriolidae	
124.	*Oriolus oriolus* (Linnaeus, 1758)	Golden Oriole
	Paridae	
125.	*Parus major* Linnaeus, 1758	Great Tit
	Passeridae	
126.	*Passer domesticus* (Linnaeus, 1758)	Indian House Sparrow
	Pittidae	
127	*Pitta brachyuran* (Linnaeus, 1766)	Indian Pitta
	Ploceidae	
128.	*Ploceus philipinus* (Linnaeus, 1766)	Weaver Bird
129.	*Ploceus benghalensis* (Linnaeus, 1758)	Black-breasted Weaver
130.	*Ploceus manyar* (Horsfield, 1821)	Streaked Weaver
	Pycnonotidae	
131.	*Pycnonotus cafer* (Linnaeus, 1766)	Red-Vented Bulbul
132.	*Pycnonotus leucotis* (Gould, 1836)	White-Eared Bulbul
	Rhipiduridae	
133.	*Rhipidura albicollis* (Vieillot, 1818)	White-Throated Fantail
	Sturnidae	
134.	*Sturnus pagodarum* (Gmelin, 1789)	Brahminy Starling
135.	*Acridotheres tristis* (Linnaeus, 1766)	Common Myna
136.	*Acridotheres ginginianus* (Latham, 1790)	Bank Myna
137.	*Sturnus contra* Linnaeus, 1758	Asian Pied Starling
	Sylviidae	
138.	*Turdoides striatus* (Dumont, 1823)	Jungle Babbler
139.	*Turdoides caudatus* (Dumont, 1823)	Common Babbler
140.	*Turdoides earlei* (Blyth, 1844)	Striated Babbler
131.	*Chrysomma sinense* (Gmelin, 1789)	Yellow Eyed Babbler
	Nectariniidae	
142.	*Dicaeum agile* (Tickell, 1833)	Thick-billed Flowerpecker
143.	*Nectarinia asiatica* (Latham, 1790)	Purple Sunbird
	Zosteropidae	
144.	*Zosterops palpebrosus* (Temminck, 1824)	Indian White-Eye
	Order: Pelecaniformes	
	Family: Threskiornithidae	
145.	*Pseudibis papillosa* (Temminck, 1824)	Red-naped Ibis
	Order: Piciformes	
	Family: Megalaimdae	
146.	*Megalaima zeylanica* (Gmelin, JF, 1788)	Large Green Barbet
147.	*Megalaima haemacephala* (Statius Muller, 1776)	Crimson-breasted Barbet
	Picidae	
148.	*Dinopium benghalense* (Linnaeus, 1758)	Black-rumped Flameback
	Order: Psittaciformes	
	Family: Psittacidae	
149.	*Psittacula krameri* (Scopoli, 1769)	Roseringed Parakeet
150.	*Psittacula cyanocephala* (Linnaeus, 1766)	Plum Headed Parakeet
151.	*Psittacula eupatria* (Linnaeus, 1766)	Alexandrine Parakeet
152.	*Psittacula roseata* Biswas, 1951	Blossom-headed Parakeet
	Order: Strigiformes	
	Family: Strigidae	
153.	*Athene brama* (Temminck, 1821)	Spotted Owlet
	Tytonidae	
154.	*Tyto alba* (Scopoli, 1769)	Barn Owl
	Order: Upupiformes	
	Family: Upupidae	
155.	*Upupa epops* Linnaeus, 1758	Common Hoopoe

Brief account of the IUCN Red Listed species at Nangal Wetland

1. Lesser White-Fronted Goose *Anser erythropus* (VU)

This migratory species was rarely sighted and only a single individual of this species was recorded at this wetland in the month of January, 2015.

This is a vagrant species to northern India and generally found in islands, on foothills and mountain lakes. This species feeds mainly on plant matter, such as grass, moss, and seeds (Grimmett et al. 2001). Therefore, this wetland ensures the basic requirements of Lesser White-Fronted Goose and considered as suitable place for this bird.

2. Common Pochard *Aythya ferina* (VU)

This species was mainly found in open water with submerged and emergent vegetation at Nangal wetland.

3. Ferruginous Duck or White-eyed Pochard *Aythya nyroca* (NT)

This species is chiefly migratory and forms a small contributor to the duck population. During the entire study period it occurred in small numbers. This duck remains hidden in the patches of *Typha angustifolia*. This wetland meets the basic characteristics of a habitat preferred by the Ferruginous Duck, i.e., floating, submerged vegetation, and shallow marshy areas. The

ducks leave the site by April end.

4. River Lapwing *Vanellus duvaucelii* (NT)

The River Lapwing is a shore bird and its preferred habitats include shallower areas (Ali 1996). This wetland fulfils its habitat requirements as well as food and feeding habitat. They make nests on sand banks and forage mainly on ground.

5. Indian River Tern *Sterna aurantia* (NT)

This species locally migrates during the winter season and found in the study area during winter months only. It arrived in August to September. It was found in the range of 2–6 individuals during different months of the winter season.

6. Painted Stork *Mycteria leucocephala* (NT)

Painted Storks locally migrate along with other water birds. They arrived in the study area during September and left the area by March and mid April. Painted Storks are colonial nesting species and build their nests on trees in small islands situated in Nangal wetland. Nests were made of dry branches and twigs of plants.

7. Oriental Darter *Anhinga melanogaster* (NT)

It occurs at Nangal wetland due to roosting, feeding and breeding habitats provided by the wetland. It is found in a range of 1–10 individuals during different months of the year.

8. Sarus Crane *Grus antigone* (VU)

It is a resident bird of India but locally migrates to different localities subject to the availability of feeding and nesting habitats. During winter season, it prefers the nearby grasslands in the study area which provide nesting site for Sarus Crane. Their nests were located in shallow water where short emergent vegetation was dominant. Two adult pairs were seen in the surrounding area of Nangal wetland.

9. Woolly-necked Stork *Ciconia episcopus* (VU)

The Woolly-necked Stork is a widespread tropical species, which breeds in Africa and in Asia from India to Indonesia (Ali & Ripley 1987). It migrates locally in the winter season in India. It is observed that this bird stands calmly in an isolated shallow bank of the wetland and abruptly pounced upon the fishes and other small organisms in the water. Only a pair of this species was recorded at study area during January 2015.

10. Greater-Spotted Eagle *Aquila clanga* (VU)

Mainly a winter visitor, it was spotted in the wetland during the month of August and finally left the wetland completely by the end of March or mid April. Presence of feeding and roosting sites, i.e., large trees (e.g., *Acacia catechu*, *Acacia nilotica*, *Dalbergia sissoo*, *Eucalyptus globules*, *Ficus religiosa*, *Ficus benghalensis*, *Mangifera indica*), stumps of broken trees, crevices in the Shiwalik Hills largely attract this bird. It was seen in the range of 1–4 individuals during different months of the two-year period.

11. Egyptian Vulture *Neophron perenopterus* (EN)

It is a resident species and spotted mainly on large trees (*Acacia catechu*, *Acacia nilotica*, *Dalbergia sissoo*, *Eucalyptus globules*, *Ficus religiosa*, *Ficus benghalensis*, *Mangifera indica*) adjoining this wetland. Egyptian Vultures feed upon animal carcasses nearby this wetland. It was found in the range of 2–5 individuals during different months of the years.

12. Alexandrine Parakeet *Psittacula eupatria* (NT)

Alexandrine Parakeet is a local migratory species and found in maximum number during the winter months. Its preferred habitat is forested area where it lives in holes of dry trees, thick canopy of shady trees, and hill crevices. This area also provides a variety of food (i.e. plant buds, fruits, figs, berries), safe nesting and roosting sites. Maximum of 30–32 individuals were seen in the month of January 2014.

13. Blossom-headed Parakeet *Psittacula roseata* (NT)

Its preferred habitats were the open woodland and forested areas; generally found in flocks of 10–12. Its occurrence in the study area concluded that the area provides favorable conditions for breeding, feeding, and nesting purposes.

In the present study, the diversity of birds reflects that most of the species were observed mainly due to the availability of various types of microhabitats used by different species of birds. Each of these microhabitats (e.g., beneath the boulders, large stones, pebbles, and submerged vegetation) was supported with a variety of food such as fishes, crustaceans, mud-dwelling invertebrates, aquatic plants, and plankton. Unfortunately, it is observed that these organisms are on declining spree due to fragmentation of habitats caused by reclamation. During the last five decades, rampant deforestation has occurred in the catchment area of the wetland – hills were denuded which cause the silting up of the wetland. The siltation ultimately reduces the depth as well as water carrying capacity of the wetland.

Besides fragmentation of habitats, other anthropogenic activities like discharge of effluents from adjoining industries (National fertilizer limited; PACL), domestic sewage from Nangal township, rampant deforestation in the catchment area, siltation, and tourism pose a major threat to its existence. The discharge of pollutants should be stopped by strictly enforcing stringent environmental legislations of the

Table 2. Checklist of threatened and near-threatened bird species observed at Nangal Wetland during February 2013–January 2015.

Order	Family	Scientific name	Common name	Feeding habit	Status	IUCN status
Anseriformes	Anatidae	*Anser erythropus*	Lesser White-Fronted Goose	Herbivorous	Migratory	VU
		Aythya ferina	Common Pochard	Omnivorous	Omnivorous	VU
		Aythya nyroca	Ferruginous Duck	Omnivorous	Migratory	NT
Charadriiformes	Charadriidae	*Vanellus duvaucelii*	River Lapwing	Omnivorous	Local Migratory	NT
		Sterna aurantia	Indian River Tern	Carnivorous	Local Migratory	NT
Ciconiformes	Ciconiidae	*Mycteria leucocephala*	Painted Stork	Carnivorous	Local Migratory	NT
		Ciconia episcopus	Woolly-necked Stork	Carnivorous	Local Migratory	VU
	Phalacrocoracidae	*Anhinga melanogaster*	Oriental Darter	Carnivorous	Resident	NT
Gruiformes	Gruidae	*Grus antigone*	Sarus Crane	Omnivorous	Local Migratory	VU
Accipitriformes	Accipitridae	*Aquila clanga*	Greater-spotted Eagle	Carnivorous	Local Migratory	VU
		Neophron perenopterus	Egyptian Vulture	Carnivorous	Resident	EN
Psittaciformes	Psittacidae	*Psittacula eupatria*	Alexandrine Parakeet	Herbivorous	Local Migratory	NT
		Psittacula roseata	Blossom-headed parakeet	Herbivorous	Local Migratory	NT

Table 3. Seasonal average variations of threatened bird species of Nangal Wetland during February 2013– January 2015.

	Name of the Bird	Spring	Summer	Autumn	Winter	Annual Count	Mean
1.	Lesser White-Fronted Goose	-	-	-	0.1	0.1	0.025
2.	Common Pochard	-	-	-	1.133	1.133	0.283
3.	Ferruginous Duck	0.86	-	5.12	4.896	10.876	2.719
4.	River Lapwing	-	0.25	2.01	2.145	4.405	1.101
5.	Indian River Tern	0.333	0.233	3.418	3.546	7.53	1.882
6.	Painted Stork	0.508	-	10.636	11.133	22.277	5.569
7.	Woolly-necked Stork	-	-	-	0.333	0.333	0.083
8.	Oriental Darter	1.003	0.528	2.993	3.965	8.489	2.122
9.	Sarus Crane	-	0.333	1.375	1.633	3.341	0.835
10.	Greater-spotted Eagle	0.4	0.525	2.133	3.133	6.191	1.547
11.	Egyptian Vulture	1.701	1.206	2.376	2.718	8.001	2.0
12.	Alexandrine Parakeet	5.8	4.205	22.773	26.778	59.556	14.889
13.	Blossom-headed Parakeet	-	-	23.055	30.103	53.158	13.289
Total avifaunal count		**10.605**	**7.28**	**75.889**	**91.613**	**185.39**	**46.061**
Shannon-Weaver diversity index H'		**1.534**	**1.436**	**1.868**	**1.915**		

nation. Awareness should be created amongst the local people towards conservation and to understand the importance of such diverse avifauna existing in this wetland.

CONCLUSIONS

This study provides an ornithological baseline data of Red Listed species of the wetland for researchers and general public. It will also provide an opportunity to compare trends of population of these birds in future. Therefore, it is recommended that the sites, where threatened bird species were recorded should be monitored regularly in future especially during midwinter waterfowl counts.

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COMMUNICATION

Evaluation of fish diversity and abundance in the Kabul River with comparisons between reaches above and below Kabul City, Afghanistan

Ugyen Kelzang [1], Ahmad Farid Habibi [2] & Ryan J. Thoni [3]

[1] Forest Research Institute (Deemed to be University), Kaulagarh Road, PO. I.P.E., Dehradun, Uttarakhand 248195, India.
[1] Present address: Ministry of Health, P.O. Box: 726, Lhado Lam, Kawajangsa,Thimphu, Bhutan.
[2] Faryab University, Faryab Province, Afghanistan.
[3] Feather River College, 570 Golden Eagle Avenue, Quincy, CA 95971, United States.
[1] ugyen.kelzang@gmail.com (corresponding author), [2] faridhabibi558@gmail.com, [3] ryan.thoni@slu.edu

Abstract: The fish fauna of the Kabul River downstream of the City of Kabul face threats from increasing human population such as pollution, overfishing, and increased development. Despite the rapid increase of these activities leading to threats to fishes in the Kabul River, no studies have examined the changes in diversity, distribution, and abundance of fish fauna in the Kabul River surrounding of Kabul City. In this study, the Kabul River was divided into two zones (upstream and downstream) consisting of six sampling sites (3 sites per zone). Of the total of 1,190 fishes collected, Cypriniformes was the dominant order with one family, six genera, and eight species. Cyprinidae was the dominant family of that order with 81.4% (n= 969) of total individuals. Species abundance was higher in the upstream reaches in almost all analyses. Upstream sites recorded 11 species, while seven species were recorded from downstream sites. Fish species richness was significantly higher upstream versus downstream reaches (9.67 ± 1.53 vs. 6.33 ± .58; U= .00, z= -1.99, p= .04, r= .81). Species diversity upstream was significantly higher than downstream (H'= 1.90 ± 0.15, D_1= 0.81 ± 0.02). Similarly, species evenness was also higher upstream than downstream (J'= 0.84 ± 0.01). Low diversity, abundance, and evenness in downstream reaches are likely due to anthropogenic activities affecting the river in and around Kabul City.

Keywords: Anthropogenic, diversity indices, native species, pollution, species composition.

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Author details: Ugyen Kelzang is a conservation enthusiast and working on the conservation and management of aquatic biodiversity in Bhutan. He studied MSc environment management and BSc Sustainable Development. He is currently employed as a project officer at the Ministry of Health of Bhutan. Ahmad Farid Habibi is a lecturer at Faryab University in Afghanistan. His research interests include the conservation of freshwater biodiversity, environmental education, and disaster management. Ryan J. Thoni is an ichthyologist specializing in studying the diversity and evolution of Himalayan fish fauna. His research spans the Himalayas with a strong focus on Bhutan, Nepal, and the Tien Shan Range in Kyrgyzstan and Tajikistan.

Author contributions: UK performed a compilation of data, analysis, interpretation, and wrote the first draft of the manuscript. AFH did all fieldwork like field sampling and field data collection. RJT reviewed and edited the first draft of the manuscript. All authors reviewed and incorporated all the comments received from the reviewers and incorporated them in the manuscript. Before submitting, all authors read and approved the final version of the manuscript.

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INTRODUCTION

Fishes are the most diverse and abundant group of vertebrates in the world (Powers 1989; Ravi & Venkatesh 2008), making up nearly 50 % of all vertebrate diversity. Further, fishes are important keystone species in many ecosystems and exhibit diverse behaviours and ecologies (Spencer & King 1984; Allan 2004; Dudgeon et al. 2006; Wu et al. 2014). They play important roles managing balanced trophic dynamics within a system. Additionally, fishes contribute to food security throughout most of the world, making up as much as 17 % of the world population's protein intake (Bennett et al. 2018) and fishing is one of the most common livelihoods globally (FAO 2014).

An assessment done by the International Union for Conservation of Nature (Reid et al. 2013), on more than 5,000 species, reported that freshwater fishes are the most threatened group of vertebrates in the world. The Himalayan region holds a variety of both warm and cold-water fishes (Jayaram 2010). Coad (2015) reported that there are 85 species of fishes belonging to 10 families in the landlocked country of Afghanistan, however, FishBase.org (2020) reports 125 species (all freshwater species) known to occur in Afghanistan – a gulf that reflects the paucity of reliable data on fish diversity in Afghanistan. Though, several studies on the fishes have been conducted throughout different regions of the Himalaya (Vishwanath et al. 1998; Shrestha 1999; Goswami et al. 2007; Jayaram 2010; Gurung et al. 2013; Thoni & Gurung 2014; Gurung & Thoni 2015; Prasad et al. 2020), in Afghanistan, such studies are very limited in scope and number, despite the fact that several fishes found in the country are endemic and likely threatened (UNEP 2003). In order to preserve biodiversity in a given area, we must understand what the diversity is and how it is impacted by different resource uses, development processes, and management strategies.

The Kabul River is home to a diverse fish community including the globally endangered Golden Mahseer *Tor putitora* (UNEP 2008). The Kabul River is mainly used for irrigation, waste disposal, watering livestock, and fishing. The river runs through the most densely populated areas of the city. In the Kabul River, water pollution is a significant threat to the freshwater ecosystem (Weir 2018). The United Nations Environment Protection (UNEP 2003) reported pollution of the Kabul River in the city of Kabul mainly by the release of industrial effluents, domestic waste, and development activities. To date no biodiversity indices-based research efforts on fish fauna have been carried out in Afghanistan. Hence, this study aims to assess the diversity, distribution, and abundance of fish fauna in the Kabul River downstream of Kabul City compared to upstream.

MATERIAL AND METHODS

Study area

This study was conducted along reaches of the Kabul River above and below Kabul City, located at 34.542°N 68.803°E, at an elevation of 1,791 m (Figure 1). The study area was divided into two different zones: upstream, and downstream. Three sampling sites each from each zone were selected to sample fish (Figure 1; Table 1). Four sampling replicates were taken in each sampling sites, keeping 400 m distance between sampling replicates. Sites were selected to ensure that similar habitat types were represented in upstream and downstream reaches. Fish sampling was carried out between December 2019 to June 2020 by using nets (mesh sizes ranging from ½ inch to 2.5 inch) both in upstream and downstream reaches. We used different mesh sizes of nets so as to minimize the bias in sampling fishes of numerous sizes due to specific gears.

The area receives 312 mm of precipitation on an average annually, with rarer precipitation in the summer months (NEPA 2007). Average annual temperature of the area ranges from 4.3 °C to 19.6 °C, with approximately 12.4 °C to 32.1 °C during summer months and -7.1 °C to 8.3 °C in winter months (Broshears et al. 2005). The area is densely populated (Mack et al. 2009), with much of the non-wood forest product industry (mainly fruits and tree nut farming and industry) dependent upon the Kabul River and its tributaries for the disposal of effluents (dyes, metals, and minerals). A population of roughly 3–5 million people live in the greater Kabul area (Barbè 2013).

Fish sampling

Using the expertise of the local fishermen, ichthyofaunal sampling was done in the selected sampling sites. Fishes were collected using gill nets and fish traps for two days in each sampling site. Fishes were counted, photographed, and identified up to the species level when possible, before being released back into the river. Species that were not readily identified by the project team on site were photographed and all diagnostic data required for identification were taken for further identification and referred to available literature. Taxonomic studies of the fish fauna collected from this study were performed following Mishra (1959), Talwar &

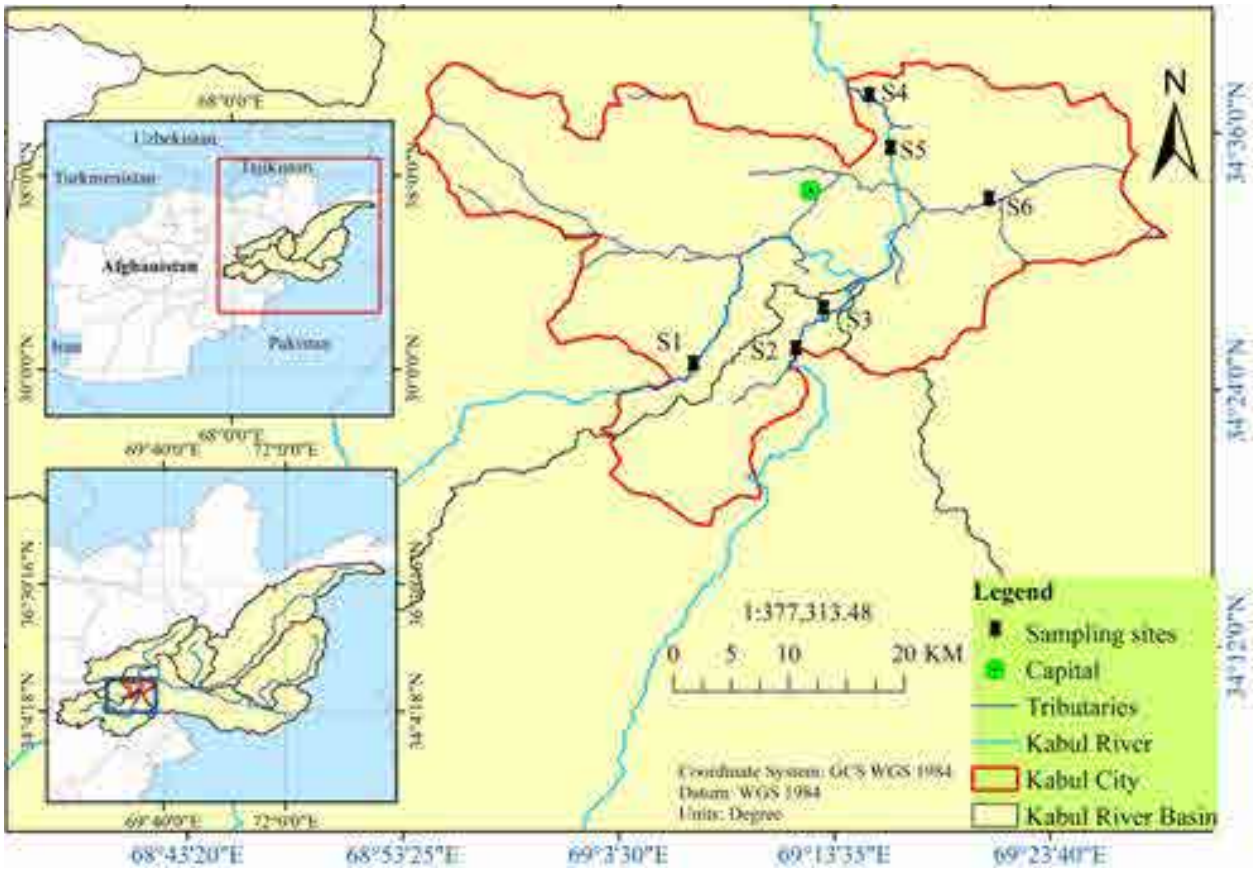

Figure 1. Map of the study area showing sampling sites, Kabul River and its tributaries, and Kabul City, Afghanistan.

Jhingran (1991), Jayaram (1981, 2010), and Coad (2014, 2015).

Analysis of data

A Mann-Whitney test, comparing species diversity and abundance was performed using IBM SPSS Statistics 23.0 to examine differences in species abundance and diversity between upstream and downstream locations. Dendrogram of Bray-Curtis coefficients of similarity (Bray & Curtis 1957) and rank abundance plots of sites were generated using BioDiversity Professional version 2.0 (McAleece 1999). As there seems to be no single diversity index more appropriate than another (Morris et al. 2014), several common diversity indices were tested. Shannon diversity index (Shannon & Wiener 1949), Simpson's diversity (Pielou 1969), Pielou evenness index (Pielou 1975), Margalef's richness index (Margalef 1958), Menhinick's index (Menhinick 1964), and Sorensen's similarity coefficient (Dice 1945; Sørensen 1948) were calculated using the following formulae:

(a) Shannon diversity index: $H' = -\sum_{i=1}^{n} p_i \ln p_i$

where p_i = the proportion of individuals belonging to the i^{th} species.

(b) Simpson's diversity: $D_1 = 1 - \sum_{i=1}^{n} p_i^2$

where p_i = the proportion of individuals belonging to the i^{th} species.

(c) Pielou evenness index: $J' = \frac{H'}{LnS}$

where H' = Shannon diversity index; S= species richness.

(d) Margalef's richness index: $D_{Mg} = \frac{S-1}{Ln(N)}$

where S= species richness; N= total number of individuals.

(e) Menhinick's index: $D_{Mn} = \frac{S}{\sqrt{N}}$

where S= species richness; N= total number of individuals.

(f) Sorensen's similarity coefficient: $CC = \frac{2C}{S1+S2}$

where C= number of species the two communities

Figure 1. Map of the study area showing sampling sites, Kabul River and its tributaries, and Kabul City, Afghanistan.

Sampling zones	Sampling sites	Geographic coordinates		Elevation (m)
		Latitude (D.M.S)	Longitude (D.M.S)	
Upstream	S1	34.41746°N	69.11657°E	1,919
	S2	34.42923°N	69.19619°E	1,814
	S3	34.4609°N	69.21761°E	1,797
Downstream	S4	34.62652°N	69.25344°E	1,761
	S5	34.58567°N	69.27003°E	1,782
	S6	34.54591°N	69.34672°E	1,776

have in common; *S1*= number of species in community one; *S2*= number of species in community two.

The initial data entering, data cleaning, data coding, calculation of some descriptive analyses, and generation of charts were conducted using Microsoft Excel 2016. The map of the study area was produced using ArcMap version 10.5.

RESULTS AND DISCUSSION

Fish composition

A total of 1,190 fishes were collected (Table 2) from the study area. Out of the total of all fishes across both zones, 81.4 % (n= 969) of belong to the order Cypriniformes, 18.2 % (n= 216) to Salmoniformes, and 0.4 % (n= 5) to Cichliformes (Figure 2). This is in line with the research carried out by Saund et al. (2012) in the Mahakali River, Nepal, where they have reported Cypriniformes as the most dominant order. Studies conducted by Shendge (2007), Aryani (2015), and Akhi et al. (2020) have reported similar community structures. However, the aquatic habitats of Afghanistan are less conducive to and are geographically isolated from many of the more diverse groups of Asian Siluriformes, resulting in our relatively low diversity of catfishes. Cyprinids can live in cold waters, tolerate very low oxygen levels, and exhibit a broad range of trophic guilds (Royce 1996). Hence, combined with historical processes, they are typically found to be more dominant in freshwater habitats throughout most of the Asian continent.

The order of Cypriniformes was represented by one family, six genera, and eight species. The second most abundant order, Salmoniformes, was represented by one family, two genera, and two species. Cichliformes was only represented by a single species. Among families, Cyprinidae was the most dominant within the study area, and Salmonidae was second most dominant family. Similarly, Dau & Parkash (2009), Cunico et al. (2011), Choubey & Qureshi (2013), Mohsin et al. (2013), Hu et al. (2019), and Herawati et al. (2020) reported Cyprinidae as the dominant family in regional censuses throughout much of Asia.

Among the predominant fish families, Cyprinidae is one of the most diverse (Boschung & Mayden 2004; Shen et al. 2016) and pollution-disturbance-tolerant families, with more than 2,000 species and 210 genera (Barbour et al. 1999; Grabarkiewicz & Davis 2008). Their ability to survive in unclean habitats validates their dominance in the most polluted part of the Kabul River (Kabul city and downstream reaches).

Species abundance

Within the upstream sites, *Schizothorax sp.* was highly abundant at sites S2 (n= 76) and S3 (n= 117) followed by *Schizothorax esocinus*. At S1, *Oncorhynchus*

Table 2. Overall fish species composition in Kabul River under Kabul City.

Family	Species	N	%
Cyprinidae	*Alburnoides holciki*	90	7.6
	Ctenopharyngodon idella	54	4.5
	Cyprinus carpio	36	3.0
	Hypophthalmichthys molitrix	81	6.8
	Schizothorax esocinus	228	19.2
	Schizothorax sp.	420	35.3
	Tariqilabeo diplochilus	48	4.0
	Tariqilabeo sp.	12	1.0
Salmonidae	*Oncorhynchus mykiss*	198	16.6
	Salmo trutta	18	1.5
Cichlidae	*Coptodon zillii*	5	0.4

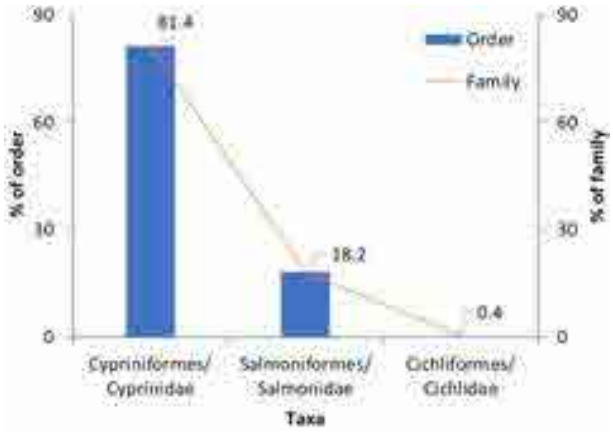

Figure 2. Composition of fishes based on order and family.

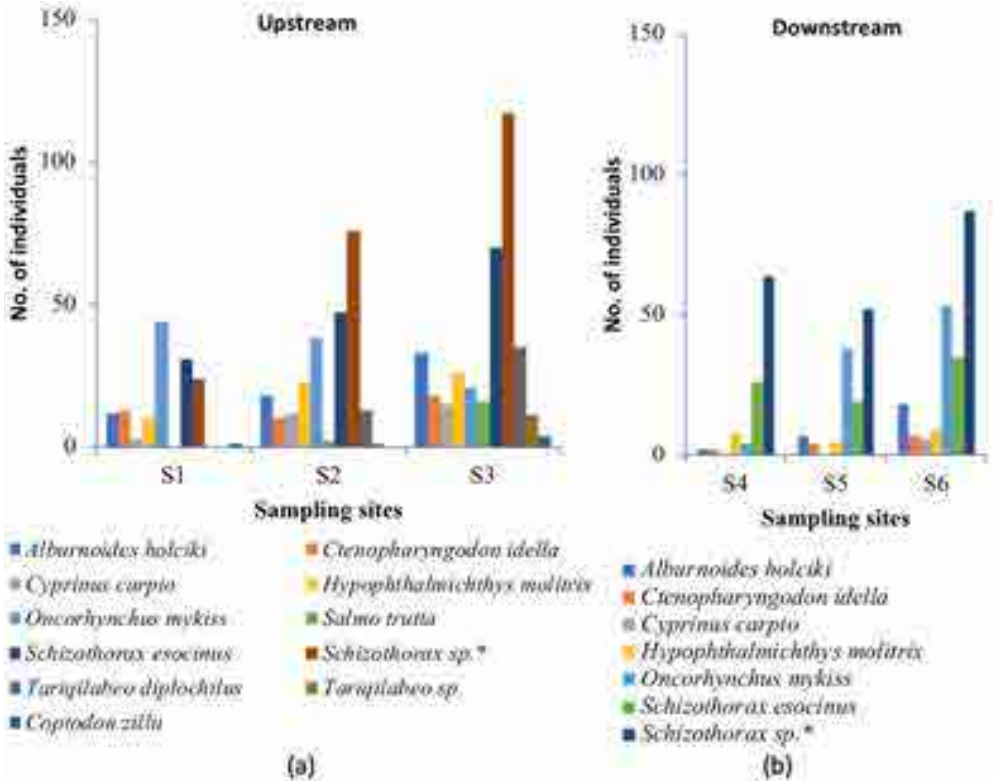

Figure 3. Species abundance in different sampling sites of (a) upstream and (b) downstream (Note: * indicates highest no. of individuals).

mykiss (n= 44) was the most abundant species, followed by *S. esocinus* (n= 31) (Figure 3a). *Schizothorax* sp. was the most abundant species at all three of the downstream sites (S4 n= 64, S5 n= 52, S6 n= 87; Figure 3b). Species abundance significantly differs among the 6 different sampling sites. *Alburnoides holciki* (n= 33), *Ctenopharyngodon idella* (n= 18), *Cyprinus carpio* (n= 15), *Hypophthalmichthys molitrix* (n= 26), *Salmo trutta* (n= 16), *Schizothorax esocinus* (n= 70), *Schizothorax* sp. (n= 117), *Tariqilabeo diplochilus* (n= 35), *Tariqilabeo* sp. (n= 11), and *Coptodon zillii* (n= 4) were recorded more in S3 than in other sites.

Overall, in upstream sites, *Schizothorax* sp. was abundant (n= 217, 72.33 ± 46.61), followed by *Schizothorax esocinus* (n= 148, 49.33 ± 19.60) and *Oncorhynchus mykiss* (n= 103, 34.33 ± 11.93). *Coptodon zillii* (n= 5, 1.67 ± 2.08) was least abundant fish species in the upstream zone (Table 3). Likewise, in the downstream, *Schizothorax* sp. (n= 203, 67.67 ± 17.79) was most abundant and *Cyprinus carpio* (n= 6, 2 ± 3.46) was least abundant.

Pandey et al. (2018) also found abundance and dominance of *Schizothorax* spp. in rivers in Uttarakhand, India. Similar reports on the abundance of schizothoracines were also made in the Tibetan Plateau (Zhang et al. 2017; Ma et al. 2020). Moreover, Kabul is a cold place located at 1,791 m and Aljazeera (2012) reported -17°C at night in February. Schizothoracines are cold-water species, also living at elevations of up to 3,323 m (Petr et al. 2002). Thus, the abundance of schizothoracines in the Kabul River is in consistence with the other rivers of the Himalaya.

While comparing overall fish abundance between upstream and downstream reaches, upstream (n= 744) was found to be higher than downstream (n= 446). This result is contrary to normal patterns of fish diversity along a river continuum (Edds 1993; Tiemann et al. 2004). In addition, the dendrogram of Bray-Curtis coefficients of similarity in the abundance of fish was produced. As per the cluster analysis, S2 and S6 had a parallel Bray-Curtis similarity in their species abundance of about 83 %. Though these sites are from different locations (upstream and downstream), the high similarity explained between these sites is mainly due to similar level of anthropogenic activities and pollution level. S1, S5, S3, and S2–S6 combined had a common similarity of about 74 %, indicating similarity in species abundance (Figure 4).

Species present at the upstream sites like *Salmo trutta, Tariqilabeo diplochilus, Tariqilabeo* sp., and

Table 3. Mean species abundance with standard deviation at upstream and downstream sites.

Species	Upstream		Downstream	
	No. of individuals	Mean ± Standard Deviation	No. of individuals	Mean ± Standard Deviation
Alburnoides holciki	63	21.00 ± 10.82	27	9.00 ± 8.19
Ctenopharyngodon idella	41	13.67 ± 4.04	13	4.33±2.52
Cyprinus carpio	30	10.00 ± 6.24	6	2.00 ± 3.46
Hypophthalmichthys molitrix	59	19.67 ± 8.50	22	7.33 ± 2.08
Oncorhynchus mykiss	103	34.33 ± 11.93	95	31.67 ± 25.11
Salmo trutta	18	6.00 ± 8.72	-	-
Schizothorax esocinus	148	49.33 ± 19.60	80	26.67 ± 8.02
Schizothorax sp.	217	72.33 ± 46.61	203	67.67 ± 17.79
Tariqilabeo diplochilus	48	16.00 ± 17.69	-	-
Tariqilabeo sp.	12	4.00 ± 6.08	-	-
Coptodon zillii	5	1.67 ± 2.08	-	-

- indicates absence.

Table 4. Native and non-native fish species recorded in different sites.

Species	Occurrence	Sampling sites					
		S1	S2	S3	S4	S5	S6
Alburnoides holciki	Native	√	√	√	√	√	√
Salmo trutta	Native	x	√	√	x	x	x
Schizothorax esocinus	Native	√	√	√	√	√	√
Tariqilabeo diplochilus	Native	x	√	√	x	x	x
Coptodon zillii	Native	√	x	√	x	x	x
Ctenopharyngodon idella	Non-native	√	√	√	√	√	√
Cyprinus carpio	Non-native	√	√	√	x	x	√
Hypophthalmichthys molitrix	Non-native	√	√	√	√	√	√
Oncorhynchus mykiss	Non-native	√	√	√	√	√	√

Coptodon zillii were not recorded from the downstream sites. This is likely because of the high intensity of ongoing habitat degradation caused by the discharge of industrial waste and sewage directly into the river system, construction activities, and the high density of human population and their associated anthropogenic effects on the downstream reaches.

Native and non-native species in sampling sites

From the total of nine species recorded from the area (lumping *Schizothorax* sp. with *Schizothorax esocinus* and *Tariqilabeo* sp. with *Tariqilabeo diplochilus*), five species were found to be native and four non-native species (Table 4).

We recorded the highest number of native species from S3 (*n*= 286), followed by S2 (*n*= 157), and S6 (*n*= 140). Similarly, as shown in Table 5, non-native fish species were recorded more in S3 (*n*= 84) followed by S2 (*n*= 83) and S6 (*n*= 75. The lowest number of non-native fish were found in S4 (*n*= 14). It was found that almost all non-native fish species were used for aquaculture in the area. The decrease in native species richness while moving from upstream to downstream was also reported by Loures & Pompeu (2019). They stated that the main reason behind such occurrence is mainly due to increase in non-native species in downstream areas.

Diversity and richness of fish species

The high species richness in S3 and S2 were indicated by Margalef's diversity index (D_{Mg}) (1.69 and 1.64, respectively), as their values were higher than other sampling sites. To examine the similarity of species

Table 5. Sorenson's similarity coefficient (whose value ranges from 0 to 1) showing degree of similarity among sampling sites.

	S1	S2	S3	S4	S5	S6
S1	1.00	0.78	0.84	0.86	0.86	0.93
S2		1.00	0.95	0.75	0.75	0.82
S3			1.00	0.71	0.71	0.78
S4				1.00	1.00	0.92
S5					1.00	0.92
S6						1.00

Table 6. Mean ± standard deviation of biodiversity indices for upstream and downstream sites in Kabul city.

Diversity Indices/ Sites	Upstream Mean ± SD	Downstream Mean ± SD
Menhinick's index (D_{Mn})	0.63 ± 0.05	0.53 ± 0.05
Margalef's diversity index (D_{Mg})	1.59 ± 0.15	1.07 ± 0.04
Shannon diversity index (H')	1.90 ± 0.15	1.36 ± 0.22
Pielou evenness index (J')	0.84 ± 0.01	0.74 ± 0.10
Simpson's diversity D_1)	0.81 ± 0.02	0.67 ± 0.09

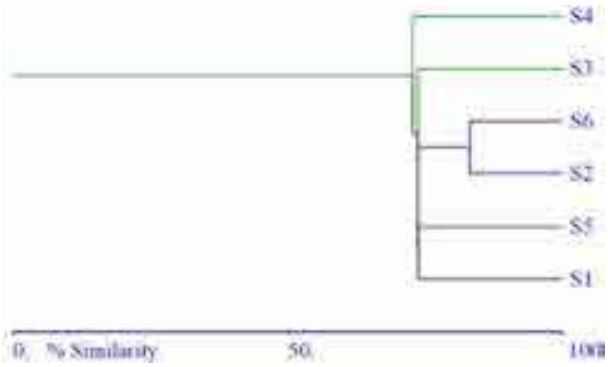

Figure 4. Bray-Curtis similarity dendrogram; cluster analysis (single linkage) based on the Bray-Curtis index of similarity applied to the fish abundance.

richness between the sampling sites, Sorenson's similarity coefficient (CC) was appraised (Table 5). Sampling sites S2 & S3, S1 & S6, S4 & S6, and S5 & S6 indicated having similarity of 95 %, 93 %, 92 %, and 92 % between them, respectively. Sorenson's similarity coefficient value between S3, S4, and S5 (CC= 0.71) was the lowest, which also shows 71 % of similarity between them.

Altogether, upstream sites recorded 11 species while downstream sites recorded seven species. High richness upstream (D_{Mn}= 0.63 ± 0.05, D_{Mg}= 1.59 ± 0.15) was supported by Menhinick's Index (D_{Mn}) and Margalef's diversity index (D_{Mg}). For downstream, Menhinick's index and Margalef's diversity index were 0.53 ± 0.05 and 1.07 ± 0.04 correspondingly, which was considerably less than upstream (Table 6). This was supported by Mann-Whitney test which revealed that fish richness upstream (9.67 ± 1.53) and downstream (6.33 ± .58) was significantly different (U= 0.00, z= -1.99, p= 0.04, r= 0.81) (Table 7).

Fish species diversity was evaluated using various diversity indices. The most diverse site among all was S3 with Shannon diversity index (H') of 2.04 and Simpson's diversity (D_1) of 0.83. S4 was the site with least diversity (H'= 1.12, D_1= 0.57). Similarly, species evenness was highest in S3 with Pielou evenness index (J') of 0.85 and lowest in S4 (J'= 0.62).

Overall, diversity of fishes was higher in reaches of the Kabul River upstream (H'= 1.90 ± 0.15, D_1= 0.81 ± 0.02) of Kabul City when compared to downstream reaches (H'= 1.36 ± 0.22, D_1= 0.67 ± 0.09) which was indicated both by the Shannon diversity index and Simpson's diversity. Likewise, species evenness was higher in reaches upstream of Kabul City (J'= 0.84 ± 0.01) compared to downstream reaches (J'= 0.74 ± 0.10). Previous studies have shown a similar pattern in which reaches of rivers upstream of densely populated areas harbour higher diversity of freshwater fishes compared to downstream (Tawari-Fufeyin & Ekaye 2007).

The higher species richness and diversity in upstream reaches in the study area may be due to the constant flow of the river, less modification of land use, less pollution and fewer developmental activities. Urban activities like urban and industrial construction leads to land use change, adding pollution and nutrients to the river system, varying hydro-morphology and hydrologic flow regimes, and creating unstable flow (as the valley remains dry in most of the winter months) which negatively effects fish diversity and richness (Grimm et al. 2000; Wang et al. 2001; Booth 2005; Walsh et al. 2005; Gebrekiros 2016).

Freshwater ichthyofauna conservation

Afghanistan is an arid and landlocked country (Breckle 2007; Wily 2015), but is abundant in water resources (Qureshi 2002). However, as much as 80 % of Afghanistan's freshwater is contaminated and water pollution is a serious threat to the conservation of aquatic biodiversity and human survival (Weir 2018). In Kabul City, solid waste, waste water (both domestic and industrial), and open sewers directly drain into the Kabul River (UNEP 2003), exacerbated by population growth (Mack et al. 2009), modifying the aquatic habitat. Habitat quality plays a great role in the fish composition,

Table 7. Mann-Whitney U test result of species richness between upstream and downstream.

	Group	N	Mean rank	Mean Sum	*U*	*z*	*p*	*r*
Species richness	Upstream	3	5.00	15.00	.00	-1.99	.04	.81
	Downstream	3	2.00	6.00				

U—Mann-Whitney U test | *z*—z statistics | *p*—significance value | *r*—effect size.

Table 8. Fish species recorded from the Kabul River in Kabul City, Afghanistan with global conservation status.

Species	Conservation status	Regional status
Alburnoides holciki	Not Evaluated	Native
Ctenopharyngodon idella		Non-Native
Cyprinus carpio		Non-Native
Hypophthalmichthys molitrix		Non-Native
Oncorhynchus mykiss		Non-Native
Salmo trutta	Least concern	Native
Schizothorax esocinus	Not Evaluated	Native
Schizothorax sp.		Native
Tariqilabeo diplochilus	Not Evaluated	Native
Tariqilabeo sp.		Native
Coptodon zillii	Least Concern	Native

diversity, and distribution in any stream or river system (McClendon & Rabeni 1987; Agarwal et al. 2018). Use of agriculture pesticides, and overfishing (Saeed 2018) are other threats to the conservation of the freshwater ecosystem in Kabul City. This study has documented 11 fish species from the area. One species of them is listed under the IUCN Red List of Threatened Species (Table 8). To conserve these species and other associated species in the area, adoption of scientific fishing or sustainable fishing methods, timely monitoring of water quality, and proper management of solid waste and waste water are urgently recommended.

CONCLUSIONS

The Kabul River downstream of Kabul City is threatened by numerous anthropogenic activities. The majority of fishes recorded from the area were from the upstream sites where the aquatic habitat was least disturbed compared to downstream sites. Intensive agriculture, infrastructural development, and ineffective management of waste in the downstream area increases sedimentation, contamination, and changes the overall aquatic habitats and their function. Our study shows that species diversity, richness, and abundance tend to decrease as we move from sites upstream of Kabul City to sites downstream of Kabul City. Thus, implementation of sustainable development practice is deemed essential, so as to manage the water resources and conserve its biodiversity. Moreover, studies on physiochemical parameters of the river, aquatic macroinvertebrates and fishes, and their association needs to be carried out to generate additional baseline information on the aquatic biodiversity of the area and to monitor water quality.

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COMMUNICATION

New record of *Myrmarachne melanocephala* MacLeay, 1839 (Araneae: Salticidae) from Jharkhand, India and biogeographical implications of the co-occurrence of its ant model *Tetraponera rufonigra* Jerdon, 1851

Rahul Kumar [1], Mirtunjay Sharma [2] & Ajay Kumar Sharma [3]

[1,3] University Department of Zoology, Vinoba Bhave University, Hazaribagh, Jharkhand 825301, India.
[1] Department of Zoology, Sheodeni Sao College, Kaler, Arwal, Bihar 824127, India.
[2] Forest Department Office, Hazaribagh, Jharkhand 825301, India.
[1] rahuldayanand33@gmail.com (corresponding author), [2] sharmamirtunjay@gmail.com, [3] ajaysharmavbu@gmail.com

Abstract: We report the occurrence of the ant-mimicking jumping spider *Myrmarachne melanocephala* MacLeay, 1839 for the first time from Hazaribagh Wildlife Sanctuary, Jharkhand, India. Digital illustrations and descriptions of the spider, the female's exuviae, and video records of a live male are also presented. The distribution pattern of *M. melanocephala* has not been studied in detail across India whereas its ant model, *Tetraponera rufonigra* Jerdon, 1851 is known to have a wide distribution. Co-occurrence of the mimic and the model implies a wider range of biogeographical distribution of these species in India.

Keywords: Distribution, eastern India, exuviae, Hazaribagh Wildlife Sanctuary, jumping spider, mimicry, myrmecomorphy.

Abbreviations: ALE—anterior lateral eye | AME—anterior median eye | md—mid-dorsal | pd—pro-dorsal | PLE—posterior lateral eye | PME—posterior median eye | pv—proventral | rv—retroventral.

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Author details: Rahul Kumar is working as an Assistant Professor at Department of Zoology, Sheodeni Sao College (Magadh University), Kaler, Arwal, Bihar. His doctoral research is going on from University Department of Zoology, Vinoba Bhave University, under Dr. Ajay Kumar Sharma. His doctoral work concerns with mimicry among terrestrial arthropods and new approaches to explore integrative taxonomy. He has research experience in molecular biology and functional genomics from School of Life Sciences, JNU, New Delhi as UGC-JRF; in nanotechnology and biotechnology from Department of Anatomy, AIIMS, New Delhi as DST-Nanomission JRF; and in biosystematics and integrative taxonomy from Division of Entomology, ICAR-IARI, New Delhi as DST-SERB JRF. Mirtunjay Sharma is a forest department employee, a Limca Book of World Record holder hobbyist entomologist-arachnologist and a famous nature photographer from Hazaribagh, Jharkhand. He is author of the book "Spiders of Jharlkhand" published by Jharkhand Biodiversity Board. Dr. Ajay Kumar Sharma is working as Associate Professor at University Department of Zoology, Vinoba Bhave University, Hazaribagh, Jharkhand and is also assigned with the positions of University Dean of Science and course coordinator of the Department of Physiotherapy in the same university. He has more than 40 years of research and teaching experience. His thrust areas of research are molecular biology, entomology and ecology.

Author contributions: Conceptualization of the research and manuscript writing was done by RK. Site visits, data collections and analyses were done by RK, MS and AKS. Manuscript was reviewed and finalized by AKS before communication. Correspondence to the journal and subsequent revisions were done by RK.

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INTRODUCTION

Ant-mimicry (myrmecomorphy) is not very uncommon among arthropods. Most myrmecomorphs display Batesian mimicry where non-ant species mimic unpalatable and aggressive ants in order to avoid predatory attacks which is the result of adaptive evolution (Cushing 1997). Myrmecomorphy has achieved a distinct level of perfection among salticids (jumping spiders). The genus *Myrmarachne* MacLeay, 1839 is one of the largest salticid genera consisting of 186 accepted species globally out of which 23 are found in India but only six of them are well characterized and all of these species exhibit Batesian mimicry displaying profound morphological as well as behavioural resemblances towards ants (Caleb 2016; Prószyński 2016; Wanless 1978; World Spider Catalog 2021; Yamasaki & Ahmad 2013; Yamasaki & Edwards 2013; Caleb & Benjamin 2017; Caleb & Sankaran 2021).

The genus *Myrmarachne* forms part of a phylogenetic group of the subfamily Salticinae Blackwall, 1841 (Maddison 2015). *Myrmarachne melanocephala* MacLeay, 1839 is the type species of the genus *Myrmarachne* which was originally described from Bengal (which corresponds to present day West Bengal in India and Bangladesh combined) (Edwards & Benjamin 2009; World Spider Catalog 2021). *M. melanocephala* mimics the worker of *Tetraponera rufonigra* Jerdon, 1851, an arboreal ant with conspicuous eyes and long slender body (Pocock 1909). This species was originally described from the Carnatic-Malabar region (which corresponds to present day Indian states: Karnataka, Kerala, Tamil Nadu, and Andhra Pradesh) (Ward 2001). The genus *Tetraponera* Smith, 1852 belongs to subfamily Pseudomyrmecinae of Formicidae which is represented by 95 extant species globally, of which 10 are found in India (Bharti & Akbar 2014; Bolton 2021).

This paper is concerned with the discovery of *M. melanocephala* from Hazaribagh Wildlife Sanctuary, Hazaribagh, Jharkhand with detailed morphological descriptions and observation on its ant model *T. rufonigra*. For the first time, in addition an undamaged whole body exuviae of a freshly moulted female *M. melanocephala* has been used here as material for morphological descriptions of this spider. Both taxonomic as well as behavioural (mimicry related) aspects have been noted. The biogeographical implications of the co-occurrence of the mimic and the model together in the same habitat has also been discussed in the Indian context.

MATERIALS AND METHODS

Sampling and collection were performed at Hazaribagh Wildlife Sanctuary, Hazaribagh, Jharkhand, India (Image 1). The spiders and ants were observed on and around Sal *Shorea robusta* trees. One male and two female spider specimens were spotted on a Sal tree trunk. The male specimen was captured alive and one freshly moulted female specimen and its undamaged whole body exuviae were manually collected and preserved in 70% ethanol for further investigations. The live male spider and ant specimens were photographed and videoed using a cellphone camera (Samsung M42). Measurements of the live male spider specimen were taken in millimeters (mm) using ocular micrometer placed within the eyepiece of a stereoscopic microscope by keeping the material on a cavity slide with a drop of water. A coverslip was temporarily placed over the cavity of the cavity slide in order to keep the material static for quick measurements. The water drop was added to create surface tension in order to keep the cover slip in firm position without killing the spider. The specimen was kept alive for behavioural studies. Note: one leg of the male spider got detached while trying to measure it alive. The ventral and dorsal sides of the palp and dentition of the live male spider were studied using hand-held magnifying glasses and stereoscopic microscope. The ethanol preserved specimen of the female spider was dissected for its epigyne, palp, and head containing chelicerae and fangs using a fine surgical scalpel. Epigyne was cleared by boiling it in 10% potassium hydroxide (KOH) solution for a minute. After boiling, the epigyne was rinsed thoroughly in water to remove excess KOH and was temporarily mounted in a drop of glycerol using coverslip on a glass slide for microscopic observations. The ethanol preserved female spider (before dissection), its undamaged whole body exuviae, and dissected epigyne, palp & head with chelicerae & fangs were photographed using Leica DFC 425C digital camera mounted over Leica M205FA stereozoom automontage microscope at National Pusa Collection, Division of Entomology, Indian Agricultural Research Institute, Pusa, New Delhi 110012. Measurements were taken in millimeters (mm) using inbuilt settings of the automontage. The format of the description follows Yamasaki (2010), Caleb (2016), and Ward (2001). The studied ethanol preserved specimen of the female spider and its exuviae were deposited in the museum collections of University Department of Zoology, Vinoba Bhave University, Hazaribagh.

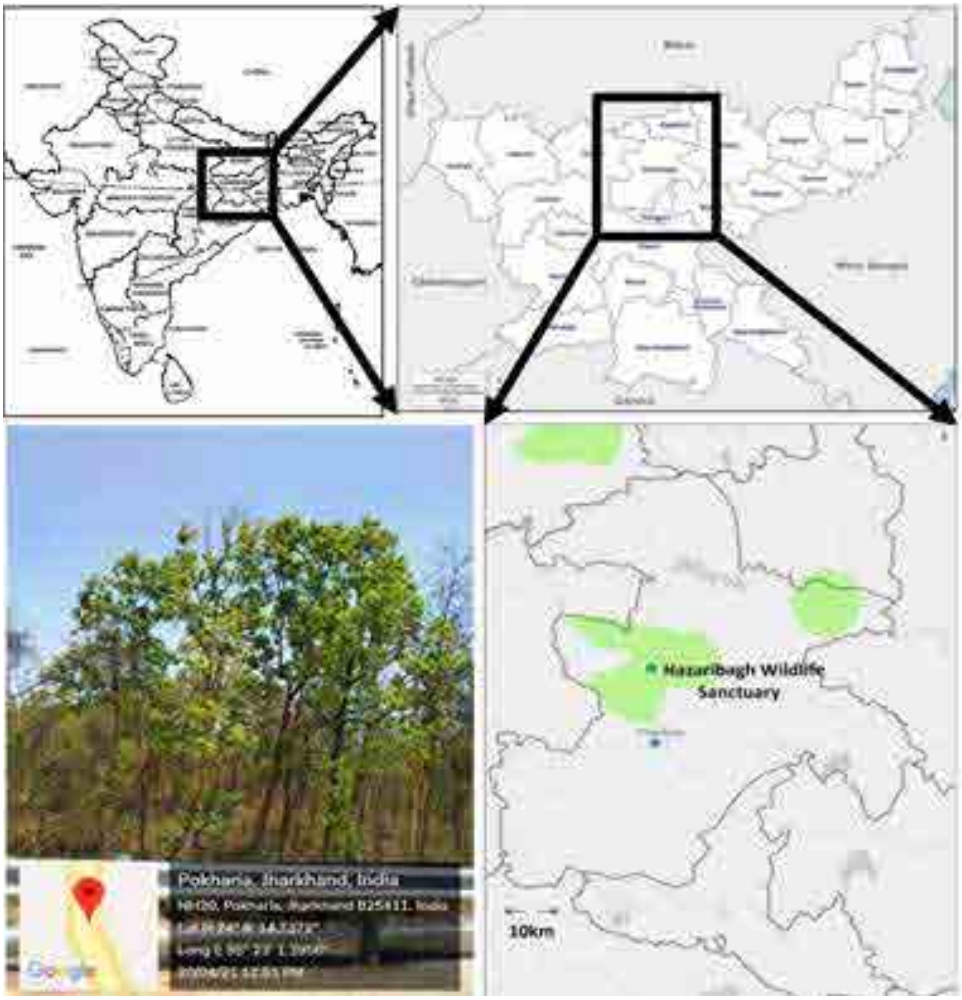

Image 1. Geographical location of Hazaribagh Wildlife Sanctuary, Hazaribagh, Jharkhand, India. The longitudes and latitudes are indicated in the lower left geo-tagged photograph, which also shows Sal trees, the dominant trees of Hazaribagh Wildlife Sanctuary.

TAXONOMIC NOTES ON THE MYRMECOMORPH

Myrmarachne melanocephala MacLeay, 1839 (Images 2A–D, 3 & 4A–E; supplementary video 1)

Myrmarachne melanocephala MacLeay, 1839: 11, pl. 1, fig. 4; Galiano, 1969: 146; Edwards & Benjamin, 2009: 5, figs. 1A–H, 2A–D, 3A–D, 4A–E, 5A–D; Yamasaki & Edwards, 2013: 15, figs. 46–58; Yamasaki & Ahmad, 2013: 541, figs. 32A–G, 33A–H, 34A–C; Benjamin, 2015: 17, figs. 17A–D, 18A–D, 19A–D; Caleb, 2016: 409, figs 20–30.

Further references may be read in World Spider Catalog (2021).

Materials examined (n=3). 1 preserved freshly moulted female specimen, 1 preserved complete whole-body exuviae of female, and 1 live male. Hazaribagh Wildlife Sanctuary (24° 8′ 14.7372″ N, 85° 23′ 1.3956″ E), Hazaribagh, Jharkhand, India, 20.iv.2021, R. Kumar & M. Sharma.

Diagnosis (following Yamasaki & Edwards 2013). Pedicel in both sexes as long as ALE-PLE. Males are further distinguished from other congeners by the shape and dentition of chelicerae. Females can be distinguished by abdominal markings and structure of epigyne (Yamasaki & Edwards 2013). For a complete diagnosis and description see Edwards & Benjamin (2009) and Benjamin (2015).

Female. Body legth 7.8; carapace length 2.25, width 1.5; abdomen length 3.4, width 1.66. Width of eye row I 1.11; II 1.1; III 1.2. Eye sizes and interdistances: AME 0.3, ALE 0.2, PME 0.05, PLE 0.2; ALE-PLE 0.8; ALE-PME 0.39. Leg spination: tibia I pv 4, rv 5; metatarsus I pv 2, rv 2; tibia II pv 3, rv 3; metatarsus II pv 2, rv 2. Pedicel 0.6 long. Cephalic region rugulose and dark brown to black, covered with white hairs; thoracic region reddish

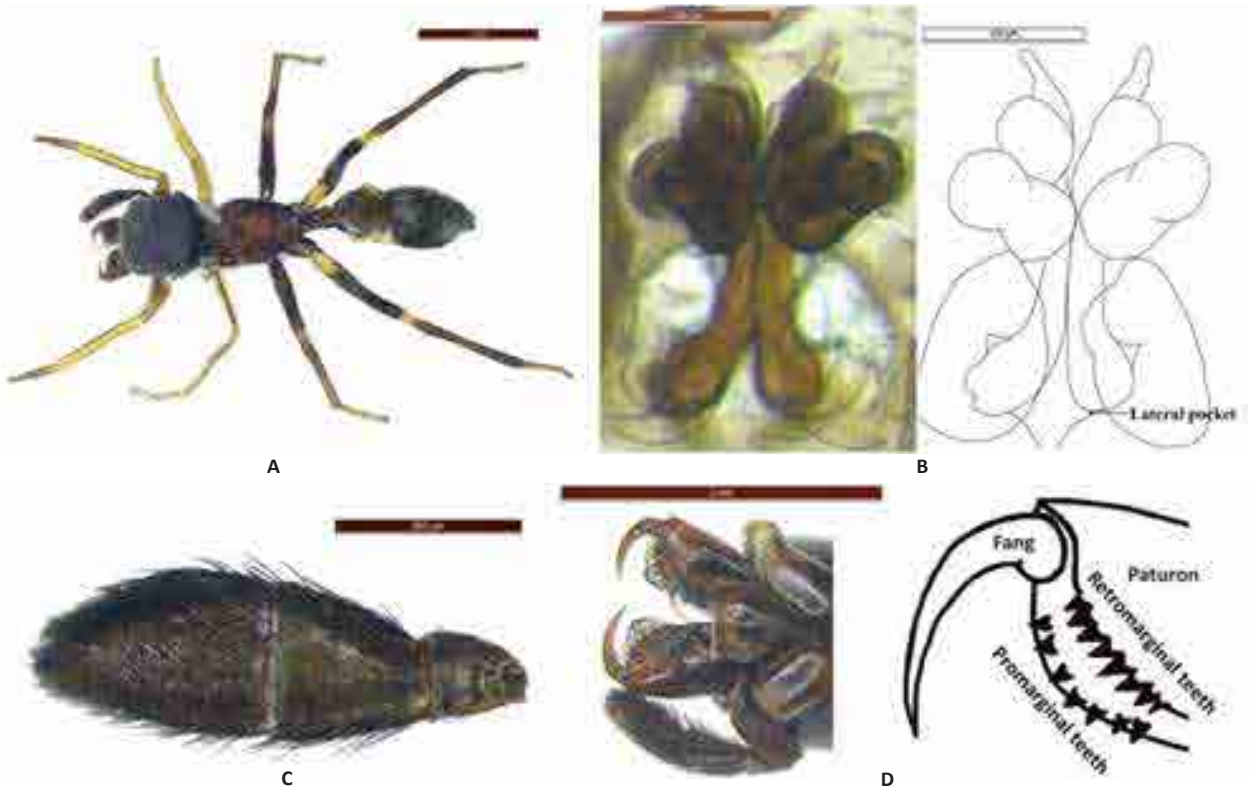

Image 2. *Myrmarachne melanocephala* MacLeay, 1839 (female): A—Habitus of preserved specimen, dorsal view | B—Epigyne, ventral view | C—Left palp, ventral view | D—Chelicerae and fangs, ventral view. Scale bars: A—2 mm | B—100 µm | C—500 µm | D—2 mm.

brown, sparsely covered with white hairs. Cephalic region slightly higher than thoracic region. Sternum brown. Chelicerae dark brown, geniculate with seven teeth on promargin and 8 teeth on retromargin (Image 2D). Legs I and II light yellow, coxae I brown, tarsi I light brown which gets darker near the tip, legs III, IV brown, trochanter and patella of leg IV yellowish, patella of leg III lighter in colour. Leg IV longest. Palp paddle shaped and fringed with preening setae (Image 2C). Abdomen elongate, and slightly constricted in the anterior third, covered with white hairs, almost oval (Image 2A). Epigyne with laterally oriented large oval copulatory atria; copulatory ducts twist to form butterfly shaped structure just before reaching ovoid spermatheca; lateral pockets present between artia just at the bases of copulatory ducts (Image 2B).

Exuviae of female: The undamaged whole body exuviae revealed morphological features of the female spider (Image 3). Exuviae contains imprints of the outer surface of spider's body. Abdominal markings (dark and lightly pigmented areas) are sharply revealed in the exuviae which is otherwise not clearly visible on the spider body. The inflated abdominal region displays the site of exit of the spider after moulting from its own exuviae. Locations of four pairs of limbs, limb markings, geniculate chelicerae, fangs, and paddle shaped pedipals are clearly visible.

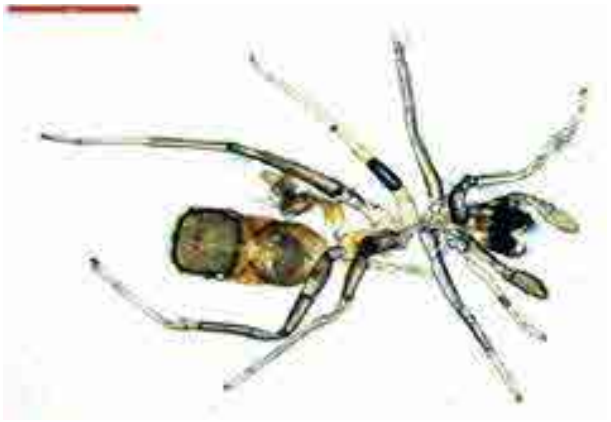

Image 3. *Myrmarachne melanocephala* MacLeay, 1839: female exuviae (whole mount). Scale bar: 2 mm.

Male: Body legth 7.5; carapace length 3, width 1.2; abdomen length 2.9, width 1.5; chelicerae 2. Pedicel 0.5 long. Legs I and II light brown but not yellow as in female, coxae and trochanters of legs I, II and III white, and tarsi I brown which gets darker near the tip, legs III

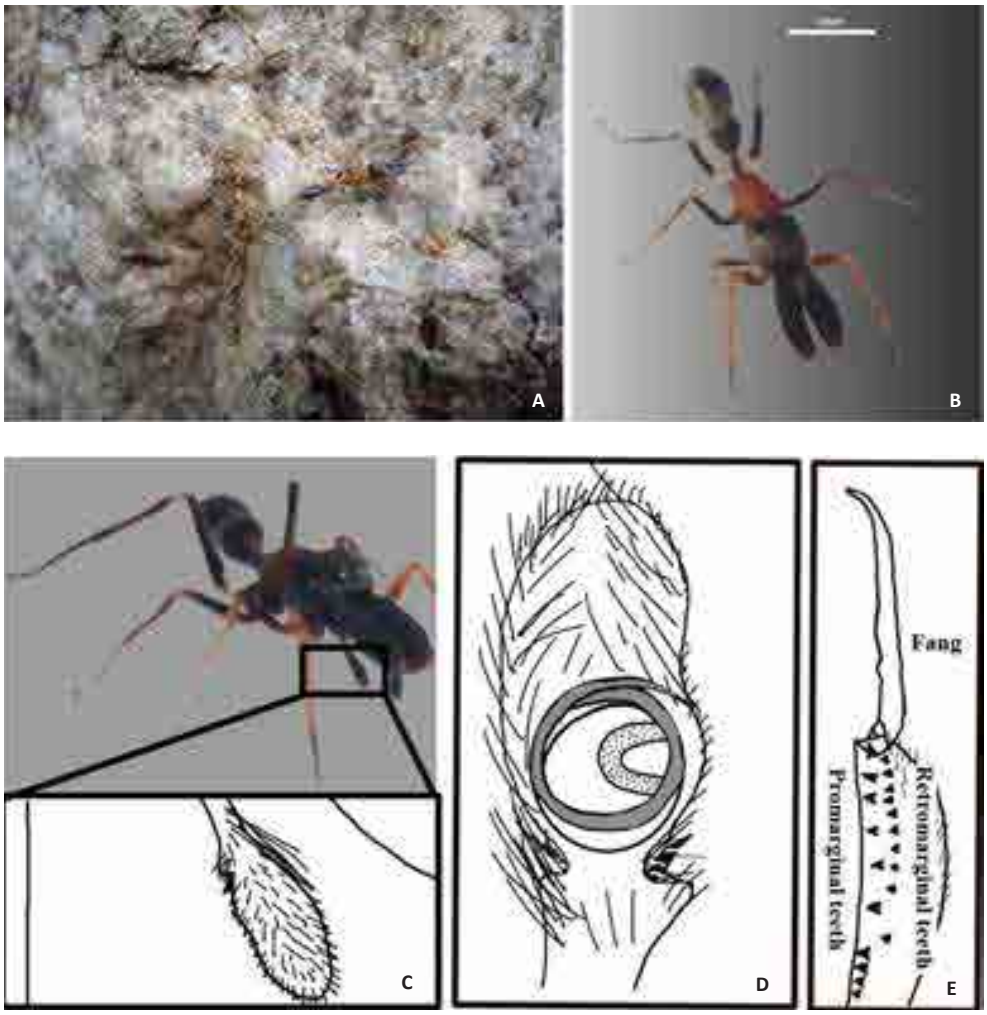

Image 4. ***Myrmarachne melanocephala*** **MacLeay, 1839 (male): A—Spider on a tree trunk | B—Habitus of a live spider, dorsal view | C—Right palp, dorsal view |D—Left palp, ventral view | E—Chelicera and fang, ventral view.**

and IV brown in colour, trochanter and patellae of leg IV white. Cephalic region rugulose and black; thoracic region reddish brown. Cephalic region slightly higher than thoracic region. Chelicerae black throughout except the region from where fangs arise which is reddish brown. Chelicerae porrect with 10 teeth each on prolateral and retrolateral margin (Images 4B, E; supplementary video 1). Sternum light brown. Abdomen elongate-oval, constricted in the anterior third. Palp with oval cymbium, round tegulum with distal-retrolateral C-shaped sperm duct, embolus with two coils, spiralled helix like retrolateral tibial apophysis with prominent flange (Images 4C, D).

Remarks: Exuviae has been used as a material for species description by some workers, and some have used it even as a holotype (Kranzfelder et al. 2017; Lin et al. 2017). We have used it here as additional material for morphological studies. We suggest that exuviae can also provide such useful information while describing a species which may not be clearly recognizable in the type or non-type material.

Biology: The spider specimens were spotted on a tree trunk at the Sal forest. Refer ecological notes on mimic-model coexistence in a subsequent section for other important details.

Distribution: Pakistan to Indonesia (Edwards & Benjamin 2009; World Spider Catalog 2021), the records from India include states of Tamil Nadu, West Bengal, Assam, Uttarakhand (Caleb 2016) and Jharkhand (present study) (Images 1 & 6).

TAXONOMIC NOTES ON THE ANT MODEL

Tetraponera rufonigra Jerdon, 1851
(Image 5A–D; supplementary video 2)

Tetraponera rufonigra Jerdon, 1851: 111; Smith, 1877: 68; Bingham, 1903: 108; Wheeler, 1922: 1015; Ward, 1990: 489; Ward, 2001: 649.

Further references may be read in Bolton (2021).

Materials examined (n= 6): 1 live solitary dealate gyne and 5 foraging live workers. Hazaribagh Wildlife Sanctuary (24°8'14.7372" N, 85°23'1.3956" E), Hazaribagh, Jharkhand, India, 20.iv.2021, R. Kumar & M. Sharma.

Diagnosis: (following Bolton 2021). Larger than other *Tetraponera* species. Bicoloured body. Head and gaster darker than mesosoma. In case of the examined specimen, head and gaster are black in contrast to the orange-brown mesosoma. The species is so distinctive that its identity has never been a matter of confusion or doubt. For a complete diagnosis and description see Ward (2001).

Dealate gyne: Large body (larger than other species of *Tetraponera*) with broad head, with small but conspicous crytalline glass like compound eyes and three ocelli. Head densely punctate but without clearly visible puncture interspaces. Clypeus with long and narrow median lobe. Bicoloued body, head and gaster dark in colour (dark brown to black) which contrast with the orange-brown mesosoma. Antennae, mandibles, tarsi and protibia light in colouration (light brown to yellowish-brown), matching with the colour of mesosoma to some extant (Image 5B). The studied specimen also shows the presence of a conspicuously wide semicircular band of highly pigmented (dark brown to black) wing rudiment which contrasts with the light orange background of the mesosoma which is characteristic feature of the dealate gyne (Image 5D).

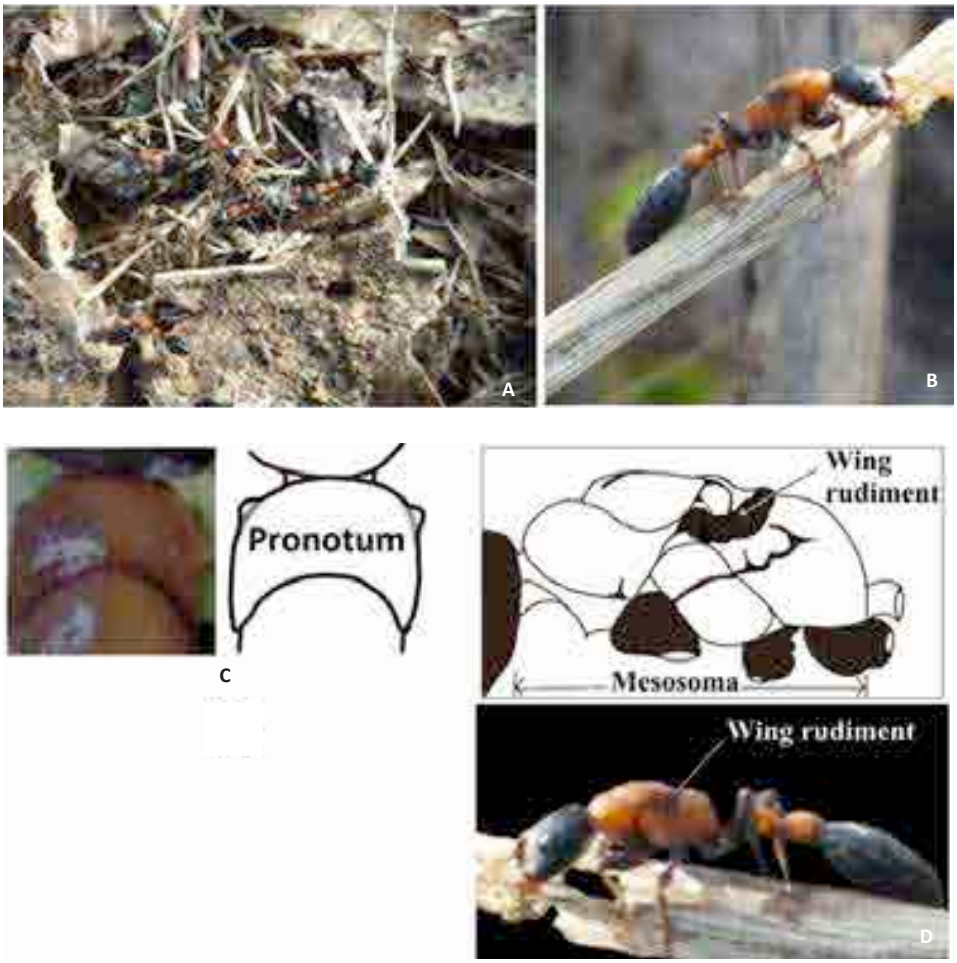

Image 5. *Tetraponera rufonigra* Jerdon, 1851 (workers and dealate gyne): A—Workers foraging on the forest floor | B—A dealate gyne cutting a twig on a tree branch | C—Magnified dorsal view of pronotum of a foraging worker | D—Lateral view of mesosoma displaying a wide dorsal semicircular band of highly pigmented (dark brown to black) wing rudiment (characteristic feature of a dealate gyne).

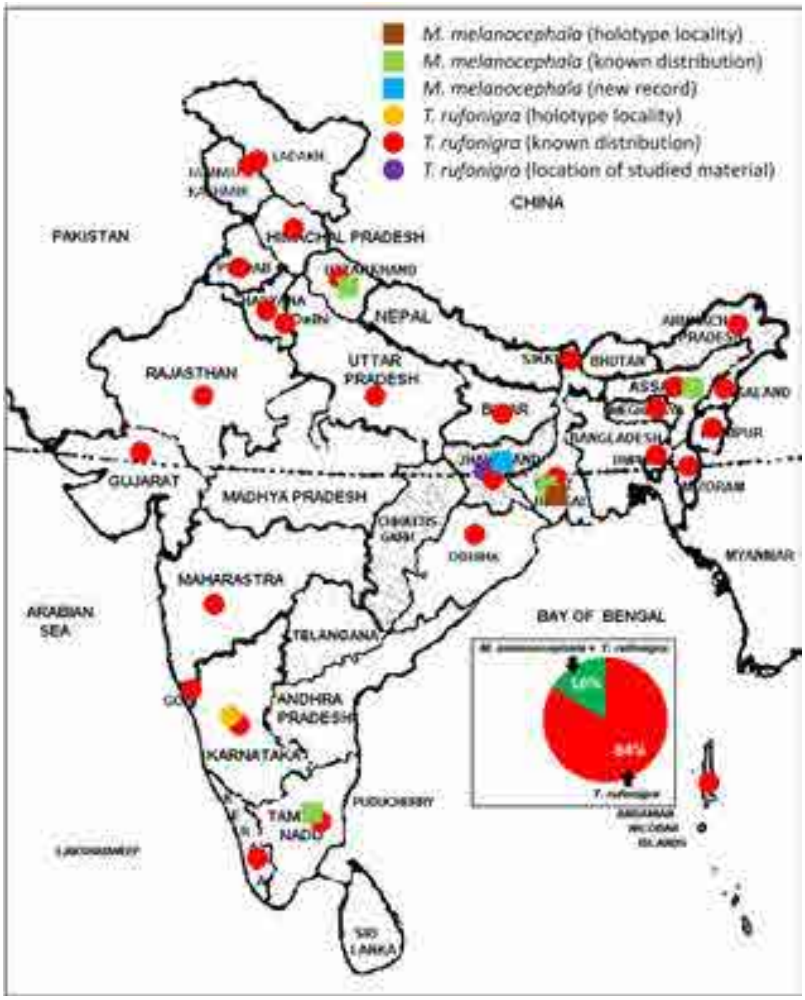

Image 6. State wise distribution of *Myrmarachne melanocephala* MacLeay, 1839 and *Tetraponera rufonigra* Jerdon, 1851 in India. Pie chart represents the percentage of distribution of *M. melanocephala* in India vis-à-vis distribution of *T. rufonigra*.

Worker: They display similar morphological features and colouration pattern like the dealate gyne except the wing rudiment which is absent in workers. Pronotum with well developed lateral margin and punctate humeral corners (Image 5C). Workers are smaller than the dealate gyne. Abdomen is more tapering in the workers compared to the more inflated abdomen of the dealate gyne (Image 5A).

Remarks: This ant is known to exhibit regional morphological variations. For example, the ants studied from some places in Sri Lanka are uniformly dark (mesosoma approaching colour of head and gaster) in comparison to the typical bicoloured ants like those found in India (head and gaster darker than mesosoma). As already reported by various workers, common morphological variations include variation in integument sculpture, colour of mesosoma, and pilosity (Ward 2001).

Biology: The ants were spotted on and around trees of the Sal forest. Refer ecological notes on mimic-model coexistence in a subsequent section for other important details.

Distribution: Pakistan to Indonesia including India (Ward 2001). Widely distributed in India; the records from India include Andaman & Nicobar Islands, Arunachal Pradesh, Assam, Bihar, Delhi, Goa, Gujarat, Haryana, Himachal Pradesh, Jammu & Kashmir, Ladakh, Jharkhand, Karnataka, Kerala, Maharashtra, Manipur, Meghalaya, Mizoram, Nagaland, Orissa, Punjab, Rajasthan, Sikkim, Tamil Nadu, Tripura, Uttar Pradesh, Uttarakhand, and West Bengal (Bharti et al. 2016) (Image 6).

DISCUSSION

Ecological notes on mimic-model co-existence

As an ideal myrmecomorph, *M. melanocephala* shares many morphological features with its ant model *T. rufonigra*. The most striking feature is its ant like bicolored body and size. Both share similar body colour pattern, body size and appearance. The female spider mimics the ant more efficiently than the male spider due to the absence of long chelicerae found in the male spider. The long pedicel of the spider mimics the whole petiolar and post-petiolar structure of ants due to its comparable length. The inflated elongate ovate abdomen of the spider and ant also appears similar in appearance. The limbs of the spider also display a lighter colouration pattern like that of the ant (Images 2A, 4A, B, 5A, B). Along with morphological resemblances, *Myrmarachne melanocephala* MacLeay, 1839 also exhibits some behavioural similarities to its ant model. In this regard, the first two pairs of legs are lighter in colour (yellowish in female) than the third and fourth pairs, and bear no stripes or markings in the spider (Image 2A). The spider waves its first pair of limbs in the air to mimic the long antennae (which is also yellowish) of the ant model occasionally. The spider also displays a zig-zag movement like the ant along with occasional salutatory movement typical of the jumping spiders (Supplementary video 1 & Supplementary video 2). Therefore, *M. melanocephala* perfectly imitates the gait and gestures of its ant model *T. rufonigra*.

Biogeographical implications of mimic-model co-discovery

Most myrmecomorphic spiders have been found to occupy spaces in close vicinity to their ant models (Pekar & Jarab 2011a). Such associations provide a space devoid of potential enemies as ants are mostly avoided by frequent predators who prey upon birds, wasps and spiders (Edmunds 1974). Association of myrmecomorphs with a particular ant species could be the result of either preference to ant dominated habitat or ant's prey preference (Pekár 2014). A large number of myrmecomorphic species go with the former strategy where they prefer to occupy ant dominated habitats and they capture prey other than ants. *M. melanocephala* fall under the same category (Edmunds 1978; Oliviera 1988; Pekár 2014; Pekár & Jarab 2011b). Apparent from their global distribution pattern, both *M. melanocephala* and *T. rufonigra* are adaptable to multiple climatic regions. The association between *M. melanocephala* and *T. rufonigra* was first observed by Pocock (1909). Global natural distribution of the ant model *T. rufonigra* completely overlaps with the reported distribution of its mimic *M. melanocephala* which means they follow a parallel biogeographical distribution pattern (Ward 2001; Yamasaki 2010). But if we look at India (which has the largest land area among the countries falling under the habitat range of the spider and the ant), we find that the myrmecomorph is confined to only five states (including the present study) as per available reports, whereas the ant model is widely distributed across Indian Territory (24 states including Jammu & Kashmir along with Ladakh and three other union territories) (Bharti & Akbar 2014; Caleb 2016) (Image 6). Therefore, in India *T. rufonigra* shows a continuous distribution pattern whereas *M. melanocephala* shows a highly discontinuous distribution pattern. This big difference in the distribution pattern may be attributed to the gap in studies pertaining to this spider in India. This is also true for many other spider species in India. The spider fauna of India has never been studied in entirety as noted by Keswani et al. (2012). This gap in study in turn may be attributed to a very small number of arachnologists in India. It can also be observed that all the states from which *M. melanocephala* has been reported also have reports of *T. rufonigra*. In the present study also, the spider mimic has been reported from the state where the ant model is already known to exist. Local extinction of *M. melanocephala* in other states where it coexisted with *T. rufonigra* in past or range expansion of *T. rufonigra* outside the states from where *M. melanocephala* have been reported may be speculated as a reason of such a sharp difference in their distribution pattern but it cannot be inferred with certainty because of the huge study gap and also due to high adaptive capabilities of these animals to multiple climatic regions, there is no apparent plausible reason to presume such extreme events in their natural history. Therefore, we suggest that *M. melanocephala* could also be present in other states from which the ant model has already been reported. *M. melanocephala* could have a wider distribution across different states of India vis-à-vis the distribution of the ant model *T. rufonigra*.

Supplementary Video 1. *Myrmarachne melanocephala* MacLeay, 1839. Live male.

Supplementary Video 2. *Tetraponera rufonigra* Jerdon, 1851. Live dealate gyne.

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Diversity of spiders (Arachnida: Araneae) and the impact of pruning in Indian sandalwood plantations from Karnataka, India

S. Padma [1] & R. Sundararaj [2]

[1,2] Forest Protection Division, Institute of Wood Science and Technology, 18th cross, Malleswaram, Bengaluru, Karnataka 560003, India.
[1] padma.rnd@gmail.com (corresponding author) [2] rsundariwst@gmail.com

Abstract: Indian sandalwood *Santalum album* L. plantations in Karnataka were surveyed to study the diversity and abundance of spider fauna. A total of 1,244 individuals belonging to 56 spider species in 40 genera under 14 families were recorded in the sandalwood plantations. Among the spider families recorded, Araneidae was the most dominant with 15 species in nine genera followed by Salticidae with 13 species in 10 genera, Thomisidae with seven species in four genera, Oxyopidae with four species in three genera, Uloboridae with four species in a genus, and Theridiidae by three species each under three genera. Lycosidae and Sparassidae are represented by two species under two genera each. The families Cheiracanthiidae, Clubionidae, Hersiliidae, Philodromidae, and Pholcidae are represented by a species each. The pruning of sandalwood revealed a significant negative effect on the occurrence and distribution of spiders.

Keywords: Ambushers, Araneidae, guild, Orb web, pruning, Salticidae, *Santalum album*, spider fauna, stalkers, Thomisidae, Uloboridae.

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Author details: Padma, S. is Research scholar in Forest Protection Division, Institute of Wood science and technology, Malleshwaram. Her research interest includes spider and insect ecology, pollination study, disease and pest management, seed germination and wildlife conservation. Dr. Sundararaj, R is working as Scientist-G and Head of Forest Protection division, Institute of wood science and technology, Bangalore. He has about 35 years of research experience in the field of protection of wood from bio-deterioration, forest entomology, integrated pest management with special reference to sandalwood and whitefly taxonomy.

Author contributions: SP—carried out the field survey, collection, identification of spiders, analysis of data and prepared the manuscript. RS—guided and assisted Ms. Padma, in every step like, designing and execution of the work and finalizing the manuscript.

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INTRODUCTION

Spiders are air-breathing carnivorous arthropods and are distributed ubiquitously in the globe except for Antarctica and have adapted to all known ecological environments except air and open sea (Foelix 1996). They are important ecological indicators, used to monitor warning signs for the environment at the earliest and as a biological control agent, since its assemblages have the ability to limit the population growth of arthropod pests and other natural enemies. Spiders are one of the known successful groups of natural predators occupying the agricultural ecosystems, and as efficient predators, they are able to suppress populations of major insect pests (Marc & Canard 1997). Therefore, relatively higher spider abundance has been considered a requirement for pest control in agricultural systems (Young & Edwards 1990; Carter & Rypstra 1995; Sunderland & Samu 2000).

Globally, spiders include about 49,368 described species in 4,215 genera under 129 families (World Spider Catalog 2021). In India, 1,875 species under 478 genera in 61 families are known (Caleb & Sankaran 2021). Considering the importance of spiders in integrated pest management strategy, the present study aimed to understand the spider diversity and distribution in sandalwood plantations of Karnataka and assess the impact of pruning of sandalwood in the distribution of spiders.

MATERIALS AND METHODS

Study area and sampling methods

An extensive survey was done in sandalwood plantations aged 2–6 years growing in different agro-forestry systems in Karnataka (Table 1, Figure 1) for a period of three years from June 2017–May 2020 and sampling was done between 0930 h to 1130 h. Active searching method of spiders was adopted and handpicked. Spiders were observed from each corner of the plant, from all the branches, flowers, fruits, and even from the ground. Spiders were photographed in their natural habitat and studied under a stereozoom microscope (Nikon SMZ 1500). The information of collection data such as place, date of collection, habitat, the colouration of spider and name of the collector were recorded. The specimens were preserved in vials with 70% ethyl alcohol and deposited in the Department of Entomology, IWST campus. Spiders were identified based on key morphological features provided by Tikader (1987), taxonomic articles available in the World Spider Catalog (2021), diagnostic drawings available in Metzner (2021), and with the help of taxonomic experts. Most of the adult spiders were identified to species level and others to genus level.

Impact of pruning on spider density

To assess the impact of pruning of sandalwood on the diversity and abundance of spiders, a study was undertaken in 2–3 years old plantations of both unpruned and pruned sandalwood during November 2019–January 2020 about 10 hectare in Kolar District, Karnataka. For this purpose, five 50 x 50 m blocks each in pruned and unpruned plantations were marked and from each block, spiders were collected from five trees at random. In unpruned trees, three different habitats (upper, middle, and lower canopies) tree stand were considered and three branches in each canopy were randomly selected for spider collection, the number of arboreal spiders in each tree was counted. In pruned trees, data was collected adopting the same methodology but only from the top canopy as the middle and the lower canopies were lost due to pruning. Three observations were taken at monthly intervals and the data analysed. From the data, comparison was

Table 1. List of Sandalwood plantation localities in Karnataka.

	District	Place/Village-Taluk	Latitude (N), Longitude (E)
1	Bangalore	Institute of wood science and technology, Malleshwaram	13.011361, 77.570444
		Environmental Management & Policy Research Institute, Doresanipalya	12.899250, 77.592222
2	Chikballapura	Bagepalli	13.803028, 77.804528
3	Chikkamagaluru	Bikkaemanae	13.260722, 75.764361
		Sevapura – Tarikere	13.703556, 75.824500
4	Chamarajanagar	Arepalya – Kollegal Taluk	12.083861, 77.102889
		Vadegere – Yelanduru Taluk	12.039444, 77.093667
		Chikkaluru – Kollegal Taluk	12.196972, 77.282778
5	Kollar	Agara – Yeldur Taluk	13.057528, 78.432389
		Kenchanahalli – Mulbagal Taluk	13.205889, 78.446194
		Mudiyanuru – Mulbagal Taluk	13.228306, 78.315972
6	Kopal	Kushtagi	15.759944, 76.196694
7	Tumkur	Timmanahalli – Chikkanayakanahalli Taluk	13.391167, 77.199611
		Bijavara – Madhugiri Taluk	13.677056, 77.236444

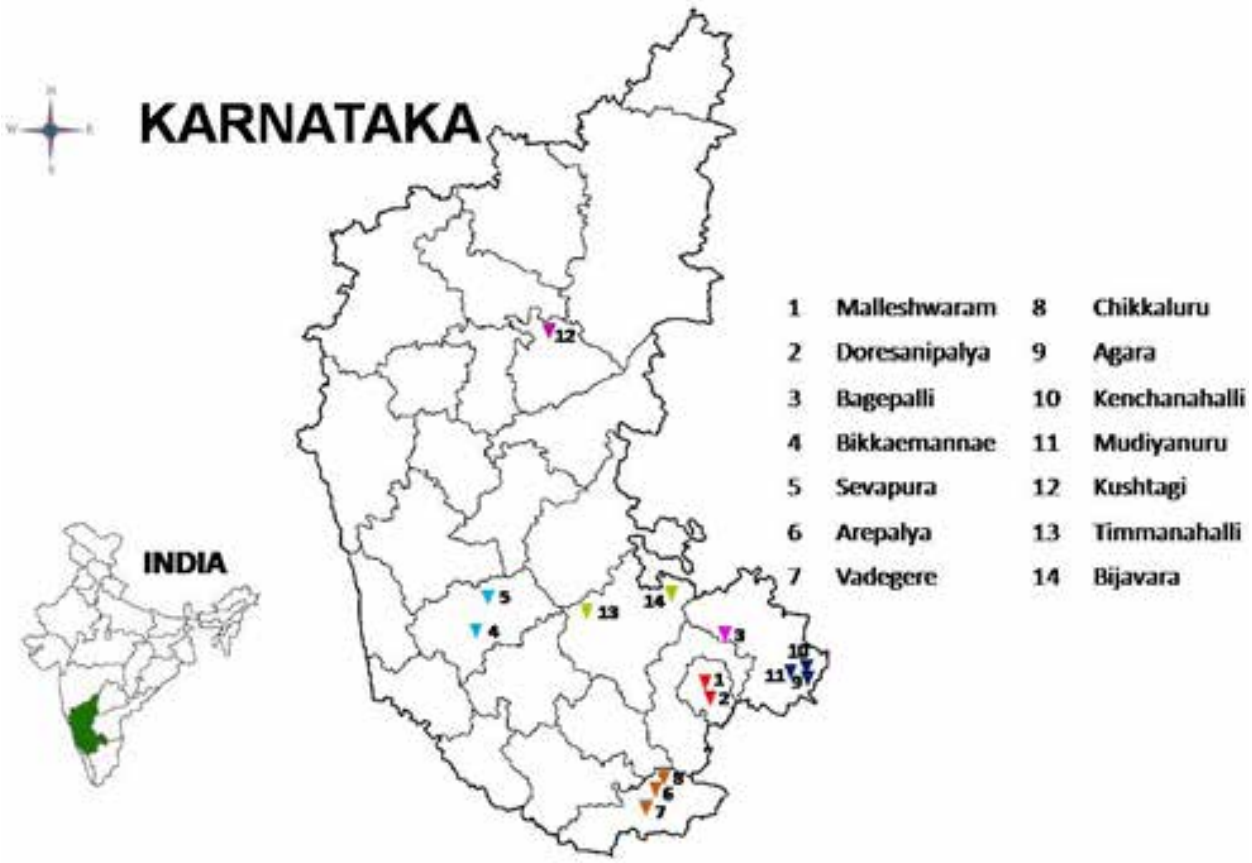

Figure 1. Map of Sandalwood plantations in Karnataka

made between the total spiders collected in unpruned and pruned plantations as well as between the spiders collected only from the top canopy of both the type of plantations by performing one-tailed ANOVA.

Guild classification

Depending upon the foraging strategies of spiders, they were categorised into eight different ecological guild structures namely, stalkers, ambushers, foliage runners, ground runners, sheet web-builders, tangle weavers, orb weavers, and space web-builders (Uetz et al 1999).

RESULTS

A total of 1,244 individuals of the 56 species of spiders in 40 genera under 14 families (Table 2) were collected and identified (Table 3) from the surveyed sandalwood plantations. Out of the 56 species (Figure 2), the family Araneidae (27%) is the most dominant in terms of species diversity with 15 species in nine genera followed by Salticidae (25%) with 13 species in 10 genera, Thomisidae (13%) with seven species in four genera, Oxyopidae (7%) with four species in three genera, and Uloboridae (7%) with four species in a single genus. Theridiidae (5%) is represented by three species under three genera and Lycosidae & Sparassidae (3%) with two species in two genera each. The families Cheiracanthiidae, Clubionidae, Hersiliidae Philodromidae, and Pholcidae (2%) are represented by a species each. In terms of the number of individuals collected, the dominant family was Salticidae with a collection of 366 individuals followed by Araneidae with 350 individuals. Among the species, *Telamonia dimidiata* was found to be more abundant with a total of 73 individuals followed by *Myrmaplata plataleoides*, *Menemerus bivittatus*, *Meotipa sahyadri*, and *Thomisus andamanensis*.

The spiders inhabiting the sandalwood plantation fall under eight ecological guilds based on their foraging mode (Figure 3). The majority of the observed spider families belong to 'orb-weavers' category with 36% dominance, followed by stalkers (30%), ambushers

Table 2. Diversity and abundance of spiders in sandalwood plantations.

	Families	Genus	Species	Individuals
1	Araneidae	9	15	350
2	Cheiracanthiidae	1	1	17
3	Clubionidae	1	1	15
4	Hersiliidae	1	1	17
5	Lycosidae	2	2	44
6	Oxyopidae	2	4	57
7	Philodromidae	1	1	13
8	Pholcidae	1	1	12
9	Salticidae	11	13	366
10	Sparassidae	1	1	37
11	Tetragnathidae	1	1	16
12	Theridiidae	2	3	78
13	Thomisidae	5	8	161
14	Uloboridae	1	4	74

Figure 3. Guilds of spiders from sandalwood plantations.

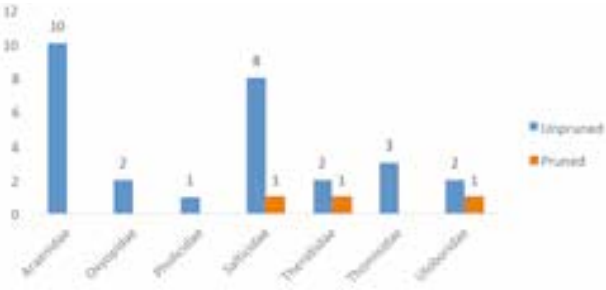

Figure 4. Comparison of spider density (or abundance) in unpruned and pruned plantations of sandalwood.

(12%), foliage runners (11%), tangled web (5%), and 2% each by ground dwellers, funnel web builders, and space web building spiders.

In the observations from around 10 hectare, unpruned

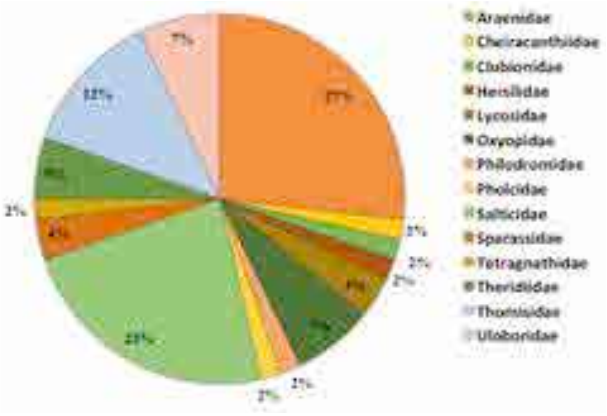

Figure 2. Details of spider families found in sandalwood plantations.

(Image 43) and pruned (Image 44) sandalwood, a total of 149 individuals belonging to 28 species under seven families and 11 individuals belonging to three species under three families were recorded, respectively. The number of spiders collected in unpruned sandalwood trees from upper, middle, and lower were 45 individuals in 11 species, 63 individuals in 21 species, and 44 individuals in 11 species, respectively. In the pruned sandalwood trees, the lower and the middle canopy was lost due to pruning and the number of spiders collected from upper canopy was only 17 individuals of three species (Figure 4). The one-way ANOVA result showed a significant difference in the overall level of diversity and abundance of spiders in pruned and unpruned sandalwood trees, F (1, 28)= 171.61, p <0.001. Also, a significant difference was seen in the upper canopy of unpruned and pruned sandalwood, F (1, 28)= 12.55, p= 0.0014. Thus, the above result indicates that the interaction of vertical branches and denser vegetation was significant and affected the composition and abundance of spiders.

DISCUSSION

The present survey is preliminary and the first dealing with spider diversity in sandalwood-based agroforestry ecosystems. Caleb & Sankaran (2021) reported 1,875 species under 478 genera in 61 families in India out of which 56 species in 40 genera under 14 families were found breeding in sandalwood plantations. This represents 2.986% and 21.95% of the total species and families, respectively, recorded in India. The number of families recorded is as high as in other biomes of India. Sandeep et al. (2020) reported 43 species of spiders under 23 families from 21 different fruit crops in Punjab. The

Table 3. Checklist of spiders in sandalwood plantations.

Family		Species
Araneidae	1	*Arachnura melanura* Simon, 1867 (Image 1)
	2	*Araneus mitificus* (Simon, 1886) (Image 2)
	3	*Araneus* sp.
	4	*Argiope anasuja* Thorell, 1887 (Image 3)
	5	*Argiope pulchella* Thorell, 1881 (Image 4)
	6	*Cyclosa insulana* (Costa, 1834) (Image 5)
	7	*Cyrtophora cicatrosa* (Stoliczka, 1869) (Image 6)
	8	*Cyrtophora citricola* (Forsskȧl, 1775) (Image 7)
	9	*Eriovixia laglaizei* (Simon, 1877) (Image 8)
	10	*Gasteracantha geminata* (Fabricius, 1798) (Image 9)
	11	*Neoscona bengalensis* Tikader & Bal, 1981 (Image 10)
	12	*Neoscona mukerjei* Tikader, 1980 (Image 11)
	13	*Neoscona nautica* (L.Koch, 1875)
	14	*Neoscona punctigera* (Doleschall, 857) (Image 12)
	15	*Nephila pilipes* (Fabricius, 1793) (Image 13)
Cheiracanthiidae	16	*Cheiracanthium* sp. (Image 14)
Clubionidae	17	*Clubiona* sp.
Hersiliidae	18	*Hersilia savignyi* Lucas, 1836 (Image 15)
Lycosidae	19	*Hippasa agelenoides* (Simon, 1884) (Image 16)
	20	*Pardosa peudoanulata* (Bösenberg & Strand, 1906) (Image 17)
Oxyopidae	21	*Hamadruas* sp. (Image 18)
	22	*Oxyopes javanus* Thorell, 1887
	23	*Oxyopes* sp. (Image 19)
	24	*Peucetia viridana* (Stoliczka, 1869) (Image 20)
Philodromidae	25	*Thanatus* sp.
Pholcidae	26	*Crossopriza lyoni* (Blackwall, 1867)
Salticidae	27	*Brettus cingulatus* Thorell, 1895 (Image 21)
	28	*Carrhotus viduus* C.L. Koch, 1846
	29	*Epeus indicus* Prószyński, 1992 (Image 22)
	30	*Hasarius adansoni* (Audouin, 1826)
	31	*Hyllus semicupreus* (Simon, 1885) (Image 23)
	32	*Menemerus bivittatus* (Dufour, 1831)
	33	*Myrmaplata plataleoides* (O.P. Cambridge, 1869) (Image 24)
	34	*Plexippus petersi* (Karsch, 1878)
	35	*Plexippus paykulli* (Audouin, 1826) (Image 25)
	36	*Rhene flavicomans* Simon, 1902 (Image 26)
	37	*Rhene flavigera* (C.L. Koch, 1846) (Image 27)
	38	*Rhene* sp.
	39	*Telamonia dimidiata* (Simon, 1899) (Image 28)
Sparassidae	40	*Heteropoda venatoria* (Linnaeus, 1767) (Image 29)
	41	*Olios milletti* (Pocock, 1901) (Image 30)
Tetragnathidae	42	*Opadometa fastigata* (Simon, 1877) (Image 31)
Theridiidae	43	*Meotipa sahyadri* Kulkarni, Vartak, Deshpande & Halali, 2017 (Image 32)
	44	*Nihonhimea mundula* (L.Koch, 1872) (Image 33)
	45	*Parasteatoda* sp.
Thomisidae	46	*Loxobates* sp. (Image 34)
	47	*Misumena* sp. (Image 35)
	48	*Thomisus andamanensis* Tikader, 1980 (Image 36)
	49	*Thomisus bulani* Tikader, 1960
	50	*Thomisus lobosus* Tikader, 1965 (Image 37)
	51	*Thomisus projectus* Tikader, 1960 (Image 38)
	52	*Tmarus* sp.
Uloboridae	53	*Uloborus* sp. 1 (Image 39)
	54	*Uloborus* sp. 2 (Image 40)
	55	*Uloborus* sp. 3 (Image 41)
	56	*Uloborus* sp. 4 (Image 42)

difference in spider fauna can be related to different time frames and methods of collection. Even environmental factors like the type of vegetation, seasonality, spatial heterogeneity, predation, prey occurrence etc. can affect species diversity (Riechert & Bishop 1990) and spiders are extremely sensitive to small changes in the habitat structure, complexity, and microclimate characteristics. Their abundance and distribution may vary from one geographic area to another (Downie et al. 1999). Spiders are polyphagous, feed on a variety of available prey even on the egg, larva/nymph, as well as adult stages of insects (Sandeep et al. 2020). Predatory spiders found breeding in the sandalwood-based agroforestry ecosystems serve as a source of successive predation against pests of sandalwood.

Most spiders exhibit excellent colouration and protective camouflage. The ant mimicking spider *M. plataleoides* and *Hersilia savignyi* resemble the bark of trees. Thomisid spiders commonly called ambushers which are "sit and wait" type of prey hunting spiders, sit on the flowers and have attractive colouration similar to the flower in which they hide. In contrast to this *Hippasa agelenoides* construct funnels/tunnels? in ground strata, hide at the small end and rush out and grab the prey (Pooja et al. 2019). Further, the difference in spider fauna is based on the vertical segregation of the foraging heights. Some spiders might prefer living in the uppermost parts of the plant, like *Nephila pilipes* and *Gasteracantha geminata*, while a few spiders like *Pardosa pseudoannulata* and *H. agelenoides* are usually found on the ground.

Arboreal spider assemblages assessed by the abundance-based measure showed a significant difference between unpruned and pruned sandalwood. Even the upper canopy inhabiting spiders were significantly less in pruned than unpruned sandalwood; this might be due to non-availability of nutritional resources and required breeding resources in the pruned trees. Pruning of sandalwood was found to have adverse effects on the diversity and abundance of spiders. Unpruned sandalwood is not only healthy, the lateral branches support erectness of the main stem and protect the tree from adverse conditions like high winds, rainstorms, and intense sunlight. It also supports the survival and existence of diverse living organisms including spiders. The presence of lateral branches increase the probability of dispersal of spiders by ballooning; also the canopy provides a conducive environment to hide from its own predators and in successful predation on prey. Pruned plants devoid of lower lateral branches having flatter branches with shorter vertical spread might increase the exposure of spiders to visually foraging predators (e.g., birds), it also narrows their habitat and the availability of natural food resources by decreasing the occurrence of prey, thus it negatively correlated with spider densities. In a given habitat, the biomass of vegetation and prey availability were the best predictions of spider abundance (Halaj et al. 1998). Rypstra (1986) documented a strong positive relationship between the diversity of web-building spiders and vegetation structural diversity across several habitats. It corroborated the dominance of orb-weaving spiders in unpruned sandalwood and enlightens the importance of branches and the natural growth of sandalwood for the occurrence of web-building spiders. Web-building spiders are stationary predators that wait for prey to approach near them. Their abundance is directly related to the physical architecture of the vegetation (Greenstone 1984). The chance of their occurrence in pruned trees is almost eliminated except fora few species of Uloboridae with a fewer number of individuals. Also, the pruned trees are susceptible to harsh wind effects and rainstorms, making them unsuitable for web-building spiders. Similarly, the occurrence of stalkers the second dominant guild, which actively jump over the prey for feeding, is directly related to the prey availability and shaded environment which hides them from other larger predators (Pooja et al. 2019). This is applicable to the rest of the spiders and their abundance. Many earlier studies confirmed that the diversity and complexity of the vegetation positively affects the abundance of spiders (Sudhikumar et al. 2005; Orguri et al. 2014; Ossamy et al. 2016).

Sundararaj et al. (2018) documented more species of insect pests and natural enemies from more diversified areas of sandalwood cultivation but with less severity of the infestations and not having requirement of the insecticidal application. Also, the plant diversity regulates insect herbivore populations by favouring the abundance and efficacy of associated natural enemies (Altieri & Letourneau 1984). Due to the pruning of sandalwood trees, the mobile ecosystem service providers like pollinators do not get a conducive environment for making their colonies and in combination with extensive applications of agrochemicals have a negative effect on the foraging ability and lifespan of pollinators and their resilience which leads to a colossal loss of pollination and apiculture (Sundararaj et al. 2020). Agroforestry practices enhance habitat diversification, increase soil productivity, support native fauna in agricultural landscapes and more resilience towards pests (Torres et al. 2015). The presence of fringe areas

Image 1. *Arachnura melanura*

Image 2. *Araneus mitificus*

Image 3. *Argiope anasuja*

Image 4. *Argiope pulchella*

Image 5. *Cyclosa insulana*

Image 6. *Cyrtophora cicatrosa*

Image 7. *Cyrtophora citricola*

Image 8. *Eriovixia laglaizei*

Image 9. *Gasteracantha geminata*

Image 10. *Neoscona bengalensis*

Image 11. *Neoscona mukerjei*

Image 12. *Neoscona punctigera*

Image 13. *Nephila pilipes*

Image 14. *Cheiracanthium* sp.

Image 15. *Hersilia savignyi*

Image 16. *Hippasa agelenoides*

Image 17. *Pardosa pseudoannulata*

Image 18. *Hamadruas* sp.

Image 19. *Oxyopes* sp.

Image 20. *Peucetia viridana*

Image 21. *Brettus cingulatus*

Image 22. *Epeus indicus*

Image 23. *Hyllus semicupreus*

Image 24. *Myrmaplata plataleoides*

Image 25. *Plexippus paykulli*

Image 26. *Rhene flavicomans*

Image 27. *Rhene flavigera*

Image 28. *Telamonia dimidiata*

Image 29. *Heteropoda venatoria*

Image 30. *Olios milleti*

Image 31. *Opadometa fastigata*

Image 32. *Meotipa sahyadri*

Image 33. *Nihonhimea mundula*

Image 34. *Loxobates* sp.

Image 35. *Misumena* sp.

Image 36. *Thomisus andamanensis*

Image 37. *Thomisus lobosus*

Image 38. *Thomisus projectus*

Image 39. *Uloborus* sp. 1

Image 40. *Uloborus* sp. 2

Image 41. *Uloborus* sp. 3

Image 42. *Uloborus* sp. 4

of natural undisturbed vegetation is probably crucial in the maintenance of such a healthy predatory complex (Lalnunsangi et al. 2014). Sundararaj et al. (2019) commented that the increase in incidence of stem borer is of great concern as it causes very extensive and serious damage in perennial trees like sandalwood. Once they are infested with stem borer, it paves way for the infestation of decay fungi and such infestation is carried throughout the life of sandalwood, resulting in more than one third loss of heartwood. Similarly, the wound caused by the pruning will serve as the entry point of decay fungi and other bio-deteriorating agents leading to colossal damage of wood in the standing trees. Many other reports also corroborate the concept of habitat diversification, heterogeneity, and un-pruning of plants for the balanced co-existence of pests and their natural enemies thus regulating the adverse effects of pests on the plantations (Scheidler 1990; Coddington & Levi 1991; Whitmore et al. 2002; Tews et al. 2004; Buchholz & Schroder 2013; Sattler et al. 2021).

CONCLUSION

Sandalwood plantations support diversity of spider fauna and they play an active role in regulating the population of phytophagous insects. The pruning of sandalwood shows an adverse effect on the diversity and abundance of spiders. Hence it is recommended not to do pruning or do the pruning only in unavoidable situations. This will increases the habitat and nutritional resources of natural enemies like spiders and facilitate to keep pest populations under control.

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Image 43. Unpruned Sandalwood tree.

Image 44. Pruned Sandalwood tree.

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COMMUNICATION

New records of cheilostome Bryozoa from the eastern coast of India encrusting on the exoskeleton of live horseshoe crabs of Indian Sundarbans

Swati Das [1], Maria Susan Sanjay [2], Basudev Tripathy [3], C. Venkatraman [4] & K.A. Subramanian [5]

[1–4] Zoological Survey of India, M- Block, New Alipore, Kolkata, West Bengal 700053, India.
[1,2] Department of Zoology, University of Madras, Chennai, Tamil Nadu 600025, India.
[5] Zoological Survey of India, Southern Regional Centre, 130, Santhome High Road, Chennai, Tamil Nadu 600028, India.
[1] swtds4788@gmail.com (corresponding author), [2] mariasanjay257@gmail.com, [3] tripathyb@gmail.com, [4] cvramanmbs@gmail.com, [5] subbuka.zsi@gmail.com

Abstract: Bryozoans are common commensal on hard surfaces and cover slow-moving animals like molluscans, sea turtles, brachyuran crabs, and horseshoe crabs. A total of six species of bryozoans belonging to four genus under three families of order Cheilostomatida were recorded encrusting on the carapaces of horseshoe crabs collected from Indian Sundarbans along the east coast of India and two among them, viz., *Biflustra savartii* (Audouin, 1826) and *Sinoflustra arabianensis* (Menon & Nair, 1975) are reported for the first time. Additionally, *Jellyella tuberculata* (Bosc, 1802) is reported for the first time from West Bengal coastal waters, previously known only from the Odisha coast of India. Both male and female horseshoe crabs were found to have been encrusted with bryozoan mats, although adequately not known about the life stages of their encrustation.

Keywords: Bryozoa, *Carcinoscorpius rotundicauda*, East coast, Epibionts, Indian Sundarbans, *Tachypleus gigas,* Xiphosura.

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Author details: Swati Das is currently working as a research fellow and pursuing her PhD from Madras University, Chennai. Her research topic is on the ecology of Indian Horseshoe Crabs. Her research interests include ornithology, herpetology, wildlife biology, conservation biology, and wildlife photography. Maria Susan Sanjay is a research fellow working on taxonomy of marine bryozoans and also has research interest in ecological conservation and environmental studies. Dr. Basudev Tripathy is a senior scientist having more than 20 years of research experience in zoological research, especially on marine biology and wildlife conservation. He has published more than 100 peer reviewed scientific papers and books as well as book chapters. He has research projects both on the east and west coast of India. Dr. C. Venkatraman is a senior scientist who conducts regular field surveys in coastal habitats of eastern and western coasts of India. He is also an expert in mammals and birds in different habitats. Dr. K.A. Subramanian specializes in aquatic insect diversity and freshwater biodiversity conservation.

Author contributions: SD, BT and KAS designed the survey, SD conducted field survey and collected specimens, MSS examined and identified the specimens, SD and MSS compiled the information, illustration, and prepared the first draft of the manuscript, KAS and BT did manuscript correction, and all authors contributed to drafting the manuscript.

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INTRODUCTION

Bryozoa is considered a minor phylum placed in between phylum Mollusca and Echinodermata and are ancient, microscopic, sessile, and colonial coelomates inhabiting both marine & freshwater ecosystem (Soja 2006). They can erect or encrust on all types of hard, permanent or ephemeral substrates (Canu & Bassler 1920; Harmer 1926; Osburn 1940; Cook 1968; Ziko & Hamza 1987; Xi-Xing 1992; Key et al. 1996). Although mostly found in the littoral zone, bryozoans have been reported up to 6,000 m depth in the marine realm. Studies on the Indian bryozoan fauna are scarce except for some notable documentation by Annandale (1912) and Thornely (1907, 1916), and after that by Menon (1967), Menon & Nair (1967), Nair (1973), Pillai (1978, 1981), Raveendran et al. (1990), Swami & Karande (1987, 1994), Geetha (1994), Swami & Udayakumar (2010), Soja (2006), Mankeshwar et al. (2015), Tripathy et al. (2016), and Venkatraman et al. (2018). However, very few scientific publications are available on the bryozoan fauna of the east coast of India (Robertson 1921; Shrinivaasu et al. 2015).

The horseshoe crabs are marine chelicerates that migrate to nearshore waters during lunar cycles for spawning. Represented by only four extant species within Xiphosura, two species of horseshoe crabs, *Tachypleus gigas* (Müller, 1785) and *Carcinoscorpius rotundicauda* (Latreille, 1802) are known to occur along the upper east coast of India, co-occurring mainly along the West Bengal and Odisha Coast (Annandale 1909; Roonwal 1944; Debnath 1992; Tripathy et al. 2018). *C. rotundicauda* is the most abundant of the two species in Indian Sundarbans (Saha 1989; Debnath 1992; Tripathy et al. 2018). Xiphosurans serve as host species for a variety of organisms, viz., bryozoans, barnacles, oysters, tunicates, coelenterates, flatworms, annelids, isopods, diatoms, amphipods, gastropods, polychaetes, and green algae (Humm & Wharton 1942; Roonwal 1944; Rao & Rao 1972; Davis & Fried 1977; Mackenzie 1979; Shuster 1982; Jeffries et al. 1989; Saha 1989; Debnath 1992; Key et al. 1996). However, *T. gigas* and *C. rotundicauda* are found mainly infested by bryozoans, barnacles, mussels, oysters, limpets, and polychaetes (Botton 2009). There are scanty records on the epizoic bryozoans reported from exoskeleton of horseshoe crabs. Notable works have been carried out by Pearse (1947), Butler & Cuffey (1991), Allee (1922), Watts (1957), and Key et al. (1996). In India, Rao & Rao (1972), Debnath (1992) and Patil & Anil (2000) reported an unidentified species of *Membranipora* as epizoic bryozoa on both *T. gigas* and *C. rotundicauda*. As such, studies on biological studies on horseshoe crabs are limited and commensalism, symbiosis and parasitism on horseshoe crabs, are scantily known from India. The present work attempted documentation of bryozoan species encrusting on the carapaces of horseshoe crabs for the first time from India.

MATERIALS AND METHODS

Study area

Field surveys have been conducted in the Sagar Island and Patiboni areas of the Indian Sundarbans. The Sagar Island (21.791°N, 88.131°E) is situated at the western part of Indian Sundarbans and is the largest island of the Sundarban deltaic complex (Figure 1). Hoogly river borders north and west with Muriganga River in the east and Bay of Bengal in the south. It is a tidal dominated island and characterized by tidal creeks, mud flats/salt marshes, mangroves and sandy beaches/dunes. The Patiboni in Frezerganj (21.578°N, 88.246°E) is well known for its fishing activities, located eastward to the Sagar Island and having a more sandy substrate at the intertidal zones (Figure 1). The estuarine area of the Sagar Island (Tripathy et al. 2018) and Patiboni area of Frezerganj are considered as potential habitats for both species of horseshoe crabs.

Methods

The present study was conducted from March to December 2019 as part of the first authors doctoral research. Sampling was done during the end of high tide and the beginning of low tide, keeping a gap of two hours during the full moon/new moon period to avail the maximum exposed intertidal zone. *C. rotundicauda* and *T. gigas* were observed carefully on the mudflats and wherever encountered on horseshoe crabs, the bryozoan colonies were scraped off from the exoskeleton (Cephalothorax, telson, appendages, gills, and eyes) using a scalpel blade (Tan et al. 2011). The bryozoan specimens were preserved using 70% ethanol in a glass/plastic container and labelled properly in the field itself. The specimens were brought to the base camp and washed thoroughly with freshwater for automatic removal of any debris. In the base camp laboratory, collected bryozoan specimens were soaked with sodium hypochlorite (0.5%) for eight hours to remove the organic tissue and later soaked in distilled water for four hours (Shrinivaasu et al. 2015) and then dried for identification and thereafter photographed with Nikon

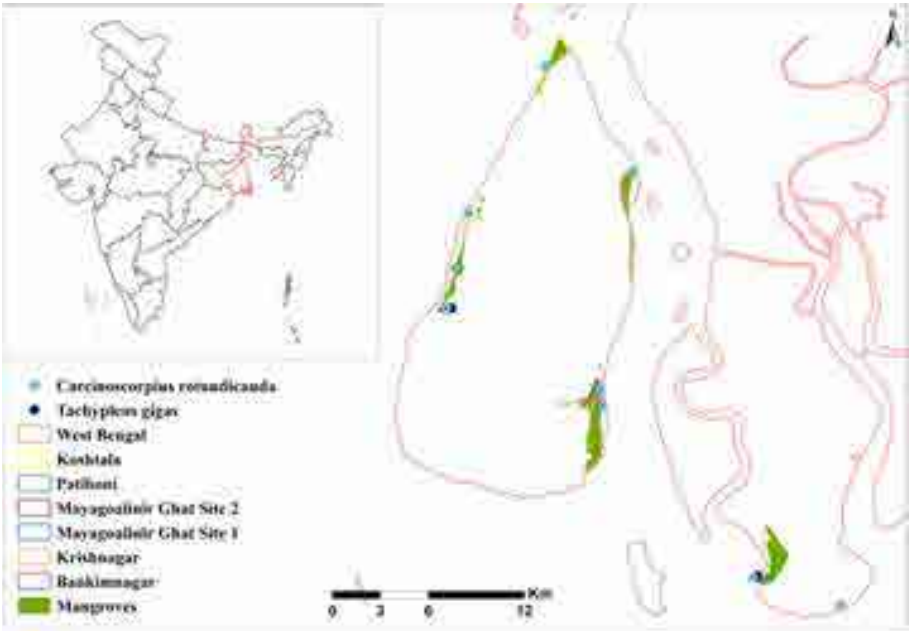

Figure 1. Study area map showing sampling sites of horseshoe crabs.

D7000 with 105 mm VR lens, post-processing with Adobe Photoshop CS6. The specimen was brought to ZSI HQ, Kolkata, for comparing with other museum specimens of the same families and genus, present in the Zoological Survey of India, which is part of the National Zoological Collections. In the field, fouled horseshoe crabs were counted, sexed and measured. After data collection and sampling of bryozoan specimens, horseshoe crabs were released back to the sea. The bryozoan colonies were observed under a stereomicroscope (Leica EZ4), for which the identified colonies were given a gold-palladium coating under vacuum condition and scanning electron micrographs were prepared with a Zeiss Evo 18 special edition SEM, using the "Smart SEM version 5.09" image processing software.

RESULTS

A total of 58 *Carcinoscorpius rotundicauda* (Image 2) and six *Tachypleus gigas* were observed for bryozoan encrustation examination during the study period. Out of 58, 11 *C. rotundicauda* (six male and five female) and five *T. gigas* (four male and one female) were found encrusted with bryozoan mat. A total of six bryozoan species belonging to five genera under three families of order Cheilostomatida were documented encrusting on the exoskeleton of horseshoe crabs from the Indian Sundarbans. The study further confirmed the presence of two bryozoan species, viz., *Biflustra savartii* (Audouin, 1826) and *Sinoflustra arabianensis* (Menon & Nair, 1975), on the carapaces of horseshoe crabs, reported to be recorded for the first time from the Bay of Bengal, previously known from the Arabian sea (Menon & Menon 2006). *Jellyella tuberculata* (Bosc, 1802), previously known only from the Odisha coast of India (Menon & Menon 2006), was reported for the first time from the West Bengal coast during this study.

Systematic Account

Kingdom: Animalia
Phylum: Bryozoa
Class: Gymnolaemata
Order: Cheilostomatida
Suborder: Membraniporina
Superfamily: Membraniporoidea
Family: Membraniporidae
Genus *Biflustra* d'Orbigny, 1852

1. *Biflustra savartii* (Audouin, 1826)

Image 1A

Location: Bankimnagar, Sagar Island, Sundarbans

Substratum: Encrusted on prosoma of *Carcinoscorpius rotundicauda* (A female without telson).

Description: Colony encrusting, forming a unilaminar sheet on the substratum arranged in longitudinal rows. Zooids sub-rectangular or sub-hexogonal, curved and raised distally and angular at the two proximal corners, separated by a raised ridge with a distinct mural rim.

Opesia occupying most of the frontal area, deep and oval, slightly smaller than the frontal membrane, nearly occupying two-thirds of the frontal area.

Distribution: It is a very common species worldwide in the tropical and sub-tropical seas reported from Indonesia and all along the Pacific coast. Earlier, it was reported from Cape Comorin (Menon 1967) and the Mangalore coast (Thornely 1907) in India.

2. *Biflustra hugliensis* (Robertson, 1921)

Image 1B

Location: Patiboni (Frezerganj), Bankimnagar (Sagar Island)

Substratum: Encrusted on prosoma of male *Tachypleus gigas* and female *Carcinoscorpius rotundicauda*.

Description: Colony encrusting, zooecia elongated, aperture occupying three fourths of the front, separated by a delicate calcareous mural rim. Distal portion of the zooid overarching the pre-seeding zooid. Operculum semi-circular, straight at its proximal border, much wider than long. Cryptocyst marginally developed, granular on its surface, serrated coarsely on its inner margin. Ovicells and avicularia are wanting.

Remarks: Earlier, a colony of encrusting *Biflustra hugliensis* was identified from the posterior of the carapace of *Lepidochelys olivacea* (Olive Ridley Sea Turtle) from the Gulf of Kachchh, Gujarat (Frazier et al. 1992).

Distribution: Although a species of tropical and subtropical seas, this species was first identified from the mouth of the Hugli River, Bay of Bengal (Robertson 1921) and subsequently reported from the Gulf of Kachchh, Gujarat (Frazier et al. 1992). Except for these two records, there is no report of this species from anywhere else in India.

Genus: *Jellyella* Taylor & Monks, 1997

3. *Jellyella tuberculata* (Bosc, 1802)

Image 1C

Location: Bankimnagar (Sagar Island) and Patiboni (Frezerganj)

Substratum: Encrusted on ventral side of prosoma of a male *Tachypleus gigas* as well as encrusted on the shell of a mollusc found on the right prosoma of a female *Carcinoscorpius rotundicauda*.

Diagnosis: Colony encrusting, multi-serial. Zooids rectangular to sub-rectangular, quincuncially arrangement, opesia elongate-oval, bordered by a very narrow cryptocystal rim laterally and a cryptocystal shelf proximally; cryptocyst sparsely tubercular. Gymnocyst proximally, starting at the corners of the zooid, then as a thin continuous proximal rim, the gymnocyst arches forward, forming small pockets beneath, especially at the corners; in fully calcified zooids the gymnocystal tubercles can be stoutly developed, completely concealing the proximal cryptocyst.

Distribution: A widely distributed species of the major oceans, this species is reported from North Carolina to Brazil along the Atlantic coast, California to up to Peru along the Pacific coast. Among the Indian Ocean countries, it is reported from Japan and Bangladesh and in India, it has been earlier reported from the coast of Odisha (Menon & Menon 2006).

Family: Electridae

Genus: *Conopeum* Gray, 1848

4. *Conopeum reticulum* (Linnaeus, 1767)

Image 1D

Location: Patiboni (Frezerganj)

Substratum: Encrusted on ventral side of prosoma of a male *Tachypleus gigas*.

Description: Encrusting, colonies appear as whitish patches with uneven growing margin. Zooecia quincuncially arranged, chitinous outline distinct. Shape of zooecia variable, but generally longer than wide, very much elongated in certain cases. Cryptocyst tuberculated, developed all-round the opesia with tubercles projecting into the opesia. The tubercles are more or less of the same length, small tubercles are present in the proximal region of the cryptocyst. In certain Zooids the proximal region of the opesia is broader than the distal region.

Remarks: This species is known to be found on fouling organisms which have been previously identified from the carapace and appendages of the *Neptunus pelagicus* (Swimming Crab) caught in a trawl net in Cochin (Menon 1967).

Distribution: *Conopeum reticulum* is a warm water Indo- Pacific species. This is recorded from Tortuges Island, Florida (Osburn 1950); Indonesia (Harmer 1926); Java, Sumatra, and Myanmar (Marcus 1937). In India, it has been reported from the Arabian Sea along with the Lakshadweep Islands and the Cochin coast (Menon 1967) as well as the Bay of Bengal from Chilka Lake (Annandale 1915).

Family: Sinoflustridae

Genus: *Sinoflustra* Liu & Yang, 1995

5. *Sinoflustra amoyensis* (Robertson, 1921)

Image 1E

Location: Patiboni (Frezerganj) and Bankimnagar

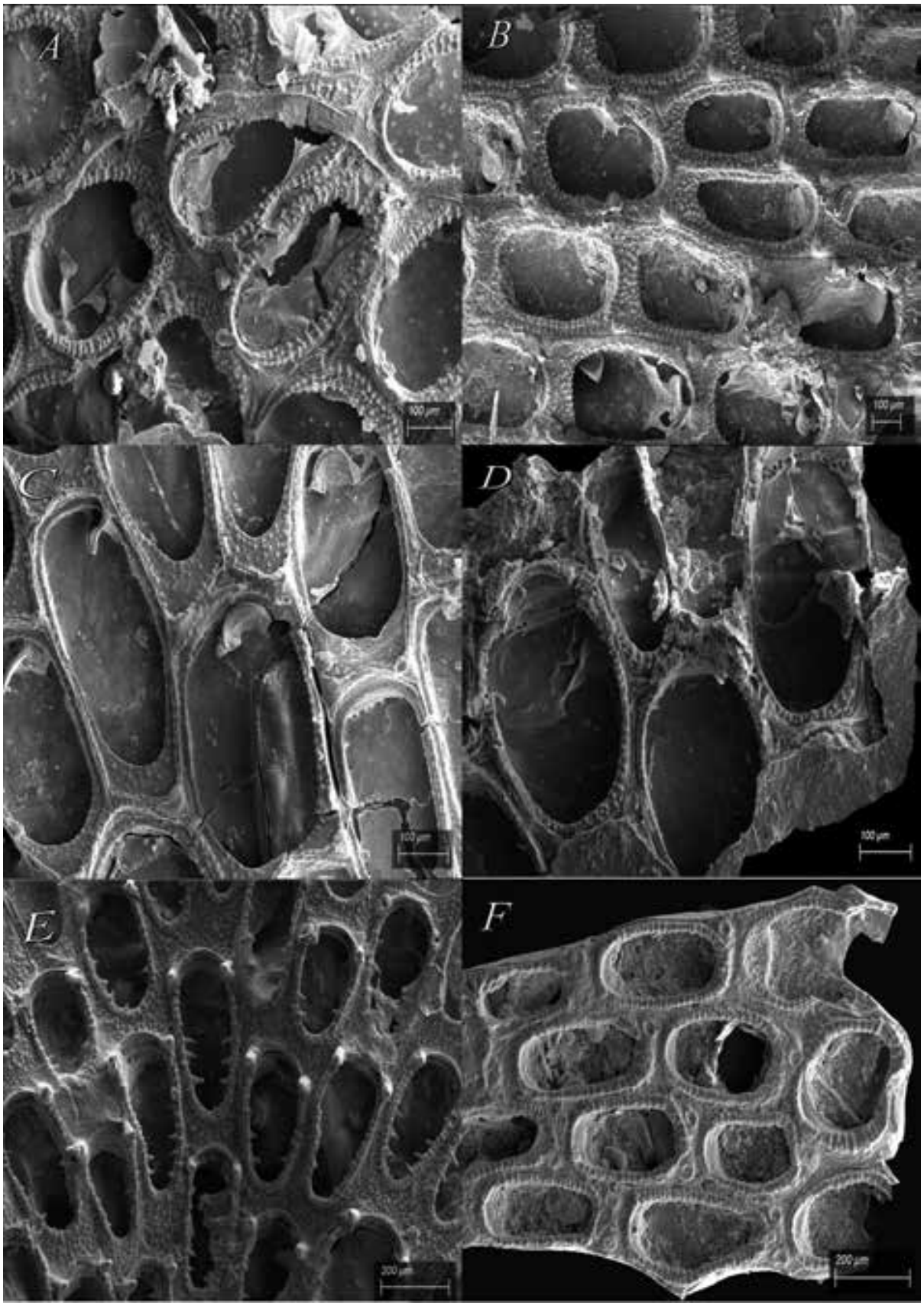

Image 1. A—Biflustra savartii (Audouin 1826) | B—Biflustra hugliensis (Robertson, 1921) | C—Jellyella tuberculata (Bosc, 1802) | D—Conopeum reticulum (Linnaeus, 1767) | E—Sinoflustra amoyensis (Robertson, 1921) | F—Sinoflustra arabianensis (Menon & Nair, 1975).

(Sagar Island)

Substratum: Encrusted on prosoma of a male *Carcinoscorpius rotundicauda* and and also found encrusted on hardened sediments found on the right side of the prosoma of a female *Carcinoscorpius rotundicauda*.

Description: Colony encrusting, white. The zooecia are moderate in size and very delicate and chalk like, zooids elongated rectangular, arranged in quincuncial series, and separated by a distinct fine groove. The mural rim is thin, raised and smooth on its edge. No gymnocyst. Frontal membrane large, occupying the whole of the frontal area. Cryptocyst marginal, narrowest distal to the opesia, developed laterally and proximally, smooth and granular in younger colonies, and granular on its surface in older colonies, with strong cryptocystal spinules. It contains six strong cryptocystal spinules on each side equidistant from each other, on its inner border proximal to the orifice. Opesia elongate and reduced by the cryptocystal spinules. A strong conical spine is present on each distal corner of every zooid.

Distribution: This species has been reported to have its presence since the Pliocene era and distribution range in the Indo-Pacific region. It has been originally collected from Amoy of China; in India, this species has the report of its presence in the Holocene rocks of the west coast of Maharashtra, Ernakulam channel from Cochin, and also from the coast of West Bengal (Menon & Menon 2006).

6. *Sinoflustra arabianensis* (Menon & Nair, 1975)

Image 1F

Location: Patiboni (Frezerganj)

Substratum: Encrusted on the dorsal side of prosoma of a male *Tachypleus gigas*.

Description: Colony encrusting. Grows flat, disk-like structures in the absence of any hindrance. Zooecia elongated, quadrangular the distal portion of the preceding zooecium slightly over arch the proximal portion of the succeeding zooid. Opecia occupying three-fourths of the front, being narrowed distally. Gymnocyst present, slightly extensive proximally. Cryptocyst with spinules, the size of the spinules decrease at the distal portion of the cryptocyst. Ancestrula possesses a pair of branched spines.

Distribution: It has been reported only from Cochin along the coast of the Arabian Sea (Menon 1967). This is the first report from the Bay of Bengal and also from the Indian Sundarbans region.

DISCUSSION AND CONCLUSION

Bryozoans are important macro fouling community in the coastal waters of India. So far, very little is known on the bryozoan species diversity and their association with horseshoe crabs and other organisms with hard surfaces and substratum. In India, the upper eastern coast is a preferred breeding and spawning ground for two species of horseshoe crabs: *Tachypleus gigas* and *Carcinoscorpius rotundicauda.* Both the species are in the data deficient category of the IUCN Red List; however, placed in the Schedule IV category of the Indian Wildlife Protection Act, 1972. The Mangrove Horseshoe Crab *Carcinoscorpius rotundicauda* (Latreille, 1802) is more common on the mudflats of the Indian Sundarbans than the Indian Horseshoe Crab *Tachypleus gigas* (Müller, 1785) although occurring in a sympatric habitat. In the present study, it was observed that adult male and female horseshoe crabs are host for bryozoan mats and the reason could be multiple. As most marine organisms compete for substrate space (Paine 1974; Jackson 1977; Connell & Keough 1985) to attach with suitable host species for their dispersal and gene flow (Wahl 1989), unoccupied and clean, bare exoskeletons of horseshoe crabs may act as an ideal surface for colonization of bryozoan species and probably help them to expand their range of distribution. Currents generated by the movement of hosts, respiration and feeding of the host (Bowers 1968; Wahl 1989; Gili et al. 1993) may help in capture of suspended food particles to the bryozoans. Additionally, host species may also protect bryozoan species from predators like amphipods, annelids, echinoids, isopods, nudibranchs, pycnogonids, and gastropods and in return, bryozoans help the host species via camouflage (Key et al. 1996, 2000; Patil & Anil 2000). As studies elsewhere (Renouf 1932; Cadee 1991) suggest bryozoan encrustation can reduce the effectiveness of the host's organs, hence, it can be inferred that epizoic bryozoans may impair the sight of horseshoe crabs as bryozoan mats were found encrusting on the compound eyes of horseshoe crabs during the present study, although bryozoan growth was also found on the mouth, gills, legs and telson of horseshoe crabs. Therefore, these aspects need further investigation to study the occurrence of any parasitic organisms of Bryozoa, which may impair the movement/ function of organs of horseshoe crabs. Overall, the interaction between a horseshoe crab and epizoic bryozoan is found non-symbiotic and facultative (Key et al. 1996) and as epizoic bryozoans have a less negative impact on horseshoe crabs, both co-exist.

Image 2. Field image of bryozoa (pale brown coloured mat) encrusting on the carapace of *Carcinoscorpius rotundicauda*.

Reporting of two species of Bryozoa for the first time from the east coast of India and one new report from the West Bengal coast clearly indicates that further intense surveys will bring more details on Bryozoa and their relationship with horseshoe crabs. Investigations are also required documenting ecological factors that regulate the epizoic bryozoan distribution on horseshoe crabs.

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COMMUNICATION

On the pteridophytes of Bherjan-Borajan-Padumoni Wildlife Sanctuary, Assam, India

Pranjal Borah [1] & Jayanta Barukial [2]

[1] Department of Life Sciences, Dibrugarh University, Dibrugarh, Assam 786004, India.
[2] P.G. Department of Life Sciences, Debraj Roy College, Golaghat, Assam 785621, India.
[1] borahpranjal27@gmail.com (corresponding author), [2] barukialjayanta@gmail.com

Abstract: A preliminary survey on the pteridophytic flora of Bherjan-Borajan-Padumoni Wildlife Sanctuary of Assam, India revealed a total of 33 species belonging to 23 genera and 15 families. Most of the species belong to the family Pteridaceae followed by Polypodiaceae and Thelypteridaceae. A brief taxonomic description of each species is provided. *Stenochlaena palustris* (Burm.f.) Bedd., an edible fern, grows abundantly all over, especially in the openings and clearings.

Keywords: Fern, Polypodiaceae, Pteridophytic flora, Pteridaceae, *Stenochlaena,* taxonomic description, Thelypteridaceae.

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Author details: Pranjal Borah is a PhD scholar at Dibrugarh University, Assam, pursuing research in the area of plant taxonomy. Dr. Jayanta Barukial is the Associate Professor and Head of the Department of Botany and PG Department of Life Sciences, Debraj Roy College, Assam and a recognized PhD supervisor of Dibrugarh University. His research interest is in the field of plant taxonomy, cytology, molecular taxonomy, environmental issues.

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INTRODUCTION

Pteridophytes, also known as ferns and fern-allies, flowerless and seedless plants that once dominated the world vegetation 280–230 million years ago. The main plant body is sporophytic and the dominant phase in its life cycle. Chapman (2009) estimates that there are about 12,000 species of ferns and fern-allies across the world. According to Moran (2015), "worldwide, there are about 13,600 species of ferns and lycophytes". According to a survey, the pteridophytic flora of India comprises around 1,000 species belonging to 191 genera and 67 families including 47 endemic Indian ferns (Dixit 1984) and in another report, more than 1,100 species of pteridophytes belonging to 144 genera and 34 families with about 235 endemic species (Chandra 2000) from India. According to Fraser-Jenkins et al. (2017), "altogether there are about 1135 species including 42 exotics and 53 further subspecies", from the Indian subcontinent.

The Bherjan-Borajan-Padumoni is one of the smallest wildlife sanctuaries of Assam covering 7.22 km^2 of area spreading across three blocks located in Tinsukia district of the Upper Brahmaputra Valley of Assam, India which consists of three separate forests, namely Bherjan, Borajan, and Padumoni. The forest is the home for an endangered primate species, i.e., Western Hoolock Gibbon. Bherjan, Borajan, and Padumoni are tiny isolated pockets of lowland tropical forest covering an area of 105 ha, 493 ha, and 176 ha respectively and an ideal habitat for primate species like the Bengal Slow Loris, Assamese Macaque, Pig-tailed Macaque, Rhesus Macaque, Capped Langur, Stump-tailed Macaque, and Western Hoolock Gibbon. The three areas are disjoint and unconnected by tea gardens and human settlement. These are entirely on the flat plains of the Brahmaputra Valley. There are small, scattered marshes, with swamps, covered with dense growth of grass and *Alpinia* herb. The natural vegetation of all these areas is tropical wet evergreen 'rainforest' type. Bherjan is almost entirely covered with trees with a closed canopy. The original vegetation has been replaced by a fairly old mixed plantation dominated by the deciduous species *Lagerstroemia parviflora* and *Terminalia myriocarpa*. The Padumoni part is mostly in a degraded state due to large-scale felling. The canopy has been very badly broken up. Only a few mature trees of *Artocarpus, Bombax*, *Lagerstroemia*, and *Mesua* species can be seen. Borajan is a pocket of excellent rainforest, dominated by *Dipterocarpus macrocarpus*. Except for Teak, all the species as in the other two forest pockets are found. Bamboo species are found in all areas.

In Assam, a few systematic works on pteridophytes have been accomplished, like Kachroo (1953), Panigrahi (1960, 1968), Panigrahi & Chowdhury (1961, 1962), Dutta et al. (1980), Handigue & Konger (1986), Kachroo et al. (1989), Borthakur et al. (2001, 2018), Devi & Majumdar (2003), Sen & Ghosh (2011), and Kalita (2015).

METHODS

A number of field visits were undertaken to the study area in the year 2019–2020 (Figure 1). The different pteridophytes were collected from a range of habitat; however, those species which are Red Listed (IUCN) or used as food or shelter were left untouched. Under such circumstances, digital photographs of the concerned species were taken. The specimens were preserved and studied with standard literature like Baishya & Rao (1982), Jamir & Rao (1988), and Borthakur et al. (2001, 2018). The plants were collected from the field, cleaned, and pressed for the preparation of herbarium. Herbariums are prepared by following standard herbarium technique (Jain & Rao 1977) and deposited at the Botany Department, Debraj Roy College, Golaghat, Assam. Digital photographs of the specimens were also taken and some of them are displayed (Image 1).

The families are enumerated in text according to Fraser-Jenkins (2009). However, the genera and species within the families are listed alphabetically. The taxonomic citation is based on published literature and IPNI, Tropicos, and The Plant List.

RESULTS

A total of 33 species of pteridophytes belonging to 23 genera and 15 families are recorded. The plants are enumerated with a brief taxonomic description of each species.

Selaginellaceae

1. ***Selaginella monospora*** Spring; Collection No. DRC- 5005.

Terrestrial. Stem about 40 cm long, prostrate, ascending, branched. Leaves dimorphic, green, midrib prominent, lateral leaves ovate. Strobilus up to 8 mm long, terminal, simple, sporophylls spiral, spore green.

2. ***Selaginella semicordata*** (Wall. ex Hook. & Grev.) Spring; Collection No. DRC-5006.

Terrestrial. Stem slender, branched with related

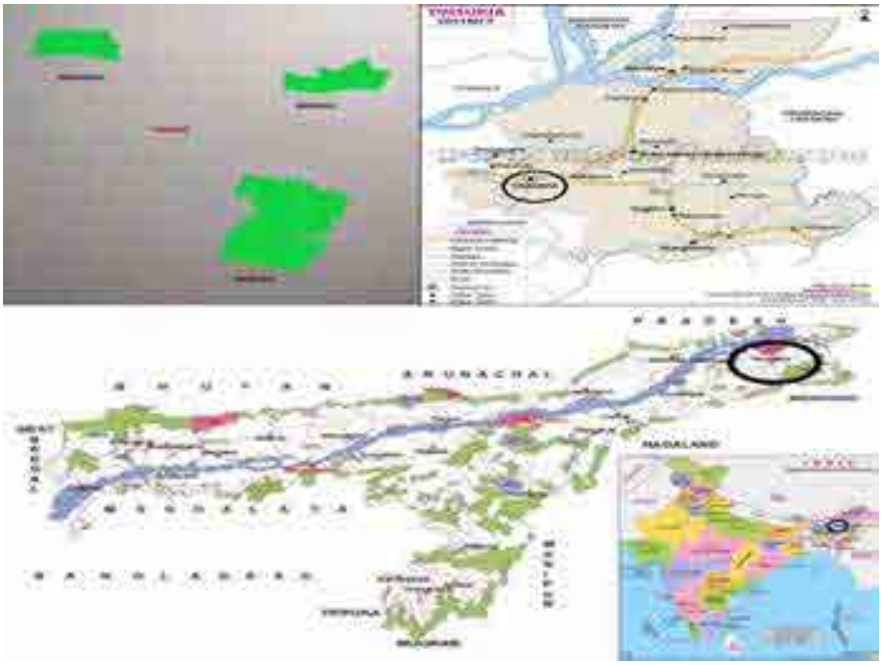

Figure 1. Study area – Bherjan-Borajan-Padumoni Wildlife Sanctuary.

dichotomy, rhizophore arises from forking. Leaves spirally arranged, lanceolate, entire, membranous. Strobilus up to 0.6 cm long, sporophyll lanceolate, ciliate at base; sporangia oval, orange in colour, spore oval, dark brown.

Marattiaceae

3. ***Angiopteris evecta*** (G.Forst.) Hoffm.; Collection No. DRC- 5015**.**

Terrestrial. Tree like fern. Rhizome erect, cylindrical, broad. Stipes swollen at base, adaxially flattened, abaxially rounded, whitish linear streaks all over, with small brown scales and minute hairs. Lamina bipinnate; pinnae subopposite, with long swollen stalk, oblong-lanceolate, veins simple or forked twice, almost parallel, reaching the margin. Sori sub-marginal, ellipsoid; sporangia up to six pairs in two rows, which is boat-shaped. Spores hyaline, tetrahedral, pale green.

Gleicheniaceae

4. ***Dicranopteris linearis*** (Burm.f.) Underw.; Collection No. DRC- 5016**.**

Terrestrial. Rhizome long creeping, densely covered by hairs, scales absent; hairs minute, multicellular, reddish-brown. Stipes slender, straggling, rigid and polished; apical bud covered by brown hairs. Fronds pinnate or dichotomously branched; margin curved, deeply covered with brown hairs; rachises repeatedly forked, covered with dark-brown hairs; veins prominent, 2-forked, free; lamina light green; texture hard. Sori small, globose, without paraphyses, in the two rows on both sides of the costa. Spores numerous, trilete, deeply grooved.

Polypodiaceae

5. ***Microsorum pteropus*** (Bl.) Copel.; Collection No. DRC- 5021**.** Aquatic. Rhizome creeping, fleshy, green, apex scaly; lanceolate. Fronds simple or 3/5 - lobate, lanceolate, veins distinct above and below, main veins rather wide apart, lamina very dark, dirty green, often black when dry. Sori small, globose, scattered irregularly within the main areoles; sporangia slender stalked, oval. Spores yellowish-green.

6. ***Microsorum punctatum*** (L.) Copel.; Collection No. DRC- 5025**.**

Epiphyte. Rhizome short creeping. Fronds without distinct stipe, simple, sessile, lanceolate or elliptic, base decurrent, margin entire, midrib across at the base, veins visible but not prominent; pinnae glabrous above and below, dark green when fresh, blackish when dry. Sori numerous, small, round, irregularly scattered on upper half of the frond; sporangia oval, short-stalked. Spores yellowish-green.

7. ***Pyrrosia lanceolata*** (L.) Farewell.; Collection No. DRC- 5029.

Epiphyte. Rhizome wide creeping, slender, clothed with scales; base rounded, margin profusely hairy, entire. Lamina simple, lanceolate acute apex, base decurrent, entire or wavy, green and glossy above, brownish below,

upper surface glabrous, lower surface densely covered by stellate hairs, veins immersed; lamina wrinkle up on drying. Sori irregularly distributed on the anterior half of lamina; sporangia dark-brown, naked. Spores greenish-yellow.

8. ***Pyrrosia piloselloides*** (L.) M.G.Price; Collection No.:- DRC-5032.

Epiphyte. Rhizome long creeping, clothed with scales; lamina dimorphic, simple; sterile lamina sessile or shortly stalked, roundish or obovate, base cuneate, margin entire; stipe of fertile frond scaly at base, grooved adaxially, straw-coloured; fertile lamina linear to oblong, apex round, base decurrent, margin entire; veins indistinct. Sori marginal, linear, continuous along the tip of lamina; sporangia oval, short stalked dark-brown. Spores oval to elliptic, light-brown.

Lygodiaceae

9. ***Lygodium flexuosum*** (L.) Sw.; Collection No. DRC-5037.

Climber. Rhizome creeping, short, covered by dark-brown, multicellular, uniseriate hairs. Stipes glabrous, abaxially rounded, adaxiaily flattened, dark-brown. Fronds widespreading, tripinnate, glabrous; primary pinnae alternate, bears two to three pinnules alternately; pinnules oblong-lanceolate, simple or terminal leaflets forked, basal leaflets often large, separate or lobed with 2–3 leaflets, sterile leaflets finely toothed; texture firm; rachis and costa densely or sparsely pubescent all over; veins distinct, free, reaching the margin; fertile leaflets a little narrower than the sterile ones. Sporangia arranged adaxially protruding from the margin; sporangia large, short stalked, about five pairs, arranged in two rows, alternate.

10. ***Lygodium japonicum*** (Thunb.) Sw.; Collection No. DRC- 5038.

Climber. Rhizome long creeping, covered with black hairs. Stipes scaly at base. Fronds wide-spreading, tripinnate; primary pinnae forked, opposite; fertile pinnae much contracted giving an appearance of dissected lamina; texture herbaceous; primary rachis scabrous; secondary rachis ridged; veins distinct, free, reaching the margin. Sori finger like, marginal projections which are greenish when young and dark brown at maturity; sporangia short stalked, arranged in two rows, alternate. Spores small, numerous.

Pteridaceae

11. ***Acrostichum heterophyllum*** L.; Collection No. DRC- 5040.

Epiphytes. Rhizome long creeping, densely covered by scales; apex acuminate, centre dark brown, pale-brown in the rest. Stipes of sterile fronds covered with scales similar to rhizome. Lamina dimorphous, simple or elliptic, apex rounded, margin entire; costa and veins indistinct, immersed; texture thick, fleshy, more or less covered by stellate hairs when young, sparsely or rarely when matured, lamina pale or dark-green; linear oblong, apex rounded. Sori confluent along the tip of lamina, sporangia oval, short stalked, intermingled with stellate hairs, dark-brown. Spores oval to elliptic, hyaline, light-brown.

12. ***Adiantum capillus-veneris*** L.; Collection No. DRC-5055.

Terrestrial. Rhizome short creeping, densely clothed with brown, narrow, lanceolate, acuminate, entire scales; Stipes slender scaly at base, glabrous and dark glossy above. Lamina bipinnate, lanceolate, cuneate at base, lower margin straight or concave and entire, outer margin rounded, lobed, lobes crenate, sterile lobes with more or less rounded, finely toothed edges; rachis uncovered; veins dichotomously branched. Sori elliptic or linear; sporangia globose, small and short stalked. Spores smooth walled.

13. ***Pityrogramma calomelanos*** (L.) Link.; Collection No. DRC- 5057.

Terrestrial. Rhizome short, erect, glossy above, black. Lamina oblong-triangular, subcoriaceous, bipinnate, pinnae in the lower half of the lamina more or less equal; gradually shortened towards apex, lower surface covered with white waxy powdery substance, lobes oblique, elliptic, toothed; rachis black-ebeneous, glossy; veins dichotomously radiated, free. Sori continuous throughout the lower surface. Spores tetrahedral.

14. ***Pteris biaurita*** L.; Collection No. DRC- 5045.

Terrestrial. Rhizome erect, short, scaly at the apex; linear-lanceolate, margin hairy, dark brown. Stipes glabrous except at base, adaxially grooved. Lamina bipinnatifid, glabrous; pinnae up to 12 pairs, sub-opposite, lanceolate, sessile or shortly stalked, margin lobed, apex rounded, margin entire; pinnae pale green; veins distinct, other veins forked once. Sori confluent along the margin of the sinus but not reaching the apex of the lobes. Spores tetrahedral, dark brown.

15. ***Pteris ensiformis*** Burm.f.; Collection No. DRC-5046.

Terrestrial. Rhizome erect, short, scaly; scales linear-lanceolate, entire, shining, dark-brown. Stipes glabrous, polished, slender, abaxially rounded, adaxially grooved. Fronds dimorphous, but sometimes some fronds partly fertile and partly sterile; Fertile lamina bi-pinnate, glabrous; the segments very narrow and

Image 1. I—*Pyrrosia lanceolata* (L.) Farw. | II—*Acrostichum heterophyllum* L. | III—*Lygodium flexuosum* (L.) Sw. | IV—*Lygodium japonicum* (Thunb.) Sw. | V—*Microsorum punctatum* (L.) Copel. | VI—*Microsorum pteropus* (Bl.) Copel. | VII—*Angiopteris evecta* (G.Forst.) Hoffm. | VIII—*Blechnum orientale* L. | IX—*Cyathea gigantea* (Wall. ex Hook.) Holtt. | X—*Stenochlaena palustris* (Burm.) Bedd. | XI—*Dicranopteris linearis* (Burm.f.) Underw. | XII—*Vittaria elongata* Sw. © Pranjal Borah

elongated, entire; lamina pale-green; rachis glabrous, grooved above, pale-brown; veins distinct on both surfaces, simple or forked, free. Sori confluent, marginal, developing basipetally. Spores dark brown, tetrahedral.

16. ***Pteris longipinnula*** Wall. ex J. Agardh.; Collection No. DRC- 5047.

Terrestrial. Rhizome erect, densely clothed with scales; scales linear, reddish-brown. Stipes erect, slender, abaxially rounded, adaxially grooved, scaly at base. Lamina bipinnatifid, with 3 - 8 pairs of lateral pinnae and an apical pinnae, apex caudate; lobes gradually reduced towards apex, often auricled; rachis and surface of the pinnae uncovered; spinules present on upper surface; veins free, forked once. Sori marginal, continuous nearly to the apex of the lobes. Spores triangular to 'T'-shaped, dark brown.

17. ***Pteris semipinnata*** L.; Collection No. DRC- 5048.

Terrestrial. Rhizome short-creeping, densely scaly; dark brown. Stipes erect, tufted, slender, glabrous, dark brown at base, pale brown above. Lamina pinnate, ovate-lanceolate, glabrous; upper part of lamina cut down nearly to the rachis into numerous close entire

linear lobes; costae and costules minutely grooved on the upper surface; veins free, fine, forked once. Sori linear, continuous along the margins of lobes except quite near reaching the sinus. Spores triangular to oval, pale brown.

18. ***Pteris vittata*** L.; Collection No. DRC- 5049.

Terrestrial. Rhizome suberect, short, densely covered by scales at apex, membranaceous, entire, pale-brown. Stipes pale-brown, clothed with linear, silky, pale-brown scales. Lamina simple pinnate with a single, elongate, linear, terminal pinnae like the lateral ones; pinnae numerous, opposite or subopposite, reduced to deflexed auricles, all pinnae sessile, linear-lanceolate, acuminate at apex; veins simple or forked once, free, distinct on both surfaces. Sori all along the margin, except at base and apex; indusia membranaceous. Spores round, yellowish-green.

19. ***Vittaria elongata*** Sw.; Collection No. DRC- 5053.

Epiphyte. Rhizome short creeping, thick, slender branched, densely scaly. Stipes flattened. Lamina simple, linear-oblong lanceolate, gradually tapering towards both ends, apex acuminate, margin entire, midrib distinct; veins slightly distinct above and below, simple, immersed, parallel; lamina dark green. Sori linear, confluent; sporangia short stalk. Spore pale yellowish-green.

Cyatheaceae

20. ***Cyathea gigantea*** (Wall. ex Hook.) Holtt.

Terrestrial. Tree like fern. Trunk massive, erect, densely covered by scales dark brown. Stipes tufted, glossy, scaly at base, glabrous above, abaxially rounded, adaxially grooved, dark purple. Lamina bipinnate, deltoid, dark- green when fresh, brownish when dry; oblong-lanceolate, alternate, shortly stalked, about 20 cm apart, acuminate at apex about 2 cm apart, apex acuminate, margin lobed half way to the costae, rounded apex, margin crenate; texture of lamina herbaceous; rachis slightly dark brown. Sori median on the veins, spherical and inverted 'V' shape, exindusiate; sporangia numerous, compact.

21. ***Cyathea spinulosa*** Wall. ex Hook.

Terrestrial. Tree like fern. Trunk erect, up to 3 m or more tall. Stipes and rachis strongly aculeate or spiny, scales linear-lanceolate, long hair-pointed, black. Lamina bipinnate, short stalked; rachis of pinnules and main veins of lobes scaly below, but the latter glabrous above; lamina coriaceous; veins usually forked once, free. Sori large, round, indusium completely covering the sorus when young, soon breaking irregularly.

Dennstaedtiaceae

22. ***Microlepia speluncae*** (L.) Moore; Collection No. DRC- 5063.

Terrestrial. Rhizome long creeping, stout, hairy; pale-brown. Stipes rounded below, grooved above, short hairy, purplish-green. Lamina tripinnate or quadripinnate; pinnae about eight pairs, alternate, petiolate; ovate-lanceolate, apex acuminate, largest pinnule narrowly deltoid, subopposite or alternate, shortly stalked, basal acroscopic leaflet much larger than the rest; ultimate pinnules, veins slightly distinct, forked once, free, not reaching the margin. Sori submarginal, near the base of the sinuses between the lobes, indusia cup-shaped, hairy; sporangia copious. Spores yellowish-brown.

Lindsaeaceae

23. ***Sphenomeris chinensis*** (L.) Maxon; Collection No. DRC- 5067.

Terrestrial. Rhizome short creeping, stout, covered by scales; scales hair-like, stiff, dark-brown. Lamina tripinnate or quadripinnatifid, distal part bipinnatifid, lanceolate, apex acuminate, acroscopic base truncate, basiscopic base cuneate; secondary pinnae about eight pairs, alternate, shortly stalked, acute; tertiary pinnae about three pairs, alternate, shortly stalked, obovate, apex rounded, base cuneate. Sori marginal or submarginal at the end of veins; indusial attached basally. Spores bilateral and brown.

Thelypteridaceae

24. ***Amblovenatum opulentum*** (Kaulf.) J.P.Roux.; Collection No. DRC- 5069.

Terrestrial. Rhizome creeping, densely scaly; scales narrow, linear brown. Stipes erect, slender, grooved, hairy at grooves, scaly at base. Lamina simple pinnate, lanceolate, apex acuminate; pinnae about 20–30 pairs, alternate or subopposite, sessile; apex obtuse or rounded, margin wavy, clothed with small yellowish glandular hairs; lamina dark green. Sori mostly confined to lobes, globose, often much immersed and visible as punch form dots on the upper surface; indusia thin, sporangia slender stalked. Spores dark in colour.

25. ***Christella parasitica*** (L.) H.Lev.; Collection No. DRC- 5072.

Terrestrial. Rhizome creeping, densely scaly; linear-lanceolate, apex acuminate, margin more or less clothed with short, soft hairs. Simple pinnate, pinnae numerous, alternate or subopposite, sessile, margin lobed two-third to the costa, lobes up to 20 pairs, oblique, basal acroscopic lobe slightly larger than the others; rachis copiously covered by long and short hairs; costa, eostules

Image 1. XIII—*Christella parasitica* (L.) H.Lev. | XIV—*Adiantum capillus-veneris* L. | XV—*Amblovenatum opulentumI* (Kaulf.) J.P.Roux. | XVI—*Araiostegia divaricata* (Bl.) M.Kato. | XVII—*Sphenomeris chinensis* (L.) Maxon | XVIII—*Pityrogramma calomelanos* (L.) Link. | XIX—*Diplazium esculentum* (Retz.) Sw. | XX—*Diplazium dilatatum* Bl. | XXI—*Microlepia speluncae* (L.) Moore | XXII—*Pteris biaurita* L. | XXIII—*Pteris semipinnata* L. | XIV—*Pteris vittata* L. © Pranjal Borah

and veins covered by short acicular or glandular hairs; veins up to 10 pairs, upper surface covered with thick, acicular hairs. Sori medial or submarginal on the veins up to five pairs.

26. ***Cyclosorus interruptus*** (Willd.) H. Ito.; Collection no. 5065.

Terestrial. Rhizome long creeping, clothed with scales at the apex; scales ovate, acuminate at apex, margin entire. Stipes slender, sparsely scaly and black at the base, glabrous and brown above, adaxially grooved, abaxially flattened. Lamina elliptic-lanceolate, simple pinnate with an apical pinnae; lateral pinnae numerous, sessile or very shortly stalked, basal pinnae not reduced, rachis grooved and hairy; veins slightly distinct below and densely covered by long, soft acicular hairs, upper surface glabrous; lamina pale green; sori medial on the veins, in two rows, arranged in V-shaped; indusia reniform, hairy. Spores pale brown.

Aspleniaceae

27. ***Asplenium nidus*** L.; Collection No. DRC- 5076

Epiphyte. Rhizome erect, short, stout, apex clothed

with scales. Stipes dark to pale brown, glabrous above, scaly at base; lamina simple, lanceolate, gradually narrowed at both ends, glabrous; midrib strongly raised on the upper surface, veins nearly simple or 2-forked; almost parallel. Sori linear, borne along each veinlet on upper half of the lamina, nearly reaching margin from the midrib; indusia linear, narrow, superficially attached at base, slightly curved, greenish-grey. Spores light brown.

Athyriaceae

28. ***Diplazium dilatatum*** Bl.

Terrestrial. Rhizome erect, stout, apex densely clothed with scales; apex acuminate, margin with many teeth, thin, dark brown. Stipes scaly at base, glabrous above, abaxially rounded, adaxially grooved. Lamina ovate, bipinnate or tripinnatifid; primary pinnae seven pairs, alternate, shortly stalked or sessile, slightly ascending, pinnae up to 12 pairs, subopposite to alternate shortly stalked, simple or forked once, reaching the margin, texture herbaceous; lamina dark green above, pale green below, glabrous. Sori linear, confluent, indusia linear, entire, pale brown; sporangia slender stalked. Spores oval, pale brown.

29. ***Diplazium esculentum*** (Retz.) Sw.

Terrestrial. Rhizome erect, apex densely covered by scales, linear, lanceolate, apex long acuminate, dark-brown. Stipes stout, erect, sparsely scaly at base, dark-brown at base, pale-brown above. Lamina bipinnate at base, simple pinnate at apex, rarely simply pinnate, deltoid, apex acuminate, base truncate, basal pair of pinnae slightly reduced; pinnae up to seven pairs, basal one or two opposite or sub-opposite, others alternate; petiolate, narrowly deltoid, with a deeply lobed terminal pinnae, apex acuminate, lamina pale-green, hairs densely distributed all over the lamina. Sori in two rows near the margin, dark brown. Spores reniform, pale-brown.

Dryopteridaceae

30. ***Bolbitis heteroclita*** (Presl.) Ching; Collection No. DRC- 5082.

Terrestrial. Rhizome long creeping, soft, brittle, apex clothed with ovate-lanceolate, darkbrown scales; Stipes green, sparsely covered by scales. Fronds usually in two or three alternate rows; they vary from simple to pinnate and loosely placed; pinnae usually trifoliate, simple leaves and terminal pinnae of pinnate leaves similar, veins prominent, lateral veins raised, secondary veins anatomising without included veinlets, marginal veins free. Fertile lamina simple or pinnate; apical pinnae lateral, fertile lanceolate with acute apex, margin smooth and shortly stalked. Sori covering the whole lower surface and brown.

Davalliaceae

31. ***Araiostegia divaricata*** (Bl.) M.Kato.; Collection No. DRC- 5085.

Epiphyte. Rhizome creeping, densely scaly all over; scales, apex long acuminate, base broad, thin, transparent, brown. Stipes firm, erect, scaly at base, glabrous above, chestnut brown, tripinnatifid, deltoid-lanceolate, apex acute or acuminate; apex acuminate, base cuneate; secondary pinnae up to 12 pairs, alternate, sessile or shortly stalked, margin deeply cut down to lobe nearly to the costules; margin sharply toothed or crenate; veins not conspicuous, uniform, free, not reaching the margin; lamina dark reddish-brown when dry, glabrous. Sori half cup-shaped, obliquely placed as regards the central veins in the tooth, submarginal, brownish; indusia tubular or half cup-shaped, as long as broad.

Blechnaceae

32. ***Blechnum orientale*** L.; Collection No. DRC- 5087.

Terrestrial. Rhizome creel, densely scaly, massive, linear-lanceolate, apex acuminate, shining, dark brown. Stipes tufted, erect, scaly at base, glabrous above, reddish-brown at the base, grey brown above. Lamina ovate to linear-lanceolate, apex acute, simple pinnate; costa grooved above, rounded below; veins slightly distinct, simple or forked once or two times, free; lamina pale green, glabrous above and below, glossy. Sori linear along either side of the costa, continuous nearly to the apex, dark brown; indusia narrow, firm with entire margin. Spores round to oval, translucent, yellowish-brown.

33. ***Stenochlaena palustris*** (Burm.f.) Bedd.; Collection No. DRC- 5090.

Climber. Rhizome scandant, long creeping, thick, sparsely scaly, often climbing on trees; scales ovate, apex acuminate, margin ciliated, dark-brown at the centre, pale-brown at the periphery. Lamina dimorphic; stramineous, glabrous, adaxially grooved, abaxially rounded; simple pinnate; pinnae 8–15 pairs, lanceolate, apex acuminate, hard, rachis similar to stipe; veins distinct, simple or rarely once forked, reaching the margin; lamina green, glabrous on both surfaces, shining. Fertile lamina borne at the distal part of the plant, more or less same size and shape with the sterile one, but pinnae much contracted. Sori densely covering the lower surface except midrib and the extreme apex;

sporangia large, stalked, crowded. Spores monoiete, pale-green, spinulose.

DISCUSSION

The vegetation of the study area is mostly dominated by the angiosperms. Out of the 33 species of pteridophytes, two species belong to fern-allies and 31 species belong to true ferns. The two species of fern-allies belong to the family Selaginellaceae. Considering the habitat, 25 plants are terrestrial, seven plants epiphytic, and one aquatic (Figure 2). Among them, three species are trees, three species are climbers and remaining 27 species are either herbs or shrubs (Figure 3). Three species namely *Angiopteris evecta* (G.Forst.) Hoffm., *Cyathea spinulosa* Wall. ex Hook. and *Cyathea gigantea* (Wall. ex Hook.) Holtt. are tree ferns. *Microsorum pteropus* (Bl.) Copel. is the only aquatic fern found there. *Lygodium flexuosum* (L.) Sw., *Lygodium japonicum* (Thunb.) Sw., and *Stenochlaena palustris* (Burm. f.) Bedd. are climbers. *Cyclosorus interruptus* (Willd.) H. Ito is grown abundantly in swamp areas. *Pityrogramma calomelanos* (L.) Link. is commonly called as silver fern due to its silver colour spores and found to be growing in the forest and also grow on stored bricks or nearby brick making industries. Epiphytic ferns *Microsorum punctatum* (L.) Copel. and *Asplenium nidus* L. are seen to be growing plentifully in tree trunks not only in the forest but also adjoining areas. *Diplazium esculentum* (Retz.) Sw. is widely used as vegetables in the nearby area. The fern species like *Cyathea gigantea* (Wall ex Hook.) Holtt. and *Diplazium esculantum* (Retz.) Sw. were observed to be taken as food by *Trachypithecus geei* during their study in Kakoijana reserve forest, Assam. However, no record traced the existence of this endangered primate species in the present study area. Due to the subsistence of other primate species including the endangered Hoolock Gibbons, these two fern species were kept unscathed and only digital photograph were taken.

The family Pteridaceae has the greatest number of genera, i.e. 5; among them, the genus *Pteris* has highest number of species. In India, the family Thelypteridaceae is represented by 80 species and 16 hybrids (Fraser-

Table 1. Number of pteridophyte taxa in genera and families.

Family	Genus	Number of taxa
Selaginellaceae	*Selaginella*	2
Marrattiaceae	*Angiopteris*	1
Gleicheniaceae	*Dicranopteris*	1
Polypodiaceae	*Microsorum*	2
	Pyrrosia	2
Lygodiaceae	*Lygodium*	2
Pteridaceae	*Acrostichum*	1
	Pteris	5
	Adiantum	1
	Pityrogramma	1
	Vittaria	1
Cyatheaceae	*Cyathea*	2
Dennstaedtiaceae	*Microlepia*	1
Lindsaeaceae	*Sphenomeris*	1
Thelypteridaceae	*Amblovenatum*	1
	Christella	1
	Cyclosorus	1
Aspleniaceae	*Asplenium*	1
Athyriaceae	*Diplazium*	2
Dryopteridaceae	*Bolbitis*	1
Davalliaceae	*Araiostegia*	1
Blechnaceae	*Blechnum*	1
	Stenochlaena	1

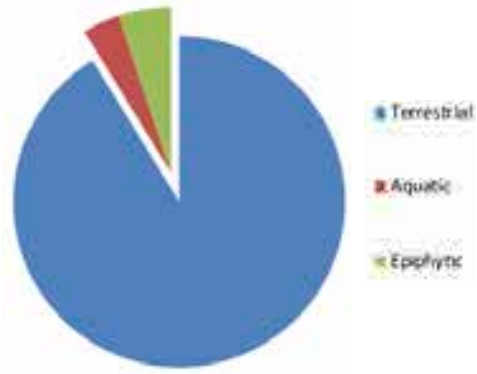

Figure 2. Habitats of pteridophytes.

Figure 3. Different habits of pteridophytes.

Jenkins et al. 2017) while only three species are recorded from the present study area. Most of the families and genera have a single number of species (Table 1).

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COMMUNICATION

Population status of *Heritiera fomes* Buch.-Ham., a threatened species from Mahanadi Mangrove Wetland, India

Sudam Charan Sahu [1], Manas Ranjan Mohanta [2] & N.H. Ravindranath [3]

[1,2] Maharaja Sriram Chandra Bhanjadeo University (Erstwhile North Orissa University), Baripada, Odisha 757003, India.
[3] Centre for Sustainable Technologies, Indian Institute of Science, Bengaluru, Karnataka 560012, India.
[1] sudamsahu.bdk@gmail.com (corresponding author), [2] manasranjan.mrm@gmail.com, [3] ravi@ces.iisc.ernet.in

Abstract: *Heritiera fomes* Buch.-Ham. is assessed as an endangered mangrove species by IUCN, and information on population status is lacking. The present study assesses the status of *H. fomes* in Mahanadi Mangrove Wetland on the east coast of India. Three forest blocks were selected and sampled for this study. Among these, the mean girth at breast height (GBH) of *H. fomes* was the highest in Hetamundia (HD) forest block. GBH of *H. fomes* was inversely proportional to the cumulative disturbance index (R^2= 0.7244, p value <0.005). The relative density was maximum for *H. fomes* (56%) at Bhitarkharnasi (BK), and for *Excoecaria agallocha* at Hetamundia (HD; 35%) & Kansaridia (KD; 54%), respectively. *Excoecaria agallocha* is a dominant species possibly impacting natural populations of *H. fomes*. Climate change and rising sea levels may also negatively affect the existence of this species. Therefore, appropriate strategies should be taken for conservation of this globally threatened mangrove species prior to its extinction.

Keywords: Conservation, disturbance index, diversity indices, East Coast of India, relative density, threatened mangroves.

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Author details: Sudam Charan Sahu, MSc, PhD, F.I.A.T. is working as an assistant professor in the Department of Botany, Maharaja Sriram Chandra Bhanjadeo University, Baripada (Odisha), India. His specialization and research fields include plant taxonomy, ethnobotany, forest ecology, climate change and biodiversity conservation. He is recognized as Fellow of Indian Association for Angiosperm Taxonomy. Manas Ranjan Mohanta (MSc, MPhil in Botany) is doing his PhD in botany at Maharaja Sriram Chandra Bhanjadeo University, Odisha, since 2017. He is an active researcher in the field of biodiversity, ecology and climate change. Prof. N.H. Ravindranath is working as professor (Retd.) in the Centre for Sustainable Technologies, Indian Institute of Science Bangalore, India. He focused his research, advocacy and publications on various dimensions of climate change -mitigation assessment, impact of climate change and vulnerability assessment in forest and agro-ecosystems, adaptation and climate resilience, forest ecology, CDM and REDD+ Projects.

Author contribution: Study design: NHR, SCS. Fieldwork: SCS, MRM. Data analysis: SCS Writing: SCS, MRM Feedback: NHR, SCS.

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INTRODUCTION

Mangrove ecosystems are important with respect to their contribution towards biodiversity, carbon storage, ecosystem balance, prevention of soil erosion, economic development, health care and protection against natural calamities (Ellison 2008). Mangrove flora are major reservoirs of biological carbon that contribute significantly towards mitigation of climate change (Mohanta et al. 2020). The social economy in coastal areas is highly dependent on vegetation directly or indirectly through fishing activity, tourism, and medication (Alongi 2008).

Lack of conservation and protection of mangrove habitats in recent decades has resulted in sparse distribution of species and regional extinctions; 35% of mangrove area was lost between 1980–1990 alone worldwide (Valiela et al. 2001). However, an increase in land cover by mangroves has been observed over the last few years in some Indian states, including Maharashtra, Gujrat, Odisha, and Andhra Pradesh (ISFR 2017; Khare & Shah 2019). Odisha has 243 km^2 under mangrove vegetation in the coastal districts of Balasore, Bhadrak, Jagatsinghpr, Kendrapara, and Puri (ISFR 2017).

Information on threatened species is needed for formulation of conservation policies helpful in defining marine protected areas and resource utilization for coastal development (Polidoro et al. 2010). Studies of distribution, ecology, adaptation, and threat assessment are all prerequisites for effective management of resources in general, and threatened species in particular (Lewis et al. 2016; George et al. 2019). Recent global assessment reveals that 16% of total species of mangrove (70) are under threat of extinction.

In India, two species, *Heritiera fomes* Buch.-Ham. (Endangered) and *Sonneratia griffithii* Kurz (Critically Endangered) are under the IUCN category of threatened species (Polidoro et al. 2010). *H. fomes* (Sterculiaceae) is native to India, Bangladesh, Malaysia, Myanmar, and Thailand. In India, it is found only in the Sundarbans in West Bengal, and Bhitarkanika (abundant) and Mahanadi Mangrove Wetland (MMW; rare) in Odisha. *H. fomes* is locally called 'Bada Sundari' in Odisha. It mostly grows towards landward in low saline (5–15 PSU) habitats with fresh water association in upstream estuarine zones and in high intertidal regions. Climate change, sea level rise and salinification of coastal habitats have had adverse effects on sustainability of this species in different habitats. Hence, it can be taken as an indicator of global climate change and sea level rise.

H. fomes is an important traditional medicinal plant, with reported activity to treat infections and diseases including goiter, skin diseases, gastrointestinal disorders, diabetes, and cancer (Mahmud et al. 2014; Islam et al. 2019). Timbers of the plant have high utility due to their hard and elastic nature. The timbers are used as constructive material for bridges, houses, boats, and hard boards (Ghosh et al. 2004). Locally, the timber is used as fire wood as well. However, the species is disappearing due to absence of fresh water and low seed viability (Kathiresan 2010). There is chance of local extinction of *H. fomes* in India as populations are declining rapidly due to anthropogenic and natural pressures (Kathiresan 2010). In Bangladesh, the species is facing the problem of dieback causing a severe loss of mangroves (Hussain & Acharya 1994). Due to its threat of extinction and lack of data regarding its population structure, it is essential to assess the population status of *H. fomes* for further planning to conserve and manage this species.

MATERIALS AND METHODS

Study area

The Mahanadi mangrove wetland is located on the eastern coast of India in Kendrapara district of Odisha, which lies between 20.30–20.53 N and 86.66–86.80 E. The area is covered with dense mangrove forest which extends from Hukitola Bay (North) to Paradip Port (South). The climate of the area is generally tropical monsoon in nature, with about 2,000 mm of rainfall annually. The area faces severe cyclonic storms each year peaking during May–July and October–November. The tidal amplitude ranges as high as 6 m during monsoon and as low as 1.2 m. in dry seasons. The combination of fresh water streams and tidal water in the inter-tidal regions of the Mahanadi river mouth provide luxuriant habitats for mangrove flora. However, there is variation in the salinity level at different seasons, and areas based on the precipitation and distance from sea to river and creeks, respectively. The salinity level of water becomes higher as 11.5 to 19.9 pptv near the sea and becomes lower at interior mangrove regions (landward) as 0.3 to 0.7 pptv (Ravishankar et al. 2004). The wet land is divided into eight forest blocks, i.e., Kansaridia (KD), Bhahar Kharnasi (BK), Bhitar Kharnasi (BK), Hukitola, Jambu, Kantilo, Kendrapatia, and Hatamundia. In these forest blocks two important species *Heriteira fomes* and *Sonneratia griffithii* are found which are considered as globally threatened plant species.

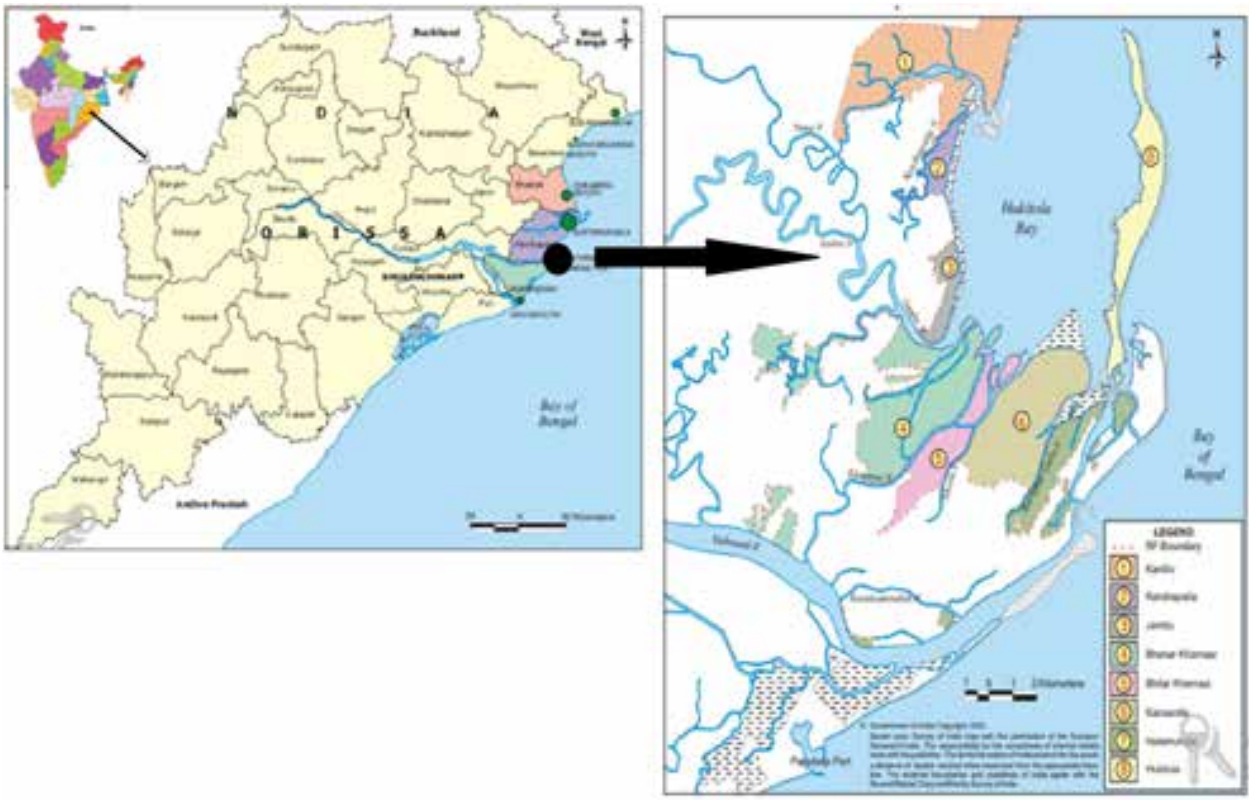

Figure 1. Study area showing forest blocks of Mahanadi Mangrove Wetland (MMW) (Adapted from Atlas of mangrove wetlands of India, part-3, Odisha).

Data collection

Field surveys were carried out to study the population status of *H. fomes* in MMW from 2013 to 2016. After searching all the forest blocks of MMW, this species was found only in three reserve forests: Bhitarkharnasi (BK), Hetamundia (HD), and Kansaridia (KD). We laid nine quadrats (20 × 20 m) in total, three in each forest block. Woody trees with GBH ≥10 cm were considered for the study. The size class wise distribution of plants was estimated considering three levels, i.e., <10 cm (lower GBH class), 10–20 cm (mid GBH class), and ≥ 20 cm (higher GBH class). Distributions of plants in these classes were compared to understand the future trend of distribution of the species. To study the regeneration status of *H. fomes*, stems <10 cm girth were counted and recorded under each plot. For studying the stem size class distribution, plants with <10 cm GBH were treated as *seedlings* and those of ≥10 cm GBH as *trees* (Pascal 1988). The global positioning system (GPS-Garmin Oregon-600) was used to record spatial location (latitude, longitude, and altitude) of each quadrat.

The data were analyzed through different diversity indices (Shannon-Weiner index and Simpson's index) and other diversity parameters (Menhinick's species richness and evenness) following Magurran (2004).

Relative density was also calculated following the formula,

Relative Density = 100* (Density of one species/ Density of all species)

where, density was calculated as number of individuals of the species/ha.

Each forest block was observed to determine the type and level of disturbance following Tadwalkar et al. (2012). Observations were based on disease infection, cut stumps, and salinity of tidal water. These three features were measured through four levels, i.e., 0= no impact, 1= low impact, 2= moderate impact, and 3= high impact (Patwardhan et al. 2016). Cut stumps were taken as a sign of active anthropogenic disturbance whereas salinity of tidal water and disease infections were as natural disturbances. The salinity of the water was determined by following standard methodology given by APHA (2005). A cumulative disturbance index (CDI) was estimated for different forest blocks by adding these three scores. The estimated CDI were compared against other diversity parameters and mean GBH values of *H. fomes* in different forest blocks to evaluate the correlation between them.

RESULTS AND DISCUSSION

Among eight studied forest blocks, *H. fomes* was found only in three: Bhitarkharnasi (BK), Hetamundia (HD), and Kansaridia (KD) reserve forests. These forest blocks comparatively represented with low salinity conditions due to absence of continuous tidal water. The cumulative species richness of all the studied plots was 10, including a single herb species named *Acanthus ilicifolius* L. The other woody species were *H. fomes*, *Excoecaria agallocha* L., *Cynometra iripa* Kostel., *Xylocarpus granatum* J.Koenig., *Avicennia officinalis* L., *Phoenix palludosa* Roxb., *Ceriops tagal* (Perr.) C.B.Rob., *Pongamia pinnata* (L.) Pierre, and *Rhizophora apiculata* Blume. *H. fomes* was found to occur at an altitude of 6–25 m. The detailed ecological information of sampling sites is given in Table 1. The Shannon diversity index varied among the three forest blocks as HD having the highest diversity index (1.32 ± 0.18) followed by KD (1.26 ± 0.01) and BK (1.16 ± 0.20) (Table 2). The overall Shannon diversity index was 1.25 ± 0.15. Simpson's Index was highest at HD (0.70 ± 0.04) followed by KD (0.64 ± 0.01) and BK (0.60 ± 0.09). Here, the HD seems to have better diversity than BK but closer to the KD. The visible variation in the diversity indices values is may be due to the differences in potential threat effects or soil nutrient status or both. However, the lower diversity indices of mangrove forest compared to other tropical forests ecosystem is quite common due to lower species richness (Gevana & Pampolina 2009; Stanley & Lewis 2009; Joshi & Ghose 2014).

The total number of individuals of *H. fomes* recorded in nine plots (0.36 ha) of three forest blocks was 482, including 398 trees and 84 regenerating individuals (Seedlings). BK possessed 231 individuals followed by HD (133) and KD (118). The values of tree number in the region is quite satisfactory but number of seedlings was very low, indicated towards reduction of population size in future because the number of juveniles must exceed the number of trees to ensure population expansion (Upadhyay & Mishra 2014). Similarly, for a stable population size these numbers should be equal or nearly equal to satisfy one to one replacement condition (Upadhyay & Mishra 2014). But the cumulative result of these nine studied plots put the ratio near 5 : 1 (Tree : Seedlings), which indicates poor regeneration status of the species in the area and urgent need for conservation.

The distribution of GBH class revealed that in BK, 25 individuals had stems less than 10 cm GBH (seedlings), 78 had stems between 10–20 cm, and 128 had stems greater than 20 cm (mature trees), indicating a healthy population structure with good representation of individuals of all size classes. In HD, stems less than 10 cm GBH (seedlings) was 39 individuals followed by stems between 10–20 cm at 78 individuals and stems greater than 20 cm (mature trees) at 16 individuals. In KD, stems less than 10 cm GBH (seedlings) was 20 individuals followed by stems between 10–20 cm at 64 individuals and stems greater than 20 cm (mature trees) at 34 individuals (Figure 2). Among these three forest blocks, there was a visible difference among of matured tree numbers. BK was bearing the highest number whereas it was lowest in HD, indicating the difference in the level of potential threat among two blocks. The reason evaluated for less number of mature trees in HD was the more anthropogenic activities in the region (Highest CDI, Table 1). KD showed less number of seedlings than other forest blocks indicating poor regeneration status of *H. fomes* in this block. It may be due to more salinity (6.8 ± 1.2 pptv) and disease infection. The lowest salinity level (4.7 ± 1.5

Table 1. Ecological information of study sites.

Forest block/ Plot no.	Latitude (degree, minute)	Longitude (degree minute)	Altitude (meter)	Density (ha^{-1})	Mean GBH	CDI
BK-1	20.393	86.719	21	2475	19.49	4
BK-2	20.364	86.719	25	1200	31.02	3
BK-3	20.371	86.726	23	2100	22.96	4
HD-1	20.352	86.767	13	1000	14.55	6
HD-2	20.355	86.768	9	1275	10.45	7
HD-3	20.35	86.765	6	1050	16.26	5
KD-1	20.368	86.763	17	1040	18.90	5
KD-2	20.369	86.719	16	925	15.40	6
KD-3	20.37	86.719	15	975	15.79	4

BK—BhitarKharnasi | HD—Hetamundia | KD—Kansaridia (1, 2, 3 represents sampling plots).

Table 2. Diversity indices in three forest blocks.

Diversity index	Bhitarkharnasi (BK)	Hetamundia (HD)	Kansaridia (KD)	Overall
Shannon-Weiner	1.16±0.20	1.32±0.18	1.26±0.01	1.25±0.15
Simpson	0.60±0.09	0.70±0.04	0.64±0.01	0.65 ±0.06
Evenness	0.61±0.08	0.72±0.09	0.58±0.01	0.64±0.09
Menhinick	0.45±0.03	0.43±0.10	0.51±0.01	0.46±0.06

Note: mean ± standard deviation are presented.

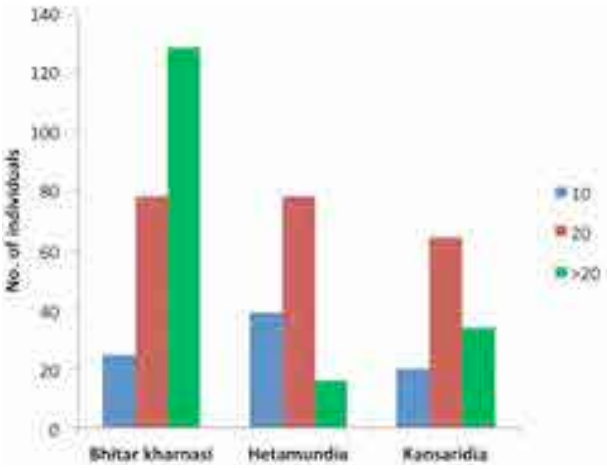

Figure 2. Distribution of no. of individual trees in different GBH classes (in cm).

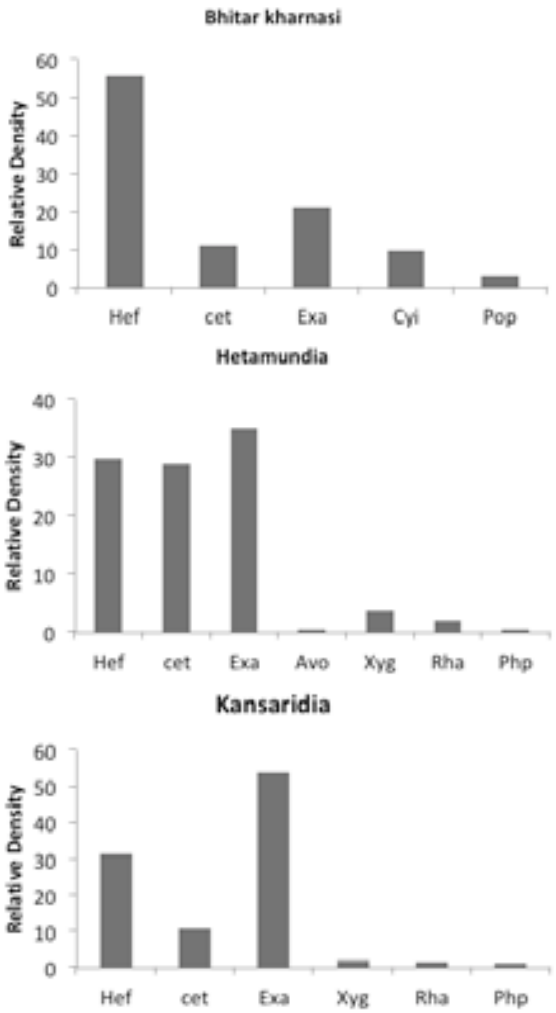

Figure 3. Relative density of *H. fomes* and its associated species. Hef—*H. fomes* | Exa—*Excoecaria agallocha* | Cyi—*Cynometra iripa* | Xyg—*Xylocarpus granatum* | Avo—*Avicennia officinalis* | Php—*Phoenix palludosa* | Cet—*Ceriops tagal* | Pop—*Pongamia pinnata* | Rha—*Rhizophora apiculata*.

pptv) and moderate anthropogenic disturbance in BK supposed to support highest tree density and seedling density among blocks. Different parameters like viable seed number, germination, establishment, and growth are the indicators of regeneration of plant community and also structurally reforms the community based on the age group distribution to the habitat (Cunningham 2001). The relative density was highest for *H. fomes* (56%) at Bhitarkharnasi and *Excoecaria agallocha* at HD (35%) and KD (54%), respectively (Figure 3). This indicates that *Excoecaria agallocha* is invading and dominating in a very fast rate due to its more ecological adaptations to the existing environmental conditions.

The mean CDI for the three forest blocks were: 3.36 (BK), 6 (HD), and 5 (KD). In the analysis, the CDI was found to be negatively correlated with mean GBH of each plot (R^2= 0.7244, p value <0.005) (Figure 4). However, there was a clear indication cumulative disturbances in the distribution of higher GBH class individuals in HD. Similarly, the lowest mean CDI value in BK supported the maximum distribution of trees with higher GBH class. The CDI value did not show any significant correlation with other variables like density and altitude. However, it was found that CDI value was highest in the forest block at lower altitude and similarly it was less in higher altitude. This was clearly showing the tidal effect on habitat modification and distribution of flora. The density among study plots showed high variability, ranging from 925 to 2,475 individuals/hectare. Variation was also observed among plots within forest blocks,

Image 1. *H. fomes* infected with gall cankers. © Sudam Charan Sahu.

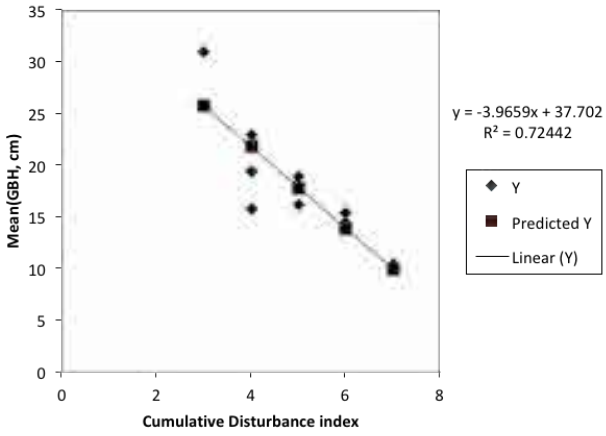

Figure 4. Cumulative disturbance index versus mean GBH.

being highest in BK and lowest in KD. These variations are common due to uneven distribution of plants due to tidal effects and variations in soil nutrient status (Xin et al. 2013). The role of human disturbances cannot also not be ignored.

Threats

H. fomes grows well in low salinity condition about 2–5 PSU (Mitra et al. 2004; Ravishankar et al. 2004). Growth of mangroves is impacted by salinity level (Mitra et al. 2004). The higher salinity level in water affects the concentration of chlorophyll pigments a and b in leaves that decreases chances of sustainability of low salt tolerant plants in those regions (Clough 1985). Hence, salinity level can be a cause for stunted and rare distribution of flora or even to their regional extinction. In our study, lowest mean GBH was found in HD forest block indicating highest Cumulative Disturbance Index (CDI) due to high salinity (5.4 ± 1.3 pptv) and disease infection. In Bangladesh Sundarban, about 20% of the entire forests have been affected due to top dying disease in *H. fomes* (Kathiresan 2010). Natural conditions like excessive flooding, increased soil salinity, sedimentation, imbalance in soil nutrients, and cyclone induced threats are the known factors for the disease. In the present study we observed some *H. fomes* trees were infected with gall cankers (Image 1).

Biological invasion is a major threat to biodiversity (Biswas 2003; IUCN 2003). In the present study no known invasive species was reported, but the domination of some true mangrove species and their associates was observed which might be giving inter-specific competition to *H. fomes* in different aspects. These species of MMW might have impacts on the natural population of *H. fomes* in competing for light and nutrients to suppress natural regeneration and cause physical damage. We recorded seven such species belonging to seven families and seven genera. Out of seven species, *Excoecaria agallocha* L., *Acanthus ilicifolius* L., and *Ceriops decandra* (Griff.) W.Theob. are pre-dominating the study area. The distribution of *E. agallocha* and *C. decandra* in the region may also have negative impact over the *H. fomes*. It is because a previous study at Sundarban mangrove reported a negative association between *H. fomes* with *E. agallocha* and *C. decandra* (Ellison et al. 2000). Further, we assumed that the future environmental conditions may support extensive growth of *Excoecaria agallocha* in the region because the species is highly salt tolerant, faster growing, and have high ability to colonize in degraded habitats (Harun-or-Rashid et al. 2009). The other important species were *Derris trifoliate* Lour., *Clerodendru minerme* (L.) Gaertn., *Eichhornia crassipes*

(Mart.) Solms, and *Saccharum spontaneum* L.. Although, the relationship *H. fomes* with these species is not clear but there must be a negative interaction in them that supposed to affect the regeneration of the species due to inter specific competitions. Hence, the nature of relationship between *H. fomes* and other invasive species is the part of future research.

The unscientific utilization and management of resources is a major threat to biodiversity. Globally, there is not been a single policy that ensures sustainable use and conservation of mangrove resources (Romanach et al. 2018). Repeated logging and unscientific exploitation of plant species force distributions to be sparse. However, the present condition in the study areas are much organized and restricted for logging and other activities due to active involvement of forest department. But extensive logging of large trees for construction and firewood in these areas was quite frequent in the past. The interaction with local people revealed that the information about the threat status of the species was completely unknown by the local communities. There was complete absence of awareness programs regarding environmental education and threatened species in the area among tribes. This was the one among the valid reasons for disperse distribution of the species.

The study site is located in the eastern coast of India where tropical cyclonic storms are very common, specifically the coast of Odisha state. Disastrous tsunamis with high tidal force and above 150 km/hr wind speed severely affect coastal mangrove vegetation almost each year. Recent examples of such natural calamities are cyclone Phailin (2013), cyclone Hudhud (2014), and cyclone Fani (2019). The disastrous effect of the super cyclone in 1999 to the coastal areas of Odisha is well known. Apart from immediate damage, post-cyclonic changes in habitat create issues such as increased infections and temperature reduction (Shengyan et al. 2019). Thus it is a major challenge for forest managers to protect mangrove diversity and effectively implement conservation strategies. In these conditions, the regeneration and sustainability of *H. fomes* is highly affected due increase in habitat salinity levels and disease after cyclones.

Conservation measures

Effective conservation measures are essential for the sustainability of *H. fomes* in the region. This can be achieved by supply of fresh water to high salinity areas, for better growth and regeneration. Preparation of specialized habitats and plantation areas with optimal salinity condition for *H. fomes* may aid conservation in the area. Further, plantation areas could be established at a safe distance from the sea so that required amounts of fresh and saline water can be channeled, and arrival of high tidal water during cyclones and other natural calamities prevented. The present policies of plantation of mangrove flora are quite successful in the area, but the active and effective participation of local people is lacking. Here, it can be suggested that the population strength of *H. fomes* in the area can be achieved through active participation of local people and taking the species at high priority.

H. fomes has been reported to be infected by different pests and diseases that directly affect regeneration. Hence, effective research to the problem is required to overcome this issue in an eco-friendly way. Use of artificial pesticides may be an option, but use of bio pesticides will be better for healthy ecosystem development. Germination of this species is low, and seedlings are few. Further study of germination and seed viability of this species in different environmental conditions is required.

Inter-specific competition is common in natural ecosystems, and it is a major determinant of population structures. Further study is needed to observe the impact of *Excoecaria agallocha* and other species on the life cycle of *H. fomes*. The awareness programs regarding importance of biodiversity and sustainable utilization of the resources to be conducted in regular intervals in the coastal areas. Government and local community should involve in plantation of *H. fomes* in suitable areas where the salinity level is low and sufficient supply of fresh water is available. Tree cutting should be completely avoided providing alternative livelihood for the local communities. The Coconut plantation, oil extraction, tourism promotion, and small scale industry development can be seen as alternatives for livelihood development for the associate communities. Further, climate change and sea level rise may negatively affect existence of this species (increase in salinity level) and appropriate adaption strategies may be taken for conservation of the globally threatened mangrove species *H. fomes* prior to its extinction in the region.

In summary, well-organized and coordinated efforts of researchers, forest managers, and administrators are needed to achieve the goal of *H. fomes* conservation. Fruitful investment of funds, effective implication of policies, continuous supervision, and evaluation are key to effective conservation strategies.

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COMMUNICATION

Additions to the lichenized and lichenicolous fungi of Jammu & Kashmir from Kishtwar High Altitude National Park

Vishal Kumar [1], Yash Pal Sharma [2], Siljo Joseph [3], Roshinikumar Ngangom [4] & Sanjeeva Nayaka [5]

[1,3,4,5] Lichenology Laboratory, CSIR-National Botanical Research Institute, Rana Pratap Marg, Lucknow, Uttar Pradesh 226001, India.
[1,2] Department of Botany, University of Jammu, Jammu & Kashmir 180006, India.
[1] vishalbotany2014@gmail.com, [2] yashdbm3@gmail.com, [3] siljokl@gmail.com [4] rkngangom@gmail.com,
[5] nayaka.sanjeeva@gmail.com (corresponding author)

Abstract: The present study reports 14 lichenized and two lichenicolous fungi new to the mycota of Jammu & Kashmir. The lichenized fungi are *Buellia aeruginascens* (Nyl.) Zahlbr., *Caloplaca pachycheila* Poelt & Hinter., *Cladonia cervicornis* ssp. *verticillata* (Hoffm.) Ahti, *Hafellia curatellae* (Malme) Marbach, *Hafellia subnexa* Marbach, *Hafellia tetrapla* (Nyl.) Pusswald, *Leptogium askotense* D.D.Awasthi, *Nephromopsis laii* (A. Thell & Randlane) Saag & A.Thell, *Polycauliona phlogina* (Ach.) Arup, Frödén & Søchting, *Pyxine cognata* Stirt., *Rinodina conradii* Körb., *Rinodina intermedia* Bagl., *Rinodina oxydata* (A.Massal.) A.Massal., and *Squamulea squamosa* (B.deLesd.) Arup, Søchting & Frödén. The lichenicolous fungi include *Abrothallus microspermus* Tul. and *Lichenoconium lecanorae* (Jaap) D.Hawksw. The species are enumerated along with their present distribution.

Keywords: Ascomycota, biodiversity, northern India, taxonomy, the Himalaya, union territory.

موجودہ مطالعہ میں ۱۴ لائیکنائزڈ اور دو لائکنیکولس فنگی کی اطلاع دی گئی ہے جو کہ جموں و کشمیر کے مائکوٹا کے لئے نئی ہیں ۔ لائسنائزڈ فنگی بوئیلیا ایروگیناسینس ،کیلوپلاکا پیچیچیلہ ،کلاڈونیا سرویکورنس ایس ایس پی ورٹیسلاٹا ، بافیلیا کورٹیلی بافیلیا سبنیکسا ، بافیلیا ٹیٹراپلا ، لیپٹوجیم اسکوٹینس ، نیفروموپسس لائنئی ، پولیکولینا فلوجنا ، پیکسین کوگناٹا ، رینوڈینا کونراڈائی ، رینوڈینا انٹرمیڈیا۔ رینوڈینا آکسیڈیٹا ، اور سکومیلیا سکوآموسہ موجود ہیں۔ ان کے علاوہ دو لایکنکولوس فنگی ابروتھالس مائکرو اسپرمس اور لایکنوکونیم لیکنورئی بھی شامل ہیں۔ساتھ ہی تمام انواع کے موجودہ پھیلاو کا بھی شمار کیا گیا ہے۔

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Author details: Vishal Kumar is a PhD Scholar and also working as a project associate at Lichenology Laboratory. He has been working on the diversity of lichens of KHANP. Dr. Yash Pal Sharma is a professor of Botany and coordinator of UGC SAP DRS-II. His expertise includes mycology, plant pathology, and mushroom biology. Dr. Siljo Joseph is DST-Inspire faculty. His expertise includes taxonomy of Arthoniales, a primitive group of lichens and lichenicolous fungi. Roshinikumar Ngangom is a junior research fellow. Dr. Sanjeeva Nayaka is senior principal scientist. His expertise includes taxonomy of microlichens especially *Lecanora sensu lato* group.

Author contributions: VK contributed to field survey, lichen collection, identification and manuscript writing; YPS designed the study and contributed in collection of lichen specimens and improved the manuscript; SJ contributed in identity confirmation of lichenized and lichenicolous fungi and improved the manuscript; RN identified the *Buellia* and *Hafellia* species and manuscript writing; and SN contributed in identity confirmation of species and improvement of the manuscript.

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INTRODUCTION

The union territory of Jammu & Kashmir (J&K) represents a predominant Himalayan landscape which lies between coordinates 32.733–36.966 N latitudes and 73.433–80.5 E longitudes and is one of the 'hotspots' of lichen diversity in India (Sheikh et al. 2006). Due to great altitudinal variation, unique terrain, diverse vegetation, and varied climate, J&K offers a wide range of habitats for the growth and colonization of lichenized fungi.

Kishtwar High Altitude National Park (KHANP) situated in district Kishtwar of J&K is surrounded by beautiful snow-capped Himalaya and lies between coordinates 75.990E longitude and 33.582N latitude. The national park covers an area of approximately 2,200 km^2 with an altitude range of 1,200–6,000 m. KHANP experiences temperate to alpine climatic regimes. The average temperature during the summer months is 16 °C and in winter months it ranges 9–11 °C. The average annual rainfall is about 920 mm. The upper reaches of KHANP are characterized by severe and prolonged winter and short summer seasons. The prominent vegetation includes both coniferous and broad-leaved deciduous forests. *Abies pindrow* (Royle ex D.Don) Royle, *Pinus wallichiana* A.B.Jacks., *P. gerardiana* Wall. ex D.Don, and *Cedrus deodara* (Roxb. ex D.Don) G.Don are the prominent conifers. At lower elevations, *Quercus oblongata* D.Don, *Q. floribunda* Lindl. ex A.Camus, *Aesculus indica* (Wall. ex Cambess.) Hook., *Juglans regia* L., *Prunus persica* (L.) Batsch, *Pyrus pashia* Buch.-Ham. ex D.Don, and *Fraxinus excelsior* L. are prominent.

Smith (1931), Schubert & Klement (1966), and Awasthi & Singh (1970) are the pioneer contributors to lichen study in J&K. Later, several researchers (Sheikh et al. 2006, 2009; Khan et al. 2010; Solan et al. 2010; Kumar et al. 2012; Khare et al. 2020) made significant contributions towards understanding the lichen mycota of the region. Recently, Khare et al. (2020) compiled an inventory reporting 424 lichen species from the J&K, while Kumar & Sharma (2020) added five species of parmelioid lichens from KHANP as new additions to the lichen mycota of J&K.

The studies on the lichenicolous fungi in India have been initiated recently with the publication of the first list of these fungi by Zhurbenko (2013) that included 42 taxa based on the collections from J&K. Afterwards, Joshi (2018), and Joshi et al. (2016, 2018, 2020a,b) made noteworthy contributions to this group of organisms from J&K. However, no exhaustive documentation of the lichenized and lichenicolous fungi has been attempted for KHANP. While inventorying the lichen mycota of KHANP the authors came across several interesting specimens of lichenized and lichenicolous fungi.

MATERIALS AND METHODS

The lichen specimens were collected from different localities of the KHANP during 2017–2020. The samples were preserved in the herbaria of University of Jammu (HBJU) and CSIR-National Botanical Research Institute, Lucknow (LWG). The morpho-anatomical characters were studied under a stereo-zoom (Leica S8APO) and compound microscope (Leica DM2500), and identified by following the literature (Awasthi 1991, 2007; Joshi 2008; Marbach 2000; Hawksworth et al. 2010; Sheard 2010; Singh & Sinha 2010). The chemistry was studied through spot tests and thin layer chromatography (solvent system C) was performed following Orange et al. (2001). A brief description of only lichenicolous fungi are provided as they are not readily available.

RESULTS

Enumeration of lichenized fungi

1. ***Buellia aeruginascens*** (Nyl.) Zahlbr., Cat. Lich. Univers. 7: 331. 1931. *Lecidea disciformis* var. *aeruginascens* Nyl., Bull. Soc. linn. Normandie, sér. 2 2: 191. 1868. (Caliciaceae) (Image a).

Specimen examined: HBJU 16052, 10.xi.2020, J&K, Kishtwar district, KHANP, Palmar, on bark, 33.455N, 75.684E, 2,513 m, coll. V. Kumar & Y.P. Sharma.

Distribution: India (Mizoram) (Logesh et al. 2017), Chile, South America and Australia (Hafellner et al. 1989).

2. ***Caloplaca pachycheila*** Poelt & Hinter., Biblioth. Lichenol. 50: 168. 1993. (Teloschistaceae) (Image b).

Specimens examined: HBJU 16044, 17.vii.2018, J&K, Kishtwar district, KHANP, Palmar, on rock, 33.456N, 75.685E, 2,510 m, coll. V. Kumar & Y.P. Sharma; LWG19-035707 22.iv.2019, J&K, KHANP, Sonder, on rock, 33.471N, 75.826E, 2,090 m, coll. V. Kumar & Y.P. Sharma.

Distribution: India (Uttarakhand) (Mishra & Upreti 2015), and Pakistan (Poelt & Hinteregger 1993).

3. ***Cladonia cervicornis* ssp. *verticillata*** (Hoffm.) Ahti, The Lichenologist 12: 126 1980. *Cladonia verticillata* (Hoffm.) Schaer., Lichenum Helveticorum Spicilegium. 1: 31 1823. (Cladoniaceae) (Image c).

Specimens examined: HBJU 16060, 17.vii.2018,

J&K, Kishtwar district, KHANP, Ekhala, on soil 33.451N, 75.738E, 1,750 m, coll. V. Kumar & Y.P. Sharma; LWG 18-035706 17.vii.2018, on soil 33.470N, 75.819E, 2,100 m, coll. Kumar & Y.P. Sharma.

Distribution: India (Manipur, Meghalaya, Uttarakhand, and West Bengal) (Awasthi 2007) and widely distributed in Asia, Australasia, Europe, and America (Ahti 2007).

4. ***Hafellia curatellae*** (Malme) Marbach, Biblioth. Lichenol. 74: 255. 2000. *Buellia curatellae* Malme, Arkiv før Botanik 21A 14: 18 1927. (Caliciaceae) (Image d).

Specimen examined: HBJU 16047, 22.iv.2019, J&K, Kishtwar district, KHANP, Sonder, on twigs of *Cedrus deodara,* 33.469N, 75.828E, 2,240 m, coll. V. Kumar & Y.P. Sharma.

Distribution: India (Andhra Pradesh, Mizoram, Odisha, and Tamil Nadu) (Singh & Sinha 2010; Reddy et al. 2011; Nayak et al. 2016; Logesh et al. 2017), Africa, Australia, Brazil, New Caledonia, Papua New Guinea, Sri Lanka, and Thailand (Marbach 2000; Weerakoon 2014).

5. ***Hafellia subnexa*** Marbach, Biblioth. Lichenol. 74: 285. 2000. (Caliciaceae) (Image e).

Specimen examined: HBJU 16049, 22.iv.2019, India, J&K, Kishtwar district, KHANP, Sonder, on twigs of *Cedrus deodara* 33.471N, 75.822E, 2,048 m, Vishal Kumar & Y.P. Sharma.

Distribution: India (Arunachal Pradesh) (Bajpai et al. 2018), Japan, Malaysia, Russia, Thailand (Marbach 2000; Buaruang et al. 2017; Ezhkin & Schumm 2018)

6. ***Hafellia tetrapla*** (Nyl.) Pusswald, Biblioth. Lichenol. 74: 288. 2000.

Buellia callispora var. *tetrapla* (Nyl.) J. Steiner, Bull. Herb. Boissier, sér. 2, 7: 645. 1907. (Caliciaceae) (Image f).

Specimen examined: HBJU 16050, 21.iv.2019, India, J&K, Kishtwar district, KHANP, Sonder, on twigs of *Cedrus deodara* 33.472N, 75.823E, 2,030 m, Vishal Kumar and Y. P. Sharma.

Distribution: India (Uttarakhand) (Singh & Sinha 2010; Rai et al. 2016), South America, Australia, Brazil, Hawaii, New Zealand, South Africa, Réunion, Nepal, and Uruguay. (Marbach 2000).

7. ***Leptogium askotense*** D.D.Awasthi, Norw. Jl Bot. 24: 63 1977. (Collemataceae) (Image g).

Specimens examined: HBJU 16054, 22.iv.2019, India, J&K, Kishtwar district, KHANP, Ekhala, on bark 33.450N, 75.739E, 1,830 m, Vishal Kumar & Y.P. Sharma;

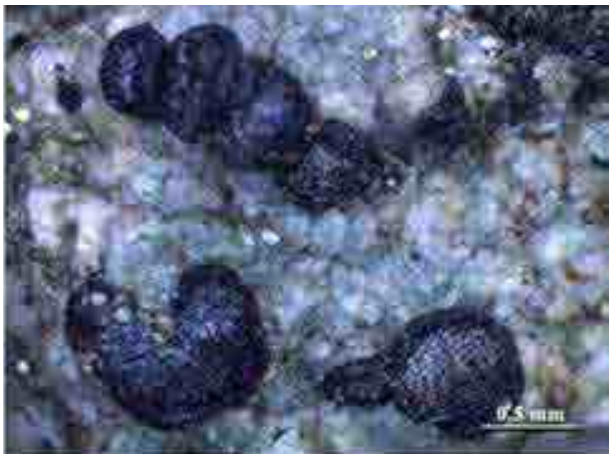

Image a. *Buellia aeruginascens* (Nyl.) Zahlbr. © Lichen lab., CSIR-NBRI

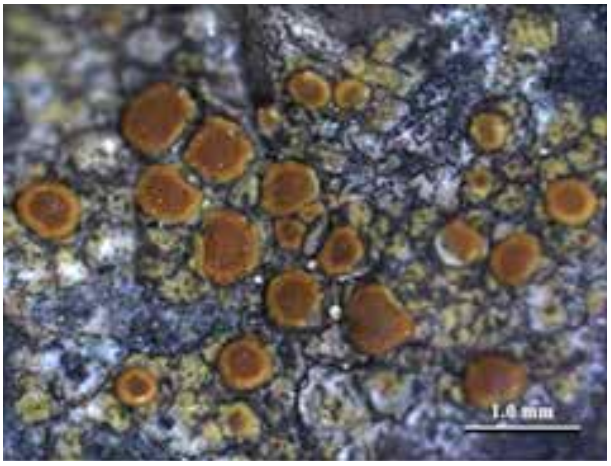

Image b. *Caloplaca pachycheila* Poelt & Hinter. © Lichen lab., CSIR-NBRI

Image c. *Cladonia cervicornis* subsp. *verticillata* (Hoffm.) Ahti. © Lichen lab., CSIR-NBRI

LWG19-035708, 22.iv.2019, on bark 33.451N, 75.741E, 1,750 m, Vishal Kumar & Y.P. Sharma.

Distribution: India (Arunachal Pradesh, Manipur, Sikkim, Uttarakhand, and West Bengal (Singh & Sinha 2010) and China (Xia et al. 2018).

8. ***Nephromopsis laii*** (A. Thell & Randlane) Saag & A. Thell, Bryologist 100: 111 1997. *Cetrariopsis laii* A.Thell & Randlane, Cryptogamie Bryologie Lichénologie 16: 46 1995. (Parmeliaceae) (Image h).

Specimen examined: HBJU 16092, 10.vii.2017, India, J&K, Kishtwar district, KHANP, Marwah, on bark 33.667N, 75.700E, 2,600 m, Vishal Kumar & Y.P. Sharma.

Distribution: India (Sikkim, Nagaland and West Bengal**),** China, Japan, Nepal, Taiwan and Vietnam (Singh & Sinha 2010).

9. ***Polycauliona phlogina*** (Acharius) Arup, Frödén & Søchting, Nordic Jl Bot. 31: 53 2013. *Parmelia citrina var. phlogina* Ach., Methodus, Sectio post. Stockholmiæ: 180 1803. *Scythioria phlogina* (Ach.) S.Y. Kondr., Kärnefelt, Elix, Thell & Hur, *Acta bota. Hung.* 56: 164 2014. *Caloplaca phlogina* (Ach.) Flagey, Mém. Soc. ému. Doubs, sér. 6 1: 250 1886. (Teloschistaceae) (Image i).

Specimen examined: HBJU 16074, 22.iv.2019, India, J&K, Kishtwar district, KHANP, Sonder, on decaying wood of *Cedrus deodara* 33.472N, 75.819E, 2,050 m, Vishal Kumar & Y.P. Sharma.

Distribution: India (Madhya Pradesh and Uttarakhand) (Joshi 2008), Caribbean, Fennoscandia, North America, and Mexico (Arup 2006).

10. ***Pyxine cognata*** Stirt., Proc. Roy. phil. Soc. Glasgow 11: 311 1879. *Pyxine berteriana* var. *himalaica* D.D. Awasthi, Phytomorphology 30: 366 1982. (Caliciaceae) (Image j).

Specimen examined**:** HBJU 16072, 17.vii.2018, India, J&K, Kishtwar district, KHANP, Palmar, on bark 33.455N, 75.683E, 2,500 m, Vishal Kumar & Y.P. Sharma.

Distribution**:** India (Arunachal Pradesh, Himachal Pradesh, Madhya Pradesh, Manipur, Nagaland, Tamil Nadu, and Uttarakhand (Singh & Sinha 2010)), Australia (Elix 2009), Brazil (Aptroot et al. 2014), China (Yang et al. 2019), and Thailand (Mongkolsuk et al. 2012).

11. ***Rinodina conradii*** Körb., Syst. lich. Germ.: 123 1855. (Physciaceae) (Image k).

Specimen examined: HBJU 16056, 10.vii.2017, India, J&K, Kishtwar district, KHANP, Marwah, on bark 33.669N, 75.700E, 2,530 m, Vishal Kumar & Y.P. Sharma.

Distribution: India (West Bengal hills) (Singh & Sinha

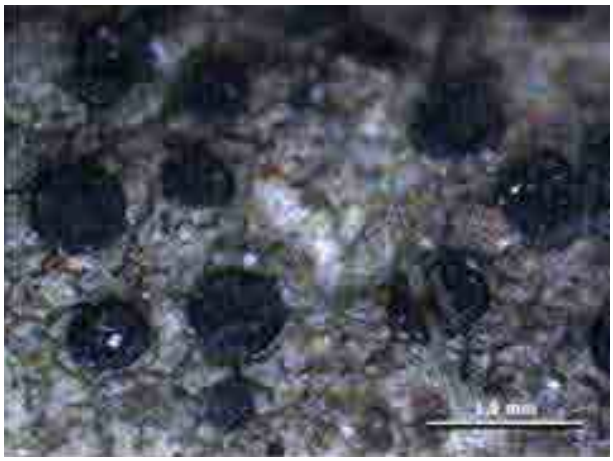

Image d. *Hafellia curatellae* (Malme) Marbach. © Lichen lab., CSIR-NBRI

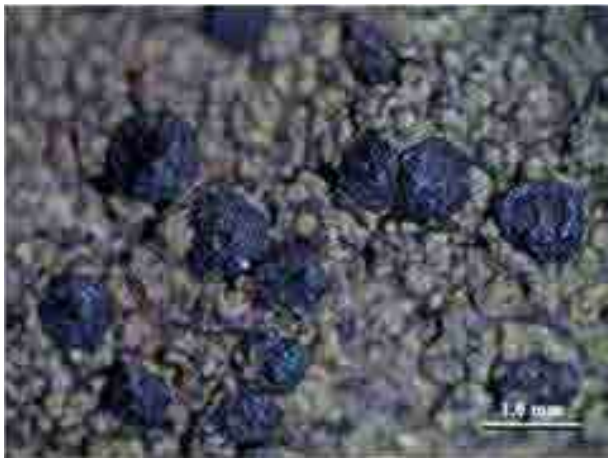

Image e. *Hafellia subnexa* Marbach. © Lichen lab., CSIR-NBRI

Image f. *Hafellia tetrapla* (Nyl.) Pusswald. © Lichen lab., CSIR-NBRI

Image g. *Leptogium askotense* D.D. Awasthi. © Lichen lab., CSIR-NBRI

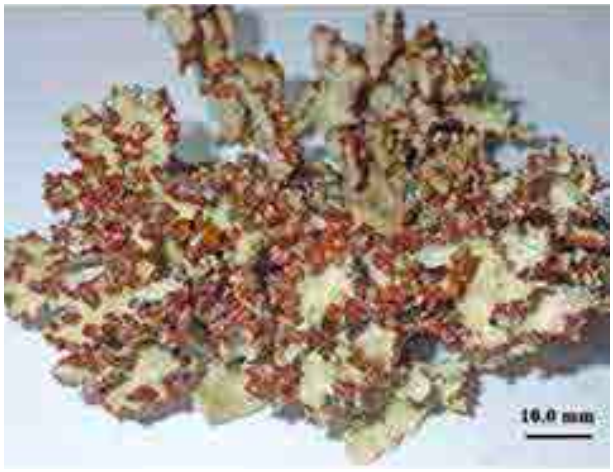

Image h. *Nephromopsis laii* (A. Thell & Randlane) Saag & A. Thell. © Lichen lab., CSIR-NBRI

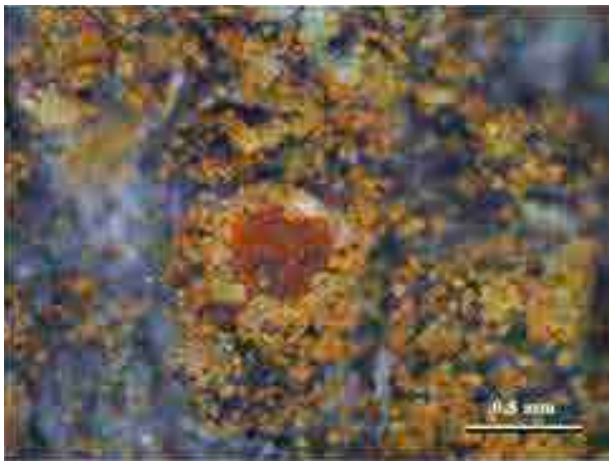

Image i. *Polycauliona phlogina* (Ach.) Arup, Frödén & Søchting. © Lichen lab., CSIR-NBRI

2010), Australia, Bhutan, New Guinea & New Zealand, and temperate regions of Northern America, central & southern Europe (Singh & Sinha 2010).

12. ***Rinodina intermedia*** Bagl., Comm. Soc. crittog. Ital. 1: 315 1863. (Physciaceae) (Image l).

Specimen examined: HBJU 16048, 10.vii.2017, India, J&K, Kishtwar district, KHANP, Marwah, on bark 33.669N, 75.703E, 2,400 m, Vishal Kumar & Y.P. Sharma.

Distribution: The species has a restricted distribution and is only known from Uttarakhand (Gupta et al. 2016) and West Bengal (Singh & Sinha 2010). The species is widely distributed in dry and warm temperate regions of northern hemisphere including Caribbean, Macaronesia, southern Europe, United Kingdom, Ecuador, Kenya, Africa, and South America (Mayrhofer et al. 2001).

13. ***Rinodina oxydata*** (A. Massal.) A. Massal., Geneacaena lichenum noviter proposita ac descripta: 19 1854. *Mischoblastia oxydata* A. Massal., Ricerche sull'autonomia dei licheni crostosi: 42 1852. (Physciaceae) (Image m).

Specimen examined: HBJU 16051, 17.vii.2018, India, J&K, Kishtwar district, KHANP, Palmar, on rock 33.456N, 75.685E, 2,510 m, Vishal Kumar & Y.P. Sharma.

Distribution**:** India (Assam, Madhya Pradesh, Tamil Nadu, Uttarakhand, West Bengal (Singh & Sinha 2010; Gogoi et al. 2019)), southern Africa, Asia, Australia, Brazil (Kashik 2006), eastern & southern North America, Scandinavia, and Europe (Sheard 2010).

14. ***Squamulea squamosa*** (B. de Lesd.) Arup, Søchting & Frödén, Nordic Jl Bot. 31: 56 2013. *Placodium squamosum* B. de Lesd., Annals Cryptog. Exot. 6: 123 1933. *Caloplaca squamosa* (B. de Lesd.) Zahlbr., Cat. Lich. Univers. 10: 629 1940. (Teloschistaceae) (Image n).

Specimen examined: HBJU 16079, 22.iv.2019, India, J&K, Kishtwar district, KHANP, Ekhala, on rock 33.449N, 75.741E, 1,810 m, Vishal Kumar & Y.P. Sharma.

Distribution**:** India (Uttarakhand) (Mishra & Upreti 2015), California and Arizona southwestern North America (Wetmore 2003).

Enumeration of lichenicolous fungi

1. ***Abrothallus microspermus*** Tul., Annls Sci. Nat., Bot., sér**.** 3 17: 115 1852. *Abrothallus smithii* var. *microspermus* (Tul.) Linds., Quart. J. Microscop. Sci. 5: 34 1857. (Abrothallaceae) (Image o).

Specimen examined: HBJU 16058, 19.vii.2019, India, J&K, Kishtwar district, KHANP, Marwah, on twigs 33.669N, 75.700E, 2,550 m, Vishal Kumar & Y.P. Sharma.

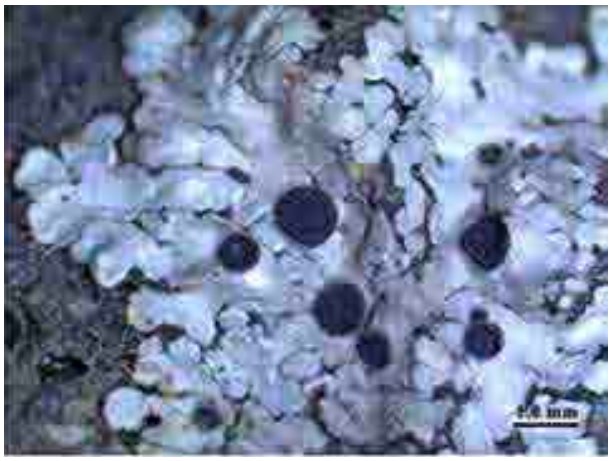

Image j. *Pyxine cognata* Stirt. © Lichen lab., CSIR-NBRI

Image k. *Rinodina conradii* Körb. © Lichen lab., CSIR-NBRI

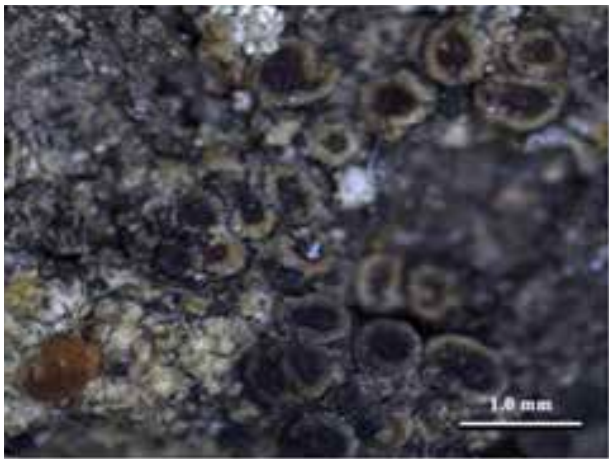

Image l. *Rinodina intermedia* Bagl. © Lichen lab., CSIR-NBRI

Description: Ascomata rounded, convex, black, 0.15–0.30 mm in diam., hymenium hyaline, hypothecium pale brown, Hymenium I–, K+ green. Asci 8-spored. Ascospores brown, 1-septate, 11–14.5 × 4.5–5.5 µm.

Host: *Punctelia neutralis* (Hale) Krog

Distribution: India (Arunachal Pradesh, Himachal Pradesh and Uttarakhand) (Joshi et al. 2018), Romania (Czarnota et al. 2018), Switzerland, Great Britain, southern Ural Mountains (Urbanavichene et al. 2013), North America (Cole & Hawksworth 2001, Diederich 2003, Kocourková et al. 2012), South Korea (Kondratyuk et al. 2013), and New Zealand (Longán & Gómez-Bolea 1999).

2. *Lichenoconium lecanorae* (Jaap) D. Hawksw., Bull. Br. Mus. nat. Hist., Bot. 6: 270 1979. *Coniosporium lecanorae* Jaap, Verh. bot. Ver. Prov. Brandenb. 47: 71 1905. (Abrothallaceae) (Image p).

Specimen examined: HBJU 16079, 21.iv.2019, India, J&K, Kishtwar district, KHANP, Sonder, on bark of *Cedrus deodara* 33.470N, 75.815E, 2,325 m, Vishal Kumar & Y.P. Sharma.

Description: Conidiomata pycnidia, scattered, blackish, ovoid, immersed to partially erumpent, 0.06–1.0 mm in diam., conidiophores absent, conidiogenous cells brown, conidia simple, brown, subglobose, 3.0–5.0 × 2.0–3.5 µm.

Host: *Lecanora* sp.

Distribution: India (Himachal Pradesh, Uttarakhand) (Joshi et al. 2016), Great Britain, Ireland, Canary Island, Spain (Hawksworth et al. 2010), and Ukraine (Darmostuk 2019).

DISCUSSION

The 16 species reported in the present study belong to 12 genera and eight families. Most of these species are crustose except for *Cladonia cervicornis* subsp. *verticillata* which is fruticose, while *Leptogium askotense*, *Nephromopsis laii* and *Pyxine cognata* are the foliose species. The study reports two interesting species of *Rinodina*, namely *R. conradii* and *R. intermedia* having 3-septate and submuriform ascospores respectively. Such species of *Rinodina* are rare in India, and previously, their distribution was confined to Uttarakhand and West Bengal. It is quite surprising that earlier workers overlooked both the species in the area, which is considered as the 'hot spot' of lichen diversity.

Further, among the 16 taxa reported as new to Jammu & Kashmir, the species *Buellia aeruginascens*,

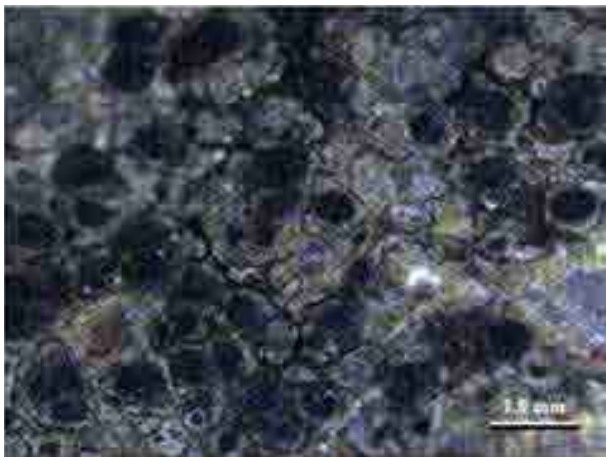

Image m. *Rinodina oxydata* (A. Massal.) A. Massal. © Lichen lab., CSIR-NBRI

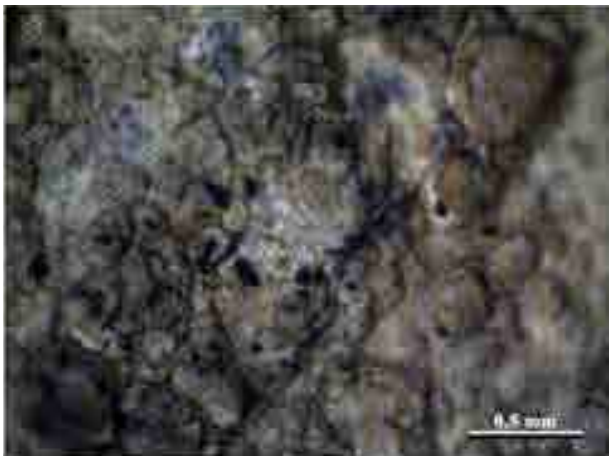

Image p. *Lichenoconium lecanorae* (Jaap) D. Hawksw. © Lichen lab., CSIR-NBRI

Image n. *Squamulea squamosa* (B. de Lesd.) Arup, Søchting & Frödén. © Lichen lab., CSIR-NBRI

Image o. *Abrothallus microspermus* Tul. © Lichen lab., CSIR-NBRI

Hafellia curatellae, Hafellia subnexa, *Rinodina conradii* and *Rinodina oxydata* were previously reported from the northeastern Himalaya. The distribution of these species in western Himalaya reveals the continuous distribution of these species throughout the Himalayan belt. Although, *Nephromopsis laii* so far known only from eastern Himalaya but some of the specimens available at LWG indicate its occurrence in western Himalaya. Two species of lichenicolous fungi, *Abrothallus microspermus* and *Lichenoconium lecanorae*, extend their distribution within India, and *Punctelia neutralis* is observed as a new host for *Abrothallus microspermus*.

In the recent inventory of lichenized fungi for Jammu & Kashmir, Khare et al. (2020) listed 424 species, however, they missed the inclusion of four species (*Cetraria potaninii*, *Montanelia sorediata*, *Xanthoparmelia somloënsis*, and *X. taractica*) reported by earlier workers. Meanwhile, Kumar & Sharma (2020), while compiling the family Parmeliaceae reported five species as new to J&K from KHANP. After the inclusion of four species missed by Khare et al. (2020), five species reported by Kumar et al. (2020) and 14 species reported in the present study, the total number of lichenized fungi in Jammu & Kashmir rises to 447 species. Compared to other states within western Himalaya, this number is less, whereas Himachal Pradesh (ca. 520 species) and Uttarakhand (ca. 1,200 species) with similar climatic conditions are well-explored for lichen diversity. Similarly, in the case of lichenicolous fungi, after adding two new records, the total is raised to 68 species, while neighbouring Himalayan states such as Uttarakhand harbour 101 species and Himachal Pradesh records 32 species.

CONCLUSION

The frequent encountering of previously unreported species from KHANP indicates the unexplored diversity of lichen and lichenicolous fungi. The unique topography, climate, and prevalence of broadleaved as well as coniferous and mixed forest stands in KHANP are the plausible habitats which support luxuriant growth and proliferation of both lichenized and lichenicolous fungi. However, KHANP needs to be surveyed intensively, especially in the high altitudinal and inaccessible areas. A thorough survey would yield many more new additions to J&K as well as novel taxa to science.

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SHORT COMMUNICATION

Is release of rehabilitated wildlife with embedded lead ammunition advisable? Plumbism in a Jaguar *Panthera Onca* (Mammalia: Carnivora: Felidae), survivor of gunshot wounds

Eduardo A. Díaz [1], Carolina Sáenz [2], E. Santiago Jiménez [3], David A. Egas [4] & Kelly Swing [5]

[1] Universidad San Francisco de Quito, Colegio de Ciencias de la Salud, Escuela de Medicina Veterinaria, Diego de Robles s/n, Quito 170901, Ecuador.
[1,2] Universidad San Francisco de Quito, Hospital de Fauna Silvestre TUERI, Diego de Robles s/n, Quito 170901, Ecuador.
[3,4] Universidad San Francisco de Quito, Colegio de Ciencias e Ingeniería, Departamento de Ingeniería Química, Diego de Robles s/n, Quito 170901, Ecuador.
[5] Universidad San Francisco de Quito, Colegio de Ciencias Biológicas y Ambientales, Estación de Biodiversidad Tiputini, Diego de Robles s/n, Quito 170901, Ecuador.
[1] eadiaz@usfq.edu.ec (corresponding author), [2] csaenz@usfq.edu.ec, [3] eder.jimenez@estud.usfq.edu.ec, [4] degas@usfq.edu.ec, [5] kswing@usfq.edu.ec

Abstract: Lead poisoning is a threat to wildlife, particularly after ingestion of lead ammunition derived from hunting activities. Little information, however, is available concerning plumbism in wild animals that survive the trauma associated with gunshot wounds. This study presents a possible example of lead intoxication by embedded pellets in a Jaguar *Panthera onca* nineteen months after being injured by a shotgun blast. In addition, the possible path of incorporation of lead into the trophic chain after the eventual release and death of an impacted animal, thereby expanding and prolonging the toxic effects of lead ammunition, is discussed. Direct intoxication by ammunition retained in the body of wild animals, as well as the indirect impacts on predators and scavengers that consume their flesh, should be sufficient reasons to reconsider the release of individuals with embedded lead ammunition into the wild.

Keywords: Blood lead levels, endangered species, lead-free ammunition, trophic web.

The Jaguar *Panthera onca,* is the largest American felid, and the only living representative of the genus *Panthera* in the New World (Caragiulo et al. 2016). Historically distributed from the southwestern United States to southern Argentina, Jaguars inhabit a wide range of ecological zones, from tropical moist forests, to xeric shrublands, to tropical dry forests, to grasslands and savannas (Sanderson et al. 2002). The IUCN Red List classifies the species globally as Near Threatened since 2002; the population trend is decreasing due to habitat loss and direct human persecution (Quigley et al. 2017). Currently, although the species is included in Appendix I of the Convention on International Trade in Endangered Species (CITES 2019), threats have continued or intensified at local and regional scales, and Jaguars have already disappeared from 55% of their historical range. The majority of subpopulations are Endangered

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or Critically Endangered (De la Torre et al. 2018). In Ecuador, where hunting remains one of the main threats to the species, two subspecies are separated by the Andean highlands, the Endangered *Panthera onca onca* from Amazon rainforest (Espinosa et al. 2011a), and the Critically Endangered *P. onca centralis* from the western coast (Espinosa et al. 2011b).

Lead ammunition is highly toxic for wildlife, especially in long-lived scavengers and predators (Gil-Sánchez et al. 2018). Intoxication of wildlife following ingestion of lead ammunition has long been recognized (Pain et al. 2019), contributing to population decline of some threatened species (Fernandez et al. 2011; Finkelstein et al. 2012; Garbett et al. 2018). Nonetheless, little is known about the impact of retained lead projectiles from gunshot wounds, despite a high incidence of embedded lead in wild animals secondary to hunting injuries (LaDoucer et al. 2015, Berny et al. 2017). This study describes lead poisoning through retained ammunition in an Endangered Amazon Jaguar subsequent to its recovery from multiple firearm injuries, and the possible incorporation of lead into the trophic chain after incidental ingestion by scavengers.

Material and Methods

On 31 October 2016, a juvenile female Jaguar was transferred from the province of Sucumbíos in northeastern Ecuador to the Wildlife Hospital TUERI of Universidad San Francisco de Quito (USFQ) for evaluation of injuries caused by a shotgun blast. Radiographic series (Sharp Ray LWX-20P) revealed the presence of 18 pellets scattered dorso-anteriorly; six of these were removed surgically (Image 1). The patient gradually improved and was transferred to the recovery center to complete the rehabilitation process two months after admission. In the following nine months, the Jaguar exhibited natural behaviors in terms of hunting and fishing, as well as aversion to and flight from human presence, which indicated excellent potential for successful release into the wild. Eleven months after her original injuries, the Jaguar was captured from its enclosure for clinical evaluation and to assess the possible reabsorption of embedded lead; blood lead levels (BLL) were measured by atomic absorption spectrophotometry (Buck Scientific 210VGP).

Showing no indications of complicating factors, the patient was clinically discharged but still held in

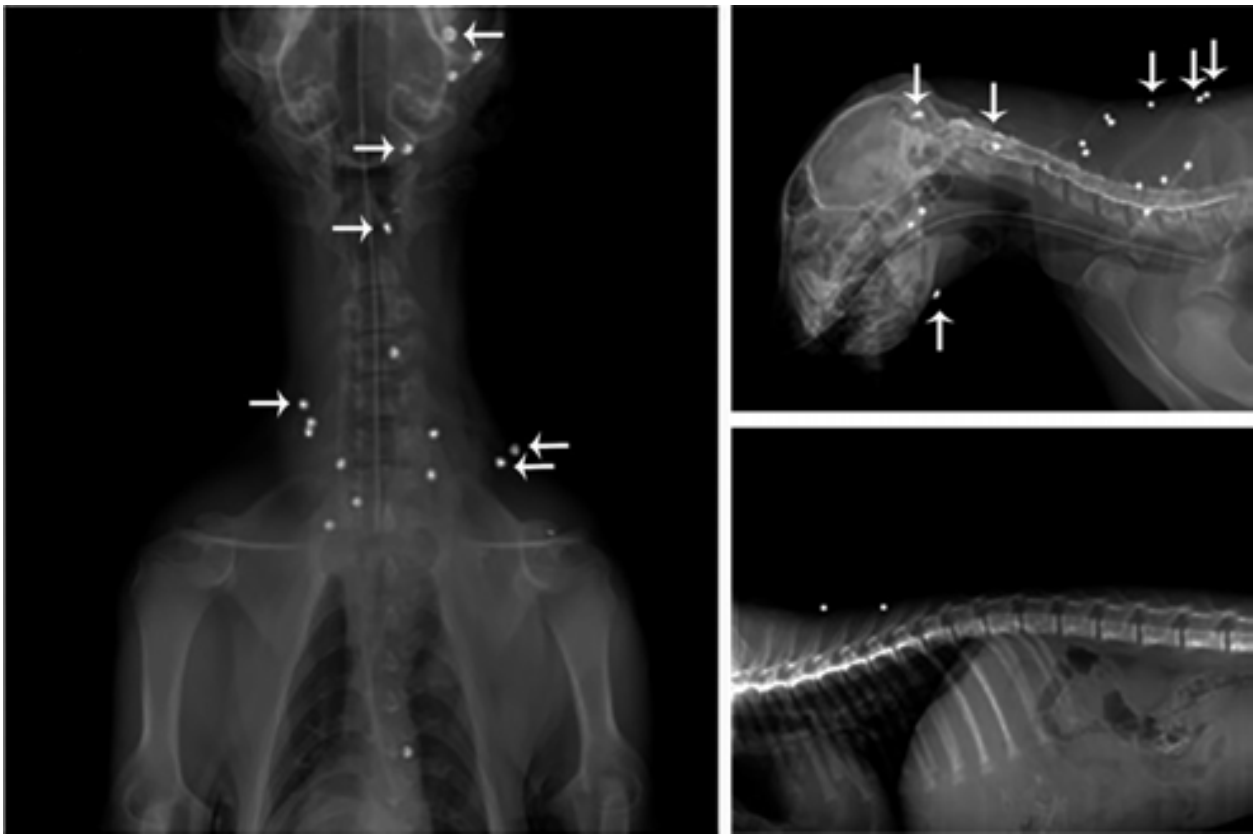

Image 1. Radiographs showing the presence of 18 lead pellets scattered dorso-anteriorly in a juvenile female Jaguar. Arrows indicate the six pellets removed surgically.

natural-setting captivity while her eventual release into a remote area of Yasuní Biosphere Reserve was planned. In the following eight months, she was captured twice more, specifically for the placement of a satellite collar (Telonics TGW-4577-4) for post-release monitoring, and ultimately to evaluate her overall condition for transfer to the release site. Following release on 21 May 2018, the Jaguar was tracked for four days after which the satellite device stopped transmitting movements; the animal was found dead four days later. The carcass presented an advanced state of decomposition and was being scavenged by vultures at the time of encounter. Remains were transferred to Wildlife Hospital TUERI for forensic analysis, including radiology (Sharp Ray LWX-20P) and scanning electron microscopy (JEOL JSM-IT300LA) of bones. Blood samples collected on the day of release were analyzed post-mortem by atomic absorption spectrophotometry (Buck Scientific 210VGP) to determine the possible reabsorption of embedded lead into general circulation.

Results

As previously mentioned, after surgery, twelve lead pellets remained embedded in the Jaguar's body; none within the digestive system or skeletal articulations (Image 1), sites classically considered to present elevated risks (Eward et al. 2011). Eleven months later, no clinical symptoms of lead intoxication were identified, and BLL measurement was negative to the sensitivity limit 0.001 µg/dl. After release, satellite tracking showed movement for four days – 2.7, 1.5, 1.2, and 0.3 km/day, respectively. The advanced state of decomposition presented by the carcass when located only allowed radiological examination; no superficial evidence of the cause of death could be ascertained due to the putrefied condition of the body. None of the 12 pellets remaining in the animal's body were detected by radiographic series. Scanning electron microscopy showed no traces of lead in the bone samples. Atomic absorption spectrophotometry analysis of blood samples collected on the day of the release revealed high BLL (1,223 µg/dl) in noteworthy contrast to earlier samples.

Discussion

Embedded lead has been identified as a risk factor causing plumbism in humans and experimental animals, but it has been poorly investigated in wildlife (LaDoucer et al. 2015; Berny et al. 2017). According to our knowledge, there are no data that relate the presence of embedded projectiles with BLL in wild mammals, but in humans, values greater than 25-40 µg/dL can cause symptoms that range from quite mild to coma and death (Bustamante & Macias-Konstantopoulos 2016). In the present study, no obvious outward symptoms were identified during the time that the Jaguar remained in captivity. Nevertheless, although BLL were not detected during the first eleven months, eight months later they reached one of the highest values recorded to date for a wild felid (Burco et al. 2012; North et al. 2015). This could be due to the type of exposure. In the case of chronic exposure, symptoms appear progressively and become incrementally more severe as time passes. Conversely, severe symptoms can erupt suddenly in acute exposures (Kim et al. 2015). Therefore, absence of evident clinical symptoms, and sudden death of the Jaguar, may have been due to acute absorption of lead.

Pain, weakened muscle strength, sensory abnormalities and brain inflammation can appear as acute symptoms in plumbism. More severe manifestations occur at very concentrated exposures, and symptoms abruptly worsen to include delirium, loss of muscular coordination, convulsions, ataxia, paralysis, coma and death (Sanders et al. 2009; Flora et al. 2012). Following release, satellite tracking revealed that the distance moved by the animal progressively decreased in the subsequent days (2.7, 1.5, 1.2, and 0.3 km/day).

In an effort to corroborate the hypothesis of acute exposure, a bone analysis was performed seeking to determine the presence of lead. The accumulation of lead in bones is indicative of long-term exposure due to its extended residence time, in contrast to BLL that is used to measure recent exposure because of the short half-life of lead in the blood (Green & Pain 2019). Scanning electron microscopy did not detect lead residues in bone samples, confirming that the embedded reabsorption would not have been chronic.

In most cases of plumbism, lead is ingested and absorbed into the bloodstream through the intestinal tract. Acute onset of nervous symptoms is a potential condition of captive felids fed hunted game animals (North et al. 2015). In our case, the Jaguar did not receive hunted meat or any other type of food that could contain traces of lead, making it is impossible that the poisoning occurred in this way; any BLL should come through reabsorption from the ammunition embedded in its body. In human cases, lead toxicity with intra-articular retained ammunition is indeed considered a risk, but extra-articular embedded lead, when difficult to extract, is routinely permitted to remain in tissues indefinitely without surveillance for lead toxicity. However, lead toxicity associated with extra-articular retained ammunition, although uncommon, may be

asymptomatic and difficult to diagnose yet debilitating and potentially lethal (Eward et al. 2011; Grasso et al. 2017). This fact could corroborate our findings in the present case. Although there seems to be no clear relationship between the amount of lead retained, residence time or location in the human body, embedded lead cannot be considered inert or safe (De Araújo et al. 2015).

Primary treatment in cases of retained lead ammunition usually includes chelation, followed by complete surgical removal of retained projectiles, in order to prevent systemic toxicity (Bustamante & Macias-Konstantopoulos 2016). Nevertheless, sometimes the elimination of projectiles would require complicated surgical approach resulting in extensive tissue dissection and high morbidity in a patient weakened by trauma (De Araújo et al. 2015). When surgical removal of ammunition fragments is contra-indicated, there are currently no long-term treatment methods available, since the source of exposure remains in the body, and prolonged chelation would cause adverse health effects such as hepatotoxicity or nephrotoxicity (McQuirter et al. 2004; Flora & Pachauri 2010). Therefore, these patients should be considered at chronic risk for lead poisoning and monitored periodically (Moazeni et al. 2014).

Finally, in the radiological tests performed on the Jaguar carcass, none of the 12 embedded pellets was detected. A likely explanation is incidental ingestion by scavengers; three species of vultures were identified next to the Jaguar cadaver: the American Black Vulture *Coragyps atratus*, the Greater Yellow-headed Vulture *Cathartes melambrotus*, and the King Vulture *Sarcoramphus papa*. Therefore, lead projectiles retained in the Jaguar's body could have had devastating effects not only for the Jaguar itself, but also for other species upon entering the trophic web through carrion consumers. In South America, with lead poisoning being a major widespread conservation threat for the Andean Condor *Vultur gryphus* (and probably for other sympatric carnivores also), urgent conservation actions to reduce this toxin in the wild are necessary (Wiemeyer et al. 2017). In this sense, evidence on the adverse effects of the use of lead ammunition on wildlife is ample. Because the change to non-toxic alternatives is possible and would allow important benefits for nature conservation (Kanstrup et al. 2018; Cromie et al. 2019), the strategy should be considered and implemented on a much broader scale.

In conclusion, some limitations of this work have been the lack of more thorough BLL monitoring during the time that the patient remained in captivity due to the difficult handling of the species, and the impossibility of assessing the presence of lead in other soft tissues after death because of the advanced state of decomposition in which the carcass was found. According to the authors' knowledge, the present study suggests for the first time that the presence of embedded pellets can be associated with a significant blood lead concentration in a wild felid. This situation reinforces the need for better understanding of the toxic effects of lead in wildlife surviving gunshot wounds. Until then, each patient with lead ammunition retained in its body should be considered at chronic risk for itself and a potential danger to other species that may eventually feed on it. Therefore, release of individuals with embedded lead projectiles should be carefully considered by wildlife managers when complete removal of lead fragments is not possible.

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SHORT COMMUNICATION

New record of the Sewing Needle Zipper Loach *Paracanthocobitis linypha* Singer & Page, 2015 (Teleostei: Cypriniformes: Nemacheilidae) from the Chindwin drainage of Manipur, India

Yumnam Rameshori [1], Yengkhom Chinglemba [2] & Waikhom Vishwanath [3]

[1–3] Department of Life Sciences, Manipur University, Canchipur, Manipur 795003, India.
[1] rameshori.yumnam@gmail.com, [2] chinglemba.yengkhom@gmail.com (corresponding author), [3] wvnath@gmail.com

Abstract: *Paracanthocobitis linypha* Singer & Page, a freshwater nemacheiline zipper loach, is reported for the first time from the Lokchao River of Manipur (headwaters of Chindwin drainage), in northeastern India. The species is diagnosed in having an incomplete lateral line, flank with 10–14 thin dark bars, long bars occasionally alternating with short bars extending up to about lateral mid-line, interspaces broader than bar width. Morphometric and meristic data of the examined specimens were compared with the original description to validate the species identity.

Keywords: Freshwater nemacheiline, Lokchao River, new report, northeastern India.

Fishes of the genus *Paracanthocobitis* Grant, 2007 are widely distributed in southern and southeastern Asia, ranging from the Indus drainage in eastern Pakistan to the Mekong drainage in Cambodia and Laos (Rainboth et al. 2012). The genus is diagnosed in having a thickened lower lip, swollen medially, densely covered by papillae, the two halves are in contact anteriorly and globulous medially, followed laterally up to the rictus by a thin, narrow, and smooth part; upper lip with several rows of papillae; 9½–15½ branched dorsal-fin rays; anus closer to anal-fin origin; male suborbital flap is located more posteriorly with its extremity under the middle of the eye, the lower edge of the lateral ethmoid is marked by a groove extending forwards beyond the nostrils (Kottelat & Vishwanath 2021).

Hora (1921) reported the presence of *Paracanthocobitis zonalternans* (Blyth, 1860) from the Chindwin drainage and *P. botia* (Hamilton, 1822) from the Brahmaputra drainage of Manipur, northeastern India. Recently, Kottelat & Vishwanath (2021) clarified that *P. zonalternans*, which Hora recorded from the Chindwin drainage is actually *P. marmorata* Singer et al., 2017. Additionally, Vishwanath & Laisram (2001) also clarified that Hora's report of *P. botia* from Manipur was erroneous as the collection was made from a place named Ghaspani in the present state of Nagaland, India, and extended the distribution of *P. botia* to the Barak drainage in Manipur.

A recent ichthyological survey in the Lokchao River of Manipur, Chindwin drainage, resulted in the collection of 10 specimens of *Paracanthocobitis*. After detailed examination, the specimens were identified as *Paracanthocobitis linypha* Singer & Page, 2015 and the species is hereby reported for the first time from the Chindwin drainage in Manipur, northeastern India.

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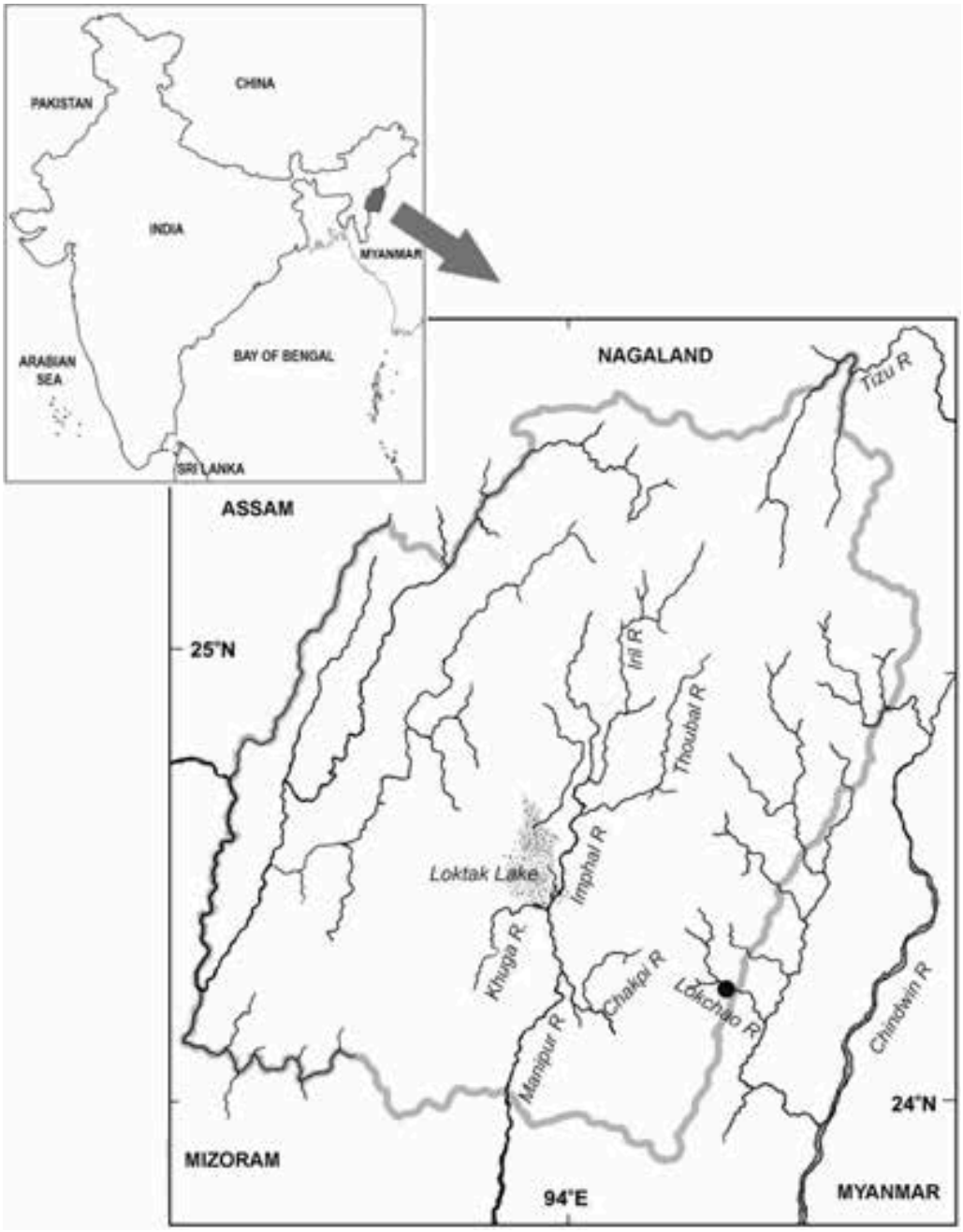

Figure 1. Map of Manipur showing the sampling site of *Paracanthocobitis linypha* in the Lokchao River, Chindwin drainage, northeast India.

Materials and Methods

Measurements and counts follow Singer & Page (2015). Measurements were made with digital callipers on the left side of the specimens to the nearest 0.1 mm. Measurements of body parts and head length are presented as proportions of standard length (SL) and subunits of head, as that of head length (HL). Fin rays, pores on lateral line and cephalic lateralis system were counted under a stereo-zoom microscope using transmitted and reflected light. The values in parenthesis following a count indicate the frequency of that count. Specimens are preserved in 10% formalin and deposited in the Manipur University Museum of Fishes (MUMF), Imphal.

Results

Paracanthocobitis linypha Singer & Page, 2015 (Image 1)

Common name: Sewing Needle Zipper Loach

Materials examined: MUMF 18051–18055, 5 ex.,

Image 1. Lateral view of *Paracanthocobitis linypha*, MUMF 18056, male, 41.7 mm SL. © Yumnam Rameshori.

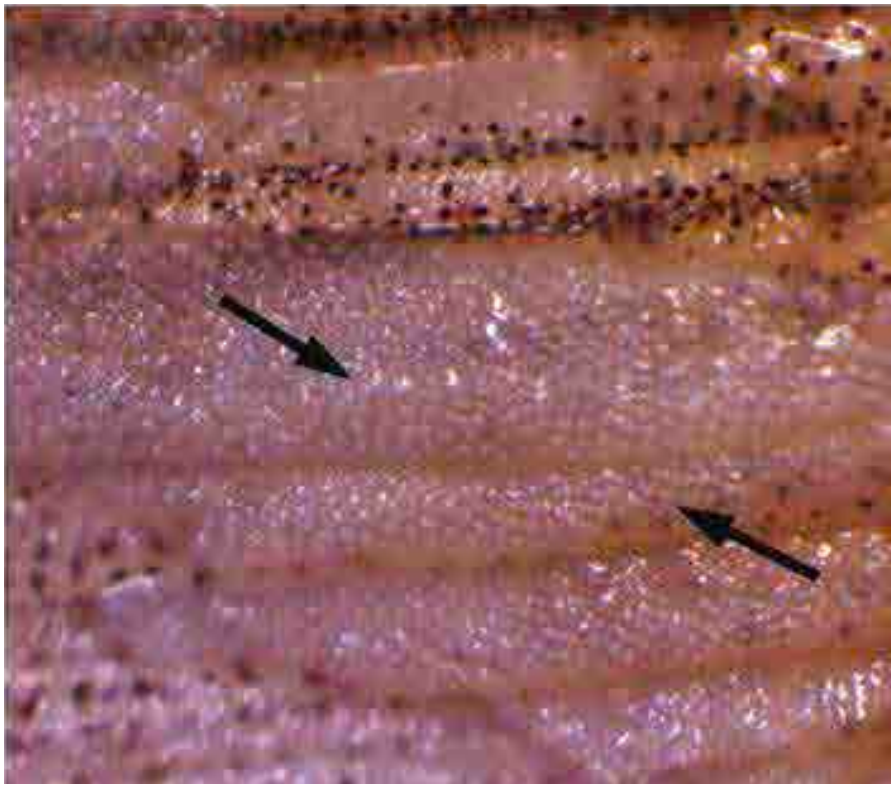

Image 2. Pectoral fin of male of *Paracanthocobitis linypha*, MUMF 18056, 41.7 mm SL, showing tubercles. © Yumnam Rameshori.

females, 09.v.2019, Lokchao River, Tengnoupal District, Manipur, India, 24.239°N 94.271°E, 261 m, 37.4–43.1 mm SL, coll. Yumnam Rameshori & Achom Darshan; MUMF 18056–18060, 5 ex., males, same data as above.

Diagnosis: *Paracanthocobitis linypha* is distinguished from all other species of *Paracanthocobitis* by the following combination of characters: 10–14 thin dark bars on flank, long bars occasionally alternating with short bars extending up to about lateral mid-line; interspaces wider than bars; an incomplete lateral line; absence of axillary pelvic lobe; males with suborbital flap.

Description: Morphometric and meristic data are presented in Table 1 and 2 respectively. Body moderately elongate, anterior sub-cylindrical, posterior compressed; body depth greatest at dorsal-fin origin. Dorsal profile of body arched, rising gently from tip of snout to dorsal-fin origin, then sloping evenly to caudal-fin base; ventral profile almost straight up to anal-fin origin, then inclined gently towards end of caudal peduncle. Head depressed, snout slightly rounded, maximum head width 1.6–1.9 times interorbital width. Eyes almost spherical, situated close to dorsal profile of head, nearer to tip of snout than to end of opercle, not visible in ventral view. Caudal

Table 1. Morphometric data of *Paracanthocobitis linypha* (n= 10).

	MUMF 18051–18060		Singer & Page (2015)
	Range	Mean ± SD	Range
Standard length (mm)	37.4–44.8		26.1–42.9
% SL			
Body depth	18.7–20.6	19.5±0.7	13.7–18.5
Head length	22.9–25.2	24.2±0.6	18.8–22.9
Caudal-peduncle depth	12.1–14.9	13.3±0.9	7.9–12.4
Pre-dorsal length	48.0–52.8	50.3±1.6	40.4–50.7
Pre-pelvic length	54.4–59.4	57.2±1.4	47.6–54.1
Pre-anal length	76.6–83.3	79.9±2.4	72.7–79.7
Snout length	8.4–10.0	9.5±0.5	6.0–9.0
Pectoral-fin length	20.2–25.9	23.2±2.3	17.5–21.8
Pelvic-fin length	16.9–20.1	18.7±1.0	15.5–18.0
% HL			
Eye diameter	21.0–25.0	23.0±1.0	24.0–30.9
Interorbital width	31.0–34.0	32.0±1.0	24.1–35.3

Table 2. Meristic counts of *Paracanthocobitis linypha* (n= 10).

	MUMF 18051–18060	Singer & Page (2015)
Branched dorsal-fin rays	8½ (2), 9½ (2), 10½ (6)	9½–11½
Branched anal-fin rays	5½ (10)	5½
Pectoral-fin rays	11 (8), 12 (2)	11–13
Pelvic-fin rays	7 (2), 8 (8)	8
Caudal fin ray count	8 + 8 (10)	8 + 8

peduncle 0.9–1.2 times longer than deep.

Body and belly completely covered by embedded scales. Lateral line incomplete, ending before end of adpressed pelvic fin, in some specimens reaches up to at least anal-fin origin. Cephalic lateral line system with 5–7 supraorbital, 3–4+10 infraorbital, 6 preoperculo-mandibular and 3 supratemporal pores. Anterior and posterior nostrils adjacent. Mouth moderately arched, about 1.7–2.1 times wider than long. Lips thin, fleshy and papillated. Processus dentiformis present. Lower lip with a deep medial interruption. Barbels 3 pairs; inner rostral barbel slightly extend beyond base of maxillary barbel, outer rostral and maxillary barbel reaching slightly beyond vertical to posterior rim of eye.

Dorsal fin with 8½ (2) or 9½ (2) or 10½ (6) branched rays, its origin slightly in advance to vertical of pelvic-fin origin. Anal fin with 5½ (10) branched rays; pectoral fin with 11 (8) or 12 (2) rays; pelvic fin with 7 (2) or 8 (8) rays. Axillary pelvic lobe absent. Caudal fin slightly emarginate to truncate, lobes equal, with 8+8 (10) branched rays.

Sexual dimorphism: Males with prominent suborbital flap; dorsal surface of pectoral fin of males with thick unculiferous pad covered by small conical tubercles (Image 2).

Coloration: In 10% formalin, body background pale yellowish with 10–14 thin dark bars on flank, most of them continuous with saddles on dorsum, long bars occasionally alternating with short bars extending up to about lateral mid-line; interspaces wider than bars. Dorsum of head with many dark spots. Dorsal fin with 5–6 rows of black spots. Pectoral, pelvic, and anal fin hyaline with little pigments on proximal end. An ocellus with more or less round black spot near dorsal margin of caudal-fin base. Caudal fin with 6–7 rows of V-shaped dark bands with vertices pointed towards distal end of caudal-fin.

Distribution: Presently known from the Irrawaddy and Sittang drainages in Myanmar. The occurrence of *Paracanthocobitis linypha* in the Lokchao River extends the natural occurrence range of the species into the Chindwin drainage of Manipur, northeastern India.

Discussion

Grant (2007) proposed *Paracanthocobitis* as a subgenus of *Acanthocobitis* Peters, 1861 with *Cobitis zonalternans* Blyth, 1860 as the type species. However, Kottelat (2012) did not recognize the subgenus *Paracanthocobitis* stating that the differentiating characters of *Paracanthocobitis* from *Acanthocobitis* are not clear, and the designation of the subgenus was not on the basis of actual examination of specimens, except one live individual and few photographs. Subsequently, Singer & Page (2015) recognized *Paracanthocobitis* as a distinct genus and listed 14 species including *P. linypha* which they described from the Irrawaddy and Sittang drainages in Myanmar.

At present, 18 species of *Paracanthocobitis* are considered valid (Fricke et al. 2021). The morphometric and meristic data of the examined *Paracanthocobitis* specimens collected from Manipur are in sync with the original morphometric and meristic data as well as characters in the description, except for few deviations such as body depth and pre-pelvic length (Table 1). Also, the examined specimens have 8½–10½ (vs. 9½–11½) branched dorsal-fin rays (Table 2). In the original description of *P. linypha*, the lateral line was suggested to end before distal end of adpressed pelvic fin; however, in some of the specimens examined from Manipur, lateral line reaches up to at least anal-fin

origin. These minor differences may be due to limited coverage of populations in the original description, and habitat variations. Detailed analysis is required to assess location-specific threats, and to understand the status and trends in population of the species.

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SHORT COMMUNICATION

Field identification characters to diagnose *Microhyla mukhlesuri* from closely related *M. mymensinghensis* (Amphibia: Microhylidae) and range extension of *M. mukhlesuri* up to West Bengal State, India

Suman Pratihar [1] & **Kaushik Deuti** [2]

[1] Department of Zoology, Sukumar Sengupta Mahavidyalaya, Keshpur, West Bengal 721150, India.
[2] Zoological Survey of India, Herpetology Division, 27 JL Nehru Road, Kolkata, West Bengal 700016, India.
[1] pratihar_vu@rediffmail.com (corresponding author), [2] kaushikdeuti@gmail.com

Abstract: *Microhyla mymensinghensis* and *Microhyla mukhlesuri* were recorded from West Bengal, also analyzed 12 characters to separate the species. We also hereby first time confirm the presence of *Microhyla mukhlesuri* from the main land in India

Keywords: Amphibia, first record, frogs.

Twenty-seven species have been described within the last 15 years (Frost 2021), yet *Microhyla* remains one of the most taxonomically exciting groups of Asian frogs. Microhylidae is one of the most species rich family of Anura, comprising 690 species in 12 subfamilies (Frost 2020). Previous mitochondrial phylogenies have confirmed that *Microhyla mukhlesuri* Hasan, Islam, Kuramoto, Kurabayashi & Sumida, 2014 is sister to *M. fissipes* Boulenger, 1884 and that together they are sister to *M. mymensinghensis* Hasan, Islam, Kuramoto, Kurabayashi & Sumida, 2014 (Hasan et al. 2014; Howlader et al. 2016; Yuan et al. 2016). Asian congeners, *M. chakrapanii* Pillai, 1977, *M. mukhlesuri*, and *M. mymensinghensis* are nested along with *M. fissipes* Boulenger, 1884 and together these four species are the sister group to the clade containing *M. mixtura* and *M. okinavensis* (Garg et al. 2019). The *M. fissipes* species group consists of two subclades (Poyarkov et al. 2019). Clade one species reported from Laos, Thailand, Myanmar, Philippines, Singapore, southrn Asia, and the Andamans (*M. fissipes, M. mukhlesuri*, *M. mymensinghensis, M. chakrapanii*). And the other clade comprising species from mainland China (Garg et al. 2019).

Microhyla mymensinghensis was first described from Mymensingh, Bangladesh together with *M. mukhlesuri* (see Hasan et al. 2014). *Microhyla mymensinghensis* was recorded from Manipur, Meghalaya, Nagaland, Tripura, and West Bengal in India. But *M. mukhlesuri* has been listed only from Mizoram state in the northeastern India (Garg et al. 2019). No details were reported to confirm the finding. Our study confirms the presence of both species in West Bengal, by analyzing 16 morphometric characters to separate these species. We also hereby confirm the presence of *Microhyla mukhlesuri* from

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the Gangetic Plain of West Bengal in India, as it was described from Bangladesh (Hasan et al. 2014).

Materials and Methods

Field work was conducted during late evening in the months of May–July 2020 in Kharagpur, Medinipur Sadar (22.2500˚N, 87.6500˚E), Ghatal and Jhargram (22.0559˚N, 87.1518˚E) areas of West Midnapore district in the state of West Bengal, India. Habitats searched included marshes, pools, riverbanks and sandy soils inside grass, leaf litter and under boulders. Morphometric and meristic studies on the preserved specimens were done at the laboratory of the Herpetology Division, Zoological Survey of India, Kolkata using a LEICA EZ-4 stereo binocular microscope and a Heerburg magnanoscope. Measurements were done with Mitutoyo Digital caliper to the nearest 0.1 mm. Four specimens were collected (ZSI A 14818, ZSI A 14819, ZSI A 14871 and ZSI A 14872) and identified as *Microhyla mukhlesuri* (Image 1a, Table 1a). Five specimens were collected (ZSI A 14680, ZSI A 14681, ZSI A 14682, ZSI A 14873 and ZSI A 14874) and identified as *Microhyla mymensinghensis* (Image 1b, Table 1b). We found no *Microhyla ornata* in the sampling site (Midnapore, West Bengal) during our survey.

For species-level analysis we examined 16 morphological characters to elucidate species identification (1) Body size (SVL) (2) Head length and head width (HL/HW) (3) extent of Tibiotarsal articulation (4) Shape of Terminal phalanges on toes (5) Shape and size of Inner and outer metatarsal, metacarpal tubercle; (6) Webbing on toes (7) length of femur and tibia (8) Dorsal spotting. (9) extent of Lateral stripe (10) pattern on the anus. (11) FAL= Forearm length, LAL= Lower arm length, HAL= Hand length, FAW= Forearm width 12. Axilla-Groin distance (A-G) (Table 1). We also have added HL, HW, FAW, TL and A-G ratios with SVL (Table no 2). We have grouped the species based on characters described by Hassan et al. (2014).

Principal Component Analysis (PCA) was performed on 16 morphometric measurements from specimens of both *Microhyla mukhlesuri* (n= 4) and *Microhyla mymensinghensis* (n= 5) using PAST 3.0 Software. Before doing the PCA, a normality test was done for all the variables. PCA factor scores for principal components (PC) with eigenvalues >1.0 were reported. Factor scores of the first two components were visualized

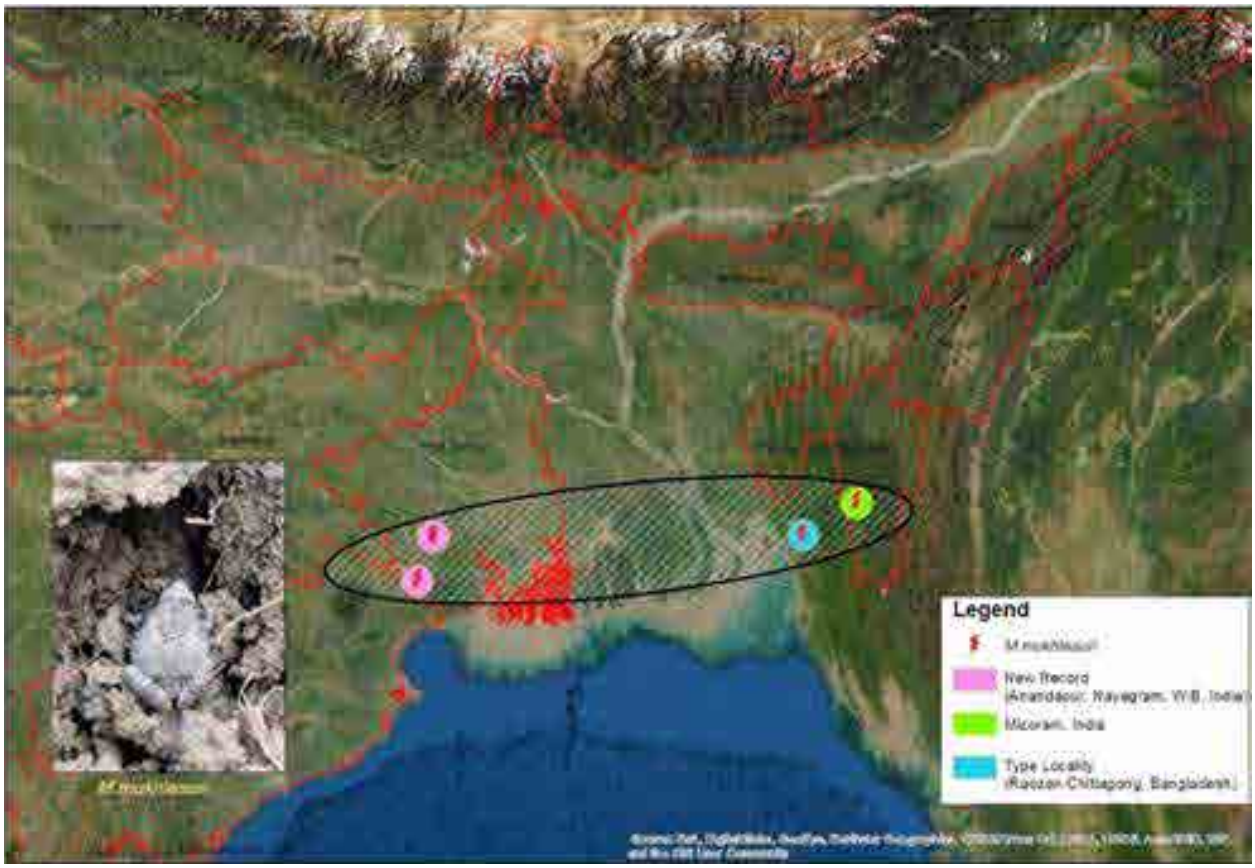

Image 1. Range extension of Microhyla mukhlesuri to West Bengal State.

Table 1a. Sixteen morphometric character values (in mm) for *Microhyla mukhlesuri*.

Specimen No	ZSI A 14819	ZSI A 14818	ZSI A 14871	ZSI A 14872	Mean
Sex	male	male	male	female	
SVL	20.86	18.92	19.84	20.76	20.09
HL	4.28	4.71	3.98	3.78	4.18
HW	4.56	5.44	4.35	4.36	4.67
SL	2.39	2.57	2.27	2.58	2.45
FAL	3	3.14	4.52	4.29	3.73
LAL	3.09	3.05	3.5	3.67	3.32
HAL	4.17	3.07	3.9	3.06	3.55
FAW	1.08	1.13	1.2	1.33	1.17
IMC	0.48	0.57	0.42	0.44	0.47
OMC	0.42	0.51	0.32	0.38	0.4
A-G	8.52	8.96	8.87	11.33	9.42
FL	8.15	8.23	8.18	8.41	8.24
TL	10.8	9.97	10.56	10.37	10.42
FoL	9.89	10.16	9.41	9.35	9.7
IMT	0.79	0.7	0.69	0.87	0.76
OMT	0.53	0.38	0.52	0.46	0.47

Table 1b. Sixteen morphometric character values (in mm) for *Microhyla mymensinghensis*.

Specimen No	ZSIA 14680	ZSIA 14681	ZSIA 14682	ZSIA 14873	ZSIA 14874	Mean
Sex	male	male	female	male	male	
SVL	17.72	18.07	17.97	18.86	17.22	17.96
HL	3.79	3.9	3.74	3.83	3.43	3.73
HW	4.45	5.71	4.42	4.72	5.23	4.9
SL	1.97	2.41	2.35	2.5	2.22	2.29
FAL	4.48	3.71	3.8	4.65	3.55	4
LAL	3.27	3.02	3.4	4.02	3.37	3.41
HAL	3.81	3.77	3	3.86	3.44	3.57
FAW	1.11	1.2	1.02	1.45	1.34	1.22
IMC	0.45	0.42	0.44	0.68	0.55	0.5
OMC	0.37	0.34	0.38	0.55	0.48	0.42
A-G	5.62	6.55	6.14	8.53	7.6	6.88
FL	6.16	6.43	7.94	7.94	6.62	7.01
TL	10.02	9.13	10.29	9.67	9.11	9.64
FoL	8.4	7.53	8.64	8.67	8.13	8.27
IMT	0.58	0.67	0.54	0.54	0.51	0.57
OMT	0.34	0.42	0.38	0.42	0.36	0.38

on scatterplots to assess the degree of morphological differentiation between specimens of the two species.

Results

Two *Microhyla* species were collected during the present study *Microhyla mukhlesuri* (n= 4) *and M. mymensinghensis* (n= 5). The specimens were identified to belong to the genus *Microhyla* by the following morphological characters: absence of vomerine teeth, hidden tympanum, elliptical tongue, short snout, small eyes not protuberant and invisible from the ventral side, indistinct canthus rostralis and fingers free of webbing. Four specimens were identified as *Microhyla mukhlesuri* (Image 2a) based on size, extent of tibio-tarsal articulation, mark on anus, forearm width, tibia length and shape of terminal phalanges (Garg et al. 2019; Hasan et al. 2014). This is the first record of *Microhyla mukhlesuri* from entire Gangetic plains of India, West Bengal (Nayagram, 22.0361˚N, 87.1717˚E) (Image 1) which extends its range by 494 km from its type locality (Rhozan, Chittagong, Bangladesh) and by 568 km away from Mizoram, India (which was the only record from India Garg et al. 2019). Whereas *M. mymensinghensis* (Image 2b) is identified based on size, tibia length, mark on anus and forearm width (Garg et al. 2019; Hasan et al. 2014). We found *M. mukhlesuri* differs from *M. mymensinghensis* by its relatively larger adult size (Garg et al. 2019) and inverse U-shaped black mark above the anus for *M. mukhlesuri* whereas crescent-shaped black mark present above the anus in *M. mymensinghensis* as described by Hassan et al. (2014).

Identifying taxonomic characters to differentiate *M. mukhlesuri* and *M. mymensinghensis* is problematic. Both species exhibit similar extent of tibiotarsal articulation (when the hind leg is adpressed) up to the snout or between the eye and snout and a lateral stripe that also extends to near the snout. Garg et al. (2019) paid attention to the shape of terminal phalanges, though the holotype description by Hassan et al. (2014) focused on forearm width, tibial length and mark on anus. We would like to focus on five putative distinguishing characteristics (a) an inverse U shape mark on the anus for *M. mukhlesuri* (vs crescent shaped mark in *M. mymensinghensis*) (Hassan et al. 2014); (b) a larger SVL in *M. mukhlesuri* (19.92–20.86 mm) (n= 4), vs. shorter (17.22–18.86 mm) (n= 5) in *M. mymensinghensis*, (c) *Microhyla mymensinghensis* has longer Tibia (TL) than *Microhyla mukhlesuri*, (d) *Microhyla mymensinghensis* has thicker fore-arm (FAW) than *Microhyla mukhlesuri* (Hassan et al. 2014), and (e) terminal phalanges of fourth toe tip knobbed but flattened in *M. mukhlesuri* (vs. knobbed but not flattened in *M. mymensinghensis*)

Image 2: a—*Microhyla mukhlesuri* (top) from Jhargram, West Bengal on 30 June 2020 during evening observation, in preservation | b—*M. mymensinghensis* (bottom) from Midnapore, West Bengal on 29 June 2020 during night, in life. © Suman Pratihar

(Garg et al. 2019) (Table 1). Based on these characters we have identified and classified the specimens examined in this study.

In addition to aforementioned described characters, we identified a few supplementary characters to differentiate two species more confidently: (a) shape of inner metacarpal tubercle elongated in *M. mukhlesuri* vs. rounded in *M. mymensinghensis*; (b) large inner metatarsal tubercle, i.e., about 0.76 (±.08) mm in *M. mukhlesuri* vs about 0.57 (±.06) mm in *M. mymensinghensis*; (c) most significantly, axilla-groin distance 47% of SVL in *M. mukhlesuri* vs 38% of SVL in *M. mymensinghensis.* Both these species were observed co-occurring in humanized / agricultural habitats in the sampled areas (Image 3a, b).

Microhyla mukhlesuri showed differences with *M. mymensinghenis* in terms of morphology. Principal Component Analysis (PCA) for the specimens of both the species (*M. mukhlesuri, n*= 4; *M. mymensinghensis, n*= 5) recovered two Principal Components (PC) with eigenvalues > 1.0 that accounted for 85.8% of the total variance. PC1 explained 74.09% variance with highest loadings for A-G, TL, SVL and FoL. PC2 explained 11.71% variance with highest loadings for A–G, and HW. The remaining factors explained 14.2% of the variations. For the combined data set for both male and female projections of the factor planes 1 and 2 showed distinct clusters for the two species (Figure 1).

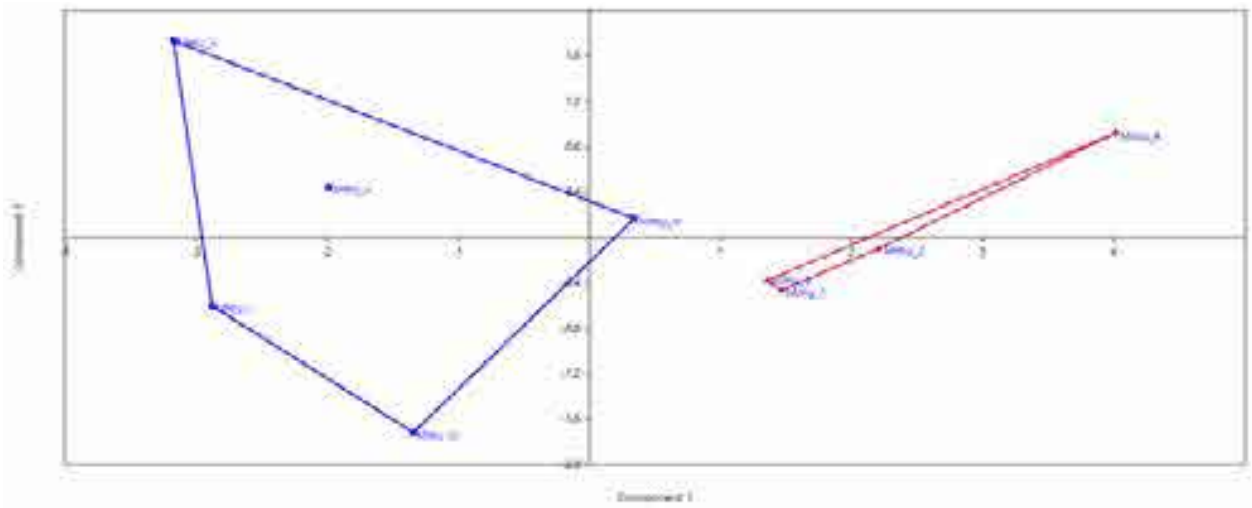

Figure 1. Principal component analysis (PCA) Scatter plot depicting morphometric differences between *Microhyla mukhlesuri* and *Microhyla mymensinghensis*.

Image 3. Habitat of (a) *Microhyla mukhlesuri* (left) and (b) *M. mymensinghensis* (right). © Chandan Dandapat

Table 2. Ratios of morphometric character values for *Microhyla mukhlesuri* and *Microhyla mymensinghensis.* For character abbreviations see Materials & Methods.

Ratios	*Microhyla mymensinghensis*	*Microhyla mukhlesuri*
HL/SVL	.21±.01	.22±.02
HW/SVL	.27±.04	.24±.03
FAW/SVL	.07±003	.06±.005
AG/SVL	.38±.04	.47±.06
TL/SVL	.54±.02	.51±.01
HL/HW	.76±.09	.89±.03

Discussion

Previously, *Microhyla 'ornata'* like species were grossly grouped with four known species—*M. mukhlesuri, M. mymensinghensis, M. nilphamariensis,* and *M. ornata*. In 2018 two well-supported species groups were established – (1) *M. mukhlesuri* and *M. mymensinghensis*, along with *M. fissipes* from southeastern and eastern Asia, and (2) *M. nilphamariensis* and *M. ornata*, along with *M. taraiensis* from Nepal (Garg et al. 2018). A prominent lateral stripe extends from belly to nostril in *M. mukhlesuri* and *M. mymensinghensis* whereas a less prominent lateral stripe extends from shoulder to belly in *M. nilphamariensis* and *M. ornata.*

An inverse U shape mark on the anus for *M. mukhlesuri* (vs crescent shaped mark in *M. mymensinghensis*); larger SVL in *M. mukhlesuri* (19.92–20.86 mm) vs. shorter (17.22–18.86 mm) in *M. mymensinghensis* and terminal phalanges of toes knobbed but tip flattened in *M. mukhlesuri* (vs. knobbed but not flattened in *M. mymensinghensis*) are used to group the two species. In addition to this we have identified axilla-groin distance, size of metatarsal tubercle and shape of metacarpal tubercle to differentiate these two species more confidently. The PCA results reveal two different clusters on the scatterplot, representing two different species – *Microhyla mukhlesuri* (n= 4) and *M. mymensinghensis* (n= 5).

Microhyla mukhlesuri has been reported only from Mizoram state in the northeast India (Garg et al. 2019). With two males and two female specimens we hereby for first time confirm the presence of *Microhyla mukhlesuri* from the Gangetic Plain in West Bengal, apart from Mizoram. We are optimistic about the wider distribution of *Microhyla mukhlesuri* in the Gangetic plains. Nevertheless we do encourage genetic studies of these *Microhyla* frogs, especially after finding geographic contact zones where two similar-looking, genetically-allied congeners *Microhyla mukhlesuri* and *M. mymensinghensis* co-occur, throwing open necessity for further fine-scale diagnosis, preferably morphological, between them.

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SHORT COMMUNICATION

First report of *Scipinia horrida* (Stål) (Heteroptera: Reduviidae) from Assam, with comments on related genus *Irantha* Stål

Anjana Singha Naorem [1], Santana Saikia [2], Anandita Buragohain [3], Rubina Azmeera Begum [4], Swapnil S. Boyane [5] & Hemant V. Ghate [6]

[1–4] Department of Zoology, Cotton University, Panbazar, Guwahati, Assam 781001, India.
[5,6] Post-Graduate Research Centre, Department of Zoology, Modern College of Arts, Science and Commerce (Autonomous), Shivajinagar, Pune, Maharashtra 411005, India.
[5] Present Address: Ashoka Trust for Research in Ecology and the Environment, Royal Enclave, Srirampura, Jakkur, Bengaluru, Karnataka 560064, India.
[1] anjanasingha@cottonuniversity.ac.in, [2] santanasaikia7@gmail.com, [3] anagohain30@gmail.com, [4] begumrubinaazmeera@gmail.com, [5] boyane.swapnil@gmail.com, [6] hemantghate@gmail.com (corresponding author)

Abstract: Presence of reduviid bugs *Scipinia horrida* (Stål, 1861) and *Irantha* sp., belonging to the family Reduviidae and subfamily Harpactorinae, is reported here for the first time from Guwahati, Assam. We provide images and comparative comments on these two bugs.

Keywords: Assassin bugs, Harpactorinae, Iranthini.

Four specimens of small reduviid bugs collected in Guwahati (Assam, India) were identified as *Scipinia horrida* (Stål, 1859) (three specimens) and *Irantha* sp. (one specimen) based on keys in Distant (1904). Distant (1904) had placed these two genera under 'division' Polididusaria (= Polididini Distant, 1904) stating that 'In this division the anterior femora are granulate, generally nodose or nodulose, and always spinous'. The genus *Irantha* Stål, 1861 was separated from closely related genus *Scipinia* Stål, 1861 on the basis of the length of the first two visible segments of labium. Thus the first joint of labium is longer than second in *Irantha* while the first and second joints are subequal in *Scipinia*.

Maldonado-Capriles (1990) included eight species under *Scipinia* in the Catalogue, of which only one, namely *S. horrida* is known from India. Huang et al. (2007) reviewed *Scipinia* and described one new species from China, thus the total number of species under this genus stands at nine. Ambrose (2006) listed *S. horrida* and stated its distribution as: China, India, Indonesia (Java), Myanmar, Philippines, and Sri Lanka; this list also included names of places from southern India and Calcutta (=Kolkata). Huang et al. (2007) also listed Sikkim as another locality along with several places from China. Apparently, *S. horrida* has not so far been recorded from Assam. Originally described as *Sinea horrida* Stål, 1859, the species was then transferred to the genus *Scipinia* Stål, 1861 of which it is the type species (Maldonado-

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Capriles 1990).

Three species of *Irantha* are known from India: (i) *I. armipes* (Stål, 1855), (ii) *I. consobrina* Distant, 1904, and (iii) *I. pepparai* Livingstone & Ravichandran, 1988; all these three species have been recorded from southern India (Ambrose 2006). We are, however, not aware of any *Irantha* recorded from Assam. *Irantha armipes* was originally described as *Harpactor armipes* by Stål (1855) and is the type species of the genus *Irantha* Stål, 1861; only three species were listed by Maldonado-Capriles (1990) (namely *I. armipes*, *I. consobrina*, and *I. bramarbas* Breddin, 1903) without reference to *I. pepparai*. Chen et al. (2005) described a new species of *Irantha* from China, *Irantha nigrina* Chen, Zhao & Cai, 2005 which then becomes the fifth species under this genus.

Both, *S. horrida* and *Irantha* sp. belong to the subfamily Harpactorinae, the largest subfamily of Reduviidae, with over 2,800 described species under 320 genera (Weirauch et al. 2014). Most of the members of this family are predators and play an important role in the ecosystem.

The genera *Scipinia* and *Irantha,* and the included species *Scipinia horrida* as well as *Irantha armipes,* have been redescribed in detail with several illustrations (see Chen et al. 2005; Huang et al. 2007), so here we are only giving brief comments and photographic illustrations of the two species. Comparative images of both these species are given here. The specimen of *Irantha* was collected in a spider web and because the genital region was damaged, we are treating that as *Irantha* sp. close to *I. armipes.* We are also providing some images of the type specimen of *I. armipes,* preserved in the Swedish Museum of Natural History, Stockholm, Sweden (NHRS). In the recent work Zhao (2008) placed *Irantha* and *Scipinia* under the new tribe Iranthini.

Methods

Scipinia specimens were collected from pigeon pea plantation of Horticulture Research Station, Guwahati, by hand picking method, killed with ethyl acetate and preserved in ethanol. For *Irantha* sp., a single damaged individual was found dead in a spider web. Specimens were studied under the Leica stereozoom (MZ6) and photographs were taken with an attached Canon PowerShot S50 camera. Several images of the bugs were stacked using Combine ZM software and the images were processed with Adobe Photoshop CS5. Measurements were done with Erma stage and ocular micrometre. For the preparation of male genitalia, the pygophore was separated from body by dipping the abdomen in hot KOH for 3–5 minutes and the insect was briefly rinsed with 5% acetic acid, washed in 70 % alcohol and dry mounted subsequently. Different views of pygophore were first photographed and then the phallus was removed after treating the pygophore in hot KOH further for 5 minutes. Pygophore and phallus were photographed under Leica as mentioned above.

Material examined: *Scipinia horrida* two males, one female; *Irantha* sp. one male (abdomen damaged). Both species were collected in Assam (Assam Insects nos. 16 to 18 (*Scipinia*), Assam Insects no. 19 (*Irantha*)). Specimens are currently preserved in Modern College, Pune.

Taxonomy

Reduviidae Latreille, 1807
Harpactorinae Amyot & Audinet-Serville, 1843.
Iranthini Zhao, 2008
Scipinia Stål, 1861 (type species *Sinea horrida* Stål, 1859)
Scipinia horrida (Stål, 1859)
For various other synonyms, please refer to Maldonado-Capriles (1990).

Brief description: Total length: Male 11 mm, female 11.5 mm. Colour and vestiture: Body mostly ochraceous; dorsally a narrow median region of anteocular and major postocular region of head, very narrow median region of anterior lobe of pronotum, lateral margins of scutellum, clavus and membrane of hemelytra, thoracic sterna, especially mesosternum, dark brown; lateral area of abdomen with blackish patches in basal half; legs with femora reddish-ochraceous, tibia and tarsi dark brown. Whole body covered with small, adpressed, yellowish setae and some scattered, long, transluscent setae, which are more numerous and conspicuous on legs (Image 1A); head and thoracic region densely pubescent on ventral side (Image 1C,F).

Structure: Head cylindrical; anteocular slightly shorter than postocular (much shorter than postocular if neck is included); deep transverse sulcus at level of eyes as seen laterally. Head dorsally bears three pairs of long spines: one pair near antennal base, one above eyes and one behind eyes, along with many (about 10 pairs) small spines in between long spines as well as in posterior part of head. Eyes globular, with its inferior margin not reaching ventral margin of head; ocelli widely separated and also far from eyes, situated near base of third spine on head (Image 1B,D). Antennae four segmented, first antennomere longest, remaining subequal. Labium with first visible segment slightly longer than visible segment II, visible segment III smallest. Thorax with pronotum almost hexagonal in shape, broadest in middle with

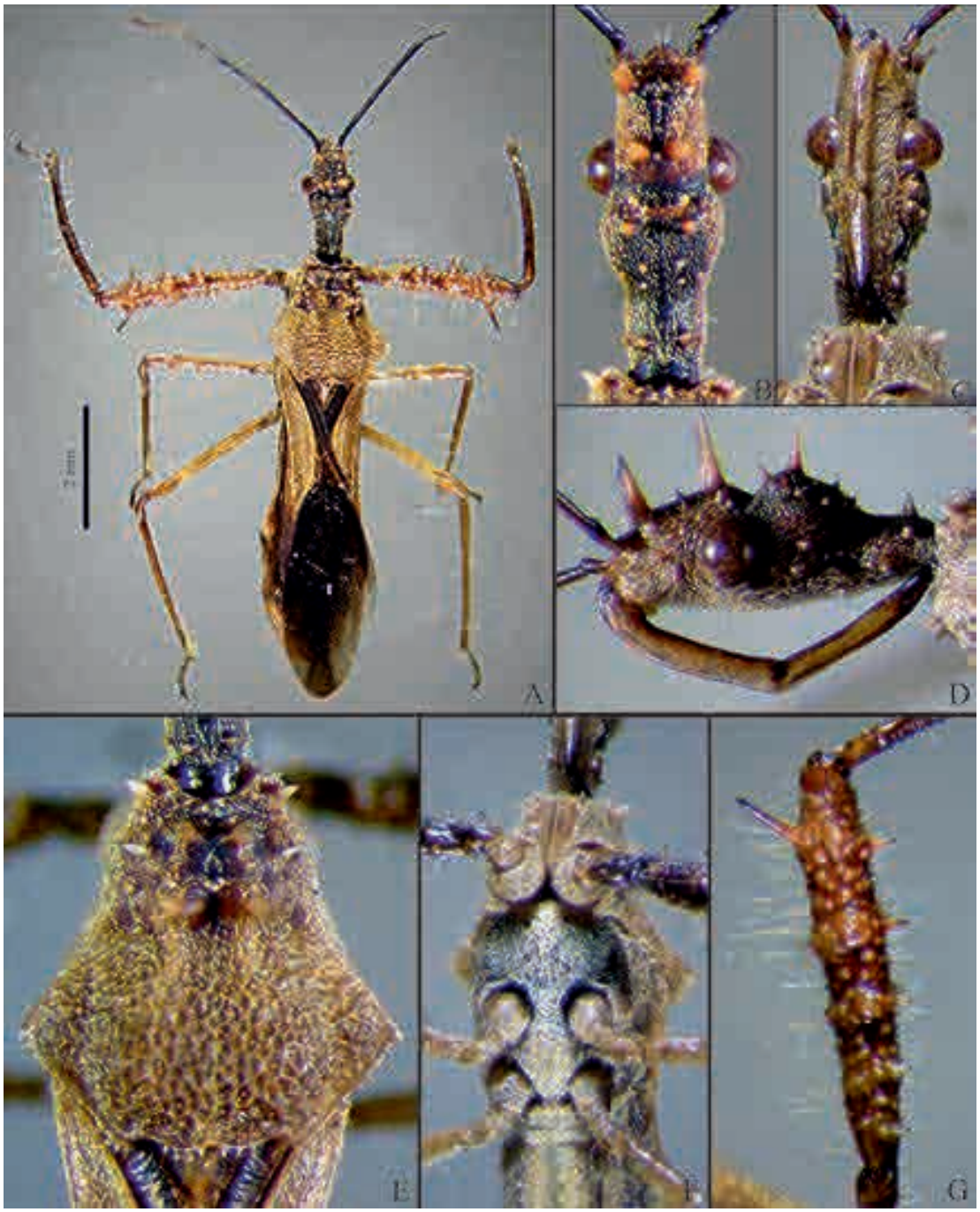

Image 1. *Scipinia horrida*: A—Dorsal habitus | B, C & D—Head in dorsal, ventral and lateral view, respectively | E—Pronotum in dorsal view | F—Thoracic sterna in ventral view | G—Fore femur. © H.V. Ghate.

angular humeral angles, narrowed at anterior and posterior margins, anterior margin straight, posterior margin strongly sinuate over scutellum; pronotum divided into small anterior and large posterior lobe; anterior lobe with many blunt tubercular spines and two pairs of large spines, posterior pair with Y shaped or bifurcate spines (Image 2A); posterior lobe strongly rugulose with beehive like pattern of deep punctures (Image 1E). Scutellum is very small and triangular. Abdomen, in case of male, is slim and slender, with almost triangular visible part of pygophore, in ventral view (Image 2B); in case of female, abdomen is dilated in fourth and fifth segment.

Legs with fore femur moderately incrassate, with numerous pale tubercles, armed with whorls of fine spines, one dorsoapical spine longest, projected

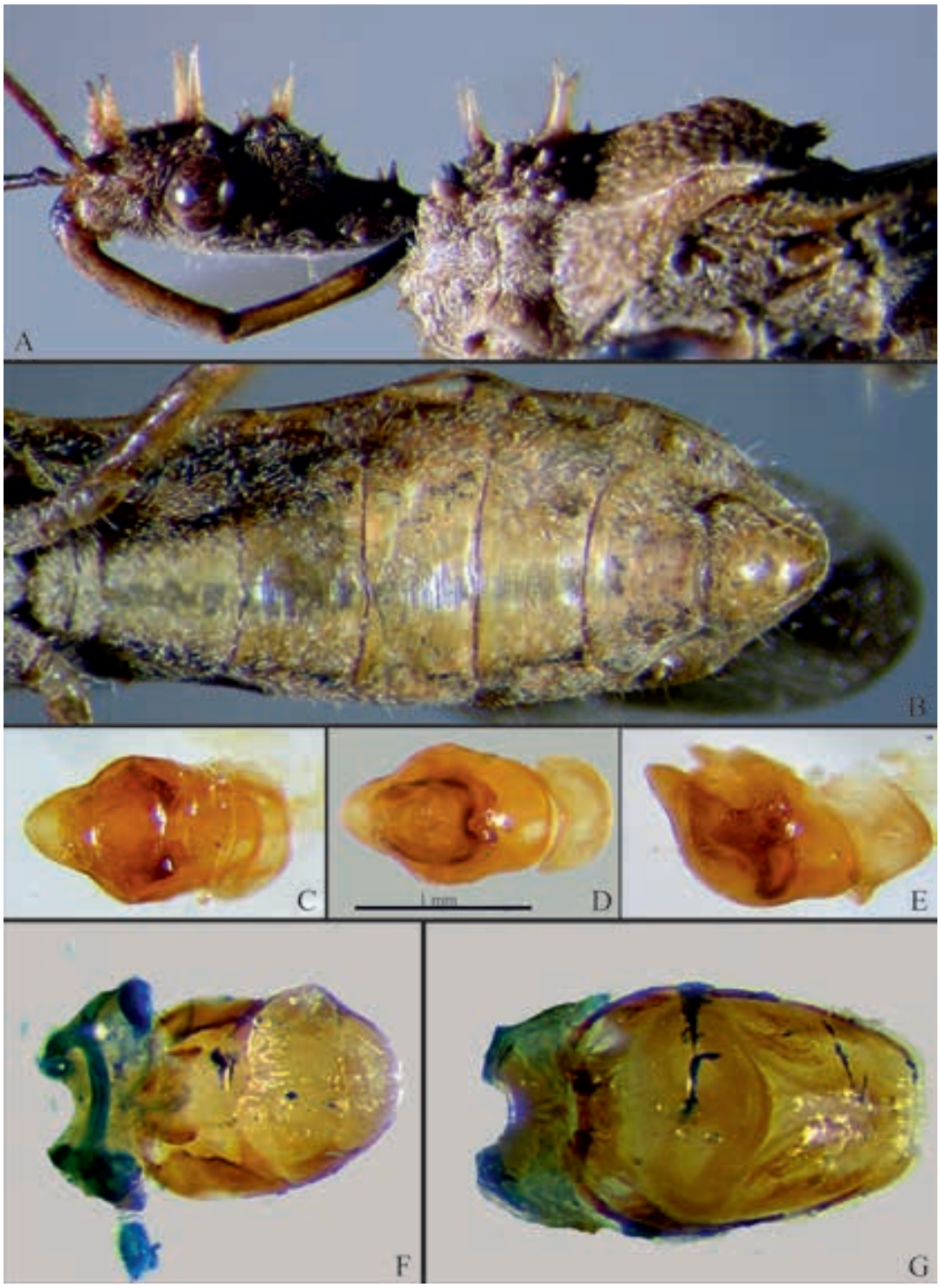

Image 2. *Scipinia horrida*: A—Lateral view of head and pronotum | B—Ventral view of abdomen | C–E—Pygophore in dorsal, ventral and lateral view, respectively | F & G—Phallus in dorsal and ventral view, respectively. © H.V. Ghate.

outwardly (Image 1A,G); tibia thin and slightly curved inward in distal one third, with many small tubercles ventrally and an apical large and triangular tubercle; tarsus three segmented, claws relatively long. Mid- and hind legs with some long spine like setae, femora slightly nodulose; mid legs shortest. Hemelytra pass beyond tip of abdomen.

Pygophore elongate oval, as shown here in dorsal, ventral and lateral views (Image 2C–E); parameres absent. Phallus in dorsal and ventral view is also

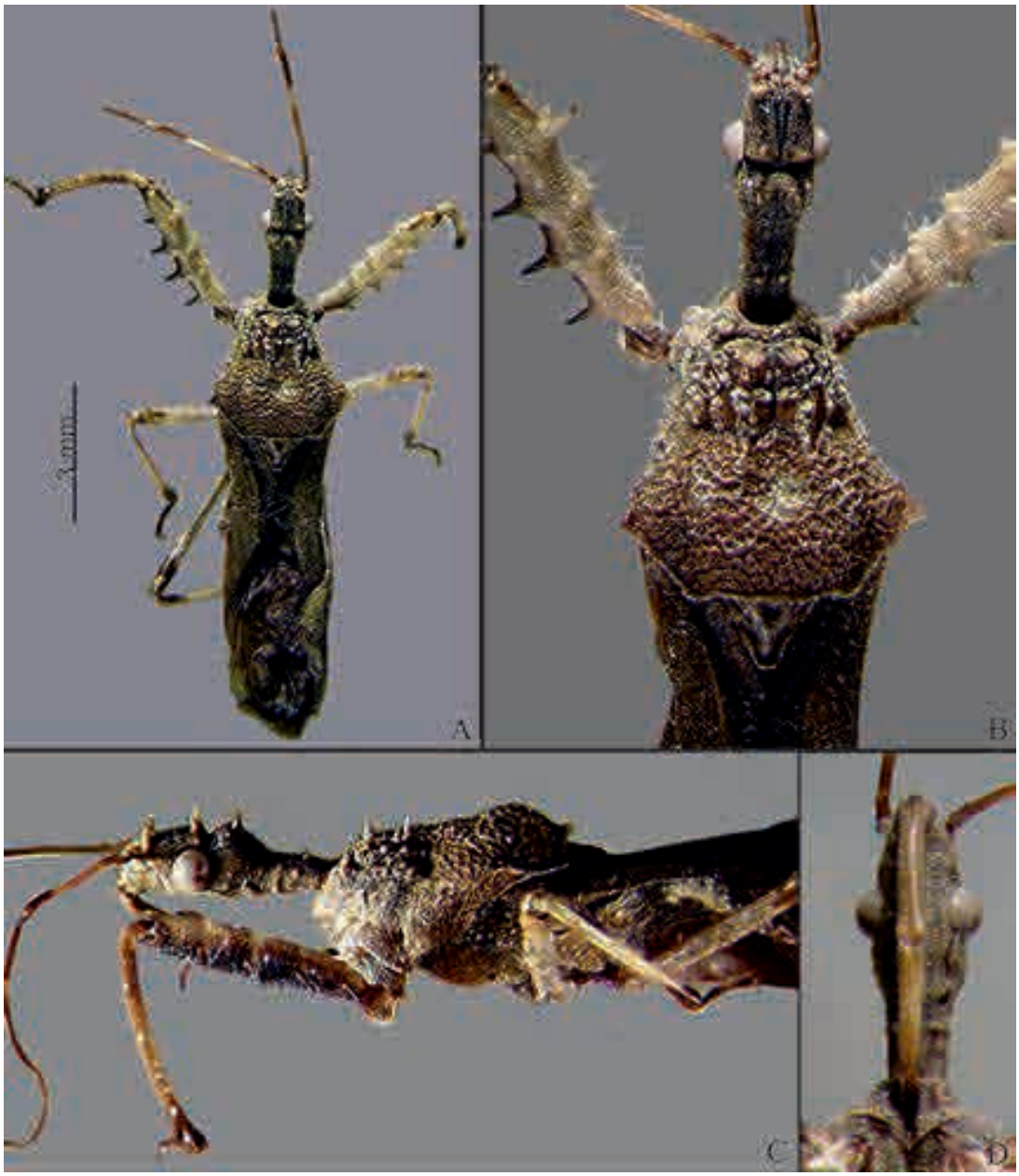

Image 3. *Irantha* sp.: A—Dorsal habitus | B—Details of head and pronotum in dorsal view | C—Lateral view | D—Ventral view of head. © H.V. Ghate.

illustrated (Image 2F,G).

Distribution: India: (Andaman & Nicobar Islands (South Andaman), Sikkim, Tripura, Karnataka, Tamil Nadu, and West Bengal, Meghalaya), China, Indonesia, Myanmar, Philippines, and Sri Lanka (Distant 1904, Ambrose 2006, Bhagyasree 2018, Huang et al. 2007, Mukherjee & Hassan 2016)

***Irantha* Stål, 1861**

Type species by monotypy: *Harpactor armipes* Stål, 1855.

For various other synonyms of *Irantha armipes*, refer to Maldonado-Capriles (1990).

Specimen examined: *Irantha* sp. close to *I. armipes* (Stål, 1855) (total length: 12 mm, male).

Comments: *Irantha* sp. illustrated here has deceptively similar appearance to *Scipinia horrida*, what could possibly lead to a misidentification. However, careful observations revealed the following significant

Image 4. Habitus of type specimen of *Irantha armipes*: A—Dorsal view | B—Ventral view | C—Lateral view | D—Labels. © The Swedish Museum of Natural History; photographed by Gunvi Lindberg, 2019.

differences or diagnostic characters.

Irantha has longer neck like region than *Scipinia*; fore femur in *Irantha* is with many long and strong spines (Image 3A), in *Scipinia* fore femur is with many small and only one long subapical spine (Image 1G); first visible labial segment is distinctly longer than second in *Irantha* (Image 3D) and it is only slightly longer than second in *Scipinia* (Image 1C,D); pronotal humeral angles are sharp in *Irantha* (Image 3B) but are slightly blunt in *Scipinia* (Image 1E); in *Scipinia* the spines on dorsal side of head and pronotum are strong and long and the long spines in posterior pair of pronotum are bifurcate at tip (Image 2A) while in *Irantha* the spines on head and pronotum are small and none is bifurcate at tip (Image 3C). Abdomen is broadly similar but comparative images are not given as it is damaged in this specimen of *Irantha*.

Image 4 includes the dorsal (4A), ventral (4B) and lateral (4C) views of the syntype of *Irantha armipes* preserved in The Swedish Museum of Natural History, along with its labels (4D). The characters of this species are clearly observed in this well-preserved specimen studied by C. Stål. The lateral view shows the characters of spines on head and pronotum, labial segments and the nodulose and spiny fore femora very well.

Distribution: *Irantha armipes* is known from India (Karnataka and several localities in southern India), Sri Lanka, and Nepal (Ambrose 2006, Bhagyasree 2018 checklist) but apparently it is so far not recorded from Assam.

Discussion

The two genera *Irantha* and *Scipinia* are closely related to each other and have similar body form and genital structure and may be synonymized in future, as sometimes it is difficult to assign the related species (Huang et al. 2007). We hope that the illustrations provided here will help to easily distinguish these two species found in India. Chen et al. (2005) have listed other related genera and commented on their narrow distribution while Huang et al. (2007) also pointed out that all species of *Irantha* are distributed only in the Oriental and Australasian Regions.

Das & Ambrose (2007) studied bionomics of *I. armipes* (from specimens collected in Kanyakumari, Tamil Nadu) and gave several illustrations of adult and nymphal morphology. Das et al. (2010) studied predation of *Helicoverpa* by *Scipinia*, however, information about the bionomics of *S. horrida* is still unknown.

The distribution records of most insects found in India are rather poor; detailed, well-illustrated redescriptions of most species are also necessary as their identification is still problematic (Ghate 2013). Correct identification helps to authentically add to the record of distribution and also to the study of comparative aspects of bionomics or phylogeny.

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SHORT COMMUNICATION

Flesh fly (Diptera: Sarcophagidae): male terminalia, diversity and expanded geographical distribution from India

Kanholi Sreejith [1], Shuvra Kanti Sinha [2], Santanu Mahato [3] & Edamana Pushpalatha [4]

[1,4] Department of Zoology, University of Calicut, Malappuram, Kerala 673635, India.
[2] Calyptrate Research Laboratory, Department of Zoology, Sreegopal Banerjee College, Hooghly, West Bengal 712148, India.
[3] Biopsychology Laboratory and Institution of Excellence, University of Mysore, Mysuru, Karnataka 570006, India.
[1] sreejithkanholi@gmail.com, [2] suvrosinha@gmail.com, [3] santanumahato94@gmail.com,
[4] drepushpalatha@gmail.com (corresponding author)

Abstract: Despite its veterinary, medical and forensic importance, the biodiversity of sarcophagid flies (Diptera: Sarcophagidae) has remained poorly investigated in India. We have performed a survey of Sarcophagidae species in connection with a study conducted on Diptera, which exposed the flesh fly diversity in and around the campus of the University of Calicut, Kerala, India. The survey was conducted using traps baited with decomposing fish and chicken liver and by the sweeping method. Eleven species were collected, including four species recorded from this state for the first time, one of which is new to the Indian mainland and the second record after Sundarbans Biosphere Reserve. Male terminalia of *Sinonipponia bengalensis, Parasarcophaga choudhuryi, Boettcherisca karnyi*, and *Boettcherisca nathani* are illustrated. This result expands the knowledge on the geographical distribution and habitat occupancy of sarcophagid species as well as their forensic relevance and provides a background for future systematic investigations.

Keywords: Abundance, *Boettcherisca karnyi, Boettcherisca nathani,* diversity, forensic importance, morphology, new record, *Parasarcophaga*, sarcophagid fly.

Abbreviations: AP—Apical plate of Paramere | LP—Lateral plate of Paramere | S—Styli of glans | T—Theca | V—Ventralia | UoC—University of Calicut.

Sarcophagid flies (Diptera: Sarcophagidae), commonly known as flesh flies, are abundant in all zoogeographic regions of the world with approximately 171 genera and 3,094 species (Pape et al. 2011). Out of these, 504 species in 50 genera have been described from India (Nandi 2002; Sinha & Nandi 2002a,b). Flesh flies show a large range of feeding habits, with adult flies feeding on nectar, fruit juice, and decomposing animal matters; they carry different types of germs on their body surface, which may cause diseases in humans and other animals, and larvae of some species are parasitic on various invertebrates, breed in vertebrate and invertebrate carrion, faeces or decaying organic matter (Pape 1987, 1996; Amoudi et al. 1992; Al-Misned 2000; Al-Misned et al. 2001; Graczyk et al. 2005; Pape et al. 2010; Al-Khalifa et al. 2020). This variety of feeding methods can have a direct impact on their capacity as pathogenic vectors and the larvae of some species cause myiasis in humans as well as in different animals (Dodge 1955; Zumpt 1965; Greenberg 1973, Crump & Pounds 1985; Guimaraes & Papavero 1999;

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Hagman et al. 2005; Stevens et al. 2006; Bermudez et al. 2010; Mello-Patiu & Luna-Dias 2010; Kelehear et al. 2020). Whereas sarcophagid flies are associated with decomposing carcasses and human bodies (Cherix et al. 2012; Vasconcelos et al. 2014; Al-Khalifa et al. 2020), the study of larval and pupal developments found in carcasses improves their effectiveness as useful insects in forensic science investigations (Pape 1996; Wells et al. 2001; Sinha & Mahato 2016; Ren et al. 2018; Samerjai et al. 2020).

Nandi (1990) documented nine species of flesh flies from different parts of Kerala and reported *Parasarcophaga* (*Liosarcophaga*) *dux* (Thomson) for the first time from Kerala. Nandi (2002) documented 20 flesh fly species in Miltogramminae (one species) and Sarcophaginae (19 species) from Kerala (Table 1). In the present faunistic survey, we aimed to contribute to the knowledge of the flesh fly diversity on the campus of the University of Calicut and the distribution of Sarcophagidae in Kerala — the most biodiversity-rich state in southern India.

Materials And Methods

The present survey was carried out at the University of Calicut Campus, Thenjipalam, Kerala (Figure 1).

Study area

The main campus of the University of Calicut is located in Tirurangadi Taluk of the Malappuram District, Kerala, southern India. The main campus is spread over 600 acres on the rural outskirts of Malappuram between 11.1340°N, 75.8952°E, and the last five years have experienced a mean minimum temperature of 28.9°C and a mean maximum of 30.5°C. The main habitats around the campus include gardens, botanical gardens, rubber plantations, various aquatic habitats such as ponds, paddy fields, reservoirs, orchards with mango, jackfruit, zapota, and guava, and terrestrial habitats such as primary and secondary plant successions. The Calicut University Botanical Garden (CUBG) is the largest and most diverse botanical garden of any university garden in the country, covering 45 acres and home to over 2,500 species of vascular plants. CUBG is considered one of the

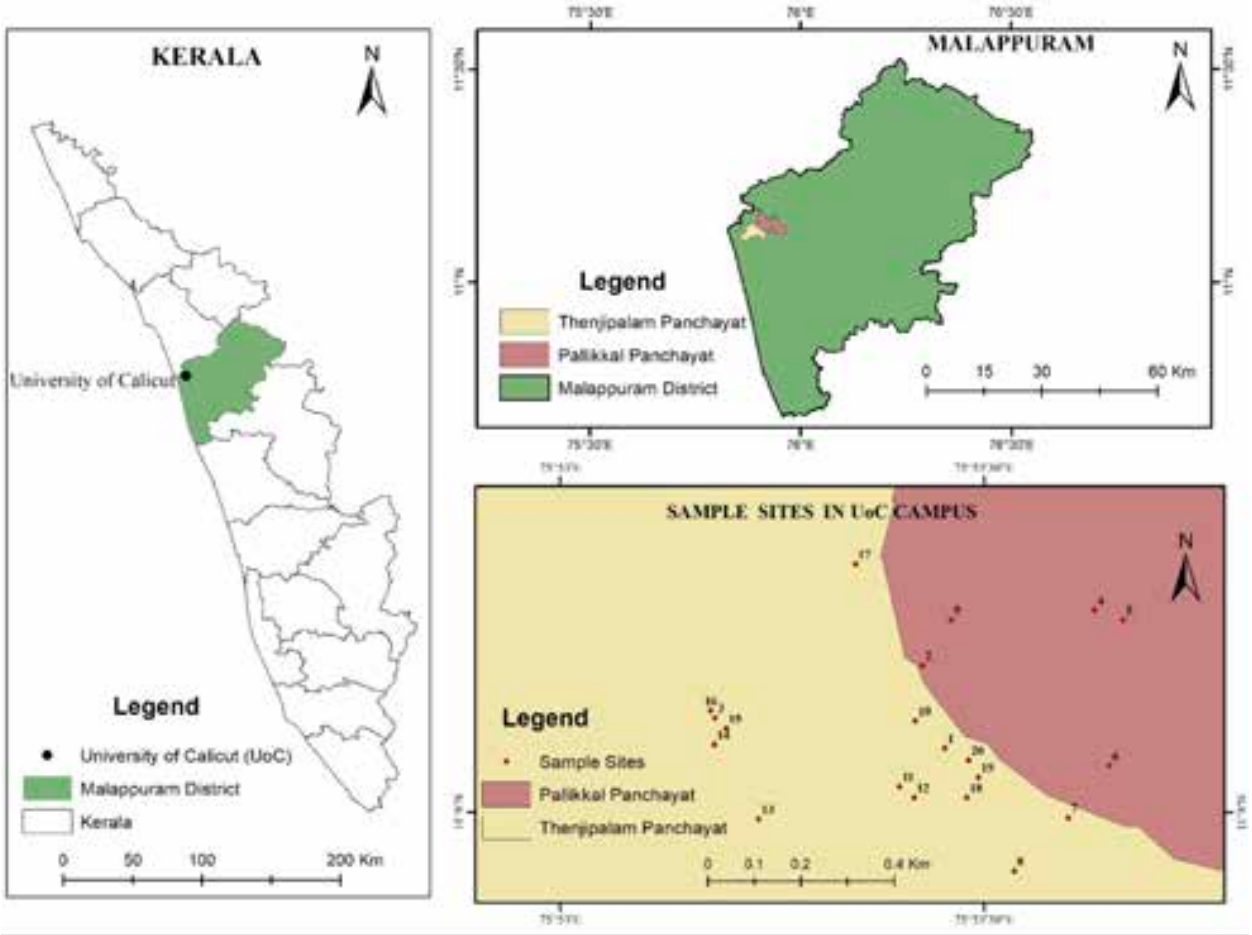

Figure 1. Sampling sites at University of Calicut (UoC).

most important ex situ conservation centres for the rare and endangered flora of the Western Ghats, a UNESCO World Heritage site. The area receives south-west and north-east monsoons, the greater portion of the rainfall, however, is received from the south-west monsoon between June and September. The average annual rainfall of the district is 2,741 mm (IMD 2020).

Field methods and identification

As part of the study of dipteran diversity, a field collection programme for a faunistic survey was conducted by the team in the university campus and adjacent areas to establish documentation of flesh fly species. Collections of specimens in the university campus were done using traps baited with decomposing fish and chicken liver combined with entomological hand nets by standard sweeping. The flies were clustered around the bait, but the flies were from the Calliphoridae family and more from Muscidae. The number of flesh flies was surprisingly low. One observation was that flies were more in shady areas than in open sunshine. Flesh flies have also been found throughout the day. The specimens were identified in the laboratory using the keys, drawing illustrations of the male terminalia in Nandi (2002), and by observing chaetotaxy (arrangement of setae and bristles on the body) and the four species reported for first time from Kerala were dissected for confirmation of species identity. Since sarcophagid flies are not considerably different from each other, therefore, the characteristics of the genitalia are the only criteria for identifying them up to species level. this key was primarily focused on the characteristics of the genitalia.

Male terminalia were photographed with a Nikon Coolpix camera by keeping dissected terminalia in a cavity block under stereoscopic trinocular microscope.

Results

A total of 23 individuals of flesh flies were collected from the University of Calicut campus and these were identified as comprising 11 species, of which, Nandi (2002) had previously reported seven from Kerala (Table 1). Four of the 11 species were newly recorded from the state of Kerala, i.e., *Sinonipponia bengalensis* Nandi, *Parasarcophaga* (*Liosarcophaga*) *choudhuryi* Sinha & Nandi, *Boettcherisca karnyi* (Hardy), and *Boettcherisca nathani* Lopes. *Boettcherisca karnyi* (Hardy) was recorded for the first time from the Indian mainland as previously recorded from Andaman Island (Nandi 2002). The characteristic features of the four new distributional records from Kerala are quite interesting:

Table 1. Species of flesh fly recorded during this study.

	Flesh fly species	Distribution	Source
1	*Protomiltogramma obscurior* (Villeneuve)	Coast of Malabar	Nandi 2002
2	*Blaesoxipha nathani* Lopes	Coast of Malabar	Nandi 2002
3	*Boettcherisca peregrina* (R-D)	Kerala	Nandi 2002
4	*Parasarcophaga ruficornis* (Fabricius)	UoC, Kerala	Nandi 2002, present study
5	*Parasarcophaga dux* (Thomson)	UoC, Kerala	Nandi 2002, present study
6	*Parasarcophaga brevicornis* Ho	UoC, Kerala	Nandi 2002, present study
7	*Parasarcophaga* (*Curranea*) *scopariiformis* (S-W)	Walayar Forest	Nandi 2002
8	*Parasarcophaga* (*Pandelleisca*) *bainbriggei* (S-W)	Kurumbagram	Nandi 2002
9	*Parasarcophaga sericea* (Walker)	Kerala	Nandi 2002
10	*Parasarcophaga hirtipes* (Wiedemann)	Kerala	Nandi 2002
11	*Parasarcophaga misera* (Walker)	UoC, Kerala	Nandi 2002, present study
12	*Parasarcophaga albiceps* (Meigen)	UoC, Kerala	Nandi 2002, present study
13	*Robineauella walayari* (S-W)	Karikal, Palghat, Walayar Forest	Nandi 2002
14	*Thyrsocnema* (*Pseudothyrsocnema*) *longistylata* Shinonaga & Lopes	Karikal, Palghat, Cinchona	Nandi 2002
15	*Thyrsocnema* (*Pseudothyrsocnema*) *indica* Shinonaga & Lopes	Calicut, Cinchona, Muttupatty, Munnar	Nandi 2002
16	*Harpagophalla kempi* (S-W)	Trivancore	Nandi 2002
17	*Iranihindia martellata* (S-W)	UoC, Kerala, Willingdon island	Nandi 2002, present study
18	*Iranihindia futilis* (S-W)	Several localities	Nandi 2002
19	*Seniorwhitea reciproca* (Walker)	UoC, Kerala	Nandi 2002, present study
20	*Leucomyia cinerea* (Fabricius)	Malabar Coast	Nandi 2002
*21	*Sinonipponia bengalensis* Nandi	UoC, Kerala	present study
*22	*Parasarcophaga* (*Liosarcophaga*) *choudhuryi* Sinha & Nandi	UoC, Kerala	Present study
**23	*Boettcherisca karnyi* (Hardy)	UoC, Kerala	Present study
*24	*Boettcherisca nathani* Lopes	UoC, Kerala	Present study

*—newly recorded from Kerala | **—newly recorded from Indian mainland. UoC—University of Calicut.

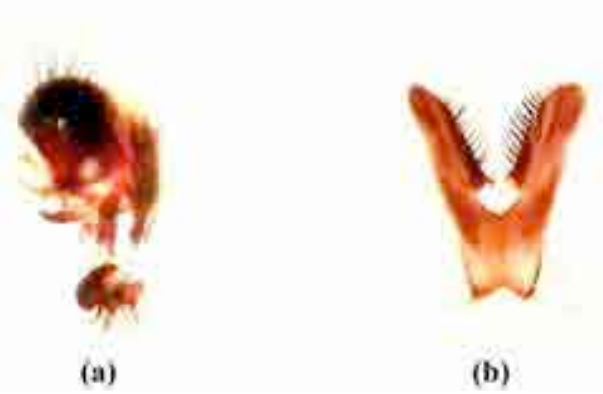

Image 1. Male genitalia of *Parasarcophaga choudhuryi* Sinha & Nandi: a—inner and outer forceps, lateral view | b—fifth sternite. © Department of Zoology, Sonamukhi College.

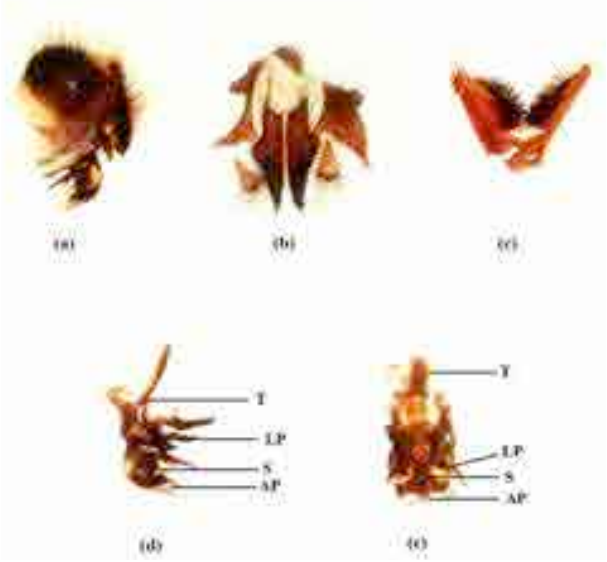

Image 2. Male genitalia of *Sinonipponia bengalensis* Nandi: a—inner and outer forceps, lateral view | b—inner and outer forceps, posterior view | c—fifth sternite | d—penis, lateral view | e—penis, ventral view. © Department of Zoology, Sonamukhi College.

***Parasarcophaga* (*Liosarcophaga*) *choudhuryi* (Sinha & Nandi)**

Parasarcophaga (*Liosarcophaga*) *choudhuryi* is a smaller fly with a slender body. Its ventralia is oval and wide, with a longer stylus of glans (Image 1). Body length 8–9 mm. Parafrontal and parafacial black with golden pollen, the former with short scattered hairs; the latter with a row of short black hairs near the eye margin of which lower 3 are stouter. Frontal bristles 9; acrostichal bristles 0+1, dorsocentral bristles 4+5, mesopleural bristles 7–8, hypopleural bristles 6–7. Prostigmatic and propleural bristles well developed and accompanied by short hairs. 5th sternite Y-shaped with stout spines on inner sides and long hairs terminally on arms; inner forceps slightly curved with the groove at the apex; outer forceps almost oval with few hairs terminally. Apical plate of paraphallus slightly curved backward with the anterior membranous region and elongated apical process; styli of glans slightly longer than apical plate of paraphallus and with serrations at tip; ventralia almost oval with wide trilobed, posterior lobe with the curved chitinous area.

***Sinonipponia bengalensis* Nandi**

Sinonipponia bengalensis also is rather small in size. Its fifth sternite is characterised by the presence of a long seta. Terminalia of this species also shows peculiar features having long and pointed styli of glans, and both an apical and a lateral plate of paraphallus (Image 2). Body length 6–9 mm. Width of frons about two-fifth that of one eye; frontal vita black, parafrontal and parafacial black with silvery pollen. Frontal bristles 10; acrostichal bristles 0+1, dorsocentral bristles 5+4, mesopleural bristles 6, hypopleural bristles 8–9. 5th sternite Y-shaped with short spines laterally and one long and several short hairs terminally on arms. Inner forceps almost straight, slightly curved and with a notch at the end; outer forceps dumb-bell shaped with hairs on distal end; apical plate of paraphallus pointed at end with backward projection; a lateral plate of paraphallus almost pointed, sclerotized and with basal membranous outgrowth; styli of glans long and crosses the apical part of paraphallus with anterior serrations. Ventralia black, pointed, hook-like and curved anteriorly.

***Boettcherisca karnyi* (Hardy)**

Boettcherisca karnyi is quite similar in external appearance to *Boettcherisca nathani* and has minute differences in the male terminalia (Images 3). Body length 8–12 mm. Frontal bristles 11. Outer vertical bristles absent, inner vertical well developed; acrostichal bristles 0+1, dorsocentral bristles 5+5, mesopleural bristles 5, hypopleural bristles 9. Prostigmatic and propleural bristles well developed and accompanied by short hairs. 5th sternite Y-shaped with short window and two rows of closely set bristles laterally on arms. Apical plate of paraphallus curved pointed at the apex and with a pair of long pointed lateral processes; a lateral plate of paraphallus well developed with a pair of large two pointed unequal lateral plates of which anterior one more developed. Ventralia bilobed, well developed, spinous, and anterior margin almost rounded.

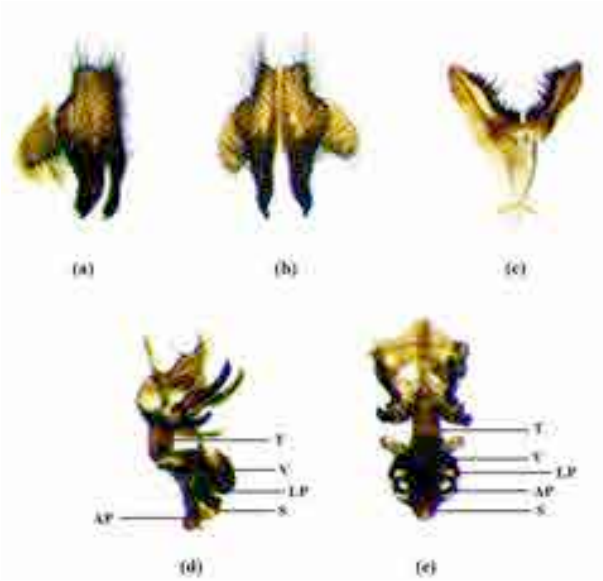

Image 3. Male genitalia of *Boettcherisca karnyi* (Hardy): a—inner and outer forceps, lateral view | b—inner and outer forceps, posterior view | c—fifth sternite | d—penis, lateral view | e—penis, ventral view. © Department of Zoology, University of Calicut.

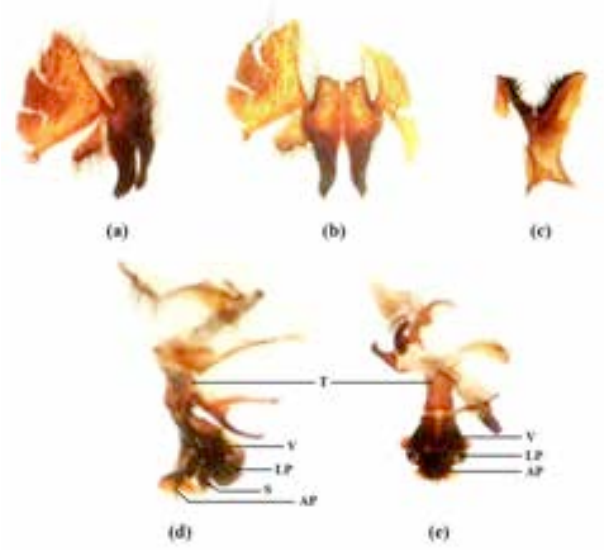

Image 4. Male genitalia of *Boettcherisca nathani* Lopes: a—inner and outer forceps, lateral view | b—inner and outer forceps, posterior view | c—fifth sternite | d—penis, lateral view | e—penis, ventral view. © Department of Zoology, Sonamukhi College.

Key to genera and species newly recorded from Kerala:

1. Ventralia large and almost rounded 2
   Ventralia pointed hook-like and curved anteriorly; an apical plate of paraphallus with a backward projection; styli of glans serrated anteriorly ..... *Sinonipponia bengalensis* Nandi

2. Styli of glans with or without apical incision 3
   Styli of glans slightly longer than apical plate of paraphallus and with serrations at tip ..... *Parasarcophaga* ..... (*Liosarcophaga*) *choudhuryi* (Sinha and Nandi)

3. Apical plate of paraphallus membranous; styli of glans with comb-like process anteriorly ..... *Boettcherisca nathani* Lopes
   Apical plate of paraphallus curved pointed at the apex and with two subapical hairs; styli of glans with a median and two lateral processes ..... *Boettcherisca karnyi* (Hardy)

***Boettcherisca nathani* Lopes**

The apical plate of paraphallus and styli of glans of *Boettcherisca nathani* are similar in appearance to *Boettcherisca karnyi*, but in *Boettcherisca nathani* only the ventralia part is with more digit form processes (Image 4). Body length 10–11 mm. Width of frons about three-fifth of one eye. Its width at the narrowest point of frons about more than twice that of each parafrontal; frontal bristles 12. Post gena black with numerous long brownish hairs; acrostichal bristles 0+1, dorsocentral bristles 5+5, mesopleural bristles 6, hypopleural bristles 8. Inner forceps almost triangular with hairs on its broad distal end; posterior paramere terminally hook-shaped; apical plate of paraphallus membranous, curved, pointed at the apex and with a pair of long lateral processes; a lateral plate of paraphallus sclerotized with two unequal pointed processes; styli of glans with apical incision and comb-like processes anteriorly. Ventralia large with short digit form processes and its anterior margin rounded.

Conclusions

The present study on flesh fly species in the University of Calicut campus revealed a relatively high level of diversity of flesh flies showing the presence of nearly 50% of previously reported species of Kerala, in the University Campus. The species density of pulp flies is exceptionally high, but there is no evidence of the threat to these flies in the study area. *Parasarcophaga* (*Liosarcophaga*) *choudhuryi* Sinha & Nandi was reported previously only from Indian Sundarbans by Sinha & Nandi (2002) and its presence in Kerala is surprising. *Boettcherisca karnyi* (Hardy) was reported in India only from Andaman Islands earlier. This trend of species diversity is very astonishing and more species may be

discovered if thorough surveys are conducted in the future. The present paper provides photographs of the male terminalia of *Parasarcophaga* (*Liosarcophaga*) *choudhuryi* Sinha & Nandi, *Sinonipponia bengalensis* Nandi, *Boettcherisca karnyi* (Hardy) and *Boettcherisca nathani* Lopes for the first time. Moreover, the first reports of four species of flesh flies from this state along with one species newly recorded from the Indian mainland are also very attractive. Efforts should be made to study the diversity and abundance of these flies in various parts of Kerala.

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SHORT COMMUNICATION

Checklist of moths (Heterocera) of Tadong, Sikkim, India

Prayash Chettri [1], Yuki Matsui [2], Hideshi Naka [3] & Archana Tiwari [4]

[1] Department of Zoology, Darjeeling Government College, Darjeeling, West Bengal 734101, India.
[2,3] Department of Agriculture, Tottori University, Tottori 680-8550, Tottori, Japan.
[4] Department of Physics, Sikkim University, Gangtok, Sikkim 737102, India.
[4] Department of Physics, Banaras Hindu University, Varanasi, Uttar Pradesh 221005, India.
[1] prayashchettri96@gmail.com, [2] mothya22@gmail.com, [3] chun@tottori-u.ac.jp, [4] archana.tiwari.ox@gmail.com (corresponding author)

Abstract: This study attempts to create a checklist of moths recorded from two different parts of Tadong in Sikkim, located in the northeastern Himalaya of India. Out of 160 photographed specimens of moths, 133 species were identified and classified. Sixteen families of moths were recorded out of which Erebidae (30.83%) had the highest number of species followed by Geometridae (24.81%), and Crambidae (18.05%) while the other families comprised of 26.30% of the total species.

Keywords: Biodiversity, Eastern Himalaya, Erebidae, Geometridae.

Sikkim, a northeastern Himalayan state, is known for its biodiversity and strategic location surrounded by Nepal, Bhutan, and China. Several new species of butterflies, insects, and birds have been identified in the region (Kalawate 2018), but there are few reports on the sighting or identification of moth species. They play important roles in ecosystems as pollinators for many plants, and they are food for many predators, including bats and birds (Scoble 1992).

During 19th–20th Century, Hampson (1892, 1894, 1895, 1896) and Bell & Scott (1973) documented moths of this region. Dudgeon (1898–1901) documented moths from Sikkim and Bhutan. Kirti & Sodhi (2002) recorded 30 species of footman moths from Sikkim. The State Fauna Series holds records of moths from Ctenuchidae and Limacodidae, with 24 species and 40 species, respectively (Chaudhury 2003), Saturniidae with 26 species (Gupta 2003), Zygaenidae with 66 species (Bhattacharya 2003), Arctiidae with 182 species (Chaudhury 2003), and Geometridae with 265 species (Ghosh 2003). Kirti & Sodhi (2003) recoded 24 species belonging to subfamily Arctiinae from Sikkim. Sanyal et al. (2018) recorded 4,107 species with Sikkim having the greatest moth diversity. Chandra et al. (2019) also recorded 1,274 species of moths in 'Assemblages of Lepidoptera in Indian Himalaya through Long Term Monitoring Plots,' where many of the species of moths were recorded from the state of Sikkim.

The aim of the present study is to create a baseline checklist of moths from Tadong region in Sikkim for further update and addition to the inventory of moths of Sikkim.

Materials and Methods

An opportunistic survey was conducted where moths were photographed as they came towards light sources (LED, incandescent or compact fluorescent bulbs) illuminating residential premises. They were

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photographed in two different localities in Tadong (Figure 1a–c) viz., Gairi Gaon (27.314N & 88.601E) and 6th Mile area (27.3127N & 88.593E) within the period of 2017–2019. The altitude of the sites ranged from 1,099–1,356 m (Table 1). Study sites are located between two watercourses, Rani Khola and Rorochu. The region has taken on urban characteristics as land resources have been encroached continuously due rapid unplanned development (Figure 1d) (Chettri & Lama 2014). There is a gradual change in vegetation from alpine to subtropical and temperate deciduous forest in the region (Tamang et al. 2005). The temperature has been increasing in recent decades and precipitation fluctuates each year (Kumar et al. 2020).

The survey included photographing moths near the light sources using a smartphone camera (12MP).

Table 1. Geographical location of survey sites at Tadong, Sikkim, India.

Survey Sites	GPS Coordinates	Altitude (m)
Gairi Gaon	27.314N & 88.601E	1,099
6th Mile	27.312N & 88.593E	1,356

Morphological characters were considered for the identification. Different sources were used including Walker (1866), Haruta (1992–2000), Irungbam et al. (2016), Shubhalaxmi (2018), Kirti & Singh (2015), Sondhi & Sondhi (2016), and Uniyal et al. (2016). Online portals such as Indian Biodiversity Portal (Vattakaven et al. 2016), iNaturalist, LepIndex (Beccaloni et al. 2003), and BOLDSYSTEMS (Ratnasingham & Hebert 2007) were also utilised for the identification. Classification has been

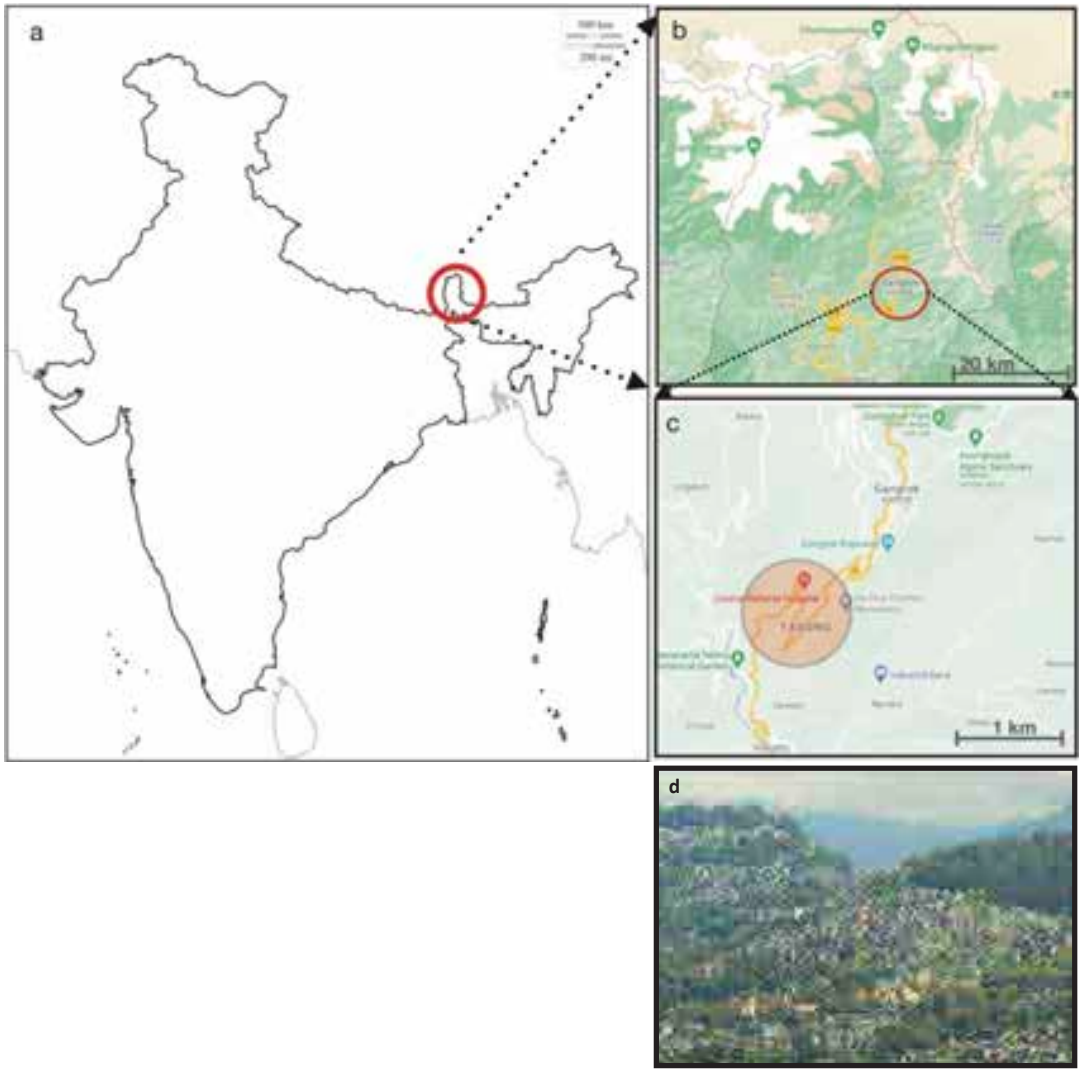

Figure 1. Location of survey site: a—Border region where the survey sites were located with respect to the map | b—Magnified scale indicating topography within the geographical boundary | c—GPS beacon showing approximate location of survey sites (Gairi Gaon and 6th Mile), Tadong, Sikkim | d— Close-up view of the study sites showing human settlement encroached landscape.

followed according to van Nieukerken et al. (2011) and Nuss et al. (2003–2021). PAST3 (Computer Software) was used to calculate diversity indices. Species contribution to diversity of each family was determined by calculating the dominance index= ni×100/N where (ni) is individuals of particular species and (N) is the total no. of species (Mishra et al. 2016).

Results and Discussion

During the study a total of 160 individual moths were photographed, from which 133 species were identified from the region. Of the identified specimens 112 were identified to species level, and 21 to the genus level (Images 1–133). Looking at species contribution to the diversity it was found that family Erebidae had the highest number of moths with 41 species, followed by Geometridae with 33 species and Crambidae with 24 species. Other families including Noctuidae, Notodontidae, Pyralidae, Drepanidae, Eupterotidae, Nolidae, Zygaenidae, Bombycidae, Limacodidae, Lasiocampidae, and Thyrididae accounted for 26% of total species (Table 2, Figure 2). All the identified species are listed in Table 3. Diversity indices were calculated using Past3 software, which showed Fisher's alpha, Shannon index, evenness, and Chao-1 to be 4.752, 1.975, 0.4504, and 21, respectively. Hence, the species diversity seems quite high. These values could be later used to collate species diversity (abundance, richness, evenness) of moths of this region.

Table 2. Number of moth species belonging to different families.

	Family	No. of species
1	Erebidae	41
2	Geometridae	33
3	Crambidae	24
4	Noctuidae	7
5	Nolidae	5
6	Notodontidae	5
7	Pyralidae	5
8	Drepanidae	3
9	Eupterotidae	2
10	Zyganidae	2
11	Bombycidae	1
12	Euteliidae	1
13	Limacodidae	1
14	Lasiocampidae	1
15	Thyrididae	1
16	Tortricidae	1
Total		133

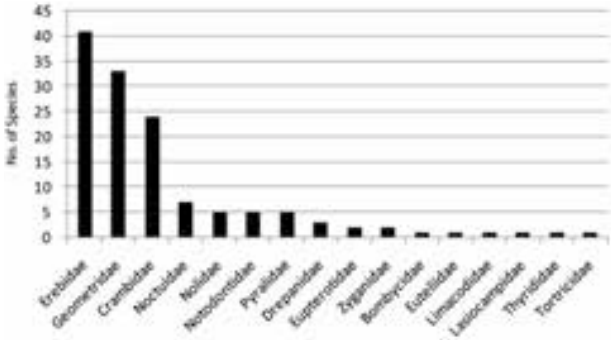

Figure 3. Histogram showing distribution of number of identified species belonging to different families.

Conclusion

In this study, we have attempted to create a baseline checklist of moths from Tadong, Sikkim region. This work adds to the inventory of moths of this region which could be utilised for future studies.

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Table 3. Checklist of moths recorded during this survey.

	Family	Subfamily	Scientific name	Author and Year of description	Months observed (2017–2019)	Location
1	Bombycidae	Bombycinae	*Penicillifera apicalis*	Walker, 1862	September	GG
2	Crambidae	Acentropinae	*Eristena* sp.		June	SM
3	Crambidae	Acentropinae	*Parapoynx fluctuosalis*	Meyrick, 1899	August, June	SM
4	Crambidae	Odontiinae	*Heortia vitessoides*	Moore, 1885	May	SM
5	Crambidae	Pyraustinae	*Hyalobathra coenostolalis*	Snellen, 1890	October	SM
6	Crambidae	Pyraustinae	*Pagyda auroralis*	Moore, 1888	September	GG
7	Crambidae	Pyraustinae	*Sclerocona* sp.		October	SM
8	Crambidae	Spilomelinae	*Agrotera basinotata*	Hampson, 1891	June	SM
9	Crambidae	Spilomelinae	*Arthroschista hilaralis*	Walker, 1859	August	SM
10	Crambidae	Spilomelinae	*Bradina diagonalis*	Guenée, 1854	November	GG
11	Crambidae	Spilomelinae	*Cnaphalocrocis medinalis*	Guenée, 1854	October	GG
12	Crambidae	Spilomelinae	*Diaphania indica*	Saunders, 1851	June	SM
13	Crambidae	Spilomelinae	*Glyphodes crithealis*	Walker, 1859	May	GG
14	Crambidae	Spilomelinae	*Leucinodes orbonalis*	Guenée, 1854	July	SM
15	Crambidae	Spilomelinae	*Cnaphalocrocis trapizalis*	Guenée, 1854	November	SM
16	Crambidae	Spilomelinae	*Maruca vitrata*	Fabricius, 1787	October	GG
17	Crambidae	Spilomelinae	*Metoeca foedalis*	Guenée, 1854	November	GG
18	Crambidae	Spilomelinae	*Patania scinisalis*	Walker, 1859	September	GG
19	Crambidae	Spilomelinae	*Perisyntrocha ossealis*	Hampson, 1896	October	GG
20	Crambidae	Spilomelinae	*Pycnarmon aeriferalis*	Moore, 1877	November	SM
21	Crambidae	Spilomelinae	*Pygospila tyres*	Cramer, 1780	March, August	GG
22	Crambidae	Spilomelinae	*Rhimphalea trogusalis*	Walker, 1859	July	SM,GG
23	Crambidae	Spilomelinae	*Spoladae recurvalis*	Fabricius, 1775	August	GG
24	Crambidae	Spilomelinae	*Synclera* cf. *univocalis*	Walker, 1859	August	SM
25	Crambidae	Spilomelinae	*Talanga* sp.		August	GG
26	Drepanidae	Drepaninae	*Callidrepana* sp.		September	SM
27	Drepanidae	Drepaninae	*Drepana pallida*	Warren, 1922	November, October	GG
28	Drepanidae	Drepaninae	*Macrocilix maia*	Leech, 1888	October	GG
29	Erebidae	Aganainae	*Asota caricae*	Fabricius, 1775	May	SM
30	Erebidae	Aganainae	*Asota plana*	Walker, 1854	April	GG,SM
31	Erebidae	Aganainae	*Mecodina cineracea*	Butler, 1879	September	SM
32	Erebidae	Arctiinae	*Adites frigida*	Walker, 1854	July	SM
33	Erebidae	Arctiinae	*Aemene taprobanis*	Walker, 1854	October	GG
34	Erebidae	Arctiinae	*Aglaomorpha plagiata*	Walker, 1855	March	GG
35	Erebidae	Arctiinae	*Barsine* cf. *cuneonotata*	Walker, 1855	July	GG
36	Erebidae	Arctiinae	*Indiania eccentropis*	Meyrick, 1894	May	GG
37	Erebidae	Arctiinae	*Camptoloma binotatum*	Butler, 1881	June	SM
38	Erebidae	Arctiinae	*Creatonotos transiens*	Walker, 1855	June	SM
39	Erebidae	Arctiinae	*Cyana* cf. *coccinea*	Moore, 1878	October	SM
40	Erebidae	Arctiinae	*Cyana* cf. *neopuer*	Singh et al. 2019	August	GG
41	Erebidae	Arctiinae	*Cyana* cf. *weerawoothi*	Lourens, 2017	October	SM
42	Erebidae	Arctiinae	*Lyclene* cf. *clamaria*	Moore, 1888	October	SM
43	Erebidae	Arctiinae	*Lyclene conjunctana*	Walker, 1866	July	GG
44	Erebidae	Arctiinae	*Lyclene dasara*	Moore, 1859	October	SM
45	Erebidae	Arctiinae	*Barsine phaeodonta*	Hampson, 1911	October	GG

	Family	Subfamily	Scientific name	Author and Year of description	Months observed (2017–2019)	Location
46	Erebidae	Arctiinae	*Nyctemera adversata*	Schaller, 1788	May	SM
47	Erebidae	Arctiinae	*Padenia duplicana*	Walker, 1863	August	SM
48	Erebidae	Arctiinae	*Zardara distorta*	Moore, 1894	June	SM
49	Erebidae	Arctiinae	*Pseudoblabes oophora*	Zeller, 1853	October	GG
50	Erebidae	Arctiinae	*Schistophleps bipuncta*	Hampson, 1891	October	GG
51	Erebidae	Arctiinae	*Juxtarxia multiguttata*	Walker, 1855	May, August	SM
52	Erebidae	Arctiinae	*Spilarctia* sp.		September	SM
53	Erebidae	Arctiinae	*Stictane* sp.		April	GG
54	Erebidae	Arctiinae	*Syntomoides imaon*	Cramer, 1780	October	SM
55	Erebidae	Boletobiinae	*Singara diversalis*	Walker, 1865	August	GG
56	Erebidae	Calpinae	*Eudocima* sp.		July	SM
57	Erebidae	Erebinae	*Anomis flava*	Anomis flava	April	GG
58	Erebidae	Erebinae	*Artena dotata*	Fabricius, 1794	October	GG
59	Erebidae	Erebinae	*Erebus gemmans*	Guenée, 1852	September	GG
60	Erebidae	Hypeninae	*Dichromia quadralis*	Walker, 1858	November	GG
61	Erebidae	Lymantriinae	*Cifuna locuples*	Walker, 1855	May	GG
62	Erebidae	Lymantriinae	*Euproctis bipunctapex*	Hampson, 1891	May	GG
63	Erebidae	Lymantriinae	*Euproctis* cf. *postica*	Walker 1865	May	GG
64	Erebidae	Lymantriinae	*Euproctis* sp.		November	SM
65	Erebidae	Lymantriinae	*Ilema* sp.		July	GG
66	Erebidae	Lymantriinae	*Pida apicalis*	Walker, 1865	December	GG
67	Erebidae	Lymantriinae	*Somena scintillans*	Walker, 1856	May	SM
68	Erebidae	Lymantriinae	*Somena similis*	Moore, 1860	October	GG
69	Erebidae	Pangraptinae	*Pangrapta pseudalbistigma*	Yoshimoto, 1993	October	GG
70	Eupterotidae	Eupterotinae	*Apha* sp.		October	GG
71	Eupterotidae	Eupterotinae	*Eupterote geminata*	Walker, 1855	September	GG
72	Euteliidae	Stictopterinae	*Lophoptera squammigera*	Guenée, 1852	August	SM
73	Geometridae	Desmobathrinae	*Eumelea* cf. *atomata*		November	SM
74	Geometridae	Ennominae	*Abraxas neomartaria*	Inoue, 1970	November	GG
75	Geometridae	Ennominae	*Arichanna transfasciata*	Warren, 1893	May	SM
76	Geometridae	Ennominae	*Biston contectaria*	Walker, 1863	September	SM
77	Geometridae	Ennominae	*Cassyma* cf. *deletaria*	Moore, 1888	September	SM
78	Geometridae	Ennominae	*Celenna festivaria*	Fabricius, 1794	June	GG
79	Geometridae	Ennominae	*Chorodna mauraria*	Guenée, 1858	May	GG
80	Geometridae	Ennominae	*Cleora fraterna*	Moore, 1888	August, November	GG
81	Geometridae	Ennominae	*Cleora* sp.		August	GG
82	Geometridae	Ennominae	*Corymica immaculata*	Warren, 1897	October	GG
83	Geometridae	Ennominae	*Darisa fratercula*	Moore, 1888	March	GG
84	Geometridae	Ennominae	*Ectropis dentilineata*	Moore, 1867	May, June	SM
85	Geometridae	Ennominae	*Gonodontis aethocrypta*	Prout, 1962	November	SM
86	Geometridae	Ennominae	*Erebomorpha fulgurita*	Walker, 1860	September	GG
87	Geometridae	Ennominae	*Parasynegia pluristriaria*	Walker, 1863	September	GG
88	Geometridae	Ennominae	*Heterostegane subtessellata*	Walker, 1862	November	GG
89	Geometridae	Ennominae	*Ourapteryx clara*	Butler, 1880	October	SM
90	Geometridae	Ennominae	*Hypomecis* sp.		October	GG
91	Geometridae	Ennominae	*Thinopteryx crocoptera*	Kollar, 1844	April	GG

	Family	Subfamily	Scientific name	Author and Year of description	Months observed (2017–2019)	Location
92	Geometridae	Ennominae	*Thinopteryx nebulosa*	Butler, 1883	October	SM
93	Geometridae	Geometrinae	*Comibaena integranota*	Hampson, 1893	September	SM
94	Geometridae	Geometrinae	*Cosmostolodes albicantena*	Warren, 1895	March	GG
95	Geometridae	Geometrinae	*Maxates* cf. *protrusa*	Butler, 1878	May	SM
96	Geometridae	Geometrinae	*Thalassodes quadraria*	Guenée, 1857	November	SM
97	Geometridae	Larentiinae	*Acolutha pictaria*	Moore, 1888	December	SM
98	Geometridae	Larentiinae	*Harutalcis* cf. *vialis*	Moore, 1888	November	SM
99	Geometridae	Larentiinae	*Syzeuxis* sp.		May	SM
100	Geometridae	Larentiinae	*Polynesia truncapex*	Swinhoe, 1892	July	GG
101	Geometridae	Oenochrominae	*Sarcinodes restitutaria*	Walker, 1863	August	GG
102	Geometridae	Sterrhinae	*Perixera absconditaria*	Walker, 1862	December	GG
103	Geometridae	Sterrhinae	*Scopula* cf. *ferrilineata*	Moore, 1888	November	GG
104	Geometridae	Sterrhinae	*Synegiodes histrionaria*	Swinhoe, 1892	March	SM
105	Geometridae	Sterrhinae	*Timandra correspondens*	Hampson, 1895	June	GG
106	Lasiocampidae	Lasiocampinae	*Trabala vishnou*	Lefèbvre, 1827	May, November	SM
107	Limacodidae	Limacodinae	*Chalcoscelides castaneipars*	Moore, 1865	August	SM
108	Noctuidae	Aganainae	*Cymatophoropsis sinuata*	Moore, 1879	May	SM
109	Noctuidae	Catocalinae	*Arcte modesta*	Hoeven, 1840	August	GG
110	Noctuidae	Heliothinae	*Heliothis peltigera*	Denis & Schiffermüller, 1775	April	SM
111	Noctuidae	Noctuinae	*Mythimna intertexta*	Chang, 1991	June	SM
112	Noctuidae	Noctuinae	*Mythimna seperata*	Walker, 1865	April	GG
113	Noctuidae	Noctuinae	*Trachea auriplena*	Walker, 1857	April	GG
114	Noctuidae	Plusiinae	*Ctenoplusia agnata*	Staudinger, 1892	April	GG
115	Nolidae	Chloephorinae	*Gabala polyspilalis*	Walker, 1865	May	GG
116	Nolidae	Chloephorinae	*Kerala* sp.		May, October	GG
117	Nolidae	Chloephorinae	*Nycteola* sp.		October	GG
118	Nolidae	Chloephorinae	*Tyana* cf. *chloroleuca*	Walker, 1866	July	SM
119	Nolidae	Risobinae	*Risoba* sp.		November	GG
120	Notodontidae	Cerurinae	*Syntypistis pallidifascia*	Hampson, 1892	October	SM
121	Notodontidae	Dudusinae	*Netria multispinae*	Schintlmeister, 2006	July	GG
122	Notodontidae	Phalerinae	*Phalera grotei*	Moore, 1859	July	SM
123	Notodontidae	Thaumetopoeinae	*Gazalina chrysolopha*	Kollar, 1844	September	SM
124	Notodontidae	Thaumetopoeinae	*Gazalina transversa*	Moore, 1879	April	SM
125	Pyralidae	Epipaschiinae	*Orthaga* sp.		October	GG
126	Pyralidae	Epipaschiinae	*Salma* sp.		September	GG
127	Pyralidae	Epipaschiinae	*Teliphasa* sp.		September	GG
128	Pyralidae	Pyralinae	*Endotricha* sp.		April	GG
129	Pyralidae	Pyralinae	*Pyralis pictalis*	Curtis, 1834	September	GG
130	Thyrididae	Striglininae	*Telchines vialis*	Moore, 1883	May	GG
131	Tortricidae	Tortricinae	*Archips* sp.		July	GG
132	Zygaenidae	Chalcosiinae	*Agalope bifasciata*	Hope, 1840	August	GG
133	Zygaenidae	Chalcosiinae	*Pidorus glaucopis*	Drury, 1773	August	SM

Note: 1) Survey sites: Gairi Gaon (GG) and 6th Mile (SM); 2) Months observed: Includes months on which the species were sited which might indicate flying duration or seasonal presence; 3) Scientific name: Genus level identifications are represented as sp. Provisional identifications as cf. or near, the former for close matches and the latter for poor matches.

Image 1—*Penicillifera apicalis* | 2—*Eristena* sp. | 3—*Parapoynx fluctuosalis* | 4—*Heortia vitessoides* | 5—*Hyalobathra coenostolalis* | 6—*Pagyda auroralis* | 7—*Sclerocona* sp. | 8—*Agrotera basinotata* | 9—*Arthroschista hilaralis* | 10—*Bradina diagonalis* | 11—*Cnaphalocrocis medinalis* | 12—*Diaphania indica* | 13—*Glyphodes crithealis* | 14—*Leucinodes orbonalis* | 15—*Cnaphalocrocis trapizalis* | 16—*Maruca vitrata* | 17—*Metoeca foedalis* | 18—*Patania scinisalis* | 19—*Perisyntrocha ossealis* | 20—*Pycnarmon aeriferalis* | 21—*Pygospila tyres* | 22—*Rhimphalea trogusalis* | 23—*Spoladae recurvalis* | 24—*Synclera* cf. *univocalis* | 25—*Talanga* sp. | 26—*Callidrepana* sp. | 27—*Drepana pallida* | 28—*Macrocilix maia* | 29—*Asota caricae* | 30—*Asota plana* | 31—*Mecodina cineracea* | 32—*Adites frigida* | 33—*Aemene taprobanis*.

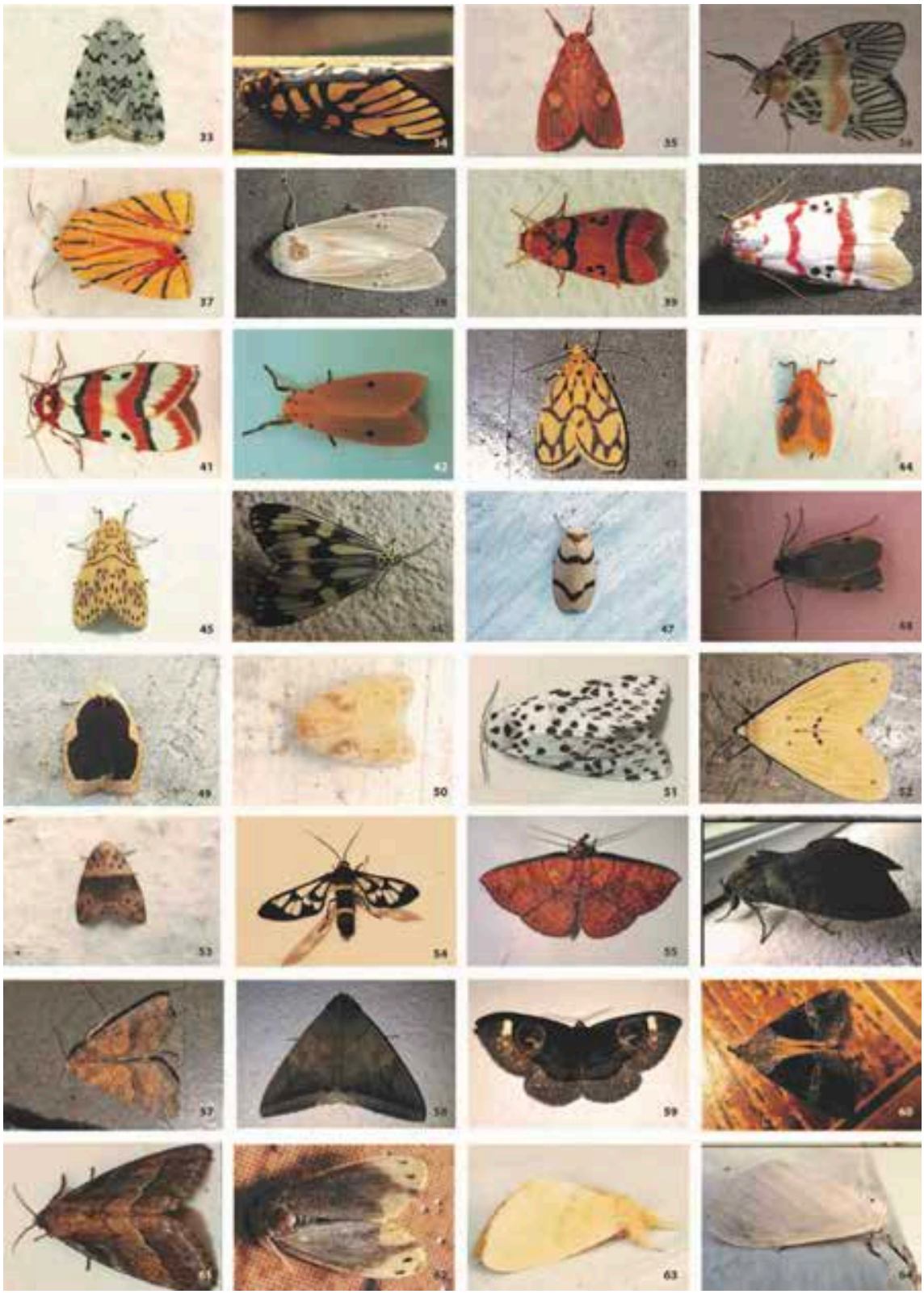

Image 34—*Aglaomorpha plagiata* | 35—*Barsine* cf. *cuneonotata* | 36—*Indiania eccentropis* | 37—*Camptoloma binotatum* | 38—*Creatonotos transiens* | 39—*Cyana* cf. *coccinea* | 40—*Cyana* cf. *neopuer* | 41—*Cyana* cf. *weerawoothi* | 42—*Lyclene* cf. *clamaria* | 43—*Lyclene conjunctana* | 44—*Lyclene dasara* | 45—*Barsine phaeodonta* | 46—*Nyctemera adversata* | 47—*Padenia duplicana* | 48—*Zadadra distorta* | 49—*Pseudoblabes oophora* | 50—*Schistophleps bipuncta* | 51—*Juxtarxia multiguttata* | 52—*Spilarctia* sp. | 53—*Stictane* sp. | 54—*Syntomoides imaon* | 55—*Singara diversalis* | 56—*Eudocima* sp. | 57—*Anomis flava* | 58—*Artena dotata* | 59—*Erebus gemmans* | 60—*Dichromia quadralis* | 61—*Cifuna locuples* | 62—*Euproctis bipunctapex* | 63—*Euproctis* cf. *postica* | 64—*Euproctis* sp. | 65—*Ilema* sp.

Images 66–97: 66—*Pida apicalis* | 67—*Somena scintillans* | 68—*Somena similis* | 69—*Pangrapta pseudalbistigma* | 70—*Apha* sp. | 71—*Eupterote* cf. *geminate* | 72—*Lophoptera squammigera* | 73—*Eumelea* cf. *atomata* | 74—*Abraxas neomartaria* | 75—*Arichanna transfasciata* | 76—*Biston contectaria* | 77—*Cassyma* cf. *deletaria* | 78—*Celenna festivaria* | 79—*Chorodna mauraria* | 80—*Cleora fraternal* | 81—*Cleora* sp. | 82—*Corymica immaculata* | 83—*Darisa fratercula* | 84—*Ectropis dentilineata* | 85—*Gonodontis aethocrypta* | 86—*Erebomorpha fulgurita* | 87—*Parasynegia pluristriaria* | 88—*Heterostegane subtessellata* | 89—*Ourapteryx clara* | 90—*Hypomecis* sp. | 91—*Thinopteryx crocoptera* | 92—*Thinopteryx nebulosa* | 93—*Comibaena integranota* | 94—*Cosmostolodes albicantena* | 95—*Maxates* cf. *protrusa* | 96—*Thalassodes quadraria* | 97—*Acolutha pictaria.*

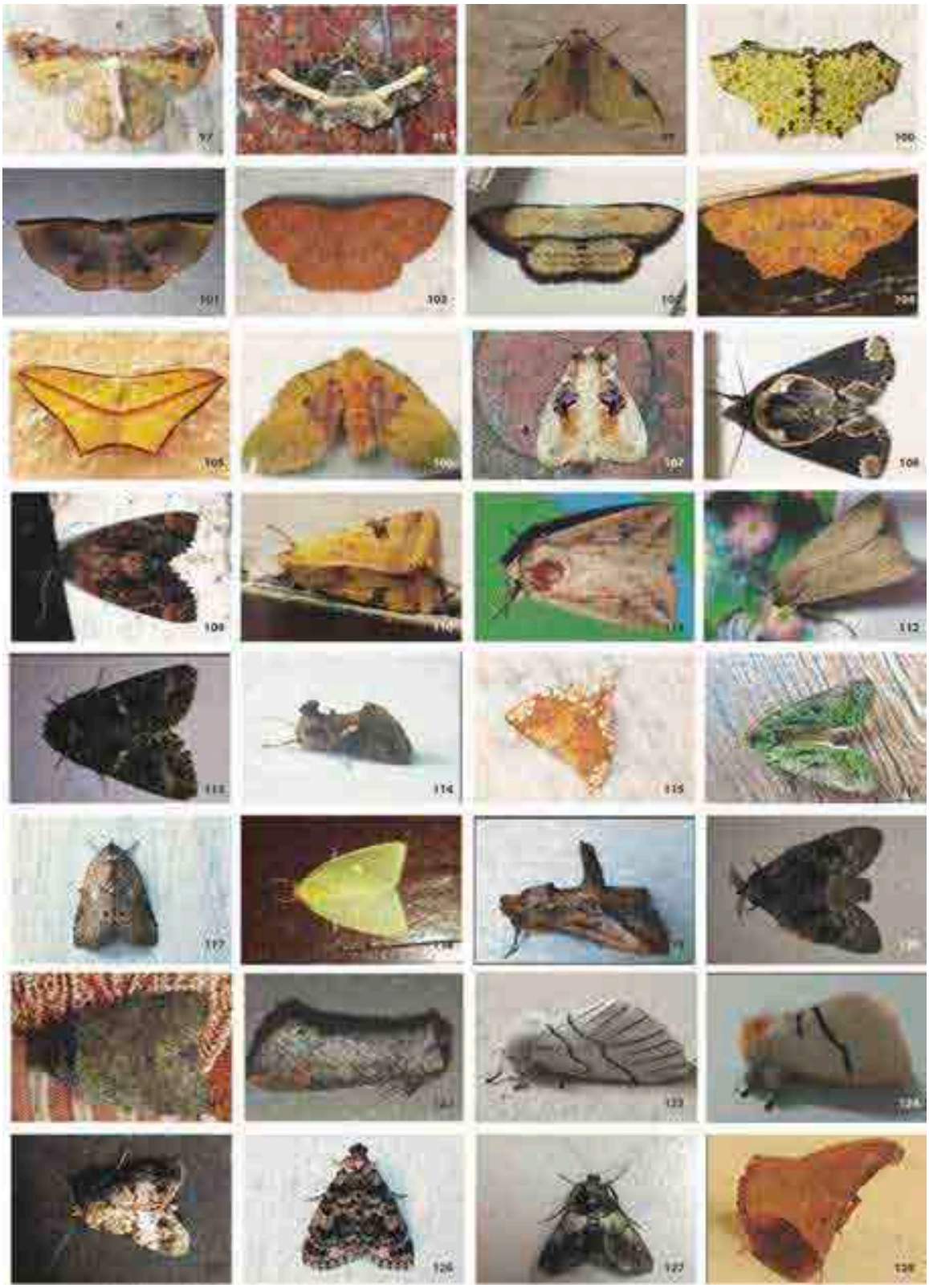

Image 98—*Harutalcis* cf. *vialis* | 99—*Syzeuxis* sp. | 100—*Polynesia truncapex* | 101—*Sarcinodes restitutaria* | 102—*Perixera absconditaria* | 103—*Scopula* cf. *ferrilineata* | 104—*Synegiodes histrionaria* | 105—*Timandra correspondens* | 106—*Trabala vishnou* | 107—*Chalcoscelides castaneipars* | 108—*Cymatophoropsis sinuata* | 109—*Arcte modesta* | 110—*Heliothis peltigera* | 111—*Mythimna intertexta* | 112—*Mythimna seperata* | 113—*Trachea auriplena* | 114—*Ctenoplusia agnata* | 115—*Gabala polyspilalis* | 116—*Kerala* sp. | 117—*Nycteola* sp. | 118—*Tyana* cf. *chloroleuca* | 119—*Risoba* sp. | 120—*Syntypistis pallidifascia* | 121—*Netria multispinae* | 122— *Phalera grotei* | 123—*Gazalina chrysolopha* | 124—*Gazalina transversa* | 125—*Orthaga* sp. | 126—*Salsma* sp. | 127—*Teliphasa* sp. | 128—*Endotricha* sp. | 129—*Pyralis pictalis.*

Images 130–133: 130—*Telchines vialis* | 131—*Archips* sp. | 132—*Agalope bifasciata* | 133—*Pidorus glaucopis.*

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SHORT COMMUNICATION

New distribution records of *Begonia* L., *B. murina* Craib and *B. poilanei* Kiew (Begoniaceae: Cucurbitales) for Laos

Phongphayboun Phonepaseuth [1], Phetlasy Souladeth [2], Soulivanh Lanorsavanh [3], Shuichiro Tagane [4], Thyraphon Vongthavone [5] & Keooudone Souvannakhoummane [6]

[1] Faculty of Environmental Sciences, National University of Laos, Dongdok Campus, Xaythany District, Vientiane Capital, Laos.
[2] Faculty of Forestry Science, National University of Laos, Dongdok Campus, Xaythany District, Vientiane Capital, Laos.
[3,6] Faculty of Natural Science, National University of Laos, Dongdok Campus, Xaythany District, Vientiane Capital, Laos.
[4] The Kagoshima University Museum, Kagoshima University, 1-21-30 Korimoto, Kagoshima, 890-0065, Japan.
[5] Association for Community Development (ACD), Salavan Province, Laos.
[1] p.phonepaseuth@nuol.edu.la, [2] p.souladeth@nuol.edu.la, [3] biokklano@yahoo.com, [4] stagane29@gmail.com, [5] thyraphon@gmail.com, [6] keooudone1988@gmail.com (corresponding author)

Abstract: *Begonia murina* Craib from central and *B. poilanei* Kiew from southern of Laos, are newly recorded in Laos. Based on Lao materials, detailed description, photographs, and notes on habitat, ecology, & taxonomic discussion of these two species compared with the Chinese, Thai, & Vietnamese types are provided.

Keyword: Bolaven plateau, description, flora of Laos, limestone karst, new record, taxonomic discussion.

Begonia L. (Begoniaceae) is one of the largest genera of angiosperms, comprising 1,989 accepted species (Hughes et al. 2015–). In Laos, 28 species have been recorded, nine of which are endemic (Ding et al. 2020; Lanorsavanh et al. 2020; Souvannakhoummane et al. 2020). The limestone karst in Laos is interesting for plant diversity, and several new species of *Begonia* were described, including *B. cladotricha* M. Hughes (Hughes 2007); *B. viscosa* Aver. & H.Q. Nguyen (Averyanov & Nguyen 2012); *B. khammouanensis* Souvann. & Lamxay; *B. hinnamnoensis* Souvann. & Lanors. (Souvannakhoummane et al. 2018); *B. tatianae* Aver; *B. quadripetiolata* Aver. & H.Q. Nguyen (Averyanov et al. 2019).

During our field surveys in Khammouan and Bolikhamxay provinces, central Laos in June–August 2019 & July–August 2020, and Champasak province, southern Laos in September 2020, we found two species of *Begonia* that morphologically placed in sect. *Diploclinium* (Lindl.) A.DC. after carefully checking relevant literature and comparing with herbarium specimens: FOF, HNL and KAG, as well as online specimen data and images of type available at Begonia Resource Centre (Hughes et al. 2015–). The first species

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was identified as *Begonia murina* Craib, which can be recognized by small globose tuber and glandular hairs indumentum in all parts, red striation on ovary and fruit, these features had been known only in Thailand (Phutthai et al. 2019). The second species is *B. poilanei* Kiew which is characterized by elongated cylindric tuber and known from southern Vietnam and China (Kiew 2007; Tian 2014; Peng et al. 2014). We here report these two taxa as new to the flora of Laos, along with their description based on Lao materials, photographs, distribution map. Consequently, the diversity of *Begonia* in Laos is increased to 30 species. The descriptions were made based on the living plants, alcohol preserved and herbarium specimens. The terminology follows Phutthai et al. (2019).

Begonia murina Craib
(Figure 1, Image 1)

in Gard. Chron. ser. 3, 83: 66. 1928; Hughes & Peng, 300 Spec. Port. Asian *Begonia*: 216. 2018; Phutthai et al., Fl. Thailand 14(3): 401. 2019.

Monoecious rhizomatous lithophytic herb, up to 15 cm tall. *Rhizome* tuber, small globose, smooth, light red to reddish brown, 3–5 mm in diameter, with many additional fibrous roots. Stemless or very short to 1 cm long, reddish, pilose. Leaves 3–5 per plant; petiole 5–9 cm long, 2–3 mm in diam., reddish, puberulous; blade asymmetric, ovate to lanceolate, 5–6 × 8–9 cm, apex acute, base cordate, margin dentate, covered with sparse short hairs, veins 4–5 per side, puberulous on both sides, adaxial surface green, abaxial surface paler. Inflorescence axillary near terminal cyme; peduncle erect, 6−10 cm long, puberulent, branched 2 times, with 2–4 male flowers and 1–2 female flowers per branch; bracts narrowly lanceolate, ca. 7 × 3 mm, membranous, reddish, slightly glandular hairy, margin fringed by glandular hairs. Staminate flower: pedicel 1.5−2.5 cm long, covered with glandular hairs, tepals 4, white, unequal, outer 2, broadly ovate, 10−12 × 14−15 mm, glandular hairy on the outer surface, margin entire covered with glandular hairs, inner 2, much smaller, elliptic to oblanceolate, white, 5−8 × 1.5−2 mm, glabrous inside, puberulous outside, margin entire, ciliate with glandular hairs; stamens bright yellow, 40−56, anther obovate, ca. 2 mm long. Pistillate flower: pedicel 1−1.2 cm long, glandular hairy, tepals 2 or 3, white, equal, outer 2, broadly ovate, 6−10 × 10−12 mm, covered with glandular hairs on the outer surface; inner 1 narrowly elliptic, ca. 6 × 2 mm. Ovary 3-locular, pale green with red striations, placentae axial, placentae 2 per locule, styles 3, stigmas bifid with twisted bands, golden yellow. Capsule green with reddish line reticulate, brown when dry, with 3 subequal wings, abaxial wing 7−8 mm long, lateral wings shorter, 6−7 mm long. Seeds numerous, ellipsoid, ca. 0.3 mm long, light brown.

Distribution: Laos (Bolikhamxay, Khammouan), Thailand.

Ecology and Phenology: In Laos, this species was found on wet rock with mosses near streams in dry evergreen forest at elevation 1,034 m (Bolikhamxay Province) and on shade cliffs of limestone karst, associated with *Paraboea* sp. (Gesneriaceae), *Amorphophalus* sp. (Araceae) and some species of limestone ferns at elevation ca. 210 m (Khammouan Province). Flowering from August to September and fruiting from August to September.

Specimens examined: SL 1708 (FOF!, HNL!, Biology Herbarium of National University of Laos!), 28.vii.2020, in dry evergreen forest, Phou Khao Khouay National Protected Area, Thaphabath district, Bolikhamxay province, Laos, 18.496N, 103.313E, 1,034 m elevation, coll. Lanorsavanh S., Souvannakhoummane K. & Khane; P002 (FOF!), 30.vii.2020, Pha Kataiy, Limestone Hill, Gnommarath District, Khammouan Province, Laos, 17.552N, 105.164E, 210 m elevation, coll. Phonepaseuth P.; 884, 26.ix.2020, ibid., coll. Souladeth P., Insisiengmai O., Sengthong A., Phengmala K., Phanpadith P.

Type: 113 (holo ABD digital image!, iso ABD digital image!), 11.xi.1927, Cult. Hort. Bot. Aberb., Thailand, coll. Kerr A.F.G.

Vernacular: ສົ້ມກຸ້ງຂົນ [(Somkoung Khon) meaning hairy begonia]

Note: *Begonia murina* Craib was originally described based on the plants collected from Kanchanaburi provinces, Thailand by Craib (1928), and formerly believed to be endemic to Thailand, being found in Sukhothai and Kanchanaburi (Phutthai et al. 2019). In Laos, it is known from Bolikhamxay and Khammouan provinces between 210–1,034 m elevations. Though Lao plants shows slight differences in leaf shape (oblique-cordiform vs. usually reniform) and colour of veins (usually green vs. reddish green), we consider these are included within the infraspecific variation of this species.

Begonia poilanei Kiew
(Figure 1, Image 2)

Adansonia 29(2): 235. (-238; fig. 2). 2007. *Begonia intermedia* D.K.Tian & Y.H.Yan, Phytotaxa 166(2): 116 (2014), nom. Illeg.; Tian, Phytotaxa 172(1): 59. 2014. *Begonia wuzhishanensis* C.-I Peng, X.H. Jin & S.M. Ku, Bot. Stud. (Taipei) 55-24:: 3. 2014; Tian, Phytotaxa 172(1): 59. 2014.

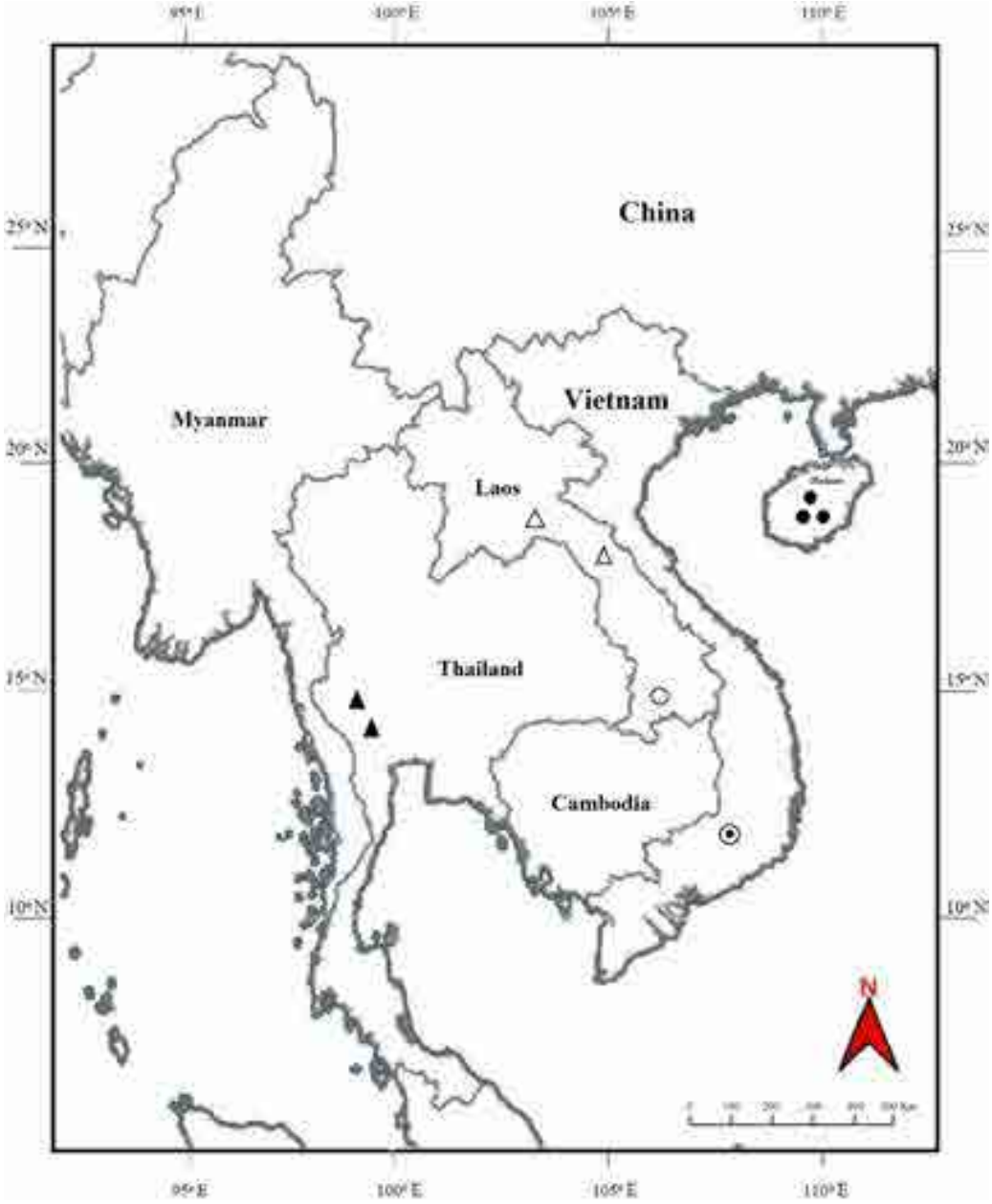

Figure 1. Distribution of *Begonia murina* Craib: (▲) in Thailand, and (△) in Bolikhamxay and Khammouan provinces, Laos. *Begonia poilanei* Kiew.: (⦿) in Vietnam, (◯) in Bolaven plateau, Laos and (●) in Hainan, China.

Monoecious rhizomatous lithophytic herb, 5–15 cm tall. *Rhizome* tuber, cylindrical, smooth, light brown, 2–4 cm long, 5–8 mm in diameter. Stem short, 0.5–3 cm long, reddish green, pilose; branched from lower nodes. Stipule narrowly triangular, ca. 5 mm long, covered with white hairs. Leaves 2(–5) per plant; petiole 5–6(–10) cm long, 2–3 mm in diameter, reddish green, puberulous; blade obliquely cordate, 6–7 × 7–9 cm, apex acute-lanceolate or aristate, tip 1–1.5 cm long, base cordate, margin serrate with ciliate, puberulous on both sides, adaxial surface green, except venation which is dark green and impressed, leaf abaxial surface paler, and reddish-green or red in veins, veins 3–4 pair per side, prominent on abaxial side. Inflorescence axillary and terminal cyme; peduncle erect, 6−15 cm long, 2–3 mm in diameter, covered with short hairs, usually with 2 branches, with female flower more than male flowers per branch, floral bracts hirsute, ovate, 4–6 × ca. 3 mm, membranous, reddish-green. Staminate flower: pedicel red to pinkish-red, 1−1.8 cm long, ca. 1 mm in diameter, pubescent; tepals 4, pink or bright pink, outer 2 larger, broadly ovate, 7−8 × 9−10 mm, with 9 distinct radial

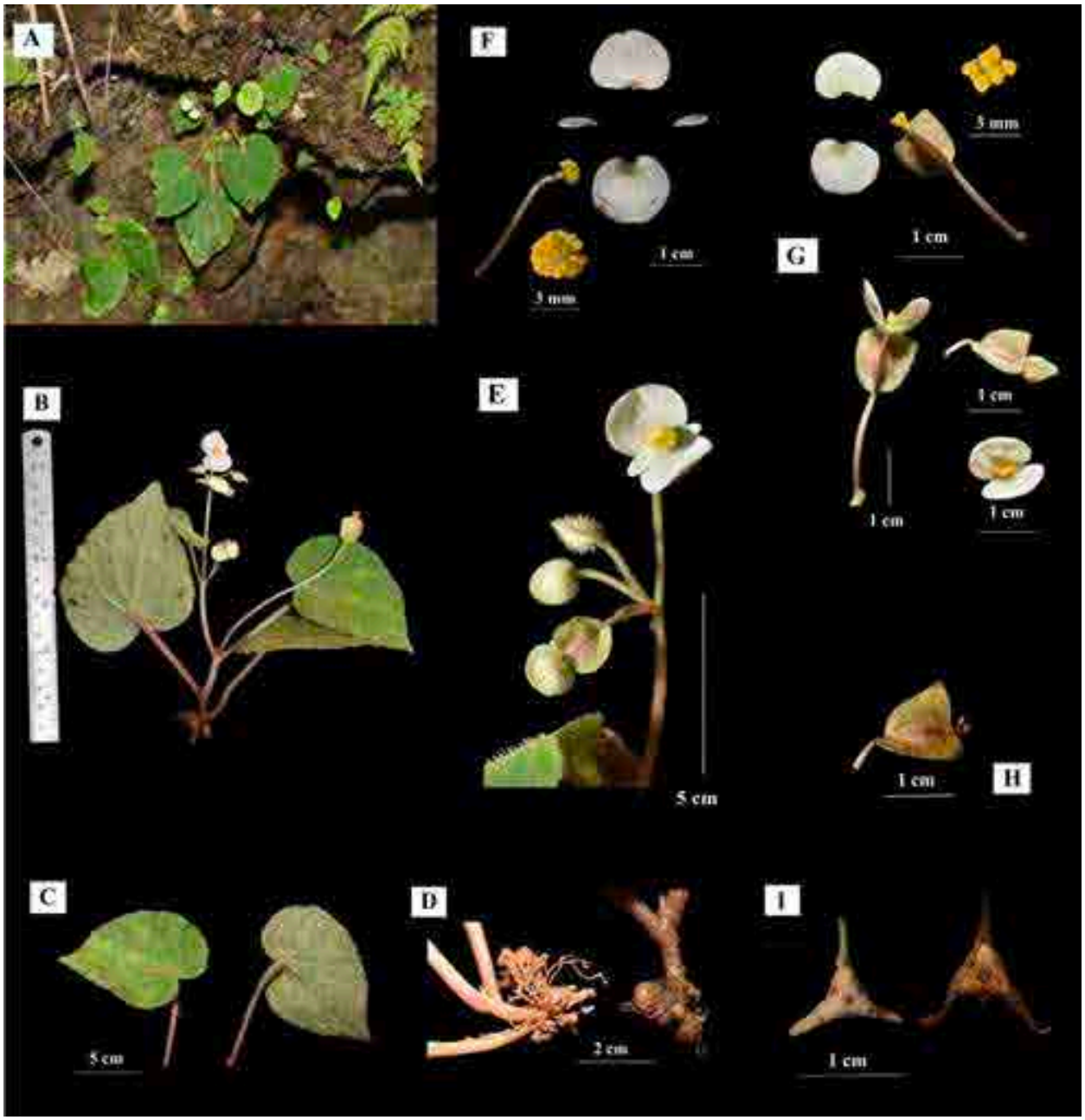

Image 1. ***Begonia murina*** **Craib: A and B—Habitat and habit | C—Leaf adaxial surface (left) and leaf abaxial surface (right) | D—Tubers | E—Inflorescence | F—Staminate flower and stamens | G—Pistillate flowers and pistil | H—Mature fruit | I—Cross-sections of capsule. © P. Phonepaseuth from P002 (FOF).**

stripes on adaxial surface with glandular hairy on the outer surface especially on margin entire, inner 2, much smaller, elliptic to oblanceolate, lighter in color, 5–8 × 2–3 mm, stamens bright yellow, 28–36, anther obovate, ca. 2 mm long. Pistillate flower: pedicel pink or pinkish red, 1–1.2 cm long, globous, tepals 3, pink, unequal, outer 2, broadly ovate, 7–8 × 8–10 mm, with 9 distinct radial stripes on adaxial surface, covered with glandular hairs on the midrib of outer surface, inner 1, elliptic, ca. 1.5 × 3 mm, ovary 3-locular, pinkish green, shiny, placentae axial, placentae 2 per locule, styles 3, stigmas bifid, golden yellow. Capsule unequally 3-winged, abaxial wing oblong, 7–8 mm long, lateral wings shorter, 4–5 mm long. Seeds not seen.

Distribution: China, Laos (Bolaven Plateau), Vietnam.

Ecology and Phenology: In Laos, this species is known only from on top of the Bolaven Plateau, Paksong District, Champasak Province at 1,270 m elevation.

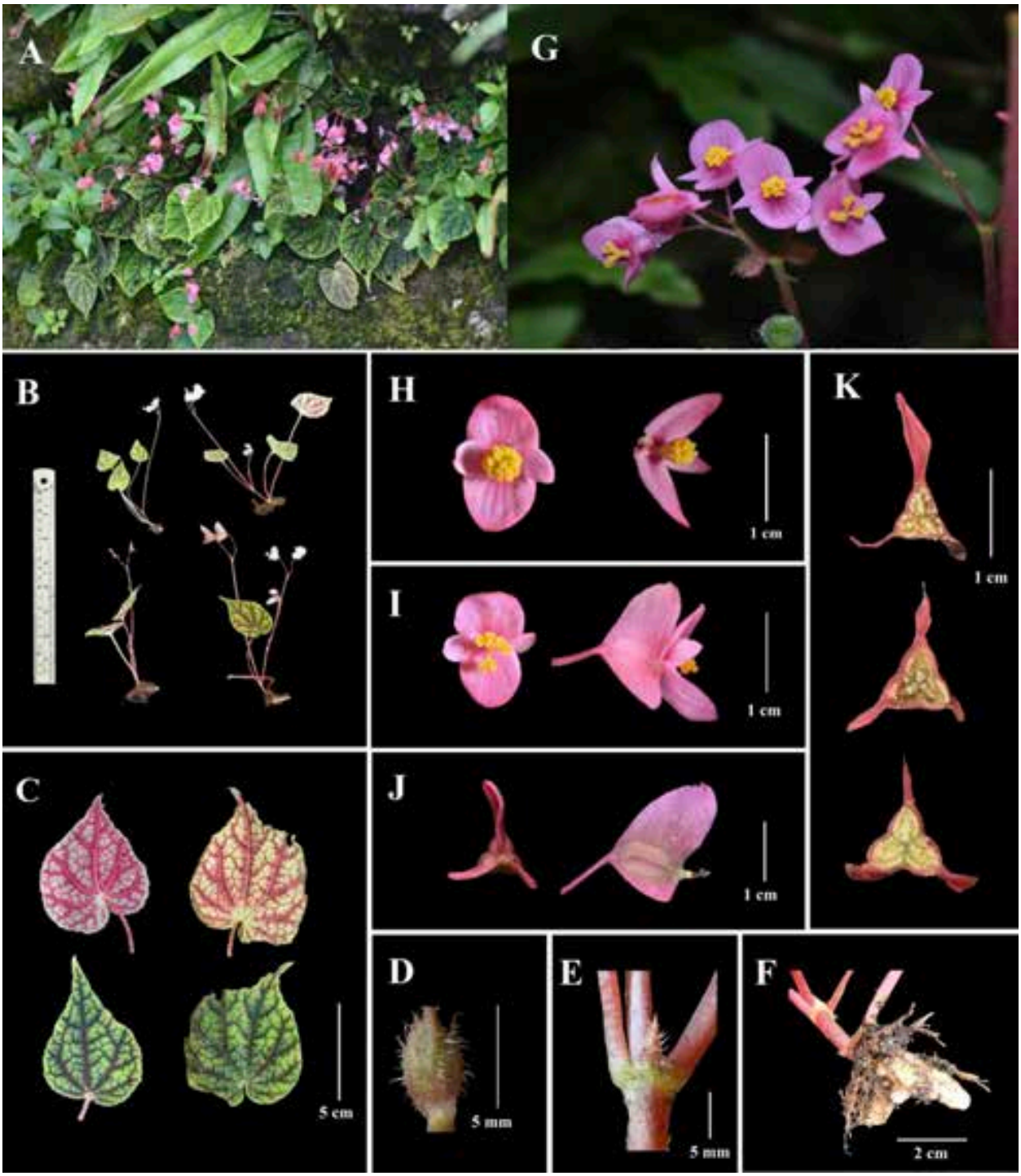

Image 2. ***Begonia poilanei*** **Kiew: A and B—Habitat and habit | C—Leaf adaxial surface (below) and leaf abaxial surface (upper) | D—Floral bract | E—Stipule | F—Tuber | G—Inflorescences | H—Staminate flowers frontal and lateral view | I—Pistillate flowers frontal and lateral view | J—Mature fruits | K—Cross-sections of capsule. © P. Phonepaseuth (A, C, D, E, G–K), K. Souvannakhoummane (B & F) from L3949 (FOF).**

Flowering and fruiting in September.

Specimens examined: L3949 (BKF, FOF!, KAG), 17.ix.2020, 15.060N, 106.208E, 1,277 m elevation, Dong Hua Sao National Protected Area, Bolaven Plateau, Paksong District, Champasak Province, Laos, coll. Souladeth P., Phonepaseuth P., Souvannakhoummane K., & Vongthavone T.

Type: 19824 (holo P [P00539147], digital image!, iso [P00539160, P00539161], digital image!), 21.x.1931, Djijuih Haut Donai District, Vietnam, Poilane E.; TDK710,

holo CSH n.v, iso CSH n.v., 28.ix.2012, Yinggeling National Natural Reserve, Qiongzhong, Hainan, China, 19.020N, 109.573E; 2,093 m, holo HAST n.v., iso PE n.v., 3.xii.2013, on wet, mossy rocky slope by a stream in forest, Nanyi village, Fanyang township, Wuzhishan city, Hainan province, China, 18.881N, 109.342E, elevation ca. 180 m, coll. Shin-Ming Ku & Xiao-Hua Jin.

Vernacular: ສົ້ມກຸ້ງກຳມະຈອນ (Somkoung Kammajon [meaning blood veins])

Note: *Begonia poilanei* Kiew was first descripted from Vietnam, Haut Donai District, Djijuih (Dalat) by Kiew in 2007, and named in honor of E. Poilane, who first discovered and collected this species in 1931. Formerly this species was stated as endemic to Vietnam. Peng et al. (2014) described *Begonia wuzhishanensis* C.-I Peng, X.H. Jin & S.M. Ku from Wuzhishan City, Hainan Province, China, and Tian et al. (2014) also described *B. intermedia* D.K. Tian & Y.H. Yan, from another city in Hainan Province in the same year, but both of them are now treated as a synonym of *Begonia poilanei* Kiew in Nomenclature of *Begonia* (Hughes et al. 2015–). In Laos, thus far this species is known only in one locality on the top plateau of Bolaven Plateau in Champasak Province. Lao plants have minor different from Vietnamese type specimen in its leaf apex: tip aristate (vs. acute).

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NOTE

A recent sighting of the Stripe-backed Weasel *Mustela strigidorsa* (Mammalia: Carnivora: Mustelidae) in Hkakabo Razi Landscape, Myanmar

Sai Sein Lin Oo [1], Tun Tun [2], Kyaw Myo Naing [3] & Paul Jeremy James Bates [4]

[1] Department of Zoology, University of Mandalay, 05032 Maha Aung Myay Township, Mandalay, Myanmar.
[2] Freelance, Nyaung Pin Seik, 05242 Popa, Kyaukpadaung Township, Mandalay, Myanmar.
[3] Department of Zoology, Pathein University, 10014 Pathein Township, Ayeyarwady, Myanmar.
[4] Harrison Institute, 15 St Botolph's Road, Sevenoaks, Kent, TN13 3AQ, UK.
[1] saiseinlinoo@mu.edu.mm, [2] tuntun094037@gmail.com, [3] kyawmyonaing77@gmail.com,
[4] pjjbates2@hotmail.com (corresponding author)

In the past, the Stripe-backed Weasel *Mustela strigidorsa* was considered to be rare (Lekagul & McNeely 1977; Burton & Pearson 1987; Treesucon 1989; Grassman et al. 2002) and was categorized as 'Vulnerable' in the 1996 IUCN Red List (Roberton et al. 2016).

Subsequently, Abramov et al. (2008) provided a comprehensive review of the animal's morphology, taxonomy, nomenclature, ecology, behaviour, and conservation status and listed over 100 distribution records from northeastern India, including Sikkim, Myanmar, southern China, northern Vietnam, Lao PDR, and northern Thailand. Contrary to Pocock (1941), Corbet & Hill (1992), and others, Nepal was omitted (with justifications). The paper concluded that it is possible that 'the species is neither particularly rare nor threatened, rather that it is an inconspicuous denizen of chronically under-surveyed regions.' It was recommended that 'all records, even single incidental ones, merit publication'.

Subsequent to Abramov et al. (2008), the Stripe-backed Weasel was discovered in northeastern Cambodia (McCann & Pawlowski 2018), and additional records were contributed from Lao PDR (Streicher et al. 2010) and Thailand (Chutipong et al. 2014). A molecular study, which included *M. strigidorsa,* was undertaken by Kurose et al. (2008). Meanwhile, its IUCN status was downgraded in 2008 to 'Least Concern' (reconfirmed in 2016) on account of its widespread distribution, presumed large population, occurrence in many protected areas, apparent tolerance of habitat modification, and hunting pressure (Roberton et al. 2016).

In Myanmar, the Stripe-backed Weasel was omitted by Yin (1967). However, some of the earliest records of this species were from Myanmar, including the first outside Sikkim and, if valid, Nepal. Thomas (1891) listed a specimen collected from Thagata, 'east of Moulmein' (= Mawlamyine), adjacent to Mount Mooleyit (= Mulayit Taung). Today, Thagata is included in Kayin State but at that time, it was assigned to Tenasserim. This may explain the confusion with Lekagul and McNeely's (1977) distribution map, which includes the whole of present day Tanintharyi Region (= Tenasserim) and only

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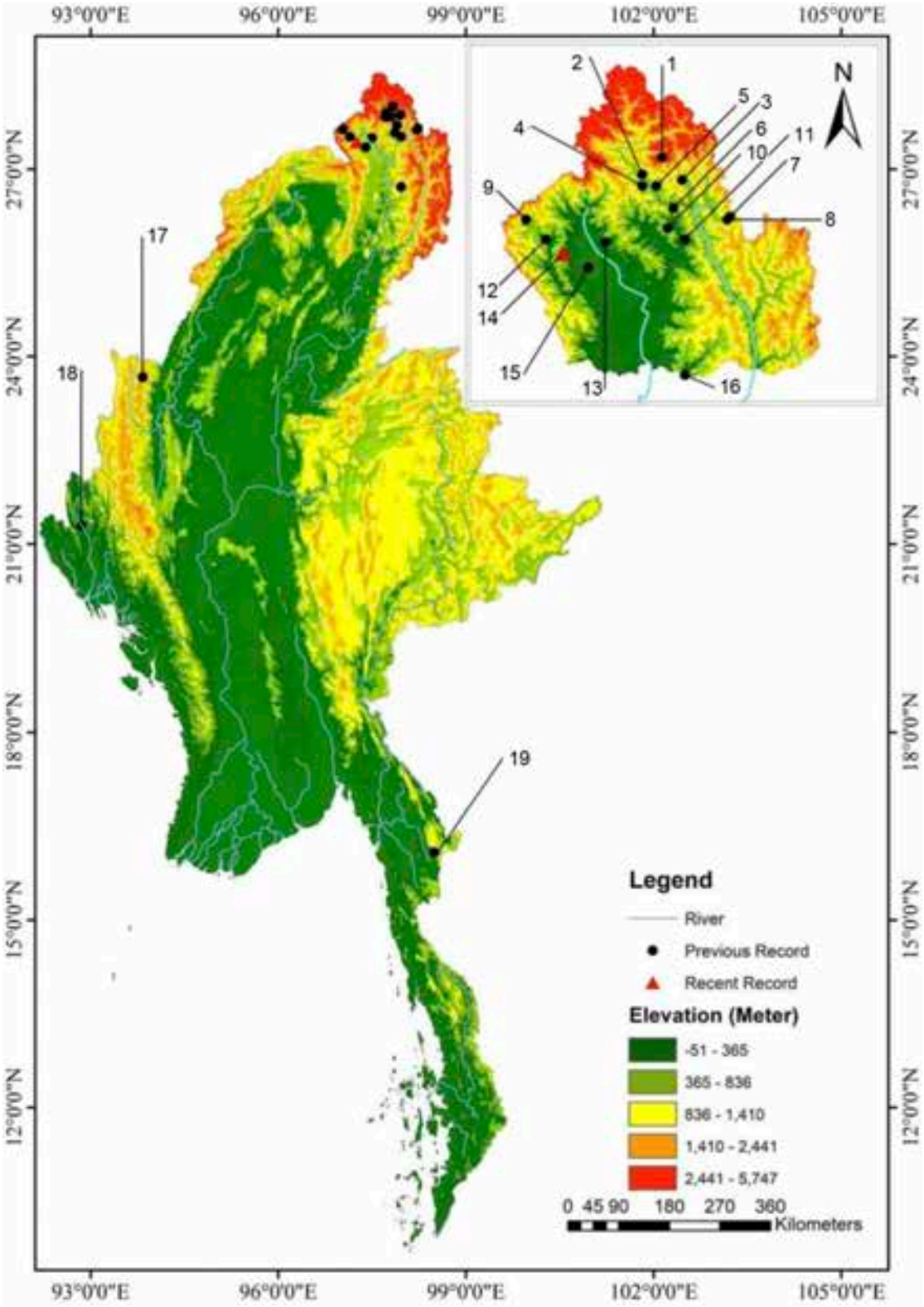

Figure 1. Known distribution of the Stripe-backed Weasel *Mustela strigidorsa* in Myanmar. Kachin State: 1—no exact loc. 1—no exact loc. (28.000°N, 97.833°E); 2—Nam Tamai (27.900°N, 97.717°E); 3—Nam Tamai (27.867°N, 97.950°E); 4—no exact loc. (27.833°N, 97.717°E); 5—Nam Tamai (27.833°N, 97.800°E); 6—Nam Tamai (27.700°N, 97.900°E); 7—Makhungam (27.650°N, 98.233°E); 8—Gushin—1 (27.633°N, 98.217°E); 9—Nam Tamai (27.633°N, 98.033°E); 10—Tasa Hku (27.583°N, 97.867°E); 11—Lanzatu (27.517°N, 97.967°E); 12—Awaddam—2 (27.517°N, 97.150°E); 13—Nam Tamai (27.500°N, 97.500°E); 14—Atet San Kawng (27.433°N, 97.250°E); 15—Putao (27.350°N, 97.400°E); 16: Gam Majaw (27.717°N, 97.967°E); Chin State: 17—96 km west of Kindat (23.667°N, 93.833°E); 18—Paletwa (21.300°N, 92.850°E); Kayin State: 19—Thagata (16.083°N, 98.500°E). All records based on Abramov et al. (2008), except for locality 14 (new record).

Image 1. Two views of a Stripe-backed Weasel *Mustela strigidorsa* photographed 2km from Atet San Kawng Village, Putao Township, Hkakabo Razi Landscape, Kachin State (27.433°N, 97.250°E).

a '?' where Thagata is located (see Abramov et al. 2008; Chutipong et al. 2014).

Subsequent records from Myanmar are listed in the Appendix of Abramov et al. (2008) and include two localities in Chin State, based on material collected in 1914 and 1915, and a series of localities in Kachin State. Of the 24 Myanmar records listed by Abramov et al. (2008), 17 are for specimens held in the Natural History Museum, London [BMNH] (collected between 1914 and 1938), and one each for the collections of the Field Museum of Natural History, Chicago [FMNH] (collected in 1931) and the Museo Civico, Genoa (collected c. 1885–1889), respectively. The remaining five are remains of dead animals, mostly skins, held by villagers in Kachin State, between 1997 and 2005.

The recent sighting of a single individual in Hkakabo Razi Landscape by TT represents the first observation of the species in Myanmar that includes photographs and video footage. It took place on 07 March 2019, at 0910 h, some 2 km from Atet San Kawng Village, Putao Township, Kachin State (27.433°N, 97.250°E) (Figure 1). The site has an elevation of c. 580 m. This elevation is lower than

Image 2. Habitat of the Stripe-backed Weasel *Mustela strigidorsa*, 2km from Atet San Kawng Village, Kachin State, Myanmar.

most other records from Myanmar, which have a range of 90 to 2,135 m and median score of 1,220 m. However, it is more consistent with those from Thailand, Lao PDR, and Vietnam, which when combined, have a range of 130 to 1,750 m (n= 26) and a median of 800 m (data are taken from Abramov et al. 2008). Geographically, the new location lies within the known distribution of the species in Kachin. In Myanmar, except for two specimens from Paletwa, western Chin State (Locality 18 in Figure 1), all the records are from the mountainous areas in the west, north, and east of the country. To date, none has been found in the central areas of the Ayeyarwady and Chindwin river basins (Figure 1).

The photographs show the characteristic pelage of this species, and in particular the diagnostic narrow, almost white stripe that runs from the crown of the head to the base of the tail (Image 1). The video shows a single animal foraging through undergrowth on the ground, searching among dried leaves and litter (Video 1). This seems typical of the species, which is reported elsewhere as being primarily solitary and diurnal in its habits (Streicher et al. 2010; Hobcroft 2011; Coudrat et al. 2014). The area is thickly vegetated and is located in the foothills of a forested mountain range, approximately 20 m from a stream (Image 2). The evergreen forest comprises large trees, shrubs, and bamboo thicket, dominated by *Shorea* spp., *Dipterocarpus* spp., and *Bambusa* spp. The climate is subtropical. Although there is considerable local variation in average temperature and rainfall, in Putao (which is situated close-by) the mean annual temperature is c. 27 °C and the mean annual rainfall is 349 mm (Aung et al. 2017). The video footage complements a previous video by Andy Merk in 2016 in Phu Kieo Wildlife Sanctuary, Thailand, which was posted on Youtube (https://www.youtube.com/watch?v=-sLLUPAvigg). This latter video shows a Stripe-backed Weasel coming to a pool to drink.

The recent photographs are some of very few taken

Video 1. Video of Stripe-backed Weasel *Mustela strigidorsa* foraging through undergrowth, 2km from Atet San Kawng Village, Hkakabo Razi Landscape. © Tun Tun.

of the animal in the wild, other than by camera-trap, and the first for Myanmar. As with reports from elsewhere in its range (Abramov et al. 2008), the Myanmar individual appears to be either unaware of the presence of humans or not particularly shy. It approached within 5 m of TT and stayed in the area for a considerable period of time. To date, this species has not recorded in camera traps in Myanmar (Zaw et al. 2008). This reflects a similar situation elsewhere in its range (Abramov et al. 2008; Datta et al. 2008; Hunter & Barrett 2018), with single published camera trap records for Lao PDR (Streicher et al. 2010) and Cambodia (McCann & Pawlowski 2018), respectively.

The population status of the Stripe-backed Weasel in Myanmar is not known. However, villagers reported it to be locally common in Kachin (Rabinowitz & Khaing 1998). This anecdotal evidence corresponds to reports in other countries, where villagers also suggest it is at least locally common (Abramov et al. 2008). It is mostly impossible to verify the identifications. Unlike earlier reports from China (Roberton et al. 2016), there is no evidence in Myanmar that it is hunted, although individuals, especially those that depredate domestic chickens, may be trapped and killed by villagers (Zaw et al. 2008). Unlike Lao PDR (Hansel & Tizard 2016), in Myanmar there are no reports of this species being sold in markets.

The incidental sighting reinforces the view that Hkakabo Razi Landscape is a refuge for rich biodiversity, including mammals (Rabinowitz & Khaing 1998; Bates et al. 2021) and birds (Renner et al. 2015). It is also important for a species that is not well covered by camera-trap by-catch (for example from Tiger surveys and monitoring) and for which there is no form of monitoring program anywhere in its range. Therefore, further study of this small carnivore species in Myanmar would be of much interest.

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NOTE

Are the uplifted reef beds in North Andaman letting nesting Olive Ridley Sea Turtle *Lepidochelys olivacea* stranded?

Nehru Prabakaran [1], Anoop Raj Singh [2] & Vedagiri Thirumurugan [3]

[1–3] Wildlife Institute of India, Chandrabani, Post Box 18, Chandrabani, Dehradun 248001, India.
[1] nehrumcc@gmail.com (corresponding author), [2] anooprajsingh23@gmail.com, [3] thirumurugan771@gmail.com

Andaman & Nicobar Islands have nesting of four marine turtle species—Olive Ridley Turtle *Lepidochelys olivacea* (Eschscholtz, 1829), Leatherback Turtle *Dermochelys coriacea* (Vandelli, 1761), Hawksbill Turtle *Eretmochelys imbricate* (Linnaeus, 1766), and Green Sea Turtle *Chelonia mydas* (Linnaeus, 1758)—of which Olive Ridley Turtle is reported to exhibit mass nesting (Bhaskar & Whitaker 1983; Namboothri et al. 2012). With major nesting and foraging grounds, North Andaman is among the vital conservation zones for all the four sea turtles (Murugan 2004; Andrews et al. 2006; Sridhar et al. 2019). For example, Interview Island is one of the largest green turtle nesting sites in North Andaman (Namboothri et al. 2012) and an earlier study suggested that the northwestern coast of the North Andaman Island should be conserved as Hawksbill Turtle sanctuary as it provides a potential nesting and feeding ground for this species (Bhaskar & Andrews 1993).

The 2004 Sumatra-Andaman earthquake and the subsequent tsunami have severely affected the entire coastal ecosystems across the Andaman & Nicobar Islands (Andrews & Vaughan 2005; Prabakaran & Paramasivam 2014). The tectonic uplift in the west coast of North Andaman has especially resulted in a huge landmass of coral reefs being exposed, and the altered hydrology resulted in a loss of more than 90% of the mangrove forest (Andrews et al. 2006; Ramakrishnan et al. 2020). Additionally, beaches used by many sea turtles as nesting ground were drastically affected by the mega-disaster (Murugan 2005; Andrews et al. 2006). The high intensity tsunami waves not only resulted in heavy deposition of sand and sediment at the shore, but it also brought a huge pile of sea debris such as plastic, wood, and polyethylene (Murugan 2005; Ramachandran et al. 2005; Rajendran et al. 2013). The turtle nesting across the Andaman Islands severely declined in the subsequent years following the disaster owing to the altered coastal lines (Murugan 2005; Namboothri et al. 2015). Though many turtle nesting beaches were affected by the uplift, the new beaches formed after the tsunami provided some hope for turtle nesting in the North Andaman (Murugan 2005; Namboothri et al. 2015).

During our survey to understand vegetation

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Image 1. The study location in the west coast of North Andaman is largely characterised by the uplifted reef beds that are often 200m to 500m wide. The red line in the centre indicates the study transect (500m).

colonization, focused on mangroves, in the uplifted reef beds near the Radhanagar creek in North Andaman on 10 February 2021 (13.411N & 92.849E), we came across four carcasses of Olive Ridley Turtles within a 500-m transect (Image 1). The carcasses were probably a week old and are characterized by the presence of degenerating flesh and foul smell.

Incidentally, the North and Middle Andaman is known to have some critical nesting beaches of marine turtles, of which the Cuthbert Bay is known to have mass nesting of Olive Ridley Turtles. Mass nesting usually occurs during the third quarter phase of the lunar cycle that coincides with the neap tide phase of the ocean (Forest Department, pers. comm. February 12, 2021). As per the local reports, the mass nesting of Olive Ridley peaked in the middle of the first week (1–7) February 2021 at the Cuthbert Bay, and our observations happened roughly a week later. Olive Ridley Turtles are likely to nest all across the Andaman Islands and during this peak-nesting season, the observed turtles could have approached the coastal line searching for the potential nesting beach but instead ended up stranded in the exposed reef bed. The site has exposed reef beds that are 100–300 m wide, and at some places, it is up to 500 m wide. Most of these uplifted reef beds are partially inundated through the complex water channels in the reef beds during high tides and are often fully exposed during low tides, except for some puddles.

Interestingly, a report that reviewed all the research work on the turtle nesting beaches in the Andaman & Nicobar Islands doesn't record nesting of Olive Ridley Turtles in the west coast of North Andaman (Namboothri et al. 2012). However, many sites especially in the east coast namely Cuthbert Bay, Harguna beach, Rutland Island, Ross & Smith islands, Ramnagar beach of North Andaman, exhibit frequent nesting of Olive Ridley Turtles (Andrews et al. 2006; Namboothri et al. 2012, 2015; Sridhar et al. 2019). Many of such sites were notified as wildlife sanctuaries to exclusively conserve and protect the sea turtles in North Andaman Island.

Most of the Olive Ridley nesting sites are from the east coast of Andaman Islands due to the upheaval of reef flats that resulted in beaches becoming inaccessible for nesting in the west coast of North Andaman (Andrews et al. 2006). Our observation suggests that the nesting turtles are either stranded in the reef beds, or there may be other factors contributing to such mortality. Note that the observation pertains to just one site in the otherwise long coast line that is usually uninhabited by humans and with a high potential for turtle nesting. In addition, utilization of the uplifted reef beds and the adjacent beaches by the nesting marine turtles is largely unknown. Therefore, a focused survey on turtle stranding in the uplifted reef beds across the North

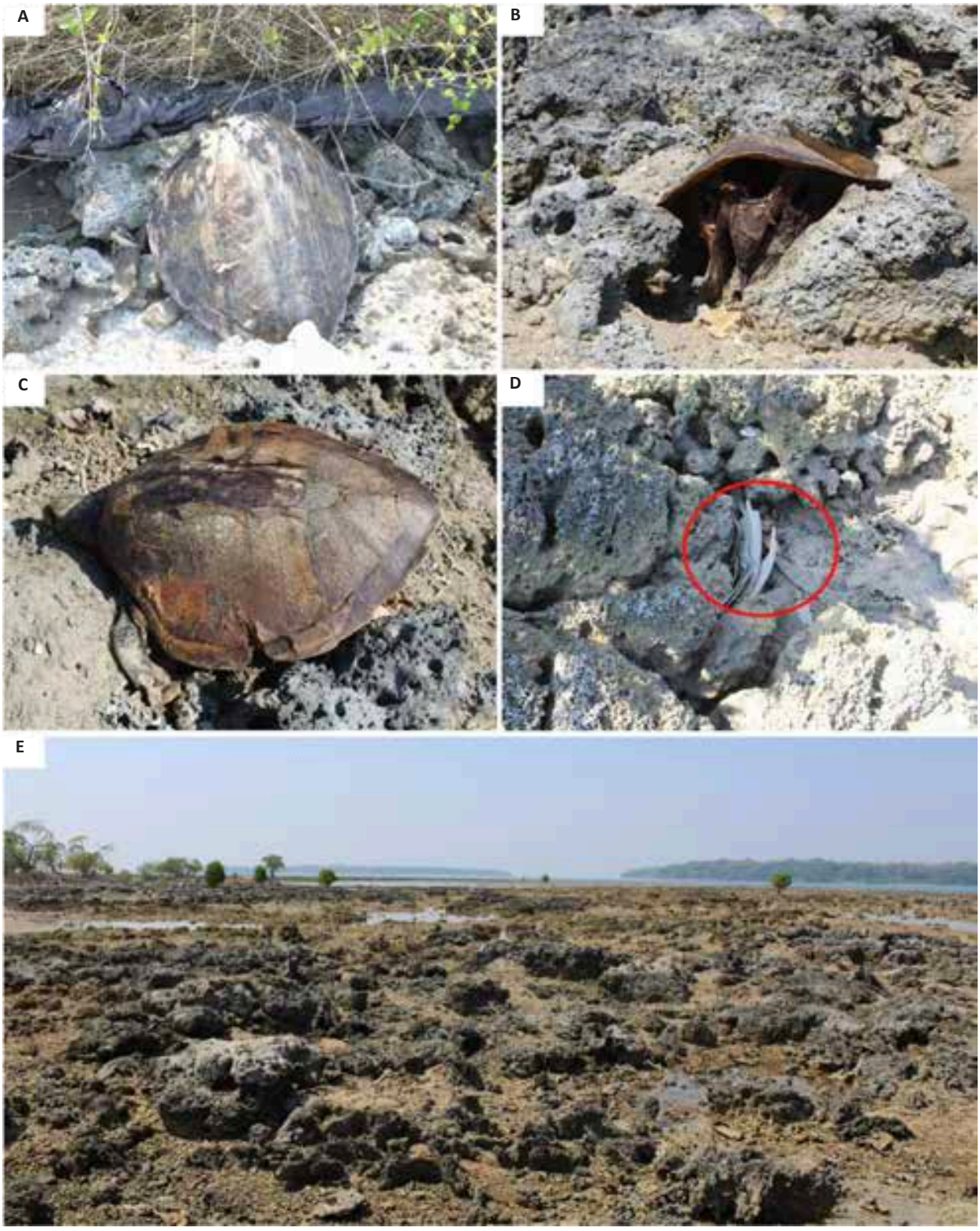

Image 2. A–C—The carcases of Olive Ridley Turtle *Lepidochelys olivacea* (Eschscholtz, 1829) observed in the study location | D—Old remaining's (bones) of the sea turtle carcase found between the exposed reef beds | E—Panoramic view of the exposed reef beds in the study site.
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Andaman during the peak-nesting season may provide better insights on the turtle mortality incidences.

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First record of the orb-weaving spider *Araneus tubabdominus* Zhu & Zhang, 1993 (Araneae: Araneidae) from India

Souvik Sen [1], John T.D. Caleb [2] & Shelley Acharya [3]

[1,3] Zoological Survey of India, Prani Vigyan Bhawan, M-Block, New Alipore, Kolkata, West Bengal 700053, India.
[2] Division of Biodiversity, Entomology Research Institute, Loyola College (Autonomous), Chennai, Tamil Nadu 600034, India.
[1] sensouvik07@gmail.com (corresponding author), [2] caleb87woodgate@gmail.com, [3] acharya.shelley@gmail.com

Abbreviations: AL—abdomen length | ALE—anterior lateral eye | AME—anterior median eye | AW—abdomen width | CL—carapace length | CW—carapace width | PLE—posterior lateral eye | PME—posterior median eye | TL—total length.

Clerck (1757) erected the orb-weaving spider genus *Araneus*, with *Araneus angulatus* Clerck, 1757 as the generotype. The genus currently has 576 described species globally, of which 18 species are known from India (Caleb & Sankaran 2021; World Spider Catalog 2021). While examining the collections from a recent faunistic survey conducted in the Kerala state of southern India, a female specimen of *Araneus tubabdominus* Zhu & Zhang, 1993 was identified. This species is currently known only from its type locality in China and is known only from its original description, which is in Chinese (World Spider Catalog 2021; Zhu & Zhang 1993). The subsequent description, which also is in Chinese and illustrations of this species (Yin et al. 1997; Song et al. 1999) are based on its original description and illustrations and not on additional material. The present paper deals with the first record of *A. tubabdominus* in India.

Material and Methods: The collected specimen was preserved in 70% ethanol. Morphological examination was done under a Leica M205A stereo zoom microscope and images were captured with a Leica DFC500 camera. All images were processed with the aid of LAS core software (version 3.8.0). All measurements are in millimeters (mm). Palp and leg measurements are given in the following order: total (femur, patella, tibia, metatarsus (except palp), tarsus). The specimen examined is deposited in the National Zoological Collections, Zoological Survey of India, Kolkata, India (NZC-ZSI).

Araneidae Clerck, 1757
Araneus Clerck, 1757

***Araneus tubabdominus* Zhu & Zhang, 1993**

(Images 1–6)

Araneus tubabdominus Zhu & Zhang, 1993: 36, figs 1–7 (male, female); Yin *et al.,* 1997: 184, fig. 101a–g (male, female); Song *et al.*, 1999: 241, figs 140Y–Z, 144N–O, 149I (male, female).

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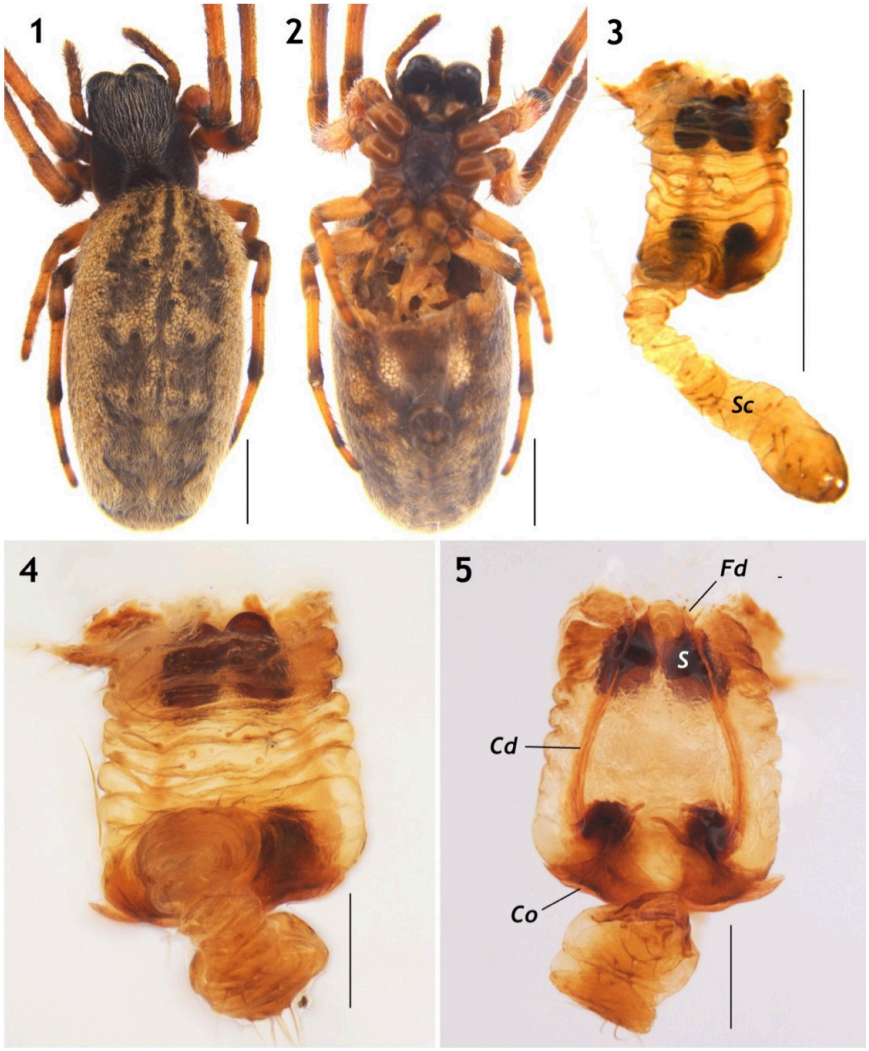

Images 1—5. *Araneus tubabdominus* Zhu & Zhang, 1993: 1—female habitus, dorsal view | 2—same, ventral view | 3—epigynal scape, ventro-lateral view | 4—epigynum, ventral view | 5—vulva, dorsal view. Abbreviations: Cd—copulatory duct | Co—copulatory opening | Fd—fertilization duct | S—spermatheca | Sc—epigynal scape. Scale bars: 1 & 2—2 mm | 3—1 mm | 4 & 5—0.3 mm.

Type material: Holotype–female, allotype–male, paratypes 2 females from Longzhou County, August 1980; 1 female paratype from Luzhai County, August 1981 (deposited in Hebei Educational College, China).

Additional material examined: 1 female (NZC-ZSI-7380/18), India: Kerala, Kannur, Kannapuram, (11.972297°N, 75.321517°E), 10m, 03.ix.2017, coll. Charesh, C.K.

Diagnosis: The species can be distinguished from all known congeners by the elongated, long, tubular abdomen without any humps (Image 1); elliptical spermatheca almost touching each other; thin, subparallel copulatory ducts (Image 5).

Redescription: Female (Images 1, 2): TL 11.43, CL 3.22, CW 2.55, AL 8.21, AW 4.10. Eyes diameter: AME>ALE>PME=PLE; inter-ocular distance: AME–AME 0.29, ALE–AME 0.70, PME–PME 0.10, PLE–PME 0.81, ALE–PLE 0.08, AME–PME 0.19. Clypeus height 0.41. Cheliceral length 1.03. Palp and leg measurements: palp 2.54 (0.64, 0.39, 0.68, 0.83); I 7.02 (1.01, 0.95, 2.70, 1.75, 0.61); II 6.74 (0.75, 0.89, 2.62, 1.77, 0.71); III 4.11 (1.10, 0.62, 1.07, 0.78, 0.54), IV 6.59 (1.40, 0.72, 2.22, 1.60, 0.65); leg formula: 1243. Carapace brown, longer than wide; cephalic part elevated than thoracic part and covered with dense white hairs (Image 1). Eyes pearly white, arranged in two recurved rows. Clypeus brown. Chelicerae dark brown; promargin with three and retromargin with four teeth. Endites and labium brown, apical margin of endites pale and scopulate. Sternum brown, longer than wide. Legs yellowish-brown, distal end of each segment greyish-brown (Image 2). Abdomen elongated oval, extending beyond spinnerets (Images

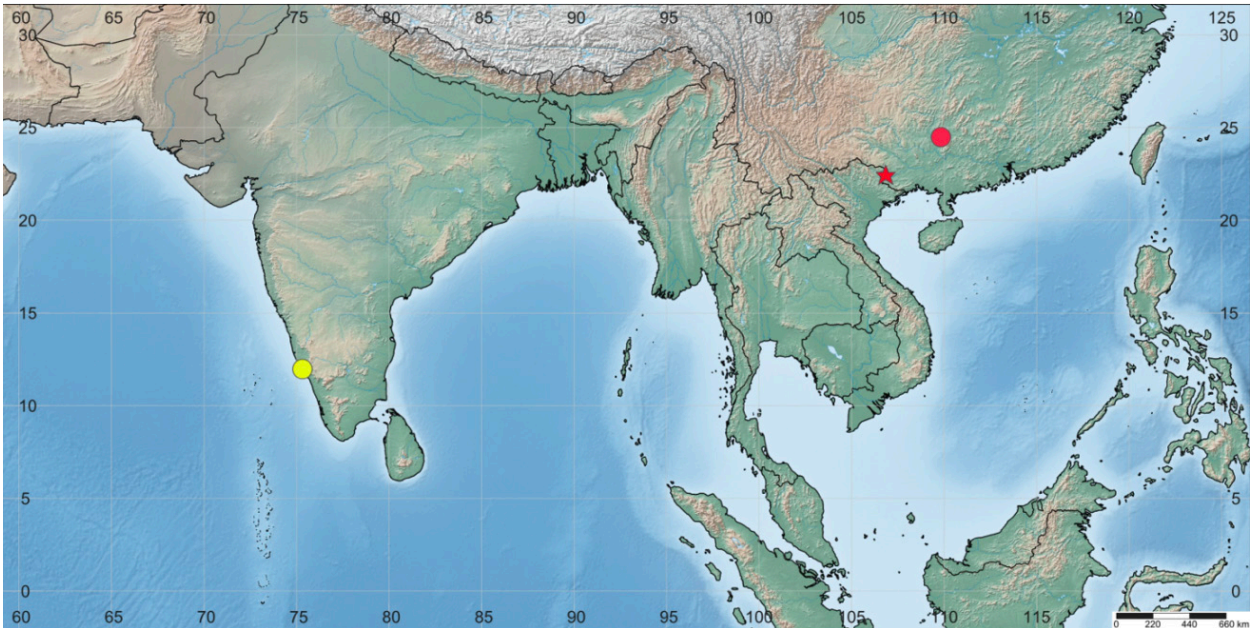

Image 6. Distributional records of *Araneus tubabdominus* Zhu & Zhang, 1993. Star indicates type locality and red circle other collecting locality in China. Yellow circle indicates collecting locality in India.

1, 2); dorsum with white reticulations and distinct median longitudinal grey marking (Image 1), with five pairs of median sigilla; venter with white reticulations and scattered grey patches, with a median grey band between epigastric furrow and spinnerets. Spinnerets grey. *Genitalia* (Images 3–5). Epigynal scape elongated, wrinkled along its entire length, with broad, blunt tip, arising from the basal trapezoid epigynal plate (Images 4, 5); spermatheca small, nearly elliptical, almost touching each other; copulatory openings located laterally lead to the spermathecae with long, subparallel, narrow copulatory ducts (Image 5).

Male: For description and illustrations of the male, see Zhu & Zhang (1993).

Distribution: China, India (new record) (Zhu & Zhang 1993; present data) (Image 6).

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NOTE

The genus *Catapiestus* Perty, 1831 (Coleoptera: Tenebrionidae: Cnodalonini) from Arunachal Pradesh with one new record to India

V.D. Hegde [1] & Sarita Yadav [2]

[1,2] North Eastern Regional Centre, Zoological Survey of India, Risa Colony, Shillong, Meghalaya 793003, India.
[1] hegde67@yahoo.co.in (corresponding author), [2] saritayadavzsi18@gmail.com

The genus *Catapiestus* Perty, 1831 belongs to the tribe Cnodalonini (Tenebrionidae: Stenochiinae), and has at present 12 species in the Oriental and Palaearctic regions, including four species already reported from various parts of India, viz, *Catapiestus bourgoini* Pic, 1912 from Malabar- Mahe, *Catapiestus piceiventris* Fairmaire, 1893 from Andaman Island, *Catapiestus indicus* Fairmaire, 1896 from Kanara & Sikkim, and *Catapiestus subrufescens* Pic, 1911 from Dudhwa National Park, Uttar Pradesh (Lang & Ren 2009; Hegde & Lal 2014). The species of this genus have quite uniform characters – strongly flattened body form and coloration and scarce or no apparent external sexual dimorphism (Lang & Ren 2009). Morphological differentiation of the species mainly depends on features of the pronotum and number of teeth or denticles of profemora (Lang & Ren 2009). In the check-list of Tenebrionidae of Arunachal Pradesh, Hegde (2019) reported only one species *C. indicus*. Examination of the collection at North Eastern Regional Centre (NERC), Zoological Survey of India (ZSI), Shillong, revealed that there are three species *C. subrufescens*, *C. piceiventris*, and *C. rugipennis* collected from Arunachal Pradesh in 1982. These three species are new records for Arunachal Pradesh while *C. rugipennis* (originally described from Japan) is the first report from India.

Material and Methods: The specimens were in the unidentified collection of NERC, ZSI, Shillong, Meghalaya, which were identified up to species level by their morphological characters following Lang & Ren (2009). The identified specimens were registered and deposited in the national zoological collections of ZSI, Shillong. The images were taken with binocular microscope using Leica DFC 450 camera.

Genus *Catapiestus* Perty, 1831

Diagnostic features: The genus *Catapiestus* was proposed by Perty (1831) with *C. Piceus* Perty, 1831 as type species. Subsequently, one species was described by Guèrin-Mèneville (1841), four species by Fairmaire (1888, 1893, 1896), three species by Pic (1911, 1912), and one species by Chûjô (1984).

Body elongate, parallel sided, strongly depressed, Body dark brown, with dense punctures. Head broad, space between eyes broad, neck slender, and nearly cylindrical. Distal six segments of antenna dilated. Maxillary palpus with apical segments strongly securiforme. The lateral margins of pronotum with serrations, and the middle and/or lateral with depression. Elytra with distinct punctures and striae.

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Legs slender, femur with or without tooth, tibial spurs extremely underdeveloped, tarsi with hairs. There is no distinct sexual dimorphism.

1. *Catapiestus subrufescens* Pic, 1911

1911. *Catapiestus subrufescens* Pic, *L'Échange, Revue Linnéenne* 27: 134.

Material examined: Reg. No. I/COL/NERC- 142, 24.viii.1982, 1 specimen (sex undiagnosed), Derok Forest, Tirap Dist., Arunachal Pradesh, India, coll. C. Radhakrishnan.

Diagnostic characters: Body length: 16 mm, body blackish-brown, strongly depressed and with dense punctures. Pronotum lateral margins curved with small radius, with more acute serrations than upper, front, corner acute, hinder corner rounded, elytra punctate striate, distal six segments of the antenna dilated (Image 1).

Distribution: India (Uttar Pradesh and Arunachal Pradesh (New Record)), China, Taiwan (Type locality, Pic 1911; Lang & Ren 2009).

Image 1. *Catapiestus subrufescens* (Reg. No. I/COL/NERC-142).

2. *Catapiestus piceiventris* Fairmaire, 1893

1893. *Catapiestus piceiventris* Fairmaire, *Notes from the Leyden Museum,* 15: 29.

Material examined: Reg. No. I/COL/NERC- 143, 24.viii.1982, 1 specimen (sex undiagnosed), Derak Forest, Tirap Dist., Arunachal Pradesh, India, coll. C. Radhakrishnan.

Diagnostic characters: Body length: 14 mm, body blackish-brown, strongly depressed and with dense punctures. Pronotum almost flat, middle with shallow depression with dense puncture (Image 2).

Distribution: India (Andaman Island (Type locality: Fairmaire 1893; Lang & Ren 2009) and Arunachal Pradesh (New Record)).

Image 2. *Catapiestus piceiventris* (Reg. No. I/COL/NERC- 143).

3. *Catapiestus rugipennis* Chûjô, 1984

1984. *Catapiestus rugipennis* Chûjô, *ESAKIA,* 22: 1.

Material examined: Reg. No. I/COL/NERC-144, 24.viii.1982, 1 specimen (sex undiagnosed), Derok forest, Tirap Dist., Arunachal Pradesh, coll. C. Radhakrishnan.

Diagnostic characters: Body length: 14 mm. Body uniformly shining dark brown, strongly depressed. Elytra punctuate striate with sparse, small punctures, punctures laterally connected with fine reticulate. Profemur with one small tooth on front ridge (Image 3).

Distribution: India (Arunachal Pradesh (new India record)), Japan **(**Amami-Oshima Island and Okinawa Honto Island (Type locality: Chûjô, 1984; Lang & Ren 2009)).

Image 3. *Catapiestus rugipennis* (Reg. No. I/COL/NERC-144).

Discussion: The species of the genus *Catapiestus* are mainly distributed in the subtropical forests of southeastern Asia (Hegde & Lal 2014). Till now only four species of *Catapiestus* are reported from India. With the report of *C. rugipennis* in this paper, the total number of known *Catapiestus* species from India now stands at five.

From Arunachal Pradesh, only *C. indicus* was previously reported (Hegde 2019). The report of *C. subrufescens, C. Piceiventris*, and *C .rugipennis* constitutes the first record from the state, thus raising the total number of *Catapiestus* to four species for Arunachal Pradesh.

The known diversity of *Catapiestus* populations in India is disjunct and largely known from the northeastern states of Arunachal Pradesh and Sikkim, along with Uttar Pradesh and the southern state of Karnataka and Puducherry from the Malabar Coast as well as Andaman Islands (Fairmaire 1893, 1896; Pic 1912; Hegde & Lal 2014; Hegde 2019). The current report of this group from Arunachal Pradesh (in Tirap) is from the lower altitudinal areas which suggest that the other hill states of northeastern India might harbour yet unknown populations of this genus, as the entire area comes under the confluence of the eastern Himalaya and the Indo-Burma biodiversity hotspots. As the hilly states of northeastern India are still largely inaccessible and poorly surveyed, there is a dearth of documentation of insect fauna from the region, which is probably the reason why the known diversity of *Catapiestus* is still low.

A key to the India *Catapiestus* fauna is provided for the benefit of easy taxonomic identification

1. The middle longitudinal groove on pronotum distinct 2
   The middle longitudinal groove on pronotum indistinct .... *C. indicus*
2. Transverse groove on the anterior pronotum absent 3
   Transverse groove on the anterior pronotum present .... *C. subrufescens*
3. Pronotum without puncture posteriorly 4
   Pronotum with puncture posteriorly ..... *C. bourgoini*
4. Anterior pronotum lifted ..... *C. rugipennis*
   Anterior pronotum depressed ..... *C. piceiventris*

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NOTE

Rediscovery and extended distribution of *Indigofera santapaui* Sanjappa (Leguminosae: Papilionoideae) from the states of Maharashtra and Gujarat, India

Kumar Vinod Chhotupuri Gosavi [1], Sanjay Gajanan Auti [2], Sharad Suresh Kambale [3] & Munivenkatappa Sanjappa [4]

[1,2] Department of Botany, HPT Arts & RYK Science College, Nashik, Maharashtra 422005, India.
[3] Department of Botany, Maratha Vidya Prasarak Samaj's Arts, Commerce & Science College, Tryambakeshwar, Maharashtra 422212, India.
[4] Mahatma Gandhi Botanical Garden, University of Agricultural Sciences, GKVK, Bengaluru, Karnataka 560065, India.
[1] kumarvinodgosavi@gmail.com, [2] autisanjay66@gmail.com, [3] skambalesu@gmail.com (corresponding author), [4] sanjappam@ymail.com

Tribe Indigofereae (Leguminosae: Papilionodeae) represented by seven genera *Cyamopsis*, *Indigasarum*, *Indigofera*, *Microcharis*, *Phylloxylon*, *Rhynchotropis*, and *Vaughania*. Of these, the first three occur in India. The genus *Indigofera* is widely distributed in tropical and subtropical regions of the world (Sanjappa 1995) with 750 species. In India, it is represented by 60 species and 10 varieties (Sanjappa 2021 in press). Of these 13 species and seven varieties are endemic to the country (Singh et al. 2015).

While surveying the hills in northern Western Ghats, the authors collected an interesting species of *Indigofera* from Ganeshkhind, Junnar (Pune district, Maharashtra), Anjaneri Hill, Pahine, Dhodamb Fort, Bordaiwat (Nashik district, Maharashtra), and Chinchali ghat (Dang district, Gujarat). After perusal of literature (Kothari 2001) it was identified as *Indigofera santapaui* Sanjappa. This species was described based on the Santapau's collection from Purandhar (Santapau 11397 (BLAT)) and is unique in the genus in having yellow flowers which turn orange after pollination. Perusal of literature (Kothari 2001; Mishra & Singh 2001; Gaikwad et al. 2014) available on the species clearly indicates that this species is critically endangered and known from type locality only.

A detailed description, image, habitat, and distribution map are provided to facilitate identification and distribution.

Indigofera santapaui Sanjappa, Bull. Bot. Surv. India 25: 202.1985; M. Ahmed. & M.P. Nayar Endemic Pl. Indian Region 99. 1987; Sanjappa, Legumes of India 194.1992 & in P.K.Hjra et al., Fasc. Fl. India 21: 117. 1995; M.J. Kothari in N.P. Singh & S. Karthikeyan, Fl. Maharashtra State 1: 711. 2000; D.K. Mishra & N.P. Singh, Endemic Threat. Pl. Maharashtra 93. 2001 (Image 1).

Type: India, Maharashtra, Pune district, Vazirgad-Purandar, 09.x.1950, coll. H. Santapau (holotype, 11397 (BLAT!).

Annual herbs up to 40 cm high; stems sparsely

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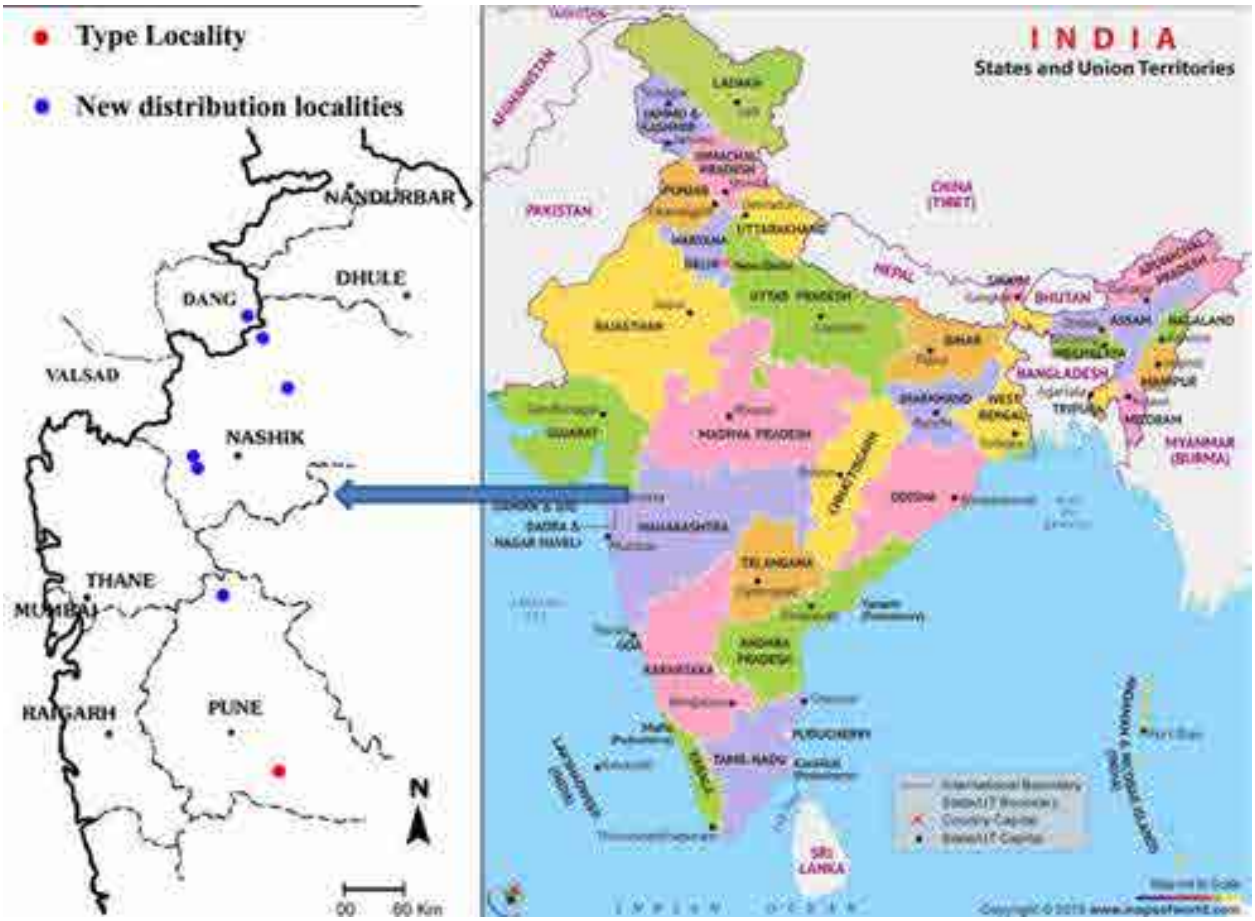

Figure 1. Distribution of *Indigofera santapaui* Sanjappa.

branched from the base, branches adpressed blackish-brown pubescent. Leaves pinnately trifoliate, 3–7 cm long, petiole 1–2 cm long, obscurely canaliculated, adpressed pubescent; leaflets obovate to obovate-oblong, 2.5–5 × 1–2 cm, cuneate at base, obtuse to rounded and mucronate at apex, adpressed pubescent, gland-dotted beneath; stipules 2–3 mm long, subulate, pubescent; petiolules 1.5–2 mm long, pubescent; exstipellate. Racemes 4–6 mm long, axillary, sessile, 5–12-flowered; rachis pubescent interspersed with glandular hairs, axillary. Flowers 4.5–5 mm long, yellow turning orange; pedicels 1–1.5 mm long similar to rachis in pubescens; bracts ca. 1 mm long, caducous. Calyx ca. 2 mm long, adpressed pubescent mixed with glandular hairs; tube short, lobes 5, up to 1 mm long. Standard ca. 4 × 3 mm, obovate, mucronate, yellow, blackish-brown strigose mixed with a few glandular hairs outside; wing petals 2.8–3 × 1.2 mm, yellow, glabrous; keel petals 2.6–4 mm long, dark strigose mixed with a few glandular hairs, spurred on sides. Stamens 10 (9+1), diadelphous, staminal sheath 2.5–3 mm long; anthers ca. 1 mm long. Ovary 1.5–2 mm long, oblong, adpressed puberulous mixed with glandular hairs; style ca. 1 mm long, glabrous; stigma capitate. Pods up to 2 cm long, sub-cylindrical, torulose, straight, reflexed, adpressed pubescent mixed with glandular hairs, sutures obscurely winged, endocarp smooth, 2–4-seeded, hairy. Seeds smooth, shining, reddish-brown.

Flowering and fruiting: Mid-August to October.

Distribution: India, Maharashtra (Pune and Nashik districts), Gujarat (Dang district) (Figure 1).

Ecological Note: *Indigofera santapaui* grows on hill slopes with well-drained soil in association with *Apluda mutica* L., *Arthraxon lancifolius* (Trin) Hochst, *Arundinella pumila* (Hochst.) Steud., *Impatiens balsamina* L., *Lavandula bipinnata* (Roth) Kuntze, and *Lobelia heyneana* Schult.

Specimens examined: SSK 14, 18.ix.2016, India, Maharashtra, Nashik district, Tryambakeshwar, Anjaneri, coll. S.S. Kambale, K.V.C. Gosavi & S.G. Auti; SSK 27, 30.ix.2017, Dhodamb Fort, coll. S.S. Kambale & K.V.C. Gosavi; SSK 28, 01.x.2017, Maliamba (Bordaiwat), coll.

Image 1. *Indigofera santapaui* Sanjappa: a—habit | b—flowering twig | c—flowers | d—pods. © K.V.C. Gosavi

S.S. Kambale & K.V.C. Gosavi, Gujarat; SSK 29, 02.x.2017, Dang district, Chinchali ghat, coll. S.S. Kambale & K.V.C. Gosavi (Herbarium, Dept. of Botany, RYK Science College, Nashik) (Image 2); 1403 (HIFP), 14.xii.1993, Pune district, Junnar, Ganeshkind Ghat, coll. B.R. Ramesh, D.De Franchschi & P.B. Viet; Sanjappa 2008, 21.ix.2014, Pune district, Junnar, Ganeshkind Ghat, 905m, coll. M. Sanjappa & A.N. Sringeswara (Herbarium specimens deposited in University of Agricultural Sciences, Bangalore, Botanical Survey of India, Western Circle Pune, Central National Herbarium Kolkata and Madras Herbarium, Coimbatore).

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Additional distribution records of *Ceropegia anjanerica*, an endemic and 'Endangered' lantern flower of the northern Western Ghats, India

Samir Shrikant Maity [1], Ajay Natha Gangurde [2], Sharad Suresh Kambale [3], Avinash Ramchandra Gholave [4], Avinash Asraji Adsul [5], Ganesh Babaso Pawar [6] & Kumar Vinod Chhotupuri Gosavi [7]

[1,7] Department of Botany, Gokhale Education Society's HPT Arts and RYK Science College, Nashik, Maharashtra 422005, India.
[2] Department of Botany, Savitribai Phule Pune University, Pune, Maharashtra 411007, India.
[3] Department of Botany, Maratha Vidya Prasarak Samaj's Arts, Commerce & Science College, Tryambakeshwar, Nashik, Maharashtra 422212, India.
[4] Department of Botany, K.V.N. Naik Arts, Commerce and Science College, Canada Corner, Nashik, Maharashtra 422002, India.
[5] Department of Botany, Gokhale Education Society's Arts, Commerce and Science College, Jawhar, District Palghar, Maharashtra 401603, India.
[6] Department of Botany, Abasaheb Marathe Arts and New Commerce, Science College, Rajapur, District-Ratnagiri, Maharashtra 416702, India.
[1]samirmaity6888@gmail.com, [2]ajaygangurde98@gmail.com, [3]skambalesu@gmail.com (corresponding author), [4]agholave@gmail.com, [5]avinash.adsul@gmail.com, [6]pawargb22@gmail.com, [7]kumarvinodgosavi@gmail.com

Genus *Ceropegia* L. (s.s.) (Ceropegiae: Apocynaceae) is represented by more than 260 taxa worldwide (The Plant List 2013) and distributed in the Canary Islands, India, Madagascar, New Guinea, northern Australia, southeastern Asia, tropical Arabica, and Africa except the Mediterranean region (Meve 2002). It is represented by 62 taxa in India and 26 taxa in Maharashtra (Kambale & Yadav 2019; Murugesan et al. 2019). Nashik district represents six species and two varieties of *Ceropegia*, *viz*., *Ceropegia anjanerica* Malpure, M.Y.Kamble & S.R.Yadav, *C. bulbosa* Roxb. var. *bulbosa*, *C. bulbosa* Roxb. var. *lushii* (Graham) Hook.f., *C. hirsuta* Wight & Arn., *C. lawii* Hook.f., *C. mahabalei* Hemadri & Ansari, *C. media* (H.Huber) Ansari, and *C. vincifolia* Hook (List modified based on personal observations, after Lakshminarasimhan & Sharma 1991).

Ceropegia anjanerica is an 'Endangered' (Pethe & Watve 2021) and endemic flytrap flower and has recently been reported from adjacent area called Navardev, Kushegaon, Igatpuri tehsil of Nashik district (Auti et al. 2019).

As a part of floristic studies on Tryambakeshwar and surrounding areas, various places have been surveyed by the authors. A recent survey made of the Bhaskargad, Bramha Hill, Bramhagiri Hill, Harihar Fort, Vatvad Hill, (Nashik District) resulted in the collection of *Ceropegia anjanerica* (Malpure et al. 2006).

Ceropegia anjanerica Malpure, M.Y.Kamble & S.R. Yadav Curr. Sci. 91(9): 1141. 2006; Karthik. et al. Fl. Pl.

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Image 1. *Ceropegia anjanerica* Malpure, M.Y. Kamble & S.R. Yadav: A—Habitat (Bhaskargad) | B—Whorled leaves (Bramhagiri) | C—Kushegaon Population | D—Vatvad population. © S.S. Maity.

India 1: 160. 2009; Kambale & S.R.Yadav, Asklepios 115: 29. 2013; Kambale & S.R.Yadav, Rheedea 29(1): 93; Auti et al. J. Bombay Nat. Hist. Soc. 116. 181. 2019. (Fig. 1, Table 1).

Perennial, erect, tuberous herbs. Stems rarely two per tuber. Leaves scabrous above, along midrib, and margin, lamina lamina elliptic-narrowly elliptic, 1.3–3.7 × 0.3–1.1 cm, glabrous otherwise. Inflorescence an extra-axillary solitary flower; corolla tube up to 1.9 cm long, gradually dilated at base, funnel-shaped towards throat, slightly curved, greenish-grey, striated with deep purple lines within, white otherwise, glabrous within; corolla lobes 1.4–1.9 cm long, greenish-yellow, obovate, attenuate, finely pubescent throughout, connate at the tip, lobes reflexed. Corona biseriate, stipitate; outer corona of five bifid lobes, 2×2 mm, yellow, ciliate within and along margin; inner corona of five erect linear lobes, c. 2 mm long, alternating with outer corona. Follicles usually in pairs, straight, tapering to a fine point, erect. Seeds ovoid, oblong, comose; coma white, silky.

Flowering & Fruiting: July–November.

Distribution: Endemic to the northern Western Ghats

Table 1. Comparison of characters at different populations.

Character	Anjaneri	Bramhagiri	Harihar fort	Kushegaon
Arrangement of leaves	opposite-decussate	whorled (Image 1B)	opposite-decussate	opposite-decussate
Lamina shape	elliptic-narrowly elliptic	elliptic-narrowly elliptic	linear to lanceolate	elliptic-narrowly elliptic
Corolla tube	green	green	green	red at the upper half (Image 1C)
Corolla lobes	Yellowish-green	Yellowish-green	Yellowish-green	yellow with reddish tinge (Image 1C)

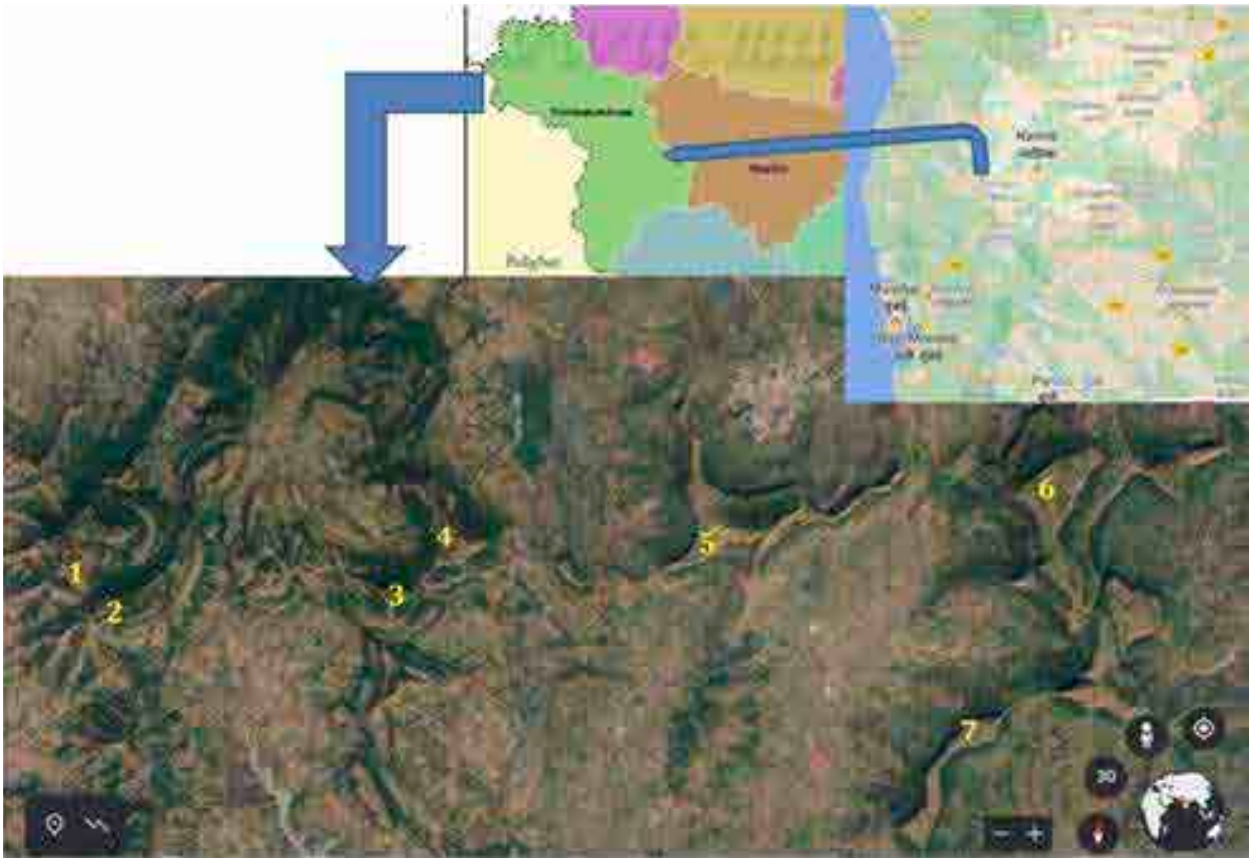

Image 2. Distribution of *Ceropegia anjanerica* Malpure, M.Y. Kambale & S.R. Yadav: 1—Vatvad Hill | 2—Bhaskargad | 3—Harihar fort | 4—Bramha Hill | 5—Bramhagiri Hill | 6—Anjaneri Hill (Type locality) | 7—Kushegaon.

of Maharashtra (Nashik district).

Habitat: Grows at an altitude of about 1,300 m in well-drained soil, in association with *Cyanotis fasciculata* (B. Heyne ex Roth) Schult.f., *Justicia procumbens* L., *Senecio bombayensis* N.P. Balakr. and *Swertia minor* Knobl.

Specimens examined: SSK-5420, 19.vii.2020, India, Maharashtra, Nashik District, Tryambakeshwar, Umbhrande, Vatvad Hill, coll. S.S. Kambale (Image 3); SSK-5421, 28.vii.2020, Bhaskargad, coll. A.N. Gangurde & S.S. Maity; SSK-5422, 3.viii.2020, Harshvadi, Harihar Fort, coll. S.S. Maity & A.N. Gangurde; SSK-5423, 4.viii.2020, Tryambakeshwar, Bramhagiri Hill, coll. S.S. Maity & A.N. Gangurde; SSK-5427, 6.ix.2020, Bramha Hill, Harshvadi-Talegaon, coll. A.N. Gangurde, S.S. Maity, A.A. Adsul & S.S. Kambale (All specimens are in the Herbarium of Department of Botany, Arts, Commerce & Science College, Tryambakeshwar).

Notes: These peculiar flytrap flowers remained unnoticed despite the localities of their occurrence were frequently visited by both botanists and amateur plant photographers. Vatvad Hill, Bhaskargad, Harihar Fort, and Brahmagiri are the places of the public interest and visited for adventurous treks during and after monsoon. Authors have visited Bramhagiri Hill several times, however, never encountered with *Ceropegia anjanerica*. This year when we visited Vatvad Hill during

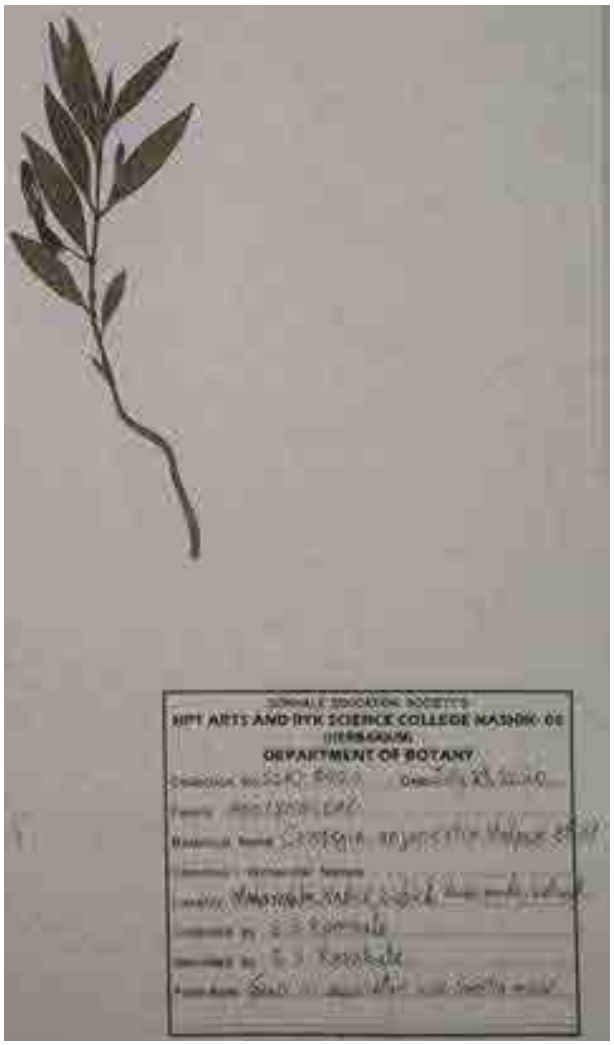

Image 3. Herbarium sheet of *Ceropegia anjanerica* (# SSK-5420).

monsoon (July 2020) we observed healthy population of *Ceropegia anjanerica*. Then, we thought that the species may occur wherever similar habitats are available. Such similar habitats are available on the very next rock outcrops which are Bhaskargad, Harihar fort, Bramha Hill and Bramhagiri Hill. Surveys undertaken to these places resulted in the collection of *Ceropegia anjanerica*. This collection highlights the need of designated surveys to locate such endemic species which are reported from their type localities only. This will help in prioritizing the conservation of threatened species.

Conservation status: *Ceropegia anjanerica* was assessed as Critically Endangered [CR B1ab (iii,v) + B2 ab (iii)] by Pethe et al. (2015) and as 'Endangered' by Pethe & Watve (2021) based on additional four locations on the IUCN Red List. Though the type locality, i.e., Anjaneri Hills, Nashik, is declared as an 'Anjaneri Conservation Reserve' and due care has been taken by Maharashtra Forest Department for its conservation, other localities are under constant anthropogenic pressure. Other than Anjaneri Conservation Reserve, all the localities are tourist places and therefore, frequent trampling by tourists will certainly destroy the habitats. Grazing is not a severe threat at the above mentioned localities. Controlled tourism and awareness amongst tourists will help in reducing the threat to some extent. Unnecessary uprooting of the tuber just for the sake of growing this endemic species in captivity should be avoided as it will not survive outside its habitat more than a year or so if appropriate care is not taken.

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NOTE

Notes on the extended distribution of *Impatiens megamalayana*, a recently described balsam in Western Ghats, India

Anoop P. Balan [1] & **A.J. Robi** [2]

[1,2] Bishop Abraham Memorial College, Thuruthicad, Pathanamthitta, Kerala 689597, India.
[1] anooppb01@gmail.com (corresponding author), [2] ajrobin80@gmail.com

The balsam family Balsaminaceae includes two genera and more than 1,000 species of fleshy herbs. *Hydrocera* Blume ex Wight & Arn. is a monotypic genus with a single species *H. triflora* (L.) Wight & Arn., and is distributed from Sri Lanka, India to Java, southern Borneo, and Sulawesi (Grey-Wilson 1980). *Impatiens* L., the other genus of the family is highly diversified and is known to have five distinct diversity hotspots, viz., tropical Africa, Madagascar, Southern India, Sri Lanka, the eastern Himalaya, and southeastern Asia (Yuan et al. 2004). In India, the genus is represented by more than 210 species, mainly distributed in the eastern Himalaya, the northeastern states, and the Western Ghats (Bhaskar 2012). The Western Ghats is one of the major centres of diversification of *Impatiens*. Nayar et al. (2014) enumerated 106 taxa of *Impatiens* from the Western Ghats of which 97 are exclusive endemics. More than 30 species have been discovered from various parts of the Western Ghats during the last 10 years (Kumar et al. 2011; Dessai & Janarthanam 2011; Narayanan et al. 2011, 2012a,b, 2013; Hareesh et al. 2015a; Prabhukumar et al. 2015a,b, 2016, 2017; Ramasubbu et al. 2015a,b, 2017, 2020a,b; Chhabra et al. 2016; Bhaskar & Sringeswar 2017; Manudev et al. 2017; Mani & Thomas 2017; Mani et al. 2018, 2020; Arigela et al. 2019; Salish et al. 2019; Subbiah & Vellingiri 2019; Vishnu et al. 2020 & 2021; Arya et al. 2021). *Impatiens* species are usually seen in open, wet grasslands and rocky hill slopes at higher elevations and are highly sensitive to micro-climatic conditions. Major populations of Impatiens in the Western Ghats are outside protected forest areas and are facing severe threat due to habitat loss and changes in climatic conditions.

Kerala, one of the smallest states in India is rich in its balsam diversity. Sasidharan (2011) enlisted 80 species from Kerala, of which 17 are endemic to the state. Since then, 24 species have been added to the balsam flora of the state including a new distributional record (Anil Kumar et al. 2011; Narayanan et al. 2011, 2012a,b, 2013; Hareesh et al. 2015a,b; Prabhukumar et al. 2015a,b; Ramasubbu 2015b; Prabhukumar et al. 2016, 2017; Manudev et al. 2017; Mani & Thomas 2017; Mani et al. 2018, 2020; Salish et al. 2019; Vishnu et al. 2020 & 2021; Arya et al. 2021). Joe et al. 2017 elevated *Impatiens rufescens* var. *agastyamalayensis* to species level, i.e., *I. agastyamalayensis* (Bhaskar) Joe, Bhaskar & Sabu. Thus, the total number of *Impatiens* in Kerala state reached 107. While exploring the Urumbikkara hills of Idukki district in central Kerala, the authors came across a small, delicate *Impatiens* with pale red

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flowers. Upon critical examination it was identified as *I. megamalayana* Ramas., a recently described balsam from the Megamalai hills of Tamil Nadu. This is the first report of occurrence of this narrow endemic species outside its type locality. Detailed description, images, distribution map and notes on habitat, ecology and conservation status are provided for easy identification and a better understanding of the species. An updated checklist of the balsams of Kerala state is also furnished for future reference.

Taxonomic Treatment

Impatiens megamalayana

Ramas., Phytotaxa 302(2): 193. 2018.

(Image 1)

Annual, succulent, erect, herbs, 25–40 cm tall; stem purplish, cylindrical with 3–5 ridges, often branched, glabrous, nodes slightly swollen, internodes 4–6 cm long. Leaves opposite, decussate; petiole 0.3–0.4 mm long, glabrous, with 1–2 pairs of extra-petiolar glands; lamina linear-ensiform, 2.6–5.0 × 0.5–0.8 cm, acute-shortly acuminate at apex, truncate or slightly cordate at base, sparsely hairy above along the midrib, smooth and sometimes purplish below, margins distinctly serrate, midrib distinct, lateral veins obscure. Inflorescence 1–2 per axil. Flowers about 5 mm across, pale purple or yellow with reddish spot; pedicellate; pedicel 1.5–1.8 cm long, hairy along one side. Sepals: lateral sepals linear, up curved, 2.0–2.5 mm long, acuminate at apex, 1–2 nerved, purplish, densely hairy; lower sepal boat-shaped, 3.5–4.2 × 1.0–1.6 mm, with 4–7 wrinkles, tip curved towards outside, densely hairy, purple, spur absent. Petals pale red with deep reddish- spot: dorsal petal ovate-orbicular, 2–2.2 × 3.5–3.8 mm, dorsally keeled, keel densely covered with unicellular hairs; lateral petals united, oblong, deeply clawed, 2-lobed, 3.2–3.6 × 2.8–3.0 mm, basal lobe small, distal lobe round at apex, dorsal auricle prominent. Stamens 5, cohering above pistil; filaments free up to ⅔rd their length, connate at apex; anthers pale yellow. Ovary ellipsoidal, 2.0–2.2 mm long, glabrous; style rudimentary; stigma minute. Capsule ovoid, turgid, 11–12 × 4–5 mm, acute, beaked, glabrous 5–9-seeded. Seeds 6–9, round with prominent caruncle, 1.0–1.2 × 0.3–0.4 mm, compressed, glossy-black.

Flowering and fruiting: September to December.

Habitat & Ecology: *Impatiens megamalayana* is usually found in wet rocky hill slopes and open

Image 1. *Impatiens megamalayana*: A—Habitat | B—Habit. © Anoop P. Balan

Image 2. Distribution map of *Impatiens megamalayana*.

grasslands at 1,000–1,200 m elevation. The plant usually grows in association with *Andrographis neesiana* Wight, *Drosera indica* L., *Impatiens stolonifera* Robi & Manudev, *Impatiens viscosa* Bedd., *Justicia procumbens* L., and *Smithia bigemina* Dalzell.

Distribution: Endemic to the Western Ghats (Kerala & Tamil Nadu) (Image 2).

Conservation status: Ramasubbu et al. (2017) assigned Critically Endangered status to *I. megamalayana* on the assumption that the taxon is strictly confined to the Megamalai hills of Tamil Nadu. However, the present report of this species from Urumbikkara hills of Kerala state necessitates a detailed field survey to assign a more appropriate IUCN status.

Notes: Urumbikkara hills and adjacent Vagamon hills are emerging tourist destinations in central Kerala. These popular hill stations are endowed with species rich evergreen forest patches, pseudo-sholas and grasslands, and are the last shelter of several Western Ghats endemic species including rare orchids and balsams. The majority of the forest patches are located outside protected forest areas, in ecologically fragile lands, and are facing severe environmental destruction due to tourism related developmental activities, illegal constructions, and encroachments. The richness of the flora of these hill stations are well evident from the recent botanical discoveries. A number of species have been described or rediscovered from these verdant hills during the last 10–12 years (Sibichen & Nampy 2007; Robi et al. 2013; Janeesha & Nampy 2015; Mathew et al. 2016; Manudev et al. 2017; Balan et al. 2019; Krishna et al. 2019; Balan & Robi 2020; Balan et al. 2020). It is important to plan eco-friendly and responsible tourism projects for Urumbikkara and Vagamon to ensure the conservation of the remaining biodiversity and greenery of these beautifull hills.

Specimens examined: Kerala, Idukki District, Urumbikkara Hills, 29.viii.2020, Anoop P. Balan & A.J. Robi 18200; 24.x.2020, Anoop P. Balan & A.J. Robi 18202 (BAM, MBGH, MH) (Image 3).

An updated checklist of *Impatiens* in Kerala state and district wise distribution is provided in Table 1. Among the districts Idukki stands first with 72 out of the 107 taxa reported from Kerala of which about 22 species are strictly endemic to the district.

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Table 1. An updated checklist of *Impatiens* in Kerala state and their district-wise distribution.

	Name of taxa	Distribution in Kerala
1	*Impatiens acaulis* Arn.	IDK, KNR, MPM, PKD, WND
2	*I. achudanandanii* V.S.A.Kumar, M.G.Govind & Sindhu Arya	TVM (Endemic)
3	*I. agastyamalayensis* (Bhaskar) A.Joe, V.Bhaskar & M.Sabu	TVM (Endemic)
4	*I. aliciae* C.E.C. Fisch.	IDK (Endemic)
5	*I. anaimudica* C.E.C. Fisch.	IDK
6	*I. auriculata* Wight	KTM, TVM
7	*I. balsamina* L.	All districts
8	*I. brittoi* B.Mani & Sinj. Thomas	IDK (Endemic)
9	*I. campanulata* Wight	IDK
10	*I. chandrasekharanii* Chandrab.	IDK
11	*I. chinensis* L.	IDK, KLM, KNR, PAT, PKD, TSR, TVM, WND
12	*I. clavicornu* Turcz.	IDK
13	*I. cochinica* Hook. f.	EKM (Endemic)
14	*I. coelotropis* C.E.C. Fisch.	IDK, PKD (Endemic)
15	*I. concinna* Hook. f.	IDK (Endemic)
16	*I. cordata* Wight	IDK, KKD, KLM, TVM, WND
17	*I. cuspidata* Wight & Arn.	IDK
18	*I. danii* Sindhu Arya, V.Suresh & V.S.A.Kumar	IDK (Endemic)
19	*I. dasysperma* Wight	IDK, KKD, KNR, MPM, PKD, WND
20	*I. denisonii* Bedd.	IDK, PKD, WND, (Endemic)
21	*I. disotis* Hook.f.	IDK, KSD
22	*I. diversifolia* Wall. ex Wight & Arn.	ALP, KLM, KNR, TSR, TVM, WND
23	*I. elegans* Bedd.	IDK
24	*I. eravikulamensis* Hareesh & Salish	IDK (Endemic)
25	*I. flaccida* Arn.	IDK, KKD, KLM, KNR, MPM, PAT, PKD, TSR
26	*I. floribunda* Wight	KLM, KSD, PKD, TVM
27	*I. fruticosa* Lesch. ex DC.	IDK, KLM
28	*I. gardneriana* Wight	KKD, KNR, KTM, MPM, PKD, WND
29	*I. glabrata* K.M.P.Kumar, Hareesh & Bhaskar	PKD (Endemic)
30	*I. goughii* Wight	IDK, KNR, PAT, PKD, TSR
31	*I. grandis* B.Heyne	IDK
32	*I. grandispora* Nampy & M.Vishnu	IDK (Endemic)
33	*I. hensloviana* Arn.	IDK, KNR, PKD, TSR, TVM
34	*I. herbicola* Hook. f.	IDK, KNR, KTM, PAT, PKD, WND
35	*I. inconspicua* Benth. ex Wight & Arn.	IDK, KLM, KNR, PAT, PKD, TVM, WND
36	*I. jerdoniae* Wight	IDK, KNR, PKD, WND
37	*I. johnii* E.Barnes	IDK (Endemic)
38	*I. johnsiana* Ratheesh, Sunil & Anil	WND (Endemic)
39	*I. josephia* Sinj.Thomas, B.Mani & Britto	IDK (Endemic)
40	*I. kulamavuensis* Pandur. & V.J. Nair	IDK (Endemic)
41	*I. laticornis* C.E.C. Fisch.	IDK
42	*I. latifolia* L.	IDK, TVM
43	*I. lawsonii* Hook. f.	KNR, WND
44	*I. leptura* Hook. f.	IDK, KLM
45	*I. leschenaultia* (DC.) Wall.	MPM, PKD
46	*I. levingei* Gamble ex Hook. f.	IDK, TVM
47	*I. ligulata* Bedd.	PKD, TSR
48	*I. macrocarpa* Hook.f.	IDK (Endemic)
49	*I. maculata* Wight	IDK, KLM, PKD
50	*I. mankulamensis* K.M.P.Kumar, R.Jagad. & Nagaraj	IDK (Endemic)
51	*I. matthewiana* Ramas. & Pandur.	IDK (Endemic)
52	*I. megamalayana* Ramas.	IDK
53	*I. minae* Ratheesh, Anil Kumar & Sivad.	WND (Endemic)
54	*I. minor* (DC.) Bennet	All districts except ALP, EKM, TVM,
55	*I. modesta* Wight	IDK, PKD, TVM
56	*I. mohana* Ratheesh, Sujana & Anil Kumar	WND (Endemic)
57	*I. munnarensis* E.Barnes	IDK (Endemic)
58	*I. munronii* Wight	PKD
59	*I. neo-barnesii* C.E.C. Fisch.	PKD
60	*I. neo-modesta* Hareesh, K.M.P.Kumar & V.B.Sreek.	PKD (Endemic)
61	*I. nidholapathra* M.Vishnu & Nampy	IDK (Endemic)
62	*I. nilgirica* C.E.C. Fisch.	IDK
63	*I. oppositifolia* L.	IDK, PKD, TSR, WND
64	*I. orchioides* Bedd.	IDK
65	*I. pallidiflora* Hook.f.	IDK (Endemic)
66	*I. pandata* E.Barnes	IDK (Endemic)
67	*I. pandurangani* K.M.P.Kumar, R.Jagad. & G.Prasad	IDK (Endemic)
68	*I. parasitica* Bedd.	IDK, KNR, PKD, WND
69	*I. parvifolia* Bedd.	IDK, WND
70	*I. pendula* B.Heyne ex Wight & Arn.	IDK
71	*I. periyarensis* B.Mani, Sinj. Thomas & Britto	IDK (Endemic)
72	*I. phoenicea* Bedd.	IDK
73	*I. platyadena* C.E.C. Fisch.	IDK (Endemic)
74	*I. pseudoacaulis* Bhaskar	PKD
75	*I. pulcherrima* Dalz.	IDK, PKD
76	*I. raktakesara* Vishnu & Nampy	IDK (Endemic)
77	*I. repens* Moon ex Wight	All districts
78	*I. rufescens* Benth. ex Wight & Arn.	TVM
79	*I. saulierea* B.Mani, Sinj.Thomas & Britto	KKD (Endemic)

80	*I. sahyadrica* V.B. Sreek., Hareesh, Dantas & Sujanapal	PKD (Endemic)
81	*I. sasidharanii* K.M.P. Kumar, Omalsree, Hareesh & V.B.Sreek.	PKD (Endemic)
82	*I. sasidharanii* var. *hirsuta* K.M.P.Kumar, Omalsree, Hareesh & V.B.Sreek.	PKD (Endemic)
83	*I. scabriuscula* B.Heyne ex Roxb.	KNR, PKD, WND
84	*I. scapiflora* B.Heyne ex Roxb.	All districts except ALP, EKM, KLM, KTM
85	*I. shailajae* Sindhu Arya & V.S.A.Kumar	TVM (Endemic)
86	*I. sholayarensis* M.Kumar & Sequiera	TSR (Endemic)
87	*I. sivarajanii* M.Kumar & Sequiera	PKD (Endemic)
88	*I. stocksii* Hook. f. & Thomson	IDK, KNR, WND
89	*I. stolonifera* Robi & Manudev	IDK, KTM (Endemic)
90	*I. tangachee* Bedd.	IDK
91	*I. tenella* B.Heyne ex Hook.f.	PKD
92	*I. theuerkaufiana* Ratheesh & Sivad.	WND
93	*I. tilo* (DC.) Suresh	KKD (Endemic)
94	*I. tomentosa* B.Heyne ex Wight & Arn.	IDK, PAT, TVM
95	*I. travancorica* Bedd.	TVM
96	*I. trichocarpa* Hook. f.	IDK
97	*I. umbellata* B.Heyne	TVM
98	*I. uncinata* Wight	IDK, TVM
99	*I. veerapazhasii* Ratheesh, Sujanapal & Meera	KNR, WND (Endemic)
100	*I. verecunda* Hook. f.	IDK (Endemic)
101	*I. verticillata* Wight	IDK, PAT, TSR, TVM
102	*I. violacea* M.Kumar & Sequiera	IDK (Endemic)
103	*I. viridiflora* Wight	IDK, PKD
104	*I. viscida* Wight	TVM
105	*I. viscosa* Bedd.	IDK, KTM, PAT, PKD, WND
106	*I. walleriana* Hook.f.	All districts
107	*I. wightiana* Bedd.	IDK,PKD, TSR (Endemic)

ALP—Alappuzha | EKM—Eranakulam | IDK—Idukki | KKD—Kozhikode | KLM—Kollam | KNR—Kannur | KSD—Kasargod | KTM—Kottayam | MPM—Malappuram | PAT—Pathanamthitta | PKD—Palakkad | TSR—Thrissur | TVM—Thiruvananthapuram | WND—Wayanad.

Image 3. Herbarium sheet of *Impatiens megamalayana* (# 18202)

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BOOK REVIEW

A look over on the scented tree of India (*Santalum album*)

S. Suresh Ramanan [1] & **A. Arunachalam** [2]

[1,2] ICAR-Central Agroforestry Research Institute, Jhansi, Uttar Pradesh 284003, India.
[1] sureshramanan01@gmail.com (corresponding author), [2] a.arunachalam@icar.gov.in

Sandalwood tree is the pride of India. It is also quoted as 'Queen of essential oils and 'Dollar earning parasite' (Rao et al. 2007). Among the 3,000 timber species in the Indian sub-continent, this tree has been present throughout Indian history. Starting from the Indian rulers, invaders and even the colonial powers have systematically focused on this tree species. Indians have systematically researched this species and there was a need for a dedicated monograph on this species. Now, the book titled "Sandalwood: Silviculture, Conservation and Applications "under review is important literature concerning the East Indian Sandalwood tree compiled by Thammineni Pullaiah, Sudhir Chandra Das, Vishwas A. Bapat, Mallappa Kumara Swamy, Vaddi Damodar Reddy, and Kondragunta Sri Rama Murthy. More than 10 authors apart from the editors have contributed to this book which contains 15 chapters covering the scientific to economic aspects of the *Santalum album*. At the very outlook, I believe that this book is written to enlighten the next generation of researchers on the *Santalum album*.

The first chapter reflects the significance of the Sandalwood tree and even the new readers can comprehend it. Overall, chapters one, two and three are introducing the tree species with new information, including a narration on the historical use of sandalwood in India, Australia, and Hawaii. It indicates the need for documenting sandalwood usage in other countries. Chapter 3 is a treatise, the authors narrate the complete story of Santalum and other members of the genus *Santalum.* The relevant photographs or figures make it easy for the readers to corroborate with the content. Chapter 4 is unique in all sense. It is well-known that sandalwood is used for carving deity idols and wooden sculptures yet, exclusive documentation on Sandalwood carving was missing to date in the scientific literature. Though there is a dearth of technical details, the authors have made due justification in their narration which is

Sandalwood: Silviculture, Conservation and Applications
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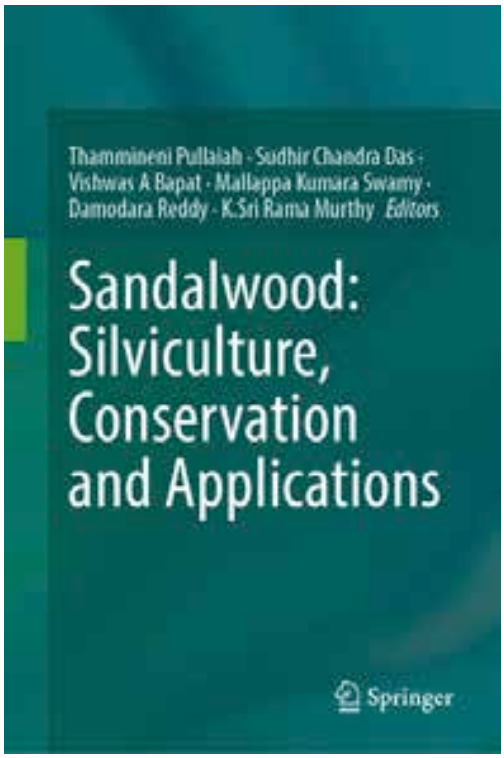

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commendable.

The next chapter deals with the medicinal property of sandalwood and its oil. Giving reference to the phytochemical property of sandalwood oil mostly, the authors also highlight the ethnobotanical used this tree. The peculiarity in this chapter will be the adulterants that are substitute in the place of the sandalwood oil apart from the synthetic prepared oil. Some of the alternate plant-derived oil which are used as a substitute is copaiba (*Copaifera langsdori*) oil, Amyris (*Amyris balsamifera*) oil and Atlas cedar (*Cedrus atlantica*). There are adulterants not only for the oil but also for the sandalwood. For instance, species like *Osyris lanceolate* and *Erythroxylum monogynum* are the most common adulterant and chapter six narrates the means and methods to identify these adulterants. Even wood from other genera of *Santalum* is commonly used as an adulterant. Among the 18 species of the genus *Santalum, the Santalum album* fetches high prices because of the superior oil quality. Technically, the α-santalol and β-santalol content in the *Santalum album* ranges from 45–50% and 15–20% respectively, whereas these values are lower in other *Santalum* members (Kumar et al. 2011). For instance, the α-santalol and β-santalol content in the *Santalum spicatum* is <20 % and <5 %, approximately. Apart from this aspect, chapter six describes the wood properties of *Santalum album.* These authors have done a commendable job in describing the Sandalwood properties and also highlighting the research gaps about the wood property of the *Santalum album.*

The heart of this book is chapter seven which deals with the silviculture of the *Santalum album*. The information in this chapter will be helpful not only forester but also to any individual growing this tree species. With the relaxations on sandalwood tree cultivation, there is increasing interest in growing sandalwood trees even among small farmers. Moreover, the projected increase in the market price of sandalwood can further motivate or lure farmers into sandal cultivation. Chapters seven, eight, and nine are written by a single author who has done extraordinary work. There are relevant photographs that make these chapters more informative and relevant for the readers. "Agroforestry is a collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos etc.) are deliberately used on the same land management unit as crops and/or animals, in some form of spatial arrangement or temporal sequence. In agroforestry systems, there are both ecological and economic interactions between the different components" (Kumar & Nair 2006). A good agroforestry system will ensure that the competition for space and nutrients between woody perennials and crops is minimum. In this context, imagine *Santalum album* a hemiparasite which always competes for space and nutrients with its adjacent plants and trees. Therefore, presuming *Santalum album* as a suitable tree for agroforestry: can be a bit unrealistic. Chapter eight titled "Cultivation of Sandalwood Under Agro-Forestry System" provides enough insights and management of this tree under agroforestry.

Being one of the highly valued trees, it is one of the highly traded both legally as well as illegally. This is the subject matter for chapters 10 and 11. Both chapters extensively narrate the production and trade network of the *Santalum album,* exclusively the illegal trade network and its implications on the natural population of this tree species. And the subsequent chapters 12, 13, and 14 gives insight into the biotechnology and tissue culture techniques for sustainable use and conservation of this tree. Chapter 14 advocates that rigid legislations are not the only means for conservation for this species and this is happening today as many states are relaxing the legislation to promote private cultivation of *Santalum album.* Largely, the book serves as a reference for the cultivation/growing of this priced tree species.

The language of this book is simple, readable and understandable by its intended audience group. The editors have attempted to do justice for the topic taken for which they have reviewed all papers on *Santalum album* and also cited papers about other sandal species to bring in analogy, perfectly. It would be slipshod in writing this review if we are not pointing out the lacunae.

The editors have not given a prelude nor a foreword detailing the content of the books. There are some errors and content organization issues. As we have always felt that the repetition of information and content is inevitable in an edited book, particularly while describing a single species. For instance, the line "Kautilya's Arthashastra (320 BC) considered Sandalwood as one of the important forest products to increase the royal revenue" in chapter 2 is repeated in the same chapter (page 14 and 15). This is one example that indicates that the editors need to revamp this book in its next edition.

However, there are some major issues that the editors have to address in their next edition. For instance, mentioning *Santalum album* as 'most valued South India tree' is not appropriate in our opinion. More importantly, it is not the most valued wood from southern India. It is one of the most valued wood in line with Red Sanders (*Pterocarpus santalinus*). Similarly, in Chapter 2, the author mentions other trees species as Chanda which is due to the local misconception and

the author have acknowledged it rather than critiquing this misconception. The exact verbatim is as follows "There are at least three kinds of sandal, namely, White Sandal (*Santalum album*) called as "Sweta Chandana", Red Sandal (*Pterocarpus santalinus*) called as "Rakta Chandana", and Sandal Ku-chandana (*Adenanthera pavonina*). I would urge the editors to look into this issue and address it with proper reference.

I strongly urge the editor to reconsider the inclusion of chapter 15 which deals with the success stories of Sandalwood. Overall the chapter narrates the experiences of farmers and other sandalwood tree growers. Considering this book as a monograph of sandalwood, the case studies narrated here are from secondary sources mostly. I feel that the author could have at least made a comparative assessment of different sandalwood growers and come out with some significant inferences. Still, this book is an irreplaceable scientific contribution and must be reading material for forestry graduates and researchers interested in this tree with an economic value.

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