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continued on the back inside cover

Caption: *Euphaea thosegharensis* **Sadasivan & Bhakare, sp. nov. (male) from Thoseghar, Satara District, Maharashtra, India. © Shriram Dinkar Bhakare.**

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ARTICLE

Spatiotemporal movement pattern of Asian Elephants *Elephas maximus* Linnaeus, 1758 in Sindhudurg District, Maharashtra, India

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Abstract: The extension of the Asian Elephant's *Elephas maximus* range in the northern Western Ghats (Sahyadri) was observed since 2002. This colonization was marked by elephant crop raiding events in the newly colonized Sindhudurg District, where the local community had no experience of living with elephants. The present study was conducted to understand the spatiotemporal patterns of crop depredation (raiding) and to prioritize areas to inform future interventions on managing this ecological phenomenon turned conflict. Data on crop raiding between 2002 and 2015 was obtained from compensation records with the state forest department, and mapped at village scale. Subsequently, we used three indices of crop raiding, viz., Crop Raiding Frequency (CRF), Relative Crop Raiding Intensity (RCRI), and Crop Raiding Vulnerability Index (CRVI). Results show a gradual northern movement of elephants and of the crop raiding zone over the period of 2002–2015. The rankings provided by CRVI, identified villages in a narrow strip of foothills of the Sahyadri mountains as severely vulnerable. With sufficient long term data, CRVI would be a highly useful index for prioritization of villages for resolving human-elephant negative interactions; and other cases of human-wildlife interactions too.

Keywords: Crop raiding, range extension, vulnerable areas, Western Ghats.

Marathi मराठी सारांश: सन २००२ पासून सह्याद्री पर्वतांत आशियायी हत्तींचा वावर उत्तरेकडे हळूहळू वाढत गेलेला दिसतो. उत्तर पश्चिम घाटातील सिंधुदुर्ग जिल्ह्यात हत्तींचा वावर वाढल्याने, तसेच येथील स्थानिक लोकांना हत्तीसोबत सहजीवनाचा कोणताही पूर्वानुभव नसल्याने पीक नुकसानीच्या घटनांमध्ये वाढ झालेली दिसून येते. याच पार्श्वभूमीवर हत्तींचा सिंधुदुर्ग जिल्ह्यातील वावर आणि पीक नुकसानी होत असलेली गावे यांचा एकंदर अभ्यास करण्यात आला. सन २००२ ते २०१५ या कालावधीत महाराष्ट्र राज्य वन विभागाकडून वेळोवेळी संकलित करण्यात आलेल्या माहितीच्या आधारे सिंधुदुर्ग जिल्ह्यातील पीक नुकसान भरपाईची आवश्यक ती गाव-निहाय माहिती एकत्र केली गेली. या माहितीचे विश्लेषण करून तीन गुणोत्तरे गाव-निहाय अभ्यासण्यात आली. यात अनुक्रमे पीक नुकसानीची वारंवारता, सापेक्ष पीक नुकसानीची तीव्रता आणि पीक-नुकसान-प्रवण गुणोत्तर यांचा समावेश होता. या गुणोत्तरांवर आधारित पीक नुकसानी दर्शविणारे नकाशे बनविण्यात आले. प्राथमिक निष्कर्षानुसार सिंधुदुर्ग जिल्ह्यातील हत्तींच्या हालचाली आणि पीक नुकसानीचा क्षेत्रीय विस्तार दक्षिणेकडून उत्तरेकडे हळूहळू सरकत गेल्याचे दिसून आले. तिन्ही गुणोत्तरांचा आणि या गुणोत्तरांवर आधारित नकाशांचा तौलनिक अभ्यास केला असता असे आढळून आले की अन्य दोन गुणोत्तरांच्या तुलनेत 'पीक-नुकसान-प्रवण गुणोत्तरा'वर आधारित नकाशा सह्याद्रीच्या पायथ्याची गावे हीच अधिक नुकसान-प्रवण असल्याचे दर्शवितो. अधिक कालावधीसाठीची आवश्यक ती सांख्यांकी माहिती उपलब्ध असल्यास 'पीक-नुकसान-प्रवण गुणोत्तरा'वर आधारित सध्याची तसेच भविष्यातील संभाव्य पीक नुकसान-प्रवण गावे प्राधान्यक्रमाने मांडणे शक्य असल्याचे दिसून आले. अशा माहितीचा वापर मोठ्या भूभागावरील हत्ती तसेच इतर वन्यप्राण्यांकडून होत असलेल्या नुकसानीवर गाव निहाय प्रभावी उपाय योजना करताना तसेच भविष्यातील धोरणात्मक नियोजन आखताना होऊ शकेल असे दिसते.

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Author contribution: MDP collected the data, MDP and VKP analysed the data and wrote the manuscript. NAM gave valuable inputs in data processing and made comprehensive thematic maps.

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INTRODUCTION

Negative interactions between humans and elephants are a consistently rising conservation and social problem across the range of elephants in Asia (Gubbi et al. 2014). Given the ancient records of crop depredation (raiding) and other negative interactions, they are part of the cultural and social memories in the areas of human-elephant interface (Sukumar 1991). Thus, these issues need to be approached by integrating the dimensions of ecology, social perception, and economics in order to resolve the conflict and mitigate the losses (Choudhury 2004; Sukumar et al. 2012; Patil & Patil 2018, 2019).

The Asian Elephant *Elephas maximus* (hereafter 'elephant') is listed as "Endangered" on the IUCN Red List of Threatened Species (IUCN 2017). It is distributed in the Indian subcontinent and southeastern Asia, where it is found in a small fraction of its historical range (Sukumar 2006). A significant elephant population is present in the Western Ghats of peninsular India, where the northern limit of population was recorded up to the Uttara Kannada landscape (Choudhary et al. 2008; Baskaran 2013; Mehta & Kulkarni 2013). The historical range of elephants in the Western Ghats is suggested to have extended farther north than the present range. Numerous petroglyphs dating from the Neolithic age and depicting elephants, have been recently discovered in Ratnagiri and Sindhudurg districts of Maharashtra (https://www.thehindu.com/news/national/other-states/the-petroglyphs-of-ratnagiri/article25265399.ece), which is north of the known limit of elephant distribution in the Western Ghats. Yet, the traditional elephant range did not include the states of Maharashtra, Goa, and northern parts of Karnataka state (Mehta & Kulkarni 2013). At the outset of the 21st century, however, an elephant herd from the Haliyal-Dandeli Forest Division moved north and colonized Belgaum Forest Division in 2001 (Baskaran 2013; Mehta & Kulkarni 2013). Since November 2002, elephants from Dandeli Wildlife Sanctuary were reported further north in the forest-plantation mosaic of Sindhudurg and Kolhapur districts of Maharashtra. Here, the elephants had not been reported for at least 100 years before this colonization, thus limiting the societal memory of living with elephants. As a consequence, the colonization was marked by many villagers reporting elephant raiding cases to the state forest department. Since then, the influx has been continuous and elephants have become resident in this area.

Crop raiding by elephants can influence the perception of local communities towards wildlife and allied services, and result in conflict situations (Balasubramanian et al. 1995). There have been demands from local people to remove elephants from their villages and send them back to the 'wild'. Following public pressure, a few elephants were captured by the forest department in 2009 from Dodamarg Taluka of Sindhudurg. They were released to their native habitat in northern Karnataka; however, understanding the habitat fragmentation in this landscape, elephants are likely to disperse more seeking forage, refuge, and water, and thus increasing interface with people (Bhaskaran et al. 2010). Hence, it is essential to understand the spatiotemporal pattern of elephant movement and the raiding hotspots in the landscape. Although the problem of crop raiding by elephants has been widespread in Sindhudurg District, the intensity and distribution of the problem was not uniform throughout. Several factors including elephant behaviour, topography, and physiography of landscape, human landuse and interventions determine these patterns. Forest department officers mentioned the number of elephants in the study area varied from 4 to 11 individuals over the study period.

Within this context, the present study was conducted to understand distinct spatiotemporal patterns in crop raiding, and to prioritize areas for future interventions so that the recurring problem can be successfully handled.

MATERIAL AND METHODS

Study area

The Sindhudurg District (15°37'–16°40' N and 73°19'–74°18'E) is the southern coastal district in western Maharashtra, with a geographical area of 5,207km^2. The study area has a tropical climate and the year could be divided into three seasons consisting of summer (February to May), monsoon (June to September), and winter (October to January). The terrain is hilly with coastal lowlands. Around 52% of Sindhudurg is covered by moist deciduous and semi-evergreen forests (FSI 2015), out of which 89% is under the ownership of private landholders and communities (Patil et al. 2016). Figure 1 depicts the location of Sindhudurg District, its talukas and villages, with reference to the forest cover and terrain. The villages with elephant crop raiding cases are numbered and the names of these 225 villages are provided in the supplementary information (Appendix 1). The Sindhudurg District is subdivided into eight talukas (administrative divisions), viz., Vaibhavvadi, Devgad, Kankavli, Malwan, Kudal, Vengurla, Sawantwadi, and Dodamarg, which in total hold 748

Figure 1. Map depicting the location of Sindhudurg District, its talukas and villages, with reference to the forest cover and terrain. Villages with elephant crop raiding cases are numbered and the names of these 225 villages are provided in the supplementary information.

villages. Approximately, 87% of the human population in Sindhudurg is engaged in agriculture with an average landholding of one hectare (www.censusindia.gov.in). Major crops include rice, millet, and pulses. Rice is planted twice a year: June to September and November to February. The second phase is locally specific based on availability of either natural water or if irrigation is available. A large proportion of land is cultivated as orchards such as mango, cashew, coconut, areca nut, banana, and pineapple. Spices like nutmeg and black pepper are cultivated within coconut orchards. Home gardens are a widely adopted traditional agroforestry system. Thus, the vegetation cover in the area is an intense mosaic of orchards, farms, and natural as well as degraded forest patches.

Data collection

Data on crop raiding between 2002 and 2015 was obtained from compensation records in the range offices of the state Forest Department. We defined a 'case' as an entry in the forest department register of compensation, which was used for reporting elephant caused damage by local people. We defined a 'raid' as a specific instance of damage of a particular crop. A single 'case', where more than one type of crop was damaged, would represent a number of 'raids'.

For each crop raiding case, the name of the crop owner, forest range of jurisdiction, taluka, village, date of crop raiding, crop damage & magnitude, and the compensation paid were noted. Data of area under cultivation for coconut, areca palm, banana, and rice was obtained from the State Agriculture Department. It must be noted, however, that the data for two years (2002 and 2015) were incomplete. Reports on crop raiding appeared towards the end of the year 2002 and therefore data was not available for earlier months. Similarly, for the year 2015, the cases recorded only till August matched with the study time-frame.

Data analysis

Hoare (1999) suggested use of Raid Frequency Index (RFI), which, in the present case, can be calculated as elephant raids per village per month; however, being an absolute index, RFI cannot be compared across studies, nor does it provide a standardized value between certain limits. Therefore, three different indices of crop raiding were used to assess spatial patterns of crop raiding by villages, viz., Crop Raiding Frequency (CRF), Relative Crop Raiding Intensity (RCRI), and Crop Raiding Vulnerability Index (CRVI).

CRF is the total raiding instances in a village over the entire study period.

$$\textbf{CRF} = N_1 + N_2 + N_3 + ... + N_i$$

Where,

N number of raiding cases in a year

i study period in years

RCRI is a plain measure of crop raiding intensity incorporating the ratio of number of raiding instances to months of raiding occurrence.

$$\textbf{RCRI} = \frac{\text{CRF}}{j}$$

Where,

j number of nominate months in which raiding occurred

CRVI is based on standardized Levin's measure, where the number of cases in a particular month is weighed (multiplied) by the number of years in which raiding occurred in that month. Here, for the purpose of this index, only the count of months out of 12 nominate months was taken and total number of months of raiding in entire study period was not considered.

$$\mathbf{CRVI} = \frac{\left(\frac{1}{\sum_{i=1}^{12} p_i^2}\right)^{-1}}{12-1}$$

$$\because p_i = \frac{q_i}{\left(\sum_{i=1}^{12} q_i\right)}$$

$$\because q_i = \frac{n_i k_i}{\sum_{i=1}^{12} n_i k_i} \times 100$$

where,

i Corresponding to the nominate months (January to December)

Number of cases in i^th month in the entire study period

Number of years in which raiding occurred in the i^th month during the study period

Spatial data for district, taluka, and village boundaries was obtained from the Survey of India for the year 2011. The basic unit in this database was village, whereas that in the compensation database was a compensation claim registered in the name of a person belonging to a particular village. The compensation data was reduced to village level by calculating the above mentioned indices. These indices were joined as attributes to the spatial database to prepare maps based on indices at the scale of villages. These rank correlations were estimated for the first 10 villages based on CRF.

Further, the compensation data was sorted by years in the study period and similarly maps of raiding frequency were prepared for each year to show the progression of the crop raiding by elephants in the study area. Apart from the crop availability, elephant movement is known to be influenced by the availability of water and habitat cover (Venkataraman 2005). High resolution (~30 m) satellite images depicting forest cover (FSI, 2015) and water (Pekel et al. 2016) were used to understand the habitat cover and water availability. The locations of affected farms and the interviewed farm owners were mapped using ArcGIS 10.6.1 (Redlands, CA).

RESULTS

From the compensation records of the forest department, information was available for 9,148 cases. The conflict situation under study was spread over an area of ~4,300km^2 of Sindhudurg District. The database revealed 244 villages (33% of the total villages) affected by crop-raiding elephants (Table 1). The top 20 worst affected villages by elephant crop raiding in various talukas during 2002 to 2015 are given in Table 2.

There was a gradual increase in raiding frequency from 2002 to 2008. Then, there was a sudden dip during 2009–10 after which it increased again (Figure 2). Again in 2015 the raiding frequency dipped. Since elephants colonized this area, the highest number of cases was recorded in the year 2007 (Figure 2). Further, four elephants in Kudal were captured by the forest department in 2009, and three were captured in 2015 and hence the frequency of crop raiding reduced during those years.

Table 1. Villages affected by elephant crop raiding (CR) in different talukas during 2002–2015 in Sindhudurg District, Maharashtra.

Taluka	No. of villages	Conflict villages	CR cases
Kudal	124	83 (67%)	4,837 (52%)
Sawantwadi	82	62 (76%)	2,642 (29%)
Dodamarg	62	47 (79%)	1,292 (14%)
Vengurla	83	20 (24%)	260 (03%)
Kankavli	105	16 (15%)	59 (1%)
Malwan	135	11 (08%)	51 (1%)
Vaibhavvadi	59	5 (8%)	7 (0.1%)
Devgad	98	-	-
Total	**748**	**244 (33%)**	**9148**

CRF and RCRI of all affected villages are shown in Figure 3 and 4, respectively. The distribution of villages in various RCRI classes is shown in Figure 5. Tulsuli K. Narur, Naneli, Wados, Karivane, Nivaje, Sonurli, and Dingne villages had highest CRF and RCRI values. CRVI was calculated for all villages (Figure 6) and the distribution of villages in various CRVI classes is shown in Figure 7. The highest CRVI was observed in the villages of Hirlok, Tulsuli K. Narur, Wados, Amberi, Pawashi, Tulsuli, and Kariwade (Table 2)

CRF, RCRI and CRVI provide useful information for identifying villages with severe problem of crop raiding. In the present case study, however, the prioritization of villages based on CRF and RCRI was found to be highly correlated for the three most affected talukas, viz., Kudal, Sawantwadi, and Dodamarg (Table 3).

DISCUSSION

Patil & Patil (2019) published trends and patterns of elephant crop raiding in the same study area during the period 2002 to 2015. They mentioned coconut palms (44%), paddy (22%), banana (20%), and areca palms (8%) were the most damaged crops by elephants. Paddy was found to be the attractant for elephants. They also found that raiding frequency was maximum during winter season which coincides with the maturity and

Table 2. Top 20 villages affected severely by elephant crop raiding based on CRF, RCRI, and CRVI in Sindhudurg District, Maharashtra (2002–2015).

Ranking	Village	CRF	Village	RCRI	Village	CRVI
1	Tulsuli K.Narur	468	Tulsuli K. Narur	39.00	Hirlok	0.82
2	Naneli	352	Naneli	29.33	Tulsuli K.Narur	0.70
3	Wados	349	Wados	29.08	Wados	0.67
4	Karivane	322	Karivane	26.83	Amberi	0.60
5	Nivaje	296	Nivaje	24.67	Pawashi	0.56
6	Sonurli	254	Sonurli	23.09	Tulsuli	0.53
7	Dingne	250	Dingne	22.73	Kariwade	0.50
8	Padlos	224	Majgaon	22.33	Wafoli	0.50
9	Mangeli	209	Kalse	20.00	Naneli	0.49
10	Hirlok	202	Padlos	18.67	Khocharewadi	0.48
11	Majgaon	201	Hewale	18.33	Ghavanale	0.48
12	Khocharewadi	169	Mangeli	17.42	Mangaon	0.48
13	Hewale	165	Hirlok	16.83	Kesari	0.47
14	Tembgaon	148	Palye	16.67	Taligaon	0.47
15	Ghavanale	144	Asoli	15.00	Karivane	0.46
16	Amberi	138	Oras Bk.	14.25	Bavlat	0.46
17	Gothos	138	Khocharewadi	14.08	Kalane	0.45
18	Mangaon	128	Gothos	13.80	Nivaje	0.44
19	Otavane	127	Tembgaon	13.45	Adali	0.44
20	Kaleli	124	Bambarde T. Kalsuli	13.44	Bengaon	0.42

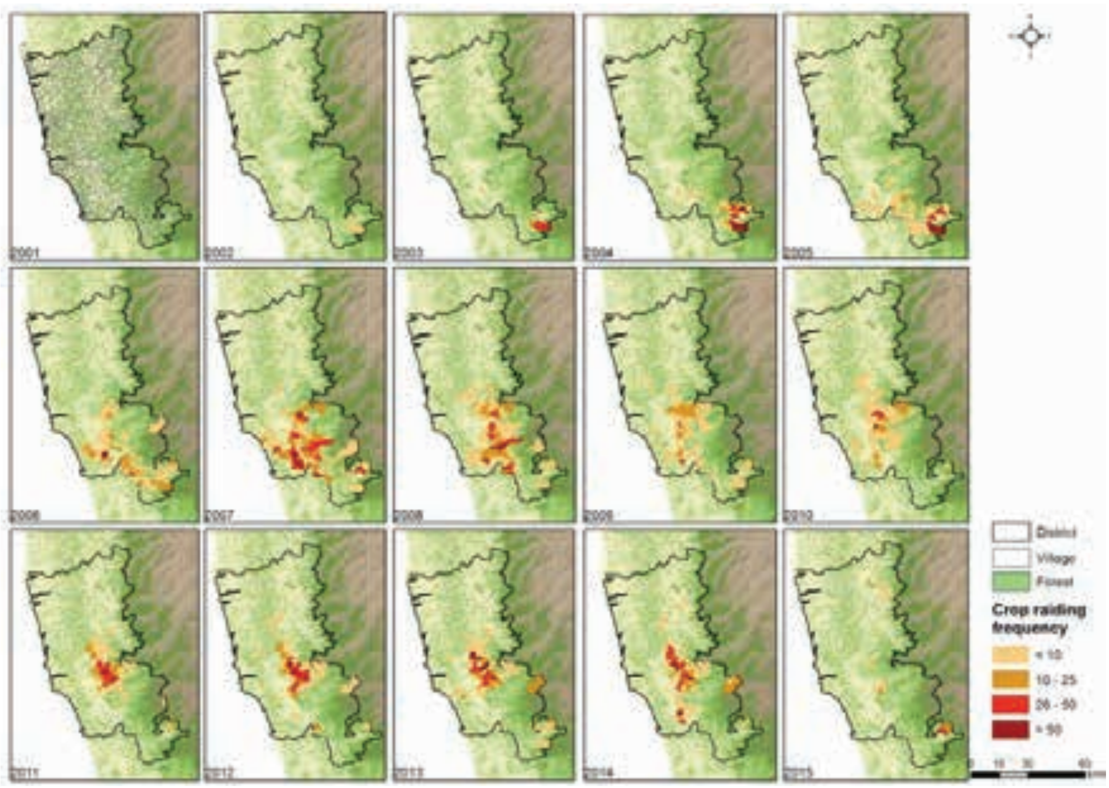

Figure 2. Annual progression of elephant crop raiding in Sindhudurg District (2002–2015).

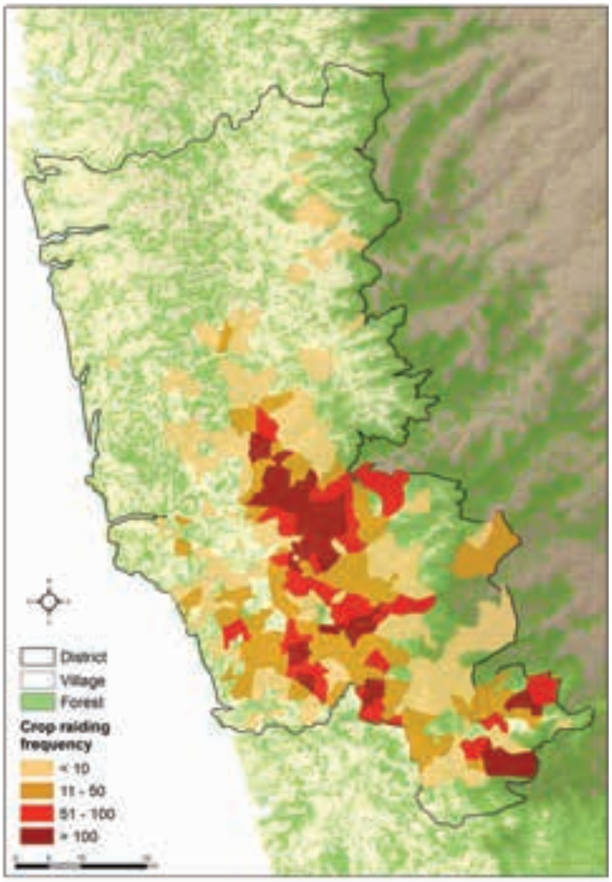

Figure 3. Crop raiding frequency (CRF) of villages in Sindhudurg District (2002–2015).

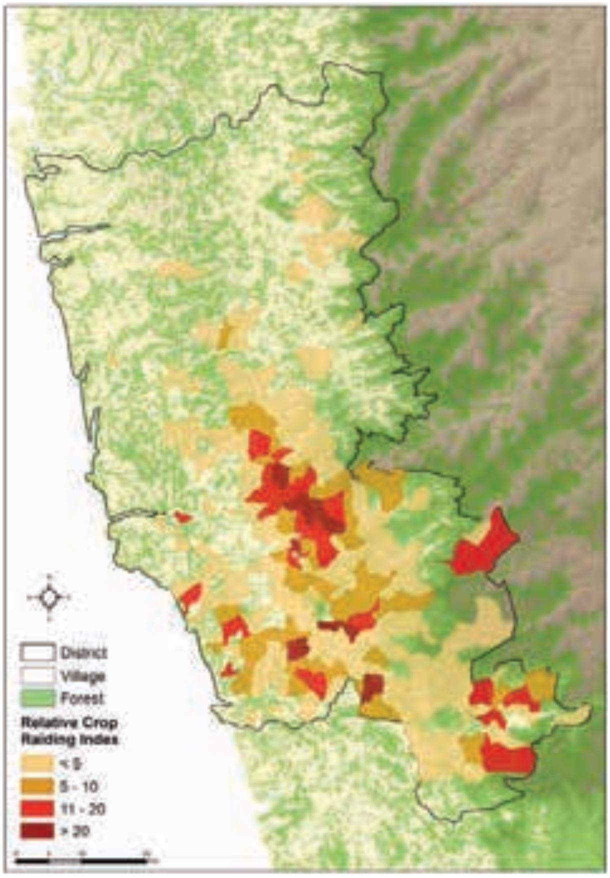

Figure 4. Relative Crop Raiding Intensity (RCRI) of villages in Sindhudurg District (2002–2015).

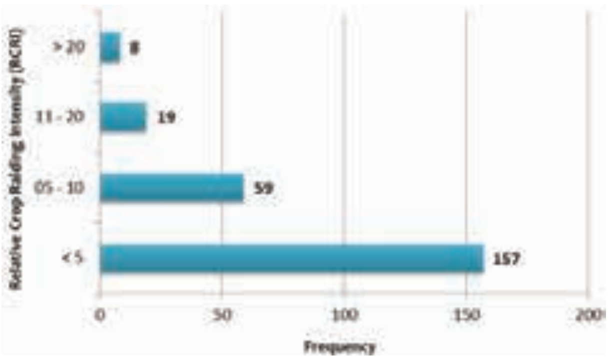

Figure 5. Frequency distribution of villages across classes of Relative Crop Raiding Intensity (RCRI).

harvesting period of paddy in the Sindhudurg. Patil & Patil (2017) published farmers' perception survey towards elephant crop raiding in Sindhudurg. Here, they presented the details of crop protection measures and their effectiveness, ongoing ex-gratia schemes by the forest department in the study area with possible coexistence approach. The present study is the extension of these two studies.

Excluding the incomplete data-years of 2002 and 2015, the trend in annual raiding frequency seems to have followed the number of elephants active in those particular years. The number of elephants active in a particular year, in turn, was dependent on the influx of elephants and efforts of the state forest department to capture and/or translocate elephants back to their southern population. Various guestimates on the number of elephants ranging 4–11 individuals was provided by the forest department and secondary sources (Sarma & Easa 2006; Mehta & Kulkarni 2013).

Gradual extension of the conflict zone over the period from southern to northern parts of Sindhudurg was observed during 2002–2015. It was also observed that crop raiding was severe in the talukas nestled in the Sahyadri Mountain ranges, while coastal talukas had relatively less cases. Similarly, because elephants extended their range from south to north, the northernmost talukas were either unaffected or less affected during the study period.

Figure 2 shows the gradual extension of conflict

Table 3. Rank correlation among Crop Raiding Frequency (CRF), Relative Crop Raiding Intensity (RCRI), and Crop Raiding Vulnerability Index (CRVI). Figures below diagonal are Spearman's r values and above diagonal are probabilities.

Kudal			
	CRF	RCRI	CRVI
CRF		<0.001	0.44247
RCRI	0.99937		0.46644
CRVI	0.27467	0.26097	
Sawantwadi			
	CRF	RCRI	CRVI
CRF		<0.001	0.57841
RCRI	0.94225		0.36547
CRVI	-0.20061	-0.32121	
Dodamarg			
	CRF	RCRI	CRVI
CRF		0.020713	0.78784
RCRI	0.71269		0.04036
CRVI	-0.09792	-0.6537	

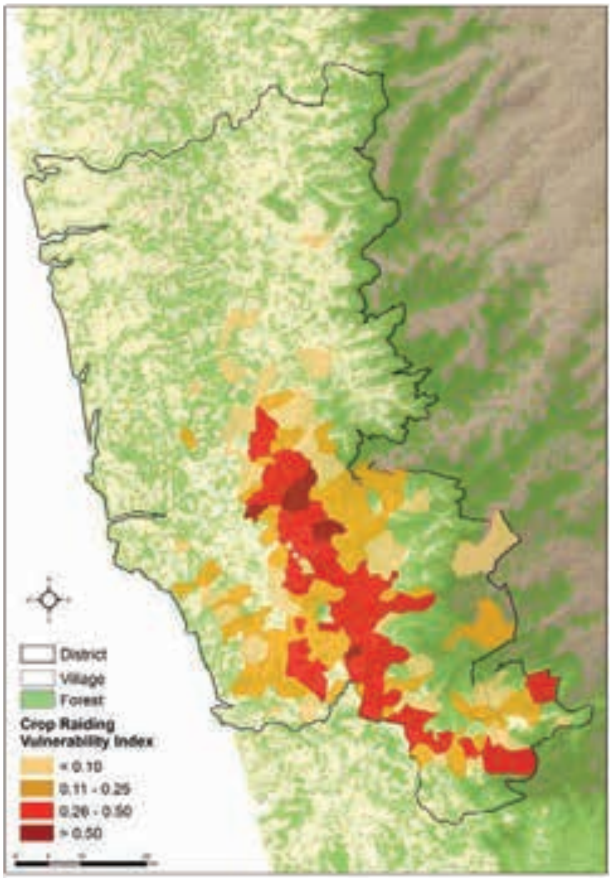

Figure 6. Crop Raiding Vulnerability Index (CRVI) of villages in Sindhudurg District (2002–2015).

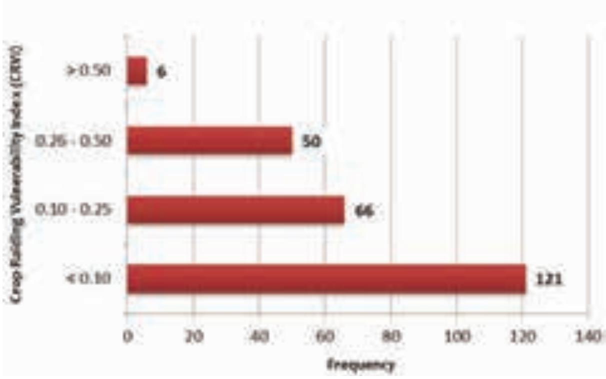

Figure 7. Frequency distribution of villages across classes of Crop Raiding Vulnerability Index (CRVI).

zone (area wise) in the study area over the period of 2002–2015. It could be clearly seen that during 2002 to 2008, the raiding events by elephants were spatially widespread and could be potentially exploratory in nature. In 2009, four elephants were captured (out of which two died) for translocating them back to the closest population in Karnataka. It is presumed by villagers and forest department personnel that these translocated elephants soon returned along with two other elephants. In this second stint from 2010 to 2015, the map clearly depicts increased crop-raiding events from the Kudal range. Towards 2014–15, the elephants started to further explore northwards.

Indices calculated in the present study are based on detailed ex-gratia records proved by the forest department. CRF indicates that villages on the steeper ranges were not affected much compared to the foothills; however, the absolute CRFs or their proportion per village do not provide opportunity for comparing the intensity of crop raiding across studies. Therefore, an attempt was made to calculate two further indices of vulnerability of villages to crop raiding based on historical data.

The high crop raiding villages identified using CRF and RCRI do not reveal the actual vulnerable villages because many of these villages were affected for a relatively brief duration with higher intensity. Here we may conclude that villages with higher CRF or RCRI may not be vulnerable as elephants might have explored these villages for available resources intensively during earlier years but, finding them unsuitable, might have altogether stopped approaching.

CRVI, as previously stated, is the number of cases in a particular month weighed by the number of years in which raiding occurred in that month. It provides a different ranking of the villages thus showing low correlation with both earlier indices (Table 3). The rankings provided by CRVI appear to provide more meaningful geographical or ecological information. A comparative look at Figures 3, 4, and 6 reveals that CRVI identifies villages in a narrow strip of foothills of Sahyadri mountains as severely vulnerable. Gross factors determining elephants' use of a certain area are food, cover and water (Fairet 2012). It appears that the best possible combination of these three factors was available to the elephants in the area identified by CRVI. Subsequently, CRVI could become a useful index to identify villages highly vulnerable to crop raiding by elephants. The prioritization of villages for resolving human-elephant negative interaction can be based on CRVI, rather than CRF or RCRI, when sufficient long-term data on elephant crop raiding is available. CRVI can also be compared across studies if crop-raiding instances are tabulated by villages or any small geopolitical units. Use of these geopolitical units will facilitate implementation of various schemes for alleviating crop raiding problem.

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Appendix 1. Name of villages with elephant crop raiding cases numbered in the Figure 1.

Map ID	Taluka name	Village name
1	Vaibhavvadi	Pimpalwadi
2	Vaibhavvadi	Narkarwadi
3	Kankavli	Pise Kamate
4	Kankavli	Bidwadi
5	Kudal	Ambrad
6	Vaibhavvadi	Mohitewadi
7	Vaibhavvadi	Khambale
8	Vaibhavvadi	Achirne
9	Kudal	Khutvalwadi
10	Kudal	Rumadgaon
11	Kudal	Pawashi
12	Kudal	Pinguli
13	Kudal	Kanduli
14	Kankavli	Ghonsari
15	Kankavli	Lore-1
16	Kankavli	Damare
17	Kankavli	Tarandale
18	Kankavli	Bhiravande
19	Dodamarg	Konas
20	Kankavli	Varavade
21	Kankavli	Ashiye
22	Kankavli	Shivdav
23	Kudal	Kusagaon
24	Kudal	Wasoli
25	Sawantwadi	Bavlat
26	Sawantwadi	Brahmanpat
27	Malwan	Chindar
28	Malwan	Asarondi
29	Kankavli	Kasavan
30	Malwan	Rathivade
31	Kankavli	Osargaon
32	Kankavli	Bordave
33	Malwan	Chunavare
34	Kankavli	Phanas Nagar
35	Malwan	Hiwale
36	Kankavli	Kalasuli
37	Kudal	Pokharan
38	Kudal	Kasal
39	Kudal	Narur
40	Kudal	Khocharewadi
41	Kudal	Humarmala
42	Kudal	Bhattwadi
43	Kudal	Bhadgaon Bk.
44	Kudal	Kunde
45	Kudal	Kusabe
46	Kudal	Waingavade
47	Kudal	Kinlos
48	Kudal	Humarmala
49	Kudal	Nirukhe (K)
50	Malwan	Golwan
51	Kudal	Padave
52	Kudal	Warde
53	Malwan	Dikval
54	Kudal	Ranbambuli
55	Kudal	Gaorai
56	Kudal	Oras Bk.
57	Kudal	Kadawal
58	Malwan	Nandos
59	Kudal	Oras Kh.
60	Malwan	Sukalwad
61	Kudal	Tembgaon
62	Kudal	Avalegaon
63	Kudal	Anav
64	Malwan	Kusarave
65	Kudal	Girgaon
66	Kudal	Karivane
67	Kudal	Nerur K.narur
68	Kudal	Digas
69	Kudal	Hirlok
70	Malwan	Kalse
71	Kudal	Pulas
72	Kudal	Rangana Tulsuli
73	Sawantwadi	Amboli
74	Kudal	Naneli
75	Sawantwadi	Kolgaon
76	Sawantwadi	Insuli
77	Kudal	Keravade K.Narur
78	Kudal	Nileli
79	Kudal	Pandur
80	Kudal	Bambarde Tarf Kalsuli
81	Kudal	Gothos
82	Kudal	Tulsuli
83	Kudal	Sarambal
84	Kudal	Bamnadevi
85	Kudal	Mitkyachiwadi
86	Kudal	Kavilkate
87	Kudal	Gandhigram
88	Kudal	Belnadi

Map ID	Taluka name	Village name
89	Kudal	Mulade
90	Kudal	Wados
91	Kudal	Amberi
92	Sawantwadi	Gele
93	Kudal	Ghavanale
94	Kudal	More
95	Kudal	Mudyacha Kond
96	Sawantwadi	Sangeli
97	Kudal	Namaspur
98	Kudal	Bengaon
99	Vengurla	Bhendamala
100	Sawantwadi	Talavade
101	Sawantwadi	Ronapal
102	Dodamarg	Zolambe
103	Dodamarg	Hewale
104	Sawantwadi	Dongarpal
105	Dodamarg	Ker
106	Kudal	Namasgaon
107	Sawantwadi	Kaleli
108	Kudal	Goveri
109	Kudal	Ghatakarnagar
110	Kudal	Raygaon
111	Sawantwadi	Kalambist
112	Sawantwadi	Ambegaon
113	Kudal	Dholkarwadi
114	Kudal	Salgaon
115	Kudal	Kattagaon
116	Kudal	Mangaon
117	Kudal	Taligaon
118	Kudal	Bambarde Tarf Mangaon
119	Kudal	Jambharmala
120	Kudal	Tendoli
121	Kudal	Bhattgaon
122	Sawantwadi	Kunkeri
123	Sawantwadi	Ovaliye
124	Sawantwadi	Madkhol
125	Kudal	Akeri
126	Kudal	Humras
127	Vengurla	Palkarwadi
128	Vengurla	Devasu
129	Vengurla	Adeli
130	Vengurla	Talekarwadi
131	Vengurla	Khanoli
132	Vengurla	Vetore
133	Vengurla	Kelus

Map ID	Taluka name	Village name
134	Sawantwadi	Nemale
135	Sawantwadi	Bhom
136	Sawantwadi	Nirukhe (S)
137	Sawantwadi	Danoli
138	Sawantwadi	Satuli
139	Sawantwadi	Charathe
140	Sawantwadi	Masure
141	Sawantwadi	Kesari
142	Vengurla	Sataye
143	Sawantwadi	Bhairavwadi
144	Vengurla	Dabholi
145	Sawantwadi	Otavane
146	Vengurla	Math
147	Vengurla	Hodawade
148	Sawantwadi	Choukul
149	Sawantwadi	Sarmale
150	Vengurla	Tulas
151	Sawantwadi	Niravade
152	Sawantwadi	Dabhil
153	Sawantwadi	Malgaon
154	Sawantwadi	Kumbharli
155	Sawantwadi	Majgaon
156	Dodamarg	Talkat
157	Dodamarg	Morgaon
158	Sawantwadi	Dingne
159	Dodamarg	Terwanmedhe
160	Sawantwadi	Vetye
161	Vengurla	Adari
162	Vengurla	Ubhadanda
163	Sawantwadi	Vilavade
164	Vengurla	Matond
165	Sawantwadi	Bhalawal
166	Sawantwadi	Kshetrapal
167	Sawantwadi	Sonurli
168	Vengurla	Pendur
169	Vengurla	Pal
170	Vengurla	Ansur
171	Sawantwadi	Wafoli
172	Dodamarg	Khadpade
173	Sawantwadi	Tamboli
174	Sawantwadi	Nhaveli
175	Sawantwadi	Degave
176	Sawantwadi	Banda
177	Sawantwadi	Nigude
178	Sawantwadi	Sherle

Map ID	Taluka name	Village name
179	Sawantwadi	Padve Majgaon
180	Vengurla	Asoli
181	Sawantwadi	Malewad
182	Dodamarg	Bhekurli
183	Sawantwadi	Padlos
184	Sawantwadi	Dandeli
185	Sawantwadi	Madura
186	Sawantwadi	Aros
187	Dodamarg	Bambarde
188	Dodamarg	Kolzar
189	Sawantwadi	Kas
190	Sawantwadi	Galel
191	Dodamarg	Ghatiwade
192	Dodamarg	Palye
193	Dodamarg	Morle
194	Dodamarg	Kumbral
195	Dodamarg	Adali
196	Dodamarg	Ugade
197	Sawantwadi	Satarda
198	Dodamarg	Sonawal
199	Dodamarg	Shirwal
200	Dodamarg	Kasai
201	Dodamarg	Girode
202	Dodamarg	Usap

Map ID	Taluka name	Village name
203	Sawantwadi	Talawane
204	Sawantwadi	Netarde
205	Dodamarg	Phondye
206	Sawantwadi	Aronda
207	Dodamarg	Bhike-Konal
208	Dodamarg	Sasoli
209	Dodamarg	Ghotgewadi
210	Dodamarg	Kalane
211	Dodamarg	Aynode
212	Dodamarg	Konal
213	Dodamarg	Ghotge
214	Dodamarg	Kendre Bk.
215	Dodamarg	Sateli Bhedshi
216	Dodamarg	Shirange
217	Dodamarg	Kudase
218	Dodamarg	Khanyale
219	Dodamarg	Mangeli
220	Dodamarg	Bodade
221	Dodamarg	Maneri
222	Dodamarg	Zarebambar
223	Dodamarg	Ambeli
224	Dodamarg	Khokaral
225	Dodamarg	Pikule

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ARTICLE

Conservation ecology of birds in Mt. Hilong-hilong, a Key Biodiversity Area on Mindanao Island, the Philippines

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Abstract: The identification of key areas for conservation and protection according to science-based evidence is an important component to circumvent the negative impacts of environmental changes within geopolitical territories and across the globe. Priority areas for biodiversity played an important role to ensure the protection of many species particularly those that are unique and threatened. There are more than 200 Key Biodiversity Areas (KBAs) in the Philippines, yet many important research and biodiversity data are either unpublished or unconsolidated. Birds are commonly studied indicators for KBA identification due to their high species richness, diversity, and sensitivity to forest ecosystems. By combining data from past and present surveys, we accounted for a total of 148 bird species of 51 families, with 20 new records from recent field surveys. Our analysis showed a high level of endemism within Mt. Hilong-hilong with 36% Philippine endemic, 14% restricted to Mindanao faunal region and 11% migrant. In terms of conservation, 8% of the species were considered in threatened categories. The species richness and endemism were higher in lowland to mid-elevation areas compared to higher elevation areas of the KBA. Endemism (i.e., Mindanao endemic) and increasing body mass were important determinants of binary extinction risk for bird species in Mt. Hilong-hilong. The high biodiversity in Mt. Hilong-hilong indicates an example of the vital role of KBAs in preserving nationally and globally important bird species. Lastly, we emphasise the importance of collaboration and integrating past and present information to synthesise relevant information to complement ongoing conservation efforts in Mt. Hilong-hilong and other key habitats in the Philippines.

Keywords: Anthropocene, collaboration, deforestation, ecological indicators, endemism.

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INTRODUCTION

The Philippines is the world's second-largest archipelago and its unique biogeographical features with more than 7,000 islands allowed the diversification of taxa, making it one of the megadiverse tropical country (Heaney & Regalado 1998). Birds are amongst the most diverse group in the Philippines, constituting more than 50% of the country's land vertebrates, and large proportions are considered distinct and globally threatened (Peterson et al. 2000), with 724 described species and at least 200 country endemics (Clements et al. 2019). These numbers will probably increase with proper taxonomic studies when integrative taxonomy approach is made (Sánchez-González & Moyle 2011; Gonzalez et al. 2013).

The diversity of birds in the Philippine contributes to the ecological balance and integrity of remnant native vegetation (Peterson et al. 2000). Birds have large range distribution, high mobility, and diverse traits that are sensitive to ecological changes (O'Connell et al. 2000; Trindade-Filho et al. 2012). Therefore high avian species richness can serve as an important ecological indicator in terrestrial ecosystems (Canterbury et al. 2000). The functional trait diversity across birds provides various key ecosystem services in different systems, from intact forests to more disturbed urbanised areas (Sekercioglu et al. 2016). Frugivorous and nectarivorous birds are vital for seed dispersal and pollination, respectively, therefore maintain gene flow and persistence of the population of many important tropical plant species (Ingle 2003; García & Martínez 2012). This group also serves as natural foresters in degraded areas through seed rain and dispersal (Gonzales et al. 2009; Mueller et al. 2014). Insectivorous birds can suppress insect pests and can reduce the use of environmentally harmful pesticides in agricultural landscapes (Koh 2008; Sekercioglu 2012). Carnivores are vital in the check and balance of prey populations, for example, rodent populations in urban or agricultural landscapes with high reproductive potential (Donázar et al. 2016).

The Philippine biodiversity, however, is threatened by various environmental and human pressures (Brooks et al. 1999) that may disrupt species diversity, their ecological function and services. Given the growing population in the Philippines, a large proportion of species and habitats are threatened by land-use changes to accommodate human needs (Brooks et al. 2002; Posa & Sodhi 2006; Posa et al. 2008). In the Philippines, over 67% of bird species are dependent on intact pristine forests (Dutson et al. 1993; Brooks et al. 1999; Gonzales et al. 2009). Deforestation poses a key threat to biodiversity loss in the country, driven by logging and shifting agriculture. For example, at least 74% of tree cover loss in 2001–2018 was caused by deforestation alone (Global Forest Watch 2020). In 2002–2019, an estimated 3.1% or 145,000ha of humid forest was lost in the Philippines, equivalent to a 12% tree cover loss (Global Forest Watch 2020).

The quality of the environment plays an important role in shaping the structure and function of biodiversity (Fried et al. 2019; Lelli et al. 2019), generally described using population density, species abundance, trait diversity, and distribution across different habitats (Davidar et al. 2005). To prevent eventual decline and species extinction, important areas for conservation such as Key Biodiversity Areas (KBAs) are identified by conservation biologists and respective governmental policymakers based on high biodiversity potential. KBA identification is not solely dependent on the species richness but in accordance to the presence of population or species that are (1) threatened globally, (2) distributed in a small restricted range (e.g., endemism), (3) restricted use during some stage of their life cycle, and lastly (4) restricted to a specific biome (Eken et al. 2004; Ambal et al. 2012). Birds are included as indicator groups for terrestrial KBAs identification due to their wide-breadth of diversity and sensitivity to ecosystem conditions (Canterbury et al. 2000; O'Connell et al. 2000; Eken et al. 2004). Currently, there are 228 KBAs in the Philippines, of which 101 are terrestrial (51,249 km^2) and 27 are fully protected, 25 partially protected, and 49 unprotected (Ambal et al. 2012). Although KBAs holds high biodiversity, not all are protected, and thus often challenged by several factors, particularly anthropogenic activities due to lack of well-defined statuary protection policy prohibiting encroachments and the persistence of threats (Butchart et al. 2015; Cai 2013; Knight et al. 2007). The effectiveness of conservation policies and initiatives often requires extensive and wide information on biodiversity, yet knowledge gaps continue to be a challenge, limiting effective and efficient decision making (Butchart et al. 2015; Nori et al. 2020).

The Island of Mindanao in the southern part of the Philippines holds many biodiversity-rich ecosystems with a high concentration of endemic species (Paz et al. 2013; Sanguila et al. 2016; Amoroso et al. 2019). The majority of the endemic and threatened species are concentrated in intact forests identified or protected by the government to conserve the species from total extinction (Sanguila et al. 2016; Amoroso et al. 2019).

Mt. Hilong-hilong (Fig. 1) is a KBA in Mindanao that lies on the boundaries of Agusan del Sur, Agusan del Norte, and Surigao del Sur Provinces in the northern portion of the Diwata Range of northeastern Mindanao or Caraga region. The whole KBA has an area of 2,432km^2 with the highest elevation at 2,012 metres above sea level (The Haribon Foundation 2018). Several taxonomic and biodiversity studies have been conducted in Mt. Hilong-hilong, focusing particularly on birds. Albeit information remains scattered or inaccessible. A major knowledge gap concerning Philippine birds in KBAs is the lack of clear understanding of the relationship of species diversity, the extent of the threatening process, and extinction risks. Understanding biotic potential and vulnerability are essential to developing effective conservation prioritisation in a certain habitat or ecosystems (Segan et al. 2016; Tanalgo & Hughes 2019). Here, we integrate field data collected in 2017 and the past survey to assess and analyse the overall biotic potential and diversity patterns for birds in Mt. Hilong-hilong in Mindanao Island, Philippines. Our study further aims to understand the conservation priorities of birds in this KBA based on their ecological status and potential threats. Our synthesis will serve as complementary science-based evidence to support ongoing conservation efforts in Mt. Hilong-hilong.

MATERIALS AND METHODS

Entry protocol and acquisition of permit

Prior to the field surveys, as a courtesy, we visited the major stakeholders from the local government and the local people in the area. This was followed by obtaining of the Wildlife Gratuitous Permit (GP # R13-2017-0036) following the procedure of the Department of Environment and Natural Resources (DENR) of the Republic of the Philippines.

Field survey

We conducted field surveys in Tandag Watershed in Mt. Hilong-hilong, Barangay Awasian, Tandag City, Surigao del Sur, situated between 9.075° N and 126.154° E. We primarily recorded birds using transects and point counts. We utilised established trails to establish 2-km transects in each elevation range. Birds were observed during peak activity, from 05.00h to 10.00h and from 14.00h to 18.00h, for four consecutive days per transect with five field researchers as observers. The samplings were performed in the first four days for transect 1 and the next four days for transect 2. The overall sampling effort was 180 observer-hours per transect. Point counts were carried out at every 250m of the transect making

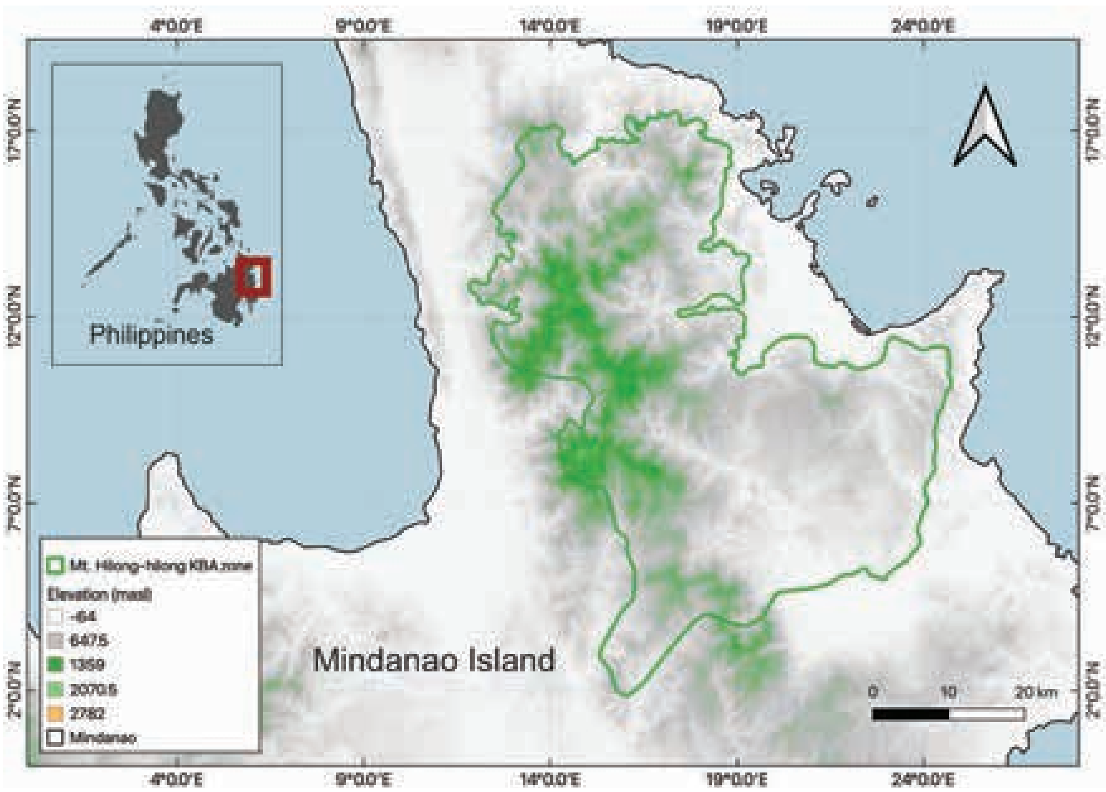

Figure 1. Elevational map of Mt. Hilong-hilong showing the boundaries of the Key Biodiversity Area. Map was generated using QGIS version 3.14.

a 9-point station on a 2-km transect line. We conducted surveys for 20 minutes at every point. All bird species observed and vocalisations during the transect walk and in the point-stations were counted.

We also performed mist-netting to supplement the sampling. We set 22 standard-sized mist nets in every site at the heights: ground nets (0–5 m above the ground; N= 8), sub-canopy nets (at 5–10 m; N= 7), and canopy nets (10m above ground; N= 7), to capture ground-dwelling, sub-canopy, and canopy-dwelling species, respectively. A total of 168 net-days was carried out. We checked nets as regularly as possible to ensure no individuals are tangled for a long period. Captured individuals were placed in a cloth bag to avoid further stress, and were then identified using field guides by (Kennedy et al. 2000). All captured individuals were released in the same area where they are captured.

Synthesis of secondary data and analyses

We performed a simple meta-analysis to evaluate the diversity patterns of birds in Mt. Hilong-hilong by combining present survey data and previously published accounts. We only included those studies that contain a complete dataset that includes elevation of records, species name, conservation status, endemism, and feeding guilds. We curated and updated the species names and their species-specific information using the data from the International Union for the Conservation of Nature Red List (IUCN 2020). We exclude in the final analysis those species with dubious identification and ecological status. The elevation of species where the species was recorded was binned in intervals (e.g., 0–100, 101–500, 500–1,000, 1,000–2,000 m) as representative of lower to higher elevation gradients. We determined species feeding guilds based on published literature (e.g., Kennedy et al. 2000; Mohagan et al. 2015; Tanalgo et al. 2015, 2019) and grouped species into frugivores (feeding on fruits), nectarivores (feeding on nectars and floral parts), granivores (feeding on seeds), insectivores (feeding on insects and small arthropods), carnivores (feeding on large invertebrates and vertebrates), and omnivores (feeding on both plant and animal resources).

We performed all statistical tests and data visualisations using the open-source software Jamovi 1.2.6 (The Jamovi Project 2020). We omitted abundance-based data (e.g., species counts) to standardise the quantification and comparison. Species richness was based on absolute species count per elevation gradient interval. We compared richness and proportion of ecological status, e.g., conservation status, population trends, endemism, and feeding guilds across elevational gradient using descriptive statistics and Chi-square test of independence (χ^2). We performed simple generalised linear modelling (GLMs) using the gamlj module in Jamovi (v 1.2.6) (Gallucci 2019) to predict the binary extinction risk (global) of species recorded in Mt. Hilong-hilong, with adult body mass (kg), endemism, and feeding group as explanatory variables. We choose the best model based on the model with the lowest Akaike information criterion (AIC) values.

We categorised and quantified key threatening process for each species as direct human-use, land-use driven, and natural threats using the species threat index following Tanalgo & Hughes (2019) based on the IUCN Red List assessment (IUCN 2020) as rudimentary analysis to determine species risk from potential threats. We classified direct threats like those that potentially impact species biology and population immediately (e.g., hunting and harvesting), land-use driven are threats that affect species habitats (e.g., deforestation and agricultural conversion), and natural threats are threats that include the climate and geological driven threats (e.g., storm or extreme heat). We compared the number and means of key threatening process across endemism and conservation status using the non-parametric Kruskal-Wallis test.

RESULT

Bird records from the recent field survey

A total of 82 bird species with 20 new species records from 14 orders, 40 families, and 66 genera were documented in the present field survey in Mt. Hilong-hilong (Supplementary Data 1 https://doi.org/10.6084/m9.figshare.13168916.v1). The number of species in the recent survey was lower compared to the 120 reported by the Philippine Eagle Foundation (2007) from the four other sites of Mt Hilong-hilong located at Adlay, Sipang-pang, Pinasandi, and RTR. White-Collared Kingfisher *Todiramphus chloris,* Tricoloured Munia *Lonchura malacca*, and Yellow-vented Bulbul *Pycnonotus goiavier* were the most observed species in all stations, particularly in the less forested areas, such as grassland and cultivated-areas. Forest-dwelling species Mindanao Hornbill *Penelopides affinis,* White-eared Brown-dove *Phapitreron leucotis,* and Yellow-breasted Fruit-dove *Ramphiculus occipitalis* were only observed in the dense dipterocarp forests of the KBA. In the present survey, eight per cent (N= 7 spp.) of the species were categorised as threatened. Whereas there were 52% (N= 43 spp.) endemic species constituted by

35 (43%) species endemic in the Philippine, and eight (10%) are endemic to Mindanao Island.

Synthesis of bird diversity patterns in Mt. Hilong-hilong

We synthesised present and previous studies to estimate bird species biodiversity in Mt. Hilong-hilong. We tallied a total of 148 bird species belonging to 51 families (Supplementary Data 1 https://doi.org/10.6084/m9.figshare.13168916.v1). This number approximately represent 20% of the 724 Philippine bird species. The families Columbidae (N= 13 spp., 9%), Muscicapidae (N= 10 spp., 7%), Cuculidae (N= 9 spp., 6%), Nectaridae (N= 9 spp., 6%), and Dicaeidae (N= 8 spp., 5%) were the most represented families. Within feeding guilds, half of the overall species were insectivorous (N= 75 spp., 51%) followed by frugivorous (N= 28 spp., 19%), and carnivorous (N= 18 spp., 12%) (Table 1). Overall, without considering the elevational gradient distribution, we found significant relationships between species feeding guild and endemism (χ^2= 21.7, *df*= 10, *P*= 0.016), and across conservation status (χ^2= 50.9, *df*= 20, *P*< 0.001).

Thirty-six per cent (N= 53 spp., 36%) of the species were country endemic, 20 species (14%) restricted to Mindanao faunal region, and 16 (11%) species were migratory (Table 1). Large proportion of species (N= 135 spp., 91%) were considered in non-threatened category (Least Concern and Near Threatened), eight per cent (N= 12 spp., 8%) were threatened (Vulnerable and Endangered), and one per cent data deficient species. Although the majority of the species were non-threatened there was a significant number of endemic species within this category (χ^2= 57.9, *df*= 8, *P*<0.001) with 30% (N= 40 spp.) endemic in the Philippines and 10% (N= 14) endemic in Mindanao Islands. There were fewer number of threatened species but there was a significantly higher percentage of species in declining population trends (N= 78 spp., 53%) versus with stable (N= 59 spp., 40%) and increasing population trends (N= 5, 3%) (χ^2= 40.70, *df*= 12, *P*< 0.001). Moreover, the 66% (N= 48 spp.) of all endemic have significantly decreasing population trends compared to only 44% (N= 32 spp.) of the non-endemic species (χ^2= 29.00, *df*= 6, *P*< 0.001) (Table 1). Furthermore, using a simple logistic regression model, we demonstrated that adult body mass and endemism were significant determinants of binary extinction risk of birds in Mt. Hilong-hilong. Our best model (AIC= 136.133) indicated that larger species (β= 0.590, SE= 0.168, *P*< 0.001) and those Mindanao (β= 3.227, SE= 0.864, *P*< 0.001) and Philippine endemic (β= 2.557, SE= 0.802, *P*< 0.001) in contrast to non-endemic species were more likely at higher risk (Fig. 2; Supplementary Data 2 https://doi.org/10.6084/m9.figshare.13169396.v1).

We found more species in the lower elevational gradient interval (N= 115 spp., 78%) albeit presence of particular families did not significantly differ across elevation gradient (χ^2= 110, *df*= 150, *P*< 0.994). Within the KBA, higher endemism proportion were recorded in the lower (49%) and mid-elevation (61%) (χ^2= 9.16, *df*= 9, *P*< 0.423) (Fig. 3), but only differed significantly within conservation status (χ^2= 21.60, *df*= 12, *P*< 0.04) (Fig. 3). We found no significant relationship amongst elevational gradient and feeding guild (χ^2= 9.92, *df*= 18, *P*< 0.934) (Fig. 3).

Table 1. Diversity summary of birds in Mt. Hilong-hilong in terms species richness according to feeding guild, endemism, movement pattern, conservation status, and population status. See Supplementary Data 1 for full list of species listed and analysed in the study https://doi.org/10.6084/m9.figshare.13168916.v1

Diversity attributes	Number of species	%	Record from new field survey
Feeding guild			
Carnivores	18	12	10
Frugivores	28	19	18
Granivores	5	3	2
Insectivores	73	49	41
Nectarivores	15	10	9
Omnivores	9	6	2
Endemism			
Non endemic	75	51	39
Philippine Endemic	53	36	35
Mindanao Endemic	20	14	8
Migration Pattern			
Full Migrant	16	11	10
Non migrant	132	89	72
Conservation status			
Data Deficient	1	1	0
Least Concern	124	84	71
Near Threatened	11	7	4
Vulnerable	11	7	7
Endangered	1	1	0
Population status			
Decreasing	79	53	43
Increasing	5	3	4
Stable	60	41	33
Unknown	4	3	2

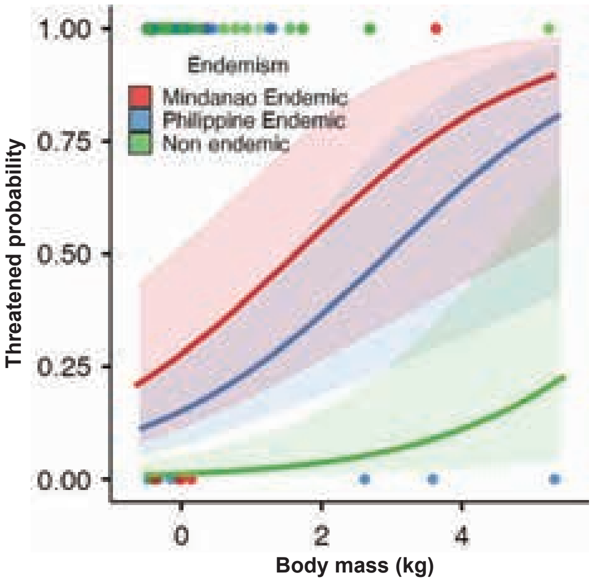

Figure 2. Simple logistic regression showing the link amongst species extinction probability, adult body mass (kg), and endemism of birds in Mt. Hilong-hilong.

Potential threats

Fundamental to developing effective conservation agenda is to identify potential threatening processes and their extent. We utilized the IUCN Red List data for each species recorded in Mt. Hilong-hilong as a rudimentary basis for determining the extent of potential threats faced by species; IUCN categories are globally standardised to provide a useful framework for our analysis. Overall, endemic and threatened species face a higher proportion of threats (Fig. 4A). Direct human use and land-use driven threats, such as land conversions are the key potential threat for the majority of the species (Fig. 4). Threatening processes significantly differed across conservation status and endemism. Overall threats (Kruskal-Wallis test: χ^2= 52.50, *df*= 4, *P*< 0.001; Land-use drive threats, χ^2= 111.29, *df*= 4, *P*< 0.001; Natural threats, χ^2= 27.81, *df*= 4, *P*= <0.001) significantly differed across conservation status except for direct human threats (Kruskal-Wallis test: χ^2= 6.62, *df*= 4, *P*= 0.157) (Fig. 4B,C). When conservation categories were compared, threatened species have higher mean threats (mean= 3.85 ± 0.99) compared to non-threatened species (mean= 1.165 ± 1.47) (Fig. 4A).

There was a significant difference in the number of species threatened by different threats categories within endemism categories (Fig. 4B,C). There were 48% and 47% of threatened by land-use driven threats in Mindanao and Philippine endemic species, respectively (Kruskal-Wallis test: χ^2= 18.02, *df*= 2, *P*< 0.001), while 84% of non-endemic species were threatened by direct-human threats (e.g., hunting) (Kruskal-Wallis test: χ^2= 19.03, *df*= 2, *P*< 0.001). Natural threats were higher among endemic species (Kruskal-Wallis test: χ^2= 10.15, *df*= 2, *P*= 0.01). In terms of average threats per species, Mindanao endemic has higher mean number of threats (mean= 2.00 ± 1.98) compared to non-endemic (mean= 1.41 ± 1.52) and Philippine endemic species (mean= 1.12 ± 1.53).

DISCUSSION

Biodiversity assessments and monitoring provide important information to understand species diversity and conservation (Tanalgo et al. 2015). Field data, particularly from rapid biodiversity surveys are often undervalued, but when carefully synthesised are useful to inform the local state of biodiversity, which aids or complement prioritise key areas, habitats, and species (Tanalgo et al. 2019). Mt. Hilong-hilong interests many natural history scientists and conservation biologist within and outside the region. Yet, most ornithological studies and surveys that occurred are rarely published. The Philippine Eagle Foundation pioneered the ornithological surveys on the western side of the mountain and reported 120 species with 51% Philippines endemics (The Philippine Eagle Foundation 2007). This was followed by an ecological study on the effects of vegetation on birds in Mt. Hilong-hilong by Paz et al. (2013). Forty-six species were observed in San Antonio located on the western side of the mountain (Hosner 2012). By combining past and current survey data from Mt. Hilong-hilong, we found an increase in recorded species and higher proportions of endemism, as other species were not previously recorded before were pooled together, supporting the importance of Mt. Hilong-hilong in conserving important populations of birds in the KBA zone. Key Biodiversity Areas are identified sites across large scale networks by identifying areas that contain unique, vulnerable, and irreplaceable population (Eken et al. 2004). KBA's primarily concerns to aid the conservation and protection of population viability of highly-threatened species or populations based on global-scale criteria (e.g., the IUCN Red List) (Margules & Pressey 2000). Although our analysis showed lower numbers of threatened species (N= 12 spp., 8%), we found a higher proportion of species with declining populations (N= 79 spp., 53%) in Mt. Hilong-hilong. Likewise, we found high proportions of species with restricted distributions (N= 73 spp., 50% endemism

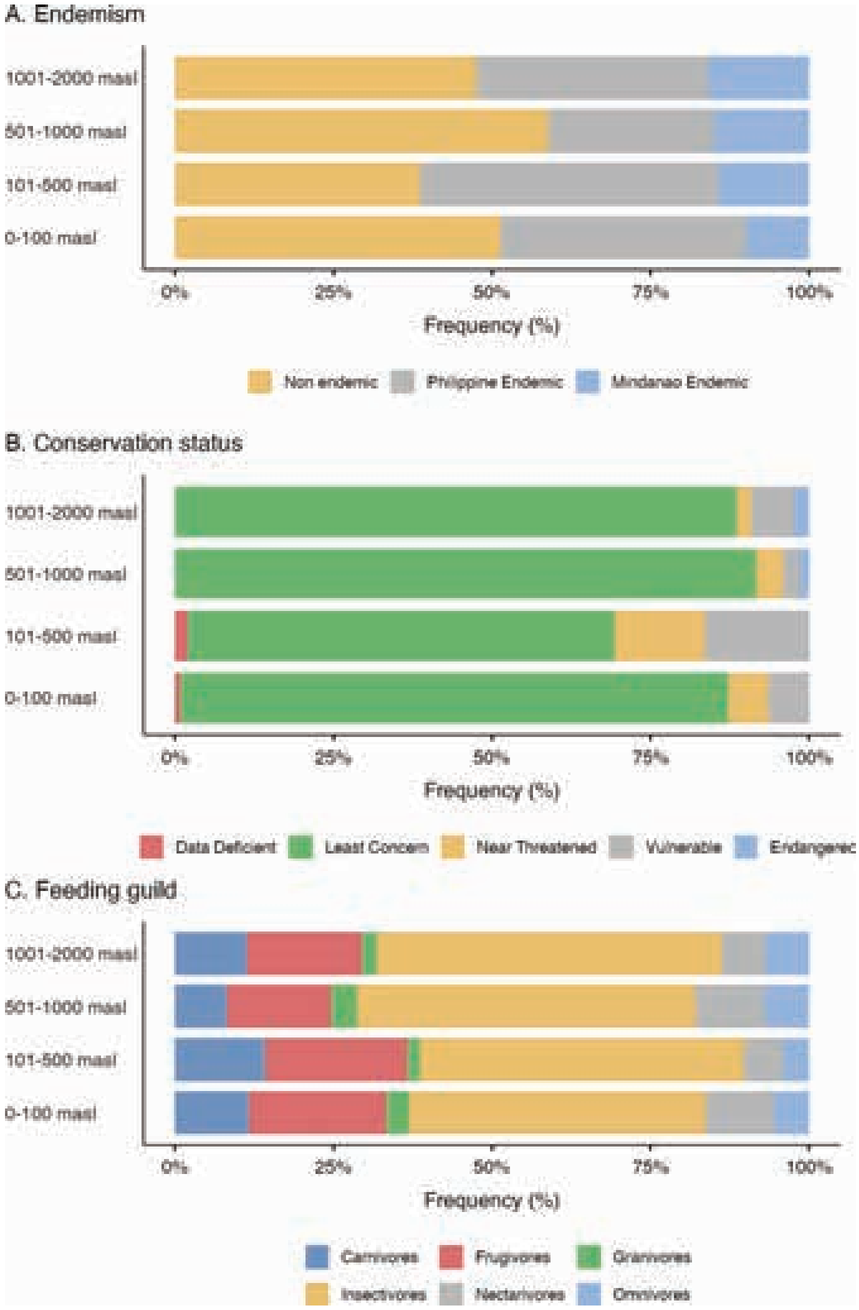

Figure 3. Distribution of birds in Mt. Hilong-hilong across elevational gradient interval based on: A—endemism, | B—conservation status | C—feeding guilds.

level) and this conforms to the other three criteria based on species irreplaceability (Margules & Pressey 2000).

Key Biodiversity Areas with relatively more intact vegetation represents an important site for conservation safeguarding populations of bird taxa from multiple threats (Plumptre et al. 2019). The risk of extinction for birds in Mt. Hilong-hilong is higher among Mindanao and Philippine endemic. Our study found high proportions of endemic species within Mt. Hilong-hilong, and this could be associated with relatively intact, denser and diverse vegetation of native plants within the KBA zone particularly in the lower to mid-elevation, thus more suitable to support wide-suit of bird species and their different life-histories. Tanalgo et al. (2019) compared different habitats in the lowlands of south-central Mindanao and found more endemic species in protected areas and at reforested sites with better vegetation structure compared to more homogenised plantations

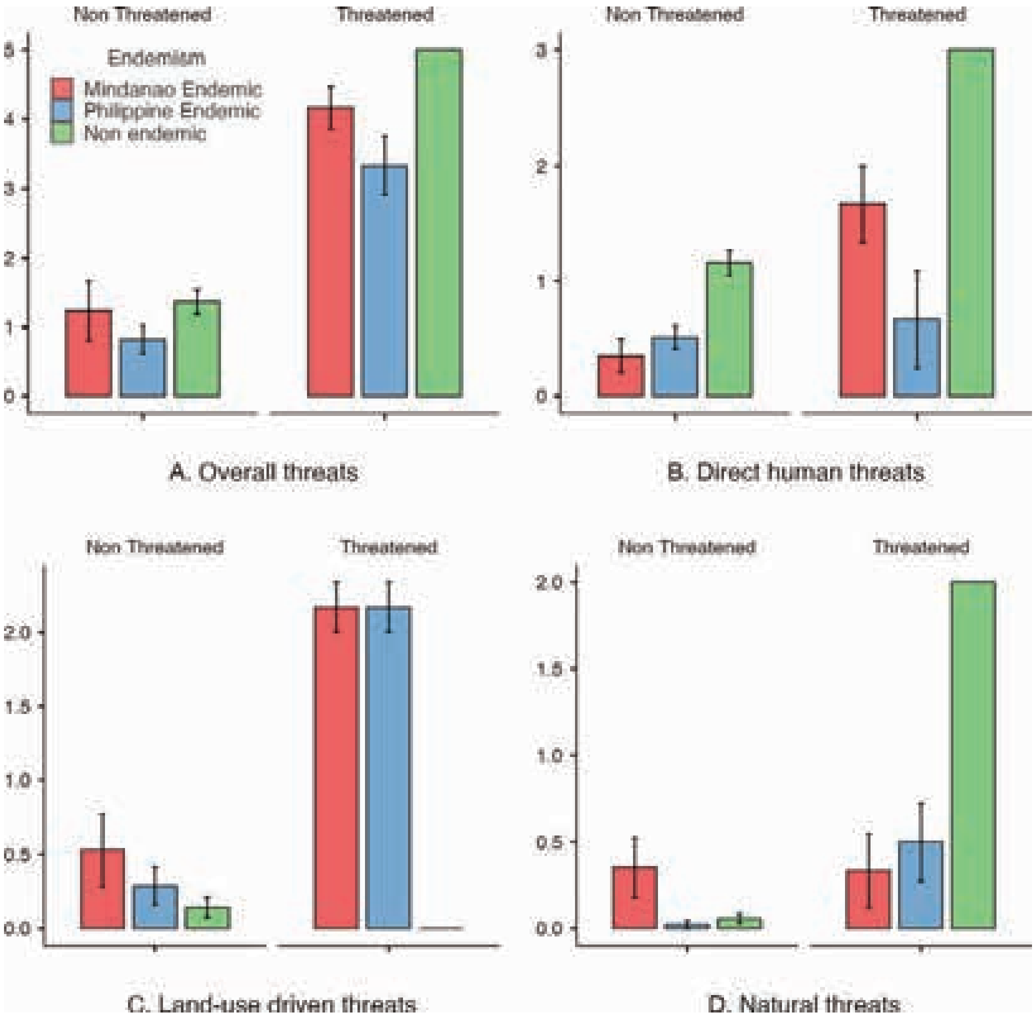

Figure 4. Species threat index of potential threatening processed based on: A—proportion of overall threats | B—direct human threats | C—land-use driven threats | D—natural threats, across endemism. Error bars represent the standard deviation.

and urbanised areas. Previous studies also showed that the density and richness of endemic bird species are strongly correlated with the vegetation intactness and structure (Mills et al. 1991; Daniels et al. 1992; Mejías & Nol 2020). Although the majority of avian species in Mt. Hilong-hilong are considered least threatened, yet large proportions are facing threats from direct-human threats such as hunting, albeit there is no clear evidence detailing the extent of this threat for birds and other wildlife in the KBA. Whereas land-use driven threats such as deforestation and agricultural expansion remain a key threat to 49% of species particularly those forest-dwelling species with narrow distributions. In contrast with other threats, deforestation and agricultural expansions led to habitat fragmentation that may immediately influence the alterations of diversity and composition of native species present in these systems (Bujoczek et al. 2020; Hatfield et al. 2020; Tchoumbou et al. 2020). Declining strict forest-dwelling species at a regional scale is widely associated with human disruption to habitats that reduce the space occupied by and affect the foraging grounds of a diverse set of species (Brooks et al. 1999; Renjifo 2001). Global meta-analyses showed that bird species richness and abundance were particularly susceptible to decline in areas with low structural heterogeneity such as plantations and farmland conversions (Bohada-Murillo et al. 2020). The continuous conversion within or near intact habitats for agricultural expansions during the last decades has driven high biodiversity loss in many hotspot regions including the Philippines (Brooks et al. 2002). Apart from the high diversity of forest-dwelling birds in Mt. Hilong-hilong, we recorded at least 16 migratory species. Intact areas (e.g., protected areas and key biodiversity areas) as interconnected networks of conserved and protected sites are crucial for migratory birds serving as routes supporting the full annual cycle of at least 9% of global migratory birds (N= 1,451 spp.) (Runge et al. 2015).

We found more endemic and threatened species in the lower elevation (0–100 m) and mid-elevations (100–500 m) of Mt. Hilong-hilong, but this should be taken with prudence as the sampling effort or the employed techniques per elevation may vary. This diversity pattern (i.e., species richness) may be explained by the vegetation structure in relationship to elevation in the KBA. In a previous study in Mt. Hilong-hilong, Paz et al. (2013) showed that vegetation and elevation were key drivers affecting endemic species distribution in the KBA. Vegetation is a key determinant of increased species richness and diversity (Canterbury et al. 2000; Tchoumbou et al. 2020) and the effect of elevation may negatively affect vegetation and consequently species diversity and richness across many animal taxa including birds (Kattan & Franco 2004; McCain 2009). In a study in the Rwandan mountains, elevation was found to have inverse effects and vegetation structure positively influenced bird diversity (Derhé et al. 2020). Similarly, this pattern was observed in the eastern Himalaya; Acharya et al. (2011) demonstrated that intermediate elevations had the highest bird species richness, where primary productivity was at the optimal peak.

In terms of feeding groups, the majority of the species recorded in Mt. Hilong-hilong are insectivorous, frugivorous, and carnivorous. Elevation has been shown to affect the distribution of functional groups, for example, elevation strongly influences insectivorous birds but not on frugivorous birds in tropical forest landscapes as influenced by their varying foraging strategies across different vegetation (i.e., more insect biomass) and climate strata (Jankowski et al. 2013; Santillán et al. 2020). Although there was no significant relationship found between feeding groups and elevation, species that were recorded strictly or specific in an elevation may represent an important indicator to future monitoring of bird response to habitat system within Mt. Hilong-hilong. Species feeding guild can indicate habitat structure or quality for species to persist. A study comparing a protected area with an agricultural area in Serengeti showed that at least 50% of insectivorous and granivorous birds found in forests were absent in agriculture, suggesting that more intact ecosystems can safeguard a large proportion of specialist species (O'Connell et al. 2000; Sinclair et al. 2002). In a similar study, bird functional diversity depended on the overall habitat types (Tanalgo et al. 2019), and the intactness of forest, in which species responded negatively to disturbance gradient, for example, omnivores, insectivores and frugivores were lowest in numbers in areas with selective logging and plantation conversions within a tropical rainforest (Tchoumbou et al. 2020). The intactness of KBAs strongly relies on the physical features (e.g., landscape structure), presence of threats, and changes in land-use (Rayner et al. 2014). To circumvent these threats, protected areas and other forms of designated sites serve as a chief tool optimising the conservation and protection of many species (Butchart et al. 2015). Conservation initiatives such as the establishments of KBAs allows the identification of important areas for protection (i.e., the establishment of protected areas) from human alteration. Yet, the identification of KBAs alone is not sufficient to ensure the protection of its ecosystems and important taxa; it requires effective monitoring of its biodiversity and the extent of the potential threatening process (Beresford et al. 2020). To optimise the role of KBA to safeguard critical habitats and their biodiversity it should be primarily protected first by the statutory policy.

In conclusion, our synthesis demonstrated the presence of high diversity of endemic and threatened bird species in Mt. Hilong-hilong harbour, and the vital role of the KBA as an important habitat for bird conservation and protection. Our study exhibited that local biodiversity could be effectively understood by integrating findings from multiple datasets, particularly those from rapid surveys and assessments (Fig. 5) (Tanalgo et al. 2019). Here, we acknowledge that our findings were based on the synthesis of the different dataset that employed varying sampling methods and approach (e.g., intensity and effort, taxonomic identification) that may have affect the robustness of data (Manu & Cresswell 2007) thus, careful interpretation is required. Yet these caveats warrant more intensive efforts and opportunities to produce robust data across elevational and vegetation gradient to fully elucidate their relationship to species diversity and other ecological indicator groups.

The rapidly changing environment and the growing development outside and the lowlands of KBA where habitat change is likely to occur and could pose important attention and concerns for conservation. For instance, from 2002–2019 at least 4.66Kha of humid primary forest was lost within the KBA zone, which most likely caused by deforestation and shifting agriculture (Global Forest Watch 2020). In addition to land-use changes, direct human impacts to birds such as hunting in the KBA may pose another threat to many populations. These threatening processes will likely

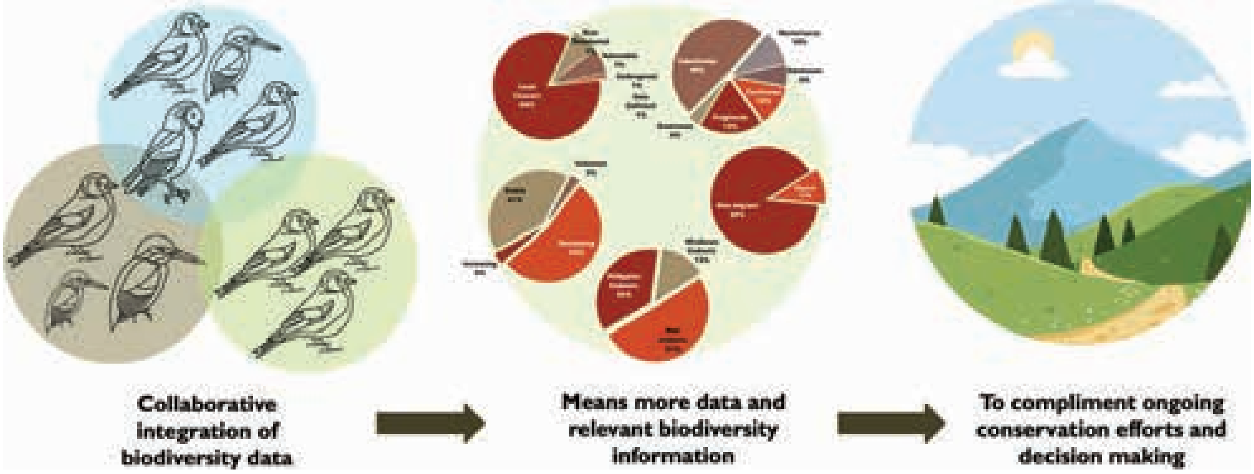

Figure 5. Schematic diagram showing the key importance of collaborative efforts for conservation such as the biodiversity data sharing and integration from different fieldwork and research to develop synthesis for clearer understanding of biodiversity patterns to inform better or complement existing conservation efforts. This figure was generated using the free version of clipart from https://logomakr.com/

affect many species particularly larger species (e.g., large-fruit doves) and those with narrow distributions (Tanalgo 2017). Thus future studies must aim to understand and explore the extent and impacts of these threats to species in Mt. Hilong-hilong. Future conservation priorities should advocate more protection of endemic species which more tends to be threatened in Mt. Hilong-hilong. Furthermore, we demonstrate here that collaborative efforts may promote effectual conservation by combining different data from different survey efforts that often remain in grey literature, enable biodiversity synthesis by increasing relevant information to better understand species diversity (Tanalgo et al. 2019). Bolstering efforts promoting transparent and collaborative science-based conservation intervention is central to better complement and sustain existing conservation management not only in Mt. Hilong-hilong (Mohagan et al. 2015; Amoroso et al. 2018) but across all other important biodiversity sites in the country (Fig. 5).

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Threatened Taxa

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ARTICLE

Nesting and hatching behaviour of Olive Ridley Turtles *Lepidochelys olivacea* (Eschscholtz, 1829) (Reptilia: Cryptodira: Cheloniidae) on Dr. Abdul Kalam Island, Odisha, India

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Abstract: This paper reports the nesting, impact of lunar phase and rainfall on mass nesting, hatching, and hatchling behaviour of *L. olivacea* in Dr. Abdul Kalam Island, Bhadrak District, Odisha. The study site is a well-known rookery for this species. A study of 15 mass nesting events between 2003 and 2020 using Rayleigh's test indicated that the onset of mass nesting was not uniform across a lunar month, but was most intense towards the beginning of the fourth quarter moon (mean lunar day = 22.44). Also, rainfall and mass-nesting data from 2015 to 2020 revealed that ≥3.2 mm rainfall in February delayed mass nesting from the second fortnight of February to the end of the first fortnight of March. Sporadic nesting continued after hatching commenced in May, and continued until the end of May 2020, with an average of three turtles nesting each day. At night, a cohort of hatchlings from individual nests emerged synchronously. Before emergence they remained a little beneath the sand surface in airy-shallow pits. During hatchling emergence these pits fill with sand, leaving depressions described as "emergence craters" in recent literature on *L. olivacea*. To study hatchling emergence 30 such craters were examined in May 2020, and the numbers of emerged hatchlings per cohort varied from 28 to 182. Of 30 craters examined, 28 were circular and two were elliptical, with diameters varying between 10 and 26 cm. Pearson's correlation coefficient between the numbers of emerged hatchlings and crater diameter was 0.38. Hatchlings took 17 min 22 sec (SD= ±5min 30 sec) on average to reach the sea from a mean distance of 34.6m.

Keywords: Arribada, Bhadrak District, cohorts, emergence crater, hatchling emergence, moon phase, sporadic nesting.

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INTRODUCTION

The Olive Ridley Sea Turtles *Lepidochelys olivacea* are the second smallest sea turtles in the world next to the Kemp Ridley *Lepidochelys kempii* (Van Buskirk & Crowder 1994). *Lepidochelys olivacea* have a circumtropical distribution and occur in India, Mexico, Costa Rica, and the Arab Peninsula, further to coastal Africa along the warm tropical and subtropical waters of the Indian and Pacific Oceans (Pritchard 1997; Pritchard & Mortimer 1999). They do not migrate from one ocean to another but move between the oceanic and neritic zones within the same ocean (Plotkin et al. 1995).

Lepidochelys olivacea populations are well known for 'arribada' (a Spanish term, meaning 'arrival by sea') wherein 1000s of pregnant turtles arrive at the same beach site to lay their eggs and nest for the next few days. The mass nesting sites for *L. olivacea* include Costa Rican and Mexican beaches (Pritchard 1997) and the Odisha coast (Bustard 1976) along the Pacific and Indian Ocean, respectively. In Odisha, Gahirmatha Wildlife Sanctuary in Kendrapada District (Bustard 1976), the Devi River mouth in Puri District (Kar 1982) and Rushikulya in Ganjam District (Pandav et al. 1994) are the three principal nesting sites for *L. olivacea*. Among these, Gahirmatha Wildlife Sanctuary is the largest known nesting centre for *L. olivacea* (Bustard 1976) with 1–8 lakh turtles nesting per year (Pattnaik et al. 2001).

Breeding and nesting of *L. olivacea* occur through the year in Costa Rican and Mexican coasts, with mass nesting in the rainy months of July–December (Hart et al. 2014), mostly during the third quarter moon (Plotkin 1994). In the Odisha coast mass nesting occurs in the dry months of January–March (Dash & Kar 1990). In Gahirmatha Wildlife Sanctuary in particular, breeding of *L. olivacea* starts in November and mass nesting occurs in January–March (Behera et al. 2010). *Lepidochelys olivacea* have the ability to delay nesting in response to heavy rainfall, because high moisture level in the beach sand reduces hatching success in the nest (Plotkin et al. 1997). The numbers of turtles participating in mass nesting are variable (Pattnaik et al. 2001). Sporadic nesting by a few individuals of *L. olivacea* along the eastern coast of India from North 24 Parganas District to Kanyakumari (21.638^{0}N, 89.075^{0}E) between December and April are common (Pandav & Choudhury 2000; Tripathy et al. 2008). After 45–50 days of incubation, the hatchlings return to the sea in April.

Hatching within a nest is synchronous (Spencer et al. 2001) and emergence occurs through group-digging behaviour customarily described as 'social facilitation' (Carr & Hirth 1961). The emergence of hatchlings from a single nest occurs in 1–4 cohorts over a few days, with the first cohort having the largest number of hatchlings (Rusli et al. 2016). Before emergence, hatchlings rest in an air-filled pit in sandy soil and during emergence, the surface sand sags into the pit (Salmon & Reising 2014), leaving a depression described as 'emergence crater' (Bishop et al. 2011). Hatchling emergence in *L. olivacea* has been studied using various methods. Among them, the numbers of hatchlings leaving the emergence crater (Burney & Margolis 1998) is considered a reliable index of hatchling emergence. After emergence, the hatchlings crawl radially out of the crater and the crawl marks are used in describing hatchling emergence (Bishop et al. 2011).

Hatchlings emerge nocturnally (Mrosovsky 1968) and move towards negative surface gradient (Salmon et al. 1992). Also, hatchlings exhibit positive phototaxy. Since the sea surface reflects moon light better than the land surface, they move seawards (Mrosovsky & Shettleworth 1968). Artificial illuminations placed on the land distract the seaward movement of hatchlings (Tuxbury & Salmon 2005). In the absence of artificial illumination, disorientation in hatchling movement is high on new moon days (Salmon & Witherington 1995).

Lepidochelys olivacea populations have declined in many countries due to various reasons: collection of eggs (Arauz 2000), destruction of nesting beaches (Pandav & Choudhury 1999), trapping of adults (Fretey 2001), intensive fishing practice using trawlers and banned nets (Pandav 2000), diseases (Herbst 1994), and global warming (Hays et al. 2003) are a few significant ones. The IUCN Red List of Threatened Species has evaluated *L. olivacea* under 'Vulnerable' category (Abreu-Grobois & Plotkin 2008).

In Gahirmatha Wildlife Sanctuary, mass nesting was delayed between February and March 2020 probably because of sporadic rainfall in February (3.2mm). Also, the nesting period (14–20 March 2020) coincided with waning phase of the moon. These observations prompted further study exploring the effect of certain environmental variables, viz., lunar phase and rainfall on mass nesting and hatching behaviour of *L. olivacea*. Although the nesting and hatching behaviour of *L. olivacea* have been reasonably well explored in Gahirmatha (Dash & Kar 1990; Silas et al. 1985; Pandav 2000; Behera et al. 2010), little information exists pertaining the influence of lunar phase and rainfall on mass nesting, and behaviour of hatchlings post emergence.

Therefore, I proceeded with this study keeping the following objectives in focus: (1) mass nesting and its relation with lunar phase, (2) effect of rainfall on mass nesting, (3) the duration of sporadic nesting, (4) the patterns in hatchling emergence and emergence craters, and (5) behaviour of hatchlings post emergence.

MATERIALS AND METHODS

Study Area

Dr. Abdul Kalam Island (previously Wheeler Island, 20.753^{0}N, 87.072^{0}E) falls under the Gahirmatha Wildlife Sanctuary, managed by the forest department of the state of Odisha (Figure 1). The Gahirmatha Beach is 2.4 km long with varying widths. The average annual temperature is 27^{o}C and the average annual rainfall is 1,530mm. *Ipomoea pescaprae* (Convolvulaceae) and *Suaeda maritima* (Amaranthaceae) usually occur abundantly on the sandy shoreline.

Methods

Hatchlings from each nest dig synchronously upwards in cohorts, forming emergence craters on the sand surface. The hatchlings gradually leave the craters and reach the surface, beginning their movement towards the sea. The number of emerged hatchlings per cohort was determined through visual observation of emergence from such craters. During the hatching period, 2–7 May 2020, 30 craters were sampled randomly and each crater was observed from 20.00h to 06.00h, and the numbers of hatchlings emerging from each crater were counted. From each crater, the movements of the first 5–10 hatchlings to the sea were observed individually and the time taken by each of them was measured using a stopwatch. The overall shape of each crater was measured for the diameter using measuring tapes. The

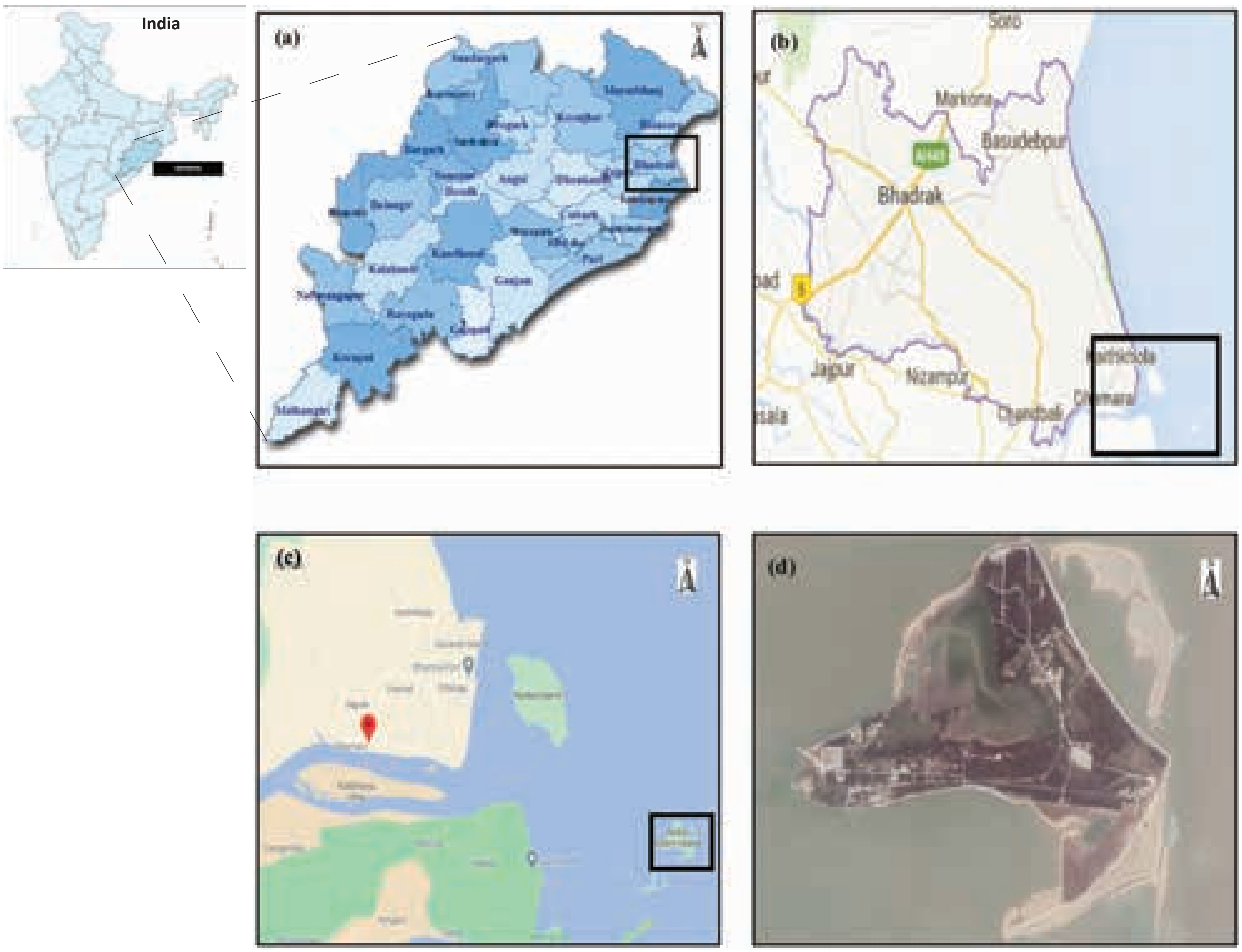

Figure 1 . Study area: a—Bhadrak District (marked) in Odisha map | b—Bhadrak coast (marked area in 'a') | c—Bhadrak coast showing the Dr. Abdul Kalam Island (marked area in 'b') | d—Gahirmatha beach in Dr. Adbul Kalam Island (marked area in 'c'). Source: odishaassembly.nic.in, censusindia.co.in and earth.google.com.

nesting data of *L. olivacea* for 2003–2020 were obtained from the archives of the Rajnagar Wildlife Division Office, Kendrapada. The rainfall data of Dr. Abdul Kalam Island for 2015–2020 were obtained from the nearest meteorological office of Dhamra Port Company Limited, Dhamra, Bhadrak District, Odisha.

The lunar days corresponding to the starting of each mass nesting were obtained from keisan.casio.com (CASIO Computer Co Ltd, 2020, Tokyo, Japan). The lunar days were then converted into angular data for using Rayleigh's test, which was done using MS Excel 2019 to verify uniformity in the occurrence of onset of mass nesting across a lunar month. The correlation between variables in the scatter plot was calculated using Pearson's correlation. Photographs of nesting and hatching were made using a COOLPIX P1000 (125X Optical Zoom Camera, Nikon Corporation, Tokyo, Japan).

RESULTS

Mass nesting (Arribada) and Lunar phase

Mass nesting of *L. olivacea* revealed that 407,204 individuals laid eggs between 14 and 20 March 2020 (Table 1). Maximum numbers (n= 98,700) nested on 17 March (fourth day) and the minimum (n= 3,600) on 20 March (seventh day) (Table 1). Mass-nesting data obtained from Rajnagar Wildlife Division for 2015–2020 revealed that a maximum of 664,897 individuals nested in 2018 and a minimum of 51,995 in 2016 (Table 2)

Rayleigh's test was done to determine if the onset (in lunar days) of 15 mass nesting events between 2003 and 2020 (Table 3) was non-uniformly distributed across a lunar month. Results indicated a highly non-uniform distribution (n= 15, r= 0.504, z= 3.81, $z_{critical}$= 2.945, α= 0.05) with a mean lunar day of 22.44 (i.e., the onset of mass nesting is at the beginning of fourth quarter moon).

Nesting period and rainfall

Mass nesting and the rainfall data for 2015–2020 (Table 4) were analysed in conjunction to study the impact of rainfall on nesting. When the rainfall in February was less than 3.2mm, mass nesting occurred in the last fortnight of February or in the first week of March. When the rainfall increased ≥3.2mm in February, mass nesting was delayed to the end of the first fortnight of March; however, rainfall in the first week of March did not delay mass nesting further, since the nesting season for *L. olivacea* ended in March.

Table 1. Mass nesting data of *L. olivacea* in 2020.

Day	Population numbers
14 March	10,076
15 March	68,311
16 March	98,135
17 March	98,700
18 March	95,541
19 March	32,841
20 March	3,600
Total	407,204

Table 2. Mass-nesting of *L. olivacea* turtles, 2015–2020.

Year	Population numbers
2015	413,334
2016	51,995
2017	603,962
2018	664,897
2019	450,949
2020	407,204

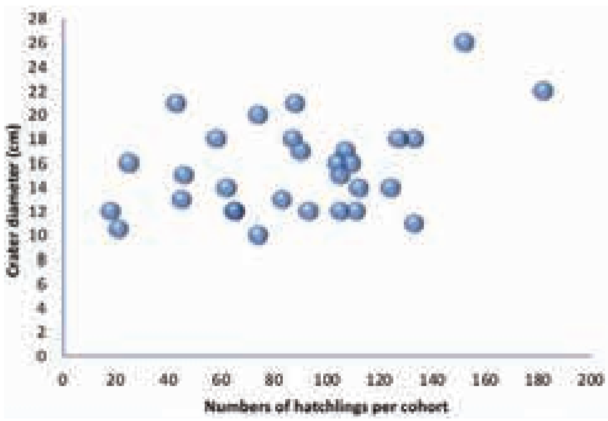

Figure 2. Scatter plot of numbers of hatchlings and crater diameter

Sporadic nesting

Sporadic nesting of *L. olivacea* at Gahirmatha started from the second fortnight of December 2019 and continued after mass nesting from 14–20 March to 1–10 May 2020. Between December and February, an average of 15 individual females of *L. olivacea* nested per day. The numbers increased to 40 per day for a week prior to and after mass nesting. During hatching (2–7 May), an average of three turtles nested on the beach every day.

Table 3. Date of initiation of 15 arribada events and corresponding lunar days, 2003–2020.

Sno	Year	Date of initiation of arribada	Lunar days (out of 29.53 days in a lunar month)	Sno	Year	Date of initiation of arribada	Lunar days (out of 29.53 days in a lunar month)
1	2003	28Feb	26.8	9	2013	17 March	5.4
2	2007	11Feb	23.1	10	2015	12 March	21.3
3	2009	20Mar	23.2	11	2016	03 March	23.7
4	2010 *	24Feb	10.2	12	2017	22 Feb	25.3
5	2010**	19Mar	2.4	13	2018	04 March	16.4
6	2011*	26Feb	23.2	14	2019	26 Feb	21.4
7	2011**	20Apr	16.7	15	2020	14 March	19.6
8	2012	15Mar	22.3	-	-	-	-

Source of mass nesting data: Archives of Rajnagar Wildlife Division, Kendrapada, Odisha Forest Department.
*—First mass nesting | **—Second mass nesting.

Table 4. Yearly rainfall and mass nesting data for Gahirmatha Beach, Dr Abdul Kalam Island, 2015–2020.

Year	Rainfall in 1–15 February (in mm)	Rainfall in 16–28 (29) February (in mm)	Rainfall in 1–15 March (in mm)	Rainfall in 16–31 March (in mm)	Period of mass nesting
2015	0	3.2	0	10.8 (29th)	12–19 March
2016	20.4	5.5	3.7	1	3, 12–20 March (48 turtles on March 3rd)
2017	0	0	0	18.2	22 Feb–1 March
2018	0	0	0	0	4–13 March
2019	0	1	1	1.8	26 Feb–5 March
2020	6.4	6.0	7.8	10 (20th, 22nd, 23rd)	14–20 March

Hatchling emergence

The hatchlings dug through the sand above synchronously to emerge from their sandy nests. At the time of emergence, usually after sunset, an emergence crater formed on the sand surface due to synchronous, collective, digging effort by a single cohort of *L. olivacea* from a nest. These craters lasted for 7–10 days and eventually were either eroded or filled up with sand spread by wind. The hatchlings reached the surface gradually with the hatchlings present near the surface pushed by emerging hatchlings below in the crater. On reaching the surface they spread themselves radially in different directions, but moved towards the sea.

The numbers of hatchlings emerging from the 30 observed individual craters were 2,763. The maximum and minimum numbers of emerged hatchlings per cohort were 182 and 18 with an average of 92.1 hatchlings per cohort. The craters were mostly circular (93.3%) and occasionally elliptical (6.7%). The crater diameter varied between 10 and 26 cm (n= 30). Pearson's correlation indicated a low but positive correlation (0.38) between the numbers of emerged hatchlings per crater and crater diameter. Therefore, when the number of emerging hatchlings per cohort increases, the crater diameter also tends to increase.

Movement of hatchlings towards sea

As soon as the hatchlings emerged, they moved towards the sea. The pace and direction of movement varied among individuals. Time taken by 280 hatchlings from 30 emergence craters to reach the sea indicated that the minimum time taken was 6 min 12 sec and the maximum was 35 min 9 sec. The average time taken by hatchlings to reach the sea from a mean distance of 34.55m was 17 min 22 sec. (SD= ± 5 min 30 sec).

DISCUSSION

Mass nesting and lunar phase

Previous reports on the numbers of mass nesting *L. olivacea* individuals at Gahirmatha Wildlife Sanctuary

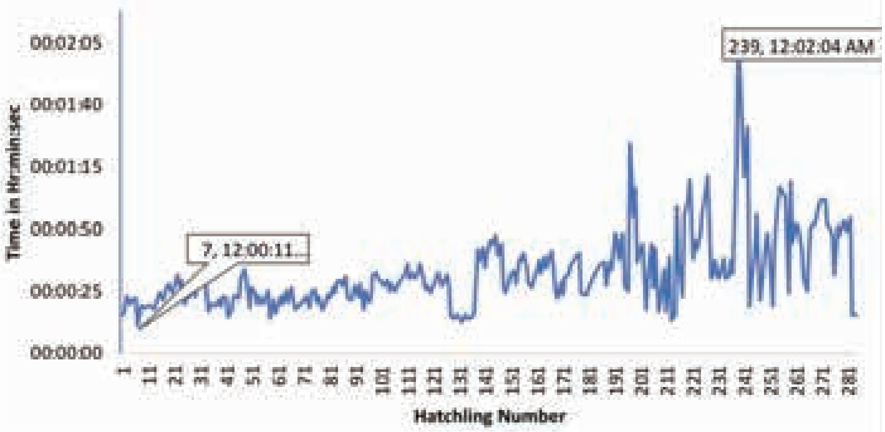

Figure 3. Time taken by individual hatchlings to move 1m

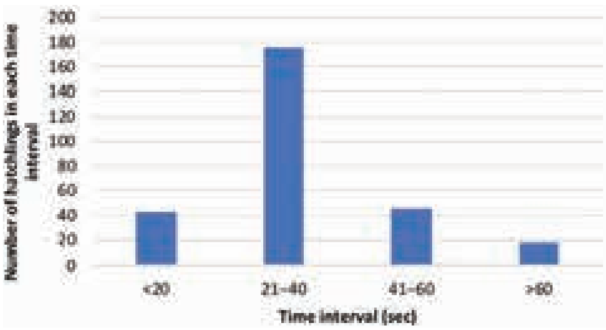

Figure 4. Numbers of hatchlings in various time intervals.

indicate varying annual numbers (Bustard 1976; Kar & Bhaskar 1982; Silas et al. 1985). The data for 2015–2020 also revealed that numbers of turtles differed every year with 51,995 turtles in 2016 and 6,64,897 in 2018. It is possible that the variation was due to changes in productivity in their foraging areas, because females needed sufficient nutrients to support their migratory and reproductive activities (Valverde et al. 2012). Also, an increase or decrease in hatching rates over many years may result in varying adult population participating in arribada (Cornelius et al. 1991). Beach exchange, where Olive Ridleys move to another beach for nesting, mortality in nets (Valverde et al. 1998) also affects the nesting population numbers. The exact reason for variation in the number of individuals in mass nesting, however, requires further study.

At Gahirmatha, the onset of mass nesting occurred at the beginning of the fourth quarter moon. Rayleigh's test showed a highly non-uniform distribution of onset of mass nesting across the lunar month with a mean lunar day of 22.44 days. According to Silas et al. 1985, mass nesting occurred on 7th day after the full moon in Gahirmatha, i.e., after 20.77 days. In Ostional Beach, Costa Rica, mass nesting usually began in the fourth quarter moon with mean lunar days of 23 (Bezy et al. 2020). In Mexico, mass nesting coincided with the third quarter moon (Plotkin 1994). In Ghana, a majority of *L. olivacea* nesting occurred in third quarter, which could be due to less light because of waning moon, and thus to avoid predators (Witt 2013). Another possible advantage of nesting during waning moon was greater prey availability post-nesting (Pinou et al. 2009) because *L. olivacea* feed primarily on crabs, which are nocturnal (Shaver & Wibbels 2007).

Nesting period and rainfall

In Gahirmatha, rainfall (≥3.2mm) in February 2020 delayed mass nesting of *L. olivacea* from February to first week of March 2020. High sand moisture content due to rainfall is indicated as a reason for reduced hatching success in the nest chamber (Packard et al. 1977). In the eastern Pacific Coast, *L. olivacea* individuals delayed nesting during extreme rainfall (>50 cm) (Plotkin et al. 1997), but not during normal precipitation levels (9cm) (Coria-Monter & Duran-Campos 2017) because arribadas coincided with rainy seasons in the eastern Pacific (Cornelius 1986). Whereas in Gahirmatha, even modest rainfall (3.2mm) delayed the mass nesting, because nesting occurred in dry periods in Odisha (Dash & Kar 1990). Since the nesting season of *L. olivacea* ended in March (Behera et al. 2010), there was no further delay in nesting beyond second week of March 2020 despite rainfall in the first week.

Sporadic nesting

Sporadic nesting of *L. olivacea* occurred almost every month along the Odisha coast, but more frequently between February and April (Dash & Kar 1990). Sporadic nesting occurred mainly between December and May

Image 1. Nesting ground for arribada of Olive Ridley turtles: a—arribada in the early morning (05.00h) | b—a female clearing the surface sand for nesting | c—a female turtle in oviposition (laying eggs) | d—hatchlings emerging from the emergence crater | e—emergence craters on the sand surface | f—an individual *L. olivacea* hatchling | g—hatchlings moving towards the sea | h—hatchlings entering the sea. © Poornima P.

along the eastern coast of India (Pandav & Choudhary 2000). During the study period in Gahirmatha, sporadic nesting was noted mainly between December and May. Between December and February, an average of 15 *L. olivacea* individuals nested sporadically. The numbers increased to 40 per day for a week prior to and after mass nesting (14–20 March). In Gahirmatha, more than 10 turtles arrived for sporadic nesting per night (Tripathy 2008). Our observations in Gahirmatha match with those of Tripathy (2008) till April 2020 but the numbers of turtles nesting sporadically in May 2020 was, on an average, only three per night.

Hatchling emergence

Mrosovsky (1968) and Witherington et al. (1990) observed that the emergence of *L. olivacea* hatchlings onto the sand surface was predominantly nocturnal. The hatchlings emerged only after sunset and before sunrise, in Gahirmatha as well. After synchronous hatching from the nests, hatchlings exhibited group-digging behaviour to reach the sand surface (Hendrickson 1958; Carr & Hirth 1961). At Gahirmatha, this behaviour was prevalent in all the nests observed. Final emergence by hatchlings on to the sand surface created emergence craters (Bishop et al. 2011) due to collapse of the cavity in which hatchlings were present (Salmon & Reising 2014). Also, the hatchlings emerged in cohorts of 1–4 from a single nest, over a period of 4–8 days, with the first cohort having maximum number of hatchlings (Rusli et al. 2016). At Gahirmatha, every time a cohort of hatchlings from a nest emerged, an emergence crater formed on the surface, which lasted 7–10 days before being either eroded or filled up with sand by wind.

The minimum and maximum number of hatchlings from individual craters (per cohort) were 18 and 182, respectively, with an average of 92.1 hatchlings. These numbers represent the emergence per cohort. Therefore, the maximum egg count per nest (clutch size) found in Gahirmatha was ≥182 considering the mortality in the nest and mortality during emergence. Whereas, Kumar et al. (2013) observed maximum egg counts of 168. The craters were mostly circular (93.3%) and occasionally elliptical (6.7%). Their diameters varied between 10cm and 26cm. There was a low but positive correlation (0.38) between numbers of hatchlings per crater and respective crater diameter, as per Pearson's correlation.

Movement of hatchlings towards sea

After emergence hatchlings typically move towards negative slope gradient (Limpus 1971), which was observed in Gahirmatha. Hatchlings also typically exhibit positive phototaxy, leading them to move towards the sea since moon light is reflected more by water than land (Carr & Ogren 1960; Mrosovsky & Shettleworth 1968). These findings also match with observations in Gahirmatha. The minimum time taken by hatchlings to move one metre was 11 sec, whereas the maximum time was 2 min 4 sec. The average time taken by hatchlings to move one metre was 33 sec (SD= ±15 sec). This is less than the time taken by *L. olivacea* in Costa Rica, 52.4 sec (Burger & Gochfield 2014) and Indonesia, 36–48 sec (Maulaney et al. 2012). Of 280 hatchlings, 62.5 % took 20–40 sec to move one metre. Considering the total time taken to reach the sea, minimum and maximum time taken was 6 min 12 sec and 35 min 9 sec, respectively. The average time taken by hatchlings in Gahirmatha to reach the sea was 17 min 22 sec (SD= ± 5 min 30 sec) for a mean distance of 34.55m, whereas it was 19 min 12 sec for a mean distance of 27.7m in Ostional Beach, Costa Rica (Burger & Gochfield 2014).

CONCLUSION

The sandy beaches of Dr. Abdul Kalam Island in Gahirmatha Wildlife Sanctuary, even though geographically small in area, continue to be one of the most important nesting site for *L. olivacea* population in the world. Adequate measures are undertaken every year by Odisha Forest and Wildlife Department to ensure protection of *L. olivacea* along the Odisha coast. Further, study of environmental factors such as rainfall, lunar phase, temperature and winds on mass nesting in Odisha in general and Gahirmatha in particular, would further enhance our understanding of *L. olivacea*'s intricate nesting and hatching behaviour.

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COMMUNICATION

Feeding ecology of Walia Ibex *Capra walie* (Mammalia: Artiodactyla: Bovidae) in Simien Mountains National Park, Ethiopia

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Abstract: Walia Ibex *Capra walie* is an endemic and endangered species residing in Simien Mountains National Park, Ethiopia. It has shifted its range within the Park in the last decade, and in this study our main objective was to provide information on their feeding ecology to inform recovery goals. We used a scan sampling method to collect foraging information during October 2009 to November 2011. Our observations suggest a diverse diet of more than 28 species of grasses, forbs, and shrubs. The most commonly used plants were *Festuca* sp., *Lobelia rhynchopetalum, Helichrysum citrispinum*, and *Helichrysum horridum*. Walia Ibex were active in feeding before and after mid-day, and time spent feeding was the highest compared with other diurnal activities. The percentage of time spent feeding on major plant species did not differ between wet and dry seasons (p> 0.05). Walia Ibex, however, tended to spend more time browsing than grazing. The generalist nature of foraging behaviour in Walia Ibex most likely contributes to complaints from the local people who witness Walia Ibex raiding crops cultivated in and around the Park. Thus, the contribution of crop raiding to the shifts in the species' range towards higher altitudes at Sebatminch within Simien Mountains National Park emphasizes the need to consider foraging ecology as community-based conservation efforts are developed to support Walia Ibex in the Park.

Keywords: Endemic, *Festuca* sp., *Lobelia rhynchopetalum,* scan sampling.

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Author contribution: DE involved in research proposal preparation, design of the research, data collection, data organization, data analysis, and write up of the manuscript. AB participated in design of the research, supervision of data collection, data analysis, and manuscript preparation. LP contributed in data analysis, location map preparation, and manuscript preparation.

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INTRODUCTION

Walia Ibex (*Capra walie* Ruüppell, 1835) is an endemic and endangered species (Gebremedhin et al. 2009; IUCN 2021) confined to Simien Mountains National Park, Ethiopia. The fascinating behaviour of this species of wild goat and its physical stature has led it to be used as a flagship species for Ethiopia. Walia Ibex is the only ibex species in Ethiopia (Nievergelt 1981; Last 1982; Haltenorth & Diller 1993), and is believed to have dispersed from the Middle East 26,000 to 14,000 years ago (Nievergelt 1981). Biologists have classified Walia Ibex as a generalist herbivore, as it obtains food through grazing and browsing, and the species is known to forage on grasses, herbs, shrubs, bushes, creepers, and lichens (Massicot 2001). Such mixed feeding behaviour is also observed in other ibex species such as the Iberian Ibex *Capra pyrenaica* (Accevedo & Cassinello 2009).

One of the current threats to walia ibex is conflict with livestock within Simien Mountains National Park. Livestock grazing in shared habitats may cause lower survival for offspring and therefore lower population growth (Namgail 2006). The problem of overgrazing of wildlife habitats is especially critical for female wildlife species using lower quality habitat areas, especially during the early lactation period (Ruttiman et al. 2008).

Indeed, the presence of livestock in the Iberian ibex habitat has a negative effect on its relative abundance and distribution, causing ibex to select poor habitats (Pelayo et al. 2007). Large areas of suitable habitats in Simien Mountains National Park have been abandoned as Walia Ibex retreated to the most inaccessible and steepest parts of the park (Hurni & Ludi 2000; Ejigu et al. 2015). The shift in range has occurred because the original Walia Ibex habitats have been modified by intensive human activities for various uses. Generally, ibexes prefer areas with steep slope and cliffs and avoid grasslands and flat hillsides (Feng et al. 2007); these realized preferences can be observed in Simien Mountains National Park, where the original habitats of Walia Ibex, especially in the central region of the park near Gich (Figure 1), have been occupied by livestock. As a result, the Walia Ibex population is now restricted to relatively inaccessible habitats within gorges and escarpments towards the eastern and southeastern parts of the Park (Hurni & Ludi 2000; Ejigu et al. 2015).

Although the range shift of Walia Ibex has been observed (Ejigu et al. 2015), biologists lack information on foraging and the feeding ecology to determine if the range shifts have pushed ibex into regions that are not able to provide resources to sustain the population in the future. Recovery goals and conservation planning require information on foraging and diet. Thus, the main objective of this research was to study feeding ecology of walia to determine the level of specificity of diet and to identify the major plant species consumed by the species to design appropriate conservation measures.

MATERIALS AND METHODS

Description of the study area

The study was carried out in Simien Mountains National Park (SMNP), which is located in the Amhara National Regional State of Ethiopia in the North Gondar Administrative Zone (37.857–38.491 ^{0}E & 13.112–13.386 ^{0}N), about 865km north of Addis Ababa and 132km north-east of Gondar Town. The foraging study was part of a larger assessment of the habitat selection and range shift of the species (Ejigu et al. 2015).

SMNP includes broad undulating plateaux and the highest mountain of Ethiopia, Ras Dejen (4,620m), which is also the fourth highest mountain in Africa (Puff & Nemomissa 2001, 2005). It is an area of high summits with unique land features in the Horn of Africa. The mountains symbolize an area of the extreme Ethiopian highlands (Hurni & Ludi 2000). Prior to the 1960s, the area had been used as a controlled hunting area, and was regarded as a royal hunting ground (Falch & Keiner 2000). During its establishment, SMNP was the smallest park in the country with an area of only 136km^2 (Hurni & Ludi 2000) but has been enlarged to 412km^2 (Anonymous 2009) (Fig. 1).

The main rainy season in SMNP lasts from the end of June to September, while the dry season encompasses December to April. Rainfall shows significant variation across different altitudes with a maximum at about 3,500m (Puff & Nemomissa 2005). Thus, annual rainfall in Simien Mountains varies from 1,000mm in the lowlands to 1,500mm in the highlands (Hurni & Ludi 2000). Meteorological data obtained from National Meteorological Agency shows that the 10-year (2000–2009) mean annual rainfall of SMNP was 1,054mm.

Ground frost commonly occurs at night during the dry season, especially in February and April. The area shows variation in mean annual minimum and maximum temperatures. As described by Hurni (1982), the mean annual temperature at Gich is 7.7^{o}C, which is often accompanied by dry winds during the daytime. At night, however, the area experiences temperature variations ranging from +2^{o}C to -10^{o}C. The 10-year (2000–2009) mean annual minimum and maximum temperature data were 8.6^{o}C and 19.9^{o}C, respectively. Despite fluctuations in daily temperatures, seasonal variations in temperature

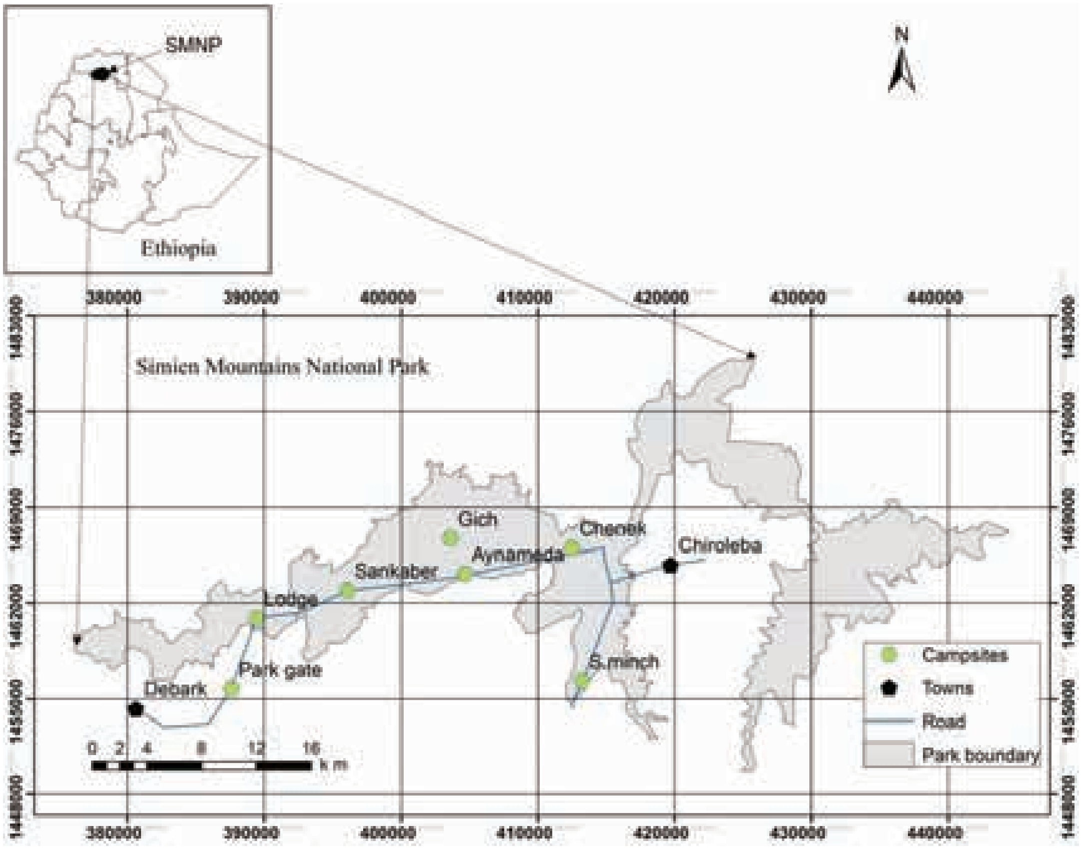

Figure 1. Simien Mountains National Park (SMNP) within Ethiopia (inset).

are minimal due to Ethiopia's proximity to the equator (Nievergelt, 1990). As a result, variations in diurnal temperature far exceed seasonal ones.

According to Puff & Nemomissa (2001), approximately 550 taxa of flowering plants grouped into over 95 families and 319 genera are known from Simien Mountains. Habitat types mainly consist of a mixture of Afro-alpine woods, heath forest, high mountain vegetation, montane savannah and montane moorland (Hurni & Ludi 2000). Common species include *Erica arborea*, *Lobelia rhynchopetalum*, *Hypericum revolutum*, *Rosa abyssinica, Helichrysum* sp., and *Solanum* sp. (Anonymous 2009).

With its unique landscape and magnificent scenery, the Park supports some of Ethiopia's most important endemic mammals in addition to the Walia Ibex, such as the Ethiopian Wolf *Canis simensis* and the Gelada Baboon *Theropithecus gelada*. Thus, the unique flora and fauna and its remarkable landscape make the Park a natural priority for conservation and centre of endemism in eastern Africa (Hurni & Ludi 2000).

At least 20 large and 14 small mammal species reside in the Park (UNESCO 2001). Large herbivores including Menelik's Bushbuck *Tragelaphus scriptus meneliki*, Grimm's Duiker *Sylvicapra grimmia*, Klipspringer *Oreotragus oreotragus* occur commonly in the park and are considered to be wild competetors with Walia Ibex (Anonymous 2009).

Field methods

Data on feeding ecology in Walia Ibex were collected for 15 days every other month from October 2009 to November 2011, including both the wet and dry seasons (Images 1–6). Dietary data for a herd of ibex were collected using the scan sampling method (Pellew 1984) with binoculars or telescope within five-minute intervals (Altman 1974), and individuals from the herd were selected randomly to start scanning (Wallace 2006). We observed each individual for 10 seconds to determine the species of plant eaten, and we observed a different animal until all animals in the herd had been sampled, following Toit & Yetman (2005). Each scan of the herd took approximately five minutes to complete, and each individual was observed from five to ten seconds after being detected.

Our sampling was designed to match the foraging patterns of Walia Ibex. *Capra* species, like other large

Image 1. Herb of Walia Ibex in open habitat of Simien Mountains National Park, Ethiopia.

Image 2. Herb of Walia Ibex in rocky habitat of Simien Mountains National Park, Ethiopia.

Image 3. Adults of Walia Ibex at the cliffs of Simien Mountains National Park, Ethiopia.

Image 4. Walia and Geladas living together in their common habitat.

Image 5. Ice formed at the mount tips of Simien during data collection period.

Image 6. Data collection by the researcher using binoculars.

herbivores, show a diurnal activity pattern of two distinct peaks of feeding and moving (Hess 2002). Thus, Walia Ibex is crepuscular, active for feeding and moving early in the morning and late in the afternoon, and resting on rocks and cliffs during the mid-day. At noon, they become inactive and tend to remain in the shade to protect themselves from hot sun and predators (Dunbar 1978; Ejigu et al. 2020). Therefore, herds were located early in the morning and followed until late in the afternoon to identify their important food sources.

The scan sampling method involves observing the individual for a five-minute session broken in the following way; observe on the focal animal for 10 seconds, mark its location, then the next focal animal for 10 seconds and so on for the entire herd. We collected the following information during scan sampling: date, time, location, age, and sex of the animal (Ruckstuhl 1998; Namgail 2006). We also identified and recorded the plant species on which Walia Ibex foraged, and we validated our observations with samples collected and identified after the herd had moved from the sampling location as adopted from Kaplin & Moermond (2000) and Gad & Shyama (2009). Due to difficulties in identification at a distance, we lumped related grass species together (Dankwa-Wiredu & Euler 2002). We quantified the time spent feeding on different plant species to calculate the proportion of time spent on each plant. Diet selection was determined from the relative proportions of the number of scans spent feeding on different plant species. We collected and pressed plants that could not be identified in the field and took to the National Herbarium, Addis Ababa University, for identification using the herbarium samples.

Analysis methods

We described the time spent foraging on different plants with proportions, and we used Chi-square tests to evaluate differences in time spent foraging on species among age and sex classes of Walia Ibex. Statistical tests were two-tailed (α = 0.05), and the data were analysed using SPSS software version 16.0 (SPSS Inc. Chicago).

RESULTS

A total of 7,387 feeding bouts were recorded during scan sampling of Walia Ibex. Our samples were evenly divided between the wet season (50.5% of bouts, n= 3,728) and the dry season (49.5%, n= 3,659). When time spent feeding on the four major food plants species was compared, Walia Ibex spent more time foraging on *Festuca* sp. during the wet season (37.2% of bouts, n= 1,387) than in the dry season (22.2%, n= 813; c^2= 3.81, *p*= 0.051). Moreover, the percentage of time spent foraging on three other main plant species did not differ between seasons (*Lobelia rhynchopetalum*, wet: 20.3%, n= 757, dry: 17.8%, n= 651, *p*= 0.423; *Helichrysum citrispinum*, wet: 17.1%, n= 638, dry: 22.3%, n= 815, *p*= 0.746; *Helichrysum horridum*, wet: 10.3%, n= 383, dry: 19.3%, n= 705, *p*= 0.095).

Although 70–80 % of their diet was from the four main plant species (*Festuca* sp., *Lobelia rhynchopetalum*, *Helichrysum citrispinum* and *Helichrysum horridum)*, Walia Ibexes were observed foraging on more than 23 and 28 plant species during the wet and dry seasons, respectively (Tables 1, 2).

Walia Ibex spent 38.0% (1416) and 22.9% (836) of time feeding on grasses, 9.6% (357) and 12.2% (446) on herbs, 48.2% (1795) and 60.4% (2210) on shrubs and 3.7% (137) and 4.1% (148) on trees during the wet and dry seasons, respectively (Fig. 2). As foraging patterns did not change between wet and dry seasons (*p*> 0.05), Walia Ibex foraging behaviour reflected that of a generalized herbivore. During the wet season, Walia Ibex spend similar time browsing and grazing, but it spent more time browsing than grazing during the dry season (c^2= 8.49, *p*< 0.05).

Adult females spent 41.7% (wet season) and 22.7% (dry season) of feeding time foraging on grasses, 27.6% & 14.7% on herbs, 24.6% & 56.6% on shrubs, and 4.7% & 3.9% on trees. Adult males spent 23.9% & 22.8% of feeding time foraging on grasses, 25.6% & 7.1% on herbs, 42.3% & 65.2% on shrubs, and 4.7% & 3.5% on trees during the wet and dry seasons, respectively. In sub-adults, yearlings and kids time spent feeding on different plants during the wet and dry seasons is also as presented in figures (Figs. 3, 4) below. Time spent feeding on grasses between the wet and dry seasons showed significant differences only in sub-adult males (c^2= 9.60, df= 1, *p*< 0.05) and kids (c^2= 8.45, df= 1, *p*< 0.05). Time spent feeding on herbs between the wet and the dry seasons showed significant differences only in adult females (c^2= 3.93, df= 1, *p*< 0.05) and in sub-adult females (c^2= 4.26, df= 1, *p*< 0.05), while time spent feeding on shrubs and trees in all age classes of Walia Ibex indicated that they fed more on shrubs and trees during the dry season than the wet season, and the difference was statistically significant (*p*< 0.01).

Feeding activities of Walia Ibex declined shortly during 08.00–10.00 h and increased after 10.00h during the wet season. Feeding reached its peak at around 11.00h and declined slowly during 11.00–13.00 h, and increased again and reached a maximum at 17.00h. During the dry season, feeding activity decreased during 08.00–11.00 h and increased during 11.00–15.00 h, and then increased sharply up to 17.00h. In the evening, however, it declined

Table 1. Plants foraged by Walia Ibex during the wet season.

	Scientific name	Family	Local name	Habit	feeding bouts	%
1	*Festuca* sp.	Poaceae	guassa	grass	1387	37.20
2	*Lobelia rhynchopetalum*	Campanulaceae	Jibra	shrub	757	20.31
3	*Helichrysum citrispinum*	Asteraceae	Yewaliashoh	shrub	638	17.11
4	*Helichrysum horridum*	Asteraceae	Tifrgina	shrub	383	10.27
5	*Thymus schymperi*	Lamiaceae	Tosign	herb	121	3.25
6	*Alchemilla pedata*	Rosaceae	Yayet joro	herb	109	2.92
7	*Erica arborea*	Ericaceae	wuchena	tree	101	2.71
8	*Mosses* & *liver*	Grimmiaceae	Yemeret shibet	herb	60	1.61
9	*Usnea* sp.	Usneaceae	Yezaf shibet	herb	42	1.13
10	*Hypericum revolutum*	Hypericae	Amja	tree	36	0.97
11	*Carex erythrorhiza*	Cyperaceae	Shefshefo	grass	24	0.64
12	Unidentified	Unidentified	Unidentified	grass	23	0.62
13	Unidentified	Unidentified	Yemidir wuchena	herb	15	0.40
14	*Spermacoce sphaerostigma*	Rubiaceae	Kesign	shrub	07	0.19
15	*Globsis* sp.	Unidentified	Unidentified	shrub	05	0.13
16	Unidentified	Unidentified	Key sar	grass	05	0.13
17	*Simenia acaulis*	Gentianaceae	Yebahir teza	herb	04	0.11
18	*Urtica simensis*	Urticaceae	sama	herb	03	0.08
19	*Clematis simensis*	Ranunculaceae	Azoareg	shrub	03	0.08
20	*Phagnalon phagnaloides*	Asteraceae	Sinbita	herb	02	0.05
21	*D. chrysanthommifilia*	Asteraceae	yewesferas	herb	01	0.03
22	*Dryopteris inaequalis*	Dryopteridaceae	yejibchama	shrub	01	0.03
23	*Solanum indicum*	Solanaceae	Embuay	shrub	01	0.03
	Total				3,728	100

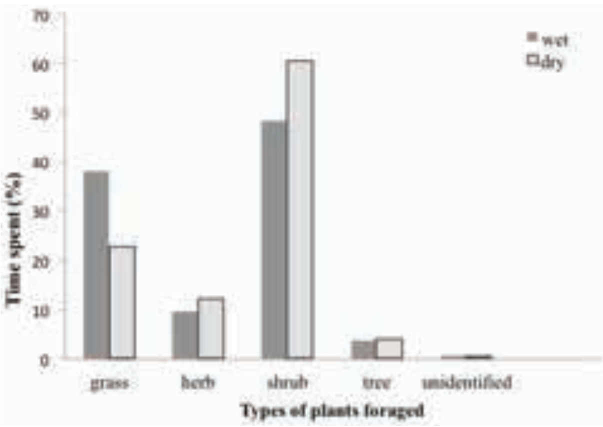

Figure 2. Percentage of time spent foraging by Walia Ibex in Simien Mountains National Park in Ethiopia during the wet and dry seasons, October 2009 to November 2011.

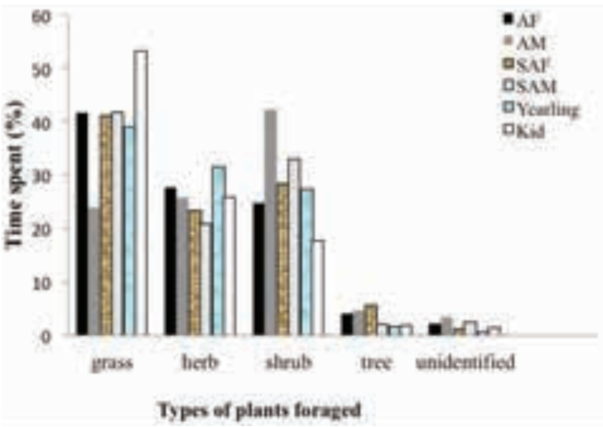

Figure 3. Percentage of time foraging by different age and sex classes of Walia Ibex in Simien Mountains National Park in Ethiopia during the wet seasons, October 2009 to November 2011. AM—Adult Males | AF—Adult Females | SAM—Sub-adult Males | SAF—Sub-adult Females.

both during the wet and dry seasons (Fig. 5). Nevertheless, feeding activity between the wet and dry seasons did not show significant difference (c^2= 0.01, df= 1, *p*> 0.05).

A total of 18, 236 diurnal activities of Walia Ibex were recorded during the entire study period. Our sampling was evenly distributed between the wet season (51.6%, n= 9,407) and the dry season (48.4%, n= 8,829). Feeding comprised 40.5% (7,387), moving 17.9% (3,261), standing 10.1% (1,849), resting 23.5% (4,281), vigilance 1.6% (289),

Table 2. Plants foraged by Walia Ibex during the dry season.

	Scientific name	Family	Local name	Habit	feeding bouts	%
1	*Helichrysum citrispinum*	Asteraceae	Yewaliashoh	shrub	815	22.27
2	*Festuca* sp.	Poaceae	Guassa	grass	813	22.22
3	*Helichrysum horridum*	Asteraceae	Tifrgina	shrub	705	19.27
4	*Lobelia rhynchopetalum*	Campanulaceae	Jibra	shrub	651	17.79
5	*Alchemilla pedata*	Rosaceae	Yayet joro	herb	220	6.01
6	*Erica arborea*	Ericaceae	Wuchena	tree	96	2.62
7	*Usnea* sp.	Usneaceae	Yezaf shibet	herb	84	2.29
8	*Thymus schymperi*	Lamiaceae	Tosign	herb	63	1.72
9	*Mosses &liver*	Grimmiaceae	Shibet	herb	57	1.56
10	*Hypericum revolutum*	Hypericeae	Amja	tree	50	1.37
11	*Carex erythrorhiza*	Cyperaceae	Shefshefo	grass	23	0.63
12	Unidentified	Unidentified	Unidentified	Unidentified	19	0.52
13	*Dryopteris inaequalis*	Dryopteridaceae	Yejibchama	shrub	13	0.35
14	*Solanum indicum*	Solanaceae	Embuay	shrub	09	0.25
15	*Kniphofia foliosa*	Asphodalaceae	Dudya	herb	06	0.16
16	*Spermacoce sphaerostigma*	Rubiaceae	Kesign	shrub	6	0.16
17	*Carduus macracanthus*	Astraceae	Kosheshile	herb	05	0.14
18	Globsis	Unidentified	Unidentified	shrub	05	0.14
19	*Siminia acaulis*	Gentianaceae	Yebahir teza	herb	03	0.08
20	*Helichrysum* sp.	Asteraceae	Unidentified	shrub	03	0.08
21	*Clematis simensis*	Ranunculaceae	Azoareg	shrub	03	0.08
22	*Urtica simensis*	Urticaceae	Sama	herb	03	0.08
23	*Phagnalon phagnaloides*	Asteraceae	Sinbita	herb	02	0.06
24	*Denbia torida*	Unidentified	Wulkfa	tree	01	0.03
25	*Acanthus ebracteatus*	Acanthaceae	Unidentified	herb	01	0.03
26	*H. splendidum*	Asteraceae	Fotena	herb	01	0.03
27	*Olea europaea*	Oleaceae	Weyera	tree	01	0.03
28	Unidentified	Unidentified	Yemidir wuchena	herb	01	0.03
	Total				3,659	100

social activity 2.1% (379), rutting 2.3% (414), and other activities 2.1% (376).

DISCUSSION

Walia Ibexes were observed while foraging on more than 28 species of plants grouped as grasses, forbs, and bushes & shrubs. The most commonly foraged plants both during the wet and dry seasons were *Festuca* sp., *Lobelia rhynchopetalum*, *Helichrysum citrispinum*, and *Helichrysum horridum*. Percentage of time spent feeding on major plant species between the wet and dry seasons did not show significant differences.

Walia Ibex tended to spend more of their time browsing than grazing. As a general herbivore, Walia Ibexes can graze and browse available forage to maximize their nutrient requirements. In the afro-alpine ecosystem of SMNP, the availability of above ground vegetation that has been browsed by Walia Ibex decreases as the altitude increases, and Walia Ibex must feed on grass at the higher altitudes. Such ability to shift in diet has allowed the Walia Ibex to respond to the loss of forage at lower altitudes after livestock grazing. During the dry season, however, as the grass becomes less palatable, the food habits of Walia Ibex mainly depended on scarcely available shrubs. Thus, they also tended to browse more during the dry season than the wet season. Our findings were similar to that reported by Dunbar (1978).

All age classes of Walia Ibex tended to spend more

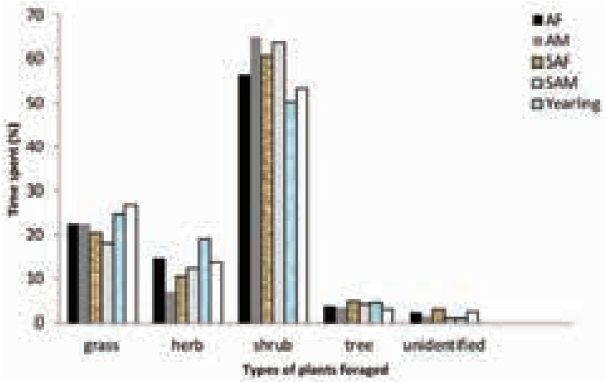

Figure 4. Percentage of time foraging by different age and sex classes of Walia Ibex in Simien Mountains National Park in Ethiopia during the dry seasons, October 2009 to November 2011. AM—Adult Males | AF—Adult Females | SAM—Sub-adult Males | SAF—Sub-adult Females.

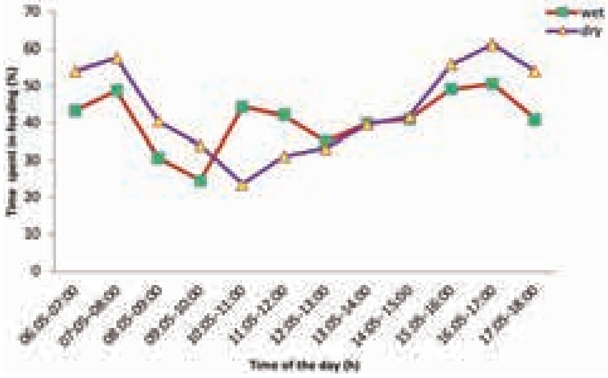

Figure 5. Duirnal feeding activity pattern of Walia Ibex in Simien Mountains National Park in Ethiopia during the wet and dry seasons, October 2009 to November 2011.

time foraging on grasses during the wet season than the dry season. Kids prefer fresh grass, and they spent more time foraging on grasses than other types of plants. Fresh and more palatable grass is present during the wet season, and kids responded to grass availability. In similar fashion, adult and sub-adult females spent more time feeding on herbs during the wet season, because of the availability of herbs during this season. All age classes of walia ibex shifted to spend more time feeding on shrubs and trees during the dry season when herbs and grasses were less available. The ability of Walia Ibex to shift to browsing during the dry season allows them to utilize essential nutrients required for their survival.

Percentage of time spent feeding in walia ibex was the highest (40.5%) and vigilance the lowest (1.6%) behaviour compared with time spent for its other diurnal activity patterns. This result is consistent with previous results conducted on foraging ecology of feral goats (Stronge et al. 1997). Although intense human and livestock disturbances are common in habitats of walia ibex, they appear to have adapted to human and livestock presence. Such low levels of vigilance also suggest a low level of predators and poaching in our study area.

Feeding behaviour in other *Capra* species was bimodal, with higher foraging activity rates detected in the earliest and latest hours of the day (Dunbar 1978; Hess 2002; Accevedo & Cassinello 2009). Time spent feeding in walia ibex was higher after 10.00h and declined in the mid-day. It increased gradually and reached its peak late in the afternoon, and then declined again in the evening. All age classes of ibex spent the majority of their time feeding in both seasons. The similar proportions of time spent feeding in wet and dry seasons are not unexpected in areas where there is minimal variation in temperatures between seasons (Nievergelt 1981, 1990). An increase in feeding time with decreasing food availability during the dry season, however, has been observed for several African grazers (Own-Smith 1982).

Adult Walia Ibex females tended to spend more time feeding than adult males, which is also true in feral goats (Stronge et al. 1997) and bighorn sheep (Ruckstuhl 1998). In ungulates, males require lower diet and habitat quality than females (Mysterud 2000). Moreover, females would be expected to select habitats that provide forage to maximize the ability to raise young because nutrition can limit reproductive success (Mysterud 2000; Ruckstuhl & Neuhaus 2002; Accevedo & Cassinello 2009). Differences in diet are more pronounced in dimorphic ungulates (Stronge et al. 1997). In Alpine Ibex, for example, adult males spent only 8.5% of the time feeding and it is likely that they compensate such reduced feeding times by foraging at night (Neuhaus & Ruckstuhl 2002). At our study site, a similar scenario has been reported for male Walia Ibex that raid crops at night. Time spent feeding in sub-adult females and sub-adult males was higher compared to both adult females and adult males as additional energy is required in these age classes for their active growth and development. As yearlings and kids are at the active stage of growth, more energy should be required for various metabolic activities. Thus, they try to spend more time feeding than time spent for other diurnal activities.

In conclusion, the generalist approach to foraging may be a key factor in the plasticity of Walia Ibex to adapt to anthropogenic disturbances in the Park. Indeed, their populations appear to be growing during the past decade (Ejigu 2013; Ejigu et al. 2013). The recovery of Walia Ibex could be augmented in SMNP through management programs designed to improve foraging habitats. The use of prescribed fire or grass cutting by local residents would initiate the growth of fresh grass used as forage by

Walia Ibex and other herbivore wildlife species of the park. Certainly, avoiding livestock gazing in the park would allow Walia Ibex to have access to more feed and fodder. If food availability in the park was sufficient, walia ibex would most likely stay within the park, which would reduce conflict from crop raiding. Such prohibition of grazing within the park will take careful work with local residents who consider the park to be a resource for their livelihood. The results obtained from feeding ecology of Walia Ibex serve to guide and design appropriate conservation planning for this critical species in Simien Mountains National Park.

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COMMUNICATION

Assessment of crop and property damage caused by *Semnopithecus vetulus nestor* (Bennett, 1833) (Mammalia: Primates: Cercopithecidae) in Gampaha District, Sri Lanka

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Abstract: In earlier times, human-monkey interactions were not a severe problem in Sri Lanka, but has recently intensified as a result of habitat fragmentation and urbanization. Due to these changes, *Semnopithecus vetulus nestor* has been listed among the 25 most Endangered primates. The objective of our study was to evaluate the intensity of human-*S.v. nestor* negative interaction by identifying the crop and property damages in villages bordering Danawkanda Forest (7.001N & 80.049E), Gampaha, Sri Lanka. We collected data using structured questionnaires interviewing households (N= 80) bordering the Danawkanda Forest from August 2014 to January 2015. Households were most affected by damage to fruits, leaves, and buds of commercially important trees (93%), followed by damage to roof tiles (76%), and frightful confrontations with the monkeys (43%). Average monthly loss per household from crop and property damage was estimated at between (Sri Lankan Rupees) LKR 2,700 and LKR 1,500. Lighting firecrackers was the most common method used by the residents (99%) to deter monkeys, where as electrified barriers were rarely used (4%). Households in close proximity to Danawkanda Forest experienced a considerable loss to their monthly income due to crop and property damage, compared to households further away. As an alternative, residents now grow ornamental plants and short trees, eliminating the structures that attract and facilitate damage by *S.v. nestor*. Awareness and active participation of residents, authorized government, and non-governmental organizations are needed to manage unplanned construction and agriculture plot extensions into the forest. These two factors trigger the human-wildlife negative interactions in general and are not limited just to monkeys.

Keywords: Danawkanda Forest, deterrent methods, human-primate conflict, human-primate negative interactions, Western Purple-faced Leaf Monkey.

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Author contribution: Sunil Wijethilaka did the field work, Lakshani Weerasekara & Kithsiri Ranawana prepared the manuscript, and Saumya Bandara did the statistical analysis.

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INTRODUCTION

Crop raiding by animals is a concern for small-scale subsistence farmers (Garriga 2014) in countries around the world like Sri Lanka, where nearly 28.5% of the population depends on agriculture (CBSL 2014). Different animal species cause different problems for farmers when they raid crops (Hill 2005). Not only parasitic invertebrates but also vertebrates like birds (Bruggers et al. 1998; Maurice et al. 2019), rodents (Lathiya et al. 2003; Sarwar 2015), Mouse Deer (Linkie et al. 2007), porcupine (Linkie et al. 2007), Wild Boar (Shafi & Khokhar 1986; Gobosho et al. 2015), Elephants (Sukumar 1990; Barnes 1996; Hill 1998; Chiyo et al. 2012) and non-human primates (Boulton et al. 1996; Pirta et al. 1997; Hill 2000; Dittus et al. 2019) are considered as crop raiding pests responsible for human-wildlife negative interactions. Non-human primates are often considered to be the most destructive crop raiders in many parts of the world (Naughton-Treves et al. 1998; Hill 2000; McLennan 2008; Hill & Wallace 2012; Hockings et al. 2012; Cabral et al. 2018). Members of the genera *Macaca*, *Papio*, and *Cercopithecus* are amongst the most frequently cited non-human primate pest species (Hill 2005). The presence of an organized social hierarchy, co-operative behavior, communication skills, combined with intelligence, dietary and behavioral flexibility, manual dexterity, and extreme agility make these primate species particularly difficult for farmers to prevent from damaging crops (Hill 2005).

The human-monkey interaction in Sri Lanka was not a severe problem in the past, but has intensified in recent decades due to agricultural, irrigational, & industrial projects, increased urban expansion, and fragmentation of natural forested areas due to an increase in the human population (Wickramagamage 1998; Rudran 2007; Marasinghe & Nathaniel 2020). Forest fragmentation in the wet and dry zones is a primary cause of rapid and widespread invasion of primates into farms and agricultural lands in search of alternative food resources (Nahallage & Huffman 2008). As a result, conflicts have intensified. These human-wildlife conflicts affect the survival of many endangered commensal species (Garriga 2014) like *Semnopithecus vetulus nestor*, as well as undermine the local human population's food security and tolerance for wildlife.

S.v. nestor (Bennett 1833) has been listed among the 25 most endangered primates of the world (Schwitzer et al. 2017) due to encroachment into their habitat by unplanned urbanization. Urbanization severely threatens the long-term survival of this endemic species (Molur et al. 2003; Rudran et al. 2009; Mittermeier et al. 2012). While studies on its behaviour and ecology have been comprehensively addressed, reports on human - *S.v. nestor* conflicts are scarce (Molur et al. 2003; Dela 2004, 2007, 2012; Rudran 2007; Mittermeier et al. 2009, 2012; Rudran et al. 2013). Thus, the objective of our study was to evaluate the intensity of human-monkey conflict by identifying the crop and property damages caused by *S.v. nestor*, and to quantify the loss incurred to the households caused by them in villages bordering Danawkanda Forest, Gampaha District in the Western Province of Sri Lanka.

METHODS

Study site

Danawkanda Forest (7.001N & 80.049E) is a secondary wet zone forest encompassing an area of 360ha, located in Gampaha District, Sri Lanka. The forest patch is surrounded by many adjacent villages. Twelve villages bordering Danawkanda Forest were randomly assessed during the study in Mahara Divisional Secretariat (Image 1). Danawkanda Hill is considered a historical land mark in the region, and contains a Buddhist monastery where people interact with the forest. The main habitat type in the study area was village home gardens dominated by the tall fruit tree species *Artocarpus heterophyllus* (Jak) (86%), *Mangifera indica* (Mango) (86%), *Cocos nucifera* (Coconut) (71%), and *Areca catechu* (Arecanut) (34%). The dominant medium-size fruit tree species were *Nephelium lappaceum* (Rambutan) (59%), *Carica papaya* (Papaw) (48%), *Musa paradisiaca* (Banana) (34%), and *Psidium guajava* (Guava) (20%).

Study subject

Semnopithecus vetulus is the only endemic colobine monkey species in Sri Lanka representing four subspecies; namely *S.v. philbricki* (Northern Purple-faced Leaf Monkey), *S.v. vetulus* (Southern Purple-faced Leaf Monkey), *S.v. monticola* (Bear Monkey), and *S.v. nestor* (Western Purple-faced Leaf Monkey) (Rudran et al. 2020). Of which *S.v. nestor* is the smallest subspecies in body size (Dela 2007) (Image 2). Its range extends across the western lowlands of Sri Lanka, in an area of high human population density, very low forest cover (Dela 2012), extensive human settlements, and agricultural activity (Dela 2007).

Survey

A pilot survey was carried out in July 2014 to identify the families that experience *S.v. nestor* raids. Structured questionnaires (N= 80) were then carried

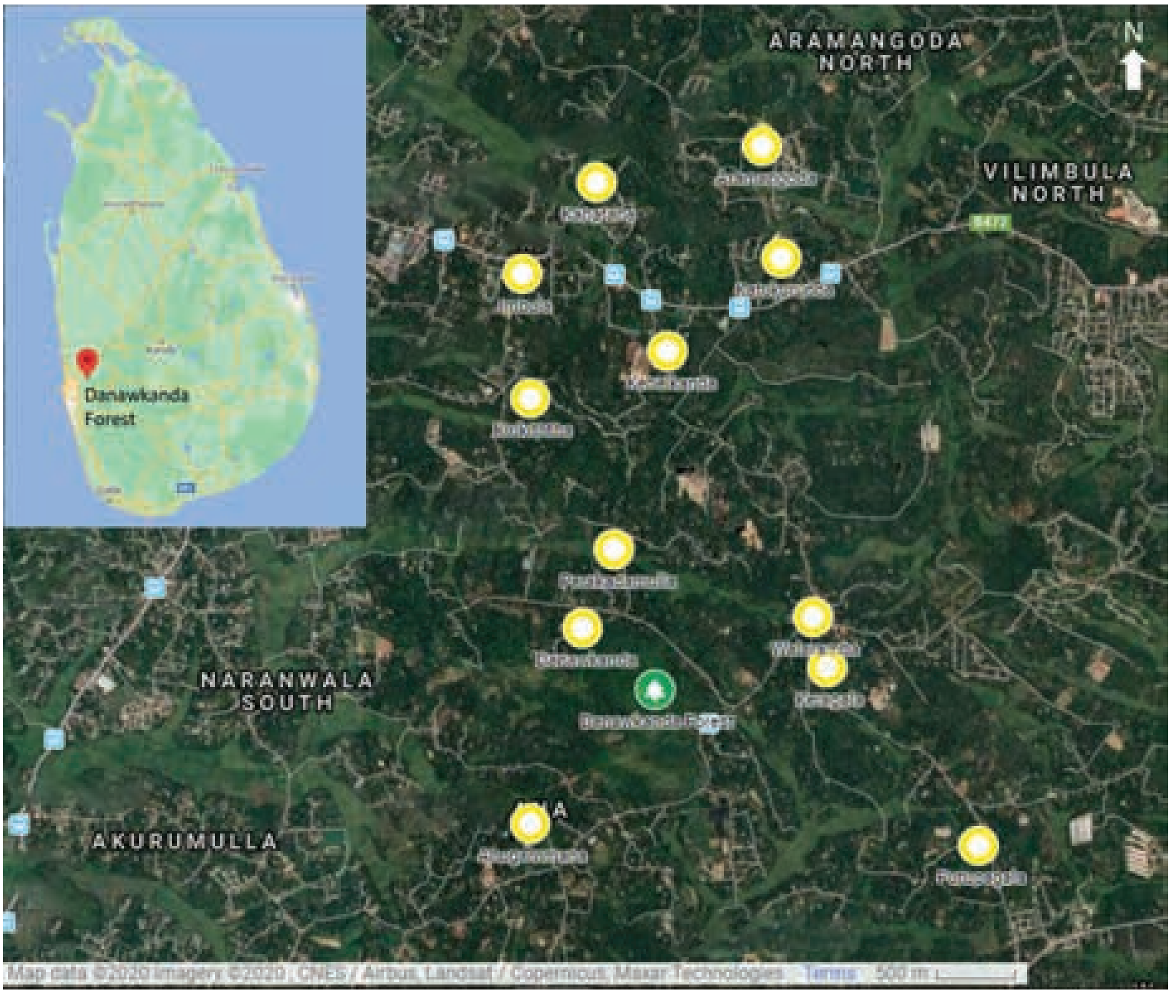

Image 1. Twelve villages bordering Danawkanda Forest, Gampaha, Sri Lanka (Google map source: Image © 2020 Maxar Technologies).

Image 2. One of the 25 most endangered primates of the world, *Semnopithecus vetulus nestor*.

out to collect data by randomly interviewing families in 12 villages bordering Danawkanda Forest from August 2014 to January 2015. The head of each household was interviewed in the relevant native language, Sinhalese or Tamil, to avoid omission of vital information. The questionnaire was composed of both closed- and open-ended questions and binary (yes/no) questions.

Data analysis

The data collected from interviews were presented as percentages of respondents given for each response (Marchal & Hill 2009). Crop and property damages, financial loss to the household, and expenditures for deterrent methods were calculated. Pearson's correlation test was performed to analyze the relationship between the money spent on firecrackers and the distance to the forest. Minitab (Version 14.0) Statistical Software was used and the level of statistical significance was set at $p \leq 0.05$.

RESULTS

Economic structure of the households in villages bordering Danawkanda Forest

Residents in the study area led a typical Sri Lankan lifestyle, of which 61% were employed (21% in the government, and 40% private sector) and 39% were unemployed, being involved in horticulture and a very few were daily-based laborers. Despite their employabiltiy, the majority were involved in friut plant (N= 78), crop plant (N= 55), and ornamental plant cultivation (N= 12). Monthly income was recorded as follows: 64% of residents earned less than LKR 25,000, 19% of residents earned LKR 35,000–50,000, and 3% of residents earned more than LKR 50,000.

Crop and property damage caused by *S.v. nestor*

Damages were categorized as crop damages, property damages, and others (Table 1). The highest number of households was affected by damages done to fruits, leaves, & buds (93%) of commercial value, breaking of roof tiles (76%), and frightful encounters (43%). The most preferred fruit species of the monkeys were *M. paradisiaca* and *C. papaya* (99%) (Table 2). The average losses per household by crop and property damages ranged between LKR 2,700 and LKR 1,500. This loss to the household caused by crop and property damage was higher in the dry season than the wet season (Fig. 1).

In addition to losses to the household caused by crop and property damages, residents spend money to buy firecrackers for chasing monkeys away. There was a strong negative correlation between the distance to the village and the average amount of money spent on firecrackers (r^2= -0.78 p= 0.0410).

Deterrent methods for *S.v. nestor* raids in villages bordering Danawkanda Forest

Deterrent methods for chasing away *S.v. nestor* were categorized as currently used methods, and proposed alternative methods (Table 3). Lighting firecrackers were the most common method used by the residents to chase away *S.v. nestor* (99%). Electrified barriers were rarely used (4%). Now most of the residents prefer to grow ornamental plants and short trees to develop an aesthetic appearance around the home and to eliminate the structures that attract and facilitate *S.v. nestor* approaching the home and property as proposed alternative methods.

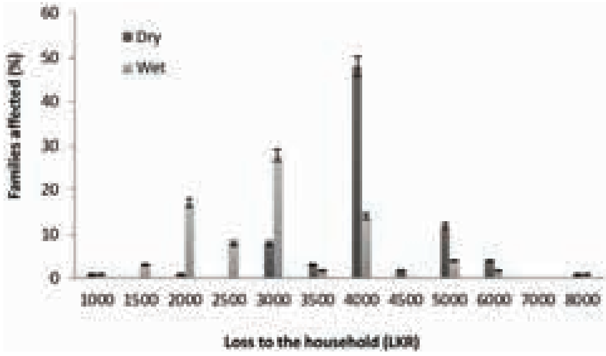

Figure 1. Approximated loss to households caused by crop and property damages during dry and wet season by *Semnopithecus vetulus nestor* with 5% error bars.

Table 1. Damage caused by *Semnopithecus vetulus nestor* in villages bordering the Danawkanda Forest, Sri Lanka.

Damage type	Number of families affected (%)
Crop damage	
Damage fruits, leaves and buds (leaf and flower buds)	93
Consume ripe and raw fruits	29
Consume crop and flowers of vegetable plants	13
Uprooting plants	13
Property damage	
Break the roof tiles	76
frightful encounters	
Scaring adults and children	43
Biting adults and children	31
Noise annoyance	41

Table 2. Fruit species ingested by *Semnopithecus vetulus nestor* in home gardens bordering the Danawkanda Forest, Sri Lanka.

Family	Species	Common name	Reported frequency of use (%)
Musaceae	*Musa paradisiaca*	Banana	99
Caricaceae	*Carica papaya*	Papaw	99
Sapindales	*Nephelium lappaceum*	Rambutan	44
Anacardiaceae	*Mangifera indica*	Mango	31
Arecaceae	*Cocos nucifera*	Coconut	20
Euphorbiaceae	*Manihot esculenta*	Manioc	08
Dioscoreaceae		Yams	08
Arecaceae	*Cocos nucifera* “king”	King coconut	05
Malvaceae	*Durio kutejensis*	Durian	04
Dipterocarpaceae	*Dipterocarpus zeylanicus*	Kiripalu	02

Table 3. Deterrent methods for raiding by *Semnopithecus vetulus nestor* into home gardens bordering the Danawkanda Forest, Sri Lanka.

Deterrent method	Households (%) employing these techniques
Currently practiced methods	
Lighting fire crackers	99
Throwing and/or thrashing stones	41
Shooting by pellet guns and catapults	18
Creating noises/shouting	26
Electricity fence/wires	04
Proposed alternative methods	
Growing decorative plants	99
Addition of short trees	99
Creating an esthetic landscape	99
Growing ornamental plants instead of crop plants	98
Elimination of structures that attract and facilitate monkeys	92
Reducing the food sources	84
Removal of tall trees	78

DISCUSSION

Crop raiding by wildlife is not a new phenomenon. It has been occurring since humans first settled down and started practicing agriculture (Sillero-Zubiri & Switzer 2001); however, the intensity of this problem is particularly problematic in areas where humans are encroaching onto once undisturbed wildlife habitats (Rudran 2007; Nahallage & Huffman 2008). It is challenging to conduct a comprehensive assessment of the damage caused by wildlife (Garriga 2014). Farmers' perceptions of loss are often greater than the actual loss, and this becomes more accentuated if the plantations are in close proximity to a protected wildlife area (Hill 2004). In the present study, we found that residents near the Danawkanda Forest are experiencing a considerable financial loss due to crop and property damage by *S.v. nestor* compared to their monthly income. Twelve villages are located within a 4km radius of Danawkanda Forest, of which 75% are located within a radius of 2km. Hence, *S.v. nestor* can easily exploit the available food resources of these villages via continuous arboreal pathways that connect the villages to the forest (Rudran 2007). Villages that are located relatively close to the forest largely experience a high frequency of crop and property damages compared to more distant villages. Similarly, previous studies have also shown that *S.v. nestor* is involved in the exploitation of human modified habitats, and that often results in crop damage and consumption and other forms of property damage (Rudran 2007; Dela 2012). Similarly, studies carried out in African countries like Uganda and in some regions in India show that farms closer to forests do actually suffer significantly more crop raiding than farms situated further away (Saj et al. 2001; Baranga et al. 2012; Karanth et al. 2013).

The vegetation structure of home gardens was the key element in attracting *S.v. nestor*. They mostly preferred taller fruit-trees that facilitated their arboreal movements, hence, home gardens with more tall trees were raided more frequently. Food sources like fruit plants were very common in home gardens in the study sites. Dela (2012) stated that *S.v. nestor* living in environments modified by humans and with abundant sources of cultivated fruits had actively adopted a more frugivorous dietary strategy, unlike that of any other colobine monkeys. Though fruits vary widely in biochemistry and quality, they are in general easily digested and contain energy-rich sugars and nonstructural carbohydrates (Kay & Davies 1994; Waterman & Kool 1994). Human edible fruits from cultivars seem to have these features (Dela 2007). Similar to Rudran (2007) in the present study, *S.v. nestor* commonly preferred fruits such as banana and papaw over other available fruits, and this might be due to their availability throughout the year, unlike most seasonal fruits. Chimpanzees are also known to cause significant damage to banana plantations (Naughton-Treves 1996). In the present study, the highest percentage of damage is done to leaves, fruits and their buds (93%), because mature leaves are generally high in fiber and protein, are more nutritious, and have lower processing costs (Oates et al. 1980; Waterman & Kool 1994). *S.v. nestor* commonly preferred both raw and ripe fruits (29%), and vegetable crops and their flowers (13%). On the other hand, roof tiles (76%) and roof sheets (13%) were frequently damaged by removing and destroying them. On occasion, they jump down on the roofs from tall trees as they move and chase one another, causing substantial damage to the roof. Unrepaired damages can lead to roof degradation.

Fear of *S.v. nestor* was common in the study area. Small children are the most common victims. Some monkeys were relatively more aggressive than others, with a few reports of people being bitten. Other primates like chimpanzees have even been known to kill children on more than 10 occasions in the Kibale Forest of western Uganda (Naughton-Treves pers. comm. 1996; Hill 2005) and baboons have caused injury and death to humans (Hill 2000; Nchanji 2002). Other prevailing problems include breaking fences, spoiling water in storage tanks and food, and the carrying off of small household items.

More than two-thirds of the residents interviewed face financial difficulties and the majority find selling of horticulture as a good remedy. They cultivate fruits and vegetables in their home gardens. Monkey foraging incursions into their home gardens cause a direct economic impact to the household. Damage to crops and property was higher in the dry season compared to the wet season. The wet season triggers flushing and fruiting of food sources in the forest, so the monkeys are able to get enough natural food at this time of year within the Danawkanda Forest. But in the dry season, food sources are scarce inside the forest. This might be the reason for intensified foraging in the adjacent home gardens, resulting in high crop and property damages at this time of the year. Conversely, many colobine species in other parts of the world feed selectively on seasonal plant parts (Davies 1991; Stanford 1991).

Most of the deterrent methods used are not harmful to the monkeys, but electrocution, shooting, poisoning, and hitting with stones are injurious. More traditional protection strategies used against other species such as creating barriers (electric fences, living fences, walls, and ditches) between wildlife and farming areas are ineffective where primates are concerned (Garriga 2014). Lighting firecrackers was the most common deterrent method used by the residents near the Danawkanda Forest. As the distance from the forest to the villages increases, the amount of money that had to be spent on firecrackers to deter *S.v. nestor* decreased. This is because the villages located more closely to the Danawkanda Forest are more frequently raided by *S.v. nestor* than the villages further away.

Apart from the currently used methods, we recommended seven alternative methods to residents in the area (see Table 3). The majority (99%) preferred to grow shorter trees instead of taller trees, because they give an aesthetic appearance to the home garden, and grow more ornamental plants instead of crop plants. This will, however, reduce the opportunities for growing valuable timber species and crop plants that can increase the monthly income of these residents.

Our study can be regarded as a baseline survey, which provides an initiative to address this rising problem in the area. We propose that *S.v. nestor* causes crop and property damages in the villages bordering Danawkanda Forest as a result of their search for nutritious food sources in home gardens at times of food scarcity in the forest. Residents who are living in close proximity to the forest, having low income, experienced a considerable economic loss to the household, leading to conflicts between humans and *S.v. nestor*. Perhaps compensatory mechanisms can help alleviate the financial losses to households. Awareness can play a vital role in encouraging villages to tolerate and mitigate crop and property damages caused by *S.v. nestor*. More efforts are needed to educate people on the importance of biodiversity and effective ways of mitigating the wildlife problem without engaging in constant conflict with them. Importantly, active participation of authorized government and non-governmental organizations needs to be involved to manage unplanned construction and agriculture extensions into the forest, which triggers negativity towards not only monkeys, but many other wildlife species as well.

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COMMUNICATION

Habitat preference of the Indian Pangolin *Manis crassicaudata* inhabiting Margalla Hills National Park, Islamabad, Pakistan

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Abstract: The Indian Pangolin *Manis crassicaudata*, is an 'Endangered' mammal species native to Pakistan but facing a risk of extinction due to hunting pressure for its scales used in trade. The current study investigated habitat preference of this unique species in the Margalla Hills National Park, Islamabad, from September 2011 to August 2012. Three habitat types, viz, human vicinity area, agricultural land, and wild/natural area, were searched for recording signs of Indian Pangolin. Data on habitat preference was collected from direct and indirect signs of the species by monitoring 85 line transects, each measuring 500m in length and 50m in width, in 17 different sampling sites. A total of 323 signs of Indian Pangolin were recorded including 299 burrows, 10 live sightings, and 14 scats of the species. The maximum number of signs were recorded in wild or unmodified natural area (55.1%), followed by those in vicinity to human use area (20.12%), while the least (24.76%) were found in agricultural area. Statistical comparison using one-way analysis of variance of pangolin field signs, among three different types of habitats studied, differed significantly (df= 48, F= 13.723, p <0.001). Similarly, LSD analysis further revealed that field signs of Indian pangolin recorded on natural or wild habitat significantly differed from those which were on agricultural land and human vicinity area (p <0.001). The study concludes that the Indian Pangolin prefers habitats in the wild or natural area over those close to human vicinity and agricultural lands.

Keywords: Burrow, endangered, hunting, pangolin, trade.

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Author contribution: TM and SA designed the study, TM supervised the study, SA collected field data, TM and FA analyzed the data and wrote the manuscript.

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INTRODUCTION

Animals make habitat choices as a result of balance between the costs and benefits perceived by them from effort and efficacy of result. Habitat use is driven by habitat-related variation in factors such as forage quality and availability, shelter, presence of predators, and breeding success. In fact, one of the most common significance is when open habitats provide good forage and closed habitats provide shelter from predation. The relative importance of finding food, mates and avoiding predators will change across different animal species but may also vary in space and time within populations of a single species.

Mammals have a 24-hour activity rhythm, based on the endocrine melatonin rhythm of the pineal gland, synchronized with the environment by means of the light/dark cycle (Bartness 1989). All activities carried out during the circadian cycle have fitness costs and benefits (Daan & Aschoff 1982). If different habitats have differential survival costs/benefits for active behaviour than for resting/sleeping, an individual's space and habitat use is likely to differ between the active and the inactive part of the circadian cycle (Halle 2000).

The Indian Pangolin *Manis crassicaudata*, is a medium-sized mammal, covered over on the dorsal side by hard keratinized scales, whereas its ventral side is without scales. The species occurs in five different countries including Pakistan, India, Sri Lanka, Nepal, and Bangladesh (Mahmood et al. 2019). It generally inhabits tropical and sub-tropical forests, dry mixed-evergreen monsoon, sub-mountain, and riverine forest (Roberts 1977; Phillips 1981). It also occurs in mangrove forest, grasslands, agricultural land, artificial landscapes (plantations), home-gardens, scrubland, and desiccated areas (Roberts 1977; Pabasara et al. 2015; Karawita et al. 2018). It is an 'Endangered' species throughout its range because of illegal trade for its scales and meat, placed in the Appendix I of the CITES, and is also the world's most trafficked mammal (Mahmood et al. 2019)

In Pakistan, the Indian Pangolin occurs in, and may have a preference for, sub-tropical thorn forests and barren hilly areas (Roberts 1977). Mahmood et al. (2014) reported that in the Potohar Plateau, there is a close association between the occurrence of the species and its burrows, and dominant tree Arabic Gum Acacia nilotica, Indian Plum *Zizyphus mauritiana*, Phulai *Acacia modesta*, shrubs (*Zizyphus nummularia*, *Calotropis procera*), and Mesquite *Prosopis juliflora* species. In Margalla Hills National Park, an earlier study reported that Indian Pangolin was recorded in areas dominated by Phulai, Northern Indian Rosewood Dalbergia sissoo and Chir Pine *Pinus roxburghii* while West Indian Lantana *Lantana camara* and Pomegranate *Punica granitum* appear important to the species' ecology (Mahmood et al. 2015). Since its habitat includes hilly areas, forest as well as grasslands, selection of habitat depends upon food availability (Jacobson et al. 1991). It forages exclusively on ants and termites species (Roberts 1997) in its habitat.

The Indian Pangolin has got an important economic role in agricultural crops and buildings (Roberts 1997). There are evidences on varied diet of the species that may consume insects, plant matter as well as grits (Karawita et al. 2020). It also plays vital role in the ecosystem concerning pest control. It is estimated that one adult pangolin can consume approximately more than 70 million insects annually (d'Aulaire & d'Aulaire 1983). Moreover, burrowing animals are very important to add up valuable contribution to increase animal's diversity and population as their burrowing activity provides shelter or breeding habitat for many other animals and thus this action increases animal diversity (Hansell 2003). Being the world's most trafficked mammal, mainly because of illegal trade in its scales, it faces a high risk of extinction in the wild (Challender et al. 2014). Without conservation efforts, its population is expected to keep on declining and the vital species may very soon be lost. For the conservation of this species, it is necessary to have baseline information about its ecology and biology including habitat preferences. So, keeping in view the importance of Margalla Hills as an important habitat of the Indian Pangolin in the country, the present study assessed its habitat preference in the Margalla Hills National Park (MHNP), Islamabad.

MATERIALS AND METHODS

Study area

The study was carried out in MHNP, Islamabad (Image 1), located between 33.716N and 73.916E, occupying approximately 17,386ha area, and it comprises of different compartments in Margalla Reserve Forest and 1–25 of the Military Grass Farms (Pakistan 2009). It also covers the Margalla Hills 12,802ha, Rawal Lake 1,702ha, and Shaker Parian 1,376ha. Since its establishment the Park is under the control of CDA (Capital Development Authority) vide notification number 443[1] / 80 (Anwar & Chapman 2000). But more recently, the MHNP has been handed over to "Islamabad Wildlife Management Board (IWMB) which has been established under the control of

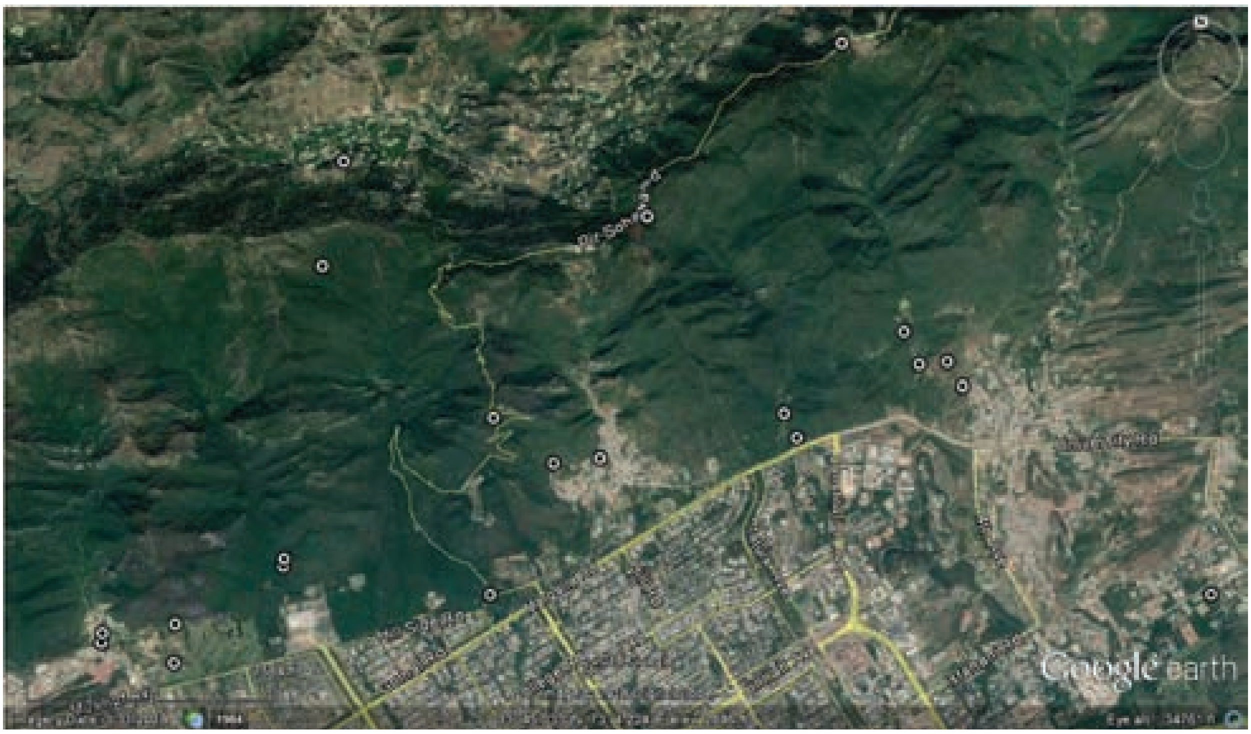

Image 1. Map of the Margalla Hills National Park, Islamabad showing locations where signs of Indian Pangolin were recorded in the Park at three different habitat types (Modified from Google Earth Inc.).

Ministry of Climate Change (MoCC), Islamabad.

The northern part of the MHNP follows the Haripur-Islamabad and Rawalpindi-Islamabad district boundaries while the forest compartments in the periphery of 37 reserve forest (RF) and 41 RF are followed by the western part of the Park boundary. Southern side of the boundary moves with the border of the forest compartments, existing boundary pillars, Siachen and Margalla road and also the center line of the nullahs like Rumli and Mandla. The eastern part of the Park boundary follows the forest compartment boundary along with the Rawalpindi-Islamabad district boundary. Finally, the boundary of Rawal Lake follows the Kashmir Highway, Murree road, Shaker Parian, the highest water mark of Rawal Lake along with 2km buffer zone and CDA pillars at some places (Pakistan 2009).

Topography of the study area is uneven, mostly comprising slopes and gullies. The rock composition is basically limestone. Its elevation ranges 450–1,580 m above sea level (Jabeen et al. 2009). On the western side elevation of the mountain is about 1,600m, which increases towards the eastern side (Anwar & Chapman 2000). The soil is colluvial, wind deposited, ranging dark brown to yellowish-brown in color with a fine texture (Hijazi 1984).

The climate is sub-tropical to semi-arid. The average maximum and average minimum temperatures of the area are 34.3ºC and 3.4°C, respectively. The area receives a reasonably high monsoon rainfall, and the annual rainfall is up to 1,200mm. Underground water table is in moderate condition having pH of 7.4 (Shinwari & Khan 1998).

The biodiversity of the park harbors about 616 species of plants, 250 birds, and 35 mammals in the National Park (Rasheed et al. 2005). The Park flora is generally dry, tropical, deciduous forest on lower slopes and sub-tropical on higher altitude. There are primarily five plant communities, on the basis of physiognomy, floristic composition and dominance, including *Olea ferruginea-Acacia modesta, Acacia modesta-Carissa opeca, Olea ferruginea-Carissa opeca, Myrisine Africana-Dodonea viscose,* and *Pinus roxburghii-Quercus incana*. The *Pinus roxburghii-Quercus incana* community is present at 900m elevation where Chir Pine are found in patches and understory cover is dominated by grasses (Anwar & Chapman 2000).

Field surveys and data collection

A reconnaissance was conducted on motor vehicle (average speed 25–30 km/h) in natural and wild areas of the park to find out the potential habitat of Indian pangolin. The potential areas were marked and their geographical coordinates were recorded. The potential areas of the animal species were identified on the basis of its burrows and fecal samples present over there and also by interviewing local people. The burrows of the Indian pangolin were distinguished from those of other vertebrates identified on the basis of their characteristics shape (being circular at their opening). The species excavates two types of burrows. These are the feeding burrows and living burrows. The feeding burrows are less deep and excavated during foraging on ants and termites, while the second types of burrows are "permanent" burrows or living burrows, which are excavated by the species for living purposes, and these are much deeper. The local people were also asked about the occurrence of pangolins in their area, just to confirm existence of the species in the study area. Information provided by the local people were verified by searching for and identifying the field signs like burrows and scats of the Indian Pangolin.

For investigation of the habitat and collection of data on the species, 17 representative sampling sites were randomly selected. Each sampling site comprised an area of about 1km². Five line transects, each measuring 500m in length and 50m in width on either side of the transect (area of each transect was 0.05km2) were established in each sampling site. Total numbers of transects searched were N= 85. Fortnightly visits to the selected sites were conducted for data collection from July 2011 to June 2012. The selected sites ranged in their elevation from 462m (Malpur) to 1,046m (Trail-3). Each visit comprised of three consecutive days. The total numbers of days of observations were N= 72. In order to ensure that we did not double count the field signs of Indian Pangolin, as the burrows were permanent signs, the scats were collected during each field visit.

Each sampling site was further divided into three different habitat types, viz., human vicinity area (HVA), agricultural lands (AGL), and wild or natural area (WNA); all these habitat types were searched for recording direct and indirect signs of the Indian Pangolin. Besides the presence of burrows and faecal matters, other signs that were searched included their foot prints and body prints, especially around the newly dug burrows (Table 1). The feeding and permanent burrows of the species were distinguished on the basis of the burrow depth; the depth of the feeding burrows was much less than the living or

Image 2. Field photographs of burrows of Indian Pangolin in the Margalla Hills National Park, Islamabad: A—living or permanent burrow | B—a feeding burrow | C—inactive living burrow | D—active living burrow. © Shaista Andleeb.

permanent burrows (Image 2). Similarly, inactive and active living burrows of the species were distinguished on the basis of activity signs around the burrows (Image 2). Also, questionnaires were developed for collecting information from the local people in different areas of the park. Data on habitat preference of the pangolin was collected from direct and indirect signs monitored along 85 line transects established in 17 sampling sites. The transects where direct and indirect signs of pangolin were found, their geographical coordinates were recorded by using geographical positioning system (Garmine Trex Vista H), later to construct a distribution map of the animal species in MHNP.

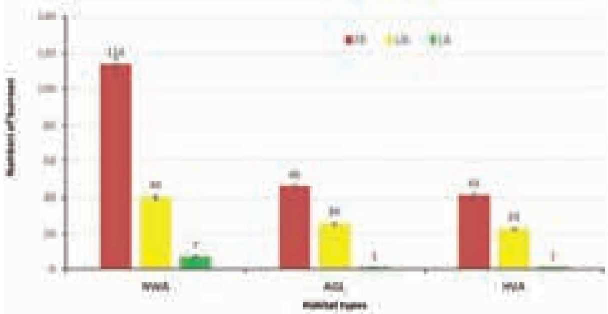

Figure 1. Numbers of burrows (Feeding burrows FB, living inactive LIA, and living active LA) of Indian Pangolin recorded in MHNP, at three different habitat types in the study area: HVA—Human vicinity area | NWA—Natural Wild area | AGL—Agricultural land.

RESULTS AND DISCUSSION

The Indian Pangolin occurs in a diversity of habitats, ranging from hilly areas to forests and grasslands, depending upon the availability of its food resources. Growing concerns over population declines due to poaching and trafficking (Challender et al. 2015; Ingram et al. 2019) have emphasized the need for more concerted conservation efforts for the species, which according to the IUCN Red List of Threatened Species, is listed as 'Endangered' due to past and anticipated population declines caused by illegal hunting (Mahmood et al. 2019). The species is included in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (Mahmood et al. 2019).

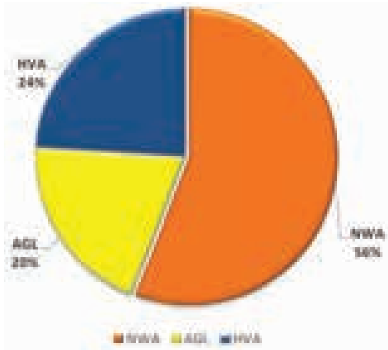

Figure 2. Percent use of each of the three habitat types by Indian Pangolin in MHNP Islamabad.
HVA—Human vicinity area | NWA—Natural Wild area | AGL—Agricultural land.

In the current study, we aimed at investigating the preferred habitat of the Indian Pangolin, among three habitat types, viz., natural or wild area (NWA), agricultural land (AGL) and human vicinity areas (HVA), in the MHNP, Islamabad. The earlier published literature shows that the species can occur in a variety of habitats like forests, grasslands, and semidesert areas (Roberts 1997).

In our study of the Indian Pangolin, a total of 323 signs were recorded, out of which 299 were burrows, 10 were live sightings and 14 were scats of Indian pangolin (Table 1). The results showed that among all field signs the maximum signs were recorded in habitat type-III (Table 2; Image 2; Figure 1), wild or natural area (n= 178; 55.1%), followed by human vicinity area (n= 80; 24.76%), while the least signs of the species (n= 65; 20.12%) were found in the agricultural land area. The maximum signs of pangolin were found in Malpur (n= 125; 38.70%) sampling site while the least signs were recorded at Trail-3 (n= 3; 0.92%) of MHNP. These findings suggest that the Indian Pangolin prefers for wild natural area over human vicinity area and agriculture land in the Park.

Karawita et al. (2018) investigated the habitat preference of Indian Pangolin in a tropical lowland rainforest in southwestern Sri Lanka. They recorded a total of 75 burrows, that included 54 feeding burrows and 21 resting burrows in four different habitat types—secondary forest, Pine-dominated forest, rubber cultivations, and tea-dominated home gardens bordering forest. The observations were made using fixed-width transects in order to characterize resting and feeding burrows of this species. They concluded that the Indian Pangolins exclusively prefer habitats with rocks and boulders under which they dig resting burrows while the location of feeding burrows largely overlaps with the distribution of prey species. In our current study in MHNP Islamabad, however, we did not find any burrows of Indian Pangolin in the rocks, but a majority were in the soft soil, and under the vegetation.

Similarly, Mahmood et al. (2014) studied the habitat

Table 1. Detail of field surveys/ transect surveys conducted on motor vehicle for Indian Pangolin distribution of in Margalla Hill National Park, Islamabad, during current study period.

Sr. #	Location	Starting transect	Geographic coordinates	Ending transect	Geographic coordinates	Distance covered	Result +/-
1	Phulwari	Phulwari Village entrance (QAU)	N: 34.001 E: 73.303 Elev: 595m	Phulwari Village (QAU)	N: 33.846 E: 73.190 Elev: 595m	6km	+Ve
2	Kalanjir	Kalanjir Valley	N: 33.918 E: 73.039 Elev: 598m.	Gandian Village	N: 33.877 E: 73.157 Elev: 579m.	4km	+Ve
3	Rumli	Ramli Village entrance	N: 33.997 E: 73.275 Elev: 591m	Ramli Village	N: 33.853 E: 73.208 Elev: 634m	6km	+Ve
4	Shahdara	Shahdara Village	N: 33.947 E: 73.318 Elev: 702m.	Mandla Village	N: 34.040 E: 73.306 Elev: 653m.	6km	+Ve
5	Gandian	Gandian Village (DaraKaao'nwni)	N: 33.751 E: 73.036 Elev: 606m.	Gandian Village	N: 33.761 E: 73.215 Elev: 619m.	8km	+Ve
6	Kalanjir	Kalanjir Village	N: 33.906 E: 73.036 Elev: 597m.	Kalanjir Village	N: 33.931 E: 73.163 Elev: 602m.	3km	+Ve
7	Rattahottar	Rattahottar	N: 33.770 E: 73.141 Elev: 643m.	Ratta Hottar	N: 33.812 E: 73.330 Elev: 631m.	3km	+Ve
8	Bari imam	Bari imam	N: 33.767 E: 73.356 Elev: 627m.	Bari imam (Mahallakamalpur)	N: 33.999 E: 73.168 Elev: 616m.	2km	+Ve
9	Trail-5	Darajangla (trail 5)	N: 33.928 E: 73.153 Elev: 630m.	Muradgalli	N: 33.926 E: 73.209 Elev: 1164m.	7km	+Ve
10	Trail-3	Trail 3 (from monal restaurant)	N: 33.962 E: 73.163 Elev: 1046m	Trail 3 (Darajangla)	N: 33.962 E: 73.131 Elev: 624m	5km	+Ve
11	Lakeview park	Lakeview park side	N: 33.970 E: 73.326 Elev: 542m	Malpur Village	N: 33.782 E: 73.100 Elev: 527m	3km	+Ve
12	Saidpur	Saidpur Village.	N: 33.900 E: 73.086 Elev: 592m	Saidpur Village.	N: 33.894 E: 73.271 Elev: 648m	3km	-Ve
13	Malpur	Malpur Village	N: 33.774 E: 73.226 Ele15v: 462m	Malpur Village	N: 33.774 E: 73.226 Elev: 467m	4km	+Ve
14	Daman -e- koh	Enterance Daman-e-koh road	N: 33.971 E: 73.130 Elev: 579m	Bodlabann	N: 33.958 E: 73.175 Elev: 869m	6km	-Ve
15	Talhar	Entrance Talhar Village	N: 33.780 E: 73.196 Elev:932m	Chak Khanna point (18RF)	N: 33.898 E: 73.168 Elev:995m	2.5km	+Ve
16	Sangjani	Sangjani Wild area	N: 33.718 E: 72.918 Elev:506m	Sangjani	N: 33.725 E: 72.919 Elev:511m	4km	+Ve
17	Shah-Allah-Ditta	Shah-Allah-Ditta Wild area	N: 33.826 E: 72.994 Elev:581m	Shah-Allah-Ditta area	N: 33.839 E: 72.998 Elev:578m	3km	+Ve
	Total					75.5km	

and population of the Indian Pangolin in Chakwal District, Pakistan. They reported that trees, herbs, and shrubs form important components of its habitat. They found the Indian Pangolin closely associated with *Acacia nilotica, Zizyphus mauritiana, Z. nummularia* and *Prosopis cineraria*. *Lantana camara* was also among the preferred vegetation type. They suggested that tree species like *Prosopis, Zizyphus* and *Acacia nilotica* may be important for the Indian Pangolin from the point of view of food because abundant termite mounds and ant's colonies occur on the soil below and on the trunks of these tree species. Moreover, *Zizyphus nummularia* and *Lantana camara* may have an important role of providing protection to the animal species. In the current study in MHNP Islamabad, the habitat type-III (NWA) is also having a similar kind of vegetation with similar species

Table 2. Percentage (%) of habitat use by Indian Pangolin *Manis crassicaudata* in MHNP, Islamabad.

Site No.	Sampling sites	Elevation (m)	Human vicinity area (%)	Agricultural lands (%)	Natural/wild area (%)
1	Malpur	462	4	18	78
2	Lake view	542	27	15	58
3	Banni galla	514	37	14	49
4	Shahdara	702	26	23	51
5	Ramli	591	24	63	13
6	Phalwari	595	47	24	29
7	Gandian	603	57	24	19
8	Kalinjir	598	47	29	24
9	Bari Imam	627	45	21	34
10	Ratta Hottar	643	12	51	37
11	Darra Jangala	630	3	0	97
12	Trail-3	1046	2	0	98
13	Talhar	932	3	8	89
14	Sangjani	506	11	7	82
15	Shah-allah-Ditta	581	2	13	85
16	NARC	496	27	32	41
17	Saidpur	670	34	0	66
	Mean ± SE		**24 ± 4.47**	**20.11 ± 4.15**	**55.88 ± 6.84**

of herbs, shrubs, & trees, which indicates why the Indian Pangolin preferred such a kind of habitat. The Indian Pangolin was found distributed at various sites surveyed including Phalwari, Kalinjar valley, Gandian Valley, Rumli, and Shahdara areas of the Park. It was also recorded in Ratta-Hottar and Bari-Imam areas of the Park. The occurrence of some old burrows at Trail-3 and Trail-5 of MHNP showed that the animal species did occur in these areas in the near past. No direct or indirect signs of the animal were found in Saidpur area; however, it was confirmed to occur around Lake View and Malpur areas. In Sangjani and Talhar areas, some old burrows revealed its presence.

During the current study period, the Indian Pangolin was found to occur at Malpur site near Rawal Lake, Phalwari area, Kalinjar Valley, Gandian Valley, Ramli and Shahdara, Ratta Hottar, NARC, and Bari Imam areas of the MHNP, at an elevation ranging 462–1,046 m. Some old living/permanent burrows of the animal species were recorded at Trail-3 and Trail-5 areas of the park, which indicates that the Indian Pangolin did occur at these sites in the past but it has moved to some other places from there now. Similarly, at Sangjani and Talhar areas of the Park, occurrence of old permanent burrows indicates its occurrence in the past at these sites. In the area of Shah-Allah-Ditta (995m), its occurrence was confirmed whereas in the area of Daman-e-Koh (579–869 m), no signs of the animal species were found. Roberts (1997) had reported that the Indian Pangolin occurs in the subtropical thorn forest of Potohar Plateau and in Rawalpindi foothills up to 750m elevation, but in the current study it has been recorded up to an elevation of 995m. The MHNP also has subtropical thorn forest.

Results of the current study confirm that the Indian Pangolin prefers natural wild area (55.88%) over human vicinity areas (24%), and agricultural land (20.11%) (Table 2; Figure 2). Statistical comparison using one-way analysis of variance (ANOVA) of pangolin field signs among three different types of habitats studied differed significantly (df =48, F =13.723, $p < 0.001$). Similarly, LSD analysis further revealed that field signs of the pangolin recorded at natural wild area habitat type significantly differed from agricultural land and human vicinity area habitat types ($p < 0.001$). Waseem et al. (2020) investigated the habitat suitability of the pangolin in Potohar Plateau and Azad Jammu & Kashmir areas. We recorded evidence of pangolin occurrence in three different types of habitats in study area; viz., natural forests, agricultural land, and the grassland. Results indicate that the natural forest land is the preferred habitat of the pangolin. This preference indicates that compared to grassland and agricultural land, more cover might be available to pangolins for refuge and protection. These results support the findings of the current study where the Indian Pangolin preferred natural wild area habitat over agricultural land and vicinity areas. The findings of the current study also get support from Perera & Karawita (2020) who reported that the the Indian Pangolin inhabits a variety of habitats, ranging from natural to anthropogenic. Subtropical/ tropical shrubland, subtropical/tropical dry forest, and subtropical/tropical moist lowland forest were the habitat types. Interestingly, 15 confirmed records of the Indian Pangolins were reported from subtropical/ tropical moist montane forests, which represent the lower and upper montane forests (cloud forests) at altitudes above 1,200m.

CONCLUSION

The current study provides information regarding habitat utilization of the Indian Pangolin. The species prefers habitats in natural or wild area over agricultural land and human vicinity areas ($p < 0.001$). The results are expected to help in managing the Indian Pangolin by conserving its preferred habitat type in the study area of Margalla Hills National Park, Islamabad, in addition to controlling its illegal trade.

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COMMUNICATION

The endangered Himalayan Red Panda: first photographic evidence from its westernmost distribution range

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Abstract: An endangered species, the Himalayan Red Panda *Ailurus fulgens* is one of the most iconic and sought-after species in the world. Although a symbolic species of the Himalayas, it is threatened by habitat loss, fragmentation, and poaching. The data collection was carried out in accordance with the Red Panda community-based monitoring protocol. Threats to the Himalayan Red Panda within the study area are reported based on key informant interviews and direct field observation. This paper provides new evidence for the presence of Himalayan Red Pandas beyond their previously-known westernmost limit (81.687778°E) across its distribution range. An average encounter rate of 0.92 signs/km was recorded from the surveyed community forests. Trees were the most preferred substrates used for defecation. Extensive resource collection, poaching, overgrazing and forest fires are identified as some of the most significant threats. In general, the study contributes to the conservation of the Himalayan Red Panda in western distribution ranges.

Keywords: *Ailurus fulgens*, arboreal, firefox, indirect sign, photographic evidence.

Abbreviation: CF—Community Forest | DDC—District Development Committee | KII—Key informant interview.

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Author contribution: Saroj Shrestha (conceptualization; data curation; investigation; project administration; supervision; writing-original draft), Sony Lama (conceptualization; data curation; investigation; project administration; supervision; writing-original draft), Ang Phuri Sherpa (funding acquisition and project administration), Sonam Tashi Lama (investigation and project administration), Dinesh Ghale (data curation and writing-review and editing).

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RED PANDA NETWORK

INTRODUCTION

The language of photography is universal, and it plays a crucial role in educating people on wildlife and environmental issues (Lott 1992; Russell 1996; Montag et al. 2005). Photo identification is one of the studies in population ecology central to a range of applied fields such as biological diversity, conservation biology, and wildlife management (Bauwens et al. 2018). Photographic identification is critical when animals are difficult to capture and when the aim of the research is to understand natural population processes and animal behavior with negligible interference (Bradfield 2004; Bauwens et al. 2018).

Researchers are using photographic identification methods to survey biological communities (O'Connell et al. 2011). Photographic images are reliable and non-invasive data collection tools to track wildlife populations (Karlsson et al. 2005; Frisch & Hobbs 2007; Carpentier et al. 2016). Species identification and monitoring using photographs can produce useful ecological data including distribution patterns, abundance, and other population parameters for analysis while minimizing time to process bulky datasets (Karlsson et al. 2005; Swanson et al. 2016). Some photographic identification approaches now use artificial intelligence to assist field biologists and citizen scientists in recognizing the species (Kumar et al. 2012). Photographic identification has been successfully adopted for an extensive range of wild animals (e.g., *Puma concolar* (Kelly et al. 2008), *Mustela kathiah* (Phan et al. 2014), *Prionailurus planiceps* (Wadey et al. 2014), *Ailurus fulgens* (Shrestha et al. 2015), *Liopholis slateri slteri* (Treilibs et al. 2016), *Vipera berus* (Bauwens et al. 2018)).

The Red Panda *Ailurus fulgens*, an endangered mammal, classified as two subspecies: the Himalayan Red Panda *A. f. fulgens* and the Chinese Red Panda *A. f. styani* (Hu et al. 2020). The Himalayan Red Panda is an endangered species (IUCN Red Data Book; Glatston et al. 2015), confined to the region of southwestern China, Nepal, India, Bhutan, and Myanmar (Glatston 1989; Yonzon & Hunter 1989; Pradhan et al. 2001). Tila Karnali River in Kalikot District of Nepal is the westernmost distribution edge (81.66° E) of the Red Panda (Himalayan Red Panda) while its easternmost distribution edge (Chinese Red Panda) is the Minshan Mountain and Upper Min Valley in Sichuan Province, in central China (Hu et al.1990; Schaller et al. 1985; DNPWC & DFSC 2018).

Nepal represents the westernmost distribution of the Himalayan Red Panda (Shrestha et al. 2021). In Nepal, the Himalayan Red Pandas are distributed in 24 districts with the potential habitat of 21,680 km^2 (Thapa et al. 2020); however, they are vulnerable to extinction due to habitat loss and fragmentation (Acharya et al. 2018) and poaching (Bista et al. 2017). Understanding the distribution of the species is a crucial prerequisite in formulating an effective conservation-dependent species management strategy (Braun 2005; Titeux et al. 2020). Nevertheless, gathering information with regard to such endangered species is both a prolonged and labor-intensive process. In addition, its elusiveness, rarity, and distribution in remote-rugged habitat limits its detection probability during field surveys (Shrestha et al. 2015). Only a few indirect evidences of the Himalayan Red Panda's occurrence have been recorded from Kalikot District in the past (Dangol & Chalise 2018). Based on direct sighting, the current study aims to reconfirm the presence and distribution of the Himalayan Red Panda in the westernmost edge of its potential habitat range in Kalikot District of Nepal.

METHODS

Study area

Nepal lies between China in the north and India to the south, east, and west. The majority of Nepal's landmass lies along the Himalaya, within a small latitudinal range of approximately 200km, the country undergoes vast altitudinal changes from 60m along the southern border, up to 8,848m of Mount Everest. This difference causes dramatic vicissitudes in Nepal's landscape and climate. Our study area, i.e., Kalikot District lies in western Nepal. Kalikot District includes six rural municipalities (RM) and three municipalities (Figure 1). This remote and rugged mountainous district spans an elevation of 728–4,790 m and is located between 28.62222^0 to 29.12556^{0}N and 81.82278^0 to 82.57944^{0}E (DDC 2008). This district possesses a significant proportion of temperate, tropical, and sub-tropical zones (Lillesø et al. 2005). The average annual temperature ranges from a minimum of 17.2°C to a maximum of 29.1°C (DHM 2017). Likewise, other districts in the mid-western development region, Kalikot also experience low average annual precipitation of 830.9mm (DHM 2017). This district is ranked as a highly vulnerable locale to climate-induced disasters such as floods, wildfires, landslides, and droughts (Ministry of Forests & Soil Conservation 2016). In Nepal, the Red Panda's presence has been documented from 24 districts and seven protected areas with potential habitat of 23,977km^2 (DNPWC & DFSC 2018).

The study was conducted in the community forest

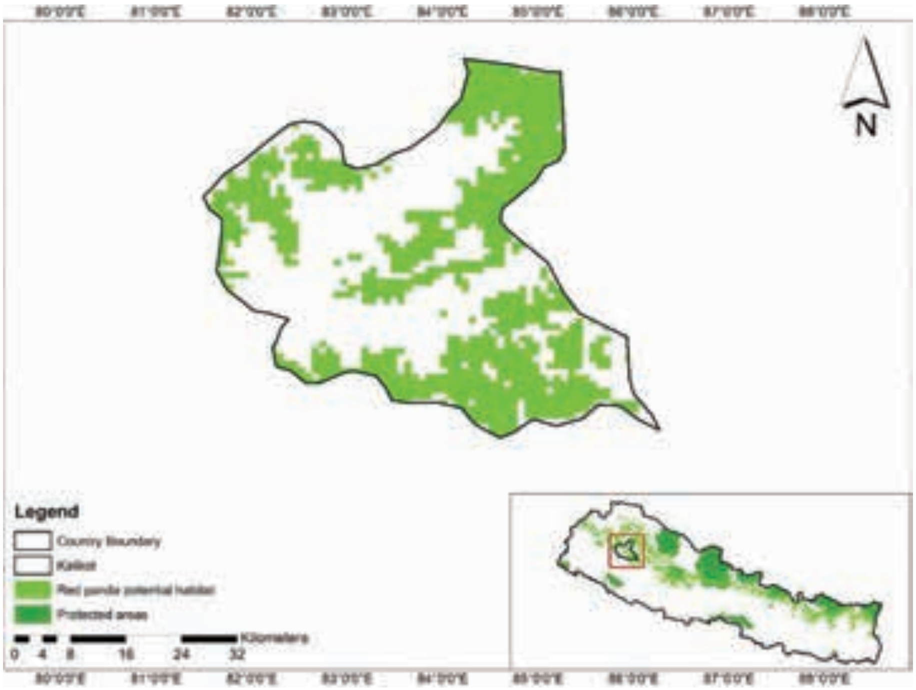

Figure 1. Study area showing potential Himalayan Red Panda habitat.

(CF) of three rural municipalities, i.e., Mahawai RM, Panchal Jhara RM, Shubhakalika RM of Kalikot District (Figure 1). The community forests: Himkalika CF, Dimreni CF, Jillitreveni CF and, Gairemela CF have temperate evergreen forests with a high dominance of common plant species such as *Abies spectabilis*, *Tsuga dumosa*, *Betula utilis, Bombax ceiba, Juglans regia, Cedrus deodara, Pinus wallichiana, Rhododendron* spp., and *Quercus semecarpifolia*. The study area is rich in medicinal and aromatic plants such as *Ophiocordyceps sinensis, Annona squamosa, Nardostachys jatamansi, Picrorhiza kurroa, Swertia chirata, Paris polyphylla, Delphinium denudatum, Morchella esculenta, Moringa oleifera, Rheum austral*, and *Dactylorhiza hatagirea* (DDC 2008). In general, forests of Kalikot harbors wide range of wildlife and bird species. The most commonly found fauna include *Muntiacus muntijak, Ursus thibetanus, Ailurus fulgens* (Dangol & Chalise 2018)*, Semnopithecus schistaceus*, *Moschus* spp., *Cervus elaphus*, *Hemitragus jemlahicus*, *Capricornis thar*, *Lophura leucomelanos*, and *Lophophorus impejanus* (Jnawali et al. 2011).

Methods

A team comprising eight field biologists surveyed four CFs of three respective RMs of Kalikot District in autumn season, i.e., October/November 2019. Altogether, 12 linear transects with an average length of 1km were established covering an area of 5.5km^2 of potential Himalayan Red Panda habitat (Ministry of Forests & Soil Conservation 2015). The transects were surveyed based on the elevation gradient of 2,500–3,400 m and accessibility of the terrain. A total of 11.98km transect length was traversed during 362 working hours in search of indirect evidence (such as scat, footprints, scratch marks, feeding signs, and/ or remains of dead animal parts) and direct sightings of the Himalayan Red Panda. Relative abundance was measured by estimating the encounter rate (ER) of Himalayan Red Panda signs per unit km of transect walk within the survey area. ER is total numbers of signs/total length of the transects traversed in kilometers (Ministry of Forests & Soil Conservation 2015).

A Canon Powershot SX40 HS camera along with GPS (Garmin eTrex 10) was used to capture photographs and record geographical location during the field survey. Predominant substrates (such as fallen logs, trees, and forest floors) used by the Himalayan Red Panda for defecation was recorded for habitat use analysis.

Potential threats to the Himalayan Red Panda were determined from direct field observation and key informant interviews (KII). Altogether, 12 divisional forest officials and 47 community forest users group (CFUG) members of all surveyed CFs were interviewed with respect to their socio-economic status, involvement in Himalayan Red Panda stewardship, knowledge on conservation importance, and the potential hazards to the species. Chi-square test was conducted to evaluate the responses from the survey interviewees regarding the pervasive human disturbances in the core habitat of the species.

RESULTS

Scats of the Himalayan Red Panda was found at 81.687778° E (Pachal Jharana RM) at an elevation of 3,216m while photographic evidence of an adult was recorded at 81.77080°E (Mahawai RM) at an elevation of 2,784 m (Image 1; Figure 2). The signs of its presence was documented from all surveyed CFs. The photographed animal was captured while foraging on the branch of *Betula utilitis* at 09.33h (Image 2, 3). The nearby vegetation of the photographed site was dominated by *Rhododendron campanulatam, Pinus wallichiana,* and dense bamboo understory (51–75 %). The nearest water body was approximately 80m away from the camera station.

Himalayan Red Panda presence signs were documented at the elevation range of 2,500–3,400 m; 70% of the records were in the range 2,650–3,100 m. An average encounter rate of 0.92 signs per km were recorded from the surveyed forests with Himkalika CF having the highest rate (ER= 1.53 signs/km) followed by Dimreni CF (ER= 0.83 signs/km), Jilli Triveni CF (ER= 0.78 signs/km), and Gairemela CF (ER= 0.55 signs/km) (Table 1).

Droppings (n= 163 piles) of Himalayan Red Panda were observed on four different substrates, i.e., ground, rock, trees, and fallen logs (Figure 3). Trees were the most preferred substrate (50.92%) followed by ground (28.83%), and fallen logs (13.50%). Rocks (6.75%) were rarely used for defecation in the study area.

Chi-square statistics (X^2= 9.96, df= 4, p-value= 0.041) was determined from the interview responses

Table 1. Encounter rate of Himalayan Red Panda in Kalikot District, Nepal.

Community forests	No. of sign plots	Transect surveyed (no)	Length of transect (km)	ER (signs/ km)
Himkalika	6	4	3.92	1.53
Dimreni	2	2	2.4	0.83
Jilli Triveni	3	4	3.85	0.78
Gairemela	1	2	1.81	0.55
Total	12	12	11.98	3.69

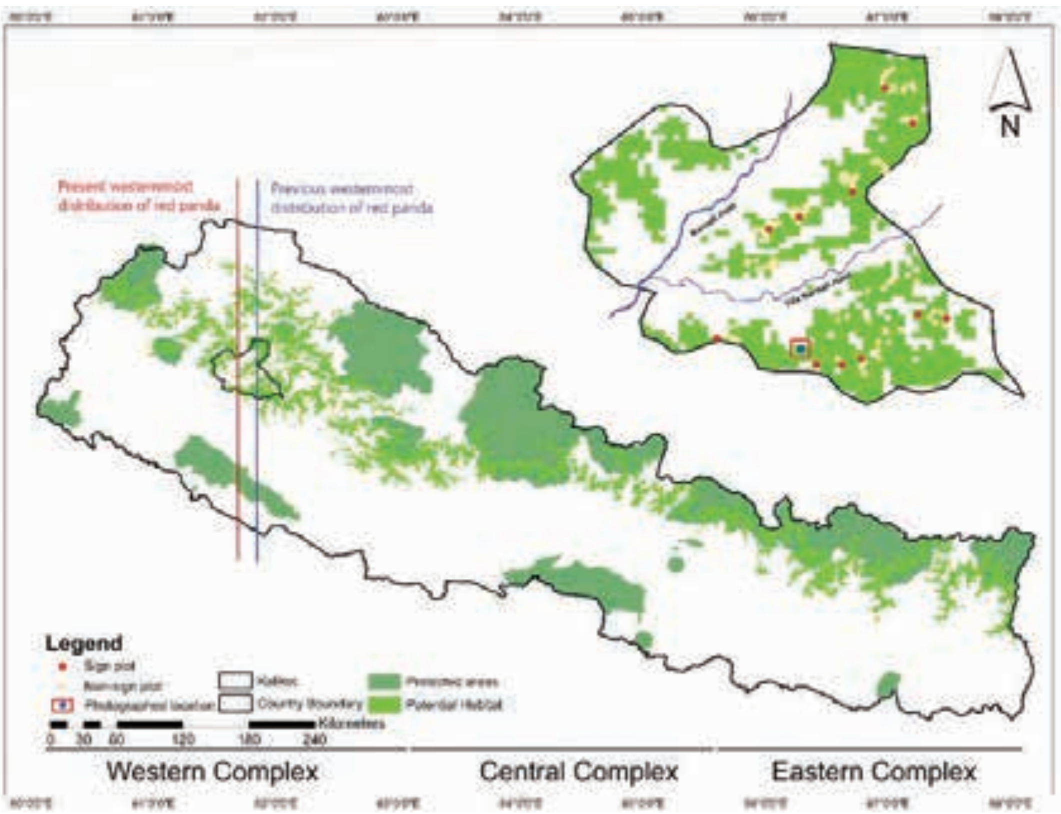

Figure 2 . Photographed location of Himalayan Red Panda

Image 1. Himalayan Red Panda scat on the tree branch

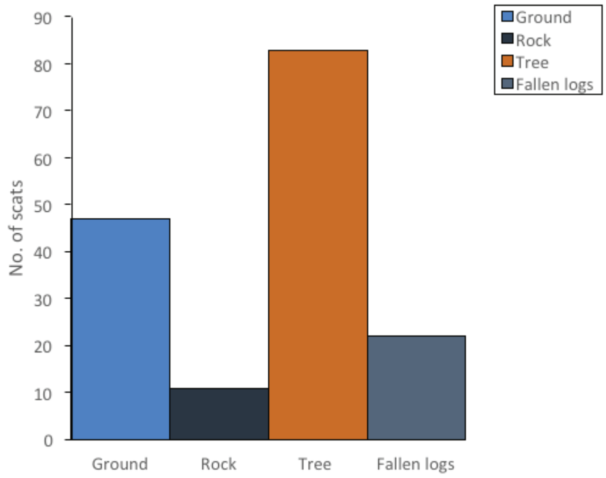

Figure 3. Substrate used for defecation by Himalayan Red Pandas.

Image 2. Satellite imagery of Himalayan Red Panda observation site.

on the existential threats in the potential habitat of the Himalayan Red Panda within the surveyed area. Of the total interviewed respondents, 38% of key informants believed that haphazard collection of fuelwood, fodder, timber, and non-timber forest products on both Government forest regimes and CFs is a key threat to Himalayan Red Panda habitat and their survival. Besides poaching (27% of respondents), unsustainable grazing practices (23% of respondents) and forest fires (12% of respondents) are some other prevailing anthropogenic activities that make this species vulnerable to extinction. The major threats identified through direct field observation include traditional transhuman herding activities, extensive resource collection, and human-induced forest fires.

DISCUSSION

This study provides documentation of photographic evidence of live Himalayan Red Panda from the westernmost distribution of its habitat range. Previously, the only indirect sign of the species was documented from Kalikot District (DNPWC & DFSC 2018). Based on ground-truthing, the occurrence of the Himalayan Red Panda has now been confirmed from Mahawai RM of Kalikot District. The distance between the recent photographed site and the location where the indirect sign was detected is 21.5km. The photographed location revealed some important information about the habitat preferences of the Himalayan Red Panda, which was photographed feeding on *Betula utilis* leaves; more than 80% of its diet includes bamboo species (Reid et al. 1991; Yonzon & Hunter 1991; Wei et al. 1999). Interestingly, feeding on leaves and fruits of this tree species has been sporadically documented in Nepal (Panthi et al. 2015; Sharma et al. 2014). Fondness for these sites with diverse vegetation such as *Betula utilis* other than bamboo leaves and shoots might be a survival approach to remain resilient in unfavorable circumstances. A similar study conducted in eastern and central Nepal showed the forests dominated by *Betula utilis*, *Rhododendron* spp., and *Abies* spp. with bamboo in the understory to be the most preferable plant species by the Himalayan Red Panda (Bista & Paudel 2013; Bista et al. 2017).

The average relative abundance (ER= 0.92 signs/km) of Himalayan Red Panda scats were found lower than the Taplejung District of eastern Nepal where an average ER was observed to be 1.36 signs/km (Lama 2019). This might be due to profligate propagation of the shrub layer and ground layer that had reduced the detection rate of indirect signs (Hemami & Dolmen 2005). On the contrary, Bista et al. (2017) detected comparatively lower encounter of 0.36 signs/km in Rasuwa District of central Nepal. The length of transect covered during the survey might not be precise enough due to inaccessible geographical terrain, which might have resulted in the varied relative abundance of Himalayan Red Panda signs in the study area. Besides, environmental factors such as precipitation, temperature, humidity, and wind can affect the detection rate of indirect signs during wildlife surveys. For instance, heavy precipitation probably degrades or takes away scats from the landscape over time (Reed et al. 2011).

Prior studies have suggested that fallen logs are an important habitat component for the Himalayan Red Panda (Wei et al. 2000; Pradhan et al. 2001) and could benefit the foraging strategy of this species. In accordance with the requirement of a nutritive diet, the Himalayan Red Panda changes the defecation substrate seasonally (Willliams 2003). For instance, defecations mostly take place on the forest floor throughout the growth season of bamboo shoots (Thapa et al. 2020).

Image 3. Himalayan Red Panda spotted feeding on *Betula utilitis* (© Nam Raj Shahi).

Similarly, this study discovered trees as the most commonly used defecation substrate. Likewise, Bista et al. (2017) observed similar results where 62.21% of total substrates recorded were the branches of the tree.

The increasing dependency of locals on forest resources has rapidly caused the Himalayan Red Panda habitat loss and fragmentation. Like eastern parts of Nepal, the study area has witnessed excessive bamboo, fuelwood, and fodder extraction in the core habitat of this species (Williams 2004). The lack of public understanding towards Himalayan Red Panda conservation has even escalated the issues. As a result, poaching and trafficking have increased at an alarming rate in western Nepal. Recently, Kalikot District was recognized as a crucial transit hub for the illegal trade of wildlife parts and medicinal plants (Red Panda Network 2019). Furthermore, unsustainable livestock grazing activities inside the CFs are causing detrimental impact on the natural resources and habitat. Panthi et al. (2017) and Lama et al. (2020) reported overgrazing pressure as one of the significant factors intensifying the effects of habitat loss and fragmentation. Another challenge to the Himalayan Red Panda conservation includes forest fires triggered due to the climate crisis and increasing anthropogenic disturbances. Slash-and-burn is a common way of cultivating medicinal plants such as *Swertia chiraita* particularly in eastern Nepal (Ministry of Forests & Soil Conservation 2015).

CONCLUSION

Wildlife photographic evidence is critical for sparking passion and interest among researchers and policymakers to take steps to help conserve fragile habitats and ecosystems. Wildlife photographs of endangered species, are valuable and hold importance in conservation efforts. This paper documents the first record (photographs from the wild) of the Himalayan Red Panda from its westernmost distribution. The Himalayan Red Panda is exposed to different anthropogenic threats as seen in this study and reported in others. Therefore, the Himalayan Red Panda habitat needs to be demarcated into two zones—a core zone and a buffer zone—in order to reduce human-related disturbances while at the same time respecting community rights of access to forest resources. This will help to conserve and protect the westernmost limit of Himalayan Red Panda distribution in the long run. The Himalayan Red Panda's habitat attributes, distribution, and food ecology in the study area need to be further researched.

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Ecological niche modelling predicts significant impacts of future climate change on two endemic rodents in eastern Africa

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Abstract: The impact of climate change on rodents is well studied, however, many of these studies are restricted to the Americas. Small- to medium-sized rodents, especially murids, are restricted in their home range and microclimatic niche breadth, and are known to be more sensitive to changes in bioclimatic conditions over time. We analyzed the effect of future climatic scenarios in the near and distant future, using two global climate models (CanESM5 and MIROC-ES2L) for two shared socio-economic pathways (SSP2-4.5 and SSP5-8.5), on two eastern Africa endemic small-bodied mice: *Stenocephalemys albipes* and *Mastomys awashensis*. Our results indicate that while *S. albipes* showed increases in area of climatic suitability in the future, *M. awashensis* is predicted to suffer severe decline in the area of its fundamental niche.

Keywords: Awash Multimammate Mouse, Ethiopian White-footed Mouse, decline, microclimate, MaxEnt.

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Author contribution: All authors contributed equally to the study, analysis, and writing the manuscript.

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INTRODUCTION

Rodents are the most diverse and abundant groups of mammals, accounting for approximately 2,200 species (Monadjem et al. 2015), distributed across the world on every continent except Antarctica (Nowak 1999). They occur in a wide range of terrestrial habitats, and serve the purpose of ecosystem engineers (Zhang et al. 2003) and keystone species in an ecosystem. Africa supports a large diversity of rodent species, with at least 463 known species (Monadjem et al. 2015), and new species described regularly; however, the ranges and habitats of some rodent species in Africa are not clearly known, due to many reasons ranging from inaccessible localities to insufficient data or resources (Kingdon 1997; Habtamu & Bekele 2008; Takele et al. 2011). This is of especial concern as rodents are not only diverse, but are an integral part of the ecosystem's functioning and health, contributing essential services (Fischer 2017). They are also of biogeographic, systematic, and conservation interest and priority (Happold 2013; Monadjem et al. 2015).

Rodents distributed in xerothermic habitats have been known to benefit from climate change towards a warmer, drier climate scenario, most likely due to their thermo-xerophilia being supported by the climatic conditions (Cameron & Scheel 2001). Climate change towards warmer and drier conditions has also resulted in an increase in species diversity in rodents in warm regions (Szpunar 2008). It is also possible that due to the effect of changing climate scenarios, migrations and emigrations take place, resulting in new regional populations being seeded and established in order to occupy the fundamental niche (Royer et al. 2016). As an extension of the conclusions drawn by Millien & Damuth (2004), treating fragmented populations as islands, it may be inferred that there is a possible slowing of the evolutionary rate of rodents as a result of climate change.

Hutchinson (1957) proposed the concept of the 'ecological niche' – an abstract representation of the biotic and abiotic factors deciding and limiting the distribution and abundance of a species. Identifying the ideal environmental niche of a species by accounting for certain limiting factors is one of the aims of ecological niche modelling (ENM) – this ideal niche is referred to as the fundamental niche (Griesemer 1994). The fundamental niche does not represent the real distribution of the species; in fact, it is usually larger than the realised distribution of the species (Soberón & Arroyo-Peña 2017). Ecological niche modelling uses presence-only or presence-absence occurrence data of a species and analyses it against a set of spatial covariates—most often, bioclimatic variables are used as the covariates in a climate change ENM study. Many diverse algorithms may be used for ENM, including generalised linear models (GLM), multivariate adaptive regression splines (MARS), and random forests (RF). MaxEnt (Phillips et al. 2006), however, is by far the most widely used algorithm due to its use of presence-only data, ease of access, customizability, and robustness (Ortega-Huerta & Peterson 2008; Elith et al. 2011; Merow et al. 2013; Radosavljevic & Anderson 2014).

Image 1. a.—Ethiopian White-footed Mouse *Stenocephalemys albipes* (Rüppell, 1842) | b—Awash Multimammate Mouse *Mastomys awashensis* (Lavrenchenko et al. 1998). © Alembrhan Assefa.

The present study analyses the effect of current and future climate scenarios on the predicted fundamental niche of two Ethiopian-endemic rodents, the Awash Multimammate Mouse *Mastomys awashensis* (Lavrenchenko et al. 1998) and the Ethiopian White-footed Mouse *Stenocephalemys albipes* (Rüppell, 1842) (Image 1). It aims to predict the impact of future climate change pathways (SSP2-4.5 and SSP5-8.5) on the niches of these species using maximum entropy (MaxEnt) modelling.

MATERIALS AND METHODS

Study area

This study is based in Ethiopia and Eritrea, as both *Mastomys awashensis* and *Stenocephalemys albipes* are endemic to this region (Image 2). *M. awashenis* is distributed in the scrublands of the Awash River bank, which primarily comprises small Acacia and Commiphora trees and thorny scrubs, and is also found in agricultural fields and wild areas of the northern highlands (Lavrenchenko et al. 1998; Meheretu et al. 2014). *S. albipes* occur in moist montane forests, scrublands at high altitudes, and agricultural fields (Yalden & Largen 1992; Tilaye 2005; Kassa & Bekele 2008) (Image 2). The study region varies widely in altitude, geography, and climatic conditions, resulting in a high diversity of biological resources and high levels of endemism. The altitude of the region varies from 115m below sea level to 4,620m above sea level, and it can be classified into three climatic zones – tropical, subtropical, and cool. The mean annual temperature ranges 16–27 ^{O}C, and the annual precipitation ranges 510–1,280 mm. While the study is restricted to Ethiopia and Eritrea, the ecological niche modelling (ENM) was conducted on the entirety of continental Africa to account for ecological niche data outside the political borders of these countries; final models were then cropped to Ethiopia and Eritrea's national boundaries.

Data collection

Occurrence data of the two study species were collected from Ethiopia and border regions in Eritrea. A total of 101 presence records were collected (34 for *M. awashensis* and 67 for *S. albipes*) from published literature (Lavrenchenko et al. 1998; Habtamu & Bekele 2008; Colangelo et al. 2010; Assefa & Srinivasulu 2019) and from GBIF (accessed August 2020) (Image 2; Appendix 1). Occurrence data of each species were spatially thinned using the package spThin (Aiello-Lammens et al. 2015) in R such that points within a 2km^2 area of each other were treated as duplicates and removed to account for spatial bias and autocorrelation

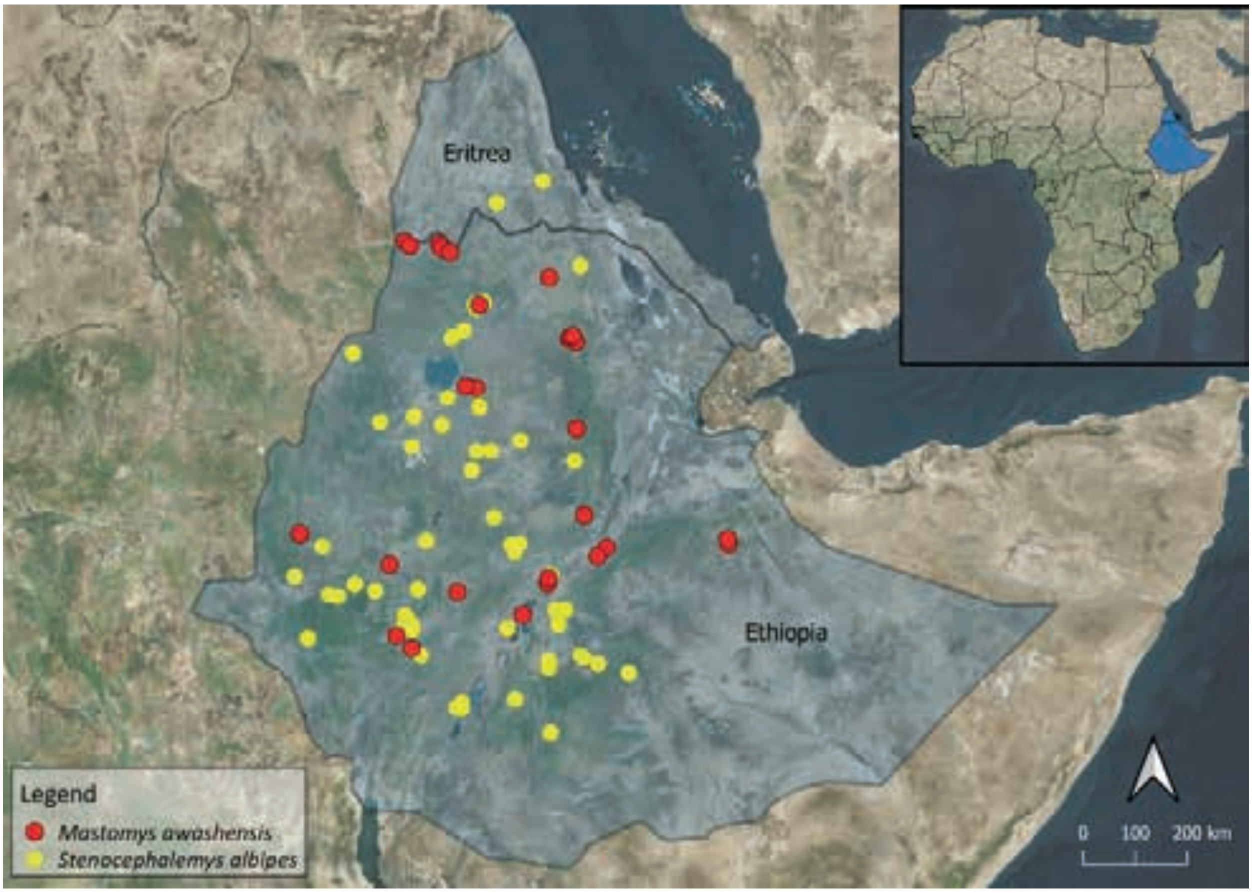

Image 2. Satellite map of the study area, with occurrence localities (before spatial rarefaction) shown (inset – satellite map of continental Africa, with study area highlighted in blue).

in sample collection.

Nineteen bioclimatic environmental variables were acquired at a resolution of 2.5 arc-minutes from the Worldclim 2 database for the current time period (Fick & Hijmans 2017). For future scenarios, 2.5 arc-minute resolution data from the Coupled Model Intercomparison Project 6 (CMIP6) were acquired for two shared socioeconomic pathways - SSP2 representing a middle-of-the-road scenario (Fricko et al. 2017) and SSP5 representing fossil-fuelled development in the future (Kriegler et al. 2017). Two global climate models were used to account for inter-model disparities in projection (Porfirio et al. 2014) - MIROC-ES2L (Tachiiri et al. 2019a,b) and CanESM5 (Swart et al. 2019a,b). Data were acquired for the 2041–2060 (near future) and 2061–2080 (distant future) time periods.

An analysis of multicollinearity conducted using the package Virtualspecies (Leroy et al. 2015) in R version 4.0.2 (R Core Team 2020) was used to select relatively uncorrelated variables for the modelling. Variables with an absolute value of Pearson's r >0.75 were subjected to pairwise comparisons of perceived ecological importance based on our understanding of the ecology and biology of the two species. All climate data were initially cropped to the extent of continental Africa; islands surrounding Africa including Madagascar were included, but southern Europe, the Middle East, and the Arabian Peninsula were not used.

Ecological niche modelling

A presence-only approach was used to model species distributions, using MaxEnt version 3.4.1 (Phillips et al. 2006); however, careful consideration of biases and selection of parameters is an essential step in order to maximise the robustness and reliability of niche models generated using MaxEnt (Derville et al. 2018). Hence, parameterisation was done according to the processes outlined in Merow et al. (2013) and Feng et al. (2019). To account for spatial bias, a Gaussian kernel density bias file of bandwidth 0.5 was created using the package SpatialEco (Evans 2020) in R, in order to weight the generation of background (pseudo absence) points for the analysis.

The model was parameterised for feature classes and regularisation multipliers using the package ENMEval (Muscarella et al. 2014). We tested a set of five regularisation multipliers: 0.5, 1, 2, 3, and 5, and six feature classes: Linear, Linear+Quadratic, Hinge, Hinge+Quadratic, Linear+Quadratic+Product, and Hinge+Quadratic+Product. Five-fold cross-validation was used and model performance was assessed using the area under the receiver operating characteristic curve (AUC) and the true skill statistic (TSS).

The continuous models for each scenario and each time period, as output by MaxEnt, were reclassified according to the maximum test sensitivity+specificity (MSS) threshold into binary models – the positive cells represented the fundamental niche of the species for each scenario and time period according to bioclimatic data. Finally, the binary models were cropped to Ethiopia and Eritrea's national boundaries. Area of climatic suitability was calculated as a percentage based on the ratio of positive to zero cells in the final binary models.

RESULTS

Ecological niche modelling

For the modelling of both *Mastomys awashensis* and *Stenocephalemys albipes*, 12 bioclimatic layers were selected based on multicollinearity analysis (Appendix 2): BIO1 (Annual mean temperature), BIO2 (Mean diurnal range), BIO4 (Temperature seasonality), BIO5 (Maximum temperature of warmest month), BIO6 (Minimum temperature of coldest month), BIO8 (Mean temperature of wettest quarter), BIO9 (Mean temperature of driest quarter), BIO14 (Precipitation of driest month), BIO15 (Precipitation seasonality), BIO16 (Precipitation of wettest quarter), BIO18 (Precipitation of warmest quarter), and BIO19 (Precipitation of coldest quarter). After data cleaning and spatial thinning, 10 occurrence points were used for *M. awashensis* and 65 occurrence points were used for *S. albipes*. Models with the lowest Δ AICc values were selected as the final models for ENM analyses of each species – for *M. awashensis* this was Linear features with RM= 0.5 (Δ AICc= 0), and for *S. albipes* this was Linear+Quadratic features with RM= 0.5 (Δ AICc= 0). The models for *M. awashensis* and *S. albipes* returned AUC values of 0.974 ± 0.009 and 0.977 ± 0.011, respectively, and TSS values of 0.735 and 0.801, indicating robust performance for both species. Mean diurnal range and temperature seasonality had high contribution to the models of both species (Table 1).

Stenocephalemys albipes ENM

The ecological niche model for *S. albipes* (MSS threshold 0.525) showed that 20.704% of the study area is climatically suitable in the current time period (Image 3; Table 2). In both future time periods, scenarios, and GCMs, there was significant increase, with an average increase of 18.437% to 39.141 ± 3.695 % in 2041–2060,

Table 1. Variable contributions of each bioclimatic layer used in the analysis, for both species.

		Percentage contribution		Permutation importance	
Variable	Name	*Stenocephalemys albipes*	*Mastomys awashensis*	*Stenocephalemys albipes*	*Mastomys awashensis*
BIO1	Annual mean temperature	41.2	0	0	0
BIO2	Mean diurnal range	15.4	27.7	12.8	18.2
BIO4	Temperature seasonality	28	47.6	38.8	74.2
BIO5	Max temperature of warmest month	0.1	0	0	0
BIO6	Min temperature of coldest month	0.1	3.8	0.6	0.1
BIO8	Mean temperature of wettest quarter	0.9	12.1	44.2	3
BIO9	Mean temperature of driest quarter	2	0.2	0.4	0.5
BIO14	Precipitation of driest month	0.5	1.9	0.4	2
BIO15	Precipitation seasonality	0.6	1	1.4	0.9
BIO16	Precipitation of wettest quarter	0.5	0.6	0.6	0.6
BIO18	Precipitation of warmest quarter	0.8	2.6	0.8	0.3
BIO19	Precipitation of coldest quarter	9.9	2.4	0	0.1

Table 2. Changes in climatically suitable areas of both species (in percentage values).

Mastomys awashensis				*Stenocephalemys albipes*			
Scenario	Time Period	CanESM5	MIROC-ES2L	Scenario	Time Period	CanESM5	MIROC-ES2L
-	Current	46.077%		-	Current	20.704%	
SSP2-4.5	2041–2060	0%	0%	SSP2-4.5	2041–2060	39.982	34.527
SSP2-4.5	2061–2080	0%	0%	SSP2-4.5	2061–2080	40.113	35.353
SSP5-8.5	2041–2060	0%	0%	SSP5-8.5	2041–2060	43.462	38.594
SSP5-8.5	2061–2080	0%	0%	SSP5-8.5	2061–2080	47.407	39.186

and a further increase of 1.373% to 40.514 ± 5.035 % in 2061–2080. There was little difference in the percentage area of future climatic suitability between SSP2-4.5 and SSP5-8.5 (Image 3; Table 2), indicating that different future climate scenarios have little impact on the overall effect of climate change on this species.

The variables with the highest percentage contribution and permutation importance for this species were temperature seasonality (BIO4; 28% contribution, 38.8% p. imp.) and mean diurnal range (BIO2; 15.4% contribution, 12.8% p. imp.) (Table 1). Additionally, annual mean temperature (BIO1) had the highest percentage contribution to the model (41.2%), but showed 0 permutation importance, and similarly, mean temperature of the wettest quarter (BIO8) showed the highest permutation importance (44.2%), but had a very low percentage contribution to the model (0.9%).

In the current scenario, highest environmental suitability (>75%) according to climate was seen at a mean diurnal range (BIO2) of 14.901 ± 1.556 ^{O}C, and a mean temperature seasonality (BIO4) of 114.903 ± 28.698 ^{O}C. In SSP2-4.5, representing a middle-of-the-road scenario, BIO2 underwent a slight decrease to a mean value of 14.137 ± 1.139 ^{O}C in the 2041–2060 time period, and further to 14.065 ± 1.185 ^{O}C in 2061–2080; BIO4 also decreased to a mean value of 109.902 ± 30.14 ^{O}C in 2041–2060, and increased to 111.027 ± 32.302 ^{O}C in 2061–2080. In SSP5-8.5, representing a fossil-fuelled economy, BIO2 underwent a decrease to a mean value of 14 ± 1.171 ^{O}C in the 2041–2060 time period, and further to 13.572 ± 1.258 ^{O}C in 2061–2080; BIO4, however, increased to a mean value of 116.249 ± 33.281 ^{O}C in 2041–2060, and further to 123.561 ± 39.416 ^{O}C in 2061–2080 (Table 3).

Mastomys awashensis ENM

The ecological niche model for *M. awashensis* (MSS threshold 0.777) showed that 46.077% of the study area is climatically suitable in the current time period (Image 4; Table 2). In both future time periods, scenarios, and

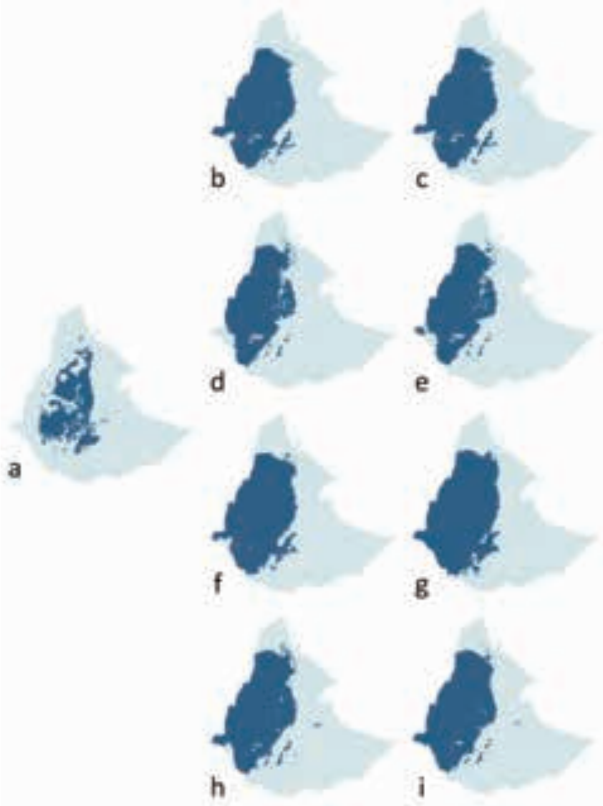

Image 3. Binary models output by MaxEnt for the distribution of *Stenocephalemys albipes*: a—current | b—2041–2060 in SSP2-4.5 and CanESM5 | c—2041–2060 in SSP5-8.5 and CanESM5 | d—2061–2080 in SSP2-4.5 and CanESM5 | e—2061–2080 in SSP5-8.5 and CanESM5 | f—2041–2060 in SSP2-4.5 and MIROC-ES2L | g—2041–2060 in SSP5-8.5 and MIROC-ES2L | h—2061–2080 in SSP2-4.5 and MIROC-ES2L | i—2061–2080 in SSP5-8.5 and MIROC-ES2L. Areas in dark blue represent high climatic suitability (i.e., the fundamental niche).

Image 4. Binary models output by MaxEnt for the distribution of *Mastomys awashensis*: a—current | b—2041–2060 in SSP2-4.5 and CanESM5 | c—2041–2060 in SSP5-8.5 and CanESM5 | d—2061–2080 in SSP2-4.5 and CanESM5 | e—2061–2080 in SSP5-8.5 and CanESM5 | f—2041–2060 in SSP2-4.5 and MIROC-ES2L | g—2041–2060 in SSP5-8.5 and MIROC-ES2L | h—2061–2080 in SSP2-4.5 and MIROC-ES2L | i—2061–2080 in SSP5-8.5 and MIROC-ES2L. Areas in dark blue represent high climatic suitability (i.e., the fundamental niche).

Table 3. Values for BIO2 (Mean diurnal range) and BIO4 (Temperature seasonality), averaged across both GCMs, for each time period and scenario for both species, at areas of high climatic suitability. Future values for *M. awashensis* are not given as it has 0 climatic suitability in all scenarios. Values are given as Mean ± standard deviation.

Stenocephalemys albipes			
Scenario	**Time Period**	**BIO2**	**BIO4**
-	Current	14.901 ± 1.556	114.903 ± 28.698
SSP2-4.5	2041–2060	14.137 ± 1.139	109.902 ± 30.14
SSP5-8.5	2041–2060	109.902 ± 30.14	14.065 ± 1.185
SSP2-4.5	2041–2060	14.065 ± 1.185	111.027 ± 32.302
SSP5-8.5	2041–2060	111.027 ± 32.302	14 ± 1.171
SSP2-4.5	2061–2080	14 ± 1.171	116.249 ± 33.281
SSP5-8.5	2061–2080	116.249 ± 33.281	13.572 ± 1.258
SSP2-4.5	2061–2080	13.572 ± 1.258	123.561 ± 39.416
SSP5-8.5	2061–2080	123.561 ± 39.416	14.935 ± 1.318
Mastomys awashensis			
Scenario	**Time Period**	**BIO2**	**BIO4**
-	Current	15.986 ± 1.075	136.481 ± 33.077

GCMs however, there was complete and total decline, resulting in 0% of the study area being climatically suitable by 2041–2060 and into the future (Image 4). This indicates that *M. awashensis* is extremely sensitive to climate change scenarios, and due to the effect of climate change alone, will lose all of its fundamental niche in the near future.

For this species, temperature seasonality (BIO4; 47.6% contribution, 74.2% p. imp.) and mean diurnal range (BIO2; 27.7% contribution, 18.2% p. imp.) were the highest contributors (Table 1). All the other variables had significantly lower percentage contribution and permutation importance.

In the current scenario, highest environmental suitability (>75%) according to climate was seen at a mean diurnal range (BIO2) of 15.986 ± 1.075 ^{o}C, and a mean temperature seasonality (BIO4) of 136.481 ± 33.077 ^{o}C (Table 3).

DISCUSSION

Ecological niche models have often been used to model and project rodent distributions and niches, but a large proportion of these studies are restricted to species found in the Americas (Martínez-Salazar et al. 2012; Bean et al. 2014; Kubiak et al. 2017; Flores-Zamarripa & Fernández 2018; Urbina-Cardona et al. 2019; Pardi et al. 2020). African rodents have also been studied using ENM techniques; Taylor et al. (2015) showed that trends in the distribution of Afromontane rodents reflect changes in biomes predicted by past, present, and future climate scenarios. McDonough et al. (2015) showed in a hindcasting-based study on the Bushveld Gerbil *Gerbiscillus leucogaster* in Zambezi, that it is significantly impacted by changing climatic scenarios, but this was not explored in terms of future climate change. A general ecological niche model fitted by Martinov et al. (2020) created an estimation of the current predicted distribution of *Mastomys* species, including *M. awashensis*, however this analysis did not estimate the fundamental niche through binary modelling, and there was no projection to future climate scenarios.

Our results are in agreement with the findings of Martinov et al. (2020), where the current distributions show high likelihood (>0.8) in areas included under our predicted current fundamental niche. Our results also emphasise the importance of ecological niche modelling and future projection of ENM analyses, due to the severity of the impact of climate change on *M. awashensis* (Ortega-Huerta & Peterson 2008).

The two species in our study—*Mastomys awashensis* and *Stenocephalemys albipes*—show significant changes as a result of changing climate scenarios. The result of our study for *S. albipes* shows a percentage area of current climatic suitability of 20.704%, with an increase of 18.437% in the near future (2041–2060), and a further increase of 1.373% in the distant future (2061–2080) in both climatic scenarios. Despite the different perspectives SSP2-4.5 and SSP5-8.5 take in terms of socioeconomic scenarios, emissions, and concentrations of greenhouse gases, there was negligible difference between the two in the future predictions of the fundamental niche of this species, suggesting that while climate change positively impacts this species, there is little impact of specific climate pathways. This result is in line with conclusions drawn by McDonough et al. (2015), where it was shown that rodent niches expanded from the last glacial maximum (approximately 200,000 years BP) through the last interglacial period (approx. 130,000 to 118,000 years BP), to the present day, most likely due to increasing temperatures across the year. The decrease in predicted future mean diurnal range most suitable for this species when compared to the current time period shows that in both shared socioeconomic pathway scenarios, this species will favour slightly colder climates. This effect is very small, however,as the largest change in mean diurnal range is from current to the 2061–2080 time period, with a 1.329 ± 0.298 ^{O}C decrease.

In the case of *M. awashensis*, the current niche is relatively large, with 46.077% appearing to be climatically suitable for this species; however, it appears to be incredibly sensitive to climate change events, as in all future scenarios and time periods, none of the study area (and also the rest of Africa) appeared to be climatically suitable. This is a massive and drastic change, which reflects the high sensitivity of this species to climate change. Seasonal variation in temperature and mean diurnal range of temperature are the most important predicting factors for this species, which leads to the inference that this species is likely to be most affected by temperatures getting generally warmer and less seasonally varied, which happens in both scenarios.

According to the MaxEnt model, both species had relatively wide areas of climatic suitability (Imgae 3, 4). For both species, the northern regions of Ethiopia and parts of southern Eritrea were climatically suitable—this included highland, some lowland regions of the Great Rift Valley, and some scattered sites in southeastern Ethiopia. *S. albipes* had climatically suitable regions in the highlands of northern, western, and central Ethiopia, including Tigray, Amhara, northern Oromia, Southern Nations, Nationalities, & Peoples' (SNNP), Addis Ababa, and eastern Benishangul-Gumaz regions. There are also some scattered suitable sites near Harari in Ethiopia, and Debub and Gash-Barka regions in Eritrea. In all future scenarios and time periods, this species' fundamental niche was seen to expand and move westward in Ethiopia and Eritrea, occupying the Tigray, Amhara, Benishangul-Gumaz, Oromia, Addis Ababa, Gambela, and SNNP regions in Ethiopia & Gash-Barka and Debub regions in Eritrea. Some scattered areas of suitability were also seen in the Eritrean & Ethiopian highlands and in the highlands south of Dire Dawa.

M. awashensis showed climatic suitability in Tigray, Amhara, eastern Benishangul-Gumaz, Oromia, SNNP, Addis Ababa, Harari, and some parts of northern Somali regions. In Eritrea, it showed high climatic suitability in Gash-Barka and Debub. For both species, the Eritrean and Ethiopian highlands formed a distinct geographical barrier, and no areas of climatic suitability were present east of the hill range. Earlier studies of both species have shown them to be restricted to highland habitats (Corti et al. 2005; Mohammed et al. 2010; Meheretu et al. 2014), however, some later studies reported them to occur from lowlands as well (Habtamu & Bekele 2008; Lavrenchenko et al. 2010). Our study corroborates these with our current predicted niche expanding to lowland regions as well as highlands.

The results of the present study show the efficacy of ecological niche modelling in offering important insights into the potential geographic distributions of African rodents. Although *M. awashensis* is present and has areas of climatic suitability in protected areas, it is likely that there are no species-specific conservation measures in place. The eventual increase in anthropogenic impact on the natural areas will only decrease the chances of the species' survival in the future, as the impact of climate change alone is very large. It is important to plan ground-truthing of the sites shown as part of the fundamental niche of both this study's species in order to ascertain their true distribution, range, and realised niche, as this will help create better conservation strategies. It is imperative that species-specific conservation measures are set in place based on the results of said ground-truthing, including in situ conservation management, captive breeding, and planned reintroductions.

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Appendix 1. Localities used in ENM analysis of *Stenocephalemys albipes* and *Mastomys awashensis*.

Name	Latitude	Longitude	Locality	Reference
Stenocephalemys albipes	5.800	39.200	Kebre Mengist, Ethiopia	GBIF
Stenocephalemys albipes	6.217	37.667	Dega Done, Gemu-Gofa, SNNP, Ethiopia	Demeke et al. 2007
Stenocephalemys albipes	6.233	37.567	Mt Dorse, Chenckia, Gemu-Gofa, SNNP, Ethiopia	GBIF
Stenocephalemys albipes	6.383	38.583	Kebre Mengist, Sidamo, Ethiopia	GBIF
Stenocephalemys albipes	6.833	40.550	Jebo Samo, Bale, Ethiopia	GBIF
Stenocephalemys albipes	6.917	39.167	Gedeb Mts., Ethiopia	GBIF
Stenocephalemys albipes	6.983	40.020	7 km SE of Goba, Bale, Ethiopia	GBIF
Stenocephalemys albipes	7.050	39.167	Webi river, north of Dodola, Arsi, Ethiopia	GBIF
Stenocephalemys albipes	7.100	39.767	Webi river, W of Dinshu, Bale, Ethiopia	Zerihun et al. 2012
Stenocephalemys albipes	7.117	39.733	5 km of W of Dinshu, Bale, Ethiopia	GBIF
Stenocephalemys albipes	7.133	39.717	Mount Gaysay, Bale, Ethiopia	GBIF
Stenocephalemys albipes	7.134	36.954	Gorka Bersa, Chebera-Churchura NP, Ethiopia	Demeke & Afework 2014
Stenocephalemys albipes	7.433	35.000	Godare forest, Tepi, Ethiopia	Lavrenchenko 2017
Stenocephalemys albipes	7.580	36.800	Seka, 3 Km N Of, Horo, Ethiopia	GBIF
Stenocephalemys albipes	7.600	38.450	Alage, Ethiopia	Agerie & Afework 2015
Stenocephalemys albipes	7.620	36.770	Buyo Kechema, Ethiopia	GBIF
Stenocephalemys albipes	7.650	36.800	Jiren Farm, Jimma, Ethiopia	Tadesse & Afework 2012
Stenocephalemys albipes	7.667	39.333	Albasso forest, Ethiopia	GBIF
Stenocephalemys albipes	7.750	36.730	Atro, Agaro, Ethiopia	GBIF
Stenocephalemys albipes	7.820	36.680	Agaro, 14 km by road SE of Mejo, Ethiopia	GBIF
Stenocephalemys albipes	7.833	39.333	Wodajo, Ethiopia	GBIF
Stenocephalemys albipes	7.917	39.283	Jawi Chilalo, Galama mtn, Arsi, Ethiopia	Mohammed et al. 2010
Stenocephalemys albipes	7.917	39.450	Mt Albasso, Camp Wodajo, Ethiopia	GBIF
Stenocephalemys albipes	8.155	35.525	Illubabor, W of Gore, Ethiopia	GBIF
Stenocephalemys albipes	8.183	35.367	Lemen, Ethiopia	GBIF
Stenocephalemys albipes	8.250	36.167	Yemenigisit Den Yebaja Chaka, Ethiopia	GBIF
Stenocephalemys albipes	8.280	36.900	Atenago, Ethiopia	GBIF
Stenocephalemys albipes	8.367	35.817	Wabo, 5 km of W of Scecchi river, Ethiopia	GBIF
Stenocephalemys albipes	8.500	34.775	Addo, 7km SW of Dembidolo, Ethiopia	GBIF
Stenocephalemys albipes	8.517	39.200	Wonji Sugarcane, Qoboluto Tumsa, Ethiopia	Serekebirhan et al. 2011
Stenocephalemys albipes	8.917	38.583	Dima Goranda, Ethiopia	GBIF
Stenocephalemys albipes	9.017	35.250	Sido Were Wele, Ethiopia	GBIF
Stenocephalemys albipes	9.050	38.520	Berifeta Lemefa, near Holetta, Ethiopia	GBIF
Stenocephalemys albipes	9.067	38.650	Menagesha forest, Shoa, Ethiopia	Afework 1996
Stenocephalemys albipes	9.117	37.050	Bako, Shoa, Ethiopia	GBIF
Stenocephalemys albipes	9.517	38.217	Subagajo, Ethiopia	GBIF
Stenocephalemys albipes	10.333	37.833	Debra Markos, Gojjam, Amhara, Ethiopia	Ejigu & Afework 2013
Stenocephalemys albipes	10.494	39.611	Yetere forest, Ethiopia	Gezahegn et al. 2016
Stenocephalemys albipes	10.667	38.167	Debre Werk, Ethiopia	GBIF
Stenocephalemys albipes	10.667	37.917	Naziret M Alem, Ethiopia	GBIF
Stenocephalemys albipes	10.739	36.800	Arditsy forest, Awi zone, Ethiopia	Getachew & Afework 2015
Stenocephalemys albipes	10.846	38.675	Borena-Sayint NP, Ethiopia	Meseret & Solomon 2014
Stenocephalemys albipes	11.117	37.317	Amedamit Mount, Amhara, Ethiopia	GBIF
Stenocephalemys albipes	11.167	36.250	Pawe area, B. Gumuz, Ethiopia	Tilahun et al. 2012

Name	Latitude	Longitude	Locality	Reference
Stenocephalemys albipes	11.267	36.833	Dangila, Amhara, Ethiopia	GBIF
Stenocephalemys albipes	11.417	37.967	Shime, Ethiopia	GBIF
Stenocephalemys albipes	11.583	37.417	Bihar-Dar, Amhara, Ethiopia	GBIF
Stenocephalemys albipes	11.717	37.917	Mahdere Marayam, Gondar, Amhara, Ethiopia	GBIF
Stenocephalemys albipes	12.350	35.783	Alatish NP, Ethiopia	Tadesse & Afework 2008
Stenocephalemys albipes	12.617	37.483	Gondar, Amhara, Ethiopia	GBIF
Stenocephalemys albipes	12.633	37.500	NE of Angereb Dam, Gondar, Amhara, Ethiopia	GBIF
Stenocephalemys albipes	12.750	37.700	Yerer mountain forest, Shoa, Ethiopia	Yonas & Fikresilasie 2015
Stenocephalemys albipes	13.133	37.917	Debark, NE Gondar, Amhara, Ethiopia	GBIF
Stenocephalemys albipes	13.133	37.917	Semien Mts, Amhara, Ethiopia	GBIF
Stenocephalemys albipes	13.192	37.893	Debir, Ethiopia	GBIF
Stenocephalemys albipes	13.232	38.038	Semien NP, Ethiopia	GBIF
Stenocephalemys albipes	13.650	39.172	Hagere-selam, Ethiopia	Meheretu et al. 2012
Stenocephalemys albipes	14.166	37.309	Habesha Adi Goshu, Ethiopia	GBIF
Stenocephalemys albipes	14.183	37.305	Kunama Adi Goshe, Ethiopia	GBIF
Stenocephalemys albipes	14.210	36.766	Adebayetown, Ethiopia	GBIF
Stenocephalemys albipes	14.251	37.270	Kunama Adi Goshe, Ethiopia	GBIF
Stenocephalemys albipes	14.284	36.688	Kafta-Sheraro NP, Tigray, Ethiopia	Alembrhan & Srinivasulu 2019
Stenocephalemys albipes	14.291	36.677	Helet Coka, Ethiopia	GBIF
Stenocephalemys albipes	14.950	38.270	Mt. Kullu, Shambiko, Eritrea	GBIF
Stenocephalemys albipes	15.332	39.064	Nefasit, Eritrea	GBIF
Stenocephalemys albipes	11.083	36.850	Aquatimo forest, Gojjam, Ethiopia	Moges & Dessalegn 2015
Mastomys awashensis	9.000	40.167	Awash, Ethiopia	Lavrenchenko et al. 1998
Mastomys awashensis	7.833	38.717	S of Ziway Lake, Ethiopia	Corti et al. 2005
Mastomys awashensis	8.383	39.150	E of Koka Lake, Bati Qelo, Ethiopia	Lavrenchenko & Corti 2008
Mastomys awashensis	9.065	42.275	Nigaya Bobasa, Babile Sanctuary, Ethiopia	Lavrenchenko et al. 2010
Mastomys awashensis	13.668	39.175	Hagere-selam, Ethiopia	Meheretu et al. 2014
Mastomys awashensis	12.600	39.517	N of Lake Hashenge, Ethiopia	Mengistu et al. 2015
Mastomys awashensis	14.210	36.766	Near Adebaye Town, Kafta Sheraro National Park, Ethiopia	Alembrhan & Srinivasulu 2019
Mastomys awashensis	14.251	37.270	Kunama Adi Goshu, Kafta Sheraro National Park, Ethiopia	Alembrhan & Srinivasulu 2019
Mastomys awashensis	14.284	36.688	Helet Coka, Ethiopia	GBIF
Mastomys awashensis	14.287	36.679	Adebaye Geter, E of Himora, Ethiopia	GBIF
Mastomys awashensis	14.184	37.305	NW of Birkuta, Ethiopia	GBIF
Mastomys awashensis	14.168	37.310	Habesha Adi Goshu, Ethiopia	GBIF
Mastomys awashensis	7.2545	36.798	Gojeb River, Ethiopia	Martynov et al. 2020
Mastomys awashensis	7.4782	36.5334	Shebe, Ethiopia	Martynov et al. 2020
Mastomys awashensis	8.2331	37.5887	Gibe National Park, Ethiopia	Martynov et al. 2020
Mastomys awashensis	8.2338	37.5823	Gibe National Park, Ethiopia	Martynov et al. 2020
Mastomys awashensis	8.4651	39.1606	Lake Koka, Bati Qelo, Ethiopia	Martynov et al. 2020
Mastomys awashensis	8.6943	36.4149	Didessa River, Ethiopia	Martynov et al. 2020
Mastomys awashensis	8.8453	40.0119	Awash National Park, Ethiopia	Martynov et al. 2020
Mastomys awashensis	9.0586	42.2796	Babile Elephant Sanctuary, Ethiopia	Martynov et al. 2020
Mastomys awashensis	9.1478	42.2624	Babile Elephant Sanctuary, Ethiopia	Martynov et al. 2020
Mastomys awashensis	9.2249	34.8662	Dhati-Welel National Park, Ethiopia	Martynov et al. 2020

Name	Latitude	Longitude	Locality	Reference
Mastomys awashensis	9.2393	34.8653	Dhati-Welel National Park, Ethiopia	Martynov et al. 2020
Mastomys awashensis	9.2449	34.8644	Dhati-Welel National Park, Ethiopia	Martynov et al. 2020
Mastomys awashensis	9.5548	39.7818	Ankober, Ethiopia	Martynov et al. 2020
Mastomys awashensis	9.5554	39.7657	Ankober, Ethiopia	Martynov et al. 2020
Mastomys awashensis	11.0526	39.6481	Kombolcha, Ethiopia	Martynov et al. 2020
Mastomys awashensis	11.7525	37.9068	Gumara River, Ethiopia	Martynov et al. 2020
Mastomys awashensis	11.7797	37.7313	Gumara River, Ethiopia	Martynov et al. 2020
Mastomys awashensis	12.5492	39.6431	Adi Mancarre, Ethiopia	Martynov et al. 2020
Mastomys awashensis	12.6393	39.5383	Adi Aba Musa, Ethiopia	Martynov et al. 2020
Mastomys awashensis	12.6551	39.5816	Kube, Ethiopia	Martynov et al. 2020
Mastomys awashensis	13.1858	37.9671	Simien Mts National Park, Ethiopia	Martynov et al. 2020
Mastomys awashensis	14.0945	37.4575	Mai-Temen, Ethiopia	Martynov et al. 2020

Appendix 2. Correlation matrix resulting from the spatial multicollinearity test of the 19 bioclimatic variables used in the analysis.

Layer	BIO1	BIO2	BIO3	BIO4	BIO5	BIO6	BIO7	BIO8	BIO9	BIO10	BIO11	BIO12	BIO13	BIO14	BIO15	BIO16	BIO17	BIO18	BIO19
BIO1	1.000																		
BIO2	-0.031	1.000																	
BIO3	0.141	-0.489	1.000																
BIO4	-0.116	0.567	-0.951	1.000															
BIO5	0.633	0.554	-0.604	0.666	1.000														
BIO6	0.681	-0.599	0.745	-0.766	-0.123	1.000													
BIO7	-0.120	0.769	-0.906	0.958	0.688	-0.805	1.000												
BIO8	0.744	0.128	0.134	-0.128	0.471	0.486	-0.074	1.000											
BIO9	0.516	-0.258	-0.074	0.116	0.405	0.330	0.001	-0.053	1.000										
BIO10	0.754	0.312	-0.501	0.556	0.957	0.077	0.516	0.496	0.561	1.000									
BIO11	0.775	-0.399	0.701	-0.713	0.022	0.969	-0.695	0.578	0.326	0.186	1.000								
BIO12	-0.051	-0.627	0.767	-0.776	-0.660	0.555	-0.800	-0.076	-0.051	-0.534	0.464	1.000							
BIO13	0.042	-0.513	0.718	-0.769	-0.565	0.574	-0.758	-0.002	-0.055	-0.452	0.527	0.920	1.000						
BIO14	-0.079	-0.478	0.463	-0.377	-0.400	0.303	-0.461	-0.063	-0.002	-0.303	0.185	0.571	0.334	1.000					
BIO15	0.425	0.282	0.092	-0.180	0.246	0.274	-0.053	0.490	-0.064	0.210	0.393	-0.154	0.111	-0.402	1.000				
BIO16	0.004	-0.501	0.716	-0.762	-0.585	0.543	-0.747	-0.029	-0.075	-0.479	0.496	0.937	0.991	0.352	0.070	1.000			
BIO17	-0.077	-0.530	0.507	-0.421	-0.436	0.342	-0.510	-0.072	0.017	-0.329	0.215	0.626	0.378	0.984	-0.428	0.394	1.000		
BIO18	-0.170	-0.513	0.610	-0.637	-0.633	0.376	-0.653	-0.035	-0.244	-0.571	0.272	0.805	0.713	0.536	-0.150	0.728	0.577	1.000	
BIO19	0.070	-0.461	0.456	-0.417	-0.318	0.404	-0.486	-0.074	0.185	-0.183	0.335	0.631	0.547	0.418	-0.208	0.562	0.454	0.279	1.000

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COMMUNICATION

Avian diversity in a fragmented landscape of central Indian forests (Bhopal Forest Circle)

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Abstract: With increasing fragmentation of natural areas and a dramatic reduction of forest cover in several parts of the world, quantifying the impact of such changes on species richness and community dynamics has been a subject of much concern. Therefore, this study intends to assess avifaunal biodiversity in fragmented forests. Forest patches between the sizes of 10ha and 700ha were identified in Bhopal Forest Circle (BFC), which covers the Vindhyan plateau. Forest patches were classified based on their size and degree of isolation. A sample of 21 forest fragments was selected using proportional sampling. Bird surveys were conducted using the point count method at each site. Three replicates were taken at each site. Avian species richness of each patch was calculated. The results suggest that species richness is positively associated with the size of the forest patches. Larger forest patches such as Binapur (166ha, Chao 1= 73), Sayar (107ha, Chao 1= 78) and Kalyanpura (133ha, Chao 1= 80) had relatively high species richness, except for patches including Narsinghgarh (393ha, Chao 1= 28) and Singota (184ha, Chao 1= 45) with high levels of anthropogenic disturbance. Smaller forest patches were found to have fewer bird species, although small forest patches with lesser degrees of anthropogenic disturbance such as Lalghati (99ha, Chao 1 = 62), Lasudli (16ha, Chao 1 = 65), Ghot (36ha, Chao 1 = 53), and Nasipur (23ha, Chao 1 =52) were more diverse than other patches. These patches were more protected due to being sacred groves (Lalghati and Lasudli) or under private ownership (Ghot and Nasipur). A total of 131 bird species were recorded from all the sampled forest patches. These results suggest that forest patches embedded in an agrarian landscape play a vital role in conserving biodiversity, hence conservation efforts should also be focused on these forest fragments.

Keywords: Avian diversity, BFC, degree of isolation, Forest patches, patch size.

Hindi संक्षेप: प्राकृतिक क्षेत्रों के बढ़ते विखंडन और विश्व के अनेक भागों के वन क्षेत्रो में हो रही कमी के साथ प्रजातियों की समृद्धि और सामुदायिक गतिशीलता पर पड़ने वाले परिवर्तनों के प्रभाव की मात्रा का आकलन करना बहुत चिंता का विषय रहा है । अतः, यह अध्ययन खंडित वनों में पक्षी विविधता का आकलन करने के लिए किया गया है। 10ha और 700ha के आकार के बीच के वन खंड, भोपाल वन वृत्त (BFC) में पहचाने गए, जो विंध्य पठार का भाग है । इन वन खंडो को उनके आकार (size) और अलगाव के स्तरो (degree of Isolation) के आधार पर वर्गीकृत किया गया । आनुपातिक नमूना चयन (proportional sampling) का उपयोग करते हुए 21 वन खंडो का नमूना चुना गया । प्वाइंट काउंट (point count) विधि का उपयोग कर के प्रत्येक वन खंड में पक्षी निरिक्षण किया गया और 3 पुनरावृति की गई। प्रत्येक खंड की पक्षी प्रजातियों की समृद्धि की गणना की गई थी। परिणाम दर्शाते हैं कि पक्षी प्रजातियों की संख्या सकारात्मक रूप से वन खंडो के आकार से जुड़ी हुई है। बीनापुर (166ha, Chao 1= 73), सायर (107ha,Chao1=78) और कल्याणपुरा (133ha, Chao 1=80) जैसे बड़े वन खंडो में अपेक्षाकृत अधिक प्रजातियों की संख्या थी। नरसिंहगढ़ (393ha, chao 1=28) और सिंगोटा (184ha, Chao 1 =45) खंडो में पक्षी प्रजातियों की संख्या कम मिली क्योंकि इन खंडो में मानवजनित गतिविधियों का उच्च स्तर पाया गया । छोटे वन खंडो में पक्षी प्रजातियों की संख्या कम पाई गई । यद्यपि लालघाटी (99ha, chao 1 = 62), लासुडली (16ha, chao 1 = 65), घोट (36ha, chao 1 = 53), और नसीपुर (23ha, chao 1 = 52) जैसे खंडो में मानवजनित गतिविधियां कम पाई गई। अतः इन वन खंडो के छोटे होने के बाद भी अन्य वन खंडो की तुलना में पक्षी विविधता अधिक पाई गई । ये वन खंड पवित्र स्थल (लालघाटी और लासूडली) या निजी स्वामित्व (घोट और नसीपुर) के अंतर्गत होने के कारण अधिक संरक्षित थे। सभी नमूना वन खंडो से कुल 131 पक्षी प्रजातियाँ दर्ज की गईं। इन परिणामों से पता चलता है कि कृषि परिदृश्य में लगे वन खंड जैव विविधता के संरक्षण में महत्वपूर्ण भूमिका निभाते हैं, इसलिए इन वन खण्डों में संरक्षण प्रयासों पर भी ध्यान दिया जाना चाहिए।

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INTRODUCTION

Habitat destruction is taking place at an alarming rate in various parts of the world. Land-use and land cover change are major causes of biodiversity loss. Vast continuous tropical forests have been transformed into remnant forests scattered across human-dominated areas in the last few decades due to growth in populations and changes in technology (Wiens 1995; Hill et al. 2011). This conversion of continuous forests into many smaller forest patches leads to physical and biological changes in the forest environment, which lead to changes in habitat structure, and subsequently to biodiversity loss. These physical and biological changes are reduced patch size, increased degree of isolation and increase in new habitat types; however, overall suitable habitat decreases with habitat fragmentation resulting in loss of species diversity (Andren 1994). The fragmentation of the patches also leads to more significant exposure to human land uses along fragment edges commencing persistent changes to the ecological structure and function of the remaining fragments leading to loss of biodiversity (Shahabuddin & Terborgh 1999; Feeley et al. 2007). Forest patches resulted from the change in land use and land cover can be defined as relatively homogenous areas which differ from its surrounding land use within the landscape (Peters et al. 2009). Recent studies indicate that the fragmentation has impacts on biotic interactions between species (Morris 2010) and if not focused can lead to a cascade effect in the tropical ecosystem, rising concerns on viability of these patches in long-term conservation (Hill et al. 2011). Forest remnants or patches need attention due to an increase in their number as a result of the intensification of agriculture and deforestation. These patches can play a vital role in conserving the biodiversity and overall health of the ecosystem in a landscape. There is a lack of information on the biodiversity of forests patches in human-modified landscapes, especially in rural areas. Conservation studies have focused on areas with a high diversity of flora and fauna, i.e., protected areas. But forest patches demarcated as reserve forests, situated in rural landscapes are deprived of attention from conservationists (Chazdon et al. 2009). These patches can play a vital role in providing refuge to important species and act as a stepping stone in corridor development. The forest patches in these landscapes are of different size, shape, degree of isolation, and degree of disturbance. Together, these patches can support a variety of flora and fauna and save important species from local extinction. Therefore, there should be studies based on integrated landscape conservation approach in these fragmented landscapes. These studies should be focused on population, their dispersal, habitat use, the effect of context, connectivity and degree of disturbance on the population of local flora and fauna (Chazdon et al. 2009). There have been various studies across the world in which community structure and composition of vegetation and animals were examined. Many of them also investigated the effect of patch level as well as landscape levels variables on the composition and configuration of the flora and fauna of the forest patches. There are also studies where community dynamics were examined in forest patches.

Oliver et al. (2011), in their study in urban parks found that park area was the best predictor of species richness of resident birds and for migratory species, the best predictors were habitat diversity and developed area within the park. In another study conducted to study the influence of regional gradients in land-use on richness, composition and turnover of bird assemblages in small forests, it was again concluded that patch area is one of the most important variables at patch level which affects the richness of the bird communities (Bennett et al. 2004). Similarly, a study conducted in urbanized tropical islands it was concluded that patch size has the highest predictive power in explaining the species richness of the resident birds of the forest patches (Suarez-Rubio & Thomlinson 2009). A study on relative effects of fragment size and connectivity on bird communities in Atlantic rain forests suggest that only terrestrial insectivores, omnivores and frugivorous birds were affected by patch area. Other feeding guilds such as understory insectivores, nectarivorous, and others were not affected by the area of the patch (Martensen et al. 2008).

There have been also attempts to study the effect of landscape and patch level variables on animal groups other than birds. A study conducted in medium- and large-sized terrestrial mammals in a fragmented rain forest by Garmendia et al. (2013) suggests that number of species increases with increase in the size of the fragmented patch. Effect of landscape metrics on butterfly species richness was studied at different spatial scale and they found a significant impact of spatial scale on landscape-butterfly richness relationship (Rossi & Halder 2010).

To understand the community structure, composition and role of these forest patches, there is a need to measure of biodiversity. Species richness is the most common measure of biodiversity but it is difficult to measure the species richness of all flora and fauna present in the study area. Therefore, sample and survey surrogate or indicators of biodiversity are taken. There is an assumption that the diversity of these indicators is correlated with the diversity of other groups of species (Rossi & Halder 2010). Avian species diversity of a forest patch embedded in a landscape mosaic can be a good biodiversity indicator. The avian diversity in these forest patches will be dependent on various factors affecting the habitat and animals at different spatial scale. Local variables deciding the avian diversity are vegetation composition and structure, forest ground cover, canopy closure, size of the patch, and shape of the patch. At a landscape scale, variables affecting the avian diversity are the degree of isolation, connectivity, proximity to other forest fragments and patch density. Avian diversity can be observed simply as species richness. Species richness is the simplest method of characterizing a community's diversity. Species diversity is described as species richness, which is the number of species and evenness which is how equally abundant species are within the community. The community in which all the species present are equally abundant is considered to be even. Population with a large number of species and high evenness is considered to be more diverse (Magurran 1988). In this study, vegetation attributes of the sampled patches of BFC were calculated the vegetation attributes of the sampled forest patches of Bhopal Forest Circle (BFC), which is a part of Vindhyan and Malwa plateau. Bird species richness (observed) was determined. Undetected species of birds were also estimated using Chao 1 and abundance-based coverage (ACE) estimators. This study was conducted in BFC of Madhya Pradesh during 2015 to 2018. This study intends to estimate the species richness in the forest fragments of central Indian landscape. Forest fragments were selected following Island Biogeography Theory by MacArthur & Wilson (1967).

MATERIALS AND METHODS

Study area

The study was conducted in Bhopal Forest Circle of Madhya Pradesh forests from March 2015 to May 2018. BFC consists of six forest divisions: Bhopal, Sehore, Rajgarh, Vidisha, Raisen, and Obaidullaganj (Fig. 1; Image 1,2). All the divisions except Rajgarh come under Vindhyan Plateau agro-climatic region while Rajgarh comes under Malwa Plateau region. BFC consists of tropical dry deciduous forests. BFC has a total forest area of about 6,906.93km^2. Out of which reserved forest is 4,076.72km^2, the protected forest is 2,761.98km^2, and the unclassified forest is 68.23km^2 (MP Forest 2020).

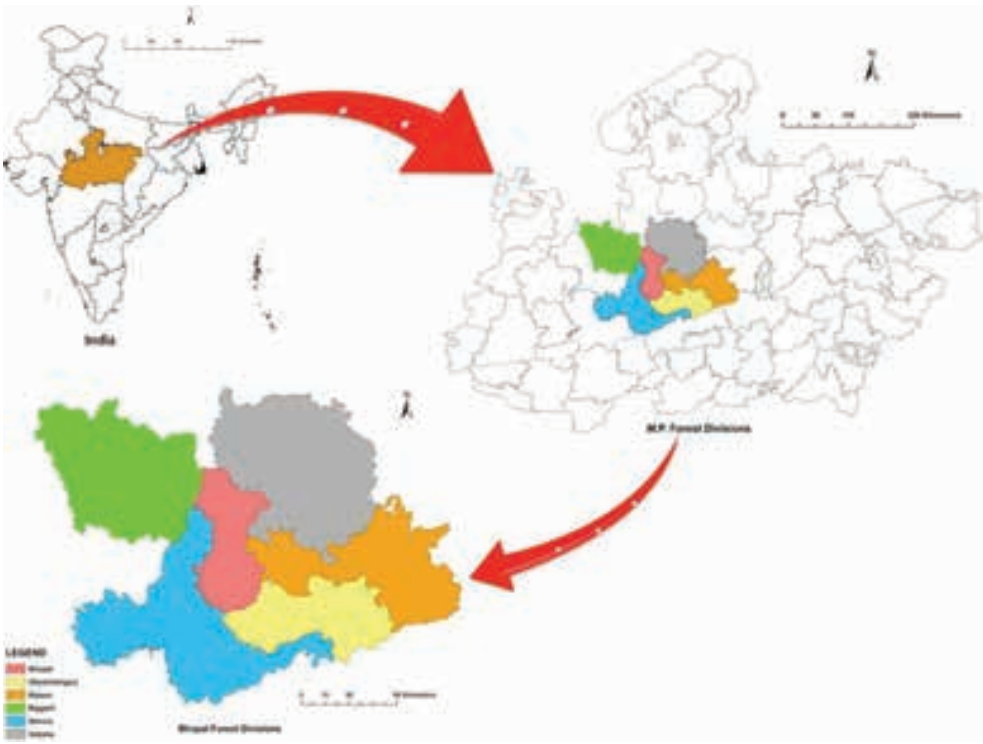

Figure 1. Geographic location of the study area in Bhopal Forest Circle in India.


Image 1 & 2. Location of the study area in Bhopal Forest Circle in India. © Madhya Pradesh Forest Department and Mr. Suman Raju.

Forest

Twenty-Two forest subtypes have been identified in Madhya Pradesh as per the classification by Champion & Seth (1968). These forest types belong to three groups, viz.: tropical dry deciduous forest, tropical moist deciduous forest, and tropical thorn forest. Tropical dry deciduous forest is the dominant group. Within sub-groups, dry teak forest is dominant (26.40%) followed by southern dry mixed deciduous forest (24.55%) and northern mix dry deciduous forest (18.55%). Rest of the forest types occupy less than 6% of forests cover (FSI, 2019). The BFC is characterized by tropical dry deciduous forest (Group 5). The major sub-groups of Group 5 and Group 6 forest types found in the study area encompass the following:

1. 5A/C 1b dry teak forest
2. 5A/C3 southern dry mixed deciduous forest
3. 5/DS1 dry deciduous scrub
4. 5/E1 *Anogeissus pendula* forest

The major species is Teak *Tectona grandis* in dry teak forests while *Butea monosperma*, *Diospyros melanoxylon*, *Acacia catechu*, *Anogeissus latifolia*, *Wrightia tinctoria*, *Lannea coromandelica*, and *Cassia fistula* are major species of mixed forests. *Anogeissus pendula* forest is dominated by *Anogeissus pendula* along with *Anogeissus latifolia.* Tree species found in dry deciduous scrub forests are *Butea monosperma*, *Acacia leucophloea, Lannea coromandelica*, *Diospyros melanoxylon*, and *Anogeissus latifolia*. In BFC, there are four protected areas; out of which three are wildlife sanctuaries (WS): Ratapani WS, Singhori WS, Narsinghgarh WS, and one is a national park: Van Vihar National Park (Table 1).

Table 1. Protected areas of BFC.

	Name of protected area	Establishment year	Area (km^2)	District
1	Narsinghgarh WS	1978	59.19	Rajgarh
2	Van Vihar NP	1979	4.45	Bhopal
3	Ratapani WS	1978	823.84	Raisen
4	Singhori WS	1976	287.91	Raisen

Sampling

The sampling unit of the study is a forest patch. A patch is defined as a relatively homogenous area which differs from its surrounding land use within the landscape (Peters et al. 2009). Patches were identified using Google Earth Pro, FRAGSTATS and ArcGIS 10.3. The forest patches were manually digitized using ArcGIS and Google Earth Pro and then they were used as the input file for FRAGSTATS program to get patch characteristics like their size and degree of isolation. A total of 98 patches were found in the study area. The area of these forest patches is in the range of 10–500 ha.

Sampling of patches

The basis of sampling was the area of patch and degree of isolation. Patches were grouped into four classes, i.e., (i) large area and high degree of isolation (8 patches), (ii) large area and less degree of isolation (36 patches), (iii) small area and high degree of isolation (6 patches), and (iv) small area and low degree of isolation (48 patches). Forest patches smaller than 100ha were considered as smaller patches while more than 100ha were considered larger patches. Forest patches having ENN distance of less than 1,500m from nearest forest were considered as patches with lower degree of isolation and vice versa. Out of the total 98 patches, 21 patches were sampled out using weighted stratified random sampling (Fig. 2). Samples were taken from each of the four classes based on their percentage of the

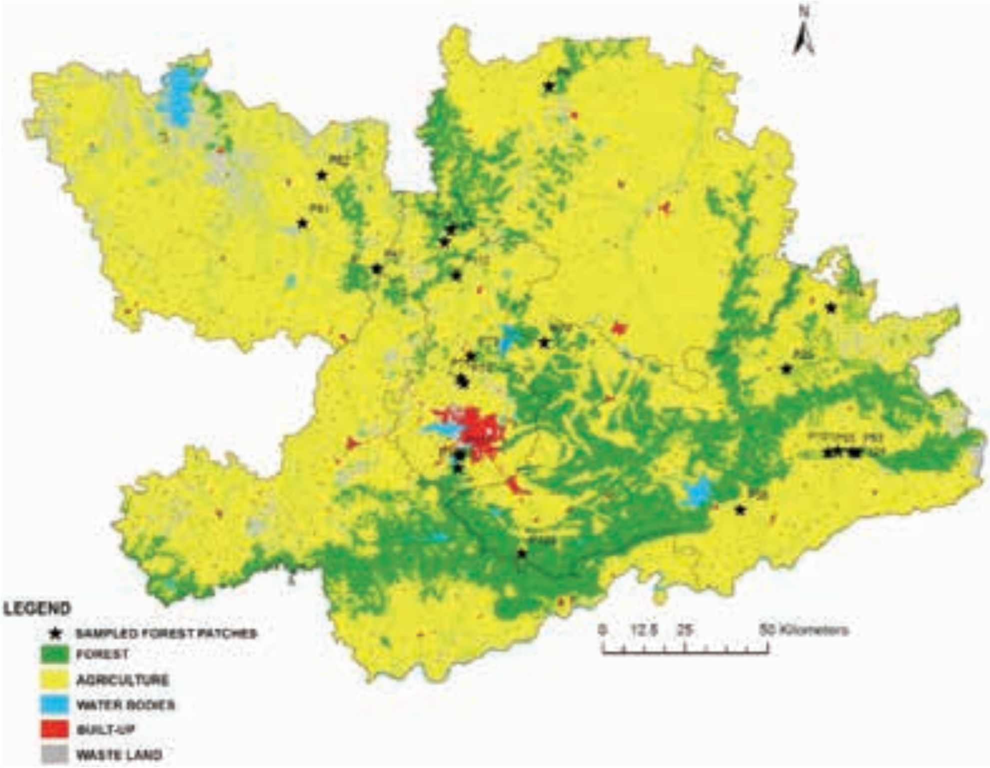

Figure 2. Sampled forest patches in the study area.

Table 2. Sampling of forest patches.

	Large size with high ENN	Large size with low ENN	Small size with high ENN	Small size with low ENN	Total number of patches
Patches	8	36	6	48	98
Total patches (%)	8.16	36.73	6.12	48.98	100
Samples	2	8	1	10	21

*ENN—Euclidean nearest neighbor distance

total number of patches found in the study area (Table 2).

During the field data collection surveys, if the patch was found to be not suitable for bird surveys due to higher forest degradation and their conversion into scrubland, resampling from the same strata was done. For example, if a sampled forest patch from large size and the large degree of isolation strata is found to be not suitable for the survey, another patch from the same group was randomly picked.

Field data collection

Bird survey

Breeding bird diversity of each forest patch was sampled using the point count method in which bird survey points were predefined within the forest patch, and at each point, bird surveys were done for 10 minutes each. Point count method was preferred over other methods since it is better suited for patchily distributed populations and for shy birds that would otherwise hide and escape detection. The points were selected within the forest patch following systematic random sampling. The minimum distance between two consecutive points was 500 m to avoid double counting. At each of these points, birds were surveyed visually as well as acoustically. The distance of the birds to the observer was also recorded using a laser rangefinder. In case of birds heard only, the distance was recorded in four distance classes, i.e., 0–10 m, 10–20 m, 20–50 m, and >50m. Each point was surveyed for three consecutive days during one replication. Bird surveys were avoided during cloudy or rainy days. Surveys were carried out in mornings 06.00–09.00 h and in evenings 16.00–18.00 h.

Avian species richness

Species richness is the simplest method of characterising community/population diversity. Species richness is the basis of many ecological models like Island Biogeography Theory (McArthur & Wilson 1967), the intermediate disturbance hypothesis (Connell 1978), as well as more recent models of neutral theory (Hubbell 2001), and meta-community structure (Leibold et al. 2005). These theories try to generate quantitative predictions of the number of coexisting species in a community; however, though it is a simple measure of diversity, it is still difficult to estimate accurately. It is always an underestimation of the surveyed community. To correct for this underestimation of species richness, there are many sampling models and estimators of asymptotic richness to estimate the undetected species (Gotelli et al. 2011). For the present study, Chao 1 (Eq. 1), ACE (Eq. 2) and Jackknife estimators were used to estimate the undetected species of birds. These estimators are used for abundance data. Therefore, the estimators were used to calculate the estimated species richness using the Palaeontology Statistics (PAST 3.0) program (Hammer et al. 2001).

a. *Chao 1*

Chao1 = S + F1(F1 - 1) / (2 (F2 + 1)), where F1 is the number of singleton species and F2 the number of doubleton species.

b. ACE: Abundance Coverage-based Estimator of species richness

$$S_{ace} = S_{abund} + \frac{S_{rare}}{C_{ace}} + \frac{F1}{C_{ace}} * \gamma_{ace}^{2} \quad (1)$$

Where:

$S_{rare} = \sum_{k=1}^{10} F_k$ is the number of rare species in a sample (each with 10 or fewer individuals).

$S_{abund} = \sum_{k=11}^{S_{obs}} F_k$ is the number of abundant species in a sample (each with more than 10 individuals)

$n_{rare} = \sum_{k=1}^{10} kF_k$ is the total number of individuals in the rare species.

$C_{ace} = 1 - f_1/n_{rare}$ is the sample cover estimate which is the proportion of all individuals in rare species that are not singletons.

γace^2 = is the coefficient of variation ,

$$\gamma_{ace}^{2} = max\left[\frac{S_{rare}}{C_{ace}} \frac{\sum_{k=1}^{10} k(k-1)f_k}{(n_{rare})(n_{rare}-1)} - 1,0\right] \quad (2)$$

RESULTS AND DISCUSSION

Therefore, in this study, 21 forest patches were surveyed for bird species diversity. A total of 131 bird species were recorded in the study area (21 forest patches). Table 3 classifies these species as Resident or Migratory; 31 out of 131 species were migratory.

Avian species richness estimation

The total number of species recorded in the patches during the field surveys is the observed species richness. Species richness of each patch was calculated using the bird survey data, but the observed species richness is not the true number of species present in the forest patches. There are always bird species which get undetected due to various reasons. To correct the species richness for all these forest patches, species richness estimators for abundance data were applied to the data. Chao 1 and ACE estimators were used in PAST 3.0 software. Non-parametric species estimators like Chao 1 and ACE, extrapolate the observed data to find the 'true' number of species present in the study area (Colwell & Coddington 1994). These estimators use the number of rare species found in the sample to estimate more number of species likely to get undetected. Species richness estimators for abundance data were applied to the survey data to estimate the improved species richness in these forest patches. Chao 1 and ACE estimators were used in PAST 3.0 software (Table 4).

To count in undetected species and estimate the true species richness, species richness estimators were applied to the overall species richness data (Table 5). The estimators used were Chao 1, Jackknife 1, Jackknife 2, and Bootstrapping.

DISCUSSION

Continuous forest areas outside protected areas are always at risk of habitat destruction and fragmentation, which leads to biodiversity loss and local extinction of certain species too. There have been various studies globally on fragmented forest patches (natural and plantations). There are very few studies from the Indian subcontinent, which are restricted mainly to plantations (Daniels et al. 1992; Bhagwat et al. 2005; Raman 2006; Bali et al. 2007); however, forest fragments outside-protected areas in the central Indian landscape have not been studied for its role in conserving biodiversity. In this study, avian diversity of these isolated forest patches has been studied to understand the role these forest patches can play in conserving biodiversity in an agrarian landscape.

The results from this study suggest that forest patches with larger sizes such as Binapur (size= 166ha, Chao 1=

Table 3. Bird species recorded during the survey from the 21 forest patches of central Indian forest landscape.

	Common name	Scientific name	Resident or migratory
1	Ashy-crowned Sparrow-lark	*Eremopterix griseus* (Scopoli, 1786)	Resident
2	Ashy Drongo	*Dicrurus leucophaeus* (Vieillot, 1817)	Migratory
3	Ashy Prinia	*Prinia socialis* (Sykes, 1832)	Resident
4	Asian Koel	*Eudynamys scolopaceus* (Linnaeus, 1758)	Resident
5	Asian Palm-swift	*Cypsiurus balasiensis* (Gray, 1829)	Resident
6	Indian Paradise Flycatcher	*Terpsiphone paradise* (Linnaeus, 1758)	Resident
7	Barn Swallow	*Hirundo rustica* (Linnaeus, 1758)	Migratory
8	Barred Buttonquail	*Turnix suscitator* (Gmelin, 1789)	Resident
9	Bay-backed Shrike	*Lanius vittatus* (Valenciennes, 1826)	Migratory
10	Baya Weaver	*Ploceus philippinus* (Linnaeus, 1766)	Resident
11	Black Drongo	*Dicrurus macrocercus* (Vieillot, 1817)	Resident
12	Black Kite	*Milvus migrans* (Boddaert, 1783)	Resident
13	Black Redstart	*Phoenicurus ochruros* (Gmelin, 1774)	Migratory
14	Black-rumped Flameback	*Dinopium benghalense* (Linnaeus, 1758)	Resident
15	Black-winged Kite	*Elanus caeruleus* (Desfontaines, 1789)	Resident
16	Blue Rock-thrush	*Monticola solitarius* (Linnaeus, 1758)	Migratory
17	Blyth's Reed-warbler	*Acrocephalus dumetorum* (Blyth, 1849)	Migratory
18	Bonelli's Eagle	*Aquila fasciata* (Vieillot, 1822)	Resident
19	Booted Warbler	*Iduna caligata* (Lichtenstein, 1823)	Migratory
20	Brahminy Starling	*Sturnia pagodarum* (Gmelin, 1789)	Resident
21	Indian Pygmy Woodpecker	*Dendrocopos nanus* (Vigors, 1832)	Resident
22	Brown Rockchat	*Cercomela fusca* (Blyth, 1851)	Resident
23	Brown Shrike	*Lanius cristatus* (Linnaeus, 1758)	Migratory
24	Cattle Egret	*Bubulcus ibis* (Linnaeus, 1758)	Resident
25	Chestnut-bellied Sandgrouse	*Pterocles exustus* (Temminck, 1825)	Resident
26	Chestnut-shouldered Petronia	*Gymnoris xanthocollis* (Burton, 1838)	Resident
27	Chestnut-tailed Starling	*Sturnia malabarica* (Gmelin, 1789)	Migratory
28	Common Babbler	*Turdoides caudate* (Dumont, 1823)	Resident
29	Common Chiffchaff	*Phylloscopus collybita* (Vieillot, 1817)	Migratory
30	Common Hawk-cuckoo	*Hierococcyx varius* (Vahl, 1797)	Resident
31	Common Hoopoe	*Upupa epops* (Linnaeus, 1758)	Resident
32	Common Iora	*Aegithina tiphia* (Linnaeus, 1758)	Resident
33	Common Kestrel	*Falco tinnunculus* (Linnaeus, 1758)	Migratory
34	Common Myna	*Acridotheres tristis* (Linnaeus, 1766)	Resident
35	Common Stonechat	*Saxicola torquatus* (Linnaeus, 1766)	Migratory
36	Common Tailorbird	*Orthotomus sutorius* (Pennant, 1769)	Resident
37	Common Woodshrike	*Tephrodornis pondicerianus* (Gmelin, 1789)	Resident
38	Coppersmith Barbet	*Psilopogon haemacephalus* (Müller, 1776)	Resident
39	Crested Bunting	*Emberiza lathami* (Gray, 1831)	Migratory
40	Crested Lark	*Galerida cristata* (Linnaeus, 1758)	Resident
41	Crested Treeswift	*Hemiprocne coronate* (Tickell, 1833)	Resident
42	Dusky Crag Martin	*Ptyonoprogne concolor* (Sykes, 1832)	Resident
43	Egyptian Vulture	*Neophron percnopterus* (Linnaeus, 1758)	Resident
44	Eurasian Collared-dove	*Streptopelia decaocto* (Frivaldszky, 1838)	Resident

	Common name	Scientific name	Resident or migratory
45	Indian Golden Oriole	*Oriolus Kundoo* (Sykes, 1832)	Resident
46	Great Tit	*Parus major* (Linnaeus, 1758)	Resident
47	Greater Coucal	*Centropus sinensis* (Stephens, 1815)	Resident
48	Green Bee-eater	*Merops orientalis* (Latham, 1802)	Resident
49	Greenish Warbler	*Phylloscopus trochiloides* (Sundevall, 1837)	Migratory
50	Grey-bellied Cuckoo	*Cacomantis passerines* (Vahl, 1797)	Migratory
51	Grey-breasted Prinia	*Prinia hodgsonii* (Blyth, 1844)	Resident
52	Grey Francolin	*Francolinus pondicerianus* (Gmelin, 1789)	Resident
53	Grey-necked Bunting	*Emberiza buchanani* (Blyth, 1844)	Migratory
54	Griffon Vulture	*Gyps fulvus* (Hablizl, 1783)	Migratory
55	House Crow	*Corvus splendens* (Vieillot, 1817)	Resident
56	House Sparrow	*Passer domesticus* (Linnaeus, 1758)	Resident
57	Hume's Leaf-warbler	*Phylloscopus humei* (Brooks, 1878)	Migratory
58	Indian Bushlark	*Mirafra erythroptera* (Blyth, 1845)	Resident
59	Indian Grey Hornbill	*Ocyceros birostris* (Scopoli, 1786)	Resident
60	Indian Nightjar	*Caprimulgus asiaticus* (Latham, 1790)	Resident
61	Indian Peafowl	*Pavo cristatus* (Linnaeus, 1758)	Resident
62	Indian Pitta	*Pitta brachyura* (Linnaeus, 1766)	Migratory
63	Indian Pond-heron	*Ardeola grayii* (Sykes, 1832)	Resident
64	Indian Robin	*Saxicoloides fulicatus* (Linnaeus, 1766)	Resident
65	Indian Roller	*Coracias benghalensis* (Linnaeus, 1758)	Resident
66	Indian Silverbill	*Euodice malabarica* (Linnaeus, 1758)	Resident
67	Jerdon's Leafbird	*Chloropsis jerdoni* (Blyth, 1844)	Resident
68	Jungle Babbler	*Turdoides striata* (Dumont, 1823)	Resident
69	Large-billed Crow	*Corvus macrorhynchos* (Wagler, 1827)	Resident
70	Jungle Prinia	*Prinia sylvatica* (Jerdon, 1840)	Resident
71	Large Cuckooshrike	*Coracina macei* (Lesson, 1831)	Resident
72	Large Grey Babbler	*Argya malcolmi* (Sykes, 1832)	Resident
73	Laughing Dove	*Spilopelia senegalensis* (Linnaeus, 1766)	Resident
74	Lesser Whitethroat	*Sylvia curruca* (Linnaeus, 1758)	Migratory
75	Little Cormorant	*Microcarbo niger* (Vieillot, 1817)	Resident
76	Long-billed Vulture	*Gyps indicus* (Scopoli, 1786)	Resident
77	Long-tailed Shrike	*Lanius schach* (Linnaeus, 1758)	Resident
78	Oriental Honey-buzzard	*Pernis ptilorhynchus* (Temminck, 1821)	Resident
79	Oriental Magpie-robin	*Copsychus saularis* (Linnaeus, 1758)	Resident
80	Oriental Turtle-dove	*Streptopelia orientalis* (Latham, 1790)	Migratory
81	Oriental White-eye	*Zosterops palpebrosus* (Temminck, 1824)	Resident
82	Paddyfield Pipit	*Anthus rufulus* (Vieillot, 1818)	Resident
83	Painted Francolin	*Francolinus pictus* (Jardine & Selby, 1828)	Resident
84	Painted Stork	*Mycteria leucocephala* (Pennant, 1769)	Migratory
85	Pale-billed Flowerpecker	*Dicaeum erythrorhynchos* (Latham, 1790)	Resident
86	Peregrine Falcon	*Falco peregrinus* (Tunstall, 1771)	Resident
87	Jacobin Cuckoo	*Clamator jacobinus* (Boddaert, 1783)	Migratory
88	Pied Kingfisher	*Ceryle rudis* (Linnaeus, 1758)	Resident
89	Plain Prinia	*Prinia inornata* (Sykes, 1832)	Resident

	Common name	Scientific name	Resident or migratory
90	Plum-headed Parakeet	*Psittacula cyanocephala* (Linnaeus, 1766)	Resident
91	Purple Sunbird	*Cinnyris asiaticus* (Latham, 1790)	Resident
92	Red Avadavat	*Amandava amandava* (Linnaeus, 1758)	Resident
93	Red-breasted Flycatcher	*Ficedula parva* (Bechstein, 1792)	Migratory
94	Red Collared Dove	*Streptopelia tranquebarica* (Hermann, 1804)	Resident
95	Red-rumped Swallow	*Cecropis daurica* (Linnaeus, 1771)	Resident
96	Red-vented Bulbul	*Pycnonotus cafer* (Linnaeus, 1766)	Resident
97	Red-wattled Lapwing	*Vanellus indicus* (Boddaert, 1783)	Resident
98	River Tern	*Sterna aurantia (*Gray, 1831)	Resident
99	Rock Bush-quail	*Perdicula argoondah* (Sykes, 1832)	Resident
100	Rock Dove	*Columba livia* (Gmelin, 1789)	Resident
101	Rose-ringed Parakeet	*Psittacula krameri* (Scopoli, 1769)	Resident
102	Rosy Starling	*Pastor roseus* (Linnaeus, 1758)	Migratory
103	Rufous-fronted Prinia	*Prinia buchanani* (Blyth, 1844)	Resident
104	Rufous-tailed Lark	*Ammomanes phoenicura* (Franklin, 1831)	Resident
105	Rufous Treepie	*Dendrocitta vagabunda* (Latham, 1790)	Resident
106	Scaly-breasted Munia	*Lonchura punctulata* (Linnaeus, 1758)	Resident
107	Shikra	*Accipiter badius* (Gmelin, 1788)	Resident
108	Short-toed Snake-eagle	*Circaetus gallicus* (Gmelin, 1788)	Resident
109	Sirkeer Malkoha	*Taccocua leschenaultia* (Lesson, 1830)	Resident
110	Small Minivet	*Pericrocotus cinnamomeus* (Linnaeus, 1766)	Resident
111	Indian Spot-billed Duck	*Anas poecilorhyncha* (Forster, 1781)	Resident
112	Spotted Dove	*Spilopelia suratensis* (Gmelin, 1789)	Resident
113	Sulphur-bellied Warbler	*Phylloscopus griseolus* (Blyth, 1847)	Migratory
114	Taiga Flycatcher	*Ficedula albicilla* (Pallas, 1811)	Migratory
115	Tickell's Blue-flycatcher	*Cyornis tickelliae* (Blyth, 1843)	Resident
116	Tickell's Leaf-warbler	*Phylloscopus affinis* (Tickell, 1833)	Migratory
117	Tree Pipit	*Anthus trivialis* (Linnaeus, 1758)	Migratory
118	Ultramarine Flycatcher	*Ficedula superciliaris* (Jerdon, 1840)	Migratory
119	Verditer Flycatcher	*Eumyias thalassinus* (Swainson, 1838)	Migratory
120	White-bellied Drongo	*Dicrurus caerulescens* (Linnaeus, 1758)	Resident
121	White-browed Fantail	*Rhipidura aureola* (Lesson, 1830)	Resident
122	White-eyed Buzzard	*Butastur teesa* (Franklin, 1831)	Resident
123	White-naped Woodpecker	*Chrysocolaptes festivus* (Boddaert, 1783)	Resident
124	White-rumped Vulture	*Gyps bengalensis* (Gmelin, 1788)	Resident
125	White-spotted Fantail	*Rhipidura albogularis* (Lesson, 1832)	Resident
126	White-breasted Kingfisher	*Halcyon smyrnensis* (Linnaeus, 1758)	Resident
127	Wire-tailed Swallow	*Hirundo smithii* (Leach, 1818)	Resident
128	Asian Woollyneck	*Ciconia episcopus* (Boddaert, 1783)	Resident
129	Yellow-crowned Woodpecker	*Leiopicus mahrattensis* (Latham, 1801)	Resident
130	Yellow-eyed Babbler	*Chrysomma sinense* (Gmelin, 1789)	Resident
131	Yellow-footed Green-pigeon	*Treron phoenicopterus* (Latham, 1790)	Resident

*Source of Latin names: IUCN Redlist (IUCN 2020).

Table 4. Observed species richness and estimated species richness of patches using Chao 1 and ACE estimators.

	Patch classes	Patch name	Species richness observed	Estimated species richness (Chao1)	Estimated species richness (ACE)
1	Small size with low ENN	Ghatkhedi	38	49	46.45
2		Lalghati	57	62	65.43
3		Satgarhi	53	56.75	59.76
4		Barkhedi	35	39	40.41
5		Durang	55	66.375	68.23
6		Nasipur	49	52.27	55.86
7		Itkhedi	43	44.5	46.79
8		Manakwada	38	48.5	43.83
9	Small size with high ENN	Padajhir	41	47	48.46
10		Ghot	50	53.27	57.14
11		Lasudli	57	65.25	66.97
12		Durgapura	35	37.62	40.55
13	Large size with low ENN	Singota	42	45	46.155
14		Kerwa	43	48	50.82
15		Pathariya	51	54	53.77
16		Kalyanpura	61	80	74.38
17		Narsinghgarh	27	28	29.76
18		Sayar	61	78	75.83
19		Binapur	64	73	75.8
20		Kishanpur	46	50	51.24
21	Large size with high ENN	Amgawa	48	51	51.3

*ENN—Euclidean nearest neighbor

Table 5. Estimated species richness of the study area.

	Estimator	Estimated species richness	Standard error
1	Chao 1	154.1	11.7
2	Jackknife 1	156.71	7.9
3	Jackknife 2	168.25	-
4	Bootstrapping	143.02	4.4

73), Sayar (size= 107ha, Chao 1= 78), and Kalyanpura (size= 133ha, Chao 1= 80), were having higher avian diversity except for forest patches Narsinghgarh (size= 393ha, Chao 1= 28), Singota (size= 184ha, Chao 1= 45) with higher degree of anthropogenic disturbances in the form of cattle grazing, fuelwood collection, and collection of non-timber forest products such as Mahua *Madhuca latifolia*, Tendu *Diospyros melanoxylon* leaves, and natural gum. Smaller forest patches were found to have fewer bird species; however, smaller forest patches with less degree of anthropogenic disturbances such as Lalghati (size= 99ha, Chao 1= 62), Lasudli (size= 16ha, Chao 1= 65), Ghot (size= 36ha, Chao 1= 53), and Nasipur (size= 23ha, Chao 1= 52) were more diverse than other smaller patches. These smaller patches were more protected due to being a sacred grove (Lalghati and Lasudli) and private ownership (Ghot and Nasipur). A study conducted in Columbian Andes in 2010 studied the effects of landscape structure on bird's richness. They found that patch area is a key driver of species richness. Species richness increases towards large patches but the effect of patch area decreases when other factors like human disturbance come into scenario (Aubad et al. 2010). In various other studies, it has been found that patch size affects the avian diversity significantly (Garmendia et al. 2013; Herrando & Brotons 2002; Aubad et al. 2010). A study conducted on sacred groves of Western Ghats suggests that patch size does not influence the diversity of birds, trees, and macro fungi (Bhagwat et al. 2005). This study suggests that the avian diversity in forest patches in an agrarian landscape depends on patch size and protection status of these patches. Forest patches with more protection due to its status of sacred grove and private ownership had more avian diversity even when the size of the patch was smaller.

CONCLUSION

In studies around the world, forest fragments were found to be rich in biodiversity. They provide habitat to various kind of plant and animal species. Therefore, there is a need to conserve and connect these forest patches embedded in the landscape matrix. The present study estimates the biodiversity of fragmented forest patches of BFC. Results of the study suggest that forest patches can support good bird diversity even after a high anthropogenic pressure in the form of grazing, fuelwood collection, and NTFPs collection. Nevertheless, patches with anthropogenic disturbances were found to have less diversity of birds in comparison to patches with lesser disturbance. Patch size certainly have a positive effect on bird diversity; however, human disturbance also affects the avian community dynamics in these forest patches. This study recorded 131 species of birds from 21 forest patches from the Vindhyan plateau. This is a good number of species, since the total number of species found in the two nearby wildlife sanctuaries are:

1. Ratapani Wildlife Sanctuary (153 species, 10 checklists) and
2. Narsinghgarh Wildlife Sanctuary (65 species, 2 checklists) (ebird 2020).

The study area is poorly studied for its biodiversity. These forest patches are of different sizes and have a different degree of isolation. A few forest patches like Ghot (privately owned) and Lasudli (sacred grove) are smaller but have high avian diversity due to their protected status. On the other hand, patches such as Pathariya and Amgawa are larger patches with low avian diversity due to higher anthropogenic pressure in the form of grazing, fuelwood collection, and non-timber forest products collection. Therefore, it can be suggested that the diversity in forest patch or fragments not just depends on its size and degree of isolation but also on the degree of anthropogenic disturbance. The ideal scenario would be larger patch size, a lesser degree of isolation (i.e., higher connectivity) and least anthropogenic pressure. The avian diversity was good in forest patches as well as the overall study area despite the anthropogenic pressure. This study fulfills the gap of biodiversity data from the study area. Even the wildlife sanctuaries in the study area have been poorly studied for its biodiversity, which makes this study important. This study also focuses on the need to conserve the forest patches by connecting the forest fragments and reducing the anthropogenic pressure as they play a vital role in providing habitat to various flora and fauna. Protecting these forest patches will help in conserving the biodiversity of the whole landscape.

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COMMUNICATION

Nest tree preference shown by Ring-necked Parakeet *Psittacula krameri* (Scopoli, 1769) in northern districts of Tamil Nadu, India

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Abstract: This paper pertains to the nesting aspects of *Psittacula krameri* with specific reference to nesting-related habitats, number of individuals encountered, inter-specific interactions, and abnormalities in 71 villages covering seven northern districts of Tamil Nadu. A total of 797 nests (500 active and 297 non-active nests) and 1,119 individuals were enumerated on 284 trees and 13 temples/buildings belonging to eight species, seven genera, and five families. The highest number of nests (320) and birds (469) occurred on *Borassus flabellifer* L., followed by *Cocos nucifera* L., *Albizia lebbeck* (L.) Benth., *Madhuca longifolia* J.F.Gmel., *Phoenix sylvestris* (L.) Roxb., and *Ficus benghalensis* L. This species prefers dead trees than living trees for nesting. The study reveals that 63.4% nests (n= 505) and 65.1% birds (n= 729) were found on dead trees of *B. flabellifer*, *C. nucifera*, and *P. sylvestris*. They generally prefer to build nests on trees situated near agricultural lands, followed by those near water bodies, human settlements, and temples/buildings. Pearson's chi-square test indicates that the birds showed preference towards certain nesting sites/nesting species. Inter-specific interactions occurred between *P. krameri* and Blue Rock Pigeon, Spotted Owlet, Indian Roller, and Black-rumped Flameback for sharing of cavities/holes for construction of nests. Abnormalities in bird's beak, cere, colour of feathers, and a suspected psittacine beak & feather disease (PBFD) were observed.

Keywords: Active nests, beak deformity, inter-specific competition, nesting trees.

Tamil Abstract சுருக்கம்: வட தமிழகத்தின் ஏழு மாவட்டங்களில் உள்ள 71 கிராமங்களில் பச்சைக்கிளிகளின் கூடு கட்டி வாழும் வாழிடங்கள், கிளிகளின் எண்ணிக்கை, பச்சைக்கிளிகளுக்கும் வேறு சிற்றினங்களுக்கிடையேயும் உள்ள தொடர்புகள் மற்றும் அசாதாரணமான/ குறைபாடு பண்புகள் பற்றி இந்த அறிக்கையில் விவரிக்கப்பட்டுள்ளது. ஐந்து குடும்பம், ஆறு பேரினம் மற்றும் எட்டு சிற்றினங்களளைச் சேர்ந்த 284 மரங்களிலும், 13 கோயில்கள்/கட்டடங்களிலும் 797 கூடுகள் (500 பயனில் உள்ள கூடு மற்றும் 297 பயனில் இல்லாத கூடு) மற்றும் 1119 பச்சைக்கிளிகள் கணக்கெடுக்கப்பட்டன. அதிகப்படியாக 320 கூடுகளும், 469 கிளிகளும் பனை மரத்தில் இருந்தது. அதற்கு அடுத்தபடியாக தென்னை, வாகை, இலுப்பை, ஈச்சம் மற்றும் ஆலமரங்களில் அதிகமான கூடுகளும், கிளிகளும் இருந்தது. இந்த பச்சைக்கிளிகள் கூடுகட்ட உயிருள்ள மரங்களைவிட இறந்த மரங்களையே அதிகம் தேர்வு செய்கிறது. 63.4% கூடுகள் (n=505) மற்றும் 65.1% எண்ணிக்கையிலான கிளிகள் (n=729) இறந்த பனை, தென்னை மற்றும் ஈச்சமரங்களில் காணப்பட்டது. பச்சைக்கிளிகள் பொதுவாக விவசாய நிலங்கள், நீர்நிலைகள், மனிதர்கள் வசிப்பிடம் போன்றவற்றிற்கு அருகாமையில் உள்ள மரங்களையும் மற்றும் கோயில்/கட்டடங்களையும் கூடுகட்டுவதற்கு தேர்வு செய்கிறது. பியர்சனின் வை வர்க்கச் சோதனையில் பச்சைக்கிளிகள் குறிப்பிட்ட இடங்களையே கூடுகட்டுவதற்கு தேர்வு செய்கிறது என தெரியவந்துள்ளது. பச்சைக்கிளிகளுக்கும், வேறு சிற்றினங்களுக்களான புறா, ஆந்தை, இந்தியன் ரோவர், மரங்கொத்தி ஆகிய பறவைகளுக்கும் கூடுகட்டுவது சம்மந்தமாக துளைகள் பங்கீடு செய்வதில் போட்டி நிலவுகிறது. கிளிகளின் அலகு, மூக்கின் மேல் உள்ள தசை ஆகியவற்றில் குறைபாடுகளும், சில கிளிகளின் சிறகின் நிறம் மற்றும் சிட்டாசின் என்ற நோயும் கண்டறியப்பட்டன.

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INTRODUCTION

The Ring-necked Parakeet or Rose-ringed Parakeet *Psittacula krameri* (Scopoli, 1769) (Aves: Psittaciformes: Psittaculidae) is a native of the Indian subcontinent and Sub-Saharian Africa and now occurs in 35 countries (Menchetti et al. 2016) such as Britain, Belgium, the Netherlands, Germany, and Spain (Braun & Wink 2013). A subspecies *P. krameri manilensis* is distributed in southern India and Sri Lanka (BirdLife International 2018). Intensive trade, accidental or deliberate release of this species into new environments and its adaptation has led to the establishment of viable populations outside its native range (Strubbe & Matthygen 2009; Neo 2012). Tolerance to human presence, an omnivorous diet and a great reproductive rate (Thabethe et al. 2013) make them successful invasive alien species and are even considered pests in the introduced European countries (Strubbe & Matthygen 2007). Many bird species use cavities as nesting sites, as it reduces the risk of predation more than other nest sites (Nice 1957; Cody 1985; Newton 1994). *Psittacula krameri* depends on trunk holes/cavities for their reproduction. They compete with other birds for nest-cavities due to their aggressive behaviour in Mauritius (Jones 1980) and Belgium (Strubbe & Matthyen 2009). In India, they widely inhabit several habitats (Rasmussen & Anderton 2005) and breeding occurs during December–May. In northern India, about 15% of *P. krameri* populations build their nests in wall holes or crevices in buildings (Grandi et al. 2016). In view of the limited resources of nest-cavities, inter-specific competitions exist between *P. krameri* and other birds (Wesolowski 2007; Cornelius 2008).

This species is considered a major agricultural pest in its native range (Khan 2002b) and in countries where it has invaded (Schackermann et al. 2014). The birds consume dry & fleshy fruits and seeds (Ali & Ripley 1968, 1987); they cause considerable damage to agricultural crops such as corn (*Zea mays* L.), sorghum (*Sorghum bicolor* (L.) Moench), paddy (*Oryza sativa* L.), safflower (*Carthamus tinctorius* L.), sunflower (*Helianthus annus* L.), fruits, and stored grains (Shivanarayan et al. 1981; Dhindsa & Saina 1994; Mukherjee et al. 2000; Shivashankar & Subramanya 2008). Abnormalities/deformities in beak, cere, and colour were observed among *P. krameri* individuals due to various reasons (Low 1992; Zwart 1995; Butler 2003; Kanwar 2019). Gokula et al. (1999) observed intra-specific differences between *Psittacula cyanocephala* and *P. columboides* in Siruvani of Tamil Nadu.

The IUCN Red List of Threatened Species has evaluated the status of this bird as 'Least Concern' because its population appears to be increasing but in view of its popularity as a pet and control by farmers due to its invasiveness, this has reduced its numbers in its native range (BirdLife International 2018). Except the above few works, no literatures are available on the study of the nesting habitats and abnormalities of *P. krameri* in Tamil Nadu. Hence, this study was carried out to fill the gaps. The objectives of this study are to assess the nesting tree preference of *P. krameri*, and identification of the nesting sites.

MATERIALS AND METHODS

Study area

The present study was carried out in 71 villages in seven districts of northern Tamil Nadu, viz., Chennai, Thiruvallur, Ranipet, Kancheepuram, Chengelpet, Villupuram, and Kallakurichi spread over 17,680km^2 (Fig. 1). Agriculture is the primary occupation in these areas except Chennai City and adjoining areas. The major crops in the study area are *Oryza sativa* L., *Sorghum bicolor* (L.) Moench, *Pennisetum glaucumi* (L.) R.Br., *Eleusine coracana* Gaertn., *Setaria italica* (L.) P.Beauvois., *Saccharum officinarum* L. (Poaceae), *Vigna radiata* (L.) R.Wilczek., and *Arachis hypogaea* L. (Fabaceae). Small-scale cultivation of ornamental flowers, vegetables, and fruits also occurs. The maximum and minimum temperatures of these districts are 37^{o}C and 28^{o}C, respectively. The average annual rainfall of the state is 907mm (Tamil Nadu 2020).

METHODS

Three informants from villages who were traditionally engaged in farming and well acquainted with the location of tall trees, groves, and birds in the study districts were selected. Along with them areas were identified that had considerable populations of *P. krameri* and their nesting sites in 71 villages covering seven districts in the northern region of Tamil Nadu. The determined nesting sites were surveyed during the breeding season from 01 November 2019 to 31 March 2020 between 06.00 & 09.00 h and 15.00 & 18.00 h when the birds are usually active. The individuals and number of nests were determined using total count method (Bibby et al. 2000). *P. krameri* usually follow communal roosting during non-breeding periods and in the breeding season the flock splits and moves to various habitats searching for cavities to construct nests. Hence, the movements

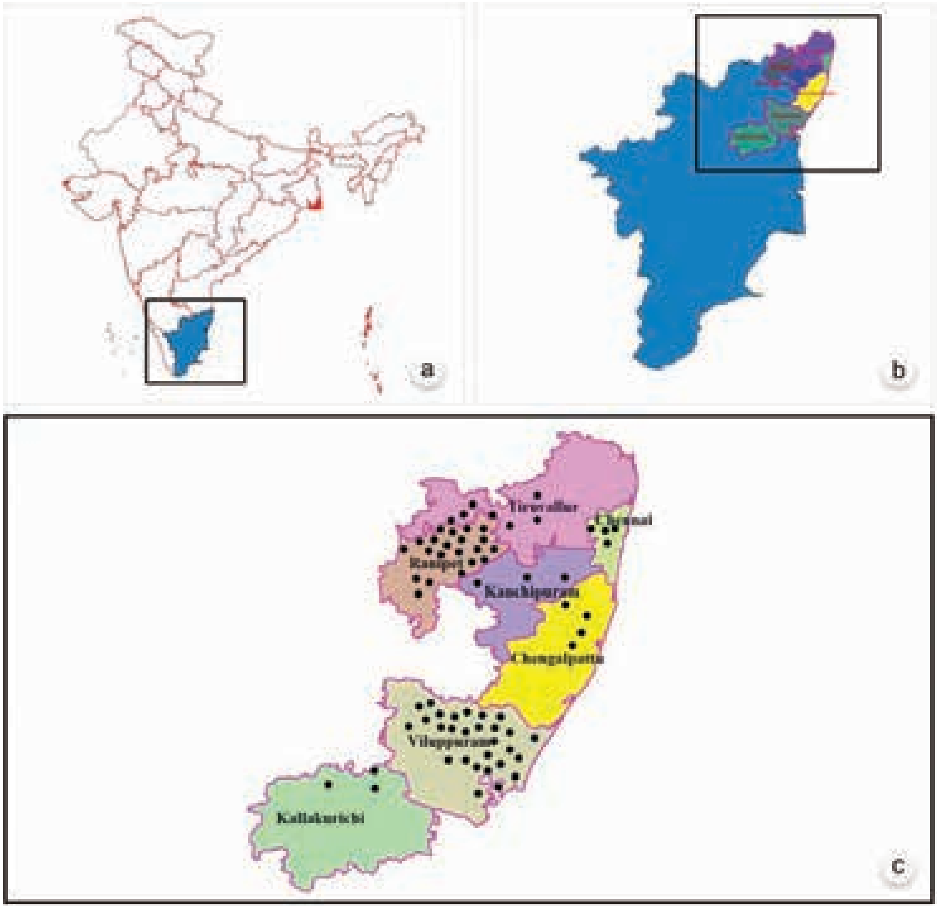

Figure 1. Study area, a—India with Tamil Nadu State highlighted | b—seven districts that are the study sites in Tamil Nadu | c—seven northern districts.

of birds, the nesting trees, excavating cavities on the trunks, holes and crevices in temples/buildings, entry and exit of birds from such cavities, number of nests, active/non-active nests, and inter-specific interactions with other birds for sharing nesting sites were observed using binoculars without causing any disturbance to the birds. The active nest cavities were ascertained by watching the frequent visits of birds to the cavities, carrying nesting materials: prolonged presence of any one of the pair in the cavity was presumed as the birds incubating eggs, and prey delivery to hatchlings. Non-active/abandoned cavities were ascertained by non-visiting of birds to the cavities during the study period after excavating cavities. The eggs and other breeding activities were not studied. Locations of the nesting trees and temples/buildings were determined using GPS. Pearson's chi-square test was applied to determine whether Ring-necked Parakeet individuals select trees, temples/buildings equally across the study area for construction of nests using SPSS (Statistical Package for Social Sciences) version 25.0 software. The test of significance was assessed at $p < 0.05$. Photographs and videos were taken using Nikon P1000 digital camera.

RESULTS

Psittacula krameri individuals and their preference of nesting sites

In the present study, a total of 284 trees belonging to five families, seven genera, and eight species were found with nests of *P. krameri,* of which *Borassus flabellifer* L. harboured the maximum numbers of nests (n= 164; 55.2%), followed by *Cocos nucifera* L. (n= 90; 30.3%*), Albizia lebbeck* (L.) Benth. (n= 10; 3.4%), and *Madhuca longifolia* J.F.Macbr. (n= 9; 3%). Temples/buildings shared about 4.4% of nesting sites. A total of 797 nests (500 active nests and 297 non-active nests) and 1,119 individuals of *P. krameri* were enumerated on the 297 nesting sites (nesting trees -284 and temples/buildings-13) in seven districts (Table 1). Maximum of 72 nests and 88 birds were observed in Gadavari Kandigai

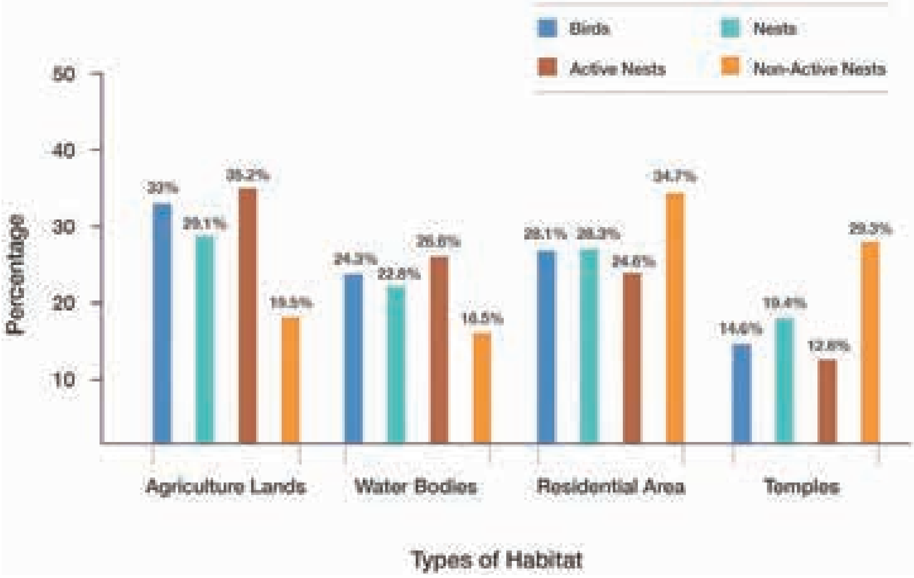

Figure 2. Distribution of *P. krameri* population and their nests in various habitats.

Village and in four villages no nests were counted but individuals of *P. krameri* were enumerated. The details of villages containing nests and birds are given in Table 2.

Of the total *B. flabellifer* trees (164) enumerated in the study area, 158 were dead and six were living trees. Among *B. flabeliifer*, maximum of 98.1% nests (n= 314) and 96.2% birds (n= 451) were found on dead trees and only 1.9% nests (n= 6), and 3.8% birds (n= 18) were enumerated on living *B. flabellifer* trees.

Out of 797 nests enumerated, 63.4% nests (n= 505) were found on dead trees of *B. flabellifer*, *C. nucifera*, and *P. sylvestris*. Similarly out of 1,119 birds counted, 65.1% birds (n= 729) were observed on these dead trees. About 26% nests (n= 208) and 16.8% birds (n= 188) were counted on temples and buildings. The remaining 10.3% nests (n= 84) and 16.4% birds (n= 184) were found on the living trees of *B. flabellifer*, *M. longifoia*, *F. religiosa*, *F. benghalensis*, *A. indica*, and *A. lebbeck*. Except roosting of birds, no nests were found on *F. religiosa* and *A. indica*. Out of total nests (797) enumerated during the current breeding season, 62.7% (n= 500) were active nests and the remaining 37.3% nests (n= 297) were non-active nests. The study reveals that the birds constructed 72.2% of active nests (n= 361) on the trunk cavities of three palm species, followed by 17.4% active nests (n= 87) on temples/buildings and 10.4% active nests (n= 52) on living trees, viz., *B. flabellifer*, *M. longifolia*, *F. benghalensis*, and *A. lebbeck*.

Chi-square test was used to determine whether any significance existed between the type of nesting sites such as trees, temples/ buildings and the number of birds, nests, active nests and non-active nests. The test revealed that there exists statistically significant association between nesting sites (trees/temples/ buildings) and the number of birds ($p< 0.05$), nests ($p< 0.05$), active nests ($p< 0.000$) and non-active nests ($p< 0.05$) in the study area.

Preference of habitats for nesting

The study also tested the relationship between the selection of nesting sites and surrounding habitats such as agricultural lands, water bodies, human settlements, and temples/buildings by *P. krameri* populations (Fig. 2). About 39.4% of nesting sites (n= 117), 29.1% nests (n= 234), and 33% birds (n= 369) occurred near agricultural lands. Thirty-five per cent of nesting sites (n= 104), 22.8% nests (n= 182), and 24.3% birds (n= 272) occurred adjacent to water bodies such as bunds of lakes, ponds, rivers, or canals. About 22.2% nesting sites (n= 66), 28.3% nests (n= 226), and 28.1% birds (n= 314) were found near human settlement areas; 19.5% nests (n= 155), and 14.6% birds (n= 164) were counted on 13 temples/buildings (3.4%). The study also revealed that a maximum of active nests 35.2% (n= 176) were found on trees located in the agricultural areas, followed by 26.6% active nests (n= 133) near water bodies, 24.6% nests (n= 124) in the human settlement areas, and 12.6% nests (n= 63) on temples/ buildings (Image 1). Statistically a significant association exists between the type of habitats such as agricultural lands, water bodies, residential areas, temple & number of birds ($p< 0.05$), nests ($p< 0.05$), active nests ($p< 0.05$), and non-active nests ($p< 0.05$). Hence, all four types of habitats had an impact on the number of birds and nests in the study area.

Table 1. Details of nesting sites, nests, non-active nests and birds counted in seven districts of Tamil Nadu.

	Nesting trees / temples / buildings	Family	No. of nesting trees/sites studied		Total No. of birds		Total No. of Nests		Active nests		Non-active nests	
			Count	%	Count	%	Count	%	Count	%	Count	%
1	*Borassus flabellifer*	Arecaceae	164	55.2%	469	41.9%	320	40.2%	232	46.4%	88	29.6%
2	*Cocos nucifera*	Arecaceae	90	30.3%	266	23.8%	185	23.2%	129	25.8%	56	18.9%
3	*Phoenix sylvestris*	Arecaceae	3	1.0%	12	1.1%	6	0.8%	6	1.2%	0	0.0%
4	*Madhuca latifolia*	Sapotaceae	9	3.0%	42	3.8%	27	3.4%	16	3.2%	11	3.7%
5	*Ficus religiosa*	Moraceae	1	0.3%	6	0.5%	0	0.0%	0	0.0%	0	0.0%
6	*Ficus benghalensis*	Moraceae	3	1.0%	18	1.6%	1	0.1%	1	0.2%	0	0.0%
7	*Azadiracta indica*	Meliaceae	4	1.3%	18	1.6%	0	0.0%	0	0.0%	0	0.0%
8	*Albizia lebbeck*	Fabaceae	10	3.4%	100	8.9%	50	6.3%	29	5.8%	21	7.1%
9	Temples/ buildings	-	13	4.4%	188	16.8%	208	26.1%	87	17.4%	121	40.7%
Total		5	297	100.0%	1119	100.0%	797	100.0%	500	100.0%	297	100.0%

Observation of inter-specific interactions

A pair of *P. krameri* competed with a pair of Blue Rock Pigeon *Columba livia* (Aves: Columbiformes: Columbidae) that had occupied one hole in a temple wall at Thiruvalangadu Village (13.1307°N & 79.7747°E), finally they chased away the blue rock pigeons, occupied the hole and continued breeding. Similar incidents of *P. krameri* competing with a Black-rumped Flameback *Dinopium benghalense* (Aves: Piciformes: Picidae), a Spotted Owlet *Athene brama* (Aves: Strigiformes: Strigidae), and an Indian Roller *Coracias benghalensis* (Aves: Coraciiformes: Coraciidae) in Gadavarikandigai Village (13.1300°N & 79.6226°E) for sharing trunk cavities were observed (Image 2).

Observation on abnormalities

In the present study, one male bird with beak deformity was observed on the compound wall of a temple in Thiruvalangadu Village (Thiruvallur District). The upper mandible of this bird was found elongated, curved and this colourless over grown part of the beak had elongated up to the neck. One female bird with swollen and distorted cere and a big nostril was observed in Gadavarikandigai Village (Ranipet District). Another bird with colour abnormality, i.e., yellow feathers on its back and four individuals (three females and one male) with loss of feathers and wart like skin on their heads were observed in Gadavarikandai Village. During the entire study period, they had the same symptoms without regeneration of new feathers on their heads (Image 3a–d).

DISCUSSION

Psittacula krameri individuals and their preference of nesting sites

In the present study, it was observed that *P. krameri* individuals selected a variety of trees for nesting, but they showed a preference towards palms (Arecaceae): *B. flabellifer*, *C. nucifera* and *P. sylvestris*. Among the palms, they prefered *B. flabellifer* (55.2%; n= 164) in the study area since 40.1% of nests (n= 320) and 41.9% birds (n= 469) occurred on them. The present observation of maximum number of nests and birds were found on *B. flabellifer* trees. The present study also reveals that they largely preferred dead palm trees for construction of nests. Except six *B. flabellifer* trees, all the palm trees (n= 158) that bore nests were dead trees. It suggests that the birds selected dead tree trunks for easy excavation of cavities using their powerful beaks. Once they select

Table 2. List of villages where nests of individuals of Psittacula krameri were counted.

	District	Name of the village	Total no. of nests counted	Total no. of the birds counted
1	Tiruvallur	Tiruvallur	15	10
2		Pugathur	13	22
3		Chinna Kadambur mottur	6	8
4		Sembedu	4	6
5		Periya Kadambur mottur	7	10
6		Mambakkam	8	12
7		Thiruvalanggadu	54	70
8	Chennai	Egmore DPI	7	20
9		Egmore	19	26
10		LIC	6	10
11		Anna Salai EB office	1	2
12	Ranipet	Nanthiveduthangal	10	14
13		Soganur	3	7
14		Gadavari kandigai	72	88
15		Mathimangalam	4	16
16		Kunnathur	3	6
17		Pallakunnathur	6	10
18		Pazhayapalayam	10	14
19		Pazhayapalayam mottur	1	2
20		Minnal	13	18
21		Marankandigai	8	8
22		Chinna Vailambadi	17	29
23		Paranji	2	14
24		Gangai mottur	21	32
25		Melandurai	23	37
26		Kizhanthurai	8	12
27		Poiyappakkam	1	2
28		Kumpinipet	4	8
29		Melakadu	21	56
30		Arumpakkam	16	28
31		Paruthiputhur	1	2
32		Nagavedu	15	24
33		Padi	8	18
34	Kanchipuram	Kanchipuram East	6	8
35		Baluchettichatram	2	5
36	Chengalpattu	Padalam	16	24
37		Ottivakkam	17	14
38		Maduranthangam	0	2
39		Palur	4	2

	District	Name of the village	Total no. of nests counted	Total no. of the birds counted
40	Villupuram	Mailam	3	4
41		Kolliyangunam	5	8
42		Nallamur	4	6
43		Thenkalavai	13	14
44		Kiledayalam	20	30
45		Nedimozhiyanur	14	28
46		Vilangambadi	24	44
47		Thenkolapakkam	5	10
48		Kutteripattu	26	24
49		Sozhiyasorkulam	6	12
50		Thenputhur	6	12
51		Kenipattu	10	12
52		Thiruvakkarai	1	2
53		Kanniyam	1	2
54		Konamangalam	3	6
55		Thazhuthali	4	4
56		Perumbakkam	0	6
57		vanur	11	18
58		Aurovile	1	2
59		Veedur	2	2
60		Siruvai	11	24
61		Pombur	6	6
62		Thenkodipakkam	4	6
63		Gingee	60	44
64		Thiruvamathur	11	4
65		Tindivanam	0	12
66		kodukur	1	2
67		Tirumangalam	0	0
68	Kallakuruchi	Tirukkovilur	38	26
69		Kizhayur	30	20
70		Koduvur	1	2
71		Thirumangalam	0	1
Total	**7**	**71**	**797**	**1119**

a dead palm tree, both male and female individuals were involved in excavating holes in the tree trunks. In Tamil Nadu indiscriminate felling of *B. flabellifer* trees for firewood and due to urbanization, widening of roads, and construction of buildings have been reported (M. Pandian pers. obs.). The study further reveals that the birds utilized the already existing cavities in living trees such as *M. longifolia*, *F. benghalensis*, and *A. lebbeck* for building nests. No incident of excavation of cavities on the above three tree species was noticed during the study period.

Ali & Rilpey (1969) reported that in India, apart from the cavities of trees this bird also utilizes existing crevices in buildings for construction of nests. In Pakistan, this bird selected holes in trees as well as crevices in buildings for construction of nests (Jahan et al. 2018). Breeding of *P. krameri* in buildings is very common in Britain, Germany, Belgium, and Japan (Braun 2004, 2007). Some breeding pairs build nests in wall holes or crevices of buildings in north India and Spain. In Pavia (northern Italy), the entire population breeds in scaffold holes of the Visconti castle and towers (Grandi et al. 2016). The present study reveals

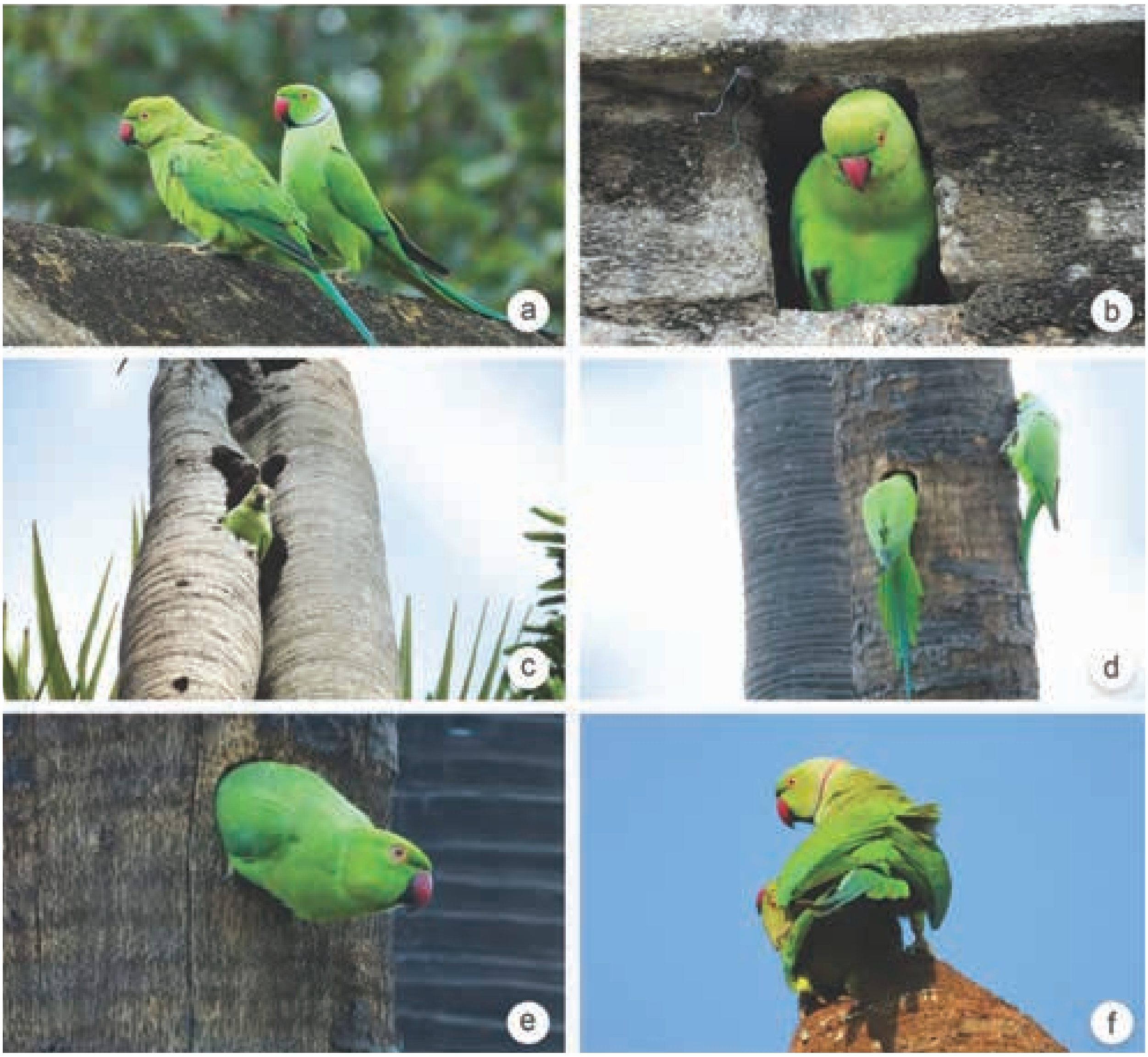

Image 1. Nesting habitats of *Psittacula krameria*: a—a pair of birds roosting on temple wall | b—female individual in wall hole in temple | c—male individual in a cavity of dead *B. flabellifer* trunk | d—a pair engaged in excavation of cavity on *B. flabellifer* trunk | e—female individual in a trunk cavity, and | f—a mating pair. © M. Pandian.

that 26% nests (n= 208) and 16.8% birds (n= 188) were counted on 10 temples and three buildings in the study area. The present observation of successful utilization of available holes/crevices in the temple and buildings for construction of nests by *P. krameri* population matches the findings of Ali & Rilpey (1969), Jahan et al. (2018), and Braun (2004, 2007).

Preference of habitats for nesting

As a social bird, *P. krameri* generally prefers to build nests on trees situated near agricultural lands. Occurrence of 29.1% nests (n= 234) and 33% birds (n= 369) on the trees situated near the agricultural lands prove that the birds preferred to breed in agricultural areas where abundant food materials are available. Another 22.8% nests (n= 182) and 24.3% birds (n= 272) were found on trees located near water bodies. Maximum nests of *P. krameri* were found in the areas where cultivation of crops occurs and near water bodies in Punjab (Khan 2002a) and Hawaii (Paton et al. 1982). In the present study, occurrence of 51.9% nests (n= 416) and 57.3% birds (n= 641) in agricultural lands and close to water bodies in rural villages clearly indicates that the birds selected nesting sites in agrarian landscapes ensuring availability of abundant food material. Hence it matches with the observations of Khan (2002a) and Paton et al. (1982).

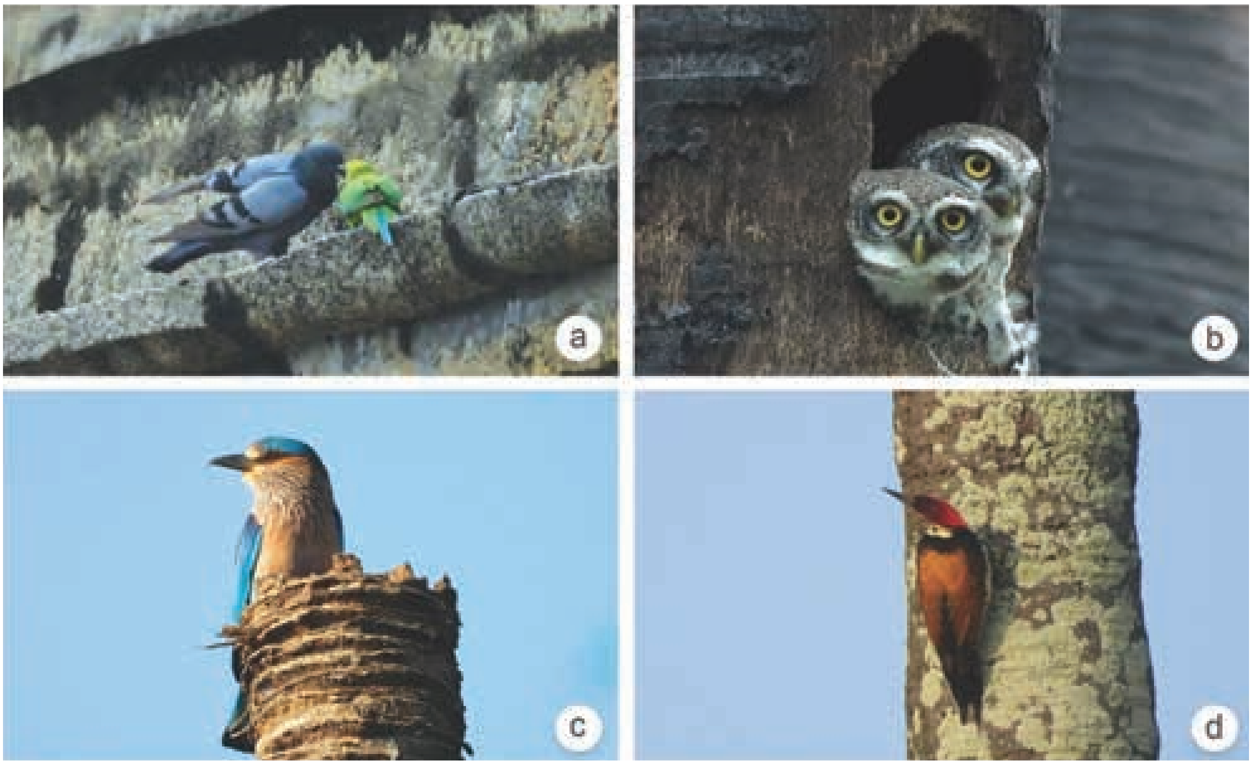

Image 2. Inter-specific competition: a—male parakeet fighting with a pair of Blue Rock Pigeons | b—nestlings of Spotted Owlet | c—Indian Roller guarding its nest on top of dead *B. flabellifer* tree, and | d—Black-rumped Flameback excavating cavity. © M. Pandian.

Image 3. Abnormalities in *Psittacula krameria*: a—male bird with beak deformity | b—female bird with cere deformity | c—female bird with suspected infection of psittacine beak & feather disease | d—female bird with colour abnormality. © M. Pandian.

This bird also preferred trees near human settlements and holes/crevices of temples/buildings for construction of nests. It suggests that the birds tolerate the presence of human.

Observation of inter-specific interactions

Cavity nesters pose a unique habitat problem. Obligate cavity nesters are associated with intra and inter-specific competition for nest sites (Collias & Collias 1984; Nilsson 1984). Jones (1980) had stated that incidents of competition between *P. krameri* and mynas *Acridotheres tristis* for sharing nest cavities in trees was reported in Mauritius. In view of the limited availability of nest-holes, inter-specific competition usually occurs between secondary cavity nesting birds in human altered landscapes (Cornelius 2008). They compete with native birds for sharing trunk-holes in Belgium also (Strubbe & Matthysen 2009). In the present study too *P. krameri* competed with a Blue Rock Pigeon, for sharing a hole in a temple, with a Spotted Owlet, an Indian Roller and a Black-rumped Flameback for sharing trunk holes in *B. flabellifer* trees during the breeding period. Hence, the present observation of inter-specific competition with other birds for sharing nesting sites corroborates with the findings of Jones (1980) and (Strubbe & Matthysen 2009).

Observation of abnormalities

Beak abnormalities may occur due to various causes such as malnutrition, infections, injury, mutations, defective bone growth, tear of rhamphotheca, and misalignment of maxilla & mandible (Oslen 2003; Handel et al. 2010; Zylberberg et al. 2018). Deformed beaks take many forms with upper/lower mandibles elongated, curved or mandibles crossed and are more prevalent in passerines (Craves 1994). Pomeroy (1962) has observed that abnormal bills in wild birds are rare with an estimated frequency of less than 0.5%. British Trust for Ornithology (BTO 2014) has recorded 36 species with beak deformities including ring-necked parakeets. In India, Kasambe et al. (2009) and Soni et al. (2019) have reported bill deformities in Yellow-billed Blue Magpie, Crow, and Common Myna. Kanwar (2019) has recorded beak abnormality in Ring-necked Parakeets in Chandigarh. In the present study, the upper mandible of one male bird was found colourless, curved and elongated up to its neck. This type of beak deformity may cause hardship to the bird while foraging and feeding chicks. Out of 1,119 birds studied, only one individual, i.e., 0.09% had a bill deformity. Hence, it confirms the view of Pomeroy (1962) that abnormal bills in wild birds are rare with an estimated frequency of less than 0.5%

One female bird with swollen and distorted cere with a big nostril was observed. Cornification and keratinization of the cere can progress to close up the nostrils. These abnormalities in cere might have been caused by the mite, *Knemidokoptes pilae* (Zwart 1995). The study reveals that one female bird with similar symptoms of swollen and distorted cere with big opening was found. The observed symptoms matched the findings of Zwart (1995).

Colour mutations in *P. krameri* such as yellow (Bhargava & Hanfee 1996), white-rose (Mahabal et al. 2015), albinism (Mahabal et al. 2016), and cinnamon green (Kushwaha & Kumar 2018) have been reported in India. In U.K., many colour mutations have occurred in captive birds (Low 1992; Butler 2003). Hence, the present observation of yellow colour mutation of feathers in the study area corroborates the findings of the aforesaid authors.

Pass & Perry (1984) and Ritchie et al. (1991) had stated that psittacine beak & feather disease (PBFD) caused by a virus has emerged as a major threat to the wild parakeet populations. The observed four *P. krameri* individuals with similar symptoms of feather loss and warty skin on their heads are suspected to have PBFD.

CONCLUSION

The present study was confined to a small geographical area covering 71 villages in seven northern districts of Tamil Nadu. Since a total of 1,119 individuals and 797 nests were enumerated in this region, it is considered a hotspot for breeding of this species. A systematic survey of the entire state would throw more light on the status and distribution of Ring-necked Parakeets in the state, and help in drafting an action plan to conserve their habitats in and around villages and also in the urban areas.

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COMMUNICATION

Two new species of *Euphaea* Selys, 1840 (Odonata: Zygoptera: Euphaeidae) from northern Western Ghats, India

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Abstract: Two new species of the damselfly genus *Euphaea* Selys, 1840 (Odonata: Euphaeidae) are described from the Western Ghats of Satara District, Maharashtra, distinguished by their distinct morphology and coloration. *E. thosegharensis* Sadasivan & Bhakare sp. nov. is similar to *E. cardinalis* (Fraser, 1924), but is distinguished by the extensor and flexor surface of all femora black while all femora bright red in *E. cardinalis*; apical fourth of Hw black while apical half of Hw black in *E. cardinalis*; genae reddish-orange, black in *E. cardinalis*; a tuft of sparse stub black hair on either side of tergite of S9 while both S8 and S9 with tufts of long ventral hairs in *E. cardinalis*. Male genital vesicle matt black, with distal border rounded angles, while vesicle black and hexagonal in shape with rounded angles in *E. cardinalis* and S9 twice the length of S10, while S9 and S10 of equal length in *E. cardinalis. E. pseudodispar* Sadasivan & Bhakare sp. nov., is very close to *E. dispar* (Rambur, 1842), but is differentiated easily by the absence of yellow patch on legs as in *E. dispar;* only apical fifth of Hw black; genae being yellowish-white, while black in *E. dispar*; male genital vesicle brownish-black & rhomboid-shaped and with no transverse rugosities while black with distal border rounded and with fine transverse rugosities in *E. dispar*; penis with single seta on each side while *E. dispar* has three pairs; sternite of S9 very prominently extending ventrally like a beak in comparison with *E. dispar*. We have identified additional morphological characters useful in taxonomy of *Euphaea* of the Western Ghats for example, tufts of ventral hairs on terminal abdominal segments genital vesicle, penile structure of males and sternite of S9 in the males, and vulvar scales of females. A taxonomic key to all known species of genus *Euphaea* of the Western Ghats is also provided.

Keywords: Additional morphological characters, Damsel fly, Endemic, Maharashtra, taxonomic key.

Abbreviations: Ax—antenodal crossveins | Fw—forewing | Hw—hindwing | Px—postnodal crossveins | Pt—pterostigma | S1–10—abdominal segments | TL—total length of the specimen including appendages | AL—abdominal length | FL—forewing length | HL—hindwing length | TNHS—Travancore Nature History Society | TORG—Travancore Odonate Research Group | KS—Kalesh Sadasivan | SDB—Sunil Hanmant Bhoite | SHB—Shriram Dinkar Bhakare | PAP—Pratima Ashok Pawar.

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INTRODUCTION

The genus *Euphaea* Selys, 1840 (Odonata: Euphaeidae) is represented by medium-sized damselflies distributed from the Western Ghats of peninsular India, northeastern India, Sri Lanka, Vietnam, and Malaya in Indochina & Borneo. India has five known species of *Euphaea* (Subramanian & Babu 2017); two species, *Euphaea masoni* Selys, 1879 and *Euphaea ochracea* Selys, 1859, are distributed in the northeastern region, while the Western Ghats has three species namely *Euphaea cardinalis* (Fraser, 1924), *E. dispar* (Rambur, 1842), and *E. fraseri* (Laidlaw, 1920) (Subramanian et al. 2018). They are characterized by males with hindwing apices more or less broadly opaque black having metallic iridescence in some light; forewings pointed, hindwing rounded and shorter than the forewing; discoidal cell traversed; thorax robust; abdomen long cylindrical in males and same length or shorter in females; abdominal segment 10 with a robust dorsal keel and its apex pointed, and the anal appendages with forcipate cerci and tiny paraprocts (Fraser 1934).

The species *E. cardinalis* is endemic to the Western Ghats and is distributed in Kerala and Tamil Nadu. It is a montane species seen above 900m south of the Palghat gap in the Anamalai, Palani, and Agasthyamalai hills. *E. dispar* is confined to the Western Ghats north of the Palghat gap from South Kanara and Coorg to the Nilgiris (Malabar Wayanad) from 1,066 to 1,828 m (Fraser 1934). *E. fraseri* is a species seen in the forested foothills of the Western Ghats and is distributed from North and South Kanara, Malabar, Coorg, the Nilgiris Wayanad, and Anamalai Hills (Fraser, 1934), and its current distribution is from Kanyakumari to Maharashtra at 100–1,200 m (Subramanian et al. 2018). Here, we describe two new species of the genus from Satara District, Maharashtra the northern Western Ghats, north of the Amboli Ghat.

MATERIALS AND METHODS

SDB came across the specimens in May 2020 at Thoseghar, Satara District of Maharashtra (Image 1). The insects were collected and preserved in absolute alcohol and compared to specimens of known species of *Euphaea* from the Western Ghats. Nomenclature follow Subramanian & Babu (2017) and Paulson & Schorr (2020). The known distribution of the species follows Subramanian et al. (2018). Taxonomic keys to the species are modified based on Fraser (1934). The morphological description follows Garrison et al. (2006). The ventro-lateral wing like structure on segment 2 is

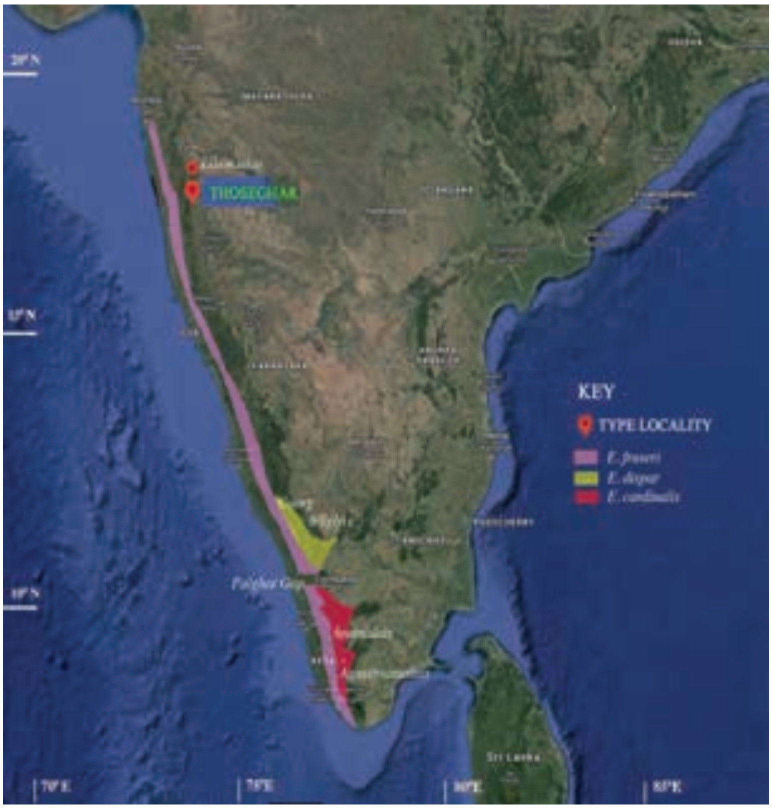

Image 1. Map showing distribution of the new damselfly species in Western Ghats, with type locality of *Euphaea thosegharensis* Sadasivan & Bhakare, sp. nov. and *E. pseudodispar* Sadasivan & Bhakare, sp. nov.

termed the pseudoauricle following Orr (2003). The scale like structure guarding the gonopore on ventrum of abdominal segment 9 (S9) is referred here to as the gonocoxae. The wing venation terminology follows Riek & Kukalová-Peck (1984). Measurements and morphological details of all species mentioned in text are based on specimens in voucher collections of TORG. Photographs of the specimens were taken with Canon (Canon Inc., Japan) EOS 70D DSLR fitted with 180mm macro lens.

Current distribution of known species of *Euphaea* is based on our personal records and Subramanian et al. (2018). The genitalia were studied by dissecting under a stereo-zoom microscope (HEADZ Model HD81) and later preserved in glycerol. Holotype and paratype are deposited in the insect collection facility of Zoological Survey of India (ZSI), Kozhikode. Additional material will be deposited in ZSI Pune and Bombay Natural History Society (BNHS), Mumbai. Illustrations were made by KS using the stereo-zoom microscope.

RESULTS

Euphaea thosegharensis Sadasivan & Bhakare, sp. nov.

(Image 2 A–G)

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Holotype: ZSI/WGRC/I.R-INV.15031, 30.v.2020, Male, wet specimen in alcohol, Thoseghar, Satara District, Maharashtra, India, 1,060m; specimen collected from a paddy field near a flowing stream, coll. SDB.

Paratype: ZSI/WGRC/I.R-INV.15032, 30.v.2020, Female, same information as the Holotype.

Additional material examined*:* Males (n= 4) and females (n= 3) bear the same collection data as the holotype, wet specimens in alcohol, will be subsequently deposited in collections of ZSI Pune and BNHS Mumbai.

Additional field records (specimens not collected): Thoseghar (1,060m): 10 males and 4 females on 30.v.20; 14 males and 6 females on 07.vi.20; 7 males and 3 females on 14.vi.20; 8 males and 4 females on 21.vi.20; 8 males and 5 females on 28.vi.20; 8 males and 2 females on 02.vii.20; 2 males and 2 females on 04.viii.20. All observations by SHB & SDB. Chikhali (1,081m): 6 males and 2 females on 26.vii.20, observed by SB & SB. Kaas Lake (1,124m): 4 males on 02. viii. 20, observed by PAP.

Description of holotype male (Image 2A & 3)

Measurements (in mm): TL (including appendages) 51, AL 42, FL 4.0, HL 31.

Head*:* The coloration of the live insect is described below (in the dead insect the colours fade with respect to the hues). Labium dark amber brown to black. Labrum reddish-orange with a faint and obscure median streak and the mandible with same colour and a faint transverse upper streak. Anteclypeus shiny dark amber brown to black. Postclypeus pinkish-red with two thin black paradorsal vertical lines and two lateral black spots near the anterio-lateral margin. Antefrons brownish-red and postfrons brownish-black. Genae are red inferiorly, middle part orange yellow and superior third red. Eyes dark amber black superiorly, middle part and laterally dark amber brown and the inferolateral aspect pale brown. Antennae shiny black and vertex matt black, with an ill-defined and obscure reddish patch, twice the size of the ocelli, with suffused margins running between the lateral ocellus and the base of the antenna on each side. This spot may be difficult to see once the specimen is preserved. The occiput, occipital bar and post-ocular region are greyish-matt black (Image 3B).

Prothorax: coloured in matt black with vermilion red spots. Anterior lobe is black with two small reddish spots at the medial part of the lateral third. Middle lobe black with the lateral triangular spots vermilion red, notopleural suture black and propleuron brownish-red. Posterior lobe black with the lateral angles pale brownish-red. No spines present (Image 3C).

Pterothorax: The ground colour of the pterothorax in the live insect is bright red with pinkish hue inferolaterally and orange dorsally. Dorsal carina black. The triangular mesothoracic acrotergite black. The paradorsal region on either side black. Nearly the whole humeral suture and the dorsal fifth of the interpleural suture marked in matt black. Mesostigmal plate black with its anterior edge pale pinkish-red. Mesepisternum red and encloses a thick black central mesepisternal stripe as thick as the paradorsal black band. This red ground colour of the mesepisternum not interrupted and is continuous all around the central black band, though very narrowly connected on the dorsal aspect near the antealar sinus. Thus, in other words the antehumeral stripe and the humeral stripes are connected around the central black band, and is coloured orange-red, the former being more orange and the later more red. Mesepimeron coloured red and encloses a central black band, with the red continuous all around the black band. Mesinfraepisternum is bordered with pale pinkish-red and has a large black spot occupying its antero-inferolateral aspect. The second lateral suture marked in back on its dorsal third. Metepisternum and Metepimeron are fully red. Metinfraepisternum pale

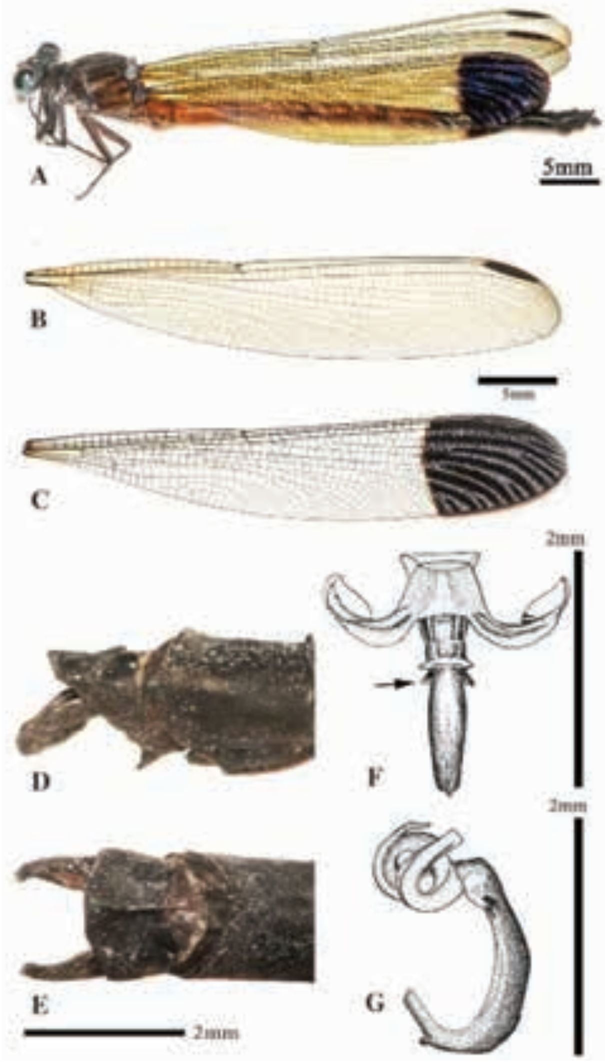

Image 2. *Euphaea thosegharensis* Sadasivan & Bhakare, sp. nov. Male: A—ZSI/WGRC/I.R-INV.15031 | B—Venation Fw | C—Venation Hw | D & E—Anal appendages | F & G—Genital lingula (arrow pointing to the setae). © Kalesh Sadasivan.

pinkish-red and its lower part is paler. Metathoracic spiracle amber brown (Image 3C).

Legs: Coxae are anteriorly greyish and pinkish on the postero-lateral aspect. The trochanter, femur, tibia, tarsus and the claws all are grey graphite black. The femur have an inconspicuous pale pinkish wash on the superior part of the flexor aspect (Image 3C).

Wings: Fw is hyaline and its tip up to 3–4 cell are faintly effumed. Veins are black. Left Fw Ax-24 & Px-35; right Fw Ax 25 & Px 36; left Hw Ax 18 & Px 32; right Hw Ax 18 & Px 31. Pt is black and is 10–11 cell wide in Fw and in Hw. Hw is hyaline and its distal fourth is coloured black with a metallic purplish to lilac violet reflex in some lights. The proximal margin of this black patch is convex and extends to 7 cells proximal to the Pt. Veins are black

Image 3. *Euphaea thosegharensis* Sadasivan & Bhakare, sp. nov. Male from field: A—lateral view | B—head and thorax dorsal view | C—lateral view of head and thorax. © Shriram Dinkar Bhakare.

Image 4. *Euphaea thosegharensis* Sadasivan & Bhakare, sp. nov. Female from field: A—lateral view | B—head and thorax dorsal view | C—lateral view of head and thorax. © Shriram Dinkar Bhakare.

and has 18–19 Ax and 31 Px. Pt is black and is 10 cell wide. Cubital space with 3 cross veins in Fw and 3–4 cross veins in Hw (Image 2B & C).

Abdomen: The general colour of abdomen is red on the proximal segments and black on the distal ones. The transition take place in S5-6, where the dorsal red merges with ventral black (Image 2A&3A). Segmental joints black. S1–S4 is fully red throughout. S2 with well-developed pseudoauricle on each side which bears two tiny black teeth at its summit; it is coloured pinkish-red on their lateral aspect. S5 is dorsally red, this red enclosing the base of the segment and distally it narrows to reach just short of the end of the segment. The distal end of the segment is black and this black color runs inferiorly and anteriorly but never reaches the base of the segment. S6 has its dorsal proximal third red and this extends along the lateral aspect of the segment to reach almost the half of the segment, and rest of the distal part black. S7 is wholly black except for a small baso-lateral red spot on each side. S8–10 are wholly black. A tuft of sparce stub black hair is seen on tergite of segment 9 near its base. No other hair tufts are seen on the ventrum of abdomen on S8 or S9. On ventral view, the gonopore margin trapezoid shaped, wider distally. Gonocoxae with their apices produced into small spines that are divergent at the tip. No tooth on the distal aspect sternite of S9 near the gonopore. Distal margin of S10 '{' shaped, hence curved and wavy at its mid-ventrum. On lateral view, the mid part of distal margin of S9 does not extend much as tooth, over the gonopore (Image 11G). Abdominal segment 9 twice the length of S10. S10 bears a broad dorsal carina and a broad keel at its distal end (Image 2D&E).

Genitalia: S2 genital vesicle matt black, with distal border and angles rounded, transversely rugose about its anterior third; its proximal extension is square and shallowly excavated. Genital lingula illustrated. Penis with six setae one each side (Image 2F&G).

Anal appendages: The anal appendages are very similar to that of other species in the genus. They have forcipate cerci and tiny paraprocts. Paraprocts with tips medially directed and hence tips converge at rest. Paraprocts of same length as the gonocoxae. The size of paraprocts are much smaller than the S10 dorsal keel. Lamina of cerci as in *E. cardinalis,* but with the tip slightly more incurved (Image 11B&G). The cerci and paraprocts are fully black (Image 2D&E).

Description of paratype female (Image 4)

Measurements (in mm): TL (including appendages) 42, AL 33, FL 32 & HL 33 mm.

Image 5. Field images of *Euphaea thosegharensis* Sadasivan & Bhakare, sp. nov.: A—male | B—female | C—courtship | D—riparian habitat of the species. © Shriram Dinkar Bhakare.

Head: Labium black; labrum pale dirty white with a faint and obscure suggestion of the median black tongue; Anteclypeus blackish-amber brown; Postclypeus pale greenish-white with the vertical paradorsal black streaks extending laterally as suffused black patch obscuring the black streak on the lateral aspect its anterior border, thus appearing as grossly black with a central pale bluish-white patch; Antefrons centrally black and laterally pale greenish white; Post frons matt black; Genae pale greenish-white to almost white; antennae black, Vertex and occiput black; eyes as in the males black and paler inferiorly (Image 4B).

Prothorax: Structure and coloration of all the three lobes are closely similar to that in the male, but coloured pale yellowish instead of pinkish-red, otherwise matt black. No ornamentations or spines present (Image 4C).

Pterothorax: The reds of the males are replaced by pale greenish-white. The mesepisternum mesepimeron, metepisternum are as in the males, but with the orange and red colours replaced with pale greenish-yellow. The central black stripe in mesepisternum and the and metepisternum are as in the males. In addition the metepimeron has a similar black streak, that the male lacks. Rest of the pterothorax is as in the males with the reds replaced by pale greenish-yellow (Image 4C).

Legs: Coxae are coloured posterolaterally in pale dirty greenish-white, and rest of the parts of the legs are matt black as in the male and is mildly pruinosed (Image 4C).

Wings: Both wings hyaline. Left Fw Ax-22 & Px-3; right Fw Ax 21 & Px 29; left Hw Ax 19 & Px 26; right Hw Ax 20 & Px 24. Pt is black and is 9–10 cell wide in Fw and 9–11 cell wide in Hw. Wings are hyaline with a faint smoky hue in life.

Abdomen: All segments are black dorsally with lateral pale greenish-yellow markings as follows: S2–3 with a large spot posterolaterally and the black of this anterolaterally merge with the yellow as brownish suffusion, S2–3 with a very narrow stripe, S4 similar to S3 but the black posterolateral spot and its proximal suffusion is much darker, S5 with a anterolateral 'T' shaped yellow mark whose central streak tapers and ends at the distal thirds, S6–7 with this anterolateral yellow streak progressively reduced to mere yellowish anterolateral triangles. S8-10 are fully black. Vulvar scale with a central shallow but wide sulcus and its postero-lateral angle is rounded. Anal appendages and ovipositor are black (Image 12F).

Variations

Males: There are some variation in the morphometrics (n= 4). Measurements (in mm) are TL (including appendages) 5.06 ± 0.21, FL 3.73 ± 0.23, HL 34.5±0.7 & AL 39.5 ± 0.71. There are only minor variations in hues and extent of coloration amongst males that we photographed from the region. In venation, in the Fw the number of Ax varies from 20–25, while Px varies from 35–36. Pt is black and is 9–11 cell wide. Hw had 17–19 Ax and 29–31 Px. Cubital space with 3–4 cross veins in all wings. The labrum, on its attached margin, in some specimens of both sexes may have a faint and obscure suggestion of a vertical median brownish-black band. Paratype females (n= 4) had variations in venation, with the Fw having 20–22 Ax and 21–24 Px, Hw with 19–21 Ax and 24–29 Px. Cubital space with 3–5 cross-veins in Fw and 3–4 in Hw. Wings have a faint smoky hue in life. The tenerals are slightly different in color. Males are more orangish when young and as they mature become more reddish. In such mature individuals, red coloration of the face and thorax is brighter, and antehumeral stripe and spots on middle lobe of prothorax is pinkish orange. In well-marked individuals, antehumeral and the humeral stripes are interrupted by the mesepisternal central black band dorsally near the antealar sinus. Abdominal segment 6 is colored red up to the half of the segment, but some individuals, observed in field, had the red restricted to the basal third to fourth.

Females: The pale greenish-yellow of females change to pale dirty brown on the thorax and to pale ochreous brown on the abdomen as the individuals age. The inferolateral aspect of thorax, coxae, trochanters, proximal femora and the ventral region of abdomen are pruinosed in older specimens. The females are sometimes heavily marked in black in which case the humeral and antehumeral stripes are very much reduced to thin irregular streaks. The pale greenish color of the genae may have a light blue wash in young individuals.

Etymology

The species name *'thosegharensis'* is a toponym derived from the type locality in Thoseghar, Satara District, Maharashtra, India.

Distribution As far as known, the species is restricted to the high-elevation streams and riparian patches of Satara District around Thoseghar, and Kaas Lake in Maharashtra, India.

Habitat and Ecology

The habits are as for the genus. The males are seen guarding parts of streams on vantage points, like rocks or on the tips of twigs. They stay on these perches for long time if not interfered by rivals or a potential mate worth investigating. Flight period is from April to August as inferred from past observations and photographs. The individuals are almost always found in the area of shallow, flowing stream with tree canopy at the edges. Males are often seen sitting on the rocks in the stream and show territorial behaviour (Image 5). Females are seen resting on the dry twigs along the edges of streams. Both retire on the dry bush twigs at the edges of streams to roost overnight.

Differential diagnosis (Table 1, 2)

The new species can be easily differentiated from all the known *Euphaea* species of Western Ghats based on morphology (Table 1) and coloration (Table 2). Based on the morphological features, it is differentiated from all others by its smaller size (Hw 34–35 mm, Abdomen 39–40 mm); the male genital vesicle being black with distal borders rounded and a tuft of sparce stub hairs on sternum of S9 only; the gonopore margin trapezoid shaped, wider distally; and the gonocoxae with their apices produced into small spines that are divergent at the tip. From *E. fraseri,* it can be differentiated based on the presence of hair tufts on the former. Length of S9 twice the length of S10 in *E. thosegharensis*, and this distinguishes it from *E. dispar* and *E. pseudodispar*, both of them having S9 length 1.5 times the length of S10*,* whereas in *E. cardinalis* S9 and S10 are of equal length. Also, this species has no tooth on the distal aspect sternite of S9 near the gonopore unlike in *E. cardinalis*. The insect is of small size in comparison with *E. cardinalis* and *E. dispar,* and is almost the same size as *E. fraseri.* Based on coloration, it is distinguished from all its congeners by the orange labrum, orange-red genae, rose red spots on lateral aspect of middle lobe of prothorax, orange red antehumeral stripe, all legs being black and the apical fourth of Hw being black. The coloration of labrum is similar to *E. cardinalis* and the antehumeral stripes are closer to *E. dispar* and *E. cardinalis* (Image 11B).

Euphaea pseudodispar **Sadasivan & Bhakare, sp. nov.**
(Image 6 A–G)
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Holotype: ZSI/WGRC/I.R-INV.15033, 26.vii.20, Male, wet specimen in alcohol, Thoseghar, Satara District, Maharashtra, India, 1,060m, specimen collected from a paddy field near flowing stream, coll. SDB.

Paratype: ZSI/WGRC/I.R-INV.15034, 26.vii.20, female, same information as the Holotype.

Additional material examined: Males (n= 4) and females (n= 3) bears the same collection data as the holotype, wet specimens in alcohol, will be subsequently deposited in collections of ZSI Kozhikode & Pune and BNHS Mumbai.

Additional field records (specimens not collected): Thoseghar (1,060m): 3 males and 1 female on 02.vii.20; 4 males and 2 females on 15.vii.20; 2 males and 2 females on 26.vii.20; 5 males and 3 females on 04.viii.20; 5 males and 2 females on 06.viii.20; all observations by SHB & SDB. Kaas Lake (1,124 m): 3 males on 02.viii.20; observed by PAP.

Description of holotype male (Image 6)

Measurements (in mm): TL (including appendages) 47; AL 36; FL 33 & HL 31.

Head: Labium coloured dark amber brown to black; labrum pale bluish-white with a very distinct and prominent median black 'tongue' shaped mark at its attached end. Mandible pale bluish-white with an upper transverse black streak. Anteclypeus shiny dark amber brown to black and postclypeus is black, antefrons & postfrons black and the genae pale bluish-white. Eyes black superiorly, middle part and laterally dark amber brownish-black and the inferolateral aspect brown; antennae shiny black; vertex matt black; occiput, occipital bar and post-ocular region are matt black (Image 7B).

Prothorax: coloured in matt black with yellowish spots. Anterior lobe fully black; middle lobe black with the lateral triangular spots yellowish, notopleural suture black and propleuron is mat black with a pair of indistinct reddish spots. Posterior lobe black with no ornamentations or spines present (Image 7C).

Pterothorax: The ground colour of the Pterothorax in the live insect is orange red with orange hue inferiorly and yellow dorsally. Dorsal carina is black. The triangular mesothoracic acrotergite black. The dorsal aspect of thorax- the Mesepisternum fully matt black. The humeral stripe yellowish orange, thin and irregular and is separated into a small spot on the dorsal end and the long stripe inferiorly. The antehumeral stripe pale yellow and tapers gradually towards the alar sinus. Thus, in other words the antehumeral stripe and the humeral stripes are not connected and significantly tapers dorsally. Mesostigmal plate mat black with its lateral lip pale pinkish-red. Mesinfraepisternum bordered with orange in the posterolateral aspect and antero-superiorly is black; these colours being separated sharply at the diagonal running from postero-superior to antero-inferior corners. Mesepimeron yellow superiorly and orange inferiorly, and encloses a central broad black band. The interpleural suture marked in reddish-black and this patch extends to about the middle of the mesepimeron. The second lateral suture marked in back on its dorsal third. Metepisternum and metepimeron are fully yellowish-orange. Metinfraepisternum brownish-orange. Venter of metathorax pale pinkish-orange. Metathoracic spiracle pale yellowish-white (Image 7C).

Legs: Coxae and trochanter of forelegs brown anteriorly and grey posteriorly. Coxae of mid and posterior legs brownish-orange. The femur, tibia, tarsus and the claws of legs are lustreless red with a cyan hue. The extensor surface of forelegs on the superior third are black. Knees are black. Claws are reddish-black to almost black (Image 7C).

Wings: Fw are hyaline, veins are black. Left Fw Ax-24 & Px-34; right Fw Ax 22 & Px 32; left Hw Ax 19 & Px 31; right Hw Ax 19 & Px 30. Pt is black and is 10 cell wide in Fw and 11 cell wide in Hw. Hindwing hyaline and its distal fifth coloured black with a metallic coppery to lilac reflex in some lights. The proximal margin of this black patch convex and extends to four cells proximal to

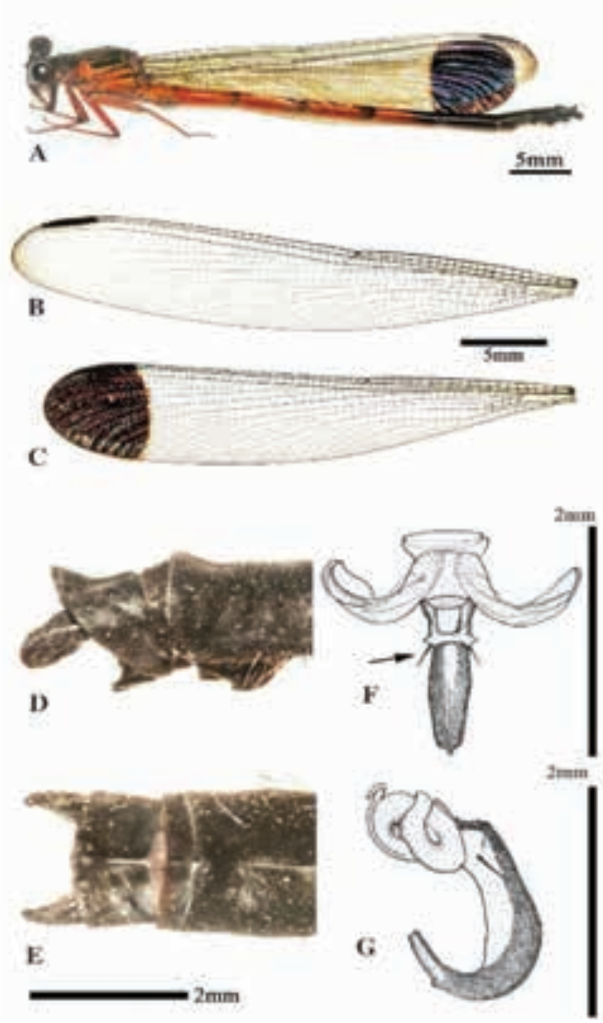

Image 6. *Euphaea pseudodispar* Sadasivan & Bhakare, sp. nov. A—holotype male ZSI/WGRC/I.R-INV.15033 | B—venation Fw | C—venation Hw | D & E—anal appendages | F & G—genital lingual (arrow pointing to the setae). © Kalesh Sadasivan.

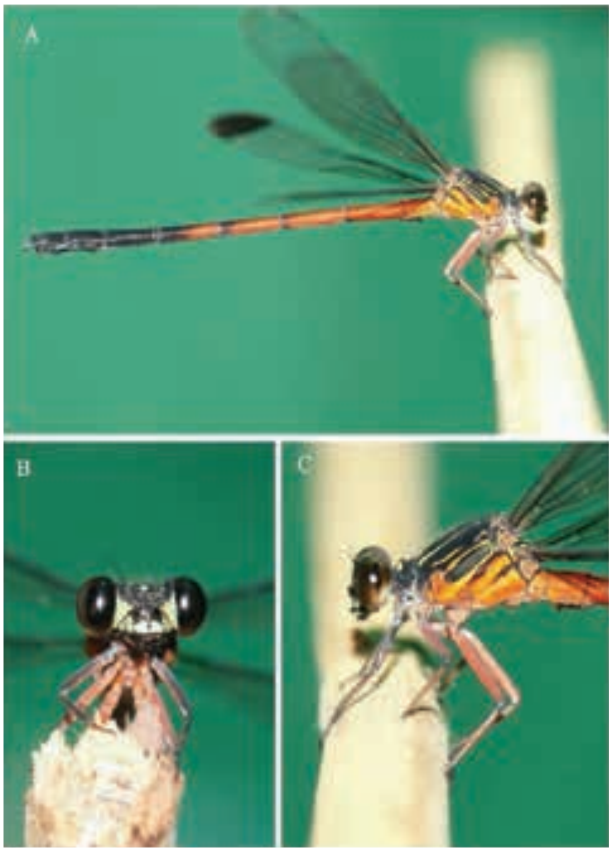

Image 7. *Euphaea pseudodispar* Sadasivan & Bhakare, sp. nov. Male from field: A—lateral view | B—head frontal view | C—lateral view of head and thorax. © Shriram Dinkar Bhakare.

the Pt. Cubital space with three cross veins in all wings (Image 6B&C).

Abdomen: The general colour of abdomen reddish-orange on the proximal segments and black on the distal ones. The transition take place in S6, where the dorsal red merges with ventral black (Image 7A). Segmental joints black. S1 yellowish and posteriorly with orange wash. S2 anteriorly orange and distally reddish-orange. S2 with a non-flanged pseudoauricle on each side which bears few tiny teeth at its summit. S3 fully reddish-orange throughout. The distal aspect of S4 near the joint with S5 with a brownish hue. S5 also reddish orange with its distal fifth brownish-black. Proximal half of S6 orange red and its distal half is black, and this transition of red to black is gradual. S7–10 fully black. S10 bears a broad dorsal carina and an abrupt dorsal keel at its distal end. A very small inconspicuous patch of moderately long brownish-orange hairs on lateral aspect of proximal part of S1, S2, and S3. A tuft of black hair seen on base of tergite of segment 8. On ventral view, S8 tergite with long hairs on its lateral border and the longest ones at its distal third. S9 tergite with long hairs on its proximal half. The sternite of S8 and S9 with a tuft of very sparse short hairs on its proximal aspect of its base. On ventral view, the gonopore margin oval. Gonocoxae with their apices blunt, no spine. No tooth on the distal aspect sternite of S9 near the gonopore. Distal margin of S10 '{' shaped, hence curved and wavy at its mid-ventrum. On lateral view, the mid part of distal margin of S9 prominently extending ventrally and it's tip extends as a very short tooth, over the gonopore (Image 11I). S9 1.5 times the length of S10. On lateral view, the tips of paraprocts hooked, with tip directed dorsally (Image 6D).

Genitalia: S2 with a matt brownish black, rhomboidal genital vesicle, with distal end angulated, and no transverse surface rugosities (Image 12D). Genital lingula illustrated. Penis with a single setae on each side (Image 6F&G).

Image 8. *Euphaea pseudodispar* Sadasivan & Bhakare, sp. nov. Female from field: A—lateral view | B—head and thorax dorsal view | C—dorso-lateral view of head and thorax. © Shriram Dinkar Bhakare.

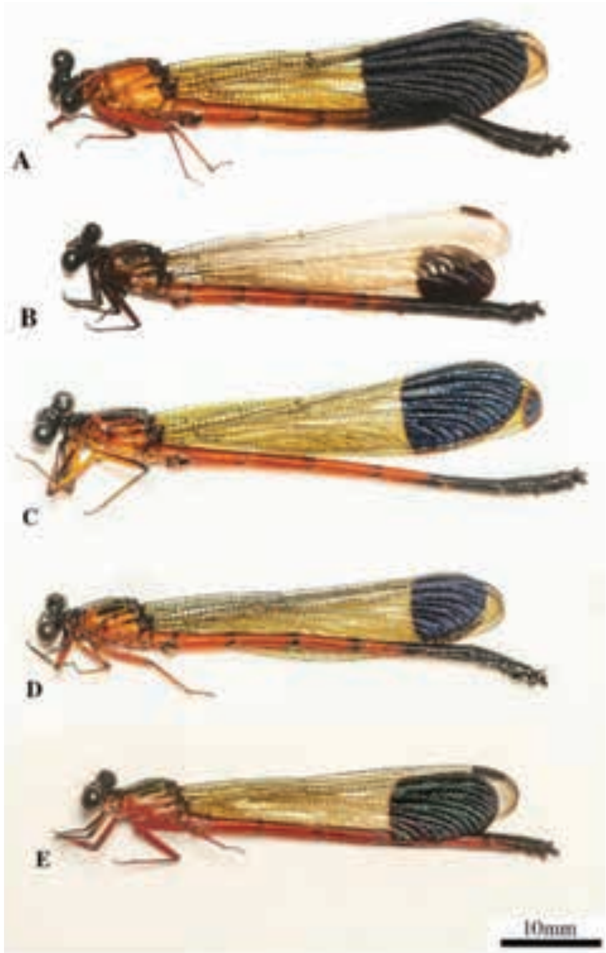

Image 9. Voucher specimen images of *Euphaea* males: A—*E. cardinalis* (Fraser, 1924) | B—*E. thosegharensis* Sadasivan & Bhakare, sp. nov. | C—*E. dispar* (Rambur, 1842) | D—*E. pseudodispar* Sadasivan & Bhakare, sp. nov. | E—*E. fraseri* (Laidlaw, 1920). © Kalesh Sadasivan.

Anal appendages: The general structure is as in the genus with the cerci and paraprocts fully black. The cerci are forcipate. On ventral view, paraprocts with tips medially directed and hence tips converge at rest. Length of paraprocts longer than that of the gonocoxae. The size of paraprocts as large as the S10 dorsal prominence (Image 6D&E, 11I).

Description of paratype female (Image 8)

Measurements (in mm): TL (including appendages) 41, AL 30, FL 32 & HL 30.

Head: Labium black; labrum pale bluish-white with a prominent median black tongue; mandible pale bluish-white with the upper transverse black streak as in the male; Anteclypeus postclypeus, antefrons and postfrons are matt black; Genae pale bluish-white; antennae black, Vertex and occiput matt black; eyes as in the males black and brown inferiorly (Image 8B).

Prothorax: Structure and pattern of coloration all the three lobes are as in the males. The lateral spots on middle lobe is coloured pale yellowish-white, otherwise the whole structure is matt black. No spines present on posterior lobe (Image 8C).

Pterothorax: The reds of the males are replaced by pale greenish-white. The antehumeral and humeral stripes are pale yellowish-blue to pale blue. The mesepisternum, mesepimeron, and metepisternum are as in the male, with the orange and red replaced with pale bluish-yellow. The central black stripe in mesepisternum and the metepisternum are as in the males. Rest of the pterothorax is as in male, with the reds replaced by pale bluish to greenish-yellow (Image 8C).

Legs: Coxae are coloured posterolaterally by pale dirty greenish-white and are usually pruinosed. The trochanters are grey. The femurs, tibia, tarsus and claws are black. The flexor aspect of the proximal fourth of forelegs, and whole length of the mid and hind tibia are coloured white (Image 8C).

Wings: Both wings hyaline. Left Fw Ax-21 & Px-29; right Fw Ax 21 & Px 30; left Hw Ax 17 & Px 28; right Hw

Ax 17 & Px 27. Pt is black and is 10–11 cell wide in Fw and Hw.

Abdomen: All segments from S1 are black dorsally with a thin dorsal carinal yellow streak. Laterally, the inferior half of all segments have yellow transverse streaks that thin out distally. The dorsal carinal streaks disappear at S6, while the lateral yellow streaks disappear after S7. The rest of the abdomen on its ventrum and the segments 8–10 are fully black. Vulvar scale without any central sulcus and its postero-lateral angle is produced as an postero-medially directed wide and blunt tooth (Image 12G). Appendages and ovipositor are black.

Variations

Males: In the paratype males (n= 4), with regards to the morphometrics there are some variations. The measurements (in mm) are TL (including appendages) 4.7 ± 0.7, FL 3.3 ± 0.1, HL 32.5 ± 0.7 & AL 36.5 ± 2.12. With respect to the coloration, the variation is usually restricted to the humeral stripes which may be thinned out to become a streak inferiorly and spot superiorly, or sometimes becomes a thin and irregular one along its entire length in some specimens as observed in field. Venation showed some variation with Fw having Ax range of 22–26 and Px of 32–34 and the Hw have 19–24 Ax, and 30–31 Px. Pt was 10–11 cells wide and the wings had usually three cubital cross veins.

Female: The paratype females (n= 2), had a variation in abdominal length from 30–33 mm-and Hw length from 30–33 mm. Not much variation in colour was noted. The variations in venation was with the Fw having Ax 21–22 & Px 29–32, and the Hw with Ax 17–19 & Px 27–28. Pt are 8–11 cells wide and there were 2–3 cubital cross veins.

Etymology

The species name *pseudodispar* is coined as reminder to the close resemblance to the species *E. dispar* (Rambur, 1842) in coloration.

Distribution

As far as known, the species is restricted to the high-elevation streams and riparian patches of Thoseghar, Satara district, in Maharashtra, India.

Habitat and Ecology

The habits are as for the genus and this species shares the habitat with *E. thosegharensis* Sadasivan & Bhakare, sp. nov. Flight period is from June to September as per our field observations and past field records.

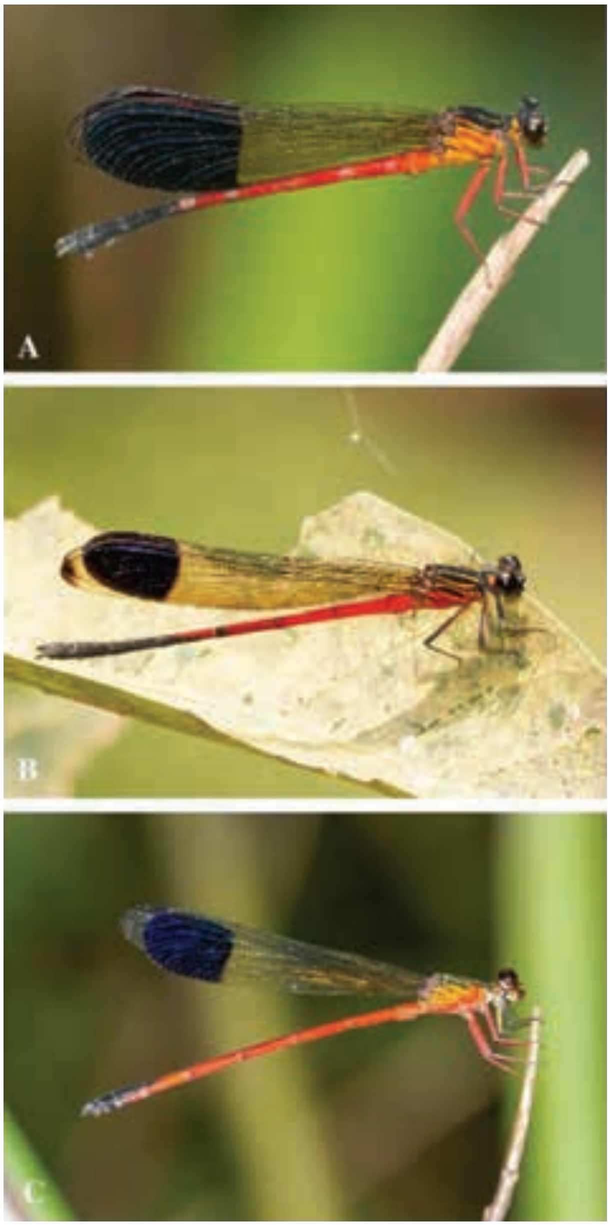

Image 10. Field images of *Euphaea* male: A—*E. cardinalis* (Fraser, 1924) | B—*E. dispar* (Rambur, 1842) | C—*E. fraseri* (Laidlaw, 1920). © Kalesh Sadasivan.

Differential diagnosis

This species can be easily differentiated from all the known *Euphaea* species of the Western Ghats based on morphology and coloration (Table 1, 2). The new species can be distinguished from *E. dispar* by the extensor surface of foreleg femora being black and those of hind and middle legs red as in *E. fraseri*, but with no yellow patch on legs as in *E. dispar.* Only the apical fifth of Hw are black in this species while the apical fourth of Hw are black in *E. dispar*, the genae of face are yellowish-white in the new species while it is black in *E. dispar* (Image

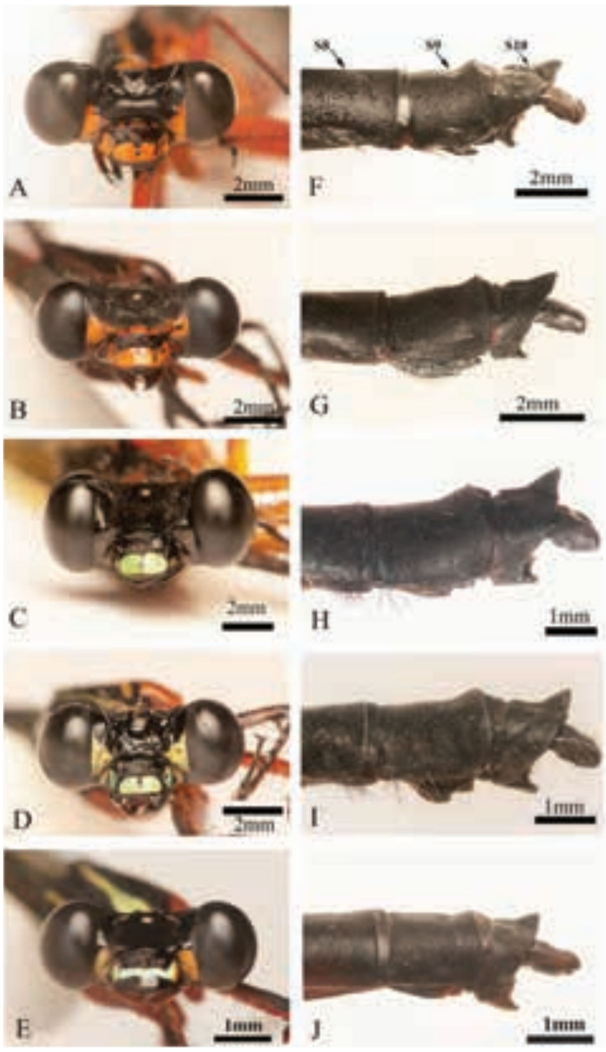

Image 11. Comparison of head and terminal abdominal segments (S8–S10) of *Euphaea* showing the hair tufts of males: A & F—*E. cardinalis* (Fraser, 1924) | B & G—*E. thosegharensis* Sadasivan & Bhakare, sp. nov. | C & H—*E. dispar* (Rambur, 1842) | D & I —*E. pseudodispar* Sadasivan & Bhakare, sp. nov. | E & J—*E. fraseri* (Laidlaw, 1920). © Kalesh Sadasivan

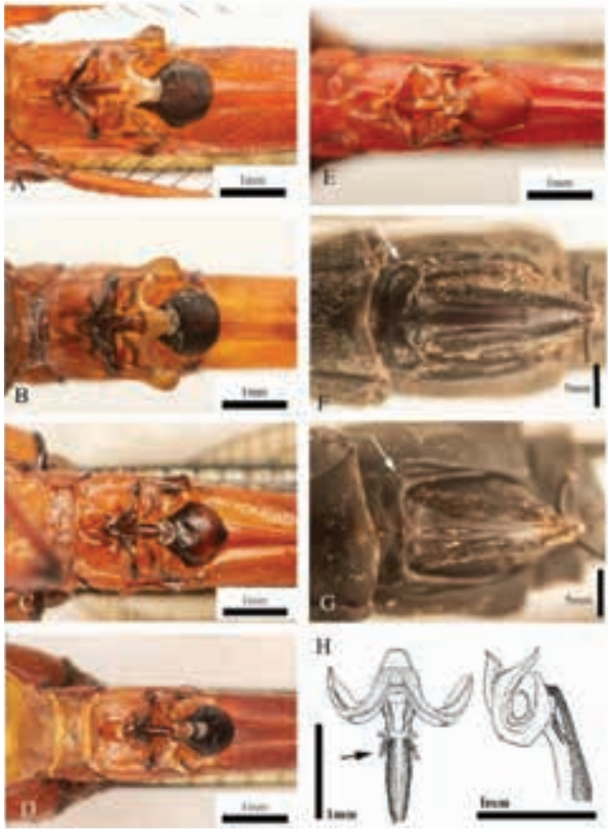

Image 12. Secondary genitalia & vesicles of males and female vulvar scales: A—*E. cardinalis* (Fraser, 1924) | B—*E. thosegharensis* Sadasivan & Bhakare, sp. nov. | C—*E. dispar* (Rambur, 1842) | D—*E. pseudodispar* Sadasivan & Bhakare, sp. nov. | E—*E. fraseri* (Laidlaw, 1920) | F—vulvar scales of *E. thosegharensis* | G—*E. pseudodispar* | H—penile structure of *E. dispar* (Rambur, 1842) (arrow pointing to the setae). © Kalesh Sadasivan.

11C&D). The color of legs are as in *E. fraseri*. Segment 9 is 1.5 times the length of S10 in this species, as is in *E. dispar*; while they are of equal length in *E. cardinalis* and S9 twice the length of S10 in *E. thosegharensis* (See key below). The new species can be distinguished from *E. fraseri* by the absence of hair tufts in the males of the latter. The colour of labrum is as seen in *E. dispar* with labrum being pale blue with its distal free border very thinly bordered with black, and with a prominent median black tongue. The pale turquoise blue labrum distinguishes it from *E. cardinalis* and *E. thosegharensis* both of which have orange to red labrum (Image A&B). The species appears similar to *E. fraseri* and *E. dispar*, because of the bluish labrum. The labrum of *E. fraseri* is coloured black in the inferior half and pale blue in the superior half and has no median black tongue (Image 11E), while the pattern in the new species is as in *E. dispar.* With respect to secondary genitalia, the penis bears a single seta on each side for the *E. pseudodispar,* while three pairs of setae are seen in *E. dispar* (Image 12H). For additional morphological differences in characters see Table 1.

The females of the *E. pseudodispar* can be easily differentiated from *E. thosegharensis* based on the bluish-white labrum with prominent black 'tongue' of the former (dirty white with indistinct central tongue in *E. thosegharensis*), the black postclypeus (pale patch on postclypeus in *E. thosegharensis*) the wider posterior lobe of prothorax (shorter posterior lobe in the latter), the structure of the vulvar scale without any central sulcus and its postero-lateral angle being produced as a wide and blunt tooth (rounded with no tooth *E. thosegharensis*) and black legs with white flexor patches

Table 1. Morphological comparison between males of *Euphaea* species of Western Ghats.

Species	Total length, Abdomen length (both including appendages), Fw and Hw length (in mm)	Venation	Male genital vesicle and pseudoauricle, and abdominal hair tufts of males	Appendages and gonocoxae
E. cardinalis (Image 11F, 12A)	Large species TL 52.5 ± 0.70 AL 43.0 ± 2.83 FL 40.0 ± 1.00 HL 38.0 ± 2.80	*Fw* Ax 23-25 Px 40 Pt 11 cell wide *Hw* Ax 17-18 Px 36-40 Pt 11 cell wide	Male genital vesicle black, hexagonal with rounded angles and distal margin round. Surface transversely rugose. On ventral view, S8 tergite with long hairs on its middle third and S9 tergite with long hairs on its proximal half. The sternites of S8 and S9 with no hair tufts.	On ventral view, the distal margin of S9 forming the border of the gonopore is 'C' shaped. Gonocoxae with their apices blunt, no spine. A pair of anteriorly directed blunt tooth on the distal aspect sternite of S9 near the gonopore. Distal margin of S10 '[' shaped, hence rectangular and stepped, at its mid-ventrum. On lateral view the mid-ventral part of distal margin of S9 extends over the gonopore as a long blunt tooth. S9 and S10 of equal length. Paraprocts with tips medially directed and hence tips converge to a point at rest. Paraprocts of same length as the gonocoxae. Lamina of cerci not well developed as in *E. dispar.*
E. thosegharensis sp. nov. (Image 11G, 12B)	Large species TL 50.6 ± 2.10 AL 39.5 ± 0.71 FL 37.3 ± 2.30 HL 34.5 ± 0.70	*Fw* Ax 20-25 Px 35-36 Pt 9-11 cell wide *Hw* Ax 17-19 Px 29-31 Pt 9-11 cell wide	Male genital vesicle black matt black, with distal border rounded angles and distal margin round. Surface transversely rugose. On ventral view, tergites of S8 and S9 with no hair tufts. A tuft of sparce stub black hair is seen on sternite of S9.	On ventral view, the gonopore margin trapezoid shaped, wider distally. Gonocoxae with their apices produced into small spines that are divergent at the tip. No tooth on the distal aspect sternite of S9 near the gonopore. Distal margin of S10 '{' shaped, hence curved and wavy at its mid-ventrum. On lateral view, the mid-ventral part of distal margin of S9 does not extend as tooth, over the gonopore. S9 twice the length of S10. Paraprocts with tips medially directed and hence tips converge at rest. Paraprocts of same length as the gonocoxae. Lamina of cerci as in *E. cardinalis,* but with the tip slightly more incurved.
E. dispar (Image 11H, 12C)	Large species TL 53.25 ± 1.06 AL 41.50 ± 2.12 FL 38.25 ± 0.35 HL 36.0 ± 1.41	*Fw* Ax 20-22 Px 31-32 Pt 10 cell wide *Hw* Ax 18 Px 31-33 Pt 10 cell wide	Male genital vesicle black matt black, rhomboid shaped with distal margin round, and surface with very fine transverse rugosities. On ventral view, the pseudoauricle rounded, less prominent than in *E. cardinalis.* S8 tergite with long hairs on distal half of its lateral border. S9 tergite with long hairs on its proximal half. The sternite of S8 with a tuft of very sparse short hairs on its proximal aspect of its base. Sternite of S9 without very sparce hairs at its base. A very small inconspicuous patch of moderately long brownish-orange hairs on lateral aspect of proximal S1 and S2. Penis with 3 setae on each side (Image 12. H).	On ventral view, the distal margin of S9 forming the border of the gonopore is 'C' shaped. Gonocoxae with their apices blunt, no spines. No tooth on the distal aspect sternite of S9 near the gonopore. Distal margin of S10 '{' shaped, hence curved and wavy at its mid-ventrum. S9 1.5 times the length of S10. Paraprocts longer than the gonocoxae. On lateral view, sternite of S9 not prominently extending mid-ventrally as in *E. pseudodispar*. The mid part of distal margin of S9 does not conspicuously extend over the gonopore. The dorsal prominence on S10 is robust and its superior border slightly curved on lateral view.
E. pseudodispar sp. nov. (Image 11I, 12D)	Small species TL 47.0 ± 0.70 AL 36.5 ± 2.12 FL 33.0 ± 1.00 HL 32.5 ± 0.70	*Fw* Ax 22-24 Px 32-34 Pt 10 cell wide *Hw* Ax 19 Px 30-31 Pt 11 cell wide	Male genital vesicle brownish-black, rhomboidal, with distal end angulated and surface with no transverse rugosities. On ventral view, the pseudoauricle angular, and more prominent than in *E. dispar*. Penis with a single seta on each side. Hair tufts as in *E. dispar.* In addition a very small inconspicuous patch of moderately long brownish-orange hairs on lateral aspect of proximal S3.	Terminal segments and appendages and Gonocoxae are similar to *E. dispar.* On lateral view, sternite of S9 very prominently extending mid-ventrally like a beak. The mid part of distal margin of this S9 beak extends as a very short tooth, over the gonopore. The dorsal prominence on S10 is short, angular and its superior border is straight on lateral view.

Species	Total length, Abdomen length (both including appendages), Fw and Hw length (in mm)	Venation	Male genital vesicle and pseudoauricle, and abdominal hair tufts of males	Appendages and gonocoxae
E. fraseri (Image 11J, 12E)	Small species TL 45.7 ± 2.10 AL 38.5 ± 3.54 FL 36.0 ± 2.8 0 HL 32.0 ± 4.20	*Fw* Ax 17-19 Px 26-29 Pt 9-11 cell wide *Hw* Ax 15-16 Px 26-27 Pt 9-10 cell wide	Male genital vesicle red, longitudinally elongated, apple shaped and distal margin round. Surface transversely rugose. Pseudoauricles not expanded laterally on ventral view. No hair tufts	The gonopore margin "W" shaped with the apices rounded and its arms divergent. Gonocoxae flat and without any spines. Distal margin of S10 '{' shaped, hence curved and wavy at its mid-ventrum. S9 is a little less than 1.5 times the length of S10. Paraprocts longer than gonocoxae. On lateral view, Sternite of S9 not extending mid-ventrally.

Table 2. Coloration comparison between males of *Euphaea* species of Western Ghats.

Species	Labrum	Genae	Lateral spots on middle lobe of prothorax	Antehumeral stripe	Femur	Black apices of wing
E. cardinalis (Image 9A,10A,11A)	Labrum bright ochreous-orange, narrowly bordered with reddish-brown, and an obscure mediobasal 'tongue' of dark brown	Orange	Yellow orange	Yellow orange	All legs red	Almost apical half (or slightly less) of Hw black
E. thosegharensis sp. nov. (Image 9B, 3A 11B)	Reddish-orange with a faint and obscure median streak	Orange red	Rose red	Orange red	All legs black	Apical fourth of Hw black
E. dispar (Image 9C, 10B,11C)	Labrum turquoise-blue, finely bordered with black and with a black mediobasal 'tongue'	Black	Orange yellow	Yellow	Fully red, with yellow patches	Apical fourth of Hw black. The tips of Fw tipped with blackish-brown
E. pseudodispar sp. nov. (Image 9D, 7A, 11D)	Labrum turquoise-blue, finely bordered with black and with a black mediobasal 'tongue'	Pale yellowish-white	Pale yellowish-white	Yellow	Font legs black, mid and hindlegs red	Apical fifth of Hw black Fw hyaline at the tips
E. fraseri (Image 9E, 10C, 11E)	Labrum pale azure-blue, with its anterior border broadly black, no medio-basal black 'tongue'	Pale yellowish	Blue	bright azure blue	Font legs black, Mid and hindlegs red	Apical fourth of Hw black

(*E. thosegharensis* has them fully black).

DISCUSSION

This paper describes two new species of *Euphaea* from the Western Ghats of Peninsular India. Though the insects are superficially similar to other *Euphaea* of Western Ghats, these two new species can be differentiated from all the others with distinct features in morphology and coloration.

Morphologically, the five species of *Euphaea* are easily told apart. Regarding the size of the species, *E. cardinalis* and *E. dispar* (TL 53.25 ± 1.06 mm) are large species and so is *E. thosegharensis* (TL 50.6 ± 2.1 mm). All these three species have total lengths more than 5cm. While *E. fraseri* (TL 45.7 ± 2.1 mm) and *E. pseudodispar* (TL 47.0 ± 0.7 mm) are much smaller, with total lengths always less than 5cm. Since the structure of anal appendages are similar, the best characters to depend are the structure of the male vesicle and the male abdominal hair tufts best seen on ventral view. With respect to the smaller species, *E. fraseri* has no hair tufts on the ventral side of abdomen on S8 or S9 (Image 11J), while *E. pseudodispar* has tufts on central part of sternite and lateral aspects of tergite on S8 and lateral tufts on proximal aspect of tergite of S9 (Image 11 I). Among the three larger species, *E. cardinalis* has hairs on S8 and S9 with tufts of long ventral hairs on the sternites; while, *E. dispar* has tuft at apex of S8 sternite and a tuft of short black hairs on its ventral surface, and about eight long stiff black hairs beneath the base of S9 sternite (Image 11H); and *E. thosegharensis* has a tuft of sparce stub black hair on either side of tergite of S9 and no hair tufts on S8 (Image 11G). The male genital vesicles are also a dependable character to differentiate them. The smaller species, *E. fraseri* has red colored, longitudinally elongated, apple shaped, while in *E. pseudodispar* they are brownish-black and pear shaped. Among the

Revised key to males of the genus *Euphaea* Selys, 1840 of Western Ghats, peninsular India
(for additional characters see Table 1&2)

1. Tufts of ventral hairs on terminal abdominal segments of males present; Antehumeral stripes on thorax not azure blue; Lateral aspect of middle lobe of prothorax with orange spots ………………………………………………………… 2
- Tufts of ventral hairs on terminal abdominal segments of males absent; Antehumeral stripes bright azure blue and lateral aspect of middle lobe of prothorax with an azure blue or pale blue spot; Male genital vesicle red, longitudinally elongated, apple shaped. TL 45.7± 2.10 mm ………………………………………………………… *E. fraseri* (Laidlaw, 1920)

2. Labrum pale turquoise blue; antehumeral stripe yellowish ………………………………………………………… 3
- Labrum orange-ochre to vermilion red; antehumeral stripe reddish-orange ………………………………………………………… 4

3. Extensor surface of all femora black, flexor surface of proximal 2/3rd all femora with bright yellow patch; Fw tipped with blackish-brown, apical fourth of Hw black; Genae black. Male genital vesicle black with distal border rounded and with fine transverse rugosities. Penis with three pairs of setae. Sternite of S9 not prominently extending ventrally. TL 53.25 ± 1.06 mm ………………………………………………………… *E. dispar* (Rambur, 1842)
- Extensor surface of all femora black, no yellow patch on legs*;* Only apical fifth of Hw black; Genae yellowish white. Male genital vesicle brownish black & rhomboid-shaped and with no transverse rugosities. Penis with single seta on each side. Sternite of S9 very prominently extending ventrally like a beak. TL 47.0 ± 0.70 mm ………………………………………………………… ***E. pseudodispar* Sadasivan & Bhakare, sp. nov.**

4. Extensor and flexor surface of all femora bright red; Apical half of Hw black; S8 and S9 with tufts of long ventral hairs. Male genital vesicle black and hexagonal in shape with rounded angles. S9 and S10 of equal length. TL 52.5 ± 0.70 mm ………………………………………………………… *E. cardinalis* (Fraser, 1924)
- Extensor and flexor surface of all femora black; Apical fourth of Hw black; A tuft of sparse stub black hair on either side of tergite of S9. Male genital vesicle matt black, with distal border rounded angles. S9 twice the length of S10. TL 50.6 ± 2.10mm ………………………………………………………… ***E. thosegharensis* Sadasivan & Bhakare, sp. nov.**

larger species, *E. cardinalis* has black hexagonal vesicle with rounded angles; while *E. thosegharensis* has them rounded and matt black; and in *E. dispar* they are matt black and scrotal shaped (Image 12 A & B).

With regards to coloration, we observed that the colors of the labrum and that of the legs of the insects were dependable field characters, the later was already used by Fraser (1934) for his keys to *Euphaea*. The bright yellow patches on femurs of *E. dispar* identifies it easily from all the other species. Blue labrum can be seen in three species, *E. fraseri, E. dispar* and *E. pseudodispar.* Amongst them, *E. fraseri* can be told apart by the labrum with inferior half black, superior half bluish-white, no median black 'tongue'; while the other two species have labrum pale turquoise blue with its distal free border very thinly bordered with black, and with a prominent median black 'tongue'. *E. dispar* (TL 53.25 ± 1.06 mm) can be distinguished from *E. pseudodispar* (TL 47.0 ± 0.70 mm) by its large size, having yellow patches on femur, black genae and in addition the differences in male vesicle and hair tufts under S8 & S9. Species with orange-ochre to vermilion red are *E. cardinalis* and *E. thosegharensis.* These are large insects of almost same size, but can be differentiated by the absence of hair tufts under S8 in *E. thosegharensis* (S8 and S9 with tufts of long ventral hairs in *E. cardinalis*) and the less extensive black apical patch in Hw in *E. thosegharensis* (restricted to apical fourth), while almost the apical half of Hw is black in *E. cardinalis.*

With respect to geographical distribution, *E. pseudodispar* and *E. thosegharensis,* both are restricted to the northern Western Ghats region north of the Amboli Ghats, and hence endemic to the region. The new species is seen in the higher reaches above 1,000m. *Euphaea cardinalis* is restricted to mountains south of the Palghat Gap, and *E. dispar* is distributed on mountains between the Palghat gap and Coorg. These two montane species are restricted below the Goa gap. With respect to geographical distribution *E. fraseri* is the only species seen in the same geographical region north of the Amboli Ghats. But, *E. fraseri* is probably distributed only in the lower elevations around the foothills below 900m all along the Western Ghats. The new taxa are currently known only from Kaas and Thoseghar regions of Satara District of Maharashtra. The species were probably overlooked for their superficial similarity to other species of *Euphaea* known from the Western Ghats. This discovery highlights the need for more systematic surveys of invertebrates in the northern Western Ghats.

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Threatened Taxa

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Author contribution: Shriram Dinkar Bhakare: Field work and came across the species for the first time, photo documented, collected the species and edited the manuscript. Vinayan P Nair: Editing of manuscript and taxonomic placement Pratima Ashok Pawar: Field work for the species and edited the manuscript. Sunil Hanmant Bhoite: Field work, photo documented, collected the species and edited the manuscript. Kalesh Sadasivan: Taxonomic description and placement, identified additional taxonomic features for the genus, wrote the manuscript and keys, edited the final manuscript.

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COMMUNICATION

Two new light attracted rove beetle species of *Astenus* Dejean, 1833 (Coleoptera: Staphylinidae: Paederinae) from Kerala, India

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Abstract: Two new light attracted species of rove beetles of the genus *Astenus* Dejean, 1833 (*Astenus keralensis* sp. nov. and *Astenus rougemonti* sp. nov.) from Malabar coastal plains of northern Kerala in southern India are described, illustrated, and compared to closely related species. First report of *Astenus kraatzi* Bernhauer, 1902 from Indian mainland and a checklist and key to all 41 species of *Astenus* recorded from the Indian mainland are provided.

Keywords: Beetles, Malabar coastal plains, Malappuram District, moist deciduous forest, northern Kerala, southern India, taxonomic key.

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INTRODUCTION

Genus *Astenus* belongs to the subtribe Astenina Hatch, 1957, of tribe Lathrobiini Laporte, 1835 (Staphylinidae: Paederinae). The genus *Astenus* Dejean, 1833 is cosmopolitan (Cameron 1931) with 468 extant species described across the world (Newton 2020). It is easily recognizable from related genera by having head more or less expanded before eyes. Other diagnostic features being, rather small and slender habitus; reticulate-umbilicate sculpture of the integument; head comparatively large with respect to pronotum; narrow neck; labrum emarginate with two small teeth; long, slender, curved and pointed mandibles; and the bilobed penultimate tarsomere (Cameron 1931).

Thirty-nine species of *Astenus* are recorded from the Indian Mainland, with 19 of them being described by Cameron (1914, 1919, 1920, 1931, 1943). Cameron (1931) gave brief descriptions and keys to 25 species of *Astenus* from the Indian Mainland. After Cameron (1931), only 11 new species of *Astenus* were added to the Indian species list; three by Cameron (1943) himself, three by Coiffait (1982), four by Biswas & Sen Gupta (1983), and one by Biswas (2003) – with all records from northern India. There is very little work on *Astenus* species from southern India with only 14 species recorded with 13 of them being reported by Cameron (1931) and one by Fauvel (1904).

Two new species of *Astenus* (*A. keralensis* sp. nov. and *A. rougemonti* sp. nov.) are described from the Malabar coastal plains of northern Kerala in southern India. A revised and modified taxonomic key and checklist to *Astenus* of Indian mainland is provided along with first records from Indian mainland and from southern India. Notes on endemism, biogeographical affinities and remarks on taxonomy of *Astenus* are also discussed.

MATERIALS AND METHODS

Specimen collection and treatment

The specimens mentioned in this paper were collected as part of a three year (2017–2019) survey on Staphylinidae conducted in the entire northern Kerala region, specifically in the Western Ghats forest regions and scattered and isolated ranges of Malabar coastal plain moist deciduous forest. The rove beetle specimens, which were later identified as new species, were collected using low intensity UV light traps (SAFS) from isolated patches of forests in Chelari (11°06’40.6”N 75°54’14.1”E) and University of Calicut campus (11°13’40”N, 75°89’52”E) located in Malabar coastal plains of Malappuram District in Northern Kerala. Collected specimens were transferred to 75% ethyl alcohol, were cleared using 10% KOH and were dissected to study the male genitalia. Species level identification was performed using new taxonomic key prepared based on type descriptions and key to species in Cameron (1931). Specimens and dissected genitalia were examined and measured under a Leica M205C stereozoom microscope. Images were taken using a Leica MC 170 HD microscope camera and enhanced using the Leica Application Suite V4.12.

The type specimens are deposited in Zoological Survey of India, Western Ghats Regional Center, Kozhikode, Kerala, India (ZSIK).

Abbreviations

The following abbreviations were used for measurements (in mm): Length of antenna (AL), head length from anterior margin of clypeus to posterior margin of head (HL), head width (excluding eyes) (HW), length of pronotum (PL), maximum width of pronotum (PW), maximum length of elytra from base to apex (EL), maximum width of elytra (EW), length of aedeagus from apex of ventral process to base of median lobe (ML), total body length (TL).

RESULTS

Taxonomy
Family Staphylinidae Latreille, 1802
Subfamily Paederinae Fleming, 1821
Tribe Lathrobiini Laporte, 1835
Subtribe Astenina Hatch, 1957
Genus *Astenus* Dejean, 1833

***Astenus keralensis* sp. nov.**
(Image 1 A–F)

urn:lsid:zoobank.org:act:A4851FFC-0051-4A03-A66F-209B44F159E5

Type material. **Holotype**: ID. S0101X19, 01.x.2019, male, India: Kerala: Malappuram: Chelari, 11.1112778N, 75.9039166E, light trap, coll. Sreevidhya, P.

Paratypes: S0210II18, 10.ii.2018, 2 males, India: Kerala: Malappuram: Chelari, 11.1112778N, 75.9039166E, light trap, coll. Sreevidhya, P.; S0320II18, 20.ii.2018, 1 male, India: Kerala: Malappuram: University of Calicut, 11.2277778N, 76.4977777E, light trap, coll. Sreevidhya, P; S0401III18, 01.iii.2018, 1 male, India: Kerala: Malappuram: Chelari, 11.1112778N,

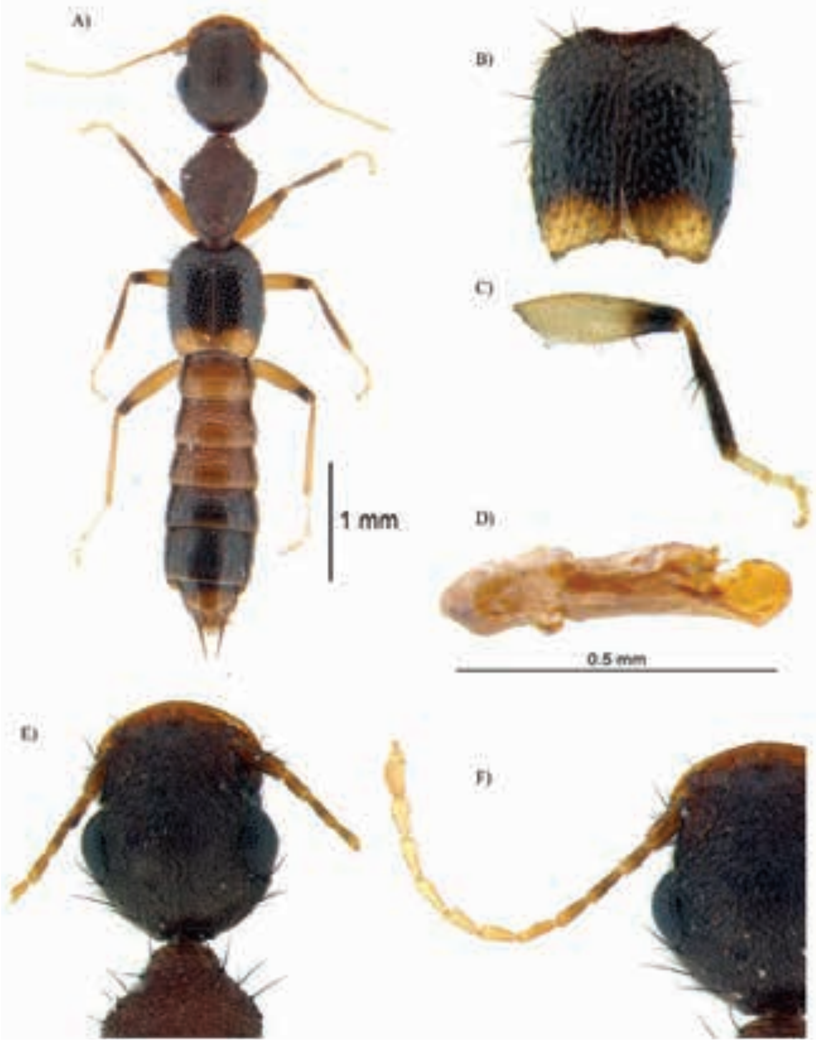

Image 1. *Astenus keralensis* sp. nov., Holotype: A—Habitus, dorsal view | B—Elytra | C—Fore leg | D—Aedeagus, lateral view | E—Head, dorsal view | F—Antenna. © Sreevidhya P.

75.9039166E, light trap, coll. Sreevidhya, P.; S0525X18, 25.x.2018, 2 males, India: Kerala: Malappuram: Chelari, 11.1112778N, 75.9039166E, light trap, coll. Sreevidhya, P.

Description

Measurements (n=7) TL: 4.394 (4.324–4.440); AL: 1.250 (1.242–1.251); HL: 0.844 (0.841–0.848); HW: 0.696 (0.682–0.709); PL: 0.770 (0.765–0.773); PW: 0.521 (0.517–0.523); EL: 0.719 (0.71–0.72); EW: 0.720 (0.717–0.722); ML: 0.5.

Colour: Head brownish-black, antennomeres I–IV dark brown and rest pale reddish-yellow; mouth parts infuscate; pronotum reddish-brown; elytra black with posterior margin in sharp contrast with distinct broad yellowish band, wider at the middle of each elytron and narrowed medially and laterally; scutellum reddish-brown; abdominal tergites III–V reddish, VI and VII dark brown, VIII dark brown with reddish posterior margin, apex of the femora dark brownish-black, fore and middle tibiae dark brownish-black, tarsi entirely yellowish; setae entirely black.

Head: Elongate, rugose, closely punctate and reticulate, disc bulged at the middle, posterior angles widely rounded, tempora with several black setae, head in front of the eyes more or less parallel, eyes prominent; antennae long, all joints longer than wide, antennomeres III–X sub equal, XI longer.

Neck: 1/5th width of head.

Pronotum: Shield like, furnished with longitudinal rugae, narrower than head, gradually expanded until about 2/3 from base, then narrowed toward neck; anterior half of pronotum on each side with five black setae; posterior margin rounded.

Elytra: Glossy, wider but shorter than pronotum, narrowed at apex and base, strongly and closely punctate, having regular pubescence and several large setae.

Abdomen: Glossy, narrower than elytra at the base and slightly widened posteriorly, pubescence fine and dark; tergites VI and VII wider than preceding ones. Posterior margin of all segments glabrous. VIIth tergite longer than others, tergite VIII the shortest; anal styles rather long.

Aedeagus: Median lobe elongated, apex rounded and slightly curved ventrally in lateral view

Female: Unknown

Etymology: Named after Kerala, a state of India, from where the specimen was collected.

Differential diagnosis: *Astenus keralensisis* is similar to *A. gratellus* (Fauvel, 1879) and *A. diversiventris* Cameron, 1943, but differs from them by its smaller size (TL 4.75mm in *A. gratellus*, TL 5.00mm in *A. diversiventris*), fore and middle tibiae dark brownish-black (fore and hind tibiae entirely yellowish in *A. gratellus*), antennal segments I–IV dark brown (antennae entirely yellow in *A. gratellus*, segments II to V infuscate in *A. diversiventris*), posterior margin of elytra distinctly yellow (elytra entirely black in *A. diversiventris*).

***Astenus rougemonti* sp. nov.**
(Image 2 A–F)

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Type material. **Holotype**: S0615X17, 15.x.2017, male, India: Kerala: Malappuram: Chelari, 11.1112778N, 75.9039166E, light trap, coll. Sreevidhya, P.

Paratypes: S0710II18, 10.ii.2018, 1 male, India: Kerala: Malappuram: Chelari, 11.1112778N, 75.9039166E, light trap, coll. Sreevidhya, P.; S0816X19, 16.x.2019, 2 males, India: Kerala: Malappuram: Chelari, 11.1112778N, 75.9039166E, light trap, coll. Sreevidhya, P.; S0922XI19, 22.xi.2019, 1 male, India: Kerala: Malappuram: Chelari, light trap, coll. Sreevidhya, P.

Description

Measurements (n=5) TL: 4.390 (4.353–4.442); AL: 1.514 (1.510–1.519); HL: 0.871 (0.870–0.871); HW: 0.733 (0.730–0.734); PL: 0.664 (0.649–0.666); PW: 0.646(0.640–0.650); EL: 0.743 (0.739–0.752); EW: 0.772 (0.769–0.778); ML: 0.4.

Colour: Head and pronotum dark reddish-yellow; elytra bicoloured with anterior half black and posterior half with pale reddish-yellow transverse band slightly extended anteriorly along the suture, sutural line yellowish posteriorly and black in anterior 1/3rd; abdominal tergites dark reddish-yellow, VIth abdominal tergite with intersegmental membrane yellow, VIIth abdominal tergite mostly brownish-black with posterior margin pale reddish-yellow; antennae, legs and mouthparts pale reddish-yellow; setae black.

Head: Elongate and somewhat rectangular**,** quite umbilicate reticulate sculpture, head in front of the eyes parallel, two pairs of anterolateral punctures with black, short and stout setae, post ocular region moderately rounded bearing three black, short and stout setae and several long slender decumbent setae, posterior margin more or less straight; labrum short and wide with two distinct teeth and two very long yellow setae, eyes bulged, antennae long, almost reaching the base of pronotum, scape broader at the apex, second antennomere shortest, III–X sub equal, XI slightly longer.

Neck: 1/3rd width of head.

Pronotum: Convex, shorter and narrower than head, distinctly narrowed anteriorly and posteriorly, widest at 1/3rd; sculpture almost similar to head but broader, space between is more “s” like; antero-lateral margin of pronotum with long erect setae.

Elytra: Glossy, finely pubescent, longer and wider than pronotum, as wide as long. Lateral margins with seven long oblique setae and numerous small setae. Anterior half more densely punctate than posterior half. Elytra narrowed apically.

Abdomen: Pubescence fine and dark, base of abdomen narrower than elytra.

Aedeagus: Median lobe narrowed from basal half to the apex, apical region pointed and curved.

Female: Unknown

Etymology: The species is named in memory and honour of late Guillaume de Rougemont, a very charming personality and a man who loved rove beetles, who guided us with the taxonomy of the genus *Astenus*.

Differential diagnosis: *Astenus rougemonti* is close to *A. leptocerus* (Eppelsheim, 1895) based on the colour pattern of elytra, but differs in having only the Vth visible abdominal tergite (VIIth tergite) black (in *A. leptocerus* all the abdominal tergites are black). It is also close to *Astenus horridus* Rougemont, 2018, an endemic of Borneo but differs from it in following characters; slightly smaller (TL 4.80 mm in *A. horridus*) VIth abdominal tergite (IVth visible tergite) not dark (VIth abdominal tergite dark in *A. horridus*), yellow fascia of elytral apex widening towards the suture (yellow fascia of elytral apex not widening towards the suture in *A. horridus*). Sculptures on the pronotum broader than on head and the space between is more‘s’ like (sculptures on pronotum as on head in *A. horridus*).

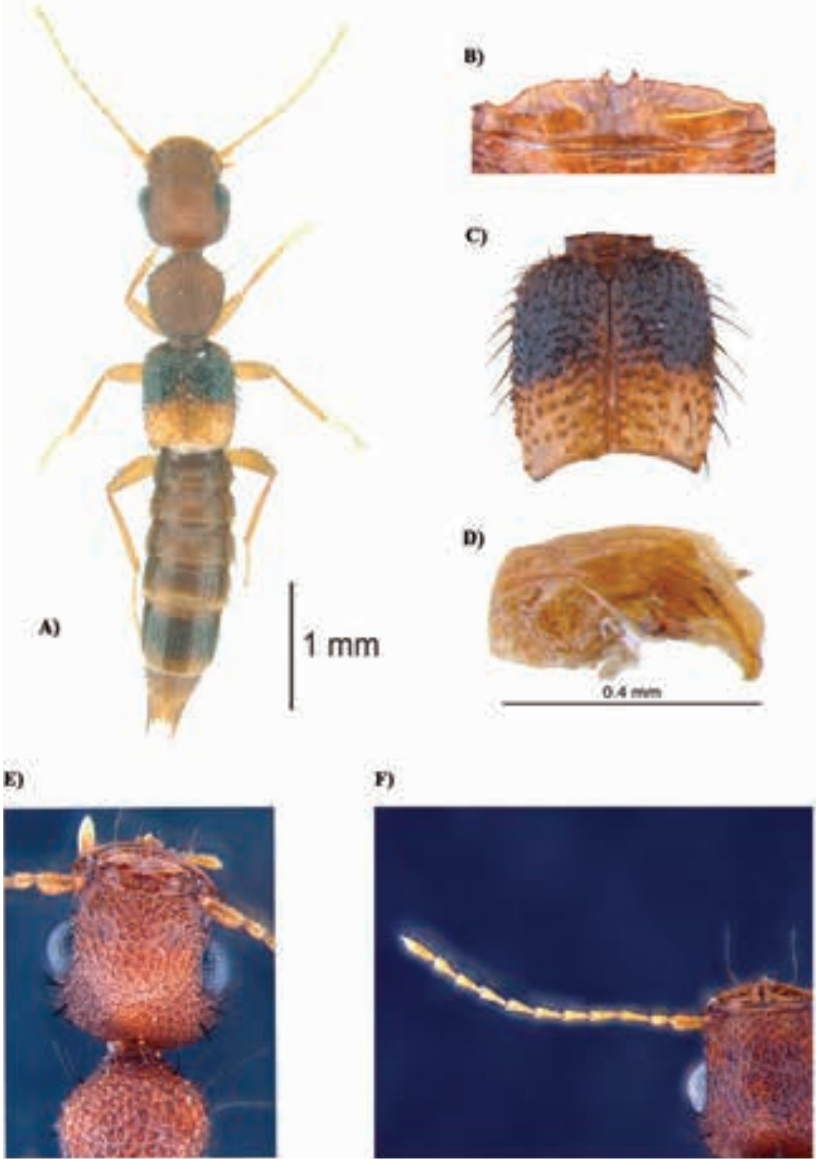

Image 2. *Astenus rougemonti* sp. nov., Holotype: A—Habitus, dorsal view | B—Labrum | C—Elytra | D—Aedeagus, lateral view | E—Head, dorsal view | F—Antenna. © Sreevidhya P.

Checklist of the genus *Astenus* (Staphylinidae: Paederinae) from India

Genus *Astenus* Dejean, 1833

Astenus Dejean, 1833: 65

Type species *Staphylinus angustatus* Paykull, 1789 (= *Staphylinus gracilis* Paykull, 1789)

***Astenus andrewesi* Cameron, 1931**

Astenus andrewesi Cameron, 1931: 71

Distribution: India: Tamil Nadu: Nilgiri Hills.

***Astenus asitus* Biswas & Sen Gupta, 1983**

Astenus asitus Biswas & Sen Gupta, 1983: 1

Distribution: India: Sikkim: Rangpo; West Bengal: Darjeeling

***Astenus bisalicus* Biswas & Sen Gupta, 1983**

Astenus bisalicus Biswas & Sen Gupta, 1983: 3

Distribution: India: West Bengal: Darjeeling.

***Astenus bispinus* (Motschulsky, 1858)**

=*Sunius bispinus* Motschulsky, 1858: 636

= *Sunius major* Kraatz, 1859: 146

Distribution: India: West Bengal: Darjeeling; Tamil Nadu: Nilgiri Hills. Sri Lanka: Kandy. Myanmar. Vietnam: Annam. Indonesia: Sumatra. Thailand.

***Astenus cachemiricus* Coiffait, 1982**

Astenus cachemiricus Coiffait, 1982: 97

Distribution: India: Kashmir

***Astenus caspiracus* Coiffait, 1982**
Astenus caspiracus Coiffait, 1982: 99
Distribution: India: Kashmir

***Astenus concolor* (Kraatz, 1859)**
=*Sunius concolor* Kraatz, 1859: 149
Distribution: India: West Bengal. Taiwan.

***Astenus diversiventris* Cameron, 1943**
Astenus diversiventris Cameron, 1943: 32
Distribution: India: West Bengal: Darjeeling.

***Astenus flavescens* Scheerpeltz, 1933**
Astenus flavescens Scheerpeltz, 1933: 1232
=*Astenus flavipennis* Cameron, 1931: 80
Distribution: India: Himachal Pradesh; Uttarakhand: Dehradun, Nakraunda, Kumaon, Haldwani; West Bengal; Manipur. Nepal: Siwaliks.

***Astenus flavus* (Kraatz, 1859)**
= *Sunius flavus* Kraatz, 1859: 149
Distribution: India Oriental "Ind. Or." as given by Kraatz 1859; Eastern India and Nepal (Newton 2020); India: Kerala: Tholpetty.

***Astenus ghumensis* Cameron, 1943**
Astenus ghumensis Cameron, 1943: 32
Distribution: India: West Bengal: Darjeeling

***Astenus gracilentus* (Fauvel, 1879)**
=*Sunius gracilentus* Fauvel, 1879: 83
=*Sunius gracilis* Kraatz, 1859: 147
Distribution: India: Himachal Pradesh; Uttar Pradesh; Uttarakhand: Dehradun, Lachiwala; West Bengal: Darjeeling; Manipur; Meghalaya; Tripura; Tamil Nadu: Nilgiri Hills. Bangladesh: Dacca. Singapore. China: Hong Kong.

***Astenus gratellus* (Fauvel, 1879)**
= *Sunius gratellus* Fauvel, 1879: 83
= *Sunius pulchellus* Kraatz, 1859: 147
Distribution: India: Uttarakhand: Dehradun; West Bengal: Darjeeling District; Maharashtra: Mumbai; Tamil Nadu: Nilgiri Hills. Sri Lanka: Colombo, Kandy. Myanmar: Tenasserim. Indonesia: Sumatra, Java. Vietnam: Tonkin. Bhutan. China: Hong Kong.

***Astenus gratus* Cameron, 1931**
Astenus gratus Cameron, 1931: 72
Distribution: India: Uttarakhand: Dehradun.

***Astenus h-signatus* Cameron, 1914**
Astenus h-signatus Cameron, 1914: 540
Distribution: India: Patkai Hills.

***Astenus hindostanus* Cameron, 1919**
Astenus hindostanus Cameron, 1919: 227
Distribution: India: Nilgiri Hills. Sri Lanka: Colombo, Kandy, Nuwara Eliya.

***Astenus indicus* (Kraatz, 1859)**
= *Sunius indicus* Kraatz, 1859: 148
= *Sunius aequalis* Blackburn, 1888: 9
= *Sunius oculatus* Sharp, 1874: 72
Distribution: India: Uttarakhand; Sikkim; West Bengal: Darjeeling; Maharashtra: Mumbai; Kerala: University of Calicut (Botanical Garden). Sri Lanka. Myanmar. Japan. Oman. Saudi Arabia. Italy. Egypt. Turkey. Iran. Afghanistan. China: Shanghai. Taiwan. Canary Islands. Eastern and western Africa. Tanzania.

***Astenus jhopus* Biswas & Sen Gupta, 1983**
Astenus jhopus Biswas & Sen Gupta, 1983: 5
Distribution: India: West Bengal: Darjeeling.

***Astenus kashmiricus* Cameron, 1943**
Astenus kashmiricus Cameron, 1943: 32
Distribution: India: Kashmir.

***Astenus kraatzi* Bernhauer, 1902**
Astenus kraatzi Bernhauer, 1902: 36
Distribution: India: Kerala: Chelari. Sri Lanka: Nalanda, Anuradhapura, Trincomalee, Colombo.

***Astenus ladakhensis* Coiffait, 1982**
Astenus ladakhensis Coiffait, 1982: 98
Distribution: India: Kashmir

***Astenus leptocerus* (Eppelsheim, 1895)**
= *Sunius leptocerus* Eppelsheim, 1895: 64
Distribution: India: Uttarakhand: Dehradun, Mussorie; Madhya Pradesh; West Bengal; Maharashtra: Nagpur; Tamil Nadu: Nilgiri Hills; Kerala: Chelari. Sri Lanka. Vietnam. Japan: Ogasawara Island. Mauritius: Rodriguez Island. Madagascar. Reunion (France). Comoros.

***Astenus maculatus* Cameron, 1920**
Astenus maculatus Cameron, 1920: 146
=*Astenus saigonensis* Cameron, 1940: 250
Distribution: India: Tamil Nadu: Nilgiri Hills. Bangladesh: Dacca. Thailand. Vietnam. China: Hong Kong, Yunnan.

***Astenus maculipennis maculipennis* (Kraatz, 1859)**
=*Sunius maculipennis maculipennis* Kraatz, 1859: 148
=*Sunius bicolon* Sharp, 1874: 72
Distribution: India: West Bengal; Meghalaya; Tamil Nadu: Nilgiri Hills; Kerala: Parambil Bazar. Sri Lanka. Vietnam. Philippines. Indonesia. China: Guangxi. Japan: Honshu, Kyushu, Shikoku. South Korea. Taiwan. Mauritius. Madagascar. Senegal. Ivory Coast.

***Astenus marginalis* Cameron, 1931**
Astenus marginalis Cameron, 1931: 77
Distribution*:* India: Uttarakhand: Chakrata, Mussorie, Kempty Falls, Manjgaon, Dhobi Ghat.

***Astenus melanurus (*Küster, 1853)**
=*Sunius melanurus* Küster, 1853: 76
=*Sunius aemulus* Rottenberg, 1870: 33
Distribution: India**:** Uttarpradesh: Lakhimpur Kheri; Uttarakhand: Dehradun; West Bengal; Manipur; Maharashtra. Indonesia: Java. Cyprus. Iran. Syria. Turkey. Croatia. France. Greece. Italy. Malta. Portugal. Slovakia. Slovenia. Algeria. Canary Islands. Egypt. Libya. Morocco. Tunisia. South Africa.

***Astenus nilgiriensis* Cameron, 1931**
Astenus nilgiriensis Cameron, 1931: 82
Distribution: India: Nilgiri Hills; Kerala: Pookkottur.

***Astenus obscurus* Cameron, 1931**
Astenus obscurus Cameron, 1931: 82
Distribution: India: Nilgiri Hills.

***Astenus peraffinis* Cameron, 1931**
Astenus peraffinis Cameron, 1931:90
Distribution: India: Nilgiri Hills.

***Astenus pulchripennis* Cameron, 1931**
Astenus pulchripennis Cameron, 1931: 76
Distribution: India: Uttar Pradesh: Lakhimpur Kheri; Uttarakhand: Chakrata, Mussorie.

***Astenus semibrunneus* Cameron, 1931**
Astenus semibrunneus Cameron, 1931: 87
Distribution: India: Uttarakhand: Dehradun; West Bengal: Darjeeling.

***Astenus setiferides* Newton, 2017**
Astenus setiferides Newton, 2017: 10
=*Astenus setiferus* Cameron, 1931: 90
Distribution: India: Nilgiri Hills; Kerala: Kambalakkad.

***Astenus sikkimensis* Biswas, 2003**
Astenus sikkimensis Biswas, 2003: 260
Distribution: India: West Bengal: Darjeeling

***Astenus simlaensis* Cameron, 1931**
Astenus simlaensis Cameron, 1931: 74
Distribution: India: Himachal Pradesh: Simla, Kotgarh, Gahan. Afghanistan.

***Astenus subnotatus* Fauvel, 1904**
Astenus subnotatus Fauvel, 1904: 51
Distribution: India: Uttarpradesh; West Bengal; Chhathisgarh: Dugeli; Maharashtra; Karnataka: Nagargali, Sampgaon. Indonesia: Java. South Africa. Lesotho. Botswana. Namibia.

***Astenus suturalis* Cameron, 1931**
Astenus suturalis Cameron, 1931: 69
Distribution: India: Uttarakhand: Chakrata: Mohana. Thailand.

***Astenus tanicus* Biswas & Sen Gupta, 1983**
Astenus tanicus Biswas & Sen Gupta, 1983: 5
Distribution: India: Uttar Pradesh: Gorakhpur: Nautanawa; Jharkhand: Singrah Falls.

***Astenus terminalis* Cameron, 1931**
Astenus terminalis Cameron, 1931: 84
Distribution: India: West Bengal; Nilgiri Hills; Kerala: Kozhippara (Nilambur). China: Hong Kong.

***Astenus varians* Cameron, 1931**
Astenus varians Cameron, 1931: 78
Distribution: India: Uttarakhand: Dehradun: Kheri Rao, Mussorie, Nakraunda, Arnigad, Kolhu Khet gad. Myanmar. Thailand. China: Yunnan, Hong Kong.

DISCUSSION

Of the 10 species collected from northern Kerala region (Image 3), three species of *Astenus* (*A. flavus* (Kraatz, 1859) from Tholpetty which is a part of the Wayanad Wildlife Sanctuary; *A. setiferides* Newton, 2017 from Kambalakkad in Wayanad Reserve Forest; *A. terminalis* Cameron, 1931 from Kozhippara in Nilambur Reserve Forest) were collected from the Western Ghats hotspot of biodiversity and seven species (*A. indicus* (Kraatz, 1859); *A. keralensis* sp. nov.; *A. kraatzi* Bernhauer, 1902; *A. leptocerus* (Eppelsheim, 1895); *A. maculipennis* (Kraatz, 1859); *A. nilgiriensis* Cameron,

Image 3. Habitus of *Astenus* from northern Kerala: A—*Astenus flavus* (Kraatz, 1859) | B—*Astenus indicus* (Kraatz, 1859) | C—*Astenus kraatzi* Bernhauer, 1902 | D—*Astenus leptocerus* (Eppelsheim, 1895) | E—*Astenus maculipennis* (Kraatz, 1859) | F—*Astenus nilgiriensis* Cameron, 1931 | G—*Astenus setiferides* Newton, 2017 | H—*Astenus terminalis* Cameron, 1931. © Sreevidhya P.

1931; *A. rougemonti* sp. nov.) were collected from Malabar coastal plain moist deciduous forest, which is an extension of the Western Ghats hotspot of biodiversity (Champion & Seth 1968).

Endemism and Biogeographic Affinities

Of the 41 species of *Astenus* recorded from Indian mainland, nine species (*A. andrewesi* Cameron, 1931; *A. hindostanus* Cameron, 1919; *A. keralensis* sp. nov.; *A. kraatzi* Bernhauer, 1902; *A. nilgiriensis* Cameron, 1931; *A. obscurus* Cameron, 1931; *A. peraffinis* Cameron, 1931; *A. rougemonti* sp. nov., and *A. setiferidus* Newton, 2017) are endemic to the Western Ghats and Sri Lanka hotspot of biodiversity with *A. keralensis* sp. nov., *A. kraatzi, A. nilgiriensis*, and *A. rougemonti* sp. nov. extending their distribution to the Malabar coastal plain moist deciduous forest region (Table 1). Another seven species (*A. asitus* Biswas & Sen Gupta, 1983; *A. bisalicus* Biswas & Sen Gupta, 1983; *A. diversiventris* Cameron, 1943; *A. ghumensis* Cameron, 1943; *A. h-signatus* Cameron, 1914; *A. jhopus* Biswas & Sen Gupta, 1983; and *A. sikkimensis* Biswas, 2003) are endemic to the eastern Himalaya

Table 1. Endemic status of *Astenus* species recorded from India.

	Species name	Distribution/ Endemism
1.	*Astenus hindostanus* Cameron, 1919	Endemic to India and Sri Lanka (WG & SL)#
2.	*Astenus kraatzi* Bernhauer, 1902	Endemic to India and Sri Lanka (WG & SL)#
3.	*Astenus gratus* Cameron, 1931	Endemic to the Indian mainland
4.	*Astenus marginalis* Cameron, 1931	Endemic to the Indian mainland
5.	*Astenus pulchripennis* Cameron, 1931	Endemic to the Indian mainland
6.	*Astenus semibrunneus* Cameron, 1931	Endemic to the Indian mainland
7.	*Astenus tanicus* Biswas & Sen Gupta, 1983	Endemic to the Indian mainland
8.	*Astenus asitus* Biswas & Sen Gupta, 1983	Endemic to the Indian mainland (EH)@
9.	*Astenus bisalicus* Biswas & Sen Gupta, 1983	Endemic to the Indian mainland (EH)@
10.	*Astenus diversiventris* Cameron, 1943	Endemic to the Indian mainland (EH)@
11.	*Astenus ghumensis* Cameron, 1943	Endemic to the Indian mainland (EH)@
12.	*Astenus h-signatus* Cameron, 1914	Endemic to the Indian mainland (EH)@
13.	*Astenus jhopus* Biswas & Sen Gupta, 1983	Endemic to the Indian mainland (EH)@
14.	*Astenus sikkimensis* Biswas, 2003	Endemic to the Indian mainland (EH)@
15.	*Astenus cachemiricus* Coiffait, 1982	Endemic to the Indian mainland (KH)†
16.	*Astenus caspiracus* Coiffait, 1982	Endemic to the Indian mainland (KH)†
17.	*Astenus kashmiricus* Cameron, 1943	Endemic to the Indian mainland (KH)†
18.	*Astenus ladakhensis* Coiffait, 1982	Endemic to the Indian mainland (KH)†
19.	*Astenus andrewesi* Cameron, 1931	Endemic to the Indian mainland (WG)*
20.	*Astenus nilgiriensis* Cameron, 1931	Endemic to the Indian mainland (WG)*
21.	*Astenus obscurus* Cameron, 1931	Endemic to the Indian mainland (WG)*
22.	*Astenus peraffinis* Cameron, 1931	Endemic to the Indian mainland (WG)*
23.	*Astenus setiferidus* Newton, 2017	Endemic to the Indian mainland (WG)*
24.	*Astenus rougemonti* sp. nov.	Endemic to the Indian mainland (WG)*
25.	*Astenus keralensis* sp. nov.	Endemic to the Indian mainland (WG)*

#—Endemic to Western Ghats (WG) and Sri Lanka (SL) | @—Endemic to Eastern Himalayas (EH) |
†—Endemic to Kashmir Himalayas (KH) | *—Endemic to only the Western Ghats (WG)

(Table 1). Four species (*A. cachemiricus* Coiffait, 1982; *A. caspiracus* Coiffait, 1982; *A. kashmiricus* Cameron, 1943; and *A. ladakhensis* Coiffait, 1982) are endemic to the Kashmir Himalaya region (Table 1).

Five species of *Astenus* (*A. indicus* (Kraatz, 1859); *A. leptocerus* (Eppelsheim, 1895); *A. maculipennis* (Kraatz, 1859); *A. melanurus* (Küster, 1853); and *A. subnotatus* Fauvel, 1904) show diverse distribution pattern with distribution ranging from Oriental realm to Afrotropical realm through Palaearctic realm with only *A. melanurus* (Küster, 1853) having European distribution.

Twenty-three species (including the two new species described; seven species endemic to the eastern Himalaya; five of the seven species (except *A. hindostanus* Cameron, 1919; *A. kraatzi* Bernhauer, 1902) endemic to the Western Ghats and Sri Lanka hot spot of biodiversity; four species endemic to the Kashmir Himalaya; and five other species (*A. gratus* Cameron, 1931; *A. marginalis* Cameron, 1931; *A. pulchripennis* Cameron, 1931; *A. semibrunneus* Cameron, 1931; *A. tanicus* Biswas & Sen Gupta, 1983)) are endemic to the Indian mainland (Table 1).

First Reports

Astenus kraatzi Bernhauer, 1902, which had distribution records only from Sri Lanka, is recorded for the first time from the Indian mainland (India: Kerala: Chelari, 11.1112778N, 75.9039166E) and two species, *A. flavus* (Kraatz, 1859) and *A. indicus* (Kraatz, 1859) are recorded for the first time from southern India.

Taxonomic Remarks

Notes on Tribe Lathrobini Laporte, 1835: There exists wide confusion on the tribe to which *Astenus* belongs. The two tribe classification (Pinophilini and Paederini) of Paederinae followed by the majority of Staphylinidae workers place *Astenus* in tribe Paederini Fleming, 1821 (Ganglbauer 1895; Casey 1905; Blackwelder 1939; Lobl & Smetana 2004; Schülke & Smetana 2015) whereas it was included in Lathrobiini by Jeannel & Jarrige (1949). Later it was confirmed that *Astenus* belongs to tribe Lathrobiini by analysing the molecular and morphological characteristics (McKenna et al. 2015; Schomann & Solodovnikov 2017) and Schomann & Solodovnikov (2017) proposed that Paederinae could be divided into not two but four tribes (Cylindroxystini; Lathrobiini; Paederini; Pinophilini).

Taxonomic status of *Astenus subnotatus* Fauvel, 1904: Fauvel described *Astenus subnotatus* as a variation of *A. melanurus* (Küster, 1853) and it was considered as a variation by Cameron (1931) also. Later the paratype of *A. subnotatus* (with locality given as Bedford Cape, South Africa) was wrongly re-described as *A. itremo* Lecoq, 1996 (a species with distribution only in Madagascar), which is evident from the paratype label (Royal Belgian Institute of natural Sciences). As per the current classification *A. subnotatus* is having

Key to species of the genus *Astenus* from the Indian mainland.

1. Antennal segment XI almost 4x longer than 10 .... *A. asitus* Biswas & Sen Gupta, 1983
- Antennal segment XI not 4x longer than 10 2
2. Species dark, entirely or in greater part black or brown 3
- Species entirely or in greater part reddish-yellow 22
3. Abdomen with first three or four visible tergites red, rest black 4
- Abdomen entirely black or brown 6
4. Abdomen with first three visible tergites red, rest black 5
- Abdomen with first four visible tergites red, rest black .... *A. gratus* Cameron, 1931
5. Elytra entirely black .... *A. diversiventris* Cameron, 1943
- Elytra black with posterior margin broadly reddish-yellow .... ***A. keralensis* sp. nov.**
6. Legs reddish-yellow, the apex of the femora black or blackish .... *A. gratellus* (Fauvel, 1879)
- Legs entirely reddish-yellow 7
7. Elytra uniformly black .... *A. bispinus* (Motschulsky, 1858)
- Elytra either black with reddish-yellow markings or reddish-yellow with black markings 8
8. Elytra with a reddish-yellow mark from postero-internal area to the postero-external angle ....
.. .. *A. leptocerus* (Eppelsheim, 1895)
- Elytra otherwise marked 9
9. Elytra reddish-yellow, more or less extensively marked with black 10
- Elytra otherwise marked 13
10. Elytra with a round black spot of variable size, sometimes extending to the epipleura; elytral suture very narrowly black .... *A. marginalis* Cameron, 1931
- Elytra with an elongate black spot narrowing basally, extending laterally on to the epipleura; elytral suture rather broadly black 11
11. Elytral spot black, elongate and transverse which forms the shape of 'H' when combined with black lateral longitudinal margin .... *A. h-signatus* Cameron, 1914
- Elytral spot black and transverse but not forming the shape of 'H' 12
12. Elytral elongate spot connected through the middle of the suture, running from one epipleuron to the other .... *A. ladakhensis* Coiffait, 1982
- Elytral elongate spot not connected through the middle of the suture .... *A. pulchripennis* Cameron, 1931
13. Elytra with the sutural and the apical margins reddish yellow 14
- Elytra otherwise marked 16
14. Elytra with narrow reddish-yellow sutural margin confined to the posterior half .... *A. kashmiricus* Cameron, 1943
- Elytra with broad reddish-yellow sutural margin almost reaching the base 15
15. Larger (6.5mm). Head longer, the post-ocular region nearly twice as long as the eye .... *A. suturalis* Cameron, 1931
- Smaller (5 mm). Head shorter, the post-ocular region slightly longer than the eye .... *A. andrewesi* Cameron, 1931
16. Elytra with the humeral angle and apical margin reddish-yellow .... *A. simlaensis* Cameron, 1931
- Elytra with only the apical margin reddish-yellow, each elytron with or without a small oblong red spot at apex near suture 17
17. Elytron with a small oblong red spot at apex near suture .... *A. bisalicus* Biswas & Sen Gupta, 1983
- Elytron without any red spot at apex near suture 18
18. Thorax with fine longitudinal rugae sculpture .... *A. varians* Cameron, 1931
- Thorax with normal reticulate-umbilicate sculpture 19
19. Elytra more coarsely and less closely punctuated, the apical margin sharply and distinctly reddish-yellow 20
- Elytra more finely and more closely punctuated, the apical margin very narrowly and obscurely reddish-yellow .... *A. obscurus* Cameron, 1931
20. Pleurites of genital segments long, extended and pointed .... *A. hindostanus* Cameron, 1919
- Pleurites of genital segments short, either slightly curved pointed or not pointed 21
21. Pleurites of genital segments short but slightly extended forming a curved point; penultimate antennomere as long as wide .... *A. caspiracus* Coiffait, 1982
- Pleurites of genital segments short and not at all extended and not forming any point; penultimate antennomere almost twice as long as wide .... *A. cachemiricus* Coiffait, 1982
22. Abdomen entirely reddish-yellow or brown 23
- Abdomen reddish-yellow, either only Vth visible tergite/ or visible tergites III–V/ or both IVth and Vth visible tergites/ or both Vth and VIth visible tergites more or less black 26
23. Abdomen entirely brown .... *A. semibrunneus* Cameron, 1931
- Abdomen entirely reddish-yellow 24
24. Larger (4 mm). Penultimate joints of antennae about three times as long as broad, sides of the elytra with several long black setae .... *A. flavescens* Scheerpeltz, 1933
- Smaller (3mm). Penultimate joints of the antennae slightly longer than broad, sides of the elytra without black setae 25
25. Post-ocular region not coarctate with the base, head more subquadrate, elytra not longer than the thorax, colour more reddish .... *A. concolor* (Kraatz, 1859)

- Post-ocular region coarctate with the base, head more suborbicular, elytra slightly longer than the thorax, colour yellowish .... *A. flavus* (Kraatz, 1859)

26. Abdomen with the only Vth visible tergite with anterior black and posterior lighter 27
- Abdomen with either visible tergites III–V/ or both IVth and Vth visible tergites/ or both Vth and VIth visible tergites black 33

27. Elytra uniformly reddish-yellow 28
- Elytra bicoloured with anterior half brown black and posterior half reddish-yellow/ or suture narrowly black anteriorly and bulging in the middle/ or with a black oval spot on each elytron 30

28. Elytra longer and broader than thorax 29
- Elytra shorter and narrower than thorax .... *A. ghumensis* Cameron, 1943

29. Sides of thorax with two long black setae .... *A. melanurus* (Küster, 1853)
- Sides of thorax with five long black setae .... *A. indicus* (Kraatz, 1859)

30. Elytra bicoloured with anterior half brown black and posterior half reddish yellow .... ***A. rougemonti* sp. nov.**
- Elytra reddish-yellow with suture narrowly black anteriorly and bulging in the middle or with a black oval spot on each elytron 31

31. Elytra reddish yellow with suture narrowly black anteriorly and bulging in the middle .... *A. sikkimensis* Biswas, 2003
- Elytra with a black oval spot on each elytron 32

32. Black spot on elytra almost reaching the epipleura and suture .... *A. subnotatus* Fauvel, 1904
- Black spot on elytra narrow and placed in the middle not reaching the epipleura or suture .... *A. kraatzi* Bernhauer, 1902

33. Abdomen with visible tergites III–V black .... *A. jhopus* Biswas & Sen Gupta, 1983
- Abdomen with either both IVth and Vth visible tergites/ or both Vth and VIth visible tergites black 34

34. IVth abdominal tergite black with light, narrow posterior margin, Vth abdominal tergite with only the base black and rest broadly lighter .... *A. maculatus* Cameron, 1920
- Vth and VIth visible abdominal tergites black with posterior margin broadly or scarcely lighter 35

35. Vth and VIth visible abdominal tergites black, their posterior margin scarcely lighter 36
- Vth and VIth visible abdominal tergites blackish, their posterior margin more or less broadly lighter 37

36. Sculpture of head and thorax of normal size .... *A. maculipennis* (Kraatz, 1859)
- Sculpture of head and thorax notably larger than usual .... *A. terminalis* Cameron, 1931

37. Sides of elytra with long black outstanding setae 38
- Sides of elytra with short black decumbent setae 40

38. Elytra with a black spot on each elytron .... *A. tanicus* Biswas & Sen Gupta, 1983
- Elytra without any black spot 39

39. Head elongate, VIth abdominal sternite yellow .... *A. setiferides* Newton, 2017
- Head suborbicular, VIth abdominal sternite black .... *A. peraffinis* Cameron, 1931

40. Larger (5 mm) and more robust, post-ocular region parallel for a short distance, then broadly rounded to the base .... *A. nilgiriensis* Cameron, 1931
- Smaller (4 mm) and narrower, post-ocular region coarctate with the base .... *A. gracilentus* (Fauvel, 1879)

verified species status with Oriental, Palaearctic, and Afrotropical distribution (Newton 2020).

Distribution of *Astenus flavus* (Kraatz, 1859): Kraatz (1859) described *A. flavus* as *Sunius flavus* with data on distribution given only as "Oriental India (Ind. Or.)" which could be anywhere in British India. Later Newton (2020) gave its distribution as confined to eastern India and Nepal. This work reports *A. flavus* form southern India with recorded distribution from the Western Ghats.

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COMMUNICATION

A new distribution record of mason wasp *Pison punctifrons* Shuckard, 1838 (Hymenoptera: Sphecidae: Larrinae) from Noida, Uttar Pradesh, India

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Abstract: This paper reports occurrence of mason wasp *Pison punctifrons* Shuckard, 1838 from Noida, Uttar Pradesh, India. This is a new distribution record for the species. This paper examines the nest architecture and prey choices of the wasp and carries the photographic record of a live *P. punctifrons* Shuckard on her nest with prey.

Keywords: Mud-nest, prey choice, range extension.

Editor: Anonymity requested.

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Author contribution: RKSB prepared the conceptual framework for the study, conducted literature survey and prepared the manuscript. ASB conducted the fieldwork including photography and prepared all the illustrations for this note.

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INTRODUCTION

Pison punctifrons Shuckard, 1838 has never been reported before from Noida or its surrounding areas, including Delhi. Existing records for this species in India, as per Pulawski (2015) are only from Bihar (Purnia), West Bengal (Barrackpore as *P. suspiciosum* Smith, 1858, now a synonym of *P. punctifrons* Shuckard), and Uttar Pradesh (Mussoorie as *P. striolatum* Cameron, 1897, now a synonym of *P. punctifrons* Shuckard). Additionally, there is one record of this species from Kerala (Sudheendrakumar 1989).

This Note reports the occurrence of *Pison punctifrons* Shuckard from Noida, Uttar Pradesh, India – a new distribution record. Figure 1 presents the distribution pattern of the species in India. Also there are details of nest and prey of *P. punctifrons* (Image 1). Classification followed here is as per Bohart (1976).

Nesting activities were studied in a single storeyed residential house in sector 33 of Noida, Uttar Pradesh, India. Location coordinates are: 28.589N & 77.354E.

Main field observations were conducted from 03 Sep 2015 to 01 Oct 2015 and again from 08 May 2020 to 06 June 2020. Additional intermittent observations were also made to keep records of the old (inactive) nests in the study area. Daytime high temperature during the study period ranged 32–37 °C in 2015 and 32–45 °C in 2020.

Opportunistic as well as systematic observations were conducted for the study of this wasp. On 03 Sep 2015, a small, black wasp was discovered building tiny barrel shaped clustered mud cells of the nest on the handrails of the stairs just about 1.5m above the ground in the study area. Observations were made and photographs taken. Contents of the last provisioned cell were collected for the identification of the prey. The nest, in general, was not disturbed.

On 08 May 2020 a wasp was spotted again building nest in the study area. Nest building and provisioning activities were observed and photographed / videographed. Contents of the last cell were collected for identification. The wasp that emerged last was also collected for the purpose of identification.

Study area was intermittently searched for old nests during the study period. Old nests were given unique identification numbers. Details of nests (location, type, substrate, number of cells, height from ground) were recorded. Photographs (or sketches) of all the old nests were maintained. Contents of older nests without exit holes were collected for examination. Fully formed wasps were found in one old nest inside a narrow cavity.

Image 1. *Pison punctifrons* Shuckard at nest with prey.

A basic 100x optical microscope was used for the examination of the wasp including forewing venation. Same setup was used for the identification of the prey (spiders) to the family level. Focus stacking technique was used to photograph wasp and smaller spiders using combination of microscope and digital camera/ mobile phone. Inkscape vector graphics software was used for preparing line diagrams.

Identification of *Pison punctifrons* Shuckard is based on the original descriptions of Indian *Pison* Spinola species by earlier workers. Identification of spiders has been done with the help of (Tikader 1987; Jocqué 2007).

Forewing venation for identification

Of the many variables in *Pison* Spinola, none is more striking than the forewing venation. Wings have three or two submarginal cells, and the two-celled condition is clearly the result of complete reduction of the second cell (Bohart 1976). Arrangement of recurrent veins produces variety of wing patterns. The m-cu crossveins of the forewing have been called the recurrent veins. In wings with three sub-marginal cells the first recurrent vein is received by submarginal cell 1 or 2 or is interstitial. The second recurrent vein is received by submarginal 2 or 3 or is interstitial (Bohart 1976). This wing venation pattern is the most crucial clue to the identification of *Pison* Spinola species.

Pison Spinola species in India with three or two sub-marginal cells

Antropov (1994) reviewed 'agile' group of *Pison* Spinola species (species having forewings with only two sub-marginal cells). So far as Indian species are concerned, this study included *P. pulawskii* Antropov, 1994, *P. erythropus* Kohl, 1884, *P. agile* (Smith, 1869), *P. differens* Turner, 1916, and *P. rothneyi* Cameron, 1897.

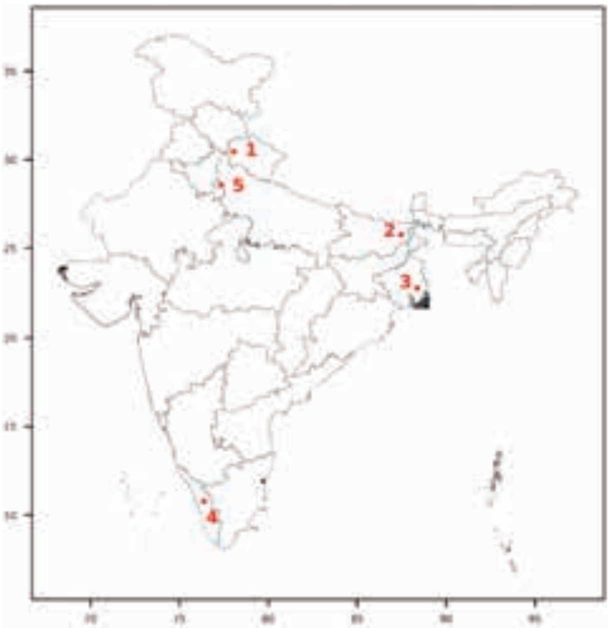

Figure 1. Distribution of *Pison punctifrons* Shuckard in India. 1—Mussoorie (Uttarakhand) | 2—Purnia (Bihar) | 3—Barrackpore (West Bengal) | 4—unidentified location (Kerala) | 5—Noida (Uttar Pradesh).

We used this information for segregating Indian *Pison* Spinola species into two categories: *Pison* Spinola with three sub-marginal cells in the forewing and those with two sub-marginal cells (See Table 1). Bingham (1897) provides descriptions of the Indian *Pison* Spinola species.

As per Table 1, there are only five *Pison* Spinola species found in India with three submarginal cells and this includes one doubtful species namely *Pison fasciatum* Radoszkowski.

Genus *Pseudonysson* Radoszkowski, 1876 is presently a synonym of genus *Pison* Jurine in Spinola, 1808. *Pseudonysson fasciatus* Radoszkowski, 1876 has been synonymized with *Pison fasciatum* (Radoszkowski, 1876) (Bohart 1976).

Turner (1916) writes about *Pison fasciatus* (Radoszkowski, 1876):

"The description is poor, but apparently the species is allied to *Pison algiricum* Kohl, 1898, but with normal antennae. To this species I assign an Indian specimen with some doubt. Hab. S.E. Caucasus; Chapra, Bengal (Mackenzie)". There is no other information available about this species from any other source. So, ignoring this doubtful species, there are only four *Pison* Spinola species in India with three submarginal cells.

Additional description

Female. Total length 9mm, forewing 6mm, and colour entirely black. Forehead and prothorax thickly punctured (Image 2). Clypeus with a large protruding median lobe with rounded apical margin, without lateral lobes (Figure 2). Clypeus and the face below the eye incision (notch) densely covered with silvery pubescence. Propodeum at base coarsely and obliquely striated (Image 3). Abdomen smooth and shining. Silvery bands on the apical margins of the abdominal segments become conspicuous in flight, under certain lighting conditions when the wasp approaches nest. Forewings hyaline with darker apical margins. Forewings with three submarginal cells, the second much smaller and petiolated. Veins dark brown. The first recurrent vein (1m-cu) received near the apex of the first submarginal cell, aligning and apparently merging with the crossvein; the second recurrent vein (2m-cu) received at the apex of the second submarginal cell merging with the crossvein (Image 4). Facial details as shown in Figure 2 are based on a composite image obtained using focus stacking technique.

Comparison for identity confirmation

We will now compare the forewing venation details with the description of other workers to confirm identification of the species as *Pison punctifrons* Shuckard.

Forewing venation of Noida *Pison* Spinola species is closer to the description of *Pison suspiciosus* Smith (a synonym of *P. punctifrons* Shuckard) as given by Smith (1858), "The first recurrent nervure received at the apex of the first submarginal cell; the second at the apex of the second submarginal".

In case of Noida *Pison* Spinola species first recurrent vein is received "near the apex" (not "at the apex"), however this difference needs to be viewed in the light of the descriptions given by Shuckard (1838) for *P. punctifrons* and *P. spinolae*, "…the recurrent nervures inosculating with the transverso-cubitals…". He further adds that "…this species at first sight much resembles the *P. spinolae* Shuckard, but, upon examination, it is at once distinguished by its very coarse sculpture, and the size of its second submarginal cell".

Shuckard (1838) describes *P. spinolae* as follows, "… the petiolated submarginal cell very minute, and receiving the two recurrent nervures at the inosculating points of its transverse cubitals". As per Shuckard, arrangement of recurrent veins is identical in *P. punctifrons* and *P. spinolae*.

Forewing venation of *P. spinolae* is shown in Figure 3 based on the illustration given by Harris (1994). The arrangement of recurrent veins of *P. spinolae* is exactly same as that of Noida *Pison* Spinola species. First recurrent vein received near the apex of the first

Table 1. *Pison* Spinola species in India as per Pulawski (2015). Species with two sub-marginal cells segregated as per Antropov (1994).

	Name	Authority	Synonyms	Authority	Geographic Location
A.	***Pison* Spinola species with three sub-marginal cells:**				
1.	*P. argentatum*	Shuckard, 1838	*P. fuscipalpe*	Cameron, 1901	Bombay, Bangalore
2.	*P. fasciatum*	(Radoszkowski, 1876)			India (?)
3.	*P. orientale*	Cameron, 1897			Barrackpore
4.	*P. punctifrons*	Shuckard, 1838	- *P. suspiciosum* *P. striolatum*	- F. Smith, 1858 Cameron, 1897	Purnia, Kerala (no specific location) Barrackpore Mussoorie
5.	*P. rugosum*	F. Smith, 1856	- *Pisonitus rugosus* *P. appendiculatum*	- F. Smith, 1869 Cameron, 1897	Barrackpore
B.	***Pison* Spinola species with two sub-marginal cells:**				
6.	*P. agile*	(F. Smith, 1869)	*P. koreense*		Southern India, Sri Lanka
7.	*P. differens*	R. Turner, 1916			Assam, Shillong
8.	*P. erythropus*	Kohl, 1884	*Parapison rufipes*	F. Smith, 1869	Uttar Pradesh: Mainpuri.
9.	*P. obliteratum*	F. Smith, 1858			Kumaun, northern India
10.	*P. pulawskii*	Antropov, 1994			Rajasthan: Udaipur
11.	*P. rothneyi*	Cameron, 1897	*P. crassicorne*	Cameron, 1897	Barrackpore

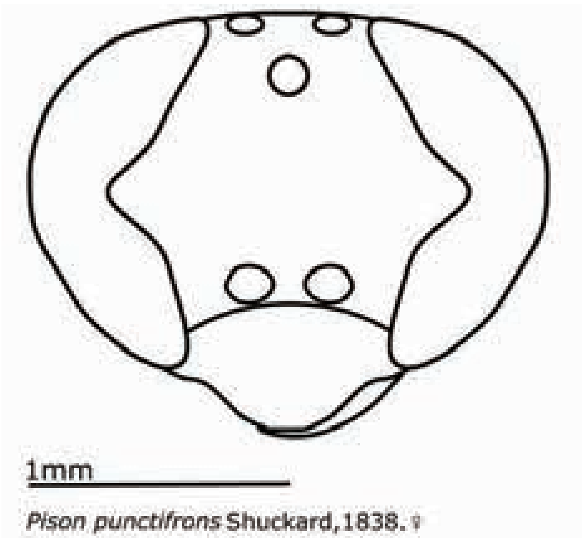

Figure 2. Facial details of female *Pison punctifrons* Shuckard.

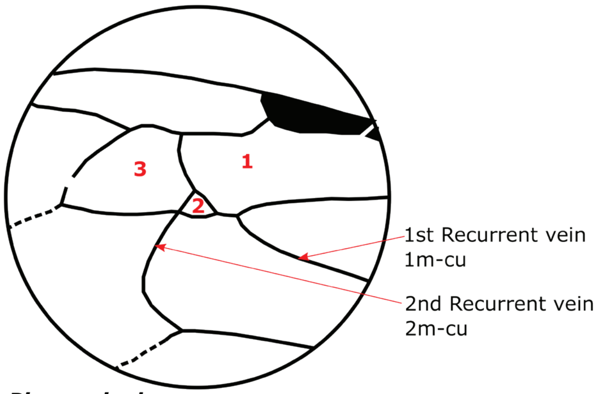

Figure 3. Forewing venation (Part) of *Pison spinolae* Shuckard (based on Harris 1994)

submarginal cell and the second recurrent vein received at the apex of the second submarginal cell. This confirms the identification of the wasp as *P. punctifrons* Shuckard.

Darker apical margin of the forewing and arrangement of recurrent veins are sufficient keys to differentiate *P. punctifrons* from other *Pison* species of India with three submarginal cells.

In case of *P. argentatum* the first recurrent vein is received towards the apex of the first submarginal cell, and the second recurrent vein received about the middle of the second submarginal cell (Shuckard 1838).

In case of *P. orientale* Cameron, the recurrent veins are received shortly in front of the transverse cubital (Cameron 1897).

In case of *P. rugosum* Smith, the first recurrent vein is received towards the apex of the first submarginal cell, and the second recurrent vein received about the middle of the second submarginal cell (Smith 1856). This description of the forewing venation is similar to that of *P. argentatum* and additional features need to be included in the identification key.

Nest location and architecture

All nests are located in absolutely sheltered positions away from the sun or rain; in the semi-covered areas of the house which include verandah, underside of the staircase, or courtyards. Substrate of the nest is a plastered wall, wood or steel. Junction of two walls or a corner of the junction of three walls (e.g., interior corner of a square niche in the wall); grooves and cavities in the wooden windows are preferred locations. No nest is found in the middle of a smooth wall or a ceiling unless a cracking plaster creates some sort of groove or uneven surface.

Well defined horizontal or vertical linear grooves in the wooden window panels are often used as a nesting site. Raised wooden beadings on doors and windows or putty around the glass panes also provide similar junction of two surfaces and therefore offer good nest sites.

Nest is a cluster of tiny mud cells. Three types of nests were recorded in the study area:

1. Type 1 – Free standing nests which vaguely look like a small bunch of tiny grapes (Image 5). Completed nest is fully visible.
2. Type 2 – Nests inside pre-existing grooves. In this case direction of the groove; whether horizontal or vertical decides the progression of the nest and final nest looks quite linear in shape (Image 6). Completed nest is partially visible.
3. Type 3 – Nests inside holes or cavities in the wooden windows (Image 7). Completed nest is not easily visible.

All three types of nests were found in close proximity to each other. Types 1 and 3 nests were attributed to *Pison punctifrons* by identifying the adult wasps associated with these nests. Type 2 nests were attributed to the same wasp on the basis of the pupal cases found in the cells which were identical to the pupal cases found in Types 1 and 2 nests. Individual cells of the Type 2 nest were also similar to the cells of Types 1 and 3 nests.

Basic unit of the nest is a fragile barrel shaped ½ mm thick mud cell, 9mm long with an external diameter of 5mm in the middle and 3mm at both the ends. Though this is generally true for Type 1 nests, Type 2 nests built in

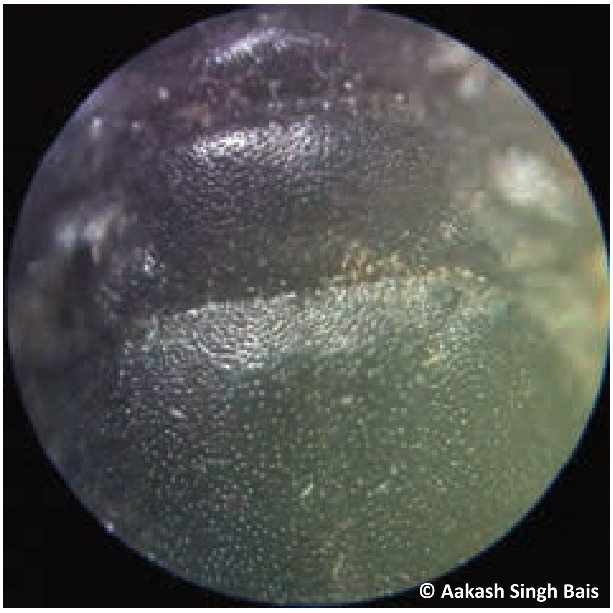

Image 2. *Pison puntifrons* Shuckard. Punctured pronotum and mesoscutum.

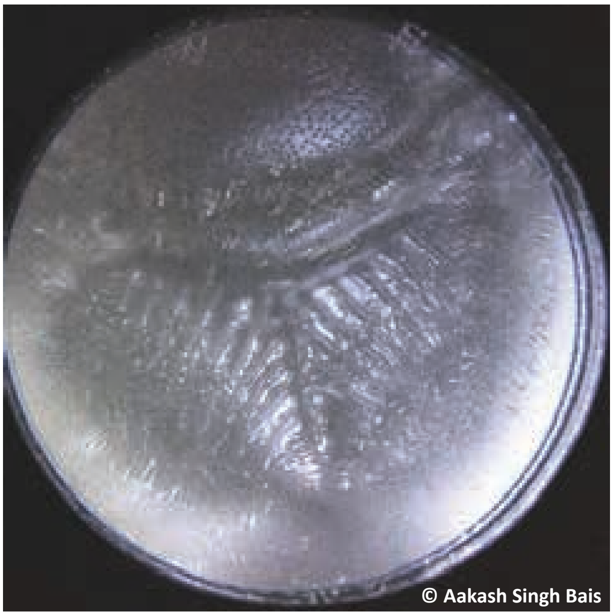

Image 3. *Pison punctifrons* Shuckard. Propodeum.

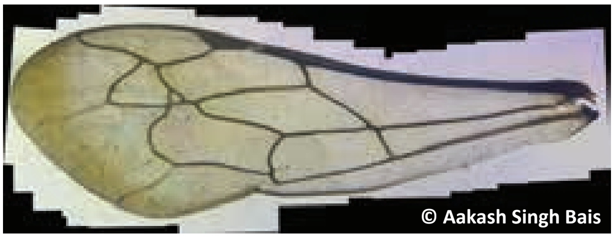

Image 4. Left forewing venation of *Pison punctifrons* Shuckard.

pre-existing narrow grooves were found to be of longer length. For example, two Type 2 nests built in 4 x 4 mm linear vertical groove in the wooden window were found to be having longer cells. First nest (Type 2) contained three cells of 12mm and one cell of 16mm (Image 6a,b). Second nest (Type 2) had two cells of 12mm and one cell of 16mm.

The substrate is not lined and thus becomes a part of the cell. Any cracks in the substrate are repaired by filling them with mud. Two adjoining cells built on the original substrate are independent and do not share a common partition wall. Cell construction begins from the bottom of the barrel and ends at the top 3mm opening which is closed immediately after provisioning of the cell is completed and egg laid.

During the study period (2015–2020), 21 nests were built in the study area. Details of these old inactive (and also active nests under observation) were collected. Nest type, substrate, height from the ground and number of cells for each nest were recorded. Out of total 21 nests 10 were Type 2 (48%), eight Type 1 (38%), and three Type 3 (14%). Substrate for the 11 nests was cement plaster (52%), eight were built on wood (38%), and one each on metal and glass putty (5% each). All nests were located 1.2–3.35 m above the ground level. Frequency distribution plot of number of cells vs number of nests is presented in Figure 4.

While recording old nests in the study area, one cluster of mud cells was found just inside a window latch hole, 15mm diameter and 20mm deep, in the top element of a wooden window frame. This was a Type 3 nest (Image 7). It contained a cluster of five mud cells. Architecture of this partly hidden nest was discovered by sequentially breaking the nest cells using a wooden toothpick and separately collecting the contents of each cell in a dish. Breaking sequence followed 5-4-3-2-1. Pencil torch was used to illuminate the interior portion of the cavity. Mental images formed during the process were used to immediately draw the rough sketch showing arrangement of the nest cells.

One intact pupa was found in each of the two exterior cells (Cell 4 and 5). Three interior cells 1, 2, & 3, which were fully or partly blocked by the two exterior cells returned perfectly formed but dead adult wasps, one in each cell. It is tentatively suggested that probably these adult wasps could never find a passage to get out of the cells because of the obstruction created by the exterior cells.

Image 5. *Pison punctifrons* Shuckard nest. Type 1.

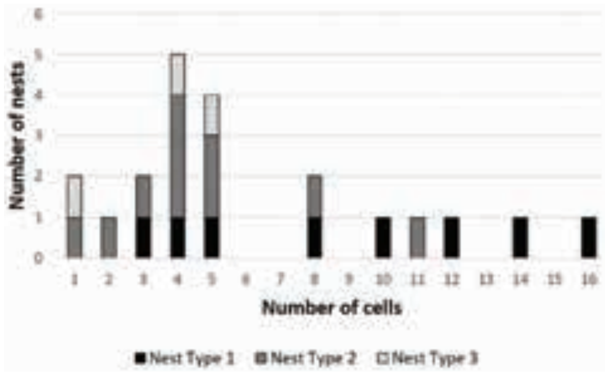

Figure 4. Frequency distribution plot. Number of cells vs number of nests.

Active nest observations

On 08 May 2020 at 13.15h a *Pison punctifrons* wasp was spotted at the nest, building the third cell of the nest. This was a Type 1 nest. At 13.30h the cell was closed. Before closing the nest, the wasp was seen inserting her abdomen inside the cell as if pushing the contents to make room for more spiders. But we soon realized that the wasp actually deposited the egg, as soon after, mud was brought and the opening was sealed. Immediately after sealing the cell she began building the 4th cell from where she ended the last cell, i.e., from the end

Image 6a. *Pison punctifrons* Shuckard nest. Type 2. Front view.

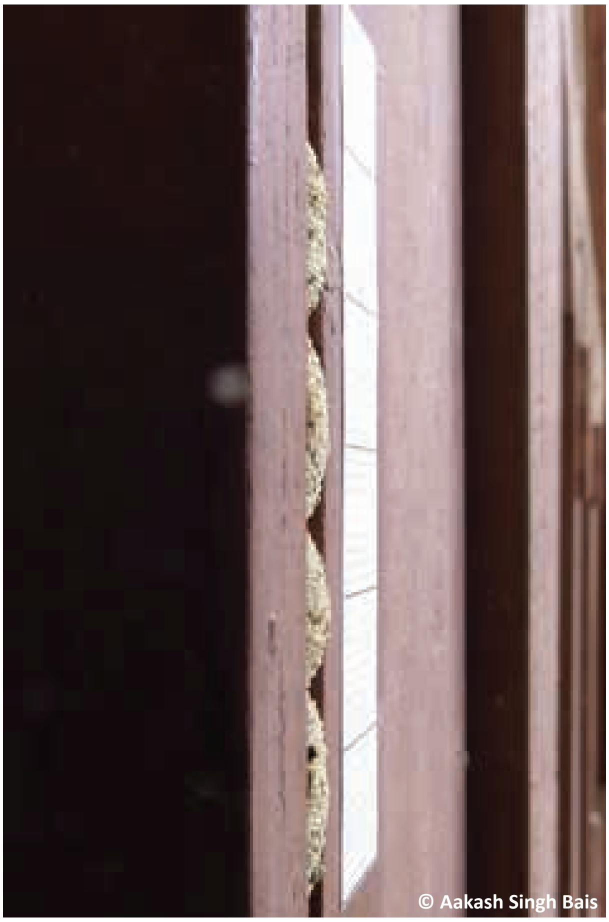

Image 6b. Same *Pison punctifrons* Shuckard nest. Type 2. Side view.

cap of the 3rd cell. Construction of the 4th cell began at 13.38h and the same was completed in 70 minutes. The wasp made 18 trips to bring the mud pallets for this cell. Nineteenth, the last visit to the nest was at 14.37h for the final inspection before provisioning began. At 15.00h the first spider was brought to the cell. At 15.40h we closed the field work for the day.

Next day on 09 May 2020, she continued provisioning the same cell 4 and finally closed it at 13.34h. The egg was most probably laid at 13.00h. Immediately after closing cell 4, construction of cell 5 began. At 16.45h when the field work ended for the day, cell number 5 was still under construction.

Next day on 10 May 2020 no activity was seen, the wasp did not visit the nest. Rains followed a dust storm at 11.45h. Fifth cell was still open and without any spider. Weather remained cloudy for the rest of the day and the wasp was never seen around the nest. Next day on 11 May 2020, the wasp did not arrive at the nest till 13.30h and assuming that no more cells would be added, we collected the contents of the last sealed cell 4 for examination leaving behind sealed cells 1, 2, & 3. Empty cell 5 also needed to be removed for this. Wasps from cells 1, 2, & 3 emerged on 06 June 2020. Wasp from cell 3 was collected for identification.

The building process

Cell construction begins from the bottom of the barrel. Having laid the base, wall of the barrel is raised in multiple segments. The wasp precariously holds the substrate or previously laid segment of the barrel wall to raise it further by depositing and spreading wet mud paste, brought in the shape of a pallet. The wasp spends much time inside the cell while construction is in progress and only occasionally visits the outer surface for inspection. Inside of the cell is rendered smooth while outside remains rough.

While building nest cell the wasp produces high frequency sound by vibrating her wings. Recorded sound frequencies ranged 4–11 kHz with maximum amplitude at 6072 Hz.

Starr (2004) has described the nesting behaviour

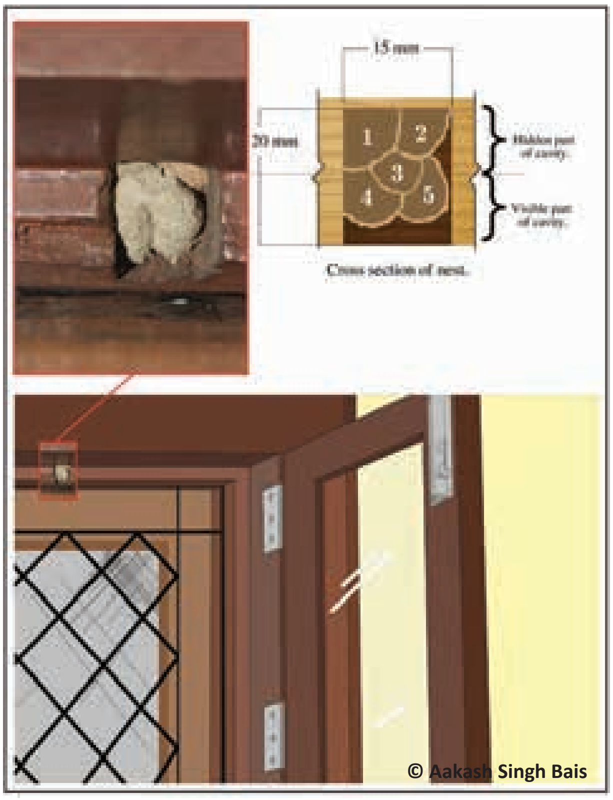

Image 7. Pison punctifrons Shuckard nest. Type 3.

of *P. argentatum* and also provided the photographs of the nest. Type of free nests built by *P. argentatum* are different in appearance from those built by *Pison punctifrons.* Nests of the *P. rugosum* as illustrated by Horne (1870) are also different in appearance.

Observations about the prey

Season I (03 September 2015–14 February 2016). The wasp that was spotted on 03 September 2015 completed and sealed four cells by 05 September 2015. After completing the fifth cell, except the top opening, she started bringing small spiders. It took her 10 minutes to 45 minutes to bring one spider to the cell. At 19.30h (on 05 Sep 2015) the wasp was seen resting in the cell, head just protruding out of the cell. Next day on 06 Sep 2015 at 08.00h the wasp was still in the cell, in the same position. At 22.30h also the cell was not yet sealed. Next day on 07 September 2015 the wasp never visited the cell and it remained open. On 01 October 2015 exit holes were observed on two of the cells.

On 14 February 2016 the nest built by this wasp was collected and its contents examined. It had five cells. Three cells were empty with exit holes. One cell returned an intact pupal case. Fifth, the last cell, the top most one, was never sealed after provisioning. It contained eight spiders belonging to three families, Oxyopidae: 2, Salticidae: 6, and Theridiidae: 1. It appears that the wasp never completed the provisioning of the last cell nor deposited any egg.

Table 2. Contents of a cell of *Pison punctifrons* Shuckard

	Family	No of spiders
1	Dictynidae	1
2	Oxyopidae	2
3	Salticidae	1
4	Theridiidae	1
5	Thomisidae	4
6	Uloboridae	1
7	Unidentified	1
	Total	11

Season II (08 May 2020–11 May 2020)

Contents of the last sealed cell 4 were collected on 10 May 2020 for identification. This cell contained 11 small to very small spiders. Family identification of these spiders is placed in Table 2. The wasp laid the egg dorso-laterally on the abdomen of a crab spider (Thomisidae). See box 8b of Image 8.

Thomisids, the crab spiders, build no webs. They live on plants and foliage. Some species run swiftly and pursue their prey while others wait in ambush inside or underneath a flower to attack and catch the insects visiting the flower for nectar. Salticids, the jumping spiders also do not build webs and actively pursue their prey on plants, foliage, logs, and other substrata. Oxyopids are hunting spiders of the plant and they chase their prey on grass and foliage. Most make little use of webs. Dictynids are very small cribellate orb weavers and make irregular snares in the foliage. Uloborids are also cribellate spiders and make complete or partial orb webs. Spiders of the family Theridiidae build irregular space webs. Going by the number of spiders in a cell from different families (Table 2), it appears that *P. punctifrons* mostly takes prey from those families that build no webs. This is similar to the prey choices made by *P. argentatum* as discovered by other workers (Starr 2004). However, a much larger prey database is required to confirm the same.

CONCLUSION

Presence of a little known wasp *Pison punctifrons*

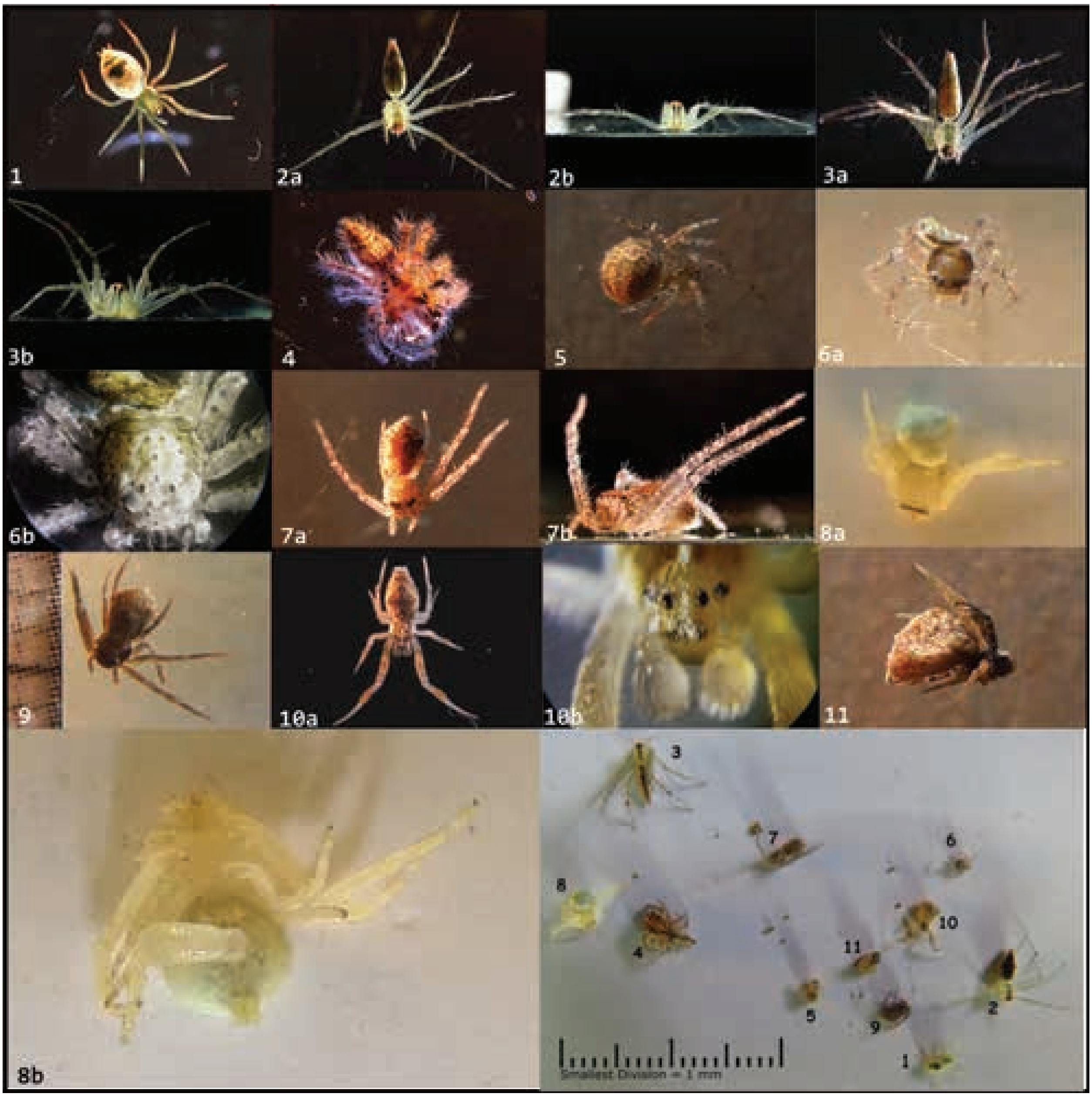

Image 8. Prey contents of one cell of a nest of *Pison punctifrons* Shuckard, 1838.
Key to spider specimens in the index card image at bottom right: 1—Dictynidae | 2, 3—Oxyopidae | 4—Salticidae | 5—Theridiidae | 6, 7, 8, 9—Thomisidae | 10—Uloboridae | 11—Unidentified.
All other magnified images are of the same specimens and share same family identification number. Few specimens have been photographed twice from two different angles to facilitate identification. Such images are labelled 2a, 2b; 3a, 3b etc. © Aakash Singh Bais.

Shuckard in Noida, Uttar Pradesh is established. The nearest historical record is from Mussoorie in Uttarakhand which is about 225km to the north. This historical record from Mussoorie is about 125 years old, when Cameron described *Pison striolatum* in the year 1896 from Mussoorie (Cameron 1896). *Pison striolatum* is presently considered to be a synonym of *Pison punctifrons*. Other historical records of the species from India are also equally old. The last published record for India is for the year 1989 from Kerala (Sudheendrakumar 1989). Because of limited information available, present status or distribution pattern of *Pison punctifrons* in India is not fully understood.

This wasp builds free standing mud nests and also utilizes pre-existing grooves and cavities. Number of cells per nest vary from one to 16. We do not know what type of nests are built by this wasp in the wild away from the human settlements. Its choice of prey appears to be small spiders mostly from the families that do not build webs; however, more work on prey choices is required to fully understand the prey preferences of this wasp.

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OPEN ACCESS

COMMUNICATION

Diversity of freshwater molluscs from the upper Brahmaputra Basin, Assam, India

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Abstract: A field survey was conducted for three consecutive years, 2015–17 to assess the diversity of freshwater molluscs (Gastropoda and Bivalvia) of the upper Brahmaputra Basin in Assam, India. Altogether, 18 gastropods and 27 bivalve species representing nine families were recorded from 17 sampling stations comprising small to large tributaries and wetlands in the flood-plains covering a total geographical area of approximately 3,500km^2. A large fraction (15.55%) of the collected mollusc species are new records from the upper Brahmaputra Basin of Assam. Rarity in the occurrence of freshwater mollusc was confirmed with singleton and doubleton species accounting for 6.66% and unique species accounting for 35.55% of the total species recorded. It was observed that most of the mollusc species of the upper Brahmaputra Basin are either in the 'Least Concern' or 'Data Deficient' category of the IUCN Red List; except for *Lymnaea ovalior* (Annandale & Prashad, 1921) and *Sphaerium austeni* Prashad, 1921 assessed as 'Vulnerable' and 'Near Threatened', respectively. A significant trend in the diversity in terms of species richness and composition was observed across the sampling stations of the northern basin and southern basin of the river Brahmaputra.

Keywords: Burhi-Dihing, Data Deficient, habitat heterogeneity, species richness, unique.

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INTRODUCTION

Freshwater molluscs are one of the most widely distributed groups of aquatic macroinvertebrates, considered an emerging wealth of the freshwater bodies (Elder & Collins 1991; Maltchik et al. 2010), and play a pivotal role in the health of the aquatic ecosystems (Fenchel & Kofoed 1976; Bertness 1984; Peterson & Black 1987; Kay 1995; Stewart et al. 1998; Strayer et al. 1999; Gutierrez et al. 2003; Vaughan et al. 2004; Lydeard et al. 2004; Budha et al. 2010). Freshwater molluscs (Gastropoda and Bivalvia) are distributed in the freshwater bodies throughout the globe except Antarctica (Schiaparelli et al. 2014). Apart from their role in the ecosystem, people across the globe exploit several species of freshwater molluscs as food, medicine, ornament, and in the craft industry (Wood & Wells 1995; Sonowal & Kardong 2020). Freshwater molluscs are also used as bio-monitoring agents in the aquatic ecosystem and in integrated fish farming (Sicuro 2015). Most of the information on the status and distribution of Indo-tropical freshwater molluscs is based on the studies in the eastern Himalaya (Budha et al. 2010); the Western Ghats (Aravind et al. 2011), and the Indo-Burma region (Köhler et al. 2012) especially in the Mekong River basin covering the nations comprising Vietnam, Laos, Cambodia, Thailand, Burma, and China. In India, pioneering work on the diversity, distribution and taxonomy of freshwater molluscs were carried out by Benson (1836, 1850, 1865), Blanford (1863, 1870, 1880), Blanford & Godwin-Austen (1908), Preston (1915), Annandale (1918), Prashad (1920, 1928), and later reviewed by Rao (1989) and Ramakrishna & Dey (2007). Research on molluscs in India is basically limited to the Western Ghats in southern India and some parts of the eastern Himalayan region. Reports on richness and diversity of freshwater molluscs from various parts of mainland India and Indo-Burma region are available (Rao 1989; Ramakrishna & Dey 2007; Budha et al. 2010; Köhler et al. 2012). A good number of research studies are going on in the southwestern parts of the Indian peninsula (Aravind et al. 2010; Ramesha et al. 2013). Ironically, no significant studies on the status and distribution of freshwater molluscs have been carried out in the Brahmaputra River basin of Assam. As a result, studies on the distribution, taxonomy and biology of mollusc population of the region remains obscure and also that of several reported species seem to be doubtful (Budha et al. 2010). Therefore, the present study is aimed to assess the diversity of the freshwater mollusc community across the upper Brahmaputra Basin (UBB), their distribution pattern and also for identification of important sites for future conservation planning of freshwater molluscs in the region.

MATERIALS AND METHODS

Study area

The Upper Brahmaputra basin (UBB) is a part of the Himalayan biodiversity hotspot and lies between the hill ranges of the eastern and northeastern Himalayan ranges. The river Brahmaputra enters Assam through the easternmost corner of Arunachal Pradesh and divides the eastern valley of Assam into two banks across the river—the northern bank and southern bank—with prominent physiographic differences. The present study area covers a total geographical area of approximately 3,500km^2 between 27.273–27.809 ^{0}N and 94.591–95.378 ^{0}E (Image 1). The area was selected because of the large-scale habitat loss during the last few decades due to recurring floods which is reported to have begun after the devastating earthquake of the 1950s and anthropogenic activities like the discharge of chemicals from oil fields and tea gardens (CPCB 2005; Baruah 2007) and urbanization.

Sampling

The survey was conducted in 17 sampling stations (Table 1) using the random sampling method for a period of three consecutive years (2015–2017) from December to February. Among the selected survey sites there were nine small and large tributaries of the Brahmaputra (site B, C, D, E, F, G, H, I, J, K, L, N, P) and four wetlands (site A, M, O, Q). Geocordinates of the sampling sites were recorded using GARMIN GPS (Model No. GPSMAP 60CSx). Ten random sampling points were selected in each sampling station and samples were collected using quadrat of 1m^2 size. The large specimens were handpicked and the smaller ones were collected from the bottom substrata by using a metal sieve of mesh size 2mm^2. Specimens were then washed, sorted into morpho-species, and representatives were brought to the laboratory for reference. Identification of the specimens was done according to Rao (1989), Ramakrishnan & Dey (2007), and by comparing with authentic voucher specimens deposited at the Zoological Survey of India (ZSI), Kolkata.

Data analysis

Abundance (N), species richness (S), the Shannon-Wiener diversity index (H) (in $\log_{10}$), Simpson index (1-D), evenness index ($E^{H/S}$), and equitability index (E_H=H/H_{max}; H_{max} = lnS) of all the sites were calculated using PAST (Paleontological Statistics, Version 3.08) programme

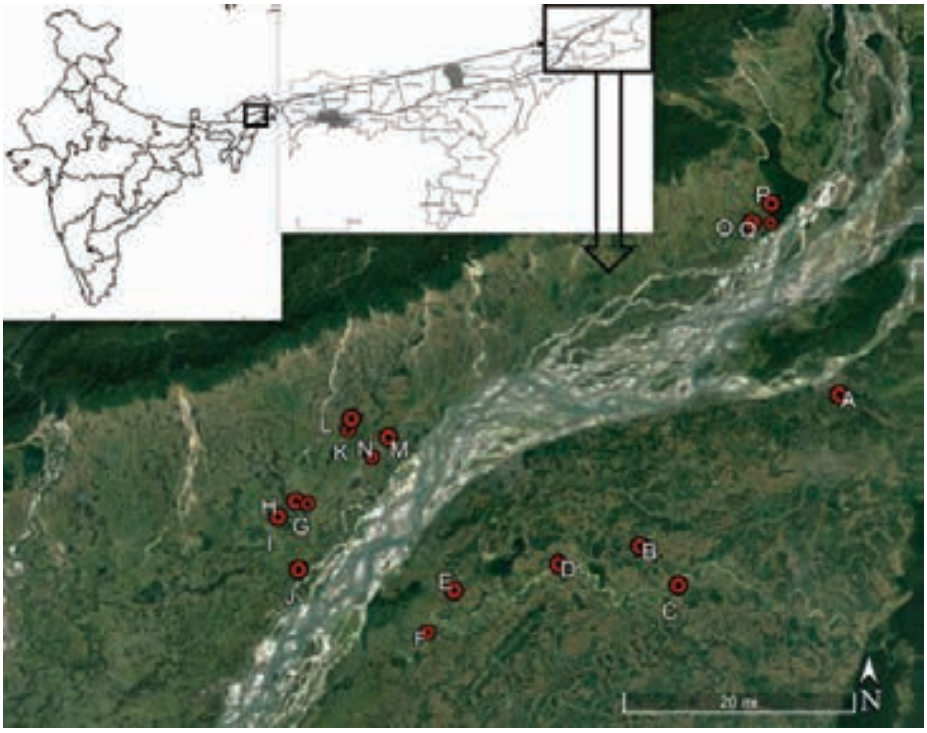

Image 1. Satellite image of the upper Brahmaputra Basin of Assam, India. Red coloured markings are different sampling stations of the study area.

Table 1. Name, assigned code and the co-ordinate of the sampling stations.

Name	Code	Latitude (⁰N)	Longitude (⁰E)
Maguri beel (Wetland)	A	27.571	95.378
Diharang river (Tributary)	B	27.381	95.101
Kulagora, Burhi-Dihing River (Tributary)	C	27.333	95.153
Hareghat, Burhi-Dihing river (Tributary)	D	27.356	94.983
Sesa river (Tributary)	E	27.325	94.839
Janzi, Burhi-Dihing River (Tributary)	F	27.273	94.802
Aamguri River (Tributary)	G	27.432	94.632
Laipulia river (Tributary) (Dusutimukh)	H	27.435	94.616
Kopahtoli (Tributary) (Bhomura guri)	I	27.415	94.591
Sisi River (Tributary)	J	27.350	94.621
Gelua river (Tributary)	K	27.524	94.688
Mesu River (Tributary)	L	27.538	94.693
Tongani Beel (Wetland) (Tongani majgaon)	M	27.515	94.745
Tongani River (Tributary)	N	27.490	94.722
Nahor Village (Wetland) (Bahir Jonai)	O	27.785	95.255
Sile river (bahir chilai) (Tributary)	P	27.809	95.282
Aagrung beel (Wetland)	Q	27.784	95.280

to evaluate the state of diversity in the studied area. Sample-based rarefaction (interpolation-extrapolation) curves for all the stations sampled were compared based on incidence data using the method proposed by Colwell et al. (2012). The non-overlap of 95% confidence intervals was used as the indication of statistical difference (Colwell et al. 2012; Gotelli & Ellison 2013). Rarefaction and extrapolation analyses were conducted using the PAST and EstimateS programme.

RESULTS

Species Abundance and Composition

From the survey conducted in the 17 sampling stations during the three years, 7,881 (all live) specimens belonging to 45 species of nine freshwater mollusc families from two classes, Gastropoda and Bivalvia, were recorded (Table 2). These comprised Viviparidae (N= 526, six species), Ampullaridae (N= 16, one species), Thiaridae (N= 1,928, five species), Pachychilidae (N= 539, one species), Lymnaeidae (N= 154, two species), and Planorbidae (N= 136, three species) from the class Gastropoda. The class Bivalvia was represented by three families, viz., Unionidae (N= 3,516, 22 species), Cyrenidae (N= 938, two species), and Sphaeriidae (N= 128, three species). *Indonaia* under the family Unionidae was recorded as the dominant genus comprising nine (20% of the total species richness) species. Among the total population recorded, *Parreysia favidens* (Benson, 1862) and *Melanoides tuberculata* (Müller, 1774) emerged as the most abundant species. Three (6.66% of the total) species were recorded as rare species, i.e., singleton species (with only one individual throughout the survey), viz., *Lymnaea ovalior* (Annandale & Prashad, 1921) (station G) & *Trapezidens exolescens* (Gould, 1843) (Station B) and doubleton species (with only two individuals throughout the survey), *Filopaludina micron* (Annandale, 1921) (Station A) from the study area. Further, 16 (35.55% of the total) species were observed to be unique, i.e., they were confined to a particular/single sampling station and seven (15.55%) species were recorded as new reports from UBB (Table 3).

Species richness and diversity assessment

The species richness and diversity indices are listed in Table 4. As for the species richness and abundance, sampling station A with 27 (60% of the total recorded) species emerged as the richest sampling station in the study area, whereas sampling station Q corresponds to only 17.77% of the total richness (Table 4). The Simpson index (1-D) and Shannon diversity index (H*)* showed a general constancy across the sampling stations (Table 4), with values 0.86±0.03 and 2.28±0.24, respectively. Evenness ($E^{H/S}$) index showed variations across the sampling stations, with values ranging between 0.47 and 0.86 (Table 4). It was observed that the southern basin (stations A–F) of UBB showed an uneven species distribution pattern ($E^{H/S}$= 0.47–0.71) than the rest of the sampling stations of the northern basin.

Species richness was evaluated through sample-based and individual-based rarefaction curves which are presented in Figures 2, 3, 4(a), and 4(b). Differences in species richness and composition were observed in both the northern and southern basins of UBB (Figure 2). On the northern basin of the river, the cluster formation of curves between sampling stations was noted due to a large overlapping (at 95% unconditional confidence intervals) at sampling stations G, H, I, J, K, L, M, and N (Figure 3(a)). In contrast to this observation, the sampling stations of the southern basin showed remarkably different values and patterns in which the sampling stations C, D, and F showed clusters of non-overlapping curves at 95% unconditional confidence intervals (Figure 3(b)).

Differences in species composition were also observed among the mollusc populations in tributaries and wetlands. Species like *Filopaludina bengalensis* (Lamarck, 1822), *M. tuberculata*, *Tarebia granifera* (Lamarck, 1822), *T. lineata* (Gray, 1828), *Brotia costula* (Rafinesque, 1833), *Lamellidens corrianus* (Lea, 1834); *L. marginalis* (Lamarck, 1819), *P. corbis* (Benson, 1856), *P. corrugata* (Müller, 1774), and *P. favidens* are common to both tributaries and wetlands; while species like *Thiara aspera* (Lesson, 1831), *L. ovalior*, *Scabies crispata* (Gould, 1843), *Balwantia soleniformis* (Benson, 1836), *Indonaia olivaria* (Lea, 1831), *I. nuttaliana* (Lea, 1856), *I. shurtleffiana* (Lea, 1856), *I. theobaldi* (Preston, 1912), *and T. exolescens* are confined to the tributaries only. Unique species like *Mekongia crassa* (Benson, 1836), *Idiopoma dissimilis* (Müller, 1774), *F. micron*, *Angulyagra microchaetophora* (Annandale, 1921), *Pila olea* (Reeve, 1856), *Gyraulus convexiusculus* (Hutton, 1849), *Sphaerium austeni* Prashad, 1921, and *Musculium indicum* (Deshayes, 1854) were recorded only from the wetlands.

DISCUSSION

Approximately, 186 species of freshwater molluscs have been estimated to inhabit freshwater rivers, streams, and lakes in the eastern Himalayan region (Budha et al. 2010) which is approximately 3% of the total global estimate (Vinarski et al. 2020). During the present survey, we recorded 45 species of freshwater molluscs from the UBB. This figure accounts for 24.19% of total freshwater mollusc species from the eastern Himalaya (Table 2). As regards the species richness, there is the possibility of encountering even more native species from the region as is indicated by the sample-based rarefaction curve (Figure 1).

Biogeographically, most families of freshwater molluscs from the eastern Himalayan and Indo-Burma hotspot region are cosmopolitan in nature (Budha et al. 2010; Köhler et al. 2012). The Unionidae and Cyrenidae,

Table 2. List of freshwater molluscs recorded across the sampling stations of upper Brahmaputra Basin of Assam.

Species	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Angulyagra microchaetophora	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Angulyagra oxytropis	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Balwantia soleniformis	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Brotia costula	-	-	-	+	+	+	+	+	-	+	+	+	+	-	+	+	+
Corbicula assamensis	+	+	+	+	-	+	+	+	-	+	-	-	-	-	-	+	-
Corbicula striatella	+	+	+	+	-	+	+	-	-	-	-	-	-	-	-	+	-
Filopaludina bengalensis	+	+	+	-	+	-	+	+	+	+	+	+	+	-	+	+	+
Filopaludina micron	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gyraulus convexiusculus	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Helicorbis cantori	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Idiopoma dissimilis	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Indonaia andersoniana	-	+	-	-	-	-	-	-	-	-	+	+	-	-	-	+	-
Indonaia caerulea	-	+	-	-	+	-	-	+	-	-	+	+	+	+	+	+	+
Indonaia lima	+	+	-	-	+	-	-	-	-	-	+	-	+	-	+	+	-
Indonaia nuttalliana	-	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Indonaia occata	-	+	-	-	-	-	-	-	-	-	+	-	+	-	+	+	+
Indonaia olivaria	-	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Indonaia pachysoma	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Indonaia shurtleffiana	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Indonaia theobaldi	-	+	-	-	+	-	+	-	-	-	+	+	-	-	-	-	-
Indoplanorbis exustus	+	-	-	-	-	-	-	+	-	-	-	-	+	-	-	-	-
Lamellidens phenchooganjensis	+	+	-	-	+	-	-	-	-	-	+	+	+	-	-	-	+
Lamellidens corrianus	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+
Lamellidens jenkinsianus	-	-	-	-	+	-	-	-	-	-	-	-	+	-	-	-	-
Lamellidens marginalis	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+
Lymnaea ovalior	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
Mekongia crassa	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Melanoides tuberculata	+	-	-	-	-	+	+	+	+	+	+	+	+	+	-	-	-
Mieniplotia scabra	+	-	-	-	-	+	+	-	+	+	+	+	-	+	-	+	-
Musculium indicum	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Parreysia corbis	+	+	+	+	+	-	+	+	+	+	-	-	-	-	+	-	-
Parreysia corrugata	-	-	-	-	+	-	+	+	+	+	+	+	-	+	+	+	+
Parreysia favidens	-	+	+	+	+	+	+	-	-	-	+	+	+	+	+	+	-
Parreysia gowhattensis	-	-	+	+	+	-	+	-	-	-	+	-	-	+		+	-
Parreysia sikkimensis	-	+	+	+	+	-	+	-	-	-	-	-	-	-	-	-	-
Parreysia smaragdites	+	+	+	+	-	-	+	-	-	-	+	-	-	+	-	-	-
Pila olea	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Pisidium sp.	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Radix rufescens	+	+	+	-	-	-	+	-	+	+	-	+	+	-	-	-	+
Scabies crispata	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Sphaerium austeni	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tarebia granifera	+	+	+	-	-	+	+	-	+	-	-	+	-	+	-	+	-
Tarebia lineata	+	+	+	-	-	+	+	+	+	+	-	+	-	-		+	-
Thiara aspera	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
Trapezidens exolescens	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	27	19	15	10	17	11	20	11	10	11	17	15	14	10	11	16	8

+—species present | -—species absent

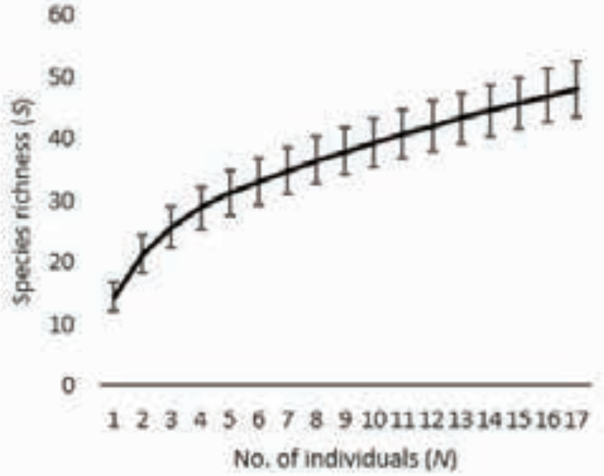

Figure 1. Sample-based rarefaction (interpolation-extrapolation) curves for incidence data from reference samples corresponding to Upper Brahmaputra basin. Error bars represent upper and lower limits of each sampling station at 95% unconditional confidence intervals.

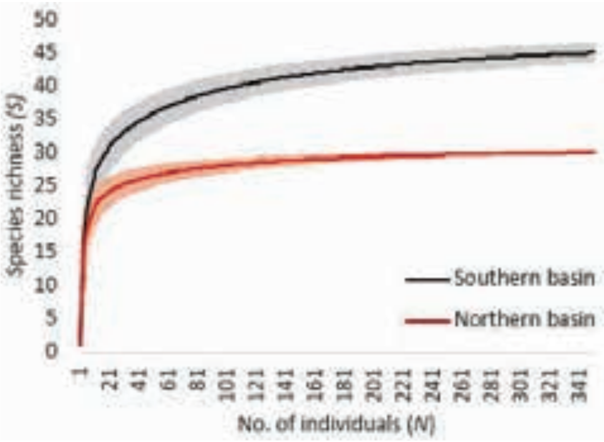

Figure 2. Individual-based rarefaction curves of northern and southern basins of river Brahmaputra. Shaded areas represent 95% unconditional confidence intervals.

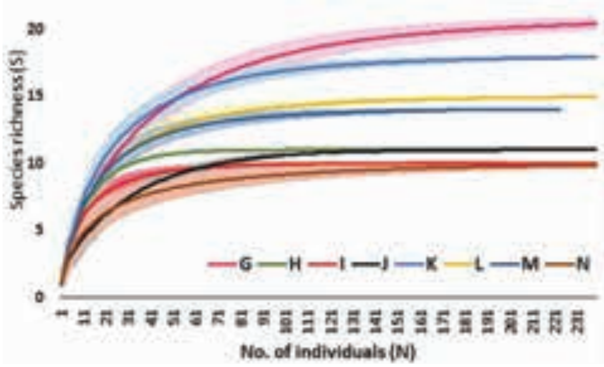

Figure 3(a). Individual-based rarefaction (interpolation-extrapolation) curves for incidence data from reference samples corresponding to sampling stations ('G', 'H', 'I', 'J', 'K', 'L', 'M' and 'N') of northern basin of river Brahmaputra. Shaded areas represent 95% unconditional confidence intervals.

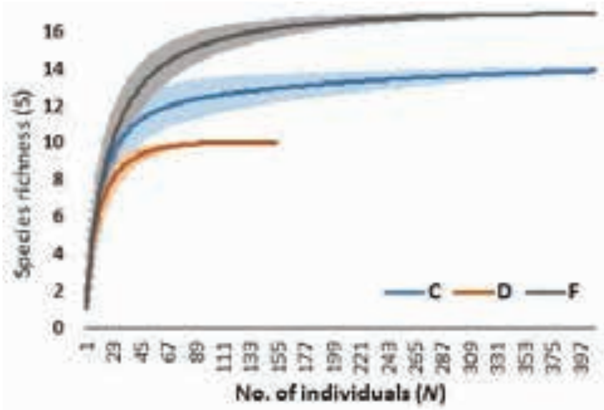

Figure 3(b). Individual-based rarefaction (interpolation-extrapolation) curves for three sampling stations of Burhi-Dihing River on the southern basin of river Brahmaputra showing non-overlapping cluster of curves at 95% unconditional confidence intervals.

for instance, are globally distributed. The scenario at the species level, however, is quite different as observed in the present investigation. We recorded 16 (35.55% of the total recorded species) unique species (Table 3) which were found confined to particular sampling station indicating the role of certain abiotic and biotic factors that might influence the habitat specificity for their survival. There are some ubiquitous species like *L. corrianus*, *L. marginalis*, *Corbicula assamensis*, *C. striatella*, *B. costula*, *F. bengalensis*, *T. lineata*, and some species of the genera *Parreysia* and *Indonaia* found in almost all sampling stations. In contrast, the presence of more than one-third unique species reflects many aspects like changes in habitat conditions across the sampling stations or narrow range of habitat adaptability of species which might have been eliminated from other sampling stations due to the factors related to habitat parameters. A more detailed study, however, will be needed to explain the issue. The species *B. soleniformis* is exclusively recorded from a short stretch of about 300m along the river Burhi-Dihing (Sampling station F). Likewise, *T. exolescens* and *S. crispata* were found only from the sampling station B and E, respectively (Image 2). Similarly, most of the unique gastropod species were exclusively found from the sampling station A (Table 2), which may be indicative of habitat heterogeneity in the region (Figure 3(b)). Further study, however, is needed to explain the causes of an allopatric pattern of distribution of these species. Reports suggest that the abundance of the malacofauna is linked to the cumulative effect of abiotic and biotic components such as alkaline nature of water, chlorine content (Ndifon

Table 3. Status of recorded freshwater molllusc of upper Brahmaputra Basin of Assam.

Unique species	Rare species	New reports
Idiopoma dissimilis	*Filopaludina micron*	*Filopaludina micron*
Filopaludina micron	*Lymnaea ovalior*	*Angulyagra oxytropis*
Angulyagra microchaetophora	*Trapezidens exolescens*	*Lymnaea ovalior*
Pila olea		*Lamellidens phenchooganjensis*
Thiara aspera		*Indonaia shurtleffiana*
Lymnaea ovalior		*Pisidium* sp.
Gyraulus convexiusculus		*Sphaerium austeni*
Helicorbis cantori		
Scabies crispata		
Balwantia soleniformis		
Indonaia pachysoma		
Indonaia shurtleffiana		
Trapezidens exolescens		
Pisidium sp.		
Sphaerium austeni		
Musculium indicum		

Table 4. Richness, abundance, and diversity indices of different sampling stations along the upper Brahmaputra Basin of Assam.

Sampling stations	Richness S	N	Simpson 1- D	Shannon H	Evenness $E^{H/S}$	Equitability E_H
A	27	1131	0.89	2.55	0.47	0.77
B	19	776	0.88	2.36	0.56	0.80
C	15	617	0.89	2.34	0.69	0.86
D	10	153	0.85	2.06	0.71	0.89
E	17	367	0.86	2.28	0.58	0.81
F	11	851	0.75	1.85	0.58	0.77
G	20	799	0.92	2.76	0.75	0.90
H	11	208	0.87	2.25	0.86	0.94
I	10	239	0.86	2.10	0.81	0.91
J	11	304	0.85	2.18	0.80	0.91
K	17	437	0.90	2.52	0.73	0.89
L	15	485	0.87	2.35	0.70	0.87
M	14	223	0.87	2.34	0.74	0.88
N	10	527	0.87	2.13	0.84	0.92
O	11	203	0.86	2.17	0.80	0.90
P	16	266	0.92	2.64	0.88	0.95
Q	8	295	0.83	1.92	0.85	0.92

& Ukoli 1989; Giovanelli et al. 2005), calcium content (Hussein et al. 2011), the presence of macrophytic vegetation, water flow (Appleton 1978), water depth and sediment (Lacoursière et al. 1975; Vincent et al. 1982), recurring flood (Thomaz et al. 2007), and so on.

Large differences in species richness and abundance were observed in different sampling stations on the southern basin and northern basin of river Brahmaputra (Figure 2). For instance, sampling stations C, D, and F showed markedly different values, with non-overlapping cluster of curves at 95% unconditional confidence intervals (Figure 3(b)), though species collected were

Image 2. Some recorded freshwater molluscs of upper Brahmaputra Basin: 1—*P. favidens mercens* (Benson, 1862) | 2—*P. f. assamensis* Preston, 1912 | 3—*P. corbis* Hanley, 1856 | 4—*B. soleniformis* (Benson, 1836) | 5—*P. gowhattensis* (Theobald, 1874) | 6—*I. nuttalliana* (Lea, 1856) | 7—*S. crispata* Gould, 1843 | 8—*L. jenkinsianus* (Benson, 1862) | 9—*T. exolescens* Gould, 1843 | 10—*C. assamensis* Prashad, 1928 | 11—*P. sikkimensis* (Lea, 1859) | 12—*I. caerulea* (Lea, 1831) | 13—*Pisidium* sp. | 14—*G. convexiusculus* (Hutton, 1849) | 15—*A. oxytropis* (Benson, 1836) | 16—*L. ovalior* (Annandale & Prashad, 1921) | 17—*R. rufescens* (J.E. Gray in Sowerby, 1822) | ©—Jyotish Sonowal.

from the same river (Burhi-Dihing, a tributary of river Brahmaputra), but from different localities. For instance, the species abundance and composition of sampling stations O, P, and Q is markedly different from that of sampling station A (Table 2) though these sites are geographically close to each other (Image 1). The most plausible explanation for this unparalleled distribution pattern may be due to differential local driving forces in river floodplain systems (RFS). According to available literature, the floodplain aquatic habitats are isolated from each other and subject to local driving forces during low water periods (Camargo & Esteves 1995; Tockner et al. 1999; Lewis et al. 2000; Thomaz et al. 2007). The influence of local driving forces induces heterogeneity leading to localized physical and chemical characteristics (that are basin-specific) like induced sediment resuspension, which affects water bodies in their morphometry and ecology. These local forces act with different intensities in the floodplain landscape, thus creating habitats with different characteristics (Thomaz et al. 2007). Thus, our present observation has corroborated the findings of previous workers.

The homogeneous distribution of species observed in various sampling stations (G, H, I, J, K, L, M, and N) along the northern basin of the river Brahmaputra (Figure 3(a)) may largely be attributed to the 'homogenization effect of flood'. It may be noted that the northern bank of the river Brahmaputra is largely affected by recurring floods every year and this has influenced not only the distribution but also the overall diversity of aquatic fauna (Furch & Junk 1985; Hamilton & Lewis Jr. 1990; Bozelli 1992; Thomaz et al. 2007). According to some other reports, however, the limnological characteristics, the composition of phytoplankton, zooplankton, fish, and macrophytes of rivers & wetlands are similar in the RFS (Thomaz et al. 2007).

The study on freshwater molluscs of the eastern Himalayan region recorded 32.3% species which falls under Data Deficient (DD) category of the IUCN Red List (Budha et al. 2010). On the other hand, the study conducted in the Indo-Burma region assessed 49.76% and 32.55% of the total recorded species under the category of Least Concern (LC) and DD, respectively (Köhler et al. 2012). Ironically, most of these DD species are known only from descriptions of the 19th or 20th century. It is noteworthy that the majority of the mollusc species recorded during the present study belonged to the LC category (39 species) and four species belonged to the DD category of the IUCN Red List, except *L. ovalior* and *Sphaerium austeni* which are assessed as Vulnerable (VU) and Near Threatened (NT) category of Red List (IUCN 2010). The presence of DD species is mainly due to lack of information on the distribution, population trends and threats (IUCN 2010) from this region.

During the present investigation, we recorded seven freshwater mollusc species which were not reported in earlier literature from this region indicating the scope for a thorough field survey in the region covering a much larger area (Table 3). For example, *L. phenchooganjensis* Preston, 1912 which was previously reported only from Phenchooganj (Bangladesh) and from Mizoram (Ramakrishna & Dey 2007) have no earlier reports from this area. There is certain information for freshwater mollusc species of eastern Himalaya, Indo-Burma as well as for the Western Ghats, however, such information is not enough to describe all the aspects of species in the present scenario. So, it may be suggested to give enough emphasis on the review of many taxonomic issues persisting in the available literature and resolve them in the light of regional context through further work (Budha et al. 2010). The inconsistencies in available data clearly indicate that determination of taxonomic status is still a major problem in establishing a local checklist and implementation of species conservation plans in the region.

CONCLUSION

The present work is based on firsthand information on the diversity, distribution, and status of freshwater mollusc population of this region. The UBB is found to be rich in freshwater mollusc diversity with 45 species from Gastropoda and Bivalvia. Records of a few unique species and new reports highlight the scope and possibility of encountering newer species from the region. More crucial aspects like the effect of environmental and ecological conditions, habitat heterogeneity, and its impact trends, however, need to be addressed with further studies. The presence of unique and rare species indicates the significance of the region as a suitable habitat for the malacofaunal population.

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COMMUNICATION

Diversity of understory flowering plants in the forest patches of Marilog District, Philippines

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Abstract: The forest patches of Marilog District, Davao are the remnants of various anthropogenic activities including logging, conversion of land for agriculture, ecotourism and human settlements. Floristic study was carried out in 2018–2019 from 100 established plots measuring 20 x 20 m, with repeated transect walks and opportunistic sampling along forest trails. One-hundred-and-four species of understory flowering plants were identified from 102 genera and 40 families. Species diversity mean values across study sites using Simpson's (*D*) and Shannon-Wiener index (*H'*) were 0.97 and 3.9, respectively. Species diversity was highest in sites 2 and 4 (*D* = 0.98; *H'* = 4.0 each) and lowest in site 5 (*D* = 0.96; *H'* = 3.7). At family level, the most abundant taxa include Zingiberaceae (26 species) (15%), Orchidaceae (19 species) (11%), Gesneriaceae (14 species) (8%), and Rubiaceae and Arecaceae (13 species each) (7%). Conservation status assessment using International Union for Conservation of Nature (IUCN) revealed 10 threatened species, while listing from the Philippines' administrative order has categorized 13 threatened species. A total of 54 species (ca. 1.14% of the total Philippine endemic vascular flora) of understory flowering plants were Philippine endemics. Findings of this study were used as additional data for the proclamation of Mt. Malambo as Local Conservation Area, which was formalized through a barangay resolution.

Keywords: Epiphytes, herbs, lianas, southern Philippines, threatened species, vines.

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Author contribution: VBA has conceptualized and proposed the research and is the program leader of the research. FMA is the Research Project Leader who helped the Program Leader in the implementation of the research. FMA, NPM, NEL and VBA collected, processed and identified specimens and likewise analyzed the data. FMA and NPM drafted the manuscript while VBA and NEL improved the manuscript.

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INTRODUCTION

The Philippine vascular flora has at least 10,158 species which are distributed to 1,942 genera in 279 families. Of these, 9,038 species are angiosperms (Pelser et al. 2011 onwards), which include understory plants. Understory species contribute to erosion control and nutrient capture (Gilliam 2007). The understory plant communities are considered good ecological indicators of forest health (Tremblay & Larocque 2001; Kerns & Ohmann 2004), biodiversity, habitat potential, umbrella species sustainability, global change impact, and disturbance risk assessment (Suchar & Crookston 2010).

Tropical montane forests are important for the provision of ecosystem services (Martínez et al., 2009). The forest patches of Marilog District, Davao City, Philippines can be classified as tropical lower montane rainforests owing to its elevation and as "Baguio de Mindanao" due to its relatively cool temperature. Twenty-five years ago, Amoroso et al. (1996) reported that Marilog forest has a clay loam soil type with elevations ranging 1,150–1,290 m. It is also home to numerous vascular flora with at least two plant species recently recorded in this country for the first time (see Amoroso et al. 2018a; Acma et al. 2019); however, humans are altering the composition of biological communities through a variety of activities, which endanger some of the plant species in the area. Some of these anthropogenic activities include plant trading and over-collection from the wild, and conversion of the forests into rest houses, restaurants, mountain resorts and farmlands. Hence, these scenarios prompted the authors to conduct an inventory and assessment of understory plants in the forest patches of Marilog District, specifically the understory flowering plants which were not yet documented.

METHODS

Permit Statement

This study was conducted from February 2018 to September 2019 after necessary permits were obtained from respective agencies, such as Barangay resolutions from Brgy. Baganihan, Brgy. Datu Salumay, and Marahan Proper; prior informed consents (PIC's); memorandum of agreement (MOA) between Central Mindanao University and the Matigsalug-Manobo Tribal People Council of Elders Davao, Inc. (MAMATRIPCEDI); and wildlife gratuitous permit from the Department of Environment and Natural Resources (DENR) - Region XI.

Study area and study sites

Floristic inventory was conducted in the five forest patches of Marilog District, which are geopolitically part of Brgy. Baganihan and Brgy. Datu Salumay situated in the northern part and Marahan Proper in the south (Fig. 1). The established sites were found within the forest patches of Marilog District and the sites are: Purok-5, Sitio New Calinan and Sitio Maharlika, Brgy. Baganihan (site 1); Mt. Malambo, Brgy. Datu Salumay (site 2); Lola Mommy's Rainforest, Sitio Epol, Brgy. Baganihan (site 3); Mt. Ulahingan, Sitio Tagumpay, Brgy. Datu Salumay (site 4); and Sitio Matigsalug, Marahan Proper (site 5).

Sites 1–4 are tropical lower montane rainforests, while site 5 is mixed to agro forest ecosystems with elevations ranging 1,000–1,345 m. Among the sites, site 2 had the highest elevation range (1,197–1,345 m). Soil substrates are clay & limestone (sites 1, 3 & 4) and clay & loam (sites 2 & 5) (Table 1). The explored forest patches in these sites were dominated by *Lithocarpus* spp. (Fagaceae), *Canarium* spp. (Burseraceae), *Palaquium philippense* (Perr.) C.B. Rob. (Sapotaceae), *Ficus* spp. (Moraceae), *Syzygium* spp. (Myrtaceae), *Astronia ferruginea* Elmer (Melastomataceae), and *Cinnamomum* spp. (Lauraceae).

Establishment of Sampling Plots and Field Sampling

Establishment of the sampling sites was based on Google Earth maps and in consultation with the barangay officials, council of elders, and tribal leaders. The presence of forests or forest patches was the primary consideration in the selection of the sites to capture the naturally growing plants in the area. The understory flowering plants were inventoried and assessed through repeated transect walks, opportunistic sampling, and documentation from the 100 established 20 x 20 m quadrats in the five sampling sites.

Collection and Processing of Specimens

The collection of plants was done by uprooting the whole plant or by cutting branches preferably with reproductive parts. The specimens were pressed in newspapers, labeled with collection number, collectors, field identification (with local names if available), site of collection, coordinates and elevations. Cardboards were placed in between sheets and tied using a twine. The herbarium specimens were then placed inside the transparent cellophane bags, processed following the wet method, and dried using a mechanical dryer. The dried herbarium specimens were deposited at the

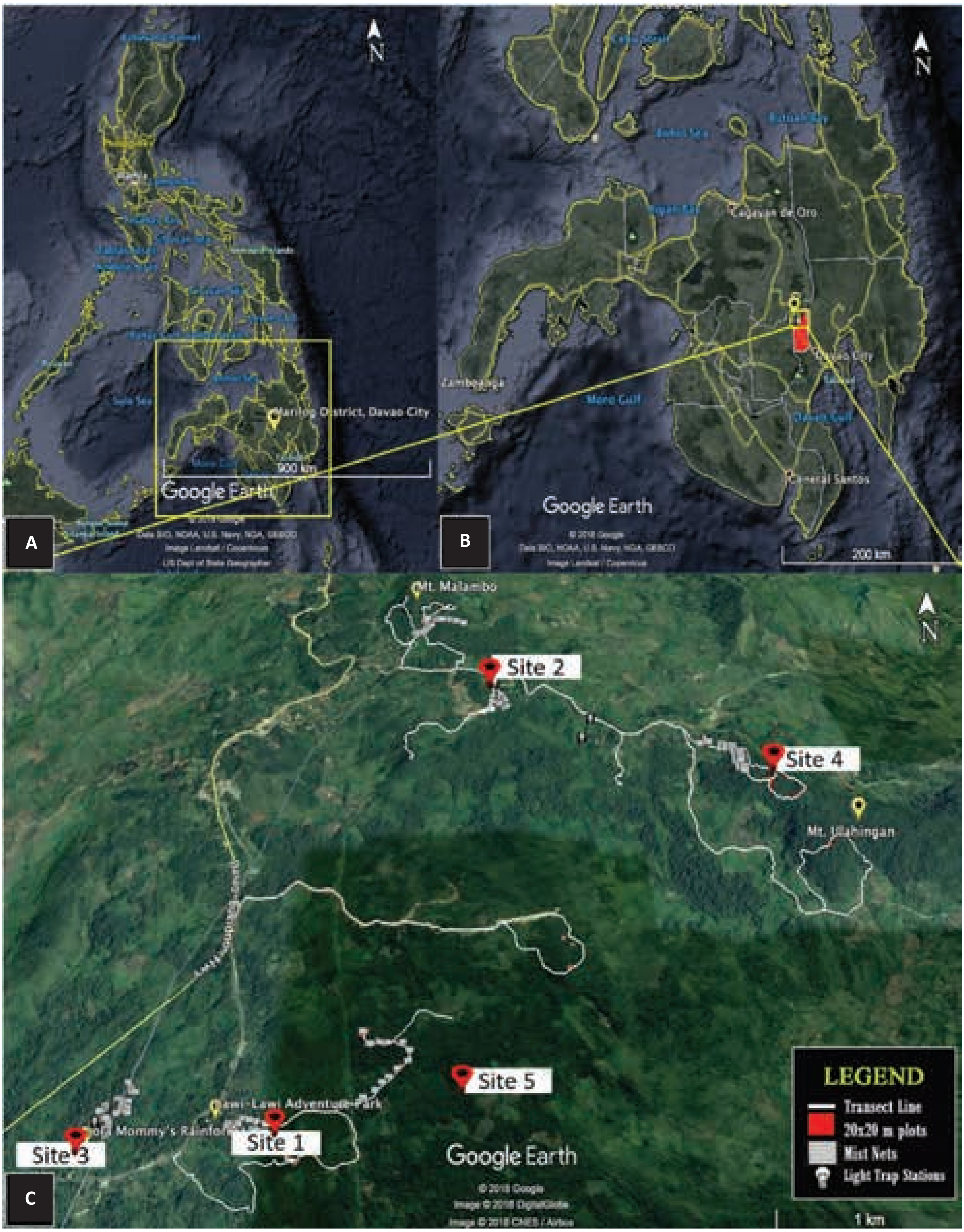

Figure 1. Map of the study site. A—Map of the Philippines | B—Map of the Mindanao Island | C—Marilog forest patches explored by the present study (©2018 Google, image ©2018 CNES/Airbus).

Central Mindanao University Herbarium (CMUH) for accessioning. Herbarium specimens were limited to three individuals of plant or plant parts per species per site as stipulated in the wildlife gratuitous permit.

Identification of Specimens and Assessment

Field guides, online database (e.g., JSTOR, Co's Digital Flora of the Philippines of Pelser et al. 2011 onwards), and literature (Aribal 2013; Amoroso et al. 2018b) were used to identify the voucher specimens.

Conservation status of the species were determined based on Department of Environment and Natural Resources (DENR) Administrative Order (DAO 2017–11), International Union for Conservation of Nomenclature (IUCN) (IUCN 2020) and publications. The ecological status of plants were assessed using Co's Digital Flora of the Philippines (Pelser et al. 2011 onwards) and DAO (2017–11).

Data Treatment and Analysis

The biodiversity index values were calculated using Simpson (1948), Shannon and Wiener (1963), and Magurran (2004). The Shannon-Wiener index (*H'*) was applied as measure of both species abundance and richness to quantify diversity of the understory flowering plants, while Simpson's index of diversity gives the probability that any two individuals drawn at random from infinitely large community belonging to the same species. Calculation for frequency, relative frequency, density, relative density and Importance Value Index (IVI) were derived from (Nguyen et al. 2015). The following formulae were used:

$$\text{Shannon-Wiener index (H')} = -\sum_{i=1}^{s} Pi\ ln\ Pi$$

where pi = ni/N, where ni is the number of individuals in species i and N is the total number of individuals in the community and *ln* is the natural logarithm.

$$\text{Simpson's index} = -\sum_{i=1}^{s} \frac{ni\ (ni-1)}{N(N-1)}$$

where ni is the number of individuals in species i and N is the total number of individuals in the community.

$$\text{Species eveness} = \frac{H'}{H'_{max}} = \frac{\Sigma\ Pi\ ln\ Pi}{ln\ s}$$

where s = number of species; pi = proportion of individuals or abundance of the i^{th} species expressed as a proportion of total cover.

$$\text{Density} = \frac{\text{Number of a species}}{\text{Total area sampled}}$$

$$\text{Frequency} = \frac{\text{Area of plots in which species occurs}}{\text{Total area sampled}}$$

$$\text{Relative density (RD)} = \frac{\text{Density of a species}}{\text{Total density of all species}} \times 100$$

$$\text{Relative frequency (RF)} = \frac{\text{Frequency of a species}}{\text{Total frequency of all species}} \times 100$$

and Species importance value index (IVI) = RD + RF.

RESULTS AND DISCUSSION

Species richness and composition across study sites

The study documented a total of 174 species of understory flowering plants, which belong to 102 genera and 40 families. Site 1 had the highest number of species (109 species), followed by site 4 (92 species), site 2 (89 species), site 3 (88 species), and site 5 (83 species) (Fig. 2). These understory flowering plants include herbs, vines, lianas, epiphytes, palms, and rattans. The relatively high species richness in site 1 can be attributed to the environmental and ecological conditions, ample sunlight and a variety of microhabitats present in the area where the understory flowering plants can favorably grow. The species which dominated in site 1 is *Freycinetia* sp. 2 (Pandanaceae) (10%), *Pandanus* sp. (Pandanaceae) (6%) in site 2 (6%), *Curculigo* sp. (Hypoxidaceae) (9%) in site 3, *Dendrochilum* sp. (Orchidaceae) (4%) in site 4, and *Pandanus* sp. 2 (12%) in site 5 (Table 2).

The total understory plants documented in this study is relatively high compared to the studies conducted at the expansion sites of Mt. Hamiguitan Range Wildlife Sanctuary (MHRWS) by Amoroso et al. (2018b) with 30 species (referred as herbs and vines) and Amoroso et al. (2018c) with 29 species (termed as other plants). Since the study area is a tropical lower montane rainforest, current findings support the report of Kessler et al. (2010) that several factors may affect local montane species richness in the Philippines, such as the size of the area sampled, climate conditions, soil type, and geographic location.

Furthermore, it is noteworthy that the species richness reported herein is relatively high compared to the previous studies (Alava 2001; Agduma et al. 2011; Aribal 2013) which included the trees, shrubs, ferns, and lycophytes in their reports. The current study reported only the flowering understory plants excluding the trees, shrubs, pteridophytes and lycophytes, but has higher number of species compared to Alava (2001) who recorded 161 species in Mt. Mayapay; Agduma et al. (2011) with 101 species in Plantinum Rubber Plantation, Makilala, North Cotabato; and Aribal (2013) with 92 species in Caimpugan Peat Swamp Forest.

At family level, the most abundant taxa include Zingiberaceae (26 species) (15%), Orchidaceae (19 species) (11%), Gesneriaceae (14 species) (8%), and Arecaceae and Rubiaceae (13 species) (7%) (Fig. 2). The significant number of Zingiberaceae in the area, especially in Brgy. Baganihan (sites 1 and 3) can be attributed to the presence of water bodies, environmental, and ecological conditions. The number of Zingiberaceae species collected is the highest number in a certain geographical area in the country as of to date (Acma et al. submitted).

In Mt. Malambo (site 2), two species of understory plants were recently reported as new family record and new species record, viz., *Mitrastemon yamamotoi* Makino (Mitrastemonaceae) (Amoroso et al. 2018) and *Plagiostachys albiflora* Ridl. (Zingiberaceae) (Acma et al. 2019), respectively.

Rasingam & Parthasarathy (2009), recorded a total density of understory plants of 851 ha^{-1} (6,812 individuals) and a species richness of 108 species (104 genera and 50 families) in forests of Little Andaman Island, India. In comparison, the present study recorded a greater species richness (174 species); however, the study of Xiao-Tau et al. (2011) reported the presence of 3068 individuals of understory plants belonging to 309 species in 192 genera and 89 families in the tropical seasonal forests of Xishuangbanna, southern China in a 100m^2 area. Further, Swamy et al. (2000) reported a total of 244 species (183 genera and 76 families) in their study on the vegetation structure and species composition of tropical ecosystems in reserve forests in the Western Ghats of Tamil Nadu, India. It was also noted that greater diversity was recorded in mid-elevation forests.

Species Diversity

Species diversity values (mean) across study sites using Simpson's (*D*) and Shannon-Wiener index (H') are 0.97 and 3.9, respectively. Species diversity is highest in site 2 (*D* = 0.98; *H'* = 4.0) and site 4 (*D* = 0.98; *H'* = 4.0), followed by sites 3 (*D* = 97; *H'* = 3.9), site 1 (*D* = 0.96; *H'* = 3.8) and lowest in site 5 (*D* = 0.96; *H'* = 3.7) (Fig. 3). Shannon-Wiener diversity values in the study sites are greater than typical values (1.5 – 3.5) in most ecological studies (Maguran, 1988; Maguran 2004). The results suggest that site 2 (Mt. Malambo) and site 4 (Mt. Ulahingan) are equally the most diverse in understory flowering plants. The low diversity value in Site 5 (Sitio

Table 1. Elevation, soil substrates and number of established plots in the study sites.

Study site	Elevation (masl)	Soil substrate	No. of plots (20x20 m)
Site 1 (Sitio New Calinan and Maharlika)	1220–1240	clay & limestone	20
Site 2 (Mt. Malambo)	1197–1345	clay & loam	20
Site 3 (Sitio Epol)	1151–1178	clay & limestone	20
Site 4 (Mt. Ulahingan)	1280–1320	clay & limestone	20
Site 5 (Sitio Matigsalug)	1,000–1,200	clay & loam	20

Table 2. Dominant species across the study sites.

Study site	No. of species	No. of individuals	Dominant species	Dominance (%)
Site 1	109	2523	*Freycinetia* sp. 2	10
Site 2	89	903	*Pandanus* sp.	6
Site 3	88	1217	*Curculigo* sp.	9
Site 4	92	1184	*Dendrochilum* sp.	4
Site 5	83	947	*Pandanus* sp. 2	12

Table 3. Top three species of understory flowering plants with high Importance Value Index (IVI).

Study site	Species	IVI
Site 1	*Freycinetia* sp. 2	13.3
	Tetrastigma sp. 1	12.3
	Calamus mollis Blanco	11
Site 2	*Pandanus* sp. 1	11
	Tetrastigma sp. 1	7.4
	Musa textilis Nées	7.1
Site 3	*Curculigo sp.*	13
	Sarcandra glabra (Thunb.) Nakai	9
	Mackinlaya celebica (Harms) Philipson	8
Site 4	*Rubus* sp.	7
	Plagiostachys escritorii Elmer	7
	Pandanus sp. 1	6.2
Site 5	*Pandanus* sp. 2	16.4
	Calamus mollis Blanco	14
	Calamus filispadix Becc.	11

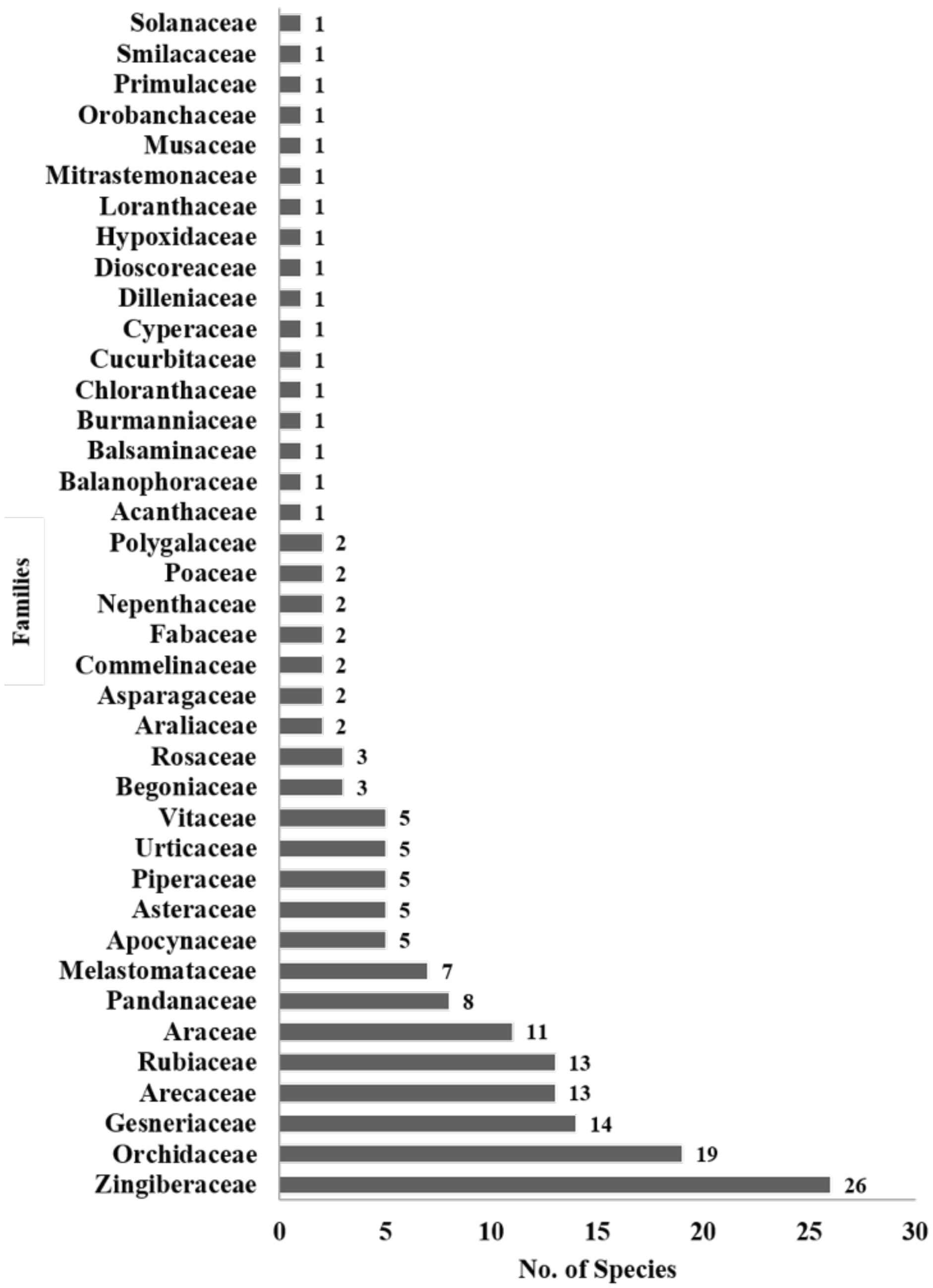

Figure 2. Species abundance of flowering understory plants in the study area.

Matigsalug) is attributed to its secondary grown and fragmented forest with dry substrates making the forest not suitable for plants to survive.

Species evenness is highest in site 4 (0.89), followed by site 2 (0.88), site 3 (0.86), site 5 (0.83) and was lowest in site 1 (0.80) (Fig. 3). The species evenness implies how equal the community is numerically.

Species Importance Value Index (IVI)

The inventory of flowering understory plants revealed that *Freycinetia* sp. 2 (IVI =13.3) obtained the highest importance value index (IVI) in site 1, *Pandanus* sp. (IVI = 11) in site 2, *Curculigo* sp. (IVI = 13) in site 3, *Rubus* sp. (IVI = 7) in site 4, and *Pandanus* sp. 2 (IVI = 16.4) in site 5 (Table 3).

Marilog District is home to five species of *Tetrastigma*, with *Tetrastigma* sp. 1 as the most observed in all sampling sites; however, identification up to the species level was not possible, since flowering and fruiting materials of the species were not available at the time

Table 4. Conservation status of understory flowering plants in Marilog Forest Reserve.

Family	Taxon	Conservation status		
		IUCN (2020)	DENR (2017)	Endemicity Pelser et al. (2011 onwards)
Apocynaceae	*Hoya apoensis* Kloppenb. & Siar.			PE
Araceae	*Alocasia heterophylla* (C.Presl) Merr.			PE
	Alocasia sanderiana W.Bull	CR	EN	PE
Araliaceae	*Schefflera simplicifolia* Merr.			PE
Arecaceae	*Calamus bicolor* Becc.			PE
	C. cumingianus Becc.			PE
	C. filispadix Becc.			PE
	C. microcarpus Becc.			PE
	C. mollis Blanco		OTS	PE
	C. spinifolius C.Mart.			PE
	Heterospathe philippinensis (Becc.) Becc.			PE
	Pinanga copelandii Becc.			PE
	P. philippinensis Becc.			PE
	P. speciosa Becc.			PE
	P. woodiana Becc.			PE
Begoniaceae	*Begonia mindanaensis* Warb.			PE
	B. pseudolateralis Warb.	LC		
Fabaceae	*Strongylodon pulcher* C.B.Rob.			PE
Gesneriaceae	*Aeschynanthus asclepioides* (Elmer) B.L.Burtt & P.Woods			PE
	A. cardinalis (Copel. ex Merr.) Schltr.			PE
	Agalmyla chorisepala (C.B.Clarke) Hilliard & Burtt			PE
	A. clarkei (Elmer) B.L.Burtt			PE
	A. persimilis Hilliard & B.L.Burtt		VU	PE
	Cyrtandra tagaleurium Kraenzl.			PE
	Monophyllaea merilliana Kraenzl.		OTS	
Melastomataceae	*Medinilla clementis* Merr.		OTS	PE
	M. copelandii Merr.			PE
Mitrastemonaceae	*Mitrastemon yamamotoi* Makino		CR	
Nepenthaceae	*Nepenthes mindanaoensis* Sh.Kurata	LC	VU	PE
	N. truncata Macfarl.	EN	EN	PE
Orchidaceae	*Ceratostylis retisquama* Rchb.f.			PE
	Coelogyne candoonensis Ames			PE
	C. cloroptera Rchb.f.			PE
	Phaius philippinensis N.E.Br.			PE
	Trichotosia odorifera (Leav.) Kraenzl			PE
Pandanaceae	*Freycinetia jagorii* Warb.			PE
	F. negrosensis Merr.			PE
	F. sphaerocephala Gaudich.			PE
Piperaceae	*Piper ensifolium* Quisumb.			PE
Rubiaceae	*Oldenlandia apoensis* Elmer			PE
	Psychotria cuernosensis Elmer			PE

Family	Taxon	Conservation status		
		IUCN (2020)	DENR (2017)	Endemicity Pelser et al. (2011 onwards)
Urticaceae	*Procris brunnea* Merr.			PE
	P. urdanetensis Elmer			PE
Zingiberaceae	*Adelmeria alpina* Elmer	LC		PE
	Alpinia haenkei C.Presl	LC		PE
	A. rufa C.Presl			PE
	Amomum dealbatum Roxb.	DD		
	Etlingera elatior (Jack.) R.M.Sm.	DD		
	E. fimbriobracteata (K.Schum.) R.M.Sm.	DD		
	E. philippinensis (Ridl.) R.M.Sm.			PE
	E. pubimarginata (Elmer) A.D.Poulsen			PE
	Globba campsophylla K.Schum.	LC		PE
	Hedychium philippinense K.Schum.		EN	PE
	Hornstedtia conoidea Ridl.			PE
	H. lophophora Ridl.			PE
	Meistera muricarpa (Elmer) Škorničk. & M.F.Newman			PE
	Plagiostachys albiflora Ridl.	LC		
	P. escritorii Elmer			PE
	Wurfbainia hedyosma (I.M.Turner) Škorničk. & A.D.Poulsen			PE
	W. mindanaensis (Elmer) Škorničk. & A.D.Poulsen			PE
	Zingiber banahaoense Mood & Theilade			PE

Legends: CR—Critically Endangered | EN—Endangered | VU—Vulnerable | OTS—Other Threatened Species | LC—Least Concern | DD—Data Deficient | PE—Philippine endemic

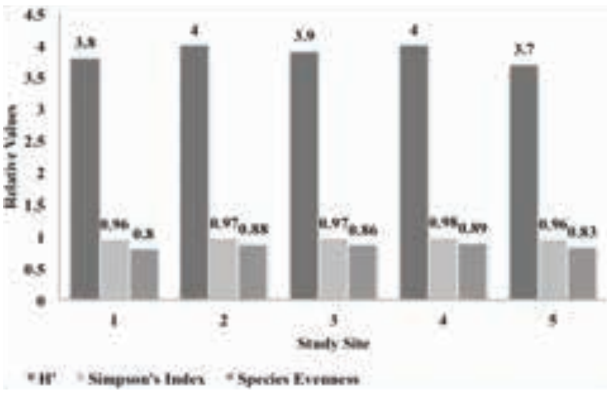

Figure 3. Species diversity and evenness across study sites.

of sampling. *Calamus mollis* Blanco, *C. filispadix* Becc., *Pandanus* sp. 1, and *Pandanus* sp. 2 were the most common rattans and pandans in the area. This implies that these species play important roles in the ecosystem and elimination of these species would result to changes in plant community structure.

Conservation Status and Endemism

Conservation status assessment revealed one Critically Endangered (CR), one Endangered (EN), seven Least Concern (LC), and two Data Deficient (DD) species following the IUCN (2020). The DAO (2017–11) listed three EN species, two Vulnerable (VU), and eight other threatened species (OTS). *Mitrastemon yamamotoi* Makino proposed as CR by Amoroso et al. (2018) was only observed in site 2 (Table 4; Image 1). Among these species, *Monophyllaea merilliana* Kraenzl. (OTS) was observed in sites 1–4 in limestone karst habitat. On the other hand, a total of 54 species of understory flowering plants were Philippine endemics. This number constitutes ca. 1.14% of the total Philippine endemic vascular flora.

Threats observed in the sampling sites

Ongoing habitat degradation through land

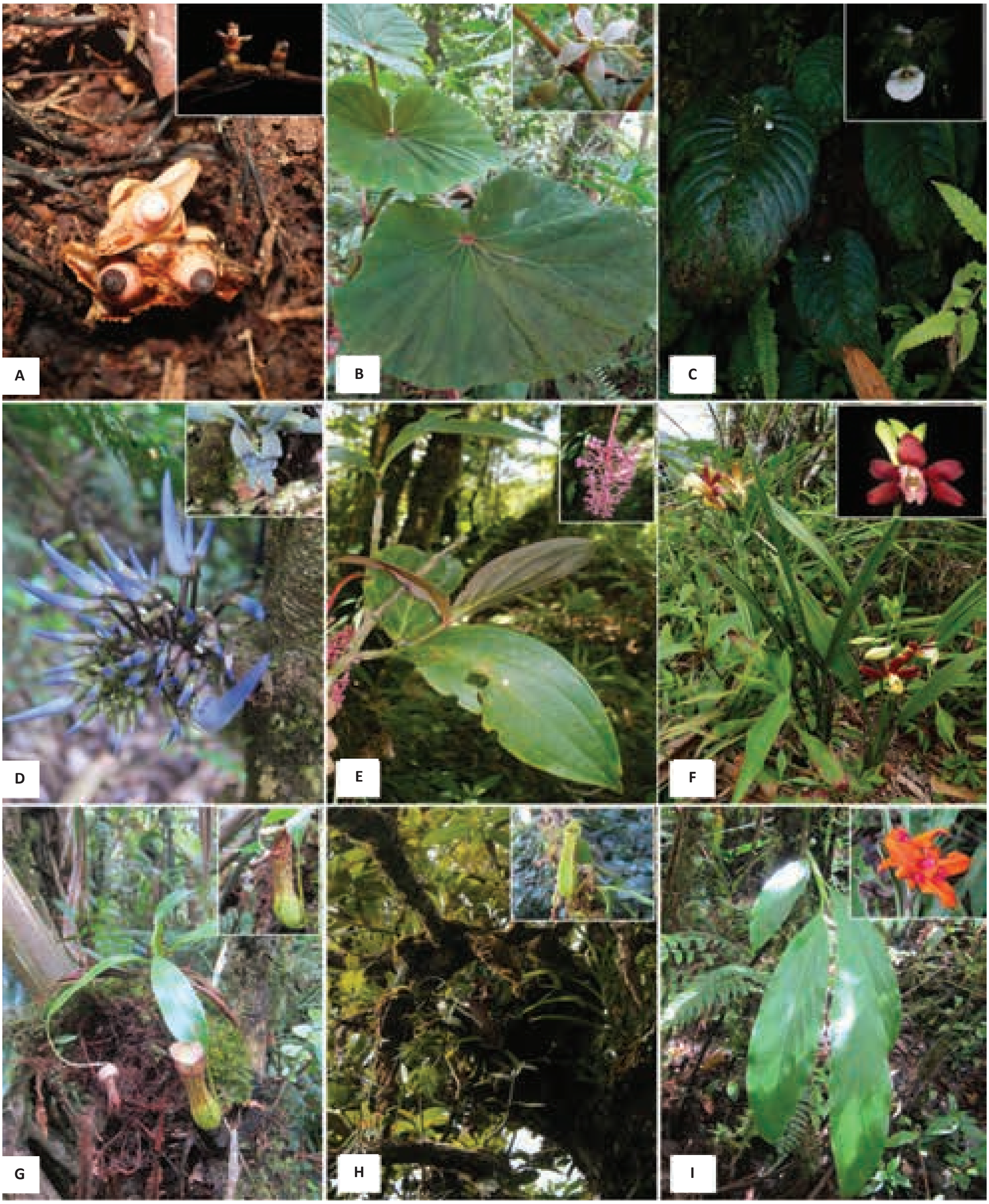

Image 1. Some threatened and endemic understory flowering plants in Marilog Forest Reserve. A—*Mitrastemon yamamotoi* Makino | B—*Begonia pseudolateralis* Warb. | C—*Monophyllaea merilliana* Kraenzl. | D—*Strongylodon caeruleus* Merr. | E—*Medinilla clementis* Merr. | F—*Phaius philippinensis* N.E.Br. | G—*Nepenthes mindanaoensis* Sh. Kurata | H—*Nepenthes truncata* Macfarl. | I—*Hedychium philippinense* K. Schum. © Authors.

conversion for agriculture and human settlements, and rampant small-scale harvesting of wild plants from the forests, are documented biodiversity threats in Marilog District. If these activities are not mitigated, the number of species will likely decline and economically-important species will be depleted in the areas.

CONCLUSIONS AND RECOMMENDATIONS

This study concludes that the Marilog District forests harbor a rich understory plant community (174 species) which is distributed in 102 genera and 40 families. The sites having high elevation and with intact forest had the highest diversity: Site 2, Mt . Malambo and site 4, Mt. Ulahingan (D = 0.98; H' = 4.0). Each site is unique as evidenced by the species which obtained the highest importance value index of the site. *Freycinetia* sp. 2 (IVI = 13.3) for site 1, *Pandanus* sp. (IVI = 11) for site 2, *Curculigo* sp. (IVI = 13) for site 3, *Rubus* sp. (IVI = 7) for site 4, and *Pandanus* sp. 2 (IVI = 16.4) for site 5. Conservation efforts should be done since the 13 threatened species recorded and 54 species overall are Philippine endemics, which represent ca*.* 1.14% of the total Philippine endemic vascular flora.

It is therefore imperative that the results gathered from this study be cascaded to the local government units (LGU's) and stakeholders to create more awareness of the richness of the understory flora in their locality and formulate additional policies and strategies for the protection and conservation of these important biological resources. Ex situ and in situ conservation are also recommended to properly protect and conserve the species and their habitats.

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OPEN ACCESS

COMMUNICATION

Legumes of Kerala, India: a checklist

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Abstract: A checklist of the legumes of Kerala State is presented. This exhaustive checklist is an outcome of extensive field surveys, collection, identification and documentation of family Leguminosae carried out across Kerala State during the period 2006–2019. A total of 448 taxa were recorded under five subfamilies and 115 genera. The majority of the legumes are herbs and shrubs, the rest being trees and woody climbers. About 81 taxa are endemic to India, especially confined to the Western Ghats biodiversity hotspot, out of which 17 are endemic to Kerala. The state is home to two Critically Endangered and six Endangered legumes, facing severe threat of extinction. *Crotalaria* is the dominant legume genus in the state with 62 taxa followed by *Desmodium* and *Indigofera*. About 57 genera are represented by single species each. Legumes are treated according to the latest phylogenetic classification of the Legume Phylogeny Working Group (LPWG). Updated nomenclature, habit, native countries, voucher specimens, and images of endemic and lesser known legumes found in the state are provided. *Crotalaria multiflora* var. *kurisumalayana* (Sibichen & Nampy) Krishnaraj & N. Mohanan is reduced as a synonym to *C. multiflora* (Arn.) Benth.

Keywords: Checklist, *Crotalaria multiflora*, endemic, Kerala, Leguminosae, LPWG, Western Ghats.

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Author contribution: SVP designed and conceptualized the study. APB and SVP conducted field surveys, collection, identification and documentation of legumes from all districts of Kerala state. APB prepared the first draft of the manuscript and SVP contributed in further editions.

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INTRODUCTION

Leguminosae with 770 genera and over 19,500 species (Lewis et al. 2013), are the third largest family of flowering plants after Orchidaceae and Asteraceae. Legumes are a significant component of nearly all terrestrial biomes, distributed throughout the world in almost all habitats and are second only to the Poaceae in their importance to human beings. The family is morphologically, physiologically, and ecologically exceptionally diverse, representing one of the most spectacular examples of evolutionary diversification in plants (LPWG 2017). Legumes are grown agriculturally, primarily for their seeds called pulses, contributing 33% of the dietary protein nitrogen needs of humans (Vance et al. 2000). Many legumes are able to do nitrogen fixation, through symbiotic association with *Rhizobium* bacteria within root nodules and thereby play an important ecological role in the terrestrial nitrogen cycle. Considering the importance of legumes, the 68th session of the United Nations General Assembly declared the year 2016 as the International Year of Pulses for their popularisation internationally.

Leguminosae in India are represented by 1,297 taxa under 179 genera, of which about 23% are strictly confined to India (Sanjappa 1992). Kerala, one of the species-rich states in the country, is exceptional because of its richness in biodiversity and endemism. According to Nayar et al. (2006), Kerala represents about 4,694 species of flowering plants under 1,418 genera and 188 families. The state constitutes only 1.18% of the geographical area of India but it accommodates about 27.57% of the flowering plants occurring in the country (Nayar et al. 2008). Sasidharan (2004) and Nayar et al. (2006) published checklists of flowering plants of Kerala, primarily based on literature. According to Sasidharan (2004), there are 381 legume species in Kerala under 93 genera out of which 82 taxa are endemic to India. Nayar et al. (2006) enumerated 389 species of legumes in Kerala under 96 genera of which 85 taxa are restricted to India. The latest treatment of Leguminosae in Kerala is that of Murthy & Nair (2016), in which they enumerated 382 species of legumes under three distinct families, viz., Caesalpiniaceae, Fabaceae, and Mimosaceae with 17, 60, & 18 genera and with 56, 281, & 45 species, respectively.

Though Leguminosae are one of the most dominant families in the state and also highly important in the economic point of view, an exclusive legume flora of the state is still wanting. To fill this lacuna, the authors have conducted extensive field surveys, collection, identification and documentation of all the legumes of the state during the last 14 years to produce a comprehensive account on the legume flora of Kerala. Regarding this, recently three new leguminous taxa and seven new records have been reported from Kerala (Predeep et al. 2008, 2009; Predeep & Balan 2010; Balan & Predeep 2016; Balan et al. 2014, 2017). The study was initially funded by the Kerala State Council for Science, Technology and Environment, Dept. of Science & Technology, Govt. of Kerala. The present checklist is the first step before the release of a legume flora of Kerala and the list is prepared based on the authors' own collections, and specimens deposited in various Indian herbaria and relevant literature.

Systematic Treatment

Leguminosae (nom. alt. Fabaceae) received its scientific name from earlier taxonomists due to its characteristic fruit (legume). Since this name was long in usage even before the code was formulated, this name was conserved by the International Code of Nomenclature (ICN). Another name Fabaceae based on the type genus *Faba* Mill. was proposed as an alternate name according to the provisions of ICN and both names are acceptable following Articles 18.5 and 18.6 of the Shenzhen Code (Turland et al. 2018). The name Leguminosae or Fabaceae encompasses all the known leguminous plants under it. Monocarpellary superior ovary with marginal placentation and leguminous fruit are the key characters of Leguminosae.

Earlier (and worth mentioning) treatment of the family Leguminosae are that of de Candolle (1825), who subdivided the family into four suborders (= subfamilies), namely, Papilionaceae, Swartzieae (now included in Papilionoideae), Mimoseae, and Caesalpineae. This system was elaborated by Bentham (1865), who recognised three major groups within Leguminosae and whose classification formed the basis for all subsequent classifications of the family for the next 150 years. Taubert (1894), Engler (1964), Thorne (1976, 2000), Polhill & Raven (1981), and many others also treated Leguminosae as one family with three subfamilies. Some other researchers treated Mimosaceae, Caesalpiniaceae, and Papilionaceae as separate families (Takhtajan 1959, 1966, 1973, 1980; Hutchinson 1964, 1969, 1973; Cronquist 1968; Dahlgren 1983; Mabberley 1997). Systematic considerations based on molecular evidences also recognize Leguminosae as a monophyletic family, with three subfamilies (Doyle et al. 2000; Lewis & Schrire 2003; Wojciechowski 2003; Lewis et al. 2005; Shipunov 2009; APG IV 2016; Judd et al. 2016). Recent molecular-based phylogenetic studies (Bruneau et al. 2008; Bello et al. 2009, 2012; Sinou et al. 2009; Cardoso et al. 2012, 2013; Gagnon et al. 2013, 2016; Koenen et al. 2013; LPWG 2013a,b, 2017; Dugas et al. 2015), however, made sweeping changes in the systematics of Leguminosae. The Legume Phylogeny Working Group-LPWG (2017) proposed a new subfamilial classification of Leguminosae, which is perhaps the most comprehensively sampled phylogenetic analysis of legumes to date. All adequately sampled phylogenetic analyses of the family indicate that the monophyletic Mimosoideae and Papilionoideae are nested within a paraphyletic assemblage of caesalpinioid lineages. LPWG (2017) recognized six subfamilies in Leguminosae: a recircumscribed Caesalpinioideae DC. (148 genera & ca. 4400 species), Cercidoideae LPWG (12 genera & ca. 335 species), Detarioideae Burmeist. (84 genera & ca. 760 species), Dialioideae LPWG (17 genera & ca. 85 species), Duparquetioideae LPWG (one genus & one species), and Papilionoideae DC. (503 genera & ca. 14,000 species). The traditionally recognised subfamily Mimosoideae is a distinct clade nested within the recircumscribed Caesalpinioideae. All the subfamilies, except the African subfamily Duparquetioideae, are well represented in Kerala.

MATERIALS AND METHODS

This checklist is the result of extensive field studies and repeated seasonal collections of plant specimens from Kerala during the period 2006–2019. The plant samples belonging to Leguminosae were collected from all areas of Kerala including coastal, midland, and highlands, all types of forest and non-forest areas in all seasons of the year. Herbarium sheets were prepared following the method suggested by Bridson & Forman (1998) and are housed in the herbarium in the Malabar Botanical Garden & Institute for Plant Sciences, Kozhikode, Kerala (MBGH). Identification was done with the help of pertinent literature including national and local floras (Hooker 1876, 1878; Bourdillon 1908; Rao 1914; Gamble 1918; Manilal & Sivarajan 1982; Manilal 1988; Ramachandran & Nair 1988; Vajravelu 1990; Mohanan & Henry 1994; Sasidharan & Sivarajan 1996; Sivarajan & Mathew 1997; Mohanan & Sivadasan 2002; Kumar et al. 2005; Sunil & Sivadasan 2009; Sasidharan 2011) and revisionary studies (Sanjappa 1986, 1995; Thothathri 1982, 1987; Babu et al. 1987; Nair 1989; Chakrabarty & Gangopadhyay 1996a,b; Singh 2001; Bandyopadhyay et al. 2006; Ansari 2008) and consultation of authentic specimens housed at CAL, CALI, KFRI, MH, TBGT & University College Herbarium, Thiruvananthapuram. The species list is based primarily on author's collections and specimens deposited in various Indian herbaria listed in Tables 1, 2, 3, with the exception of 39 reports from the literature. The checklist is arranged according to the latest phylogenetic system of classification of legumes proposed by LPWG (2017). Each species is arranged alphabetically under respective subfamilies. Habit, native countries, selected voucher specimens and litereature references are provided for each species. Plant names are updated following International Plant Names Index (IPNI—www.ipni.org), The Plant List (www.theplantlist.org) and Tropicos (www.tropicos.org). The native range of each species is given on the basis of the International Legume Database and Information Service (ILDIS—www.ildis.org) and Plants of the World Online (www.plantsoftheworldonline.org).

RESULTS

Leguminosae (Fabaceae sensu lato) in Kerala are represented by 448 taxa including 423 species, four subspecies and 21 varieties under 128 genera in five subfamilies (Tables 1, 2, 3; Images 1–64). Out of 448 taxa, 87 are introduced plants, either naturalized or under cultivation for various purposes. Among the 361 indigenous legumes, Papilionoideae dominate with 269 species, one subspecies and 16 varieties under 64 genera. Caesalpinioideae is represented by 53 taxa in 22 genera followed by Detarioideae (13/5), Cercidoideae (8/3), and Dialioideae (1/1). *Crotalaria* is the dominant genus with 59 taxa, next comes *Indigofera* (26 taxa), *Dalbergia* (18 taxa), *Tephrosia* (13), and *Vigna* (13). About 47 genera are represented by a single species only. Top 10 dominant genera are given in Fig. 1.

Life form analysis (Fig. 2) revealed that, out of the 361 indigenous legumes identified from the state, the majority are herbs (124) and shrubs (95) followed by climbers (78) and trees (64).

The district-wise analysis (Fig. 3) shows that Idukki is the legume-rich district with 267 taxa followed by Palakkad (236), Kollam (178), Wayanad (174), and Thiruvananthapuram (169). The lowest number of legumes was found in Eranakulam District (69 taxa).

Endemic and threatened legumes

Among the 361 indigenous legumes found in Kerala, 81 are endemic to India and 33 are confined to the Western Ghats-Sri Lanka biodiversity hotspot. Out of

81 Indian endemic species legumes, 32 are restricted to the Western Ghats of Kerala, Karnataka, and Tamil Nadu states. About 17 taxa, namely *Crotalaria assamica* var. *keralensis*, *Dalbergia beddomei*, *D. travancorica*, *Dialium travancoricum*, *Humboldtia bourdillonii*, *H. brunonis* var. *raktapushpa*, *H. sanjappae*, *H. unijuga* var. *trijuga*, *Kunstleria keralensis*, *Millettia pulchra* var. *munnarensis*, *Phanera murthyi*, *Sanjappa cynometroides*, *Smithia venkobarowii* var. *venkobarowii*, *S. venkobarowii* var. *glabra*, *Tephrosia travancorica*, *T. wynaadensis*, and *Vigna sathishiana* are endemic to Kerala. The distribution range of 81 Indian endemic legumes found in Kerala is analysed and represented in Fig. 4. Among the threatened legumes found in Kerala, *Dialium travancoricum* and *H. unijuga* var. *trijuga* are Critically Endangered, *Cynometra travancorica*, *Humboldtia bourdillonii*, *H. unijuga* var. *unijuga*, *H. vahliana*, *Kingiodendron pinnatum*, and *Sophora wightii* are Endangered and *Saraca asoca* is Vulnerable (IUCN 2020). *Cynometra beddomei*, which is treated as Extinct in the Red List, has been re-collected recently (Sasidharan 1998), and hence it can be categorised as Critically Endangered. During our field studies *Dialium travancoricum* is found to be the most threatened tree species in Kerala and is on the brink of extinction due to poor regeneration. This species is survived with a few numbers of very old trees in Ponmudi forest ranges of Thiruvananthapuram District. Among Endangered tree legumes, *Kingiodendron pinnatum* is facing severe threats due to over-exploitation and habitat destruction. The oleo-gum-resin of this plant species is used in gonorrhoea, catarrhal conditions of genito-urinary and respiratory tract (Kumar et al. 2011), and also in the paint industry. The species has been severely exploited for its wood oil in the past and the stem bark is collected as a substitute for *Saraca asoca*. *Dalbergia travancorica* is another highly threatened legume restricted to a few lowland urban sacred groves in Thiruvananthapuram (Jagadeesan et al. 2015).

Economically important legumes

Arachis hypogea (Groundnut), *Cajanus cajan* (Red Gram), *Canavalia gladiata* (Sword Bean), *Cicer arietinum* (Bengal Gram), *Cyamopsis tetragonoloba* (Cluster Bean), *Lablab purpureus* (Lablab Bean), *Phaseolus coccineus* (Scarlet Runner), *P. lunatus* (Lima Bean), *P. vulgaris* (French Bean), *Psophocarpus tetragonolobus* (Winged Bean), *Sesbania sesban* (Swamp Pea), *Vigna mungo* (Black Gram), *Vigna radiata* (Green Gram), *V. unguiculata* ssp. *cylindrica* (Catjang), and *V. unguiculata* ssp. *unguiculata* (Cowpea) are commonly cultivated in the state for pulses/vegetables. *Pisum sativum* (Garden Pea) is cultivated in high ranges in Idukki District. *Dalbergia latifolia* (Malabar Rosewood), *D. lanceolaria*, *D. sissoo*, and *Pterocarpus marsupium* (Kino), and *P. santalinus* (Red Sandalwood) are known for their quality timber.

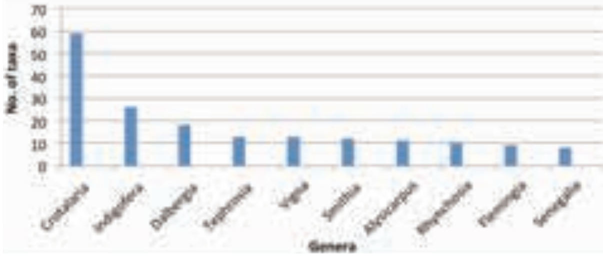

Figure 1. Analysis of dominant genera of Leguminosae in Kerala.

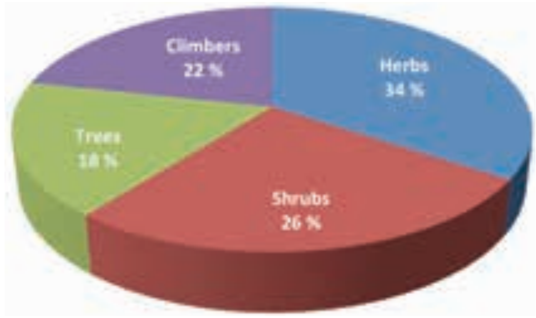

Figure 2. Life form analysis of Leguminosae in Kerala State.

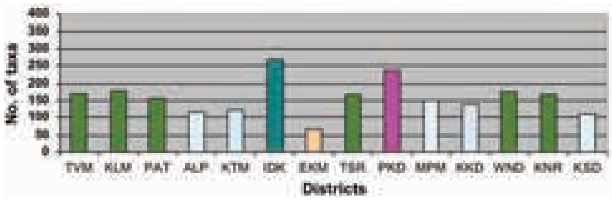

Figure 3. District wise distribution of Legumes in Kerala State: TVM—Thiruvananthapuram | KLM—Kollam | PAT—Pathanamthitta | ALP—Alappuzha | KTM—Kottayam | IDK—Idukki | EKM—Eranakulam | TSR—Thrissur | PKD—Palakkad | MPM—Malapputram | KKD—Kozhikode | WND—Wayanad | KNR—Kannur | KSD—Kasargod.

Figure 4. Distribution range wise break up of Indian and Indo-Sri Lankan endemic legumes found in Kerala State

Table 1. List of indigenous legumes documented from Kerala.

	Name of taxa	Habit	Native to	Vouchers/ Reference
	LEGUMINOSAE			
	Subfam. 1. CERCIDOIDEAE			
	1. *Bauhinia* L.			
1	*Bauhinia acuminata* L.	S	Indo-Malesia	APB 20690 (MBGH)
2	*Bauhinia purpurea* L.	T	Indian subcontinent	KKN 3550 (KFRI); APB 20088 (MBGH)
3	*Bauhinia racemosa* Lam.	T	India, China & Indo-China	NS 716 (KFRI); SVP & APB 20238 (MBGH)
4	*Bauhinia variegata* L.	T	Indian subcontinent to China	MCL 2233 (RHK); SVP 10039 (MBGH)
	2. *Phanera* Lour.			
5	*Phanera murthyi* Vadhyar & J.H.F.Benj.	CS	India (KL; E)	Vide Vadhyar & Benjamin (2019)
6	*Phanera phoenicea* (Wight & Arn.) Benth. *Bauhinia phoenicea* Wight & Arn.	CS	India (MH, KA, TN, KL; E)	NS 5219 (KFRI); SVP & APB 20087 (MBGH)
7	*Phanera scandens* (L.) Lour. ex Raf. *Bauhinia scandens* L. *anguina* (Roxb.) H.Ohashi	CS	Indo-Malesia	CAB 11859 (MH); PM 34585 (CALI); NS 5137 (KFRI)
	3. *Piliostigma* Hochst.			
8	*Piliostigma malabaricum* (Roxb.) Benth. *Bauhinia malabarica* Roxb.	T	Tropical Asia to northern Australia	SVP & APB 20084 & 20654 (MBGH)
	Subfam. 2. DETARIOIDEAE			
	4. *Cynometra* L.			
9	*Cynometra beddomei* Prain	T	India (KA, KL; E)	TFB 613 (TBGT); NS 5808 (CAL); APB 20607 (MBGH)
10	*Cynometra travancorica* Bedd.	T	India (KA, TN, KL; E)	CAB 5668 (MH); EV 62880 (CAL); KAA 3514 (CMPR)
	5. *Hardwickia* Roxb.			
11	*Hardwickia binata* Roxb.	T	India (DL to KL; E)	KAA 4058 (CMPR); SVP & APB 20255 (MBGH)
	6. *Humboldtia* Vahl			
12	*Humboldtia bourdillonii* Prain	T	India (KL; E)	SVP & APB 20531; APB 15548 (MBGH)
13	*Humboldtia brunonis* Wall. var. *brunonis*	T	India (KA, TN, KL; E)	VSR 59288 (MH); APB 20605 (MBGH)
14	*Humboldtia brunonis* Wall. var. *raktapushpa* Udayan, Tushar & S.George	T	India (KL; E)	APB 20606 & 20821 (MBGH)
15	*Humboldtia decurrens* Bedd. ex Oliver	T	India (TN, KL; E)	AGP 78079 (MH); SVP 20541 (MBGH)
16	*Humboldtia sanjappae* Sasidh. & Sujanapal	T	India (KL; E)	SVP & APB 20826 (MBGH)
17	*Humboldtia unijuga* Bedd. var. *trijuga* J.Joseph & V.Chandras.	T	India (KL; E)	MM 11273 & 11154 (TBGT)
18	*Humboldtia unijuga* Bedd. var. *unijuga*	T	India (TN, KL; E)	NM 4244; RG 94676 (MH).
19	*Humboldtia vahliana* Wight	T	India (TN, KL; E)	MM 54680 (CAL); APB 20520 (MBGH)
	7. *Kingiodendron* Harms			
20	*Kingiodendron pinnatum* (Roxb. ex DC.) Harms	T	India (TN, KL; E)	JA 16227 (CALI); SVP 20914 (MBGH)
	8. *Saraca* L.			
21	*Saraca asoca* (Roxb.) W.J.de Wilde	T	India, Myanmar & Sri Lanka	SVP 68482 (MBGH)
	Subfam. 3. DIALIOIDEAE			
	9. *Dialium* L.			
22	*Dialium travancoricum* Bourd.	T	India (KL; E)	TFB 1005 (CAL)
	Subfam. 4. CAESALPINIOIDEAE			
	10. *Acrocarpus* Wight & Arn.			
23	*Acrocarpus fraxinifolius* Wight & Arn.	T	Indian subcontinent to China	VSR 64065 (MH); PM 33638 (CALI)
	11. *Adenanthera* L.			
24	*Adenanthera pavonina* L.	T	Tropical Asia & Madagascar	SCN 2586 (CALI); SVP 10078 (MBGH)

	Name of taxa	Habit	Native to	Vouchers/ Reference
	12. *Albizia* Durazz.			
25	*Albizia amara* (Roxb.) Boivin	T	India, Sri Lanka & eastern Africa	SVP & APB 20253, 20254 & 20263 (MBGH)
26	*Albizia chinensis* (Osbeck) Merr.	T	Tropical Asia & China	SVP 20019 & 10093 (MBGH)
27	*Albizia lathamii* Hole	T	India (MP, KA, TN, KL; E)	SVP & APB 20263 & 20920 (MBGH)
28	*Albizia lebbeck* (L.) Benth.	T	Indian subcontinent to Myanmar	NS 1139 (KFRI); SVP 20293 (MBGH)
29	*Albizia odoratissima* (L.f.) Benth.	T	Indo-Malesia	APB 20044; SVP 10092 (MBGH)
30	*Albizia procera* (Roxb.) Benth.	T	Tropical Asia to Australia	JJ 17849 (CAL); NS 3859 (KFRI)
	13. *Archidendron* F.Mull.			
31	*Archidendron bigeminum* (L.) I.C.Nielsen *A. monadelphum* (Roxb.) Nielson, var. *gracile* (Bedd.) Sanjappa	T	Indian subcontinent	SVP 10059; APB 20824 (MBGH)
32	*Archidendron clypearia* (Jack) I.C.Neilsen	T	Southern & Southeastern Asia	NM 5142 (TBGT); SVP & APB 20666 (MBGH)
	14. *Biancaea* Tod.			
33	*Biancaea decapetala* (Roth) O.Deg. *Caesalpinia decapetala* (Roth) Alston	CS	Tropical Asia	SVP & APB 20618 (MBGH)
34	*Biancaea sappan* (L.) Tod. *Caesalpinia sappan* L.	T	Indo-Malesia	NCN 50935 (MH); SVP 20003 (MBGH)
	15. *Caesalpinia* L.			
35	*Caesalpinia crista* L.	CS	Indo-Malesia	NS 3822 (KFRI); SCN 1471 (CALI)
	16. *Cassia L.*			
36	*Cassia fistula* L.	T	Indian subcontinent to Myanmar	TS 10885 (CALI); SVP & APB20782 (MBGH)
37	*Cassia javanica* L. subsp. *agnes* (de Wit) K.Larsen *Cassia javanica* L. subsp. *nodosa* (Roxb.) K.Larsen & S.S.Larsen	T	Indo-Malesia	APB 20051; SVP& APB 20630 (MBGH)
38	*Cassia roxburghii* DC.	T	India & Sri Lanka	SVP20783 (MBGH)
	17. *Chamaecrista* (L.) Moench			
39	*Chamaecrista absus* (L.) H.S.Irwin & Barneby	H	Tropics & Subtropics	SVP & APB 20107 & 20987 (MBGH)
40	*Chamaecrista auricoma* (Benth.) V.Singh	H	Indian subcontinent to Indo-China	APB 20055; SVP & APB 20673 (MBGH)
41	*Chamaecrista kleinii* (Wight & Arn.) V.Singh	H	India & Sri Lanka	SVP 20483; SVP & APB 20703 (MBGH)
42	*Chamaecrista mimosoides* (L.) Greene	H	Paleotropics	SVP 20486; APB 20758 & 20899 (MBGH)
43	*Chamaecrista nigricans* (Vahl) Greene	H	Southern & southwestern Asia & Tropical Africa	SVP & APB 20702 (MBGH)
44	*Chamaecrista pumila* (Lam.) V.Singh	H	Paleotropics	MRR 1606 (CAL); SVP & APB 20598 (MBGH)
45	*Chamaecrista wallichiana* (DC.) Singh	H	Indian subcontinent	SR 4684 (RHK); NM 874 (KFRI)
	18. *Dichrostachys* (DC.) Wight & Arn.			
46	*Dichrostachys cinerea* (L.) Wight & Arn.	T	India & Sri Lanka	NS 1249 (KFRI); SVP & APB 20793 (MBGH)
	19. *Entada* Adans.			
47	*Entada rheedei* Spreng.	CS	Indo-Malesia	NS 5229 (KFRI); APB 20603 (MBGH)
	20. *Guilandina* L.			
48	*Guilandina bonduc* L. *Caesalpinia bonduc* (L.) Roxb.	CS	Paleotropics	SVP 20453 ; SVP & APB 2097 (MBGH)
49	*Guilandina major* (DC.) Small *Caesalpinia globulorum* Bakh.f. & Royen	CS	Indo-Malesia to Polynesia	Vide Subramanian (1995)
	21. *Hultholia* Gagnon & G.P.Lewis			
50	*Hultholia mimosoides* (Lam.) Gagnon & G.P.Lewis *Caesalpinia mimosoides* Lam.	CS	Indo-Malesia	EV 60457 (MH); NS 3748 (KFRI)
	22. *Mezoneuron* Desf.			
51	*Mezoneuron cucullatum* (Roxb.) Wight & Arn.	CS	Indo-Malesia	VSR 66814 (MH); APB 20608 & 20819 (MBGH)
52	*Mezoneuron hymenocarpum* Wight & Arn. ex Prain	CS	Tropical Asia to Australia	NS 5224 (KFRI)

	Name of taxa	Habit	Native to	Vouchers/ Reference
	23. *Moullava* Adans.			
53	*Moullava spicata* (Dalzell) Nicolson	CS	India (Peninsula; E)	NS 3762 (KFRI); APB 20609 & 20823 (MBGH)
	24. *Neptunia* Lour.			
54	*Neptunia prostrata* (Lam.) Baill.	H	Pantropics	JJ 17785 (MH); APB 16322 (MBGH)
	25. *Pterolobium* R.Br. ex Wight & Arn.			
55	*Pterolobium hexapetalum* (Roth) Santapau & Wagh	CS	Indian subcontinent	KAA 2083 (CMPR); SVP & APB 20248 (MBGH)
	26. *Sanjappa* E.R.Souza & Krishnaraj			
56	*Sanjappa cynometroides* (Bedd.) E.R.Souza & Krishnaraj *Inga cynometroides* Bedd. ex Baker	T	India (KL; E)	NS 10003 (CAL); SVP & APB 20763 (MBGH)
	27. *Senegalia* Raf.			
57	*Senegalia caesia* (L.) Maslin, Seigler & Ebinger *Acacia caesia* (L.) Willd.	CS	Indo-Malesia	APB 20057; SVP & APB 20256; SVP 20429 (MBGH)
58	*Senegalia catechu* (L.f.) P.Hurter & Mabb. *Acacia catechu* (L.f.) Willd.	T	Indian subcontinent	NS 1248 (KFRI); SVP & APB 20588 (MBGH)
59	*Senegalia chundra* (Roxb. ex Rottl.) Maslin *Acacia chundra* (Roxb. ex Rottl.) Willd.	T	Indian subcontinent	Vide Sasidharan (2011)
60	*Senegalia ferruginea* (DC.) Pedley *Acacia ferruginea* DC.	T	Indian subcontinent	SVP & APB 20269 & 20574 (MBGH)
61	*Senegalia pennata* (L.) Maslin *Acacia pennata* (L.) Willd. *Acacia grahamii* Vajr.	CS	Paleotropics	VSR 58742; SVP & APB 20086; APB 20058 (MBGH)
62	*Senegalia polyacantha* (Willd.) Seigler & Ebinger *Acacia polyacantha* Willd.	T	Indian subcontinent & Tropical Africa	Vide Sasidharan (2011)
63	*Senegalia rugata* (Lam.) Britton & Rose *Acacia sinuata* (Lour.) Merr.	CS	Indo-Malesia	SVP 20412; SVP & APB 20628 (MBGH)
64	*Senegalia torta* (Roxb.) Maslin, Seigler & Ebinger *Acacia torta* (Roxb.) Craib	CS	Indian subcontinent	SVP & APB 20586 & 20643 (MBGH)
	28. *Senna* Mill.			
65	*Senna auriculata* (L.) Roxb.	S	Indian subcontinent to Myanmar	JJ 17868 (MH); SVP 20466 (MBGH)
66	*Senna intermedia* (B.D.Sharma, Vivek. & Rathakr.) V.Singh	S	India (TN, KL; E)	SVP 10046; APB 20880 (MBGH)
67	*Senna montana* (B.Heyne ex Roth) V.Singh	T	India (GU, MH, AP, TN, KL; E)	SVP 68321; APB 20056 (MBGH)
68	*Senna septemtrionalis* (Viv.) H.S.Irwin & Barneby var. *pubescens* (V.Singh) V.Singh	S	India (TN, KL; E)	SVP 20072 (MBGH)
69	*Senna surattensis* (Burm.f.) H.S.Irwin & Barneby	S	Southern and Southeastern Asia	SVP & APB 20692 (MBGH)
70	*Senna timoriensis* (DC.) H.S.Irwin & Barneby	S	Tropical Asia to Australia	Vide Sasidharan (1999)
	29. *Vachellia* Wight & Arn.			
71	*Vachellia horrida* (L.) Kyal. & Boatwr. *Acacia horrida* (L.) Willd.	T	India, Myanmar & Tropical Africa	TFB 362 (MH)
72	*Vachellia leucophloea* (Roxb.) Maslin, Seigler & Ebinger *Acacia leucophloea* (Roxb.) Willd.	T	Indo-Malesia	SVP & APB 20252 (MBGH)
73	*Vachellia nilotica* (L.)P.J.H.Hurter & Mabb. subsp. *nilotica* (Benth.) Kyal.& Boatwr. *Acacia nilotica* (L.) Willd. ex Delile ssp. indica (Benth.) Brenan	T	Indian subcontinent to Iran	SCN 1454 (CALI); SVP 20458; SVP & APB 20262 (MBGH)
74	*Vachellia planifrons* (Wight & Arn.) Ragup., Seigler, Ebinger & Maslin *Acacia planifrons* Wight & Arn.	T	India & Sri Lanka	SVP & APB 20791 & 20930 (MBGH)
	30. *Xylia* Benth.			
75	*Xylia xylocarpa* (Roxb.) Taub.	T	India to Indo-China	NS 709; APB 20059; SVP & APB 20085 (MBGH)
	Subfam. 5. PAPILIONOIDEAE			
	31. *Abrus* Adans.			
76	*Abrus precatorius* L.	CS	Pantropical	SVP 20067 & 30333 (MBGH)

	Name of taxa	Habit	Native to	Vouchers/ Reference
77	*Abrus pulchellus* Wall. ex Thwaites	TH	Tropical Asia, Tropical Africa to southwestern Pacific	APB 8634; SVP 20913 (MBGH)
	32. *Aeschynomene* L.			
78	*Asechynomene aspera* L.	S	Indo-Malesia	KR 74826 (MH); NR 33698 (TBGT); SCN 1512 (CALI)
79	*Asechynomene indica* L.	S	Paleotropics	SCN 1174 (CALI); JA 16981 (CALI)
	33. *Aganope* Miq.	CS		
80	*Aganope agastyamalayana* M.B.Viswan, Manik. & Tangav.		India (TN, KL; E)	TFB 17409 (MH)
81	*Aganope thyrsiflora* (Benth.) Polhill *A. thyrsiflora* var. *eualata* (Bedd.) Thoth. & D.N.Das.	CS	India, China, Malesia	NS 5395 (CALI); APB 20053; SVP & APB 20642 (MBGH)
	34. *Alysicarpus* Neck. ex Desv.			
82	*Alysicarpus bupleurifolius* (L.) DC. var. *bupleurifolius*	H	Indo-Malesia to Polynesia	APB 20739; SVP 20290 & 20472 (MBGH)
83	*Alysicarpus bupleurifolius* var. *hybridus* DC.	H	India (MH, GA, KA, KL; E)	Vide Pokle (2017)
84	*Alysicarpus glumaceus* (Vahl) DC.	H	Paleotropics	APB 20735 & 20795; SVP 20414 (MBGH)
85	*Alysicarpus hamosus* Edgew.	H	Western Himalaya to India	TS 10821 (CALI)
86	*Alysicarpus heterophyllus* (Baker.) Jafri & Ali	H	Indian subcontinent & eastern Arabian Peninsula	SVP & APB 20676 (MBGH)
87	*Alysicarpus monilifer* (L.) DC.	H	Indian subcontinent to West Africa	KR 75538; CNM 63731; MM 63895 (MH)
88	*Alysicarpus naikianus* Pokle	H	India (MH, KL; E)	Vide Pokle (1999)
89	*Alysicarpus parviflorus* Dalzell *Desmodium alysicarpoides* Meeuwen	H	Indo-Malesia	SVP & APB 20710; APB 20749 (MBGH)
90	*Alysicarpus racemosus* Benth. *Desmodium ritchiei* Sanjappa	H	India (RJ, GU, MP, MH, OD, KA, TN, KL; E)	KAA 4746 (CMPR); PB 90985 (MH)
91	*Alysicarpus scariosus* Graham *A. scariosus* Graham var. *pilifer* (Prain) Pramanik & Thoth.	H	Indian subcontinent to Myanmar	KMS 1643 (CAL)
92	*Alysicarpus vaginalis* (L.) DC. *A. vaginalis*(L.) DC. var. *nummularifolius* Miq.	H	Paleotropics	RA 74362 (CAL); SVP 20457; TAR 8131 (CALI)
	35. *Aphyllodium* (DC.) Gagnep.			
93	*Aphyllodium biarticulatum* (L.) Gagnep. *Desmodium biarticulatum*F.Muell.	H	Indo-Malesia to Australia	SCN 10019 (CALI); SVP 20771 (MBGH)
	36. *Butea* Roxb. ex Willd.			
94	*Butea monosperma* (Lam.) Taub.	T	Indian subcontinent to China	SCN 1913 (CALI); APB 16123 (MBGH)
	37. *Cajanus* DC.			
95	*Cajanus albicans* (Wight & Arn.) Maesen	CS	India & Sri Lanka	KAA 2338 (CMPR)
96	*Cajanus cajan* (L.) Huth	S	India	SVP 20510 (MBGH)
97	*Cajanus goensis* Dalz.	CS	Indo-Malesia and China	NS 3794; JA 17127 (CALI); SVP 30386 (MBGH)
98	*Cajanus heynei* (Wight & Arn.) Maesen	CS	India & Sri Lanka	SVP & APB 20614 & 20956; SVP 30386 (MBGH)
99	*Cajanus lineatus* (Wight & Arn) Maesen	S	India & Sri Lanka	SVP 20433; APB 20864 & 20880 (MBGH)
100	*Cajanus rugosus* (Wight & Arn.) Maesen	CS	India & Sri Lanka	APB 20736; JA 12679 (CALI)
101	*Cajanus scarabaeoides* (L.) Thouars	H	Tropical Asia	APB 20050 & 20869 (MBGH)
102	*Cajanus trinervius* (DC) Maesen	S	India & Sri Lanka	SVP & APB 20201 (MBGH)
	37. *Canavalia* DC.			
103	*Canavalia africana* Dunn	CS	India, Sri Lanka, Africa and Hawaiian Islands	SVP & APB 20226; SVP 13234 & 20402 (MBGH)
104	*Canavalia cathartica* Thouars	CS	Tropical Asia, Africa & Pacifics	SVP& APB 20175; SVP 20068 (MBGH)
105	*Canvalia gladiata* (Jacq.) DC.	CS	Tropical & Subtropical Asia	EV 44721 (MH); NS 5160 (KFRI); SVP 20511 (MBGH)
106	*Canavalia mollis* Wall. ex Wight & Arn.	CS	Indo-Malesia	Vide Sasidharan (1998 & 1999)
107	*Canavalia rosea* (Sw.) DC.	H	Tropics & Subtropics	TAR 9925; VSR 64018 (CAL); APB 16201 (MBGH)

	Name of taxa	Habit	Native to	Vouchers/ Reference
	38. *Codariocalyx* Hassk.			
108	*Codariocalyx motorius* (Houtt.)H.Ohashi *Desmodium motorium* (Houtt.) Merr.	S	Tropical & Subtropical Asia	SVP 20929; APB 20762 (MBGH)
	39. *Crotalaria* L.			
109	*Crotalaria acicularis* Buch.-Ham. ex Benth.	H	Indo-Malesia-Australia	Vide Ansari (2008)
110	*Crotalaria alata* Buch.-Ham. ex D. Don	S	Himalaya to North Australia	MCL 2419 (RHK); VSR 66828 (MH)
111	*Crotalaria albida* B.Heyne ex Roth	H	Tropical Asia to northern Australia	KAA 4003 (CMPR); NM 10473 & 10743 (CALI)
112	*Crotalaria angulata* Mill.	H	India & Sri Lanka	KMS 15320 (CAL).
113	*Crotalaria assamica* Benth. var. *keralensis* Krishnaraj, N. Mohanan & V.T. Antony	S	India (KL; E)	SVP & APB 20301 (MBGH)
114	*Crotalaria barbata* Graham ex Wight & Arn.	S	India (TN, KL; E)	PM 33861; TS 11311 (CALI)
115	*Crotalaria beddomeana* Thoth. & A.A.Ansari	S	India & Sri Lanka	KMS 17489 (CAL); SVP & APB 20208 (MBGH)
116	*Crotalaria berteroana* DC.	S	India, Indonesia & Sri Lanka	CEC 4504; AM 12967 (MH)
117	*Crotalaria bifaria* L.f.	H	India & Sri Lanka	Vide Ansari (2008)
118	*Crotalaria calycina* Schrank	H	Paleotropics	CEC 2272 (MH); APB 20727 & 20896 (MBGH)
119	*Crotalaria candicans* Wight & Arn.	S	India (AP, TN, KL; E)	EV 46190 (MH).
120	*Crotalaria clarkei* Gamble	H	India (OD, AP, KA, TN, KL; E)	VSR 62109 (MH); SVP & APB 20563; APB 20743 (MBGH)
121	*Crotalaria dubia* Graham	H	Southern Asia & China	VSR 58735 (CAL); MM 61782 (CAL); SVP 20485 (MBGH)
122	*Crotalaria evolvuloides* Wight *C. evolvuloides* Wight var. *acutifolia* Gamble	H	India & Sri Lanka	VSR 58206 (CAL); APB 20047 & 20838 (MBGH)
123	*Crotalaria ferruginea* Graham ex Benth.	H	Indo-Malasia	Vide Sasidharan (1999 & 2002)
124	*Crotalaria formosa* Graham ex Wight & Arn.	S	India (TN, KL; E)	PM 3387 (CALI).
125	*Crotalaria fysonii* Dunn var. *glabra* Gamble	H	India (TN, KL; E)	Vide Sasidharan (1998)
126	*Crotalaria fysonii* Dunn var. *fysonii*	H	India (TN, KL; E)	SVP & APB 20219; APB 20829 (MBGH)
127	*Crotalaria goreensis* Guill. & Perr.	H	Tropical Africa & Australia	Vide Ansari (2008)
128	*Crotalaria grahamiana* Wight & Arn.	S	India (TN, KL; E)	MM 59332 (CAL); SVP & APB 10002 (MBGH)
129	*Crotalaria hebecarpa* (DC.) Rudd	H	Southern Asia	SVP 20482; APB 20726 & 20829 (MBGH)
130	*Crotalaria heyneana* Graham ex Wight & Arn.	S	India (KA, TN, KL; E)	NS 3325 (CALI); SVP 20408 (MBGH)
131	*Crotalaria hirsuta* Willd.	H	Indian subcontinent	Vide Vajravelu (1990)
132	*Crotalaria hirta* Willd.	H	India & Indo-China	Vide Ansari (2008)
133	*Crotalaria humifusa* Graham ex Benth.	H	Himalaya to northern Australia	SVP & APB 20947; APB 20881 (MBGH)
134	*Crotalaria juncea* L.	H	South and South East Asia & China	RA 74318 (CAL); SVP 20406 & 20438 (MBGH)
135	*Crotalaria laburnifolia* L.	S	Tropical Asia, South Africa & northern Australia	KMS 14740 (CAL); SVP 20061 (MBGH)
136	*Crotalaria laevigata* Lam.	S	India & Madagascar	SVP & APB 20945; SVP 20413 (MBGH)
137	*Crotalaria leptostachya* Benth.	S	India (Peninsula; E)	Vide Ansari (2008)
138	*Crotalaria linifolia* L.f.	H	Trop. Asia	MM 59323 (CAL); AES 13038 (TBGT)
139	*Crotalaria longipes* Wight & Arn. *Crotalaria shevaroyensis* Gamble *Crotalaria subperfoliata* Wight	S	India (AP, TN, KL; E)	JA 13017 & 17056 (CALI); SVP & APB 20963 (MBGH)
140	*Crotalaria madurensis* Wight	S	India (TN, KL; E)	Vide Ansari (2008)
141	*Crotalaria medicaginea* Lam.	S	Southern Asia to Australia	Priya K.D. 51709 (CALI)
142	*Crotalaria multiflora* Benth. *Crotalaria kurisumalayana* Sibichen & Nampy **Crotalaria multiflora* Benth. var. *kurisumalayana* (Sibichen & Nampy) Krishnaraj & N.Mohanan, syn. nov.	H	India & Sri Lanka	SMT 759 (CALI); SVP 20439; APB 20757 (MBGH)
143	*Crotalaria mysorensis* Roth	H	Indo-Malesia	NS 5147 (CALI); SVP & APB 20265 (MBGH)

	Name of taxa	Habit	Native to	Vouchers/ Reference
144	*Crotalaria nana* Burm. f. *Crotalaria nana* Burm.f. var. *umbellata* (Wight ex Wight) Trimen	H	Indo-Malesia	MM 63352 (CAL); SVP 20073; APB 20723 (MBGH)
145	*Crotalaria notonii* Wight & Arn.	H	India	TS 10003 (CALI); AAA 97189 (MH).
146	*Crotalaria obtecta* Graham ex Wight & Arn. var. *glabrescens* (Benth.) Baker	S	India (AP, KA, TN, KL; E)	KAA 7727 (CMPR); BVS 26591 (CAL)
147	*Crotalaria obtecta* Graham ex Wight & Arn. var. *obtecta*	S	India (KA, TN, KL; E)	AKP 5496 (CALI); SVP & APB 20098 & 20216 (MBGH)
148	*Crotalaria pallida* Aiton var. *obovata* (G. Don) Polhill	S	Tropical Africa to Taiwan	SVP 13279; APB 20052 (MBGH)
149	*Crotalaria pallid* Aiton var. *pallida*	S	Tropical Asia & Africa	KMS 25390 (CAL); SVP & APB 10085 (MBGH)
150	*Crotalaria peduncularis* Graham ex. Wight & Arn.	S	India (TN, KL; E)	JA 14550 (CALI); RHB s.n. (MH-12675).
151	*Crotalaria prostrata* Rottler ex Willd.	H	Indo-Malesia	RA 74415 (CAL); MCL 49052 (CAL)
152	*Crotalaria pusilla* DC.	H	India (BR to KL; E)	JJ 17882 (MH)
153	*Crotalaria quinquefolia* L.	H	Tropical Asia	PM 33476 (CALI); SVP & APB 20709 (MBGH)
154	*Crotalaria retusa* L.	S	Tropics	SVP & APB 20964; APB 20048 (MBGH)
155	*Crotalaria salicifolia* B.Heyne ex Wight & Arn.	S	India (KA, TN, KL; E)	SVP 20451; APB 20815 & 20835 (MBGH)
156	*Crotalaria scabra* Gamble	S	India (TN, KL; E)	CAB 2931 (CAL); MM 66092 (MH)
157	*Crotalaria scabrella* Wight & Arn.	H	India (KA, TN, KL; E)	SVP & APB 00121; APB 20737 (MBGH)
158	*Crotalaria semperflorens* Vent.	S	India & Malesia	SVP 20416; SVP& APB 20961 (MBGH)
159	*Crotalaria spectabilis* Roth	S	Paleotropics	MCL 1863 (RHK); APB 20830 (MBGH)
160	*Crotalaria speciosa* B.Heyne ex Roth	S	India (AP, KA, TN, KL; E)	RA 2008 (CAL)
161	*Crotalaria trichotoma* Bojer	S	Tropical Africa	APB 10999 (MBGH)
162	*Crotalaria trifoliastrum* Willd.	S	India & Bhutan	SVP & APB 20250 (MBGH)
163	*Crotalaria triquetra* Dalz.	H	India & Sri Lanka	SVP 20438; SVP & APB 20944 (MBGH)
164	*Crotalaria verrucosa* L.	H	Tropics	SCN 1204 (CALI); SVP 20805 (MBGH)
165	*Crotalaria walkeri* Arn.	S	India & Sri Lanka	SVP 20416; APB 20739 (MBGH)
166	*Crotalaria wightiana* Graham ex Wight & Arn.	S	India & Sri Lanka	SVP 20011; SVP & APB 20672 (MBGH)
167	*Crotalaria willdenowiana* DC.	S	India & Sri Lanka	Vide Nair et al. (1981)
	40. *Cullen* Medik.			
168	*Cullen corylifolium* (L.) Medik. *Psoralea corylifolia* L.	H	Tropical Africa & Asia	VTA 624 (RHK)
	41. *Cyamopsis* DC.			
169	*Cyamopsis tetragonoloba* (L.) Taub.	H	India & Sri Lanka	SVP & APB 20602 (MBGH)
	42. *Dalbergia* L. f.			
170	*Dalbergia beddomei* Thoth.	CS	India (KL; E)	KKN 3236 (KFRI)
171	*Dalbergia benthamii* Prain	CS	India & China	KKN 3237 (KFRI)
172	*Dalbergia candenatensis* (Dennst.) Prain	CS	Indo-Malesia, China, and Australia	SCN 1637 (CALI); SVP & APB 20110 (MBGH)
173	*Dalbergia congesta* Graham ex Wight & Arn.	CS	India (TN, KL; E)	Vide Sasidharan (1999)
174	*Dalbergia horrida* (Dennst.) Mabb.var. *glabrescens* (Prain) Thoth & Nair	CS	India to Indo-China	KKN 2880 (KFRI); MAL 218 (CAL)
175	*Dalbergia horrida* (Dennst.) Mabb. var. *horrida*	CS	India to Malayan Peninsula	NCN 81241 (MH); APB 20822; SVP 20966 (MBGH)
176	*Dalbergia lanceolaria* L. f.subsp. *lanceolaria*	T	Indian Subcontinent to Indo-China	SVP & APB 20225 & 20264 (MBGH)
177	*Dalbergia lanceolaria* L. f., subsp. *paniculata* (Roxb.) Thoth.	T	India to Indo-China	KKN 2837 (KFRI); SVP 20446 (MBGH)
178	*Dalbergia latifolia* Roxb.	T	Indo-Malesia	SCN 1425 (CALI); SVP & APB 20272 (MBGH)
179	*Dalbergia malabarica* Prain	CS	India (OD,MH, KA, TN, KL; E)	SVP & APB 20681; APB 20687 (MBGH)
180	*Dalbergia pinnata* (Lour.) Prain. var. *acaciaefolia* (Dalz.) Thoth.	CS	India (KA, TN, KL; E)	Vide Thothathri (1987)

	Name of taxa	Habit	Native to	Vouchers/ Reference
181	*Dalbergia pseudo-sissoo* Miq.	CS	Indo-Malesia	NA 544 (MH); NM 11091 (TBGT)
182	*Dalbergia rubiginosa* Roxb.	CS	India (Peninsula; E)	KKN 2821 (KFRI); NCN 81115 (CAL);
183	*Dalbergia sericea* G.Don.	T	Indian subcontinent to Tibet	SVP & APB 20277(MBGH)
184	*Dalbergia sissoides* Graham ex Wight & Arn.	T	India & Indonesia	VSR 62018; TFB 535 (MH); SVP & APB 20082(MBGH)
185	*Dalbergia sissoo* Roxb.	T	Tropical Himalaya to northeastern India	KKN 3212 (KFRI); SCN 1980 (CALI); SVP& APB 20768 (MBGH)
186	*Dalbergia travancorica* Thoth.	CS	India (KL; E)	Vide Jagadeesan et al. (2015)
187	*Dalbergia volubilis* Roxb.	CS	Indian subcontinent to Indo-China	KKN 3218 (KFRI); KAA 3935(CMPR)
	43. *Dendrolobium* (Wight & Arn.) Benth.			
189	*Dendrolobium triangulare* (Retz.) Schindl. *Desmodium triangulare* (Retz.) Merr.	S	Indo-Malesia & China	SVP & APB 20080; APB 20046 (MBGH)
	44. *Derris* Lour.			
190	*Derris benthamii* (Thwaites) Thwaites	CS	India & Sri Lanka	VSR 68242; NCN 64288 (CAL); KAA 4368 (CMPR)
191	*Derris brevipes* (Benth.) Baker var. *brevipes*	CS	India (MH, KA, TN, KL; E)	SVP & APB 20521 & 20616 (MBGH)
192	*Derris brevipes* (Benth.) Baker var. *coriacea* Baker	CS	India (KA, TN, KL; E)	SVP & APB 20534 & 20647 (MBGH)
193	*Derris canarensis* (Dalzell) Baker	CS	India & Sri Lanka	NS 3924 (KFRI); AM 12621; MRR 902 (CAL)
194	*Derris elliptica* (Wall.) Benth.	CS	Indo-Malesia	Vide Sasidharan (2011)
195	*Derris scandens* (Roxb.) Benth.	CS	Indo-Malesia	SVP & APB 10096 & 20077 (MBGH)
196	*Derris thothathrii* Bennet	CS	India (MH, KA, TN, KL; E)	EV 46241; BDS 43811; KV 66128 (MH)
197	*Derris trifoliata* Lour.	CS	Paleotropics	SVP & APB 20103; SVP 20772 (MBGH)
	45. *Dolichos* L.			
198	*Dolichos trilobus* L.	CS	India, Sri Lanka, Southeastern Asia & Africa	SVP & APB 20525; APB 20752 (MBGH)
	46. *Dumasia* DC.			
199	*Dumasia villosa* DC.	TH	Paleotropics	SVP & APB 20948; APB 20883 (MBGH)
	47. *Dunbaria* Wight & Arn			
200	*Dunbaria punctata* (Wight & Arn.) Benth.	TH	Tropical Asia to Australia	SVP & APB 20984; APB 20998 (MH)
	48. *Dysolobium* (Benth.) Prain			
201	*Dysolobium dolichoides* (Roxb.) Prain	CS	Indo-Malesia	PM 33017 (CALI).
	49. *Erythrina* L.			
202	*Erythrina fusca* Lour.	T	Indo-Malesia, Tropical Africa & Tropical America	SVP 20514
203	*Erythrina stricta* Roxb.	T	Indian subcontinent & southern China	SVP 10056
204	*Erythrina suberosa* Roxb.	T	Indo-Malesia	SVP 33372
205	*Erythrina subumbrans* (Hassk.) Merr.	T	Tropical Asia to China	VSR 53979 (CAL); SVP 20434 & 132474 (MBGH)
206	*Erythrina variegata* L.	T	Indo-Malesia, China & Africa	EV 60409 (CAL); SCN 2162 (CALI)
	50. *Flemingia* Roxb. ex W.T.Aiton			
207	*Flemingia grahamiana* Wight & Arn.	S	India, Indo-China & Tropical Africa	SVP & APB 20013 &20564 (MBGH)
208	*Flemingia macrophylla* (Willd.) Kuntze ex Merr.	S	Tropical Asia to Australia	SVP 20494; APB 20816 & 20822 (MBGH)
209	*Flemingia nilgheriensis* (Baker) Wight ex T.Cooke	TH	India (OD, MH, GA, KA, TN, KL; E)	EV 48862 (MH); TS 10844 (CALI); KAA 4773 (CMPR)
210	*Flemingia semialata* Roxb.	S	Indian subcontinent& Indo-China	SVP & APB 20646; APB 20879 (MBGH)
211	*Flemingia stricta* Roxb.	S	South Asia & China	NM 11202 (TBGT)
213	*Flemingia strobilifera* (L.) W.T.Aiton	S	Indo-Malesia	SVP & APB 20705; APB 20766 & 20859 (MBGH)
213	*Flemingia tuberosa* Dalzell	S	India (GU, MH, GA, KA, TN, KL; E)	Vide Prasad et al. (2011)

	Name of taxa	Habit	Native to	Vouchers/ Reference
214	*Flemingia wallichi* Wight & Arn.	S	India & Myanmar	VSR 61361; RHB 16943; KMS 15667 (MH)
215	*Flemingia wightiana* Graham ex Wight & Arn.	S	India, Sri Lanka & Bhutan	EV 49751 (CAL)
	51. *Galactia* P. Browne			
216	*Galactia striata* (Jacq.) Urb. var. *villosa* Wight & Arn. *Galactia tenuiflora* (Willd.) Wight & Arn. var. *villosa* Wight & Arn.	CS	Paleotropics	Vide Sasidharan (1999)
217	*Galactia tenuiflora* (Willd.) Wight & Arn.	CS	Indo-Malesia, Australia and Africa	SVP & APB 20592; APB 20049 (MBGH)
	52. *Geissaspis* Wight & Arn.			
218	*Geissaspis cristata* Wight & Arn.	H	Indian subcontinent, Indo-China & China	SVP 20418; SVP & APB 20682; APB 20876 (MBGH)
219	*Geissaspis tenella* Benth. *Geissaspis tenella* Benth. var. *malabarica* Sivar. & Babu	H	India (MH, GA, KA, TN, KL; E)	PM 38675 (CALI); AB 37408 (CALI); APB 20401 (MBGH)
	53. *Grona* Lour.			
220	*Grona ferruginea* (Wall. ex Thwaites) H.Ohashi & K.Ohashi *Desmodium ferrugineum* Wall. ex Thwaites	S	India & Sri Lanka	PM 33577 (CALI); SVP & APB 20251 (MBGH)
221	*Grona heterocarpa* (L.)H.Ohashi & K.Ohashi var. *gymnocarpa* (Schindl.) H.Ohashi & K.Ohashi *Desmodium heterocarpon* (L.) DC. var. *gymnocarpum* Schindl.	H	India & Sri Lanka	Vide Sasidharan (1997)
222	*Grona heterocarpa* (L.)H.Ohashi & K.Ohashi var. *heterocarpa* *Desmodium heterocarpon* (L.) DC. var. *heterocarpon*	H	Tropical Asia to southwestern Pacific	JA 14210 (CALI); SVP & APB 20773 (MBGH)
223	*Grona heterocarpa* (L.) H.Ohashi & K.Ohashi var. *strigosa* (Meeuwen) H.Ohashi & K.Ohashi *Desmodium heterocarpon* (L.) DC. var. *strigosum* Meeuwen	H	Indo-Malesia	KAA 3640 (CMPR); APB 20813 (MBGH)
224	*Grona heterophylla* (Willd.) H.Ohashi & K.Ohashi *Desmodium heterophyllum* (Willd.) DC.	H	Tropical Asia	SVP 10053; APB 20165 (MBGH)
225	*Grona styracifolia* (Osbeck) H.Ohashi & K.Ohashi *Desmodium styracifolium* (Osbeck) Merr.	H	Tropical & subtropical Asia to northwestern Pacific	SVP 20436; APB 20749 (MBGH)
226	*Grona triflora* (L.)H.Ohashi & K.Ohashi *Desmodium triflorum* (L.) DC.	H	Paleotropics	SCN 1987 (CALI); SVP & APB 20197 (MBGH)
227	*Grona wynaadensis* (Bedd. ex Gamble) H.Ohashi & K.Ohashi *Desmodium wynaadense* Bedd. ex Gamble	S	India (TN, KL; E)	SVP 20435; APB 20890 (MBGH)
	54. *Hylodesmum* H.Ohashi & R.R.Mill			
228	*Hylodesmum laxum* (DC.) H.Ohashi & R.R.Mill *Desmodium laxum* DC.	H	Southern and Southeastern Asia & China	PB 81118 (CAL)
229	*Hylodesmum repandum* (Vahl) H.Ohashi & R.R.Mill *Desmodium repandum* (Vahl) DC.	H	Paleotropcs	AKP 56363; SVP & APB 00120 & 20952 (MBGH)
	55. *Indigofera* L.			
230	*Indigofera aspalathoides* Vahl ex DC.	S	India & Sri Lanka	AB 38172 (CAL)
231	*Indigofera astragalina* DC.	H	Paleotropics	SVP 20477; SVP & APB 20594 (MBGH)
232	*Indigofera cassioides* Rottler ex. DC.	S	Indian subcontinent & Indo-China	SVP & APB 20566, 20623 & 20707 (MBGH)
233	*Indigofera coerulea* Roxb.	S	India, Iran, Pakistan, Sri Lanka & Tropical Africa	VTA 4667A (RHK)
234	*Indigofera colutea* (Burm. f.) Merr.	S	Paleotropics	NS 3739 (KFRI); SVP & APB 20584 (MBGH)
235	*Indigofera constricta* (Thwaites) Trimen	S	India, Nepal, Sri Lanka	SVP 20484; SVP & APB 20959 (MBGH)
236	*Indigofera hendecaphylla* Jacq. *I. spicata* Forssk.	H	India, Sri Lanka & Africa	SVP 20421; APB 20979 (MBGH)
237	*Indigofera galegoides* DC.	S	Indo-Malesia & China	CAB 1785; NA 1248 (MH)
238	*Indigofera glabra* L	H	India to Indo-China	MRR 2157 (CAL); SVP 20064 & 20476 (MBGH)
239	*Indigofera glandulosa* J.C.Wendl.	S	Indo-Malesia to Australia	Vide Sasidharan (1999)
240	*Indigofera hirsuta* L.	H	Pantropical	NS 765 (KFRI); SVP 20770 (MBGH)

	Name of taxa	Habit	Native to	Vouchers/ Reference
241	*Indigofera karuppiana* Pallithanam	H	India (MH, KA, TN, KL; E)	CEC 2342 (CAL); KAA 4214 (CMPR)
242	*Indigofera linnaei* Ali	H	Indo-Malesia to Australia and West Africa	SVP 20407; SVP & APB 20243 (MBGH)
243	*Indigofera longiracemosa* Boivin ex Baill.	S	India, Tropical Africa & Madagascar	CAB 6674 & 6745; MM 54878 (MH)
244	*Indigofera nummulariifolia* (L.) Livera ex Alston	H	India, Indo-China, Tropical Africa & Madagascar	SCN 2230 (CALI); MM 63840 (CAL).
245	*Indigofera pedicellata* Wight & Arn.	H	India & Taiwan	BVS 28327; PB 90988 (MH)
246	*Indigofera prostrata* Willd.	H	Indian subcontinent	EV 26291 (CAL); APB 20834 & 20873 (MBGH)
247	*Indigofera tinctoria* L.	H	Paleotropics	EV 62885; SVP 20509 (MBGH)
248	*Indigofera trifoliata* L.	H	Tropical Asia to Australia	SVP & APB 20295 & 20573 (MBGH)
249	*Indigofera trita* L.f. var. *marginulata* (Graham ex Wight & Arn.) Sanjappa	H	India (TN, KL; E)	SVP & APB 20662 (MBGH)
250	*Indigofera trita* Linn. f., var. *scabra* Ali	H	Tropics & Subtropics	SVP & APB 20662 (MBGH)
251	*Indigofera trita* L. var. *trita*	H	Paleotropics	MRR 1627 (CAL)
252	*Indigofera uniflora* Buch.-Ham. ex Roxb.	H	India (AP, KA, TN, KL; E)	SVP & APB 20943; SVP 20807 (MBGH)
253	*Indigofera vicioides* Jaub. & Spach	H	India & Africa	SVP & APB 20593 (MBGH)
254	*Indigofera wightii* Graham ex Wight & Arn.	H	India, Sri Lanka & Indo-China	SVP & APB 20620(MBGH)
255	*Indigofera zollingeriana* Miq.	T	Southern & Southeastern Asia	VSR 52299 (CAL); MM 63212 (MH)
	56. *Kunstleria* Prain			
256	*Kunstleria keralensis* C.N.Mohanan & N.C.Nair	CS	India (KL; E)	NM 9157 (CALI); SVP & APB 20780 (MBGH)
	57. *Lablab* Adans.			
257	*Lablab purpureus* (L.) Sweet	CS	India, Africa & Madagascar	SVP & APB 20613 (MBGH)
	58. *Leptodesmia* (Benth.) Benth. & Hook. f.			
258	*Leptodesmia microphylla* (Thunb.) H.Ohashi & K.Ohashi *Desmodium microphyllum* (Thunb.) DC.	H	Tropical Asia to North Australia	JA 14255 (CALI); APB 20731 & 20853 (MBGH)
	59. *Leptospron* (Benth. & Hook f.)A.Delgado.			
259	*Leptospron adenanthum* (G.Mey.) A.Delgado. *Vigna adenantha* (G.Mey.) Marechal, Mascherpa & Stanier	TH	Tropics & Subtropics	SVP & APB 20101; APB 20982 (MBGH)
	60. *Macrotyloma* (Wight & Arn.) Verdc.			
260	*Macrotyloma uniflorum* (Lam.) Verdc.	CS	Indian subcontinent & Tropical Africa	SVP 10047; SVP & APB 20271 & 20565 (MBGH)
	61. *Millettia* Wight & Arn.			
261	*Millettia peguensis* Ali	T	Southern & Southeastern Asia	SVP 20908 (MBGH)
262	*Millettia pulchra* (Benth.) Kurz. var. *munnarensis* Balan & Predeep	T	India (KL; E)	SVP & APB 20983 & 20986 (MH, MBGH)
263	*Millettia rubiginosa* Wight & Arn.	CS	India (TN, KL; E)	SVP & APB 20527 & 20613 (MBGH)
264	*Millettia splendens* Wight & Arn.	CS	India (TN, KL; E)	TS 10943 (CALI); NCN 56870 (MH)
	62. *Monarthrocarpus* Merr.			
265	*Monarthrocarpus dolabriformis* (Benth.) H.Ohashi & K.Ohashi *Desmodium dolabriforme* Benth.	H	India & Madagascar	AN 27473 (TBGT)
	63. *Mucuna* Adans.			
266	*Mucuna atropurpurea* (Roxb.) DC. ex Wight & Arn.	CS	India & Sri Lanka	AM s.n. (CAL); SVP & APB 20589 (MBGH)
267	*Mucuna bracteata* DC. ex Kurz	CS	Eastern Himalaya to China & Sumatra	APB 20991 (MBGH)
268	*Mucuna gigantea* (Willd.) DC.	CS	Indo-Malesia, South Africa to the Pacific	SVP & APB 10094; SVP 20781 (MBGH)
269	*Mucuna monosperma* DC. ex Wight	CS	Indian subcontinent to Indo-China	VSR 62026; PB 65758 (MH)

	Name of taxa	Habit	Native to	Vouchers/ Reference
270	*Mucuna pruriens*(L.) DC var. *hirsuta* (Wight & Arn.) Wilmot-Dear *Mucuna pruriens* (L.) DC. var. *thekkadiensis* Thoth. & S.Ravik.	CS	India, Thailand & Vietnam	VSR 61964; KR 755922 (MH); JA 12579 (CALI)
271	*Mucuna pruriens* (L.) DC var. *pruriens*	CS	Paleotropics	NS 3882 (KFRI); SVP & APB 20962 (MBGH)
	64. *Mundulea* (DC.) Benth.			
272	*Mundulea sericea* (Willd.) A.Chev.	S	India, Sri Lanka, Africa & Madagascar	PB 56915 (CAL); SVP 20919 (MBGH)
	65. *Neonotonia* J.A.Lackey			
273	*Neonotonia wightii* (Wight & Arn.) J.A.Lackey	CS	India, Sri Lanka, Arabian Peninsula & Tropical Africa	SVP & APB 20953; APB 20720 (MBGH)
	66. *Ophrestia* H.M.L. Forbes			
274	*Ophrestia pentaphylla* (Dalzell) Verdc.	TH	India (ML, MH, AP, KA, TN, KL; E)	RHB s.n.; VN 1085 (MH); PM 33201(CALI)
	67. *Ormocarpum* P.Beauv.			
275	*Ormocarpum cochinchinense* (Lour.) Merr.	S	Tropical Asia to southwestern Pacific	NS 4610 (KFRI); SVP 20915 (MBGH)
	68. *Ormosia* Jacks.			
276	*Ormosia travancorica* Bedd.	T	India (AN, KA, TN, KL; E)	NS 3764 (KFRI); JA 14438 (CALI); KV 66124 (MH).
	69. *Ougeinia* Benth.			
277	*Ougeinia oojeinensis* (Roxb.) Hochr. *Desmodium oojeinense* (Roxb.) H.Ohashi	T	India & Nepal	MRR 83642 (MH)
	70. *Paracalyx* Ali			
278	*Paracalyx scariosus* (Roxb.) Ali	S	Tropical Asia	JLE 18555; VSR 52378; KV 23011 (MH)
	71. *Parochetus* Buch.-Ham. ex D.Don			
279	*Parochetus communis* Buch.-Ham. ex D. Don	TH	Indo-Malesia	SVP 20040; SVP & APB 20285 (MBGH)
	72. *Phyllodium* Desv.			
280	*Phyllodium pulchellum* (L.) Desv. *Desmodium pulchellum* (L.) Benth.	S	Tropical & subtropical Asia to North Australia	SVP 20776; SVP & APB 20536 (MBGH)
	73. *Pleurolobus* J.St.-Hil.			
281	*Pleurolobus gangeticus* (L.) J.St.-Hil. ex H.Ohashi & K.Ohashi *Desmodium gangeticum* (L.) DC.	H	Paleotropics	KKN 6880 (KFRI); SVP 20001 (MBGH)
282	*Pleurolobus pryonii* (DC.)H.Ohashi & K.Ohashi *Desmodium pryonii* DC.	S	India & Sri Lanka	JA 17191 (CALI); APB 20900 (MBGH)
	74. *Polhillides* H.Ohashi & K.Ohashi			
283	*Polhillides velutina* (Willd.) H.Ohashi & K.Ohashi *Desmodium velutinum* (Willd.) DC.	S	Paleotropics	KKN 6896 (KFRI); SVP 20497 (MBGH)
	75. *Pongamia* Vent.			
284	*Pongamia pinnata* (L.) Pierre	T	Tropical Asia to southwestern Pacific	SCN 2568; SVP & APB 20784 (MBGH)
	76. *Pseudarthria* Wight & Arn.			
285	*Pseudarthria viscida* (L.) Wight & Arn.	S	Tropical Asia	NS 376 (CALI); SVP 20492 & 20785 (MBGH)
	77. *Pterocarpus* Jacq.			
286	*Pterocarpus dalbergioides* Roxb.	T	Andaman Islands	Vide Sasidharan (2011)
287	*Pterocarpus indicus* Willd.	T	Tropical Asia to western Pacific	SVP & APB 20704; SVP 20937 (MBGH)
288	*Pterocarpus marsupium* Roxb.	T	India, Nepal, Sri Lanka & Madagascar	RA 74351 (MH); SVP & APB 20239 (MBGH)
289	*Pterocarpus santalinus* L.f.	T	India (Peninsula)	MD 14548 (TBGT)
	78. *Pueraria* DC.			
290	*Pueraria phaseoloides*(Roxb.) Benth.	CS	Tropical Asia	SCN 1495 (CALI); SVP 20507 & 20786 (MBGH)
291	*Pueraria tuberosa* (Roxb. ex Willd.) DC.	CS	India, Nepal & Pakistan	SVP & APB 20706; SVP 20927 (MBGH)

	Name of taxa	Habit	Native to	Vouchers/ Reference
	79. *Pycnospora* R.Br. ex Wight & Arn.			
292	*Pycnospora lutescens* (Poir.) Schindl.	TH	Tropical Asia, Africa & Australia	SVP 20007; APB 20976 (MBGH)
	80. *Rhynchosia* Lour.			
293	*Rhynchosia acutissima* Thwaites	TH	India & Sri Lanka	MRR 696 (TBGT); KAA 2580 (CMPR)
294	*Rhynchosia cana* (Willd.) DC.	CS	India, Myanmar & Sri Lanka	KAA 2820 (CMPR); APB 20754 (MBGH)
295	*Rhynchosia capitata* (Heyne ex Roth) DC.	CS	India, Pakistan & Sri Lanka	JJ 17859 (MH)
296	*Rhynchosia courtallensis* Maesen	CS	India (AP, TN, KL; E)	PM 33797 (CALI); VDM 3467 (K)
297	*Rhynchosia densiflora* (Roth) DC.	CS	India, Myanmar, Sri Lanka & Tropical Africa	KAA 2582 (CMPR); SVP & APB 20965 (MBGH)
298	*Rhynchosia filipes* Benth.	TH	India (TN, KL; E)	Vide Sasidharan (2011)
299	*Rhynchosia hirta* (Andrews) Meikle & Verdc.	CS	India, Sri Lanka & Tropical Africa	SVP & APB 20615; APB 20825 (MBGH)
300	*Rhynchosia rufescens* (Willd.) DC.	S	Indo-Malesia	SVP & APB 00113; APB 20738 (MBGH)
301	*Rhynchosia suaveolens* (L. f.) DC.	S	India & Sri Lanka	KNS (1995); KAA 3944 (CMPR)
302	*Rhynchosia viscosa* (Roth) DC.	CS	Indian subcontinent, Africa & Madagascar	EV 27852; JJ 17867 (MH); APB 20831 (MBGH)
	81. *Rothia* Pers.			
303	*Rothia indica* (L.) Druce	H	Indo-Malesia and Australia	KR 74944 (CAL); SVP & APB 20586 (MBGH)
	82. *Sesbania* Scop.			
304	*Sesbania bispinosa* (Jacq.) W.Wight	S	Paleotropics	SCN 1985 (CALI); SVP & APB 20576 (MBGH)
305	*Sesbania javanica* Miq.	S	Tropical Asia	SVP 20653 & 10280 (MBGH)
306	*Sesbania sesban*(L.) Merr.	S	Tropical Asia & Africa	SVP & APB 20182 & 20577 (MBGH)
	83. *Shuteria* Wight & Arn.			
307	*Shuteria involucrata* (Wall.) Wight & Arn. *S. involucrata* (Wall.) Wight & Arn., var. *vestita* (Wight & Arn.) Ohashi	CS	Indo-Malesia	VSR 62101(CAL); SVP & APB 20027; APB 20764 (MBGH)
	84. *Smithia* Aiton			
308	*Smithia bigemina* Dalz.	H	India & Pakistan	NCN 69105 (MH); APB 20747 & 20872 (MBGH)
309	*Smithia blanda* Wall. ex Wight & Arn. *S. racemosa* B.Heyne ex Wight & Arn.	H	Indian subcontinent & China	JLE 26389 (MH); APB 20832; SVP & APB 20955 (MBGH)
310	*Smithia capitata* Dalzell	H	India (RJ, GJ, MP, MH, GA, KA, TN, KL; E)	JSG 15575 (MH); TS 10832 (CALI); APB 20860 (MBGH)
311	*Smithia conferta* Sm. var. *conferta*	H	Tropical Asia to Australia	RA 74417 (MH); APB 20935 (MBGH)
312	*Smithia conferta* Sm. var. *geminiflora* (Roth) T.Cooke	H	India (throughout)	SVP & APB 20235; APB 20842 (MBGH)
313	*Smithia gracilis* Benth.	H	India (KA, TN, KL; E)	AKP 56166(CALI); SVP & APB 20233 (MBGH)
314	*Smithia hirsuta* Dalzell	H	India (ML, MN, MH, AP, KA, TN, KL; E)	PB 90990 (MH); NM 10358 (TBGT); APB 20732 (MBGH)
315	*Smithia salsuginea* Hence	H	India, China & Myanmar	RA 74323 (CAL, MH); APB 20777 (MBGH)
316	*Smithia sensitiva* Aiton	H	Tropical Asia, Australia & Madagascar	CAB 9438 (MH); RA 64905 (CAL)
317	*Smithia setulosa* Dalzell	H	India (HU, MH, KA, TN, KL; E)	Stocks & Laws.n. (MH); NA 1337 (MH).
318	*Smithia venkobarowii* Gamble var. *glabra* Balan & Predeep	S	India (KL; E)	SVP 20448 (MBGH)
319	*Smithia venkobarowii* Gamble var. *venkobarowii*	S	India (KL; E)	SVP & APB 20555; APB 20717 (MBGH)
	85. *Sohmaea* H.Ohashi & K.Ohashi			
320	*Sohmaea laxiflora* (DC.) H.Ohashi & K.Ohashi *Desmodium laxiflorum* DC.	H	Tropical & subtropical Asia	PM 33038 (CALI); SVP 20912 (MBGH)
321	*Sohmaea zonata* (Miq.)H.Ohashi & K.Ohashi *Desmodium zonatum* Miq.	H	Tropical & subtropical Asia	AES 12893 (TBGT)

	Name of taxa	Habit	Native to	Vouchers/ Reference
	86. *Sophora* L.			
322	*Sophora velutina* Lindl.	S	Indian subcontinent, China & Philippines	JLE 19959 (MH); NS 5780 (CALI)
323	*Sophora wightii* Baker	S	Indian subcontinent, China to Jawa	Vide Sasidharan (2011)
	87. *Spatholobus* Hassk.			
324	*Spatholobus parviflorus* (DC.) Kuntze	CS	Indo-Malesia	SVP & APB 20654; APB 20045 & 20840 (MBGH)
325	*Spatholobus purpureus* Benth. ex Baker	CS	India (MH, KA, TN, KL; E)	SVP & APB 20767; APB 20818 (MBGH)
	88. *Stylosanthes* Sw.			
326	*Stylosanthes fruticosa* (Retz.) Alston	S	India, Sri Lanka, Africa & Madagascar	SVP 20640; SVP & APB 20571 (MBGH)
	89. *Tadehagi* H.ohashi			
327	*Tadehagi triquetra* (L.) H.Ohashi *Desmodium triquetrum* (L.) DC.	S	Tropical & subtropical Asia	APB 20844; SVP & APB 20777 (MBGH)
	90. *Tephrosia* Pers.			
328	*Tephrosia canarensis* J.R.Drum.	S	India (MH, KA, TN, KL; E)	KR 74792 (CAL)
329	*Tephrosia candida* DC.	S	Indian subcontinent	APB 16212 (MBGH)
330	*Tephrosia fusca* Wight & Arn.	S	India (TN, KL; E)	APB 16248 (MBGH)
331	*Tephrosia hookeriana* Wight & Arn.	S	India & Sri Lanka	SVP & APB 20240 & 20578 (MBGH)
332	*Tephrosia maxima* (L.) Pres.	S	India & Sri Lanka	SCN 1084 (CALI); SVP & APB 20595
333	*Tephrosia pulcherrima* (Baker) Wight ex Gamble	S	India & Sri Lanka	SVP 20069; APB 20748 & 20875
334	*Tephrosia pumila* (Lam.) Pers.	H	Paleotropics	SVP & APB 20583; APB 16212 (MBGH)
335	*Tephrosia purpurea* (L.) Pers.	S	Indo-Malesia, Africa to Soutwest Pacific	SVP 10279; APB 20043 & 16288 (MBGH)
336	*Tephrosia senticosa* (L.) Pers.	S	India, Myanmar & Sri Lanka	PM 34340 (CALI)
337	*Tephrosia tinctoria* Pers.	S	India & Sri Lanka	SVP 20422; APB 16233 & 20828 (MBGH)
338	*Tephrosia travancorica* Thoth. & D.N.Das	S	India (KL; E)	Vide Thothathri & Das (1991)
339	*Tephrosia villosa* (L.) Pers	S	Southern Asia & Africa	SVP& APB 202462; APB 16284 (MBGH)
340	*Tephrosia wynaadensis* J.R.Drumm.	S	India (KL; E)	CAB 5684 (K); NCN 64486 (MH)
	91. *Teramnus* P. Browne			
341	*Teramnus labialis* (L.f.) Spreng.	CS	Tropics & Subtropics	PM 33568 (CALI); SVP 20461 (MBGH)
342	*Teramnus mollis* Benth.	CS	Indian subcontinent & Indonesia	RA 69941 (MH); SVP 20918 (MBGH)
	92. *Uraria* Desv.			
343	*Uraria lagopodioides* (L.) DC.	H	Tropical Asia to Pacific	JA 12159 (CALI); SVP 20473 (MBGH)
344	*Uraria rufescens* (DC.) Schindl.	S	Indo-Malesia	SVP & APB 20706; APB 20845 (MBGH)
	93. *Vigna* Savi			
345	*Vigna aconitifolia* (Jacq.) Marechal	CS	Indo-Malesia to Australia	Vide Sasidharan (2011)
346	*Vigna dalzelliana* (Kuntze) Verdc.	TH	India, Pakistan & Indo-China	APB 20787, 20847 & 20848 (MBGH)
347	*Vigna mungo* (L.) Hepper	H	India	KR 48461(CAL); MCL 78 (RHK).
348	*Vigna pilosa* (Roxb.) Baker	TH	Southern & Southeastern Asia	VSR 58260 (MH); APB 16266 (MBGH)
349	*Vigna radiata* (L.) R.Wilczek	TH	Tropical Asia to Australia	SVP 20097 (MBGH)
350	*Vigna sathishiana* Balan & Predeep	TH	India (KL; E)	APB 21004 (MH)
351	*Vigna sublobata* (Roxb.)Babu & S.K.Sharma	TH	Tropical Asia to Australia	SVP & APB 20088 & 20960 (MBGH)
352	*Vigna trilobata* (L.) Verdc.	TH	Indo-Malesia	TAR 8145 (CAL); SVP 20443 (MBGH)
353	*Vigna umbellata* (Thunb.) Ohwi & H.Ohashi	TH	Tropical & subtropical Asia	SVP & APB 20946; APB 20718 (MBGH)
354	*Vigna unguiculata* (L.) Walp. subsp. *cylindrica* (L.) Verdc.	TH	Paleotropics	SVP & APB 20446 (MBGH)

	Name of taxa	Habit	Native to	Vouchers/ Reference
355	*Vigna vexillata* (L.) A.Rich. var. *angustifolia* (Schumach. & Thonn.) Baker	TH	Paleotropics	NCN 64437 (MH); AKP 56098; JA 17916 (CALI)
356	*Vigna vexillata* var. *vexillata*	TH	Paleotropics	Vide Sasidharan (2011)
357	*Vigna vexillata* var. *wightii* (Benth. ex Bedd.) Babu & S.K.Sharma	TH	India (KA, TN, KL; E)	SVP & APB 20946; APB 20751 (MBGH)
	94. *Wajira* Thulin			
358	*Wajira grahamiana* (Wight & Arn.) Thulin & Lavin *Vigna grahamiana* (Wight & Arn.) Verdc.	TH	India, Sri Lanka & Thailand	JLE 25773 (MH)
	95. *Zornia* J.F.Gmel.			
359	*Zornia diphylla* (L.) Pers. var. *diphylla*	H	Indian subcontinent to Indo-China	SVP 20478; SVP & APB 20590 (MBGH)
360	*Zornia diphylla* var. *quilonensis* (Ravi) Krishnaraj & N.Mohanan	H	India & Sri Lanka	TAR 7970 (CAL); SVP 20004 (MBGH)
361	*Zornia gibbosa* Span.	H	Tropical & subtropal Asia	VSR 66998 (MH); SVP 20075 (MBGH)

Table 2. List of introduced and naturalized legumes documented from Kerala.

	Name of taxa	Habit	Native	Vouchers/ Reference
1	*Calapagonium mucunoides* Desv.	H	Tropical America	APB 16277 (MBGH); KAA 3678 (CMPR)
2	*Centrosema molle* Mart. ex Benth.	CS	America	JA 12401 (CALI); SVP & APB 20189 (MBGH)
3	*Clitoria ternatea* L. var. *ternatea*	TH	Tropical Africa & Arabian Peninsula	AA 64770; MM 52776 (MH); SVP 10043 (MBGH)
4	*Crotalaria incana* L. subsp. *incana*	S	America	NR 4050 (MH); SMT 702 (CALI)
5	*Crotalaria incana* L. subsp. *purpurascens* (Lam.) Milne-Redh.	S	Ethiopia & Senegal	Vide Jabbar et al. (2010)
6	*Crotalaria micans* Link	S	Tropical America	SVP 20413; APB 20897; SVP & APB 20769 (MBGH)
7	*Desmodium intortum* (Mill.) Urb.	H	America	APB 20642 & 20682; APB & HS 20690 (MH)
8	*Desmodium scorpiurus* (Sw.) Desv.	H	America	SVP 20540; APB 20685 (MBGH)
9	*Desmodium tortuosum* (Sw.) DC	H	Tropical America	SVP 20504 (MBGH)
10	*Desmodium uncinatum* (Jacq.) DC.	H	Tropical America	SVP 20031; SVP & APB 20275 (MBGH)
11	*Indigofera arrecta* Hochst. ex A.Rich.	S	Tropical Africa	Vide Sasidharan (2011)
12	*Macroptilium lathyroides* (L.) Urb.	TH	Tropical America	Vide Prabhukumar et al. (2016)
13	*Mimosa diplotricha* C.Wright *M. diplotricha* var. *inermis* (Adelb.) Veldkamp	CS	Tropical America	SVP 20508; APB 20794 (MBGH)
14	*Mimosa pudica* L.	H	South America	SVP 10040 (MBGH)
15	*Senna alata* (L.) Roxb.	S	Tropical America	SCN 1275 (CALI); SVP 20999 (MBGH)
16	*Senna didymobotrya* (Fresen.) H.S.Irwin & Barnebey	S	Tropical East Africa	SVP 10045 & 20030 (MBGH)
17	*Senna hirsuta* (L.) H.S.Irwin & Barneby	S	Tropical America	SVP 10044; SVP & APB 20249 (MBGH)
18	*Senna occidentalis* (L.) Link	S	Tropical America	PM 28727 (CALI); SVP 13278 (MBGH)
19	*Senna septemtrionalis* (Viv.) H.S.Irwin & Barneby var. *septemtrionalis*	S	Tropical Africa & Central America	SVP 20025; APB 20827 (MBGH)
20	*Senna sophera* (L.) Roxb.	S	Tropical America	VSR 58695 (CAL); APB 20887 (MBGH)
21	*Senna tora* (L.) Roxb.	H	South & Central America	APB 20759; SVP 20786
22	*Senna uniflora* (Mill.) H.S.Irwin & Barneby	H	Tropical America	SVP 20804 (MBGH)
23	*Sesbania sericea* (Willd.) Link	S	Arabia & Tropical Africa	MM 120188 (MH)
24	*Sesbania speciosa* Taub. ex Engl.	S	Africa	Vide Krishnaraj et al. (2012)
25	*Stylosanthes guianensis* (Aubl.) Sw.	H	Tropical America	APB 20976 (MBGH)
26	*Stylosanthes hamata* (L.) Taub.	H	Tropical America	APB 20877 (MBGH)
27	*Trifolium repens* L.	TH	Europe	SVP 20026 & 20981 (MBGH)
28	*Vigna hosei* (Craib.) Backer	TH	Southeastern Asia & East Africa	Vide Krishnaraj et al. (2012)

Table 3. List of introduced legumes under cultivation in Kerala.

	Name of taxa	Habit	Native	Vouchers/ Reference
1	*Acacia auriculiformis* A.Cunn. ex Benth.	T	Tropical Australia	SVP 20033 & 20506 (MBGH)
2	*Acacia dealbata* Link	T	Tropical Australia	Vide Sasidharan (2011)
3	*Acacia decurrens* Willd.	T	Australia	Vide Sasidharan (2011)
4	*Acacia mangium* Willd.	T	Australia	SVP & APB 20789 (MBGH)
5	*Acacia mearnsii* De Wild.	T	Southeastern Australia	SVP & APB 00201 & 20790 (MBGH)
6	*Acacia melanoxylon* R.Br.	T	Southeastern Australia	APB 20787 (MBGH)
7	*Albizia saman* (Jacq.) F.Muell. *Samanea saman* (Jacq.) Merr.	T	Central & South America	NS 5448 (KFRI); APB 30320 (MBGH)
8	*Amherstia nobilis* Wall.	T	Myanmar to Thailand	APB 16399 (MBGH)
9	*Arachis glabrata* Benth.	H	South America	APB 16203 (MBGH)
10	*Arachis hypoegea* L.	H	South America	SVP 20465 (MBGH)
11	*Arachis pintoi* Krapov. & W.C. Greg.	H	South America	APB 16218 (MBGH)
12	*Bauhinia galpinii* N.E.Br.	S	Africa	SVP 20693 (MBGH)
13	*Bauhinia tomentosa* L.	S	Africa to Arabian Peninsula	SCN 2057 (CALI); SVP & APB 30022 (MBGH)
14	*Brownea coccinea* Jacq.	T	South America	MCL 2233 (RHK); APB 16333 (MBGH)
15	*Brownea grandiceps* Jacq.	T	South America	APB 16301 (MBGH)
16	*Caesalpinia pulcherrima* (L.) Sw.	S	Tropical America	APB 20690 (MBGH)
17	*Calliandra brevipes* Benth.	S	South America	APB 16277 (MBGH)
18	*Calliandra calothyrsus* Meisn.	S	Central America	SVP & APB 20090 (MBGH)
19	*Calliandra emarginata* Benth.	S	Tropical America	APB 16303 (MBGH)
20	*Calliandra haematocephala* Hassk.	S	Bolivia	APB 16301 (MBGH)
21	*Calliandra surinamensis* Benth.	S	Tropical America	SVP & APB 20091 (MBGH)
22	*Cassia grandis* L. f.	T	Tropical America	SVP 20909 (MBGH)
23	*Cassia javanica* L. subsp. *javanica*	T	Malesia to Papuasia	SVP & APB 20629 (MBGH)
24	*Castanospermum australe* A.Cunn. & C.Fraser	T	Australia	vide Sasidharan (2002)
25	*Christia vespertilionis* (L.f.) Bakh. F	CS	Southeastern Asia	MD 3393 (TBGT);
26	*Cicer arietinum* L.	H	Southeastern Asia	Vide Sasidharan (2011)
27	*Clitoria ternatea* Linn. var. *pleniflora* Fantz	TH	Neotropics	SVP 20799 (MBGH)
28	*Cytisus scoparius* (L.) Link	S	Europe	APB 20918 (MBGH)
29	*Delonix elata* (L.) Gamble	T	Africa	APB 20077 (MBGH)
30	*Delonix regia* (Bojer ex Hook.) Raf.	T	Madagascar	SCN 1784 (CALI); SVP 10277 (MBGH)
31	*Enterolobium cyclocarpum* (Jacq.) Griseb	T	South America	NS 5587 (KFRI); SVP & APB 20669 (MBGH)
32	*Erythrina x sykesii* Barneby & Krukoff	T	South America	Vide Sasidharan (2011)
33	*Gliricidia sepium* (Jacq.) Kunth ex Walp.	T	America	SVP & APB 20184 (MBGH)
34	*Hymenaea verrucosa* Gaertn.	T	South Africa	SVP 20930 (MBGH)
35	*Lespedeza bicolor* Turcz.	S	Japan	Vide Sasidharan (2011)
36	*Leucaena leucocephala* (Lam.) de Wit	T	Tropical America	MCL 421 (RHK); SVP 10278 (MBGH)
37	*Libidibia coriaria* (Jacq.) Schltdl. *Caesalpinia coriaria* (Jacq.) Willd.	T	Central America	SVP & APB 30302 (MBGH)
38	*Mucuna pruriens* (L.) DC var. *utilis* (Wall. ex Wight) L.H.Bailey	CS	Southeastern Asia	Vide Sasidharan (2011)
39	*Paraserianthes falcataria* (L.) I.C.Nielsen	T	New Guinea	SVP & APB20079 (MBGH)
40	*Parkia biglandulosa* Wight & Arn.	T	Bangladesh & Myanmar	VTA 1089 (RHK)
41	*Peltophorum pterocarpum*(DC.) Backer ex K.Heyne	T	Indo-China to Australia	APB 20187; SVP 68482 (MBGH)
42	*Pericopsis mooniana* Thwaites	T	Sri Lanka, Indonesia, Malesia to New Guinea	PM 32349 (CALI)

	Name of taxa	Habit	Native	Vouchers/ Reference
43	*Phaseolus coccineus* L.	CS	Central America	Vide Sasidharan (2011)
44	*Phaseolus lunatus* L.	CS	South America	SVP & APB 20233 (MBGH)
45	*Phaseolus vulgaris* L.	TH	Central America	SVP & APB 20225 (MBGH)
46	*Phyllodium longipes* (Craib) Schindl. *Desmodium longipes* Craib	S	China to Indo-China	APB 15518 (MBGH)
47	*Pisum sativum* L.	CH	Central Asia & Europe	Vide Sasidharan (2011)
48	*Psophocarpus tetragonolobus* (L.) DC.	CS	New Guinea	VTA 596 (RHK); SVP & APB 20688 (MBGH)
49	*Pithecellobium dulce* (Roxb.) Benth.	T	Tropical America	SCN 2215 (CALI); SVP & APB 20260 (MBGH)
50	*Prosopis juliflora* (Sw.) DC.	T	America	VTA 69 (RHK); SVP & APB 20259 (MBGH)
51	*Senegalia mellifera* (Benth.) Seigler & Ebinger	T	Africa	NS 5586 (KFRI); SVP & APB 20587 (MBGH)
52	*Senna fruticosa* (Mill.) H.S.Irwin & Barneby	S	Tropical America	APB 16266 (MBGH)
53	*Senna polyphylla* (Jacq.) H.S.Irwin & Barneby	S	Caribbean Islands	Sasidharan (2011)
54	*Senna siamea* (Lam.) H.S.Irwin & Barneby	T	Southeastern Asia	PM 33213 (CALI); SVP 13287 (MBGH)
55	*Senna spectabilis* (DC.) H.S.Irwin & Barneby	T	Trop. America	SVP & APB 20564; SVP 20689
56	*Sesbania grandiflora* Poir.	T	Malesia to New Guinea	SVP 20812 (MBGH)
57	*Tamarindus indica* L.	T	Tropical Africa	SVP 13286 (MBGH)
58	*Vachellia farnesiana* (L.) Wight & Arn.	T	Tropical America	Sasidharan (2011)
59	*Vigna unguiculata* (L.) Walp. subsp. *unguiculata*	TH	Africa	SVP & APB 20916 (MBGH)

Habit (H—Herb | TH—Trailing/Twining Herb | S—Shrub | CS—Climbing Shrub | T—Tree) | **Native** (AP—Andhra Pradesh | AN—Andaman & Nicobar Islands | DL—Delhi | GA—Goa | GJ—Gujarat | KA—Karnataka | KL—Kerala | MH—Maharashtra | ML—Meghalaya | MN—Manipur | MP—Madhya Pradesh | OD—Odisha | RJ—Rajasthan | TN—Tamil Nadu; E—Endemic) | **Voucher specimens** (AAA—A.A. Ansari | AGP—A.G. Pandurangan | AKP—A.K.Pradeep | AM—A. Meebold | AN—A. Nazarudeen | APB—Anoop P. Balan | BDS—B.D. Sharma | CAB—C.A. Babu | CEC—C.E.C. Fischer | EV—E. Vajravelu | JA—Jomy Augastine | JJ—J. Joseph | JLE—J.L. Ellis | JSG—J.S. Gamble | KAA— K.A. Anilkumar,KKN—K.K.N. Nair | KMS—K.M. Sebastine | KNS—K.N. Subramanian | KR—K. Ramamurthy | KV—K. Vivekananthan | MAL—M.A. Lawson | MC—M.Chandrabose | MCL—M.C. Luckose | MD—Mathew Dan | MM—M. Mohanan | MRR—M. Rama Rao | NA—N. Anilkumar | NCN—N.C. Nair | NM—N. Mohanan | NR—N. Ravi | NS—N. Sasidharan | PB—P. Bhargavan | PM—Philip Mathew | RA—R. Ansari,RG—R. Gopalan | RHB—R.H. Beddome | SCN—Sunil C.N. | SMT—Sibichen M. Thomas | SVP—S.V. Predeep | TAR—T. A. Rao | TS—T. Sabu | VDM—Van der Maesen | VGA—V.G. Augusthy,VN—V. Narayanaswami | VSR—V.S. Ramachandran | VTA—V.T. Antony).

About one-third of the legumes in Kerala have known medicinal properties (Kirtikar & Basu 1918; Ambasta 1986; Parrota 2001). These include *Abrus precatorius*, *Butea monosperma*, *Clitoria ternatea*, *Codariocalyx motorius*, *Cullen corylifolia*, *Indigofera tinctoria*, *Kingiodendro*n *pinnatum*, *Mucuna pruriens*, *Pongamia pinnata*, *Pseudarthria viscida*, and *Saraca asoca*. *Centrosema molle*, *Desmodium intortum*, *Leucaena leucocephala, Macrotyloma uniflorum*, *Sesbania sesban, Stylosanthes guianensis*, and *S. hamata* are the forage legumes found in the state. *Calopogonium mucunoides*, *Mucuna bracteata*, and *Pueraria phaseoloides* are grown as cover crops in rubber plantations.

Ornamental legumes

Amherstia nobilis, *Arachis glabrata*, *A. pintoi*, *Brownea coccinea*, *B. grandiceps*, *Bauhinia* spp., *Caesalpinia pulcherrima*, *Cassia* spp., *Clitoria ternatea*, and *Senna* spp. are widely grown in Kerala for ornamental purposes. *Albizia saman*, *Castanospermum australe*, *Cassia javanica*, *Delonix elata*, *D. regia*, *Libidibia coriaria*, *Millettia peguensis*, *Parkia biglandulosa*, and *Peltophorum pterocarpum* are the common avenue trees in the state.

Invasive legumes

Exotic legumes like *Centrosema molle*, *Mimosa diplotricha*, *Senna hirsuta*, *S. occidentalis*, *S. sophera*, *S. tora*, among others have extensively invaded the degraded forest areas and open wastelands throughout the state and are causing severe threat to the native flora. Several forage legumes introduded have escaped from farms and have become invasive in the plains especially by the road-sides during the last two decades. *Desmodium scorpiurus*, *D. tortuosum*, *Stylosanthes guianensis*, and *S. hamata* have become a serious threat to indigenous plants in the plains. *Desmodium intortum* and *D. uncinatum* are emerging as rapidly multiplying weeds in the high ranges in Idukki District. *Senna uniflora* is a recently reported weed in the plains of central Kerala.

Excluded legumes

Five legumes previously reported from the state of

Kerala (Saidharan 2004; Nayar et al. 2006) have been excluded in this checklist due to the various reasons given below:

1. *Desmodium caudatum* (Thunb.) DC.: reported from Malappuram District (Sivarajan & Mathew 1997) based on Philip Mathew 33038 (CALI) was a misidentification of *Sohmaea laxiflora* (DC.) H.Ohashi & K.Ohashi

2. *Humboldtia laurifolia* Vahl: Robert Wight's collection of '*H. laurifolia'* from 'Malabar' region of India 180 years ago was found to be a misidentification of *H. vahliana* Wight (Balan et al. 2016).

3. *Indigofera barberi* Gamble: No specimens or record of collection from Kerala found.

4. *Rhynchosia rothii* Benth. ex Aitch.: Reported from Silent valley National Park in Palakkad District (Manilal 1988) based on T. Sabu 10897 (CALI) was a misidentification of *Neonotonia wightii* (Arn.) J.A.Lackey.

5. *Vigna bourneae* Gamble: No specimens or record of collection from Kerala found.

Notes

Sibichen & Nampy (2007) described *Crotalaria kurisumalayana,* a taxon closely allied to *C. multiflora* Benth. from the Vagamon Hills of central Kerala. *C. multiflora* is an Indo-Sri Lankan species distributed in the grasslands and open hill slopes of higher elevations. The authors distinguished *C. kurisumalayana* from *C. multiflora*, mainly based on the shape of leaves, lax racemes, and sericeous ferruginous pods. Since these characters are highly overlapping, Krishnaraj & Mohanan (2012) reduced *C. kurisumalayana* to a variety of *C. multiflora* and identified the presence or absence of purple striations as the main distinguishing characters. Field studies, however, revealed that this purple striation is also not consistent and therefore the trinomial is reduced to a synonym of *C. multiflora.*

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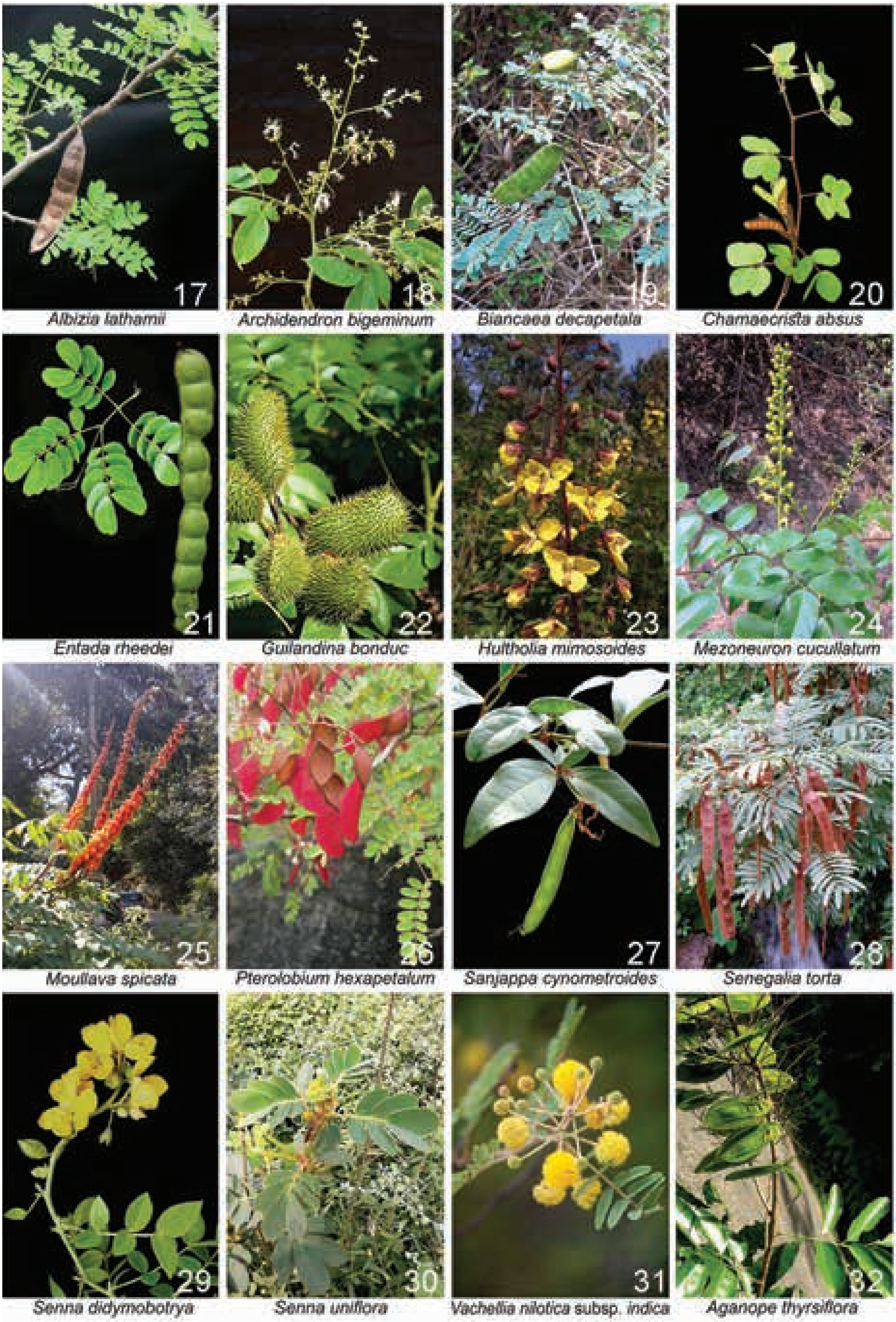
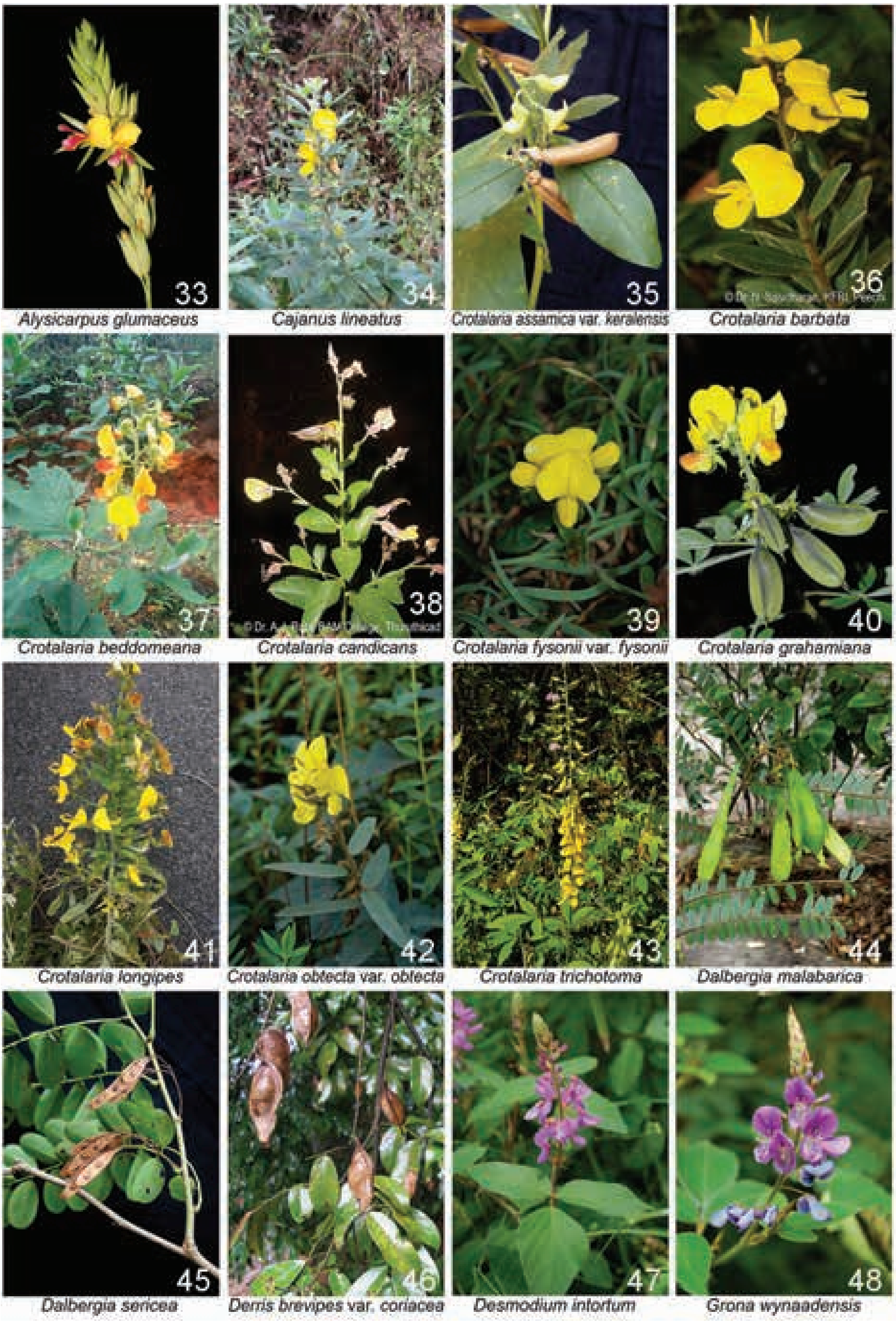
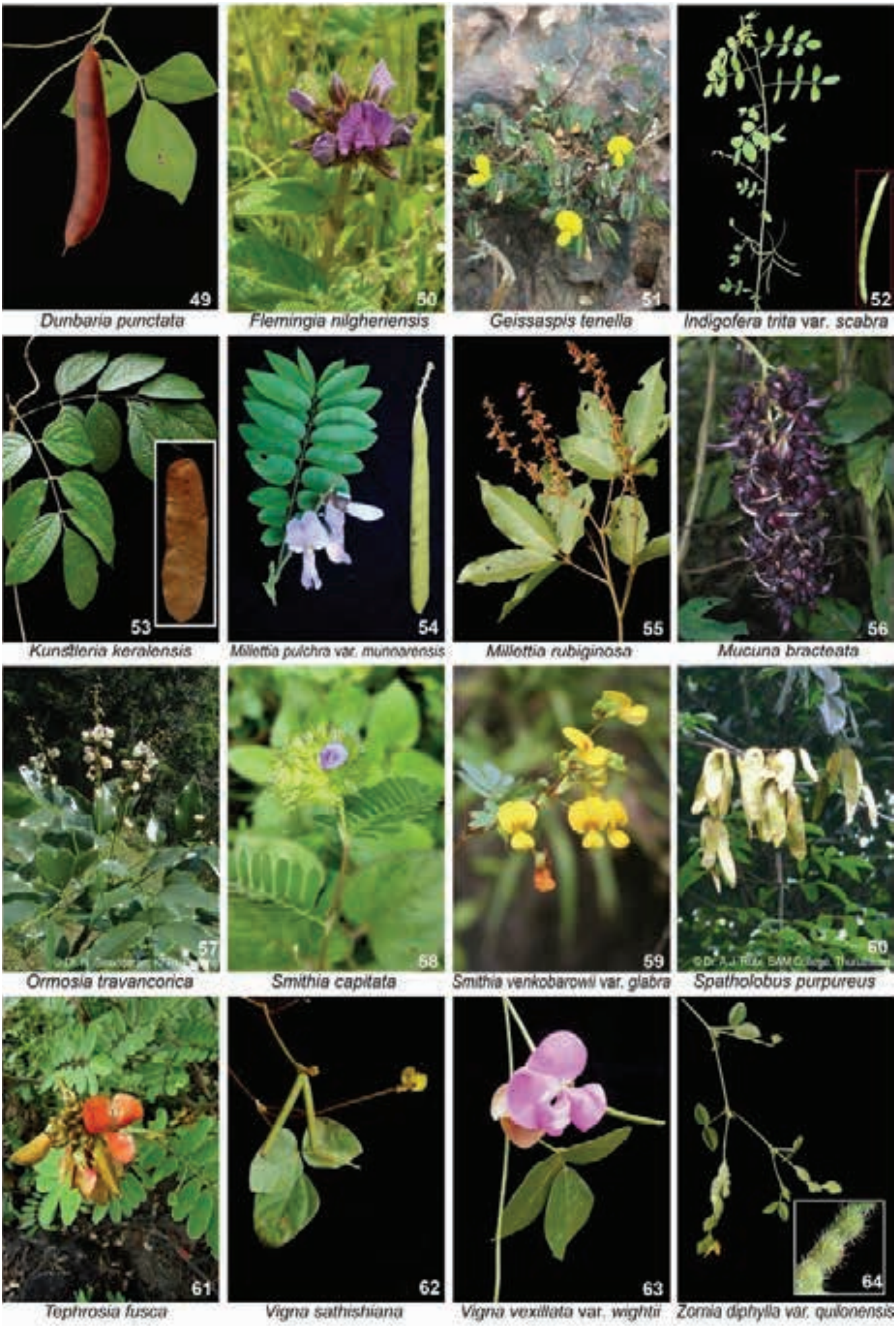
Images 1–16. Endemic or lesser known legumes of India, found in Kerala. © Authors, otherwise it is mentioned in the images.



Images 17–32 . Endemic or lesser known legumes of India, found in Kerala. © Authors, otherwise it is mentioned in the images.



Images 33–48. Endemic or lesser known legumes of India, found in Kerala. © Authors, otherwise it is mentioned in the images.



49 *Dunbaria punctata* · 50 *Flemingia nilgheriensis* · 51 *Geissaspis tenella* · 52 *Indigofera trita* var. *scabra*
53 *Kunstleria keralensis* · 54 *Millettia pulchra* var. *munnarensis* · 55 *Millettia rubiginosa* · 56 *Mucuna bracteata*
57 *Ormosia travancorica* · 58 *Smithia capitata* · 59 *Smithia venkobarowii* var. *glabra* · 60 *Spatholobus purpureus*
61 *Tephrosia fusca* · 62 *Vigna sathishiana* · 63 *Vigna vexillata* var. *wightii* · 64 *Zornia diphylla* var. *quilonensis*

Images 49–64. Endemic or lesser known legumes of India, found in Kerala. © Authors, otherwise it is mentioned in the images.

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COMMUNICATION

Legumes (Angiosperms: Fabaceae) of Bagalkot District, Karnataka, India

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Abstract: Fabaceae Lindl. or Leguminosae is one of the largest families of Angiosperms. Due to adaptability in various climatic conditions, members of the family Fabaceae are worldwide in their distribution. Globally, Fabaceae is represented by 770 genera and 19,500 taxa. Bagalkot is one of the largest districts of northern Karnataka and falls under the Deccan Peninsular region of India. The study area (Bagalkot District) is a rain shadow region and remains dry and hot throughout year. During floristic analysis of the District the authors recorded 157 species of legumes, which is communicated here in relation to habitat, life forms, distribution, classification and their importance.

Keywords: Deccan, Leguminosae, southern India, sub-family.

Kannada: ಫ್ಯಾಬಾಸೀ ಲಿಂಡ್ಲ ಅಥವಾ ಲೆಗುಮಿನೋಸೀ ಆಂಜಿಯೋಸ್ಪರ್ಮ್ಸ್‌ಗಳಲ್ಲಿರುವ ಅತಿದೊಡ್ಡ ಸಸ್ಯ ಕುಟುಂಬಗಳಲ್ಲಿ ಒಂದು. ಫ್ಯಾಬಾಸೀ ಕುಟುಂಬದ ಸದಸ್ಯರು ವಿವಿಧ ರೀತಿಯ ಹವಾಮಾನಕ್ಕೆ ಹೊಂದಿಕೊಳ್ಳುವ ಸಾಮರ್ಥ್ಯದಿಂದಾಗಿ, ವಿಶ್ವಾದ್ಯಂತ ಹರಡಿಕೊಂಡಿವೆ. ಜಾಗತಿಕವಾಗಿ, ಫ್ಯಾಬೇಸಿಯನ್ನು 770 ತಳಿಗಳು ಮತ್ತು 19,500 ಗುಂಪುಗಳು ಪ್ರತಿನಿಧಿಸುತ್ತವೆ. ಬಾಗಲಕೋಟೆ ಉತ್ತರ ಕರ್ನಾಟಕದ ಅತಿದೊಡ್ಡ ಜಿಲ್ಲೆಗಳಲ್ಲಿ ಒಂದಾಗಿದೆ ಮತ್ತು ಇದು ಭಾರತದ ಡೆಕ್ಕನ್ ಪೆನಿನ್ಸುಲರ್ ಪ್ರದೇಶದ ಅಡಿಯಲ್ಲಿ ಬರುತ್ತದೆ. ಅಧ್ಯಯನ ಪ್ರದೇಶ (ಬಾಗಲಕೋಟೆ) ಮಳೆ ನೆರಳು ಪ್ರದೇಶವಾಗಿದ್ದು ವರ್ಷಪೂರ್ತಿ ಶುಷ್ಕ ಮತ್ತು ಉಷ್ಣ ವಾತಾವರಣ ಹೊಂದಿರುತ್ತದೆ. ಜಿಲ್ಲೆಯ ಸಸ್ಯಗಳ ಅಧ್ಯಯನ ಹಾಗೂ ವಿಶ್ಲೇಷಣೆಯ ಸಮಯದಲ್ಲಿ ಲೇಖಕರು ಇಲ್ಲಿ ನಮೂದಿಸಿದ 157 ಜಾತಿಯ ಲೆಗುಮ್ಸ್‌ಗಳ ಆವಾಸಸ್ಥಾನ, ಜೀವ ವಿಧಗಳು, ಹಂಚಿಕೆ, ವರ್ಗೀಕರಣ ಮತ್ತು ಅವುಗಳ ಪ್ರಾಮುಖ್ಯತೆಯನ್ನು ಇಲ್ಲಿ ದಾಖಲಿಸಿದ್ದಾರೆ.

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Author contribution: JVD—Field exploration, collection, herbarium preparation, identification, herbarium consultation and photography. RP—Field exploration, collection, laboratory studies, literature survey and local communication. SSK—Filed exploration, collection, data analysis and nomenclatural updates. VDJ—Laboratory analysis, literature survey, ethnobotanical data. SRY—Field exploration, collection, identification, laboratory analysis and photography.

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INTRODUCTION

Legumes are the third largest group of Angiosperms in terms of species number after Orchidaceae and Asteraceae and the second economically most important family after Poaceae (FAO 2016). Globally Fabaceae consists of 770 genera and over 19,500 species (LPWG 2017) in India, Fabaceae are represented by 147 genera, 805 species, 33 sub-species, 155 varieties and 14 forms (Sanjappa 1991, 1995; Dave 2004; Chaudhary & Khan 2005; Ansari 2008; Jabbar et al. 2010; Chavan et al. 2013; Gaikwad et al. 2014). Legumes are important food crops providing highly nutritious sources of protein and micronutrients. These micronutrients greatly benefit health and livelihoods, particularly in developing countries. They have been domesticated alongside grasses in different areas of the world since the beginning of agriculture and have played a key role in early agricultural development (Gepts et al. 2005; Hancock 2012; Yahara et al. 2013). Wild bean plants are also uniquely important as fodder and green manure in both temperate and tropical regions, and are used for their wood, tannins, oils and resins, in the manufacture of varnishes, paints, dyes and medicines and in the horticultural trading (LPWG 2017). Apart from socio-economic importance, legumes are equally beneficial for ecosystems and recycling by nitrogen fixation, improve soil porosity and structure, recycling of nutrients, decrease soil pH, reduction of soil compaction and in rotation with cereals they provide a source of slow-release nitrogen to sustainable cropping system (USDA 1998; Popelka et al. 2004). Many legumes play an important ecological role as they are major components of dry deciduous forests, ground cover and many are cultivated as major crops of the region and some have ornamental potential. In brief, legumes play a major role in socio-economic development of the region. Therefore, the present study focuses on the preparation of the database of legumes of Bagalkot District. While surveying this area it is observed that the flora of this district is dominated by the family Fabaceae. The probable reason of this high diversity may be adaptability to various habitats.

MATERIALS AND METHODS

Study area

Bagalkot is a district of northern Karnataka State separated from Vijayapura in 1997. The whole region falls under the Deccan Plateau and most of it comes under a rain shadow area. Due to low rainfall and hot & dry climatic conditions, the region is dominated by dry deciduous forests, scrub jungles, and vast seasonal grasslands. The district lies at 16.316^{0}N, 76.000^{0}E and 533m altitude and having a total area of 6,552km^2 (Dalavi et al. 2019). The district is divided into six sub-district regions, namely: Badami, Bagalkot, Bilgi, Hungund, Jamkhandi and Mudhol (Fig. 1). Rabakavi-Banahatti Guledgudda and Ilkal are newly divided taluk places. Major habitats of the districts are large rocky hills, gravelly slopes, sandy plains, perennial & seasonal lakes, marshy & saline areas, ditches, rivers, and black soil plains. Average rainfall recorded in the last decade ranges 337–819 mm and the average temperature reported ranges 17–42^{0}C. June to September is the monsoon season and February to May is the actual summer season. Due to hot arid conditions the area is blessed with spiny and thorny forests interrupted with grasslands.

Data collection

A preliminary list of the species belonging to Fabaceae from Bagalkot District was prepared from all the available floras, revisions and checklists (Gamble 1935; Cooke 1958; Britto 1983; Singh 1988; Sharma & Balakrishnan 1993; Prasad & Singh 2002; Prajapati 2010; Kambhar & Katrahalli 2016; Dalavi et al. 2019). Herbarium studies were carried out by visiting some important herbaria namely BSI, CAL, MH, NGCPR and SUK, which was followed by extensive and intensive field tours throughout the district covering various habitats from June 2014 to January 2020. More than 90 tours were carried out and the data on habitat, distribution, phenology and local uses were recorded. Three to four herbarium specimens were prepared for each collected species by following standard procedures (Rao & Sharma 1990). Identifications were confirmed by using floras, revisions and all the available taxonomic literature (Gamble 1935; Cooke 1958; Matthew 1981; Sharma et al. 1984; Sharma & Balakrishnan 1993; Prasad & Singh 2002; Kanbhar & Katrahalli 2016). Problematic and notable species were identified by direct comparison with identified specimens deposited in BSI, SUK, CAL and digital herbaria such as Herbarium JCB (accessed from January 2014–December 2019), Kew Herbarium Catalogue (accessed from January 2017–March 2020) and JSTOR Global Plants (accessed from February 2017–December 2019). The nomenclature of plant species collected was updated using POWO (Plants of the world online Kew-science accessed from January 2015–December 2019) and Tropicos (tropicos.org accessed

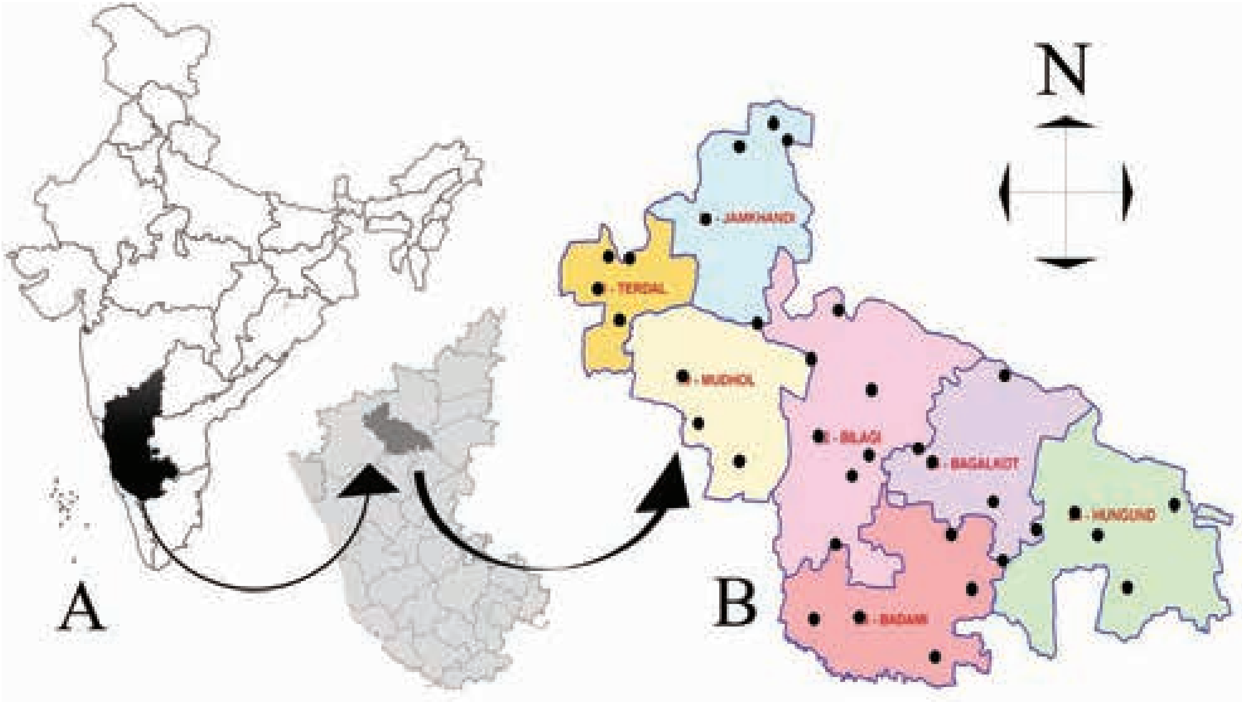

Figure 1. A—Position of Bagalkot District | B—Detailed map of study area.

from January 2017–January 2020). All leguminous taxa are grouped here according to the latest classification of Fabaceae (LPWG 2017) (Table 1). Charts and maps are provided for subfamily-wise classification and study area, respectively. Colour plates for important taxa are also provided for easy identification of species. Ethnobotanical information was collected by direct interaction with local people, ayurvedic practitioners and farmers.

RESULTS

Enumeration

A total of 157 taxa of Fabaceae have been reported from the Bagalkot District of Karnataka which measures about 15% of the total flora. All the legumes of the district belong to four subfamilies of Fabaceae, viz., Cercidoideae, Detarioideae, Caesalpinioideae and Papilionoideae; of which Papilionoideae or Faboideae is the largest subfamily with 45 genera and 106 species followed by Caesalpinioideae with 22 genera & 45 species, Cercidoideae with three genera & four species and Deratioideae with two genera & two species, respectively (Fig. 2). *Crotalaria* L. and *Indigofera* L. are the largest genera with 12 species each, followed by *Rhynchosia* Lour. with 10 taxa and *Alysicarpus* Desv. & *Senna* L. with nine species each. Fabaceae of the district consists of 48 tree species, eight shrubs, eight sub-shrubs, 74 herbs, and 18 climbers & creepers.

Endemism

Some plants are habitat specific and are endemic to peninsular India, viz., *Alysicarpus gamblei* Schindl., *Crotalaria paniculata* Willd., *C. pusilla* Roxb. ex Wight & Arn., *C. vestita* Baker found to be growing on rocky and sandy areas and are endemic to southern peninsular India (Dalavi et al. 2019). *Alysicarpus gamblei* Schindl. is only known from six localities of Karnataka and Maharashtra of which Bagalkot District has the highest population (Dalavi et al. 2019). *Vigna indica* Dixit et al. is also a dominant species of open areas and grasslands endemic to peninsular India. *Mimosa prainiana* Gamble a woody tree endemic to peninsular India which is also important member of dry forests of Bagalkot District.

Ethnobotany and economics

Many wild legumes are used as a source of medicine and food by local people. Pods of *Vachellia nilotica* (L.) P.J.H.Hurter & Mabb. are used to make tooth powder by drying and crushing the seeds; gum exuded from the stem is highly valued and used to cure many diseases and is edible, generally given to pregnant ladies in the form of small pieces mixed with dry fruits; tender branches are used as fodder for goats, timber is used in building and construction. Fresh flowers of *Sesbania grandiflora*

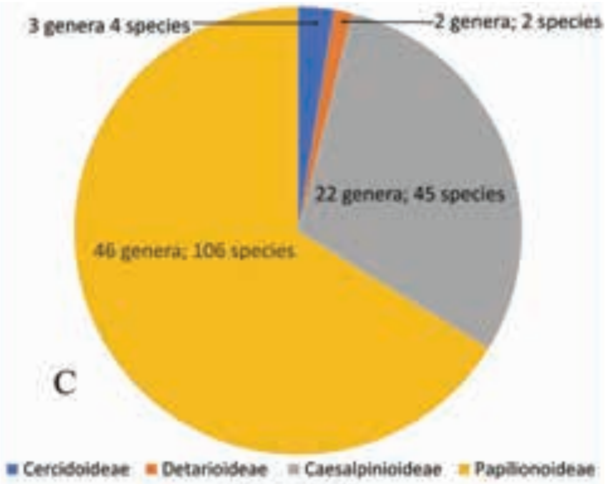

Figure 2. Subfamily wise distribution of legumes of Bagalkot District (as per LPWG 2017).

(L.) Poir are popularly eaten as a wild vegetable. Pericarp of *Vachellia farnesiana* (L.) Wight. & Arn. are dried and chewed to cure coughs. Young pods of *Vigna indica* are eaten raw as well as after cooking. Leaf powder of *Dichrostachys cinerea* (L.) Wight & Arn. is taken in water for common fever. Leaves, roots and seeds of *Senna tora* (L.) Roxb. and *S. occidentalis* (L.) Link are used to cure skin problems like itching and inflammations. Powdered seeds of *Senna sophera* (L.) Roxb. are used against ringworms. Leaf juice of *Guilandina bonduc* L. is taken to cure piles.

Economically important pulses *viz*., *Arachis hypogea* L., *Cajanus cajan* (L.) Huth, *Cyamopsis tetragonoloba* (L.) Taub., *Glycine max* (L.) Merr., *Lablab purpureus* (L.) Sweet, *Phaseolus vulgaris* L., *Pisum sativum* L., *Tamarindus indica* L., *Trigonella foenum-graecum* L., *Vigna aconitifolia* (Jacq.) Marechal, *Vigna mungo* (L.) Hepper, *Vigna radiata* (L.) Wilezek and *Vigna unguiculata* (L.) Walp. are cultivated on a large scale as vegetables. All crop legumes play an important role in the agro-economic development of the region. Avinash & Patil (2018) analysed that among the northern districts of Karnataka, Bagalkot is second largest producer of pulses and leguminous crops.

Acacia auriculiformis A.Cunn. ex Benth., *A. mangium* Willd., *Adenanthera pavonina* L., *Albizia lebbek* (L.) Benth., *Dalbergia sisoo* Roxb. ex DC., *D. latifolia* Roxb., *Delonix regia* (Bojer ex Hook.) Raf., *D. elata* (L.) Gamble, *Cassia fistula* L., *C. javanica* L., *Senna siamea* (Lam.) H.S.Irwin & Barneby, *Clitorea ternatea* L., *Parkia biglandulosa* Wight & Arn., *Pithecellobium dulce* (Roxb.) Benth., *Pongamia pinnata* (L.) Pierre, *Prosopis cineraria* (L.) Druce, *Samanea saman* (Jacq.) Merr. are extensively planted as garden and avenue plants throughout the district.

Wood of *Albizia lebbek* (L.) Benth., *Dalbergia latifolia* Roxb., *D. sisso* Roxb. ex DC., *Tamarindus indica* L., *Senegalia chundra* (Roxb. ex Rottler) Maslin, *Vachellia nilotica* (L.) P.J.H.Hurter & Mabb. is used in the construction of houses and farming equipment.

Guilandina bonduc L., *Sesbania aculeata* (Schreb.) Pers. & *S. sesban* (L.) Merr. are used as bio-fencing plants along farm yards.

Ecology

Apart from the economic potential, some legumes are dominant weeds of the region like *Aeschynomene aspera* L., *A. indica* Burm.f., *Neptunia triquetra* Benth., etc., which grow along water bodies and spread throughout. *N. triquetra* if it enters into a pond ecosystem grows aggressively and forms a dense mat on the water surface and affects other biota. *Alysicarpus bupleurifolius* (L.) DC., *A. tetragonolobus* Edgew., *Cullen corylifolium* (L.) Medik, *Desmodium scorpiurus* (Sw.) Desv. ex DC., *Prosopis juliflora* (Sw.) DC., *Senna occidentalis* (L.) Link, *S. tora* (L.) Roxb., *S. uniflora* (Mill.) H.S.Irwin & Barneby and *Rothia indica* (L.) Druce grow in cultivated fields and have adverse effects on crop productivity. *Gliricidia sepium* (Jacq.) Steud. is one of the invasive tree species rapidly encroaching the forest areas of the region and have negative effects on native flora and the natural ecosystem.

Legumes play some important ecological roles. They are the factories of nitrogen fixation being equipped with root nodules. The study area is an arid zone hence it lacks dense forests. The resulting soil erosion is due to minimum leaf litter which fails to keeps soil moisture constant, however, some legumes, *viz*., *Crotalaria hebecarpa* (DC.) Rudd., *C. orixensis* Rottler ex Willd., *Indigofera linnaei* Ali, *I. linifolia* (L.f.) Retz., *Tephrosia strigosa* (Dalzell) Santapau & Maheshw., *Eleiotis rottleri* Wight & Arn., *E. sororia* (L.) DC., and *Rhynchosia capitata* (B.Heyne ex Roth) DC. form a dense mat on soil surfaces and maintain the moisture.

CONCLUSION

Due to adaptability to the various ecological and geographical conditions Fabaceae are the most dominant family of flora of Bagalkot District. Legumes like *Acacia* Mill., *Albizia* Durazz., *Bauhinia* Plum ex L., *Cassia* L., *Mimosa* L., *Mundulea* (DC) Benth., *Phanera* Lour., *Senegalia* Raf., *Vachellia* Wight & Arn. are the

Table. 1. Checklist of legumes of Bagalkot District as per latest classification LPWG (2017).

	Name of taxon	Habit	Phenology	Habitat & Localities	Exsiccata
Sub-family: **CERCIDOIDEAE** (3 genera 4 species)					
1	*Bauhinia tomentosa* L.*	Tree	Nov–May	Dry deciduous forest (Bd, Bi, G, J, M)	JVD-247 JVD-1204
2	*Phanera purpurea* (L.) Benth.	Tree	Nov–Mar	Deciduous forests/ planted (Bd, Bg, G, H, I)	JVD-1389
3	*Phanera variegata* (L.) Benth.	Tree	Oct–May	Planted as avenue tree (Bg, J, M, N)	JVD-1390
4	*Piliostigma racemosum* (Lam.) Benth.	Tree	Mar–Sept	Deciduous and scrub forest (Bd, Bi, G, H, I, J, M)	JVD-22
Sub-family: **DETARIOIDEAE** (2 genera, 2 species)					
5	*Hardwickia binata* Roxb.	Tree	Aug–Jan	Deciduous forests/ planted (Bd, Bg, Bi, G, J, M)	JVD-1391
6	*Tamarindus indica* L. *	Tree	Apr–Sept	In forest/ planted (Throughout year)	JVD-261
Sub-family: **CAESALPINIOIDEAE** (22 genera, 45 species)					
7	*Acacia auriculiformis* Benth.*	Tree	Jan–Aug	Planted and escaped in wild (Bd, Bg, Bi, J, N, R)	JVD-1392
8	*Acacia mangium* Willd. *	Tree	Jun–Aug	Planted and escaped in wild (Bg, J, N)	JVD-1393
9	*Adenanthera pavonina* L.	Tree	Dec–Apr	Planted (Bd, Bg, J, N, R, T)	JVD-1394
10	*Albizia amara* (Roxb.) Boiv.	Tree	Apr–Aug	Deciduous and scrub forest (Throughout district) (Bd, Bg, Bi, H, J, M)	JVD-172 JVD-1285
11	*Albizia lebbeck* (L.) Benth.	Tree	Apr–Aug	Dry deciduous forests and along roadsides. (Throughout district) (Bd, Bg, Bi, H, I, J, M, R)	JVD-241
12	*Cassia fistula* L.	Tree	Feb–Apr	Along roadsides (Throughout district)	JVD-302
13	*Cassia javanica* L. *	Tree	Mar–Jul	Planted (Bg, H, J, N, R, T)	JVD-1396
14	*Caesalpinia pulcherrima* (L.) Sw. *	Tree	Throughout year	Dry deciduous forests and along roadsides (Throughout district)	JVD-249
15	*Chamaecrista absus* (L.) H.S. Irwin & Barneby	Herb	Aug–Feb	Open forests and wastelands (Throughout district)	JVD-303 JVD-847
16	*Chamaecrista mimosoides* (L.) Greene *	Herb	Jul–Nov	Gravelly slopes (Bd, Bg, Bi, G, J, M, N, T)	JVD-1397
17	*Chamaecrista pumila* (Lam.) K. Larsen.	Herb	Jul–Dec	Open forests and wastelands (Bd, G, J, T)	JVD-304 JVD-928
18	*Delonix regia* (Hook.) Raf. *	Tree	Jan–June	Planted and also escaped (Throughout district)	JVD-1398
19	*Delonix elata* (L.) Gamble *	Tree	Sept–Dec	Dry deciduous forests (Throughout district)	JVD-1399
20	*Dichrostachys cinerea* Wight et Arn.	Tree	Jun–Aug	Dry deciduous forests (Throughout district)	JVD-19 JVD-908 JVD-1291
21	*Guilandina bonduc* L.	Shrubs	Jun–Feb	Cultivated, found along roadsides and open places (Bd, Bi, G, J, M, R)	JVD-250
22	*Lysiloma latisiliquum* (L.) Benth. *	Tree	Throughout year	Planted along roadside and as fodder plant (Throughout district)	JVD-1383
23	*Mimosa hamata* Willd.	Shrub	Jul–Oct	Deciduous forests (Throughout district)	JVD-311 JVD-930 JVD-911 JVD-1209 JVD-1224
24	*Mimosa prainiana* Gamble	Shrubs	Jul–Oct	Deciduous forest (Throughout district)	(Singh 1988 Op. cit.)
25	*Mimosa pudica* L. *	Herb	Jul–Mar	Dry forests and wastelands (Throughout district)	JVD-173
26	*Neptunia triquetra* Benth.	Herb	Nov–May	Stagnant water bodies (H)	(Singh 1988 Op. cit.)
27	*Libidibia coriaria* (Jacq.) Schltdl. *	Shrubs	Throughout year	Open areas (Throughout district) (Bd, Bg, T)	JVD-1385
28	*Parkia biglandulosa* Wight & Arn.	Tree	Nov–May	Planted (Bg, J, M, N)	JVD-1386
29	*Parkinsonia aculeata* L. *	Tree	Mar–Oct	Planted (Bg, J, M, N)	JVD-1387
30	*Peltophorum pterocarpum* Aucp. Non K.Heyne. (DC.) K.Heyne *	Tree	Jul–Jan	Planted and escaped in forest (Ba, J, L, M, N, T)	JVD-171 JVD-1296

	Name of taxon	Habit	Phenology	Habitat & Localities	Exsiccata
31	*Pithecellobium dulce* (Roxb.) Benth. *	Tree	Throughout year	Dry deciduous forests and along roadsides (Throughout district)	JVD-314
32	*Prosopis cineraria* (L.) Druce.	Tree	Sept–Apr	Wastelands, dry deciduous forests and along roadsides (Throughout district)	JVD-316
33	*Prosopis juliflora* (Sw.) DC. *	Tree	Sept–Apr	Dry deciduous forests and along roadsides (Throughout district)	JVD-317 JVD-1268
34	*Samanea saman* (Jacq.) Merr. *	Tree	Apr–Aug	Planted (Bd, Bg, Bi, J, N)	JVD-1395
35	*Senegalia chundra* (Roxb. ex Rottler) Maslin	Tree	Aug–Jan	Dry deciduous forests (Throughout district)	JVD-94
36	*Senegalia rugata* (Lam.) Britton & Rose	Tree	Aug–Jan	Dry deciduous forests (Throughout district)	JVD-232
37	*Senegalia polyacantha* (Willd.) Seigler & Ebinger	Tree	Aug–Apr	Dry deciduous forests and along roadsides (Throughout district)	JVD-237
38	*Senna alexandrina* Mill.	Sub-shrubs	Nov–Jun	Open areas and wastelands (H, I)	JVD-1388
39	*Senna auriculata* (L.) Roxb.	Tree	Jul–Feb	Deciduous forests and open areas (Throughout district)	JVD-159
40	*Senna italica* Mill. subsp. *micrantha* (Brenan) Lock	Tree	Jul–Feb	Deciduous forests and open forests (Bd, Bi, G, H, I)	JVD-264 JVD-874 JVD-875
41	*Senna sophera* (L.) Roxb. *	Sub-shrubs	Oct–Feb	Open areas and wastelands (Throughout district)	JVD-1400
42	*Senna occidentalis* (L.) Link *	Herb	Jul–Feb	Open forests and wastelands (Throughout district)	JVD-68
43	*Senna siamea* (Lam.) H.S.Irwin & Barneby *	Tree	Apr–Feb	Open forests and wastelands (Throughout district)	JVD-266
44	*Senna surattensis* (Burm.f.) H.S. Irwin & Barneby	Tree	Sept–Apr	Cultivated (Bd, J)	JVD-1401
45	*Senna tora* (L.) Roxb. *	Herbs	Jul–Apr	Open areas and wastelands (Throughout district)	JVD-267
46	*Senna uniflora* (Mill.) H.S.Irwin & Barneby *	Herbs	Sept–May	Open areas and wastelands (Throughout district)	JVD-1402
47	*Vachellia eburnea* (L.f.) P.J.H.Hurter & Mabb.	Tree	Aug–Feb	Dry deciduous forests and along roadsides (Throughout district)	JVD-1403
48	*Vachellia farnesiana* (L.) Wight & Arn. *	Small tree	Aug–Feb	Dry deciduous forests (Throughout districts)	JVD-233
49	*Vachellia horrida* (L.) Kyal. & Boatwr.	Small tree	Jul–Jan	Dry deciduous forests (Throughout district)	JVD-204
50	*Vachellia leucophloea* (Roxb.) Maslin	Tree	Aug–Feb	Dry deciduous forests and along road sides (Throughout district)	JVD-236
51	*Vachellia nilotica* (L.) P.J.H. Hurter & Mabb.	Tree	Aug–Mar	Dry deciduous forests and planted along roadsides (Throughout district)	JVD-08
PAPILIONOIDEAE (46 genera, 106 species)					
52	*Abrus precatorius* L.	Climber	Sept–Jun	Dry deciduous forests (Bd, Bi, Bg, G, J, M)	JVD-07 JVD-1211
53	*Alysicarpus bupleurifolius* (L.) DC.	Herb	Aug–Nov	Grasslands and Open areas (Bd, Bg, G, I, J, M, R)	JVD-242
54	*Alysicarpus gamblei* Schindl.	Herb	Aug–Nov	Rocky hills and sandy plains (Bd)	JVD-835
55	*Alysicarpus hamosus* Edgew**.**	Herb	Sept–Nov	Gravelly plains and Grasslands (Throughout district)	JVD-138, JVD-831
56	*Alysicaprus longifolius* (Rottl. ex Spreng.) Wight & Arn.	Herb	Sept–Mar	Open areas and weed of cultivated fields (L, M)	JVD-1404
57	*Alysicarpus monilifer* (L.) DC.	Herb	Aug–Dec	Gravelly plains and Grasslands (Throughout district)	JVD-244 JVD-914 JVD-1230
58	*Alysicarpus ovalifolius* (Schum.) Leonard	Herb	Sept–Dec	Along cultivated fields and wastelands (Bd, Bg, Bi, G, I, J)	JVD-1405
59	*Alysicarpus scariosus* (Spreng.) Thwaites	Herb	Aug–Dec	Seasonal grasslands and wastelands (Bd, L)	JVD-871 JVD-876
60	*Alysicarpus tetragonolobus* Edgew.	Herb	Jul–Dec	Grasslands and Open areas (Bd, Bg, Bi, G, M)	JVD-245
61	*Alysicarpus vaginalis* (L.) DC**.**	Herb	Sept–Dec	Gravelly plains and Grasslands (Throughout district)	JVD-246
62	*Arachis hypogaea* L. *	Herb	Nov–Mar	Cultivated farms (Throughout district)	JVD-1380

	Name of taxon	Habit	Phenology	Habitat & Localities	Exsiccata
63	*Aeschynomene aspera* L.	Herb	Throughout year	Along water bodies (KS)	JVD-238
64	*Aeschynomene indica* L.	Herb	Throughout year	Along water bodies (Bd, Bg, J, R)	JVD-239
65	*Butea monosperma* (Lam.) Taubert	Tree	Dec–May	Dry deciduous forests and along roadsides (Bd, Bg, J, L, M)	JVD-248
66	*Cajanus cajan* (L.) Millspaugh	Shrub	Aug–Apr	Cultivated (Throughout district)	JVD-1381
67	*Cajanus scarabaeoides* (L.) Thouars.	Creeper	Jul–Dec	Grasslands, Wastelands and Open areas (B, J, L, M)	JVD-301 JVD-863
68	*Canavalia ensiformis* (L.) DC. *	Climber	Throughout year	Dry deciduous forests (Bd)	JVD-218
69	*Cicer arietinum* L. *	Herb	Oct–Mar	Cultivated as pulse (Throughout district)	JVD-1382
70	*Clitoria annua* J. Graham	Climber	Aug–Oct	Dry deciduous forests and along roadsides (Bd)	JVD-118
71	*Clitoria ternatea* L. *	Climber	Jun–Jan	Dry deciduous forests and along roadsides (Throughout district)	JVD-305
72	*Crotalaria bifara* L.f.	Twining herb	Sept–Jan	Open areas (Bd, L)	JVD-878
73	*Crotalaria hebecarpa* (DC.) Rudd. *	Herb	Jul–Jan	Grasslands and open areas (Throughout district)	JVD-306
74	*Crotalaria hirsuta* Willd**.**	Herb	Sept–Dec	Rare on gravelly slopes (Bd, C)	JVD-1417
75	*Crotalaria juncea* L.	Herb	Sept–May	Grasslands and open areas (Throughout district)	JVD-167
76	*Crotalaria medicaginea* Lam.	Herb	Oct–May	Grasslands and sandy plains (Bd)	JVD-1405
77	*Crotalaria orixensis* Willd.	Herb	Jun–Jan	Grasslands and open areas (Bd, Bg, J, L)	JVD-307 JVD-1294
78	*Crotalaria pallida* Aiton. Var. *pallida*	Herb	Sept–Apr	Grasslands and open areas (Throughout district)	JVD-308
79	*Crotalaria paniculata* Willd.	Herb	Nov–Apr	Rare on gravelly slopes (Bd)	JVD-1428
80	*Crotalaria pellita* Bertero ex DC.	Herb	Aug–Dec	Grasslands and open areas (Bd, L)	JVD-208 JVD-889 JVD-1283
81	*Crotalaria pusilla* DC.	Herb	Jul–Jan	Grasslands and open areas (Bd, G, H, I)	JVD-309
82	*Crotalaria retusa* L.	Shrub	Aug–Mar	Grasslands and open areas (Bd)	JVD-310
83	*Crotalaria vestita* Baker.	Herb	Jul–Dec	Open areas and seasonal grasslands (Bd)	JVD-240
84	*Cullen corylifolium* (L.) Medik.	Herb	Oct–April	Weed of cultivated fields (Throughout district)	JVD-1429
85	*Cyamopsis tetragonoloba* (L.) Taub.	Herb	Oct–May	Cultivated (Throughout district)	JVD-920
86	*Dalbergia lanceolaria* L.f.	Tree	Mar–May	Dry deciduous forests (Throughout district)	JVD-251
87	*Dalbergia latifolia* Roxb.	Tree	Feb–May	Dry deciduous forests (Throughout district)	JVD-252
88	*Dalbergia sissoo* Roxb**.**	Tree	Dec–May	Planted and escaped (Throughout district)	JVD-1430
89	*Deguelia scandens* Aubl. *	Climber	Nov–May	Dry deciduous forest (Bd)	JVD-1431
90	*Desmodium scorpiurus* (L.) DC. *	Herb	Jul–Dec	Grasslands, Wastelands and Open areas (Throughout district)	JVD-253
91	*Grona triflora* (L.) H.Ohashi & K.Ohashi	Herb	Sept–Jan	Grasslands, Wastelands and Open areas (Throughout district)	JVD-157
92	*Eleiotis rottleri* Wight & Arn.	Herb	Jun–Oct	Rare in gravelly plains and seasonal grasslands (Bd)	JVD-175
93	*Eleiotis sororia* (L.) DC.	Herb	Jul–Nov	Rare in gravelly plains and seasonal grasslands (Bd, G, H, I)	JVD-254 JVD-1289
94	*Erythrina suberosa* Roxb.	Tree	Nov–Apr	Deciduous forests (Bd, J, M)	JVD-255
95	*Flemingia strobilifera* R.Br.	Herb	Nov–Mar	Deciduous forests (Bd)	JVD-198
96	*Gliricidia sepium* (Jacq.) Walp. *	Tree	Dec–Apr	Open areas (Throughout district)	JVD-1406
97	*Glycine max* (L.) Merr. *	Herb	Oct–Apr	Cultivated (Throughout district)	JVD-1407
98	*Indigastrum parviflorum* (B.Heyne ex Wight & Arn.) Schrire	Sub-shrubs	Oct–Apr	Open areas and sandy plains (Bd, L)	JVD-1434
99	*Indigofera arnottii* (Kuntze) Peter G.Wilson	Herb	Aug–Feb	Open areas and scrubs (Bd, Bg, G, I, J, M)	JVD-1278 JVD-1278

	Name of taxon	Habit	Phenology	Habitat & Localities	Exsiccata
100	*Indigofera aspalathoides* Vahl ex DC.	Herb	Sept–Apr	Open areas and scrubs (Bd)	JVD-864
101	*Indigofera astragalina* DC.	Herb	Aug–Feb	Sandy plains (Throughout district)	JVD-1430
102	*Indigofera coerulea* Roxb.	Herb	Sept–Jan	Seasonal grasslands and wastelands (Bd, G, H)	JVD-860
103	*Indigofera cordifolia* Heyne ex Roth.	Herb	Aug–Oct	Grasslands, gravelly plains and wastelands (Throughout district)	JVD-256
104	*Indigofera colutea* (Burm.) Merr.	Herb	Jun–Dec	Grasslands, gravelly plains and wastelands (Bd)	JVD-210 JVD-1246
105	*Indigofera glandulosa* Wendl.	Herb	Aug–Feb	Open areas and weed of cultivated fields (Throughout district)	JVD-888
106	*Indigofera linifolia* (L.f.) Retz.	Herb	Jun–Dec	Grasslands, gravelly plains and wastelands (Throughout district)	JVD-161 JVD-851
107	*Indigofera linnaei* Ali.	Herb	Jun–Feb	Grasslands, gravelly plains and wastelands (Throughout district)	JVD-257
108	*Indigofera tinctoria* L.	Shrub	Oct–Jan	Open areas and scrubs (Bd)	JVD-1435
109	*Indigofera trifoliata* L.	Herb	Jul–Feb	Grasslands, gravelly plains and wastelands (Bd, Bg, L, J, M)	JVD-258
110	*Indigofera trita* L.f.	Herb	Jun–Jan	Grasslands, gravelly plains and wastelands (Throughout district)	JVD-259 JVD-861
111	*Lablab purpureus* (L.) Sweet.	Climber	Aug–Dec	Cultivated fields (Throughout district)	JVD-260
112	*Macroptilium lathyroides* (L.) Urb. *	Twining herb	Aug–Apr	Open areas and along railway track (L)	JVD-1436
113	*Macrotyloma uniflorum* (Lam.) Verdc.	Twining herb	Oct–Apr	Cultivated (L)	JVD-1437
114	*Mucuna pruriens* (L.) DC.	Climber	Aug–Jan	Dry deciduous forests and (Bd, L)	JVD-312
115	*Mundulea sericea* (Willd.) A.Chev.	Shrub	Mar–Sept	Dry deciduous forests (Bd, G, H, I, J)	JVD-21
116	*Neonotonia wightii* (Wight & Arn.) J.A.Lackey	Climber	Oct–May	Dry deciduous forests and along streams (Bd, J, R)	JVD-1295 JVD-905
117	*Phaseolus vulgaris* L.	Climber	Throughout year	Cultivated as vegetable crop (Throughout district)	JVD-1408
118	*Phyllodium pulchellum* (L.) Desv.	Sub-shrubs	Oct–Apr	Deciduous forest (Bd)	JVD-1247
119	*Pisum sativum* L. *	Climber	Oct–May	Cultivated (L, M)	JVD-1409
120	*Pongamia pinnata* (L.) Pierre	Tree	Mar–Sept	Dry deciduous forests and along roadsides (Throughout district)	JVD-315
121	*Pseudarthria viscida* (L.) Wight & Arn.	Herb	Jul–Jan	Dry scrub forests and grasslands (Bd, J, M)	JVD-318
122	*Pterocarpus marsupium* Roxb.	Tree	May–Oct	Dry deciduous forests (Bd, Bg, G, J, M)	JVD-319
123	*Pycnospora lutescens* (Poir.) Schindl.	Twining herb	Apr–Oct	Dry deciduous forests (Bd)	JVD-320
124	*Rhynchosia aurea* DC.	Creeping herb	Jul–Jan	Grasslands and open areas (Bd)	JVD-205
125	*Rhynchosia cana* (Willd.) DC.	Sub-shrubs	Dec–Apr	Open areas (Bd)	JVD-1297
126	*Rhynchosia capitata* (B.Heyne ex Roth) DC.	Creeping herbs	Sept–Jan	Sandy plains (Bd)	JVD-1298
127	*Rhynchosia hirta* (Andrews) Meikle & Verdc.	Climbing shrub	Jan–Jul	Dry deciduous forest (Bd, J)	JVD-1438
128	*Rhynchosia minima* DC.	Climber	Jul–Jan	Grasslands and open areas (Throughout district)	JVD-155 JVD-1202
129	*Rhynchosia minima* var. *laxiflora* (Camb.) Baker	Climber	Throughout year	Open areas and weed of cultivated fields (Throughout district)	JVD-1412
130	*Rhynchosia rothii* Benth. ex Aitch.	Climber	Oct–May	Dry deciduous forest (Bd, H)	JVD-1413
131	*Rhynchosia rufescens* (Willd.) DC.	Sub-shrubs	Jul–Feb	Open areas and gravelly slopes (Bd)	JVD-262
132	*Rhynchosia suaveolens* (L.f.) DC.	Shrubs	Nov–Mar	Gravelly slopes of deciduous forest (Bd, H)	JVD-1415
133	*Rhynchosia viscosa* DC.	Climber	Throughout year	Deciduous forests (Bd)	JVD-1416
134	*Rothia indica* (L.) Druce	Herb	Sept–Apr	Sandy plains (Throughout district)	JVD-828 JVD-1132 JVD-1286 JVD-913
135	*Sesbania aculeata* (Schreb.) Pers.	Sub-shrubs	Sept–Jan	Dry deciduous forests and along roadsides (L, M)	JVD-269
136	*Sesbania grandiflora* (L.) Poir. *	Tree	Sept–Feb	Cultivated as fodder and vegetable plant (Throughout district)	JVD-1370

	Name of taxon	Habit	Phenology	Habitat & Localities	Exsiccata
137	*Sesbania sesban* (L.) Merr.	Tree	Sept–Dec	Common along cultivated fields (Throughout district)	JVD-1371
138	*Smithia conferta* Sm. var. *conferta*	Herb	Oct–Dec	Wet grasslands (Bd)	JVD-1418
139	*Stylosanthes fruticosa* Mohlenbr	Herb	Throughout year	Open areas and wastelands (Throughout district)	JVD-268
140	*Stylosanthes hamata* (L.) Taub. *	Herb	Throughout year	Open areas and wastelands (Throughout district)	JVD-202
141	*Taverniera cuneifolia* (Roth) Arn.	Herb	Dec–Jul	Weed of cultivated fields (R, T)	JVD-1419
142	*Tephrosia hookeriana* Wight & Arn.	Sub-shrubs	Oct–May	Open grasslands (Bd)	Singh 1988 Op. cit.
143	*Tephrosia pumila* (Lam.) Pers.	Herb	Jul–Dec	Open areas and wastelands (Bd)	JVD-263
144	*Tephrosia purpurea* (L.) Pers.	Sub-shrubs	Jul–Dec	Open areas and wastelands (Throughout district)	JVD-098
145	*Tephrosia strigosa* (Dalzell) Santapau & Maheshw.	Herb	Jul–Dec	Open areas and wastelands (Bd, L, M)	JVD-1420
146	*Tephrosia subtriflora* Baker	Herb	Aug–Jan	Open areas and wastelands (Bd)	JVD-1425
147	*Tephrosia uniflora* Pers.	Herbs	Oct–Jun	Open areas and wastelands (Bd)	Singh 1981 Op. cit.
148	*Tephrosia villosa* (L.) Pers.	Sub-shrubs	Jul–Jan	Open areas and wastelands (Bd, G, H, I, J, M)	JVD-265 JVD-919 JVD-1213
149	*Teramnus labialis* (L.f.) Spreng.	Twining herb	Aug–Jan	Open areas and along cultivated fields (Bd, L)	JVD-1209
150	*Trigonella foenum-graecum* L.	Herb	Throughout year	Cultivated as vegetable crop (Throughout district)	JVD-1411
151	*Vigna indica* T.M.Dixit, K.V.Bhat & S.R.Yadav	Climber	Jul–Jan	Open areas and wastelands (Throughout district)	JVD-1145
152	*Vigna aconitifolia* (Jacq.) Marechal	Creeping herb	Aug–Jan	Cultivated and escaped in wild (Throughout district)	JVD-1421
153	*Vigna mungo* (L.) Hepper	Creeping herb	Aug–Jan	Cultivated (Throughout district)	JVD-1422
154	*Vigna trilobata* (L.) Verdcourt	Creeping herb	Jul–Jan	Open area sand wastelands (Throughout district)	JVD-270
155	*Vigna radiata* (L.) Wilezek	Creeping herb	Jul–Jan	Open areas and wastelands (Throughout district)	JVD-332
156	*Vigna unguiculata* (L.) Walp. *	Creeping herbs	Jul–Jan	Open areas and wastelands (Throughout district)	JVD-1423
157	*Zornia gibbosa* Span.	Herb	Jul–Jan	Open areas and grasslands (Throughout district)	JVD-334

Bd—Badami | Bg—Bagalkot | Bi—Bilgi | C—Cholachgudda | G—Guledgudda | H—Hungund | I—Ilkal | J—Jamkhandi | KS—Kudal Sangam | L—Lokapur | M—Mudhol | R—Rabkavi | T—Terdal. |(*) —non-native species (which are either introduced or invasive)

dominant components of dry deciduous forests of the district while species of *Alysicarpus* Desv., *Crotalaria* L., *Indigofera* L., *Rhynchosia* Lour., *Senna* Mill., *Tephrosia* Pers. are the dominant herbaceous legumes of the region. Kambhar & Katrahalli (2016) reported 126 species of legumes which is the dominant family from Gadag District (adjoining district of Bagalkot), while Seetharam et al. (2000) in flora of Gulbarga District (region of northeastern Karnataka) also reported Fabaceae as the most dominant family. Rain shadow area and arid climatic conditions are favourable for farming several leguminous crops. Apart from this many leguminous trees are a source of timber and economically important products and many others are used as medicinal and ornamental plants.

The present work will be helpful to the forest officials, policy makers, teachers, students and local people for study and sustainable utilizations of legumes of Bagalkot District.

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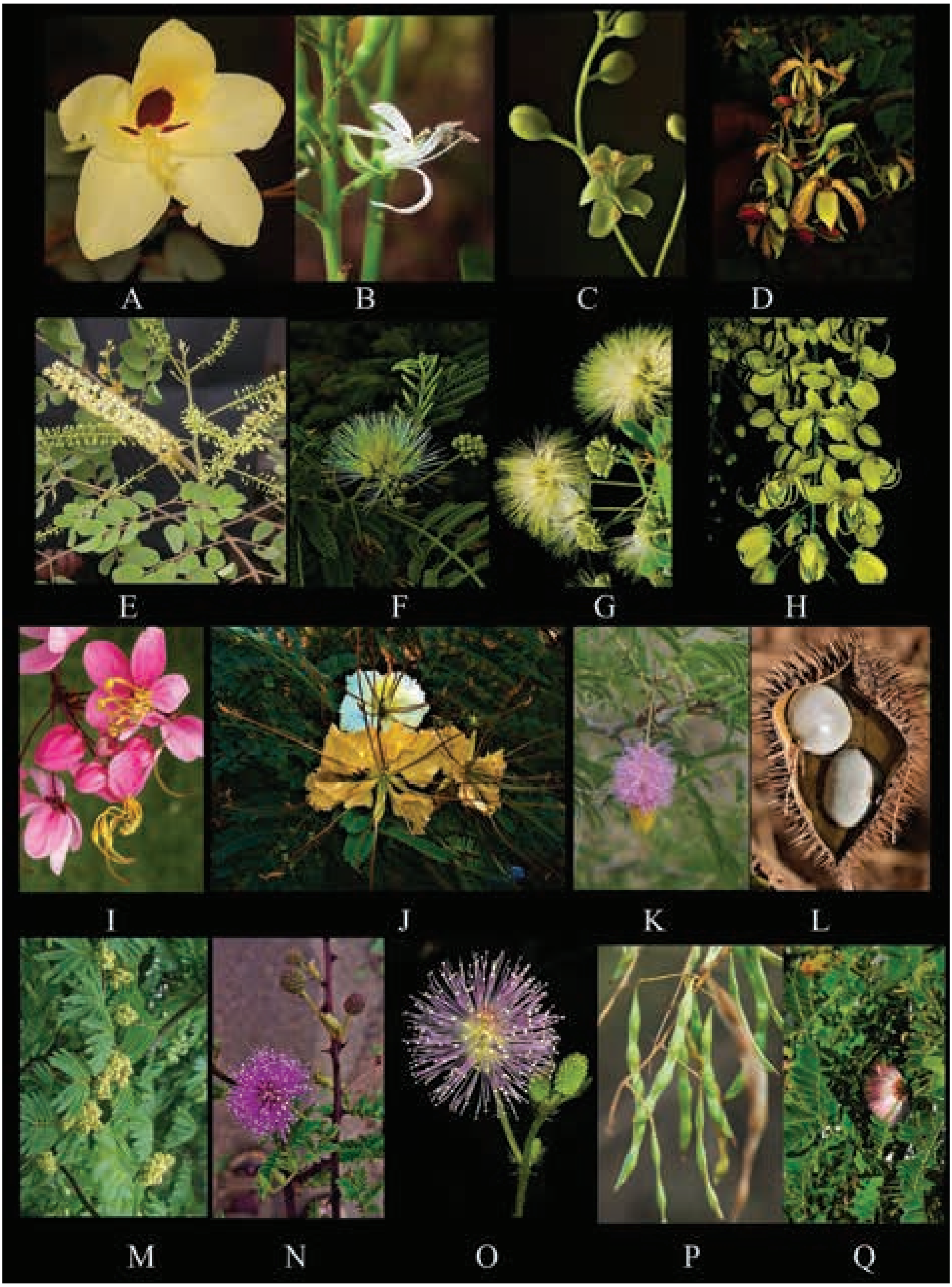

Image 1. A—*Bauhinia tomentosa* L. | B—*Piliostigma racemosum* (Lam.) Benth.—C. *Hardwickia binata* Roxb.—| D—*Tamarindus indica* L. | E—*Adenanthera pavonina* L.f.—| F—*Albizia amara* (Roxb.) Boivin | G—*Albizia lebbeck* (L.) Benth. | H—*Cassia fistula* L. | I—*Cassia javanica* L. | J—*Delonix elata* (L.) Gamble | K—*Dichrostachys cinerea* (L.) Wight & Arn. | L—*Guilandina bonduc* L. | M—*Libidibia coriaria* (Jacq.) Schltdl. | N—*Mimosa hamata* Willd. | O—*Mimosa pudica* L. | P—*Parkinsonia aculeata* L. | Q—*Samanea saman* (Jacq.) Merr. © A–C—S.R. Yadav & D–Q—Jagdish Dalavi.

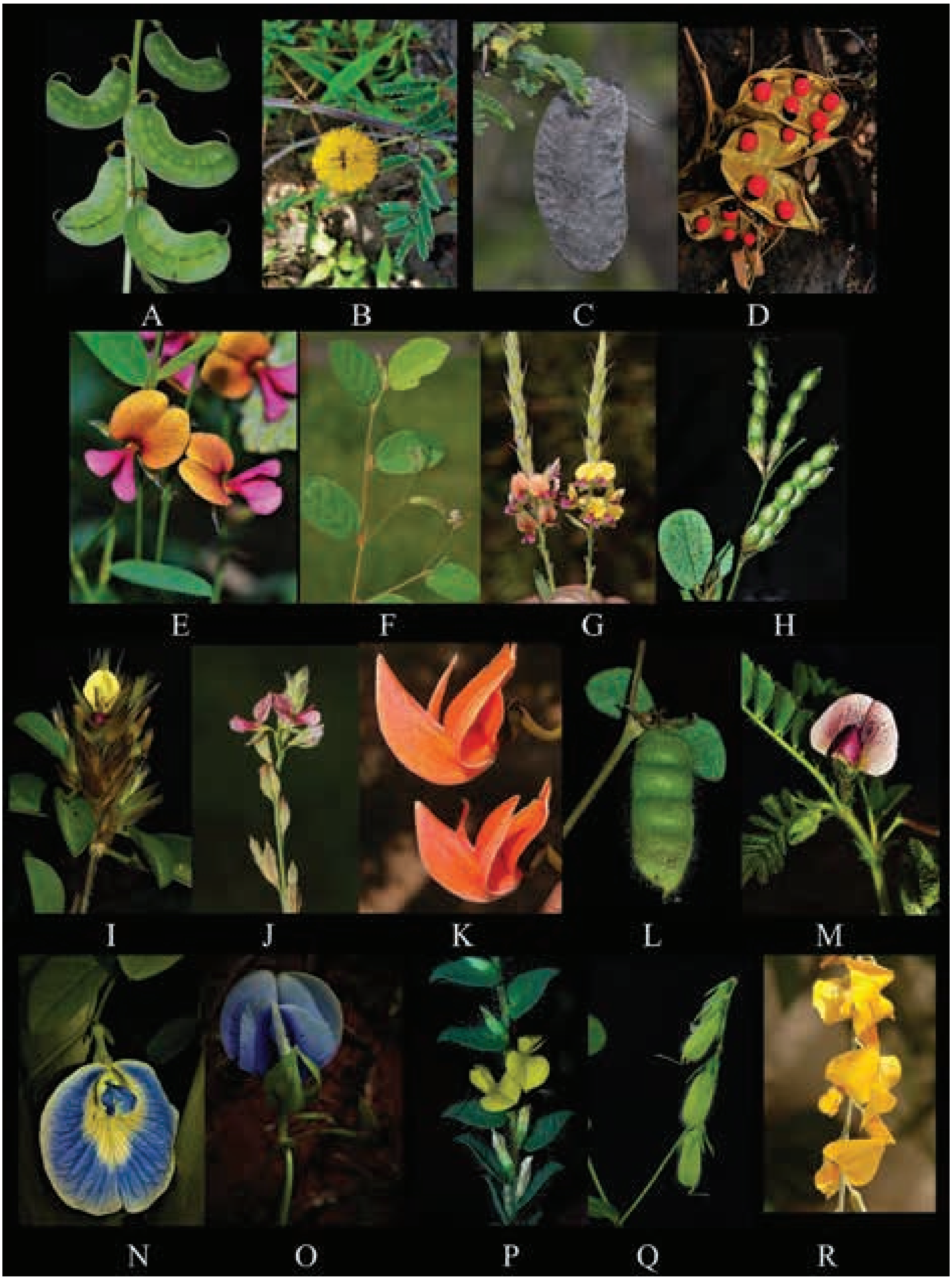

Image 2. A—*Senna italica* Mill. subsp. *micrantha* (Brenan) Lock | B—*Vachellia farnesiana* (L.) Wight & Arn. | C—*Vachellia horrida* (L.) Kyal. & Boatwr. | D—*Abrus precatorius* L. | E—*Alysicarpus gamblei* Schindl. | F—*Alysicarpus hamosus* Edgew. | G—*Alysicarpus longifolius* (Rottler ex Spreng.) Wight & Arn. | H—*Alysicarpus monilifer* (L.) DC. | I—*Alysicarpus scariosus* (Spreng.) Thwaites | J—*Alysicarpus tetragonolobus* Edgew. | K—*Butea monosperma* (Lam.) Kuntze | L—*Cajanus scarabaeoides* (L.) Thouars | M—*Cicer arietinum* L. | N—*Clitoria ternatea* L. | O—*Crotalaria bifara* L.f.| P—*Crotalaria hebecarpa* (DC.) Rudd. | Q—*Crotalaria hirsuta* Willd. | R—*Crotalaria juncea* L. © A–J, L–R—Jagdish Dalavi & K—S.R. Yadav.

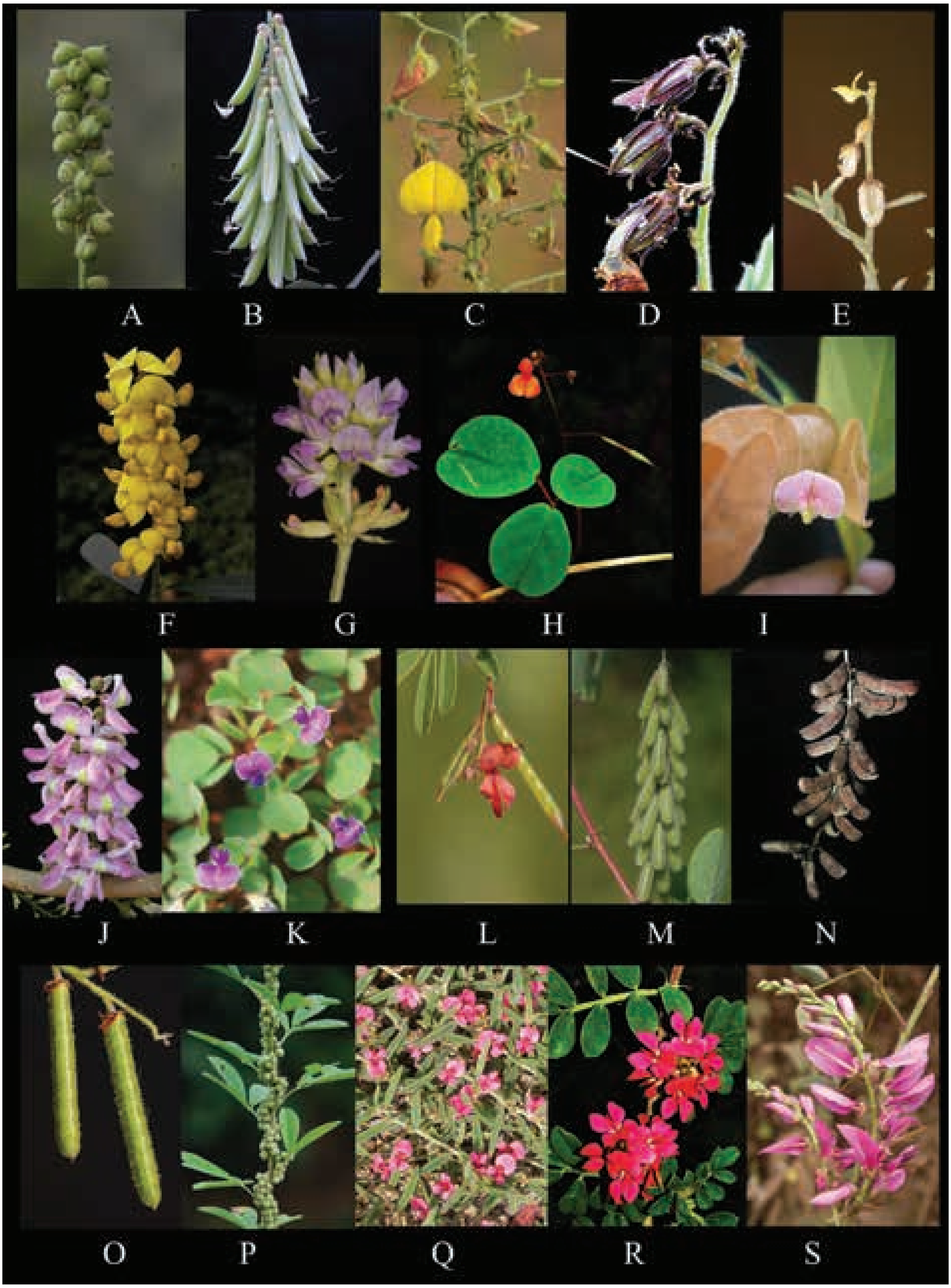

Image 3. A—*Crotalaria medicaginea* Lam. | B—*Crotalaria pallida* Aiton. | C—*Crotalaria paniculata* Willd. | D—*Crotalaria pellita* Bertero ex DC. | E—*Crotalaria pusilla* B.Heyne ex Roth | F—*Crotalaria retusa* L. | G—*Cullen corylifolium* (L.) Medik. | H—*Eleiotis rottleri* Wight & Arn. | I—*Flemingia strobilifera* (L.) W.T.Aiton | J—*Gliricidia sepium* (Jacq.) Steud. | K—*Grona triflora* (L.) H.Ohashi & K.Ohashi | L—*Indigofera arnottii* (Kuntze) Peter G.Wilson | M—*Indigofera astragalina* DC. | N—*Indigofera coerulea* Roxb.—| O—*Indigofera colutea* (Burm.f.) Merr. | P—*Indigofera glandulosa* J.C. Wendl. | Q—*Indigofera linifolia* (L.f.) Retz. | R—*Indigofera linnaei* Ali | S—*Indigofera tinctoria* L. © A–S—Jagdish Dalavi.

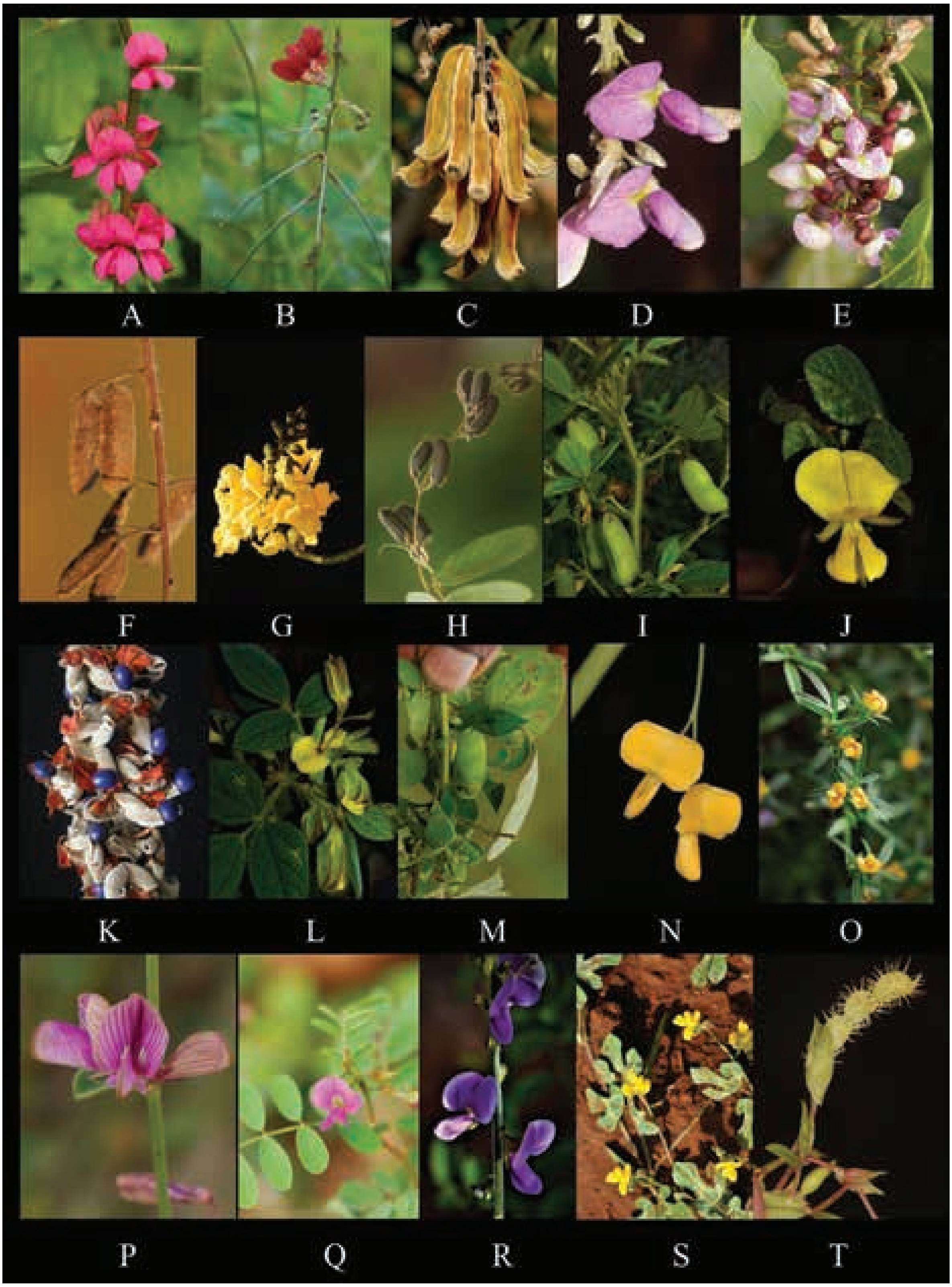

Image 4. A—*Indigofera trifoliata* L. | B—*Macroptilium lathyroides* (L.) Urb.—| C—*Mucuna pruriens* (L.) DC. | D—*Mundulea sericea* (Willd.) A.Chev. | E—*Pongamia pinnata* (L.) Pierre | F—*Pseudarthria viscida* (L.) Wight & Arn. | G—*Pterocarpus marsupium* Roxb.—| H—*Pycnospora lutescens* (Poir.) Schindl. | I—*Rhynchosia cana* (Willd.) DC. | J—*Rhynchosia capitata* (B.Heyne ex Roth) DC. | K—*Rhynchosia hirta* (Andrews) Meikle & Verdc. | L—*Rhynchosia rufescens* DC. | M—*Rhynchosia suaveolens* (L.f.) DC. | N—*Sesbania aculeata* (Schreb.) Pers. | O—*Stylosanthes fruticosa* (Retz.) Alston | P—*Taverniera cuneifolia* (Roth) Arn. | Q—*Tephrosia purpurea* (L.) Pers. | R—*Tephrosia villosa* (L.) Pers. | S—*Vigna indica* T.M. Dixit, K.V. Bhat & S.R. Yadav. | T—*Zornia gibbosa* Span. © A–H—S.R. Yadav & I–T—Jagdish Dalavi.

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COMMUNICATION

Indigenous knowledge of ethnomedicinal plants by the Assamese community in Dibrugarh District, Assam, India

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Abstract: The present investigation is an attempt to study the uses of ethnomedicinal plants in traditional knowledge system among the Assamese community of Dibrugarh District in Assam. All the relevant data were collected during 2017–2019 by following standard ethnobotanical methods through personal interviews as well as through focus group discussions with a total of 193 informants including 62 men and 131 women. The use value (UV) of the medicinal plants and informant consensus factors (F_{IC}) values were determined. In the study 174 ethnomedicinal plant species were documented belonging to 147 genera and 78 families. Except for three species, the 171 species are Angiosperms mostly collected from the wild. Among the 174 species of medicinal plants, 12 species are listed under various categories by IUCN and CITES. All these plants are used to treat various diseases that are grouped under 13 ICPC (International Classification of Primary Care) disease categories, with the highest use value (0.54) recorded in *Leucas aspera* followed by *Paederia scandens* with (0.5) use value. This confirms that these plants are important traditional herbs with potent medicinal uses. The highest informant consensus factor with the highest number of species (93) being used for the digestive system (F_{IC}= 0.76%), followed by oral and dentistry (F_{IC}= 0.73%) category. The ethnic communities in the district are rich in traditional knowledge which is evident from the use records and high degree of consensus among the informants.

Keywords: Indigenous knowledge, informants consensus factor, northeastern India, use value

Assamese Abstract: Oxomor Dibrugarh jilar axomiya xomproday lukxokolor paromporik bidhya pronalit gosthiouxodhiyo upokarita bur bortoman onuxondhan or joriyote ek odhoyon prosesta solua hoise. Xokolu praxonggik tothyo 2017-2019 ot xonggroh kora hoi pramanik gosthiboigyanik poddhotir joriyote, byoktigoto xakhyatkar duara logote obhikendro dologoto alosana. Muth 193 tothyodata, 62 purux aru 131 stri. Ouxodhi udbhid or byowohar man (UV) aru tothyodata xorboxonmoti upadan (F_{IC}) nirnoy kora hol. Ei odhoyonot, 174 gosthiouxodhiyo udbhid (147 genera aru 78 families) dostabej kora hoi. 3 ta projatir bade, 173 ta projati hoise guptobiji udbhid jikhini xorobhag bonor pora xongroh kora hoisil. 174 ta ouxodhiyo udbhid projatir majot 12 ta projati IUCN aru CITES or bibhinno prokarot xusito kora hoise. Ei xokolubur udbhid rog sikitsat byowohar hoi. Ei rog homoh 13 ta ICPC rog bibhagot rokha hoise. Ataitkoi xorbosso byowohar mulyo (0.54) nothibhukto kora hol Leucas aspera t aru Paederia scandens (0.5). Nissito kora hoi je ei udbhid hamuh xobol ouxodhi gun thoka gurutwopurno paromporik trino udbhid. Xorbosso tothyodata xorboxonmoti hetu (F_{IC}) logote xorbosso xongkhya projati (93) byowohar kora hoi hojomi pronalit (0.76%) aru moukhik aru donto pronalit (0.73%). Jilakhonor jatigoto xomproday paromporik bidhya hoise xompodxali jitu byowahar dostabej aru tothyodata xokolor usso matra xorboxonmoti pora pramanik hoi.

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Author details: Pranati Gogoi, a PhD Scholar has authored two research articles and a book chapter. Currently she is working on the floristic diversity of Dibrugarh District, Assam under Gauhati University. Dr. Namita Nath has authored more than 43 research articles, 21 books, five book chapters and edited three books. She is involved with four research projects, the ongoing one is "Inventorization of wild edible fruits of Assam with special reference to their sustainable utilization for livelihood generation".

Author contribution: PG carried out the whole field survey during the the year 2017-2019, data compilation, analysis and writing the whole manuscript. NN supervised the whole work from field survey upto the preparation of the report.

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INTRODUCTION

Indigenous knowledge plays a vital role in conservation of resources, particularly of indigenous plant species significant for indigenous communities (Cox 2000; Leonti 2002; Leonti 2011; Kayani et al. 2015). Since ancient times, the indigenous communities have been harvesting ethnomedicinal plants from the wild in different parts of the world (Malick & Cox 1996; Dhillion et al.2002; Matu & Staden 2003; Mall et al.2015; Pasquini et al.2018; Phumthum & Balslev 2018; Tomasini et al. 2019; Dixit & Tiwari 2020; Qamariah et al. 2020) and the knowledge is carried forward generation after generation (Tabuti et al. 2003). This knowledge needs to be conserved especially in countries facing high risk of threat to biodiversity due to urban developmental activities, migrations, deforestation, and natural calamities. India is one of such nations where indigenous knowledge is decreasing day by day due to the factors mentioned above. Northeastern India, a mega bio-diversity hot spot, is rich in endemic flora (Mao et al.2000; Sajeng et al. 2008; Barbhuiya et al. 2009; Mao et al. 2009; Panmei et al. 2019) and home to nearly 1,350 medicinal plants with high economic importance that are used in various ethnomedicinal preparations (Dutta & Dutta 2005). Besides being rich in floristic diversity, this region is also rich with a diversified and colorful culture and traditional knowledge system among 145 tribal communities (Ali & Das 2003). This region is considered one of the ecological hot spots of the world and has an abundance of medicinal plants known to the native people (Asati & Yadav 2004; Chauhan 2011; Dutta 2013; Salam 2013; Debbarma et al. 2017; Lanusunep et al. 2018; Panmei et al. 2019). Assam, a significant state of northeastern India falls in the Indo-Burma Global Biodiversity Hotspot (Mittermeier et al. 2011). "Assamese" is the largest indigenous community of Assam inhabiting throughout the valley of the Brahmaputra River. Studies on ethnomedicinal plants were carried out by different authors in different parts of Assam in the past by the ethnic communities; and comprehensive works have already been published (Borah et al. 2004; Saikia et al. 2006; Buragohain 2008; Talukdar et al. 2018). Dibrugarh is one of the diverse lands of northeastern India and is the largest tea producing zone in India. The land is occupied by the Assamese people who highly depend on medicinal plants for various traditional health-care practices. The Assamese community of Dibrugarh District of Assam, since time immemorial have been using medicinal plants to treat different ailments over many centuries through the traditional knowledge system that has been passed down from generation to generation (Dutta & Dutta 2005; Buragohain 2008; Sarma & Devi 2017; Talukdar et al. 2018). But due to certain factors like modern lifestyle and development in medical facilities, the utilization of these plants is rapidly decreasing. To overcome this issue, proper documentation and assessment of traditional knowledge of indigenous people is important (Teklehaymanot 2009). Due to the conversion of the forests and arable land into tea gardens for commercial purposes, there is every possibility of losing the useful medicinal plants from their natural habitat. Therefore, proper measures and conservation strategies of the available floristic wealth of this region is of utmost importance. Thus proper documentation and preservation of the ethnomedicinal knowledge has become the need of the hour before getting lost and supplanted by modern medical facilities. In the district of Dibrugarh, although some of the studies on ethnomedicinal plants have been carried out on Mishing tribe, Sonowal Kachari tribe and Ahom tribe (Boruah & Kalita 2007; Kalita & Phukan 2010; Sonowal 2013), no exhaustive work has been done on the traditional practices of the Assamese community. In addition, the tradition of using indigenous knowledge for the treatment of common ailments is neglected due to the availability of modern lifestyle and medical facilities. As a result, the traditional household practices are rapidly decreasing in this region. The traditional practices of various ethnic communities on the uses and management of medicinal plants is necessary in order to fill the gap of indigenous knowledge on ethnomedicinal plants. Thus the present survey was conducted with the objectives (1) to document the medicinal plants used by the Assamese community in Dibrugarh District, (2) proper assessment of traditional knowledge on the ethnomedicinal plants adopted by the people with regard to gender, age, and knowledge, and (3) to bring out the medicinal plants with highest ethnomedicinal importance for future value addition to their existence and preservation for long term purposes.

MATERIALS AND METHODS

Study area

The present study was carried out in the Dibrugarh District of Assam. The district lies at 108m and occupies an area of 3,381km^2. The district extends from 27.093–27.708 (latitude) & 94.562–95.485 (longitude) (Census 2011). The area stretches from the north bank of the Brahmaputra, which flows for a length of 95km through

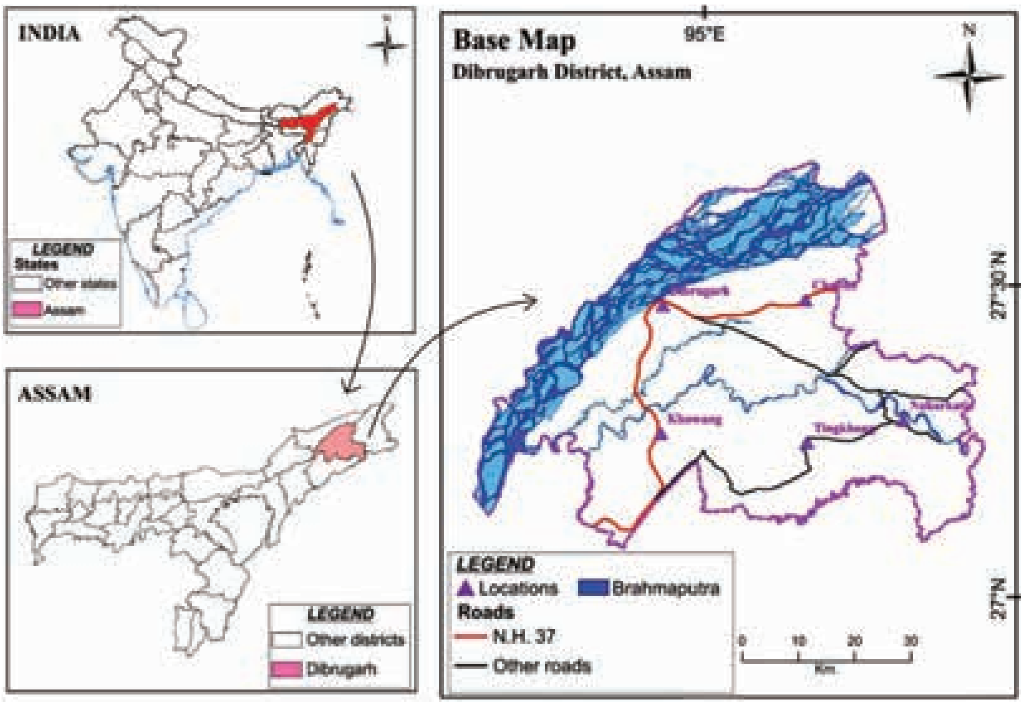

Figure 1. The study area in Dibrugarh District, Assam.

the northern margin of the district to the Patkai foothills on the south (Fig. 1). There is a large tract of tropical lowland rainforests in Dibrugarh often referred to as "The Amazon of the east" owing to its large area and thick forests. It is also home to Dibru-Saikhowa National Park, which has an area of 340km^2. It shares the park with Tinsukia District. The region lies on the bank of the Brahmaputra River and other environmental factors such as climate and topography of the region has been favorable for the growth of luxuriant vegetation. The climate of Dibrugarh is humid and sub-tropical with extremely wet summers and relatively dry winters. The climate is classified by the Koppen-Geiger system and average precipitation is 2,781mm annually (Climate data 2020). According to 2011 India census, the district has a population of 1,326,335; males constitute 51% of the population and females 49%. The sex ratio of the district is 961 per 1,000 males. The average literacy rate is 76.05%, which is higher than the national average literacy rate.

Field survey and collection of data

The study was conducted during 2017–2019 in various localities following standard ethnobotanical methods using a specially designed questionnaire (Jain 1987; Martin 1995). All the relevant data including those of traditional uses of the medicinal plants used by ethnic communities of Dibrugarh District were collected following the code of ethics (International Society of Ethnobiology 2006). Here using the specially designed questionnaire, we collected the data through personal interviews as well as through focused group discussions with a total of 193 informants. The study is significant in the sense that no such extensive work was done earlier in the district of Dibrugarh and this region has remained unexplored or under-explored in the field of floristic study also. Several visits were made to remote places namely Jokai, Madhupur, Naharkatiya, Tengakhat, Lezai, Moran, Lahowal, Borborua, Bogibeel, Khowang of the district at different time intervals for primary data collection. Based on the information obtained from the ethnic tribes (Ahom, Kachari, Mishing, Deori, Sonowal Kachari, Boro, and Chutiya) the identification of the key informants became possible. With their cooperation, the plants were collected from the forest and the local names of the given plants were recorded in a structured questionnaire, comprising of scientific name, family, local names of plants, part used, application, method of preparation and route of administration. In the present study a total of 193 informants with a strong traditional knowledge base were selected for data collection. During the process importance was given to collecting data with a detailed account of every informant including their identity, address, qualifications and tribal group. This was recorded prior to collection of traditional knowledge based information in the local language i.e.

Assamese. Before approaching the main steps of data collection, the aim and objectives of our study were explained briefly to the informants to generate their trust which was very helpful in getting accurate data. Based on the collected data it was found that out of 193 informants, 54 were above 69 years, of which 20 were males and 34 were females. In the age group of 50–59 years there were 47 informants of which 21 were males and 26 were females. In the age group of 40–49 years, there were 56 informants of which 16 were males and 40 were females. In the age group of 30–39 years, there were 36 informants of which five were males and 31 were females. Most of the informants were involved with other livelihood activities being farmers, social workers, teachers, shop keepers and house wives.

Plant collection, identification and preservation

The herbal practitioners of the Assamese community of the Dibrugarh District collected the plants during the mature stage for proper identification. For proper identification an effort was made to collect the voucher specimens related with ethnomedicinal information

Image 1. Some medicinal plants collected from Dibrugarh District, Assam: A—*Leucas aspera* | B—Informant with *Clerodendron colebrookianum* | C—Informant with *Cheilocostus speciosus* | D—Informant with *Impatiens tripetala* | E—Informant with *Paederia scandens*. Inset shows the flower | F—Informant with *Microsorum punctatum* | G—*Garcinia pedunculata* | H—*Curcuma zedoaria* | I—Informant with *Tabernaemontana divaricate*. © Pranati Gogoi.

during the flowering and fruiting periods. Collected plants were identified by the interviewers in their local language as well as correlating the plant in the field as shown by the informants (Image 1). For future record of the specimens as well as for proper taxonomic identification plant specimens were collected properly along with vivid photographs. The collected plants were made into herbarium specimens by following standard herbarium techniques (Jain & Rao 1977), and most of them were deposited at the GUBH (Gauhati University Botanical Herbarium, Assam). The specimens were identified consulting relevant literature like Flora of Assam (Kanjilal et al. 1934–1940); a checklist was made of angiosperms and gymnosperms (Barooah & Ahmed 2014); (Chowdhery et al. 2008, 2009). Online databases like The Plant Lists (www.theplantlist.org) and The International Plant Name Index (www.ipni.org) were referred.

Statistical analysis

The collected data is represented systematically in tabular form. Information such as scientific name, family, local name, use value, parts used, applications, method of preparation and route of administration were provided for each species. The collected data on the habits of plants used in Dibrugarh District of Assam was schematically recorded in a MS-Word file.

Determination of use value (uv)

The relative importance of each prescribed medicinal plant was calculated by determining the use value (Phillips et al. 1994; Zenderland et al. 2019), in order to measure the relative importance of plants used by local healers on quantitative basis:

$$UV = \Sigma\ Ui/n$$

Where Ui is the number of use-reports cited by each informant for a given species and n refers to the total number of informants. When there are many use-reports for a plant, the UV will be high, and when there are few reports for a plant, the UV will approach zero (0).

Determination of informants consensus factor (F_{IC})

Informants' consensus factor, i.e., F_{IC} is usually calculated using a formula. This is done in order to find out the homogeneity in the information given by the informants of the study area. The F_{IC} was calculated by the following formula (Trotter & Logan 1986; Henrich et al. 1998; Singh et al. 2012; Bhat et al. 2013).

$$F_{IC} = (N_{ur} - N_t) / N_{ur-1}$$

Here N_{ur} is the member of use report in a particular category of illness by informants and N_t is the number species of taxa that is used for the treatment of a particular disease category by informants of the study. The ICF values range from 0 to 1. When it is higher or close to 1, it indicates higher reports about a plant species used by the informants in a particular ailment. When the value is low or near 0, it indicates disagreement by the informants about a plant used for a certain ailment.

RESULTS AND DISCUSSION

Demography

In the Dibrugarh District, Assam a total of 193 informants of the age group ranging from 30–92 years of which 62 (32.12%) were male and 131 (67.87%) were female (Table 1). From the study it was found that the average age of the informants was 59 years. The illiteracy rate was found to be 14.5% whereas the literacy rate at the primary level was 17%, middle level was 13.9%, and secondary level was 27.4% (Table 2).

An overview of medicinal plants

In the present research work 174 plant species were used in various traditional health care practices which belong to 78 families and 147 genera. These were found to be used to cure several human diseases which were grouped under 13 ICPC (International Classification of Primary Care) disease categories. The information on traditional knowledge carried out by the tribal people of Dibrugarh District were arranged alphabetically by generic and specific names along with their families, local names, applications (Table 3). It was found that the most reported ethnomedicinal plants were herbs followed by trees, shrubs, and climbers (Figure 2). This could be due to availability of non-conventional herbs which are easy to cultivate in home gardens in comparison to trees and shrubs which take a longer time to grow. This could be due to the fact that the herbs possess potent medicinal properties and more therapeutic effects to resist illnesses (Abbas et al. 2017; Chekole 2017; Umair et al. 2017). Most of these ethnomedicinal plants are being used by the tribes in their day to day activities for their livelihood and also to get rid of severe/chronic health issues. In the present study, among the recorded species four species, viz., *Acorus calamus* L., *Clerodendrum colebrookianum* Walp. *Messua ferrea* Linn., *Sapindus mukorossi* Gaertn. are assessed as Vulnerable (VU) by IUCN Red List, three species—*Alstonia scholaris* R.Brown., *Terminalia chebula* (DC) W & A, and *Artocarpus lakoocha* Roxb.—are assessed as Near Threatened (NT), two species—*Cinnamomum tamala* Nees & Ebern and *Cissampelos*

Table 1. Distribution of ethnic informants based on age and sex.

Age group	Male	Female	No. of persons	Percentage
30–39	5	31	36	18.6
40–49	16	40	56	29
50–59	21	26	47	24.3
60–69	12	21	33	17
70–79+	8	13	21	10.8
TOTAL	**62**	**131**	**193**	

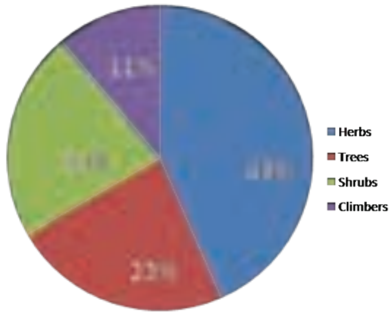

Figure 2. Diagram showing habits of documented plant species.

Table 2. Educational status of the informants.

Education level	No. of individuals	Percentage
Illiterate	28	14.5
Primary	33	17.0
Middle	27	13.9
Secondary	53	27.4
University	52	26.9
TOTAL	**193**	

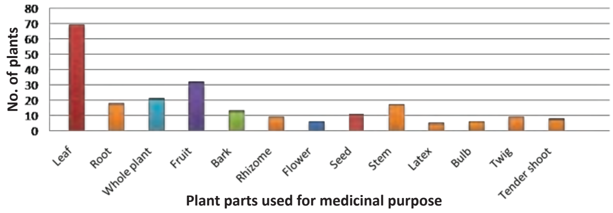

Figure 3. Parts wise use of various medicinal plant species used by Assamese community in Dibrugarh District.

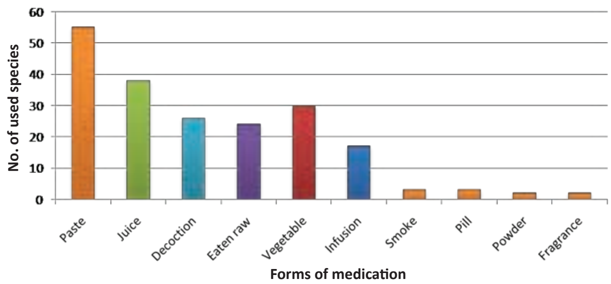

Figure 4. Various forms of medication practiced by Assamese community in Dibrugarh District.

pareira Linn.—are listed under Least Concern (LC) (Sajem et al. 2008; Molur & Walker 1998). *Curcuma caesia* Roxb. is listed under Critically Endangered (CR) category of IUCN while *Garcinia pedunculata* Roxb. is an Endangered (EN) and endemic species of the region (Mao et al. 2009). *Rhyncostylis retusa* (L.) Blume which is an epiphytic herb belonging to family Orchidaceae is also placed under the Endangered category (EN) appendix II (with strictly controlled international trade) of CITES (The Convention on International Trade in Endangered species of Wild Fauna and Flora) (Saxena 2020) (Table 4).

Plant parts used and forms of medication

The tribal communities have a strong indigenous knowledge system of using various parts of a plant and the healing properties that each of the parts. The various information collected from the tribal communities helped us to establish the importance of the different uses of herbal remedies. The most commonly used plant parts were leaf, root, whole plant, fruit, bark, rhizome, flower, seed, stem, latex, bulb, twig, and tender shoots for various purposes in their day to day lives (Figure 3). In the study it was found that during the preparation of herbal recipes the healers use either a single medicinal plant or combination of several plants in the treatment of a particular disease. The most frequently used plant parts for medicinal remedies were leaves (69 species, 39.65%). The use of leaves in comparison to other plant parts causes less harm to the plant thus ensuring sustainability and its further conservation (Panmei et al. 2019). It was followed by fruit (32 species, 18.39%), whole plant (21 species, 12.06%), roots (18 species, 10.34%), stems (17 species, 9.77%), barks (13 species, 7.47 %), seeds (11 species, 6.3 %), rhizomes (nine species, 5.17%), twigs (nine species, 5.17%), tender shoots (eight species, 4.59%), flowers (six species, 3.44%), bulbs (six species, 3.44%) (Figure 3). Out of 78 families, Euphorbiaceae represented the highest number of medicinal plants (10 species, 5.74%), which was followed by Asteraceae (eight species, 4.59%), Araceae (seven species, 4.02%), and Rutaceae (seven species, 4.02%). Other research works (Singh et al. 2000; Teklehaymanot & Giday 2007; Mesfin et al. 2009; Bhattarai et al. 2010), however, reported

Table 3. Documentation of medicinal plants used by ethnic tribes of Dibrugarh District, Assam, India.

Scientific name [Family]; Voucher No.	Common name	Use Value	Part Used	Application	Method of preparation	Route of administration
Abroma augusta L. [Sterculiaceae]; PG-367	Gorokhia korai	0.03	R	Breast cancer, internal wound healing, jaundice	Paste	Oral
Acacia farnesiana (L.) Wild [Mimosaceae]; PG-269	Torua kadam	0.03	St, B	Menstruation pain, stomachic, hypertension	Decoction	Oral
*Achyranthes aspera*L. [Amaranthaceae]; PG-167	Biyoni hakuta	0.02	L, R	Fever, cough, stomachic, bone fracture	Paste	Oral
Acorus calamus L. [Araceae]; PG-38	Bosh	0.06	Rh	Fever, gastritis	Pill	Oral, external
Aegle marmelos (L.) Correa [Rutaceae]; PG-399	Bel	0.01	Fr	Indigestion, detoxification	Water infusion	Oral
Ageratum conyzoides L. [Asteraceae]; PG-541	Gendheli bon	0.09	L	Cut	Paste	External
Alocasia indica (Roxb.) Schott [Araceae]; PG-42	Man kochu	0.14	Rh	High blood pressure, anemia, tonic	Decoction	Oral
Alocasia macrorrhiza (L.) [Araceae]; PG-43	Bor kochu	0.03	L, Rh	Anthelmintic, Toothache, Insect repellant	Paste	External
Aloe vera (L.) Burm.f. [Asphodelaceae]; PG-82	Sal kuwori	0.28	L	Fever, detoxification, skin problem	Paste	Oral, External
Alpinia nigra (Gaertn). B.L.Burtt [Zingiberaceae]; PG-134	Tora	0.01	Rh	Leucorrhea	Paste	Oral
Alstonia scholaris (L.) R. Br. [Apocynaceae]; PG-430	Chatiana	0.03	St, B	Toothache, Malaria	Paste	Oral
Alternanthera sessilis(L.) R.Br. Ex DC [Amaranthaceae]; PG-170	Mati-kanduri	0.08	TS	Gastritis, gastro-intestinal disease	Vegetable	Oral
Amaranthus spinosus L. [Amaranthaceae]; PG-171	Hati-khutura	0.03	R, TS	Diarrhoea, antidiabetic, galactogogue	Juice, vegetable	Oral
Amaranthus tricolor L. [Amaranthaceae]; PG-174	Bishalya karani	0.02	L	Stomachic	Juice	Oral
Amorphophalus paeoniifolius (Dennst.) Nicolson [Araceae]; PG-45	Ol-kochu	0.06	TS	Cancer, pinworm	Eaten raw	Oral
Ananas comosus (L.) Merr. [Bromeliaceae]; PG-98	Anaras	0.18	L, Fr	Abortive, stomachic, bleeding, pinworm	Raw	Oral
Andographis paniculata (Burm.f) Wall.ex. Nees. [Acanthaceae]; PG-463	Chirota	0.06	Wh	Stomach worm	Water infusion	Oral
Artocarpus heterophyllus Lamk. [Moraceae]; PG-302	Kothal	0.03	L	Antidiabetic	Juice	Oral
Artocarpus lacucha Buch.-Ham. [Moraceae]; PG-303	Bohot	0.09	B	Cough	Decoction	External
Averrhoa carambola L. [Averrhoaceae]; PG-582	Kordoi	0.12	Fr	Jaundice, stomachic, blood purifier	Raw	Oral
Azadirachta indica A. Juss. [Meliaceae]; PG-390	Mahaneem	0.25	L	Stomachic, toothache, anthelmintic,antidiabetic, stomachic	Decoction, vegetable, paste	Oral, External
Bacopa monnieri (L.) Pennell [Scrophulariaceae]; PG-502	Brahmi	0.1	Wh	Memory enhancer, apetizer	Vegetable	Oral
Bambusa balcooa Roxb. [Poaceae]; PG-106	Bholuka-banh	0.09	Cu, L	Insect bite	Paste	Oral, external
*Basella alba*L. [Basellaceae]; PG-69	Puroi sak	0.01	Wh	Anemia, tonic	Vegetable	Oral
Belamcanda chinensis (L.) DC. [Iridaceae]; PG-544	Surya kanti	0.01	R	Stomachic	Juice	Oral
Boerhavia repens L. [Nyctaginaceae]; PG-179	Pono nowa	0.02	L	Urinary infection	Juice	Oral
Caesalpinia bonduc(L.) Roxb. [Caesalpiniaceae]; PG-273	Letaguti	0.13	S	Pneumonia, cough	Decoction	Oral
Cajanus cajan (L.) Millsp. [Leguminosae]; PG-77	Rohar dal	0.05	T	Jaundice, urinary infection	Juice	Oral
Calamus rotang L. [Arecaceae]; PG-85	Bet gaj	0.03	Sh	Antidiabetic	Vegetable	Oral
Calamus tenuis Roxb. [Araceae]]; PG-86	Jati-bet	0.03	TS	Cough	Vegetable	Oral
Calotropis procera(Ait.) R.Br. [Asclepiadaceae]; PG-432	Akon	0.07	La, L	Rabies, bone fracture, piles	Pill, paste, infusion	Oral, external
Camellia sinensis (L.) Kuntze [Theaceae]; PG-427	Sahpat	0.02	L	Cut and wound, antioxidant, hair problem	Paste, decoction	Oral, external

Scientific name [Family]; Voucher No.	Common name	Use Value	Part Used	Application	Method of preparation	Route of administration
Capsicum frutescens L. [Solanaceae]; PG-96	Dhan jolokia	0.04	Fr	Gastritis, cough	Raw	Oral
*Carica papaya*L. [Caricaceae]; PG-47	Amita	0.14	Fr, La, S	Constipation, indigestion, galactogogue, pinworm	Raw	Oral
Cascabela thevetia(L.) Lipp. [Apocynaceae]; PG-81	Korobiphul	0.01	R	Rabies	Paste	Oral
Cassia fistula L. [Caesalpinaceae]; PG-275	Sonaru	0.01	S	Constipation	Paste	Oral
Catharanthus roseus (L.) G.Don [Apocynaceae]; PG-433	Nayantora	0.31	L	Antidiabetic, cancer, hypertension	Juice	Oral
Celtis tetrandra Roxb. [Ulmaceae]; PG-212	Sukuta	0.02	T	Stomachic, fever	Decoction	Oral
Centella asiatica(L.) Urban [Apiaceae]; PG-578	Bor-manimuni	0.19	Wh	Blood purifier, dysentery, memory enhancer, cut	Paste	Oral
Chromolina odorata (L.) King et Robin [Asteraceae]; PG-546	Jarmani bon	0.09	L	Cut and wound	Paste	External
Cinnamomum tamala (Buch.-Ham.) T.Nees & C.H.Eberm. [Lauraceae]; PG-19	Tezpat	0.02	L	Hypertension, antidiabetic	Paste, decoction	Oral
Cissampelos pareira L. [Menispermaceae]; PG-145	Tubuki lota	0.05	L, R	Fever, bone fracture	Paste	External
Cissus quadrangularis L. [Vitaceae]; PG-199	Harjura lota	0.04	St	Bone fracture	Paste	External
Citrus aurantifolia(Christn.) Swingle [Rutaceae]; PG-400	Gol-nemu	0.26	Fr, S	Diarrhea, chronic dysentery, cough, pinworm	Juice	Oral
Citrus chinensis(L.) Osbeck [Rutaceae]; PG-397	Mousumi tenga	0.08	F	Jaundice, blood purification	Juice	Oral
Citrus grandis (L.) Osb. [Rutaceae]; PG-398	Robab-tenga	0.17	Fr	Gastritis, pox, hypertension, cardiovascular disease	Juice	Oral
Citrus limon (L.) Burm. [Rutaceae]; PG-402	Kaji nemu	0.11	Fr	Antidiabetic, antidandruff, stomachic	Juice	Oral
Clerodendron colebrookianum Walp. [Verbenaceae]; PG-481	Nephaphu	0.43	L	Hypertension, menstruation pain	Decoction	Oral
Clerodendrum infortunatum L. [Lamiaceae]; PG-486	Dhopat tita	0.03	R	Pneumonia	Paste	Oral
Clitoria ternnatea L. [Papilionaceae]; PG-587	Boga aparajita	0.02	R	Abortive, stomachic, bleeding, pinworm, alzheimer	Raw,	External
Coccinia grandis (L.) Voigt. [Cucurbitaceae]; PG-258	Kunduli	0.02	Fl, Fr, L	Hypertension, antidiabetic, ear infection	Vegetable, paste	Oral, external
Colocasia esculenta (L.) Schott [Araceae]; PG-47	Kosu	0.03	L, St	Hypertension, anemia, tonic	Vegetable	Oral
Corchorus capsularis L. [Tiliaceae]; PG-121	Morapat	0.07	YT	Fever	Paste	External
Cheilocostus speciosus (Koen. ex.Retz.) J.E.Smith [Costaceae]; PG-127	Jom lakhuti	0.14	L	Ear pain	Juice	Oral, external
Croton joufra Roxb. [Euphorbiaceae]; PG-227	Goch-mahudi	0.15	B	Pneumonia, fever, dysentery, stomachic	Decoction	Oral
Cucurbita pepo L. [Cucurbitaceae]; PG-257	Ronga lao	0.01	Fr, T	Anemia	Vegetable	Oral
Curcuma aromatica Salisb. [Zingiberaceae]; PG-133	Bon-halodhi	0.2	Rh	Body pain, cough, internal healing, skin problem	Paste	Oral, external
Curcuma caesia Roxb. [Zingiberaceae]; PG-135	Kola-halodhi	0.07	Rh	Gastritis, menstruation pain, bone fracture	Paste	Oral, external
Curcuma zedoaria Rosc. [Zingiberaceae]; PG-136	Borahu	0.02	Rh	Piles, gastric	Pill	Oral
Cuscuta reflexa Roxb. [Cuscutaceae]; PG-518	Akashi-lota	0.08	St	Jaundice, tonsilitis, bone fracture, paralysis	Paste, decoction	External
Cynodon dactylon (L.) Pers. [Poaceae]; PG-111	Dubori bon	0.07	Wh	Menstruation pain, cough, tonic, eye problem	Juice	Oraal
Dactylotenium aegypticum (L.) P. Beauv. [Poaceae]; PG-104	Bobosa bon	0.03	Wh	Piles, skin infection	None	External
Datura metel L. [Solanaceae]; PG-530	Kola dhatura	0.01	L	Arthritis	Infusion	External

Scientific name [Family]; Voucher No.	Common name	Use Value	Part Used	Application	Method of preparation	Route of administration
Dendrocnide sinuata (Bl.) Chew. [Urticaceae]; PG-326	Bor Surat	0.01	Fl	Allergies, skin infection	Vegetable	Oral
Delonix regia (Bojer) Rat. [Caesalpinaceae]; PG-589	Krishna chura	0.01	B	Cough	Decoction	Oral
Dillenia indica L. [Dilleniaceae]; PG-160	Ow-tenga	0.14	Fr	Antidiabetic, hypertension, pox	Decoction	Oral
Dracena angustifolia Roxb. [Agavaceae]; PG-590	Hati-kuhiar	0.09	St	Jaundice	Juice	Oral
Drymeria cordata (L.) Wild.ex Roem.et.Schult. [Caryophyllaceae]; PG-176	Lai-jabori	0.23	Wh	Urinary infection, leucorrhoea, piles, sinusitis, skin irritation	Juice, paste, fragrance	External
Dryopteris filix-mas (L.) Schott [Dryopteridaceae]; PG-591	Bihlogoni	0.13	L	Pneumonia, fever, recovery(female after giving birth),anthelmintic	Decoction	Oral
Eclipta prostrata (L.) L. [Asteraceae]; PG-549	Keheraj	0.02	Wh	Bleeding, leucorrhea, hairfall	Paste	Oral, external
Elaeocarpus floribundus Bl. [Elaeocarpaceae]; PG-205	Jolphai	0.02	Fr	Antidiabetic	Raw	Oral
Enhydra fluctuens Lour. [Asteraceae]; PG-552	Helos	0.01	S	Antidiabetic, hypertension	Raw	Oral
Eryngium foetidum L. [Apiaceae]; PG-577	Man dhania	0.02	L	Purgative, diuretic, wound healing	Juice	Oral
Erythrina stricta Roxb [Fabaceae]; PG-288	Ronga modar	0.02	L	Jaundice	Juice	Oral
Euphorbia hirta L. [Euphorbiaceae]; PG-228	Gakhiroti bon	0.03	TS	Galactogogue to nursing mother	Vegetable	Oral
Euphorbia ligularia Roxb. [Euphorbiaceae]; PG-229	Siju	0.03	L, Ex	Stomachic, cough, finger swelling	Decoction	Oral, external
Ficus auriculata L. [Moraceae]; PG-304	Dimoru	0.06	L	Diarrhea, stomachic, tonic	Decoction	Oral
Ficus racemosa L. [Moraceae]; PG-309	Maudimoru	0.06	L	Fever, recovery(female after giving birth), detoxification	Decoction	Oral
Flacourtia jangomas (Lour) Rauesch.[Flacourtiaceae]; PG-211	Poniyol	0.03	Fr	Antidiabetic, anemia	Raw	Oral
Garcinia morella Roxb.ex.DC [Clusiaceae]; PG-218	Kuji thekera	0.38	Fr	Chronic dysentery, diarrhea, tonic	Smoke, infusion	Oral
Garcinia pedunculata Roxb. [Clusiaceae]; PG-219	Bor thekera	0.03	Fr	Stomachic	Smoke, infusion	Oral
Garcinia xanthochymus Hook.f. [Clusiaceae]; PG-220	Tepor tenga	0.07	Fr	Dysentery, pinworm	Juice	Oral
Grewia serrulata DC [Tiliaceae]; PG-371	Kukurhuta	0.02	L	Cut and wound	Paste	External
Gomphrena celosioides Mart. [Amaranthaceae]; PG-166	Leheti	0.02	TS	Antidiabetic	Vegetable	Oral
Stenoclaena palustris(Burm.f.) Bedd [Blechnaceae]; PG-592	Bonjaluk	0.04	TS	Menstruation pain	Decoction	Oral
Hibiscus rosa-sinensis L. [Malvaceae]; PG-366	Jobaphul	0.21	Fl, L	Fever, menstruation pain, leucorrhoea, hair problem	Paste	Oral, external
Hibiscus sabdarifffa L. [Malvaceae]; PG-372	Tengamora	0.08	L	Dysentery, Stomachic, Anemia	Vegetable	Oral
Houttuynia cordata Thunb. [Saururaceae]; PG-13	Mosondori	0.43	YT	Dysentery, diarrhea, stomachic	Paste	Oral
Hydrocotyle sibthorpioides Lam. [Araliaceae]; PG-580	Soru manimuni	0.33	Wh	Strengthens muscles, Dysentery, Stomachic, Hypertonic, Leucorrhoea	Paste	Oral, external
Ichnocarpus frutescens R.Br. [Apocynaceae]; PG-437	Dudhkori lota	0.02	Wh	Galactogogue	Vegetable	Oral
Impatiens tripetala L. [Balsaminaceae]; PG-414	Damdeuka	0.1	R, St, L	Menstruation, leucorrhea, jaundice, skin burn, irritation	Paste	Oral, external
Ipomoea aquatica Forsk. [Convolvulaceae]; PG-520	Pani-kolmow	0.03	T	Anemia	Vegetable	Oral
Jatropha curcus L. [Euphorbiaceae]; PG-231	Bongali era	0.12	St, Ex	Toothache, skin problem	Raw	Oral, external
Justicia adhatoda L. [Acanthaceae]; PG-465	Boga-bahok	0.09	L	Cough	Decoction	Oral

Scientific name [Family]; Voucher No.	Common name	Use Value	Part Used	Application	Method of preparation	Route of administration
Kalanchoe pinnata (Lam.) Pers. [Crassulaceae]; PG-163	Dupor tenga	0.37	L	Urethral stone, fever	Raw, paste	Oral, external
Lagenaria siceraria (Molina) Standl. [Cucurbitaceae]; PG-262	Jati-lao	0.04	T	Piles, hypertension	Juice	Oral
Lasia spinosa (L.) Thw. [Araceae]; PG-49	Chengmora	0.04	Bu, R	Recovery after child birth, cough, pneumonia	Vegetable	Oral
Lawsonia inermis L. [Lythraceae]; PG-330	Jetuka	0.05	L	Skin infection	Paste	External
Lepisanthes erecta (Thw.) Leenh. [Sapindaceae]; PG-409	Tulutha	0.02	R	Urinary infection	Paste	Oral
Leucas aspera (Willd.) Link [Lamiaceae]; PG-491	Durun	0.54	L	Sinusitis, apetizer, cough, bleeding, pox, gastritis	Juice, fragrance	Oral/Nostril
Lindernia pusilla (Willd.) Bold. [Scrophulariaceae]; PG-497	Gakhiroti bon	0.08	Wh	Lactating agent	Vegetable	Oral
Lindernia ruellioides (Colsm.) Pennell [Linderniaceae]; PG-498	Kachidoria bon	0.01	Wh	Ear pain	Juice	External
Litsea salicifolia (Roxb. ex Nees) Hook.f. [Lauraceae]; PG-24	Dighloti	0.02	L	Dysentery, flatulence	Decoction	Oral
Luffa acutangula (L.) Roxb. [Cucurbitaceae]; PG-259	Jika	0.01	S	Sinusitis	Juice	Oral
Lygodium flexuosum (L.) Sw. [Lygodiaceae]; PG-594	Kopou dhekia	0.01	L	Anthelmintic, insect repellant	Raw	External
Macrosolen cochinchinensis (Lour.) Tiegh. [Loranthaceae]; PG-165	Roghumola	0.02	L	Jaundice, menstruation pain	Juice	Oral
Magnifera indica L. [Anarcardiaceae]; PG-385	Aam	0.01	L	Antidiabetic, stomachic	Decoction	Oral
Manihat esculenta Crantz. [Euphorbiaceae]; PG-222	Himolu alu	0.04	B, Ex	Cancer, leucorrhea, eye problem	Paste	Oral, external
Mentha arvensis L. [Lamiaceae]; PG-479	Pudina	0.07	L	Urinary infection, stomachic, anti-germicidal, toothache	Paste, infusion	Oral
Messua ferrea L. [Clusiaceae]; PG-221	Nahor	0.01	B	Piles	Infusion	Oral
Microsorum punctatum (L.) Copel. [Polypodiaceae]; PG-595	Kollong	0.01	L	Purgative, diuretic, wound healing	Juice	Oral
Mikania micrantha Kunth. [Asteraceae]; PG-558	Premlota	0.14	L	Chronic dysentery, diarrhea, cut and wound	Juice	Oral
Mimosa pudica L. [Mimosaceae]; PG-292	Lajuki lota	0.12	L, R	Menstruation pain, cut, cancer, dysentery	Juice	Oral
Mimosops elengi Roxb. [Sapotaceae]; PG-425	Bokul	0.01	L	Pyrrohoea	Paste	Oral
Momordica charantia L. [Cucurbitaceae]; PG-260	Tita-kerela	0.06	T, Fr	Stomachic, antidiabetic	Vegetable	Oral
Moringa oleifera Lamk. [Moringaceae]; PG-596	Sojina	0.04	L, B	Tonic, blood purification, anthelmintic	Vegetable	Oral
Morus alba L. [Moraceae]; PG-313	Nuni	0.02	Fr	Menstruation pain	Raw	Oral
Murraya koenigii (L.) Spreng [Rutaceae]; PG-404	Narasingha	0.22	L	Anemia, stomachic, arthritis, piles	Paste	Oral
Musa balbiciana Colla [Musaceae]; PG-131	Athia kol	0.37	Rh, St, L, Fr, Fl	Toothache, stomachic, anemia, blood dysentery, pinworm, tonic	Raw	Oral
Musa sapientum L. [Musaceae]; PG-132	Kach kol	0.07	Fr	Constipation, dysentery, stomachic	Vegetable	Oral
Myrica esculenta Buch.-Ham. Ex D. Don [Myricaceae]; PG- 297	Noga tenga	0.01	B	Pyrrhoea, toothache	Powder	Oral
Nyctanthes arbor-tristis L. [Oleaceae]; PG-527	Sewali phul	0.23	Fl, L	Hypertension, detoxification, cough, fever, stonachic	Raw, juice	Oral
Ocimum tenuiflorum L. [Lamiaceae]; PG- 493	Tulsi	0.31	L	Cough, stomachic, anthelmintic	Raw, juice	Oral
Oxalis corniculata L. [Oxalidaceae]; PG-208	Tengeshi	0.07	Wh	Stomachic	Paste	Oral
Oxalis corymbosa DC. [Oxalidaceae]; PG-209	Bor tengeshi	0.07	Wh	Stomachic	Vegetable	Oral

Scientific name [Family]; Voucher No.	Common name	Use Value	Part Used	Application	Method of preparation	Route of administration
Paederia scandens(Lour) [Rubiaceae]; PG-459	Bhedailota	0.5	L	Anemia, stomachic, arthritis, piles,post maternity treatment, bleeding	Vegetable	Oral
Peperomia pellucida L. [Peperomiaceae]; PG-11	Ponow-nowa	0.02	Wh	Tonic, blood purification, antioxidant	Juice	Oral
Phlogacanthus thyrsiformis(Hardw.) Mabb. [Acanthaceae]; PG-469	Tita phul	0.02	Fl, L	Stomachic, gastritis, detoxfication, anemia, skin infection	Decoction	Oral
Phyllanthus emblica L. [Euphorbiaceae]; PG-228	Amlakhi	0.1	Fr	Antidiabetic, tonic, hair problem	Raw	Oral
Phyllanthus fraternus G.L.Webster [Phyllanthaceae]; PG-229	Bhui amlakhi	0.09	Wh, L, T	Menstruation pain, Urinary infection	Juice	Oral
Phyllanthus virgatus G. Forst. [Phyllanthaceae]; PG-230	Pani amlakhi	0.02	Fr	anti-cancer, anti-oxidant	Juice	Oral
*Physalis minima*L. [Solanaceae]; PG-533	Pokmo	0.02	Wh, R	Menstruation pain, Urinary infection	Paste	Oral
Piper betle L. [Piperaceae]; PG-7	Pan	0.09	L	Cough	Infusion	Oral
Piper longum L. [Piperaceae]; PG-8	Peepoli	0.09	S	Asthma, cough	Paste	Oral
Piper nigrum L. [Piperaceae]; PG-9	Jaluk	0.18	Fr	Anti-cancer, Fever, Pneumonia	Paste, decoction	Oral
Plumbago zeylanica L. [Plumbaginaceae]; PG-182	Agiasit	0.02	R	Tonsilities, skin cancer	Milk infusion	Oral
Pogostemon benghalensis (Burm.f.) Kuntze [Lamiaceae]; PG-492	Sukloti	0.31	L	Bleeding, hypertension, indigestion	Vegetable	Oral
Polygonum chinense L. [Polygonaceae]; PG-188	Modhu-solang	0.02	L	Stomachic, tonic	Vegetable	Oral
Polygonum glabrum Wild. [Polygonaceae]; PG-190	Bihlogoni	0.13	L	Anthelmintic, insect repellant	Raw	External
Pouzolzia zeylanica (L.) Benn. & R. Br. [Urticaceae]; PG-329	Borali bukua	0.13	Wh	Sprain, cut and wounnds	Paste	External
Psidium guajava L. [Myrtaceae]; PG-345	Modhuri am	0.49	L	Chronic dysentery, Diarrhoea, Pyrrohoea	Raw	Oral
Punica granatum L. [Punicaceae]; PG-336	Dalim	0.15	Bu	Chronic dysentery, anemia,blood purifier	Raw, smoke	Oral
Rhynchostylis retusa (L.) Bl. [Orchidaceae]; PG-79	Kopou-phul	0.02	L	Ear pain	Juice	External
Ricinus communis L. [Euphorbiaceae]; PG-233	Era gos	0.02	S	Arthritis, hair problem	Oil infusion	External
Rubus alceifolius Poir [Rubiaceae]; PG-321	Jetuli-poka	0.02	R	Pneumonia, cough	Paste	Oral
Saccharum officinarum L. [Poaceae]; PG-120	Kuhiya	0.09	St	Jaundice, tonic	Juice	Oral
Sapindus mukorossi Gaertn. [Sapindaceae]; PG-408	Moni-chal	0.03	S	Pharyngitis, cough, hair problems	Decoction	Oral, external
Sarcochlamys pulcherrima (Roxb.) Gaud [Urticaceae]; PG-330	Mechaki	0.05	L	Stomachic, galactogogue, dysentery, hypolipidemic	Decoction	Oral
Sauropus androgynus (L.) Merr. [Euphorbiaceae]; PG-249	Bari-sundari	0.05	L	Antidiabetic	Vegetable	Oral
Schumannianthus dichotomus (Roxb.) Gagnep [Marantaceae]; PG-129	Patidoi	0.01	Bu	Leucorrhea	Paste	Oral
Scoparia dulcis L. [Scrophulariaceae]; PG-500	Cheni-bon	0.08	L	Leucorrhea, cough, pneumonia, piles	Juice	Oral
Selaginella kraussiana (Kunze) A. Braun [Selaginellaceae]; PG-597		0.02	L	Leucorrhea, Jaundice	Juice	Oral
Sida acuta Burm.f. [Malvaceae]; PG-376	Sonborial	0.02	L	Jaundice	Juice	*Oral*
Smilax perfoliata Lour. [Smilaceae]; PG-66	Tikoni-borua	0.03	St	Antidiabetic, blood purifier	Vegetable	Oral
Solanum esculentum Mill. [Solanaceae]; PG-533	Soru bilahi	0.03	Wh	Burning, irritation	Juice	External
*Solanum indicum*L. [Solanaceae]; PG-534	Tita bhekuri	0.03	Fr	Blood purifier, stomachic	Vegetable	Oral

Scientific name [Family]; Voucher No.	Common name	Use Value	Part Used	Application	Method of preparation	Route of administration
Spilanthes acmella (auct.nonL.) Merr. [Asteraceae]; PG-564	Bonoria malkathi	0.23	Fr	Tuberculosis, tongue infection, internal wound healing	Infusion	Oral
Spondias pinnata (L.f.) Kurz. [Anacardiaceae]; PG-387	Amora	0.18	St, B, L, Fr	Dysentery, stomachic, Anemia, Piles	Paste, raw	Oral
Stenoclaena palustris(Burm.f.) Bedd [Blechnaceae]; PG-598	Ronga lota	0.03	L	Pneumonia, bodyache	Powder	
Syzygium cumini (L.) Skeels [Myrtaceae]; PG-344	Kola jamuk	0.28	Fr, S, B	Antidiabetic, piles	Raw, paste, infusion	Oral
Tabernaemontana divaricata (L.) R.Br. Ex Roem.et Schult. [Apocynaceae]; PG-443	Kothona phul	0.08	R	Fever, Cough, Pneumonia	Paste	Oral
Tagetes erecta L. [Asteraceae]; PG-566	Narji	0.08	L	Cut and wound	Paste	External
Tamarindus indica L. [Caesalpinaceae]; PG-599	Teteli	0.08	Fr, L	Hypertension, fever, bone fracture	Water infusion, paste	Oral, external
Terminalia arjuna (Roxb ex DC) Wight & Arn. [Combretaceae]; PG-51	Arjun	0.29	B	Cardiovascular disease, piles	Infusion	Oral
Terminalia chebula Retz. [Combretaceae]; PG-55	Hilikha	0.12	Fr	Pinworm, stomachic, anemia, constipation	Eaten raw	Oral
Thunbergia coccinea Wall. [Thunbergiaceae]; PG-473	Sunga lota	0.01	Bu	Stomachic	Paste	Oral
Tinospora cordifolia (Willd.) Hook.f. & Th. [Menispermaceae]; PG-149	Amarlota	0.12	St	Antidiabetic, bone fracture	Water infusion	Oral, external
Trachyspermum ammi (L.) Sprague [Apiaceae]; PG-581	Ajwain	0.01	S	Indigestion, gastritis	Infusion	Oral
Trigonella foenum-graecum L. [Fabaceae]; PG-266	Methi	0.07	L, S	Antidiabetic	Vegetable	Oral
Vitex negundo L. [Verbenaceae]; PG-495	Pochotia	0.16	L	Cough, insect repellant, stomachic, bone fracture, internal healing	Decoction, paste	Oral
Xanthium strumarium L. [Asteraceae]; PG-570	Agoru	0.05	S, R	Internal wound healing	Juice	Oral
Zanthoxylum nitidum (Roxb.) DC [Rutaceae]; PG-403	Tezmuri	0.35	R, St, B	Pneumonia, Fever, Cough, Toothache	Paste, decoction	Oral
Zingiber officinale Rosc. [Zingiberaceae]; PG-139	Moran ada	0.14	Rh	Whooping cough	Paste	Oral
Zizyphus mauritiana Lamk. [Rhamnaceae]; PG-316	Bogori	0.05	Fr	Pneumonia, fever, cough, Toothache, piles	Raw	Oral

L—Leaf | Wh—Whole plant | Sh—Shoot | Ex—Exudate | St—Stem | B—Bark | Fr—Fruit | Fl—Flower | R—Root | Bu—Bulb | S—Seed | Rh—Rhizome | La—Latex

Table 4. List of threatened species used by ethnic tribes in Dibrugarh District.

Taxon	Red List
1. *Acorus calamus* L.	VU
2. *Clerodendrum colebrookianum* Walp.	VU
3. *Messua ferrea* Linn.	VU
4. *Sapindus mukorossi* Gaertn.	VU
5. *Alstonia scholaris* R.Brown.	NT
6. *Terminalia chebula* (DC) W & A	NT
7. *Artocarpus lakoocha* Roxb.	NT
8. *Cinnamomum tamala* Nees & Ebern	LC
9. *Cissampelos pareira* Linn.	LC
10. *Curcuma caesia* Roxb.	CR
11. *Garcinia pedunculata* Roxb.	EN
12. *Rhyncostylis retusa* (L.)	EN

Asteraceae to be the leading family with the highest number of medicinal plants. Similarly, family Lamiaceae, Apocynnaceae, Cucurbitaceae, Amaranthaceae, Zingiberaceae, Moraceae were represented by five species each, family Apiaceae, Poaceae by four species each and family Acanthaceae, Urticaceae, Rubiaceae, Scrophulariaceae, Piperaceae were represented by three species each. The remaining 59 families contributing (82 species, 48.94%) have one or two species (Table 5). The medicinal plants that were used in various forms to cure different human ailments were plant paste (55 species, 31.6%) which was the most commonly used followed by juice (38 species, 21.83%), vegetable (30 species, 17.24%), decoction (26 species, 14.94%), eaten raw (24 species, 13.79%), infusion (17 species, 9.77%), smoke (3 species, 1.72%), pill (three species, 1.72%) and powder

Table 5. Category wise distribution of various medicinal plant taxa in Dibrugarh District.

Family	Number of genera	Percentage of genera	Number of species	Percentage of species
Euphorbiaceae	7	4.02	10	5.74
Asteraceae	8	4.59	8	4.59
Araceae	6	3.44	7	4.02
Rutaceae	4	2.29	7	4.02
Lamiaceae	5	2.87	5	2.87
Apocynaceae	5	2.87	5	2.87
Cucurbitaceae	5	2.87	5	2.87
Amaranthaceae	4	2.29	5	2.87
Zingiberaceae	3	1.72	5	2.87
Moraceae	3	1.72	5	2.87
Apiaceae	4	2.29	4	2.29
Poaceae	4	2.29	4	2.29
Solanaceae	3	1.72	4	2.29
Acanthaceae	3	1.72	3	1.72
Urticaceae	3	1.72	3	1.72
Rubiaceae	3	1.72	3	1.72
Scrophulariaceae	3	1.72	3	1.72
Piperaceae	1	0.57	3	1.72
Other 59 families	71	57.57	82	48.94
78	**147**	**100%**	**174**	**100%**

and fragrance (two species, 1.14%) each (Figure 4). For improving the palatability, honey is used as an additive by the healer which is also used for enhancing the taste of local medicines (Debbarma et al. 2017). It was found that most of the herbal preparations were given orally to cure human ailments except dermatological problems. No standardized measure for dosage consumption of medicines was prescribed by the healers in the study area. They were recommended with specific guidelines and care so that the medicine worked effectively without causing any internal problems. Examples were also cited by the healers where excessive dosage of *Cheilocostus speciosus* may lead to deafness and excessive consumption of *Clerodendrum colebrookianum* may cause low blood pressure in patients.

Use value (uv)

The most commonly used species were *Leucas aspera* (Roth) Spr with 0.54 use value and *Paederia scandens* (Lour) with 0.5 use value; they were followed by *Psidium guajava* L. with 0.49 use value, *Hottuynia cordata* Thunb. and *Clerodenndron colebrookianum* Walp. with a use value of 0.43 each, *Garcinia Morella* Roxb. ex. DC with 0.38 use value, *Kalanchoe pinnatum* (Lam.) Pers. with 0.37 use value, *Zanthoxylum nitidum* (Roxb.) DC with 0.35 use value and *Hydrocotyl sibthorpioides* Lam. with 0.33 use value. The most rarely used medicinal plants were *Phyllanthus fraternus* Webst, *Phlogacanthus thyrsiformis* (Hardw.) Mabb., *Scoparia dulcis* L., and *Lepisanthes erecta* (Thw.) Leenh., which had use values from 0.09 to 0.02. Some medicinal plants used by the ethnic communities for treating basic ailments have received many reports about their medicinal uses. The relative importance is reflected in the use values of these medicinal plants. *Leucas aspera* (Roth.) Spr. is a useful tropical plant which is harvested from the wild for local use, primarily as a medicine, but also as a food and insect repellant. It is sometimes cultivated in home gardens for local uses and as a pot herb. The plant is used traditionally as an antipyretic and insecticide (Prajapati et al. 2010). The root decoction of *Paederia scandens* (Lour.) is used to cure diarrhea and dysentery (Sen & Behera 2008). All parts of the plant have been used for different purposes: hepatoprotection, antioxidant, anti-inflammatory, anti-spasmodic, anti-cancer, anti-microbial, anti-hyperglycemic, analgesic, endothelial progenitor cells, anti-stomachic, and anti-diarrhea (Barbalho et al. 2012). The extract of *Hottuynia cordata*

Table 6. Informant consensus factor (F_{IC}) of the diseases reported by the informants.

Disease category	Use reports (N_{ur})	No. of taxa (N_t)	F_{IC}
Digestive system	176	93	0.76
Oral and dentistry	24	7	0.73
Heart and vascular system	88	26	0.72
External injuries	105	30	0.72
Hematology	88	26	0.71
Respiratory system	104	33	0.68
Infection and immunization	59	19	0.68
Pulmonary disease	60	20	0.67
Dermatological	76	27	0.65
Musculoskeletal and nervous system	20	8	0.63
Urinogenital and venereal	181	79	0.57
Endocrinology	82	36	0.56
Other (fever, cold, cough)	122	55	0.56

Thunb. is given for stomach ache (Kagyung et al. 2009). Most of the medicinal plants used by the Assamese community in Dibrugarh District were also reported in the previous studies on ethnobotany of medicinal plants used by Assamese people for various skin ailments and cosmetics (Saikia et al. 2006), ethnomedicine used by Mishing tribes of Dibrugarh District (Baruah & Kalita 2007), and some ethnomedicine used by the Tai Ahom of Dibrugarh District (Kalita & Baruah 2010). The application of each medicinal plant which was presented in our study, however, was found to be much more than what was presented in the earlier literatures. This may be due to the different number of informants interviewed during the survey. There is no report of some plants in the previous studies (Saikia et al. 2006; Talukdar et al. 2017) but have high use value such as *Leucas aspera* (Roth) Spr, *Paederia scandens* (Lour.), *Houttuynia cordata* Thunb., *Clerodendron colebrookianum* Walp. This may be due to different traditional knowledge practices that have been passed from generation to generation within the family circle.

Informants consensus factor (f_{ic})

Informants consensus analysis provides a measure of availability for the given evidence of data collection in the ethnomedicinal studies (Malla & Chhetri 2012). In this present investigation, the medicinal plants used to treat different ailments in the Dibrugarh District of Assam were classified into 13 ICPC (International Classification of Primary Care) disease categories (https://www.who.int/classifications/icd/adaptations/icpc2/en/) and the F_{IC} value of each and every disease category was calculated and depicted (Table 6). In the study, the digestive system disorder category showed the greatest agreement with an F_{IC} of 0.76%. It was followed by oral and dentistry category (0.73%), heart and vascular system (0.72%), external injuries (0.72%), hematology (0.71%), respiratory system (0.68%), infection and Immunization (0.68%), pulmonary disease (0.67%), dermatological (0.65%), musculoskeletal & nervous system (0.63%), and urinogenital & venereal (0.57%). The least agreement between the informants was recorded in the responses related to endocrinology and others (fever, cold, cough) both representing 0.56%. Previously various authors followed this F_{IC} value as a significant tool to carry out respective ethnobotanical work (Inta et al. 2013; Singh et al. 2014; Mall et al. 2015; Hosseini et al. 2017). These works show a high level of agreement among the various ethnic communities of the state of Assam having a rich traditional knowledge with diversified flora as well as fauna along with colourful culture and tradition.

CONCLUSIONS

The present investigation represents an array of information about the rich indigenous knowledge of traditional medicine and ethnobotanical potential of the various plants used by the tribal people of Dibrugarh District. A contribution of total 174 plants against 13 different disease categories has been listed. Most of these plant species belong to different families of angiosperms except three from Pteridophyta. The traditional healers and elderly villagers had given high indication scores (use value) for the plants, viz., *Leucas aspera*, *Paederia foetida*, *Psidium guajava*, *Houttuynia cordata*, *Clerodendron colebrookianum*, *Garcinia morella*, *Zanthoxylum nitidum*, *Kalanchoe pinnatum*, *Musa balbiciana*, and *Pogostemon benghalensis* have been accepted by the people as highly useful in traditional health-care practices in Dibrugarh District. Further, statistical analysis of the ethnomedicinal plants carried out by calculating their use value and informant consensus factor, have confirmed their relative importance and efficiency towards curing various ailments in Dibrugarh District. So, the plants with ethnomedicinal properties must be chemically tested for correct identification of bioactive compounds which can be further used for drug designing. This will be a great contribution to pharmaceutical and herbal industries for betterment of mankind. From the conservation point of view, the present work will be a new insight in creating awareness and setting management strategies for the ethnomedicinal plants and the floristic diversity of Dibrugarh District.

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SHORT COMMUNICATION

Marine mammal strandings in the northern Palk Bay from 2009 to 2020

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Abstract: Globally, the marine mammal population has been under threat due to various human activities. Data on stranding of these animals that are important for effective conservation planning and management, however, are not available in most of the developing countries. This paper presents observations on marine mammal strandings in northern Palk Bay, the southeastern coast of India over the last decade. In total, 21 stranding events consisting of 23 marine mammals were observed from 2009 to 2020. These stranded mammals include a Humpback Dolphin, a Blue Whale, two Finless Porpoises, and 19 Dugongs. The evident reason for the death of the dugongs and the porpoise being fishing activities, regulations on fishing practices, and intensive monitoring of the existing dugong population and their habitats are necessary. This study recommends for establishment of conservation reserve, and setting up district-level marine mammal rescue and release units in Nagapattinam, Tiruvarur, Thanjavur, Pudukkottai, and Ramanathapuram districts, comprising fishers and line departments. These units need to be sufficiently equipped in terms of equipment and infrastructure, and periodical technical training and workshops on marine mammal rescue and release procedures to quickly respond and handle marine mammal strandings in the area.

Keywords: Blue Whale, Dugong, Finless Porpoises, fishing net, Humpback Dolphin, Palk Bay, OMCAR, seagrass.

A variety of marine mammals such as dolphins, whales, dugong, and porpoise, are found in the vast marine habitat along the Indian coast. There are many incidences of these animals getting stranded and dying. As per Gopalakrishnan et al. (2014) 'stranding' refers to an animal getting outside its survival envelope, and so 'marine mammal stranding' refers to instances where a group or an animal is washed ashore and unable to move back to the sea (Aragones et al. 2010). The Central Marine Fisheries Research Institute (CMFRI) has been publishing marine mammal stranding records for more than 60 years (Jeyabaskaran et al. 2013). The earliest of such instances reported from India are in 1748 (Sathasivam 2000). A well-maintained marine mammals stranding database provides vital information about the status of marine ecosystems (Aragones et al. 2010). This paper is about the marine mammal strandings observed by Organization for Marine Conservation, Awareness and Research (OMCAR) Foundation in the northern Palk Bay from 2009 to 2020. The objective of this long-term monitoring of marine mammal stranding is to highlight their presence in this locality, and promoting their conservation in Palk Bay. This monitoring is important to not only to conserve marine mammals but also their habitats and to implement sustainable fishery activities. The monitoring creates awareness among the public,

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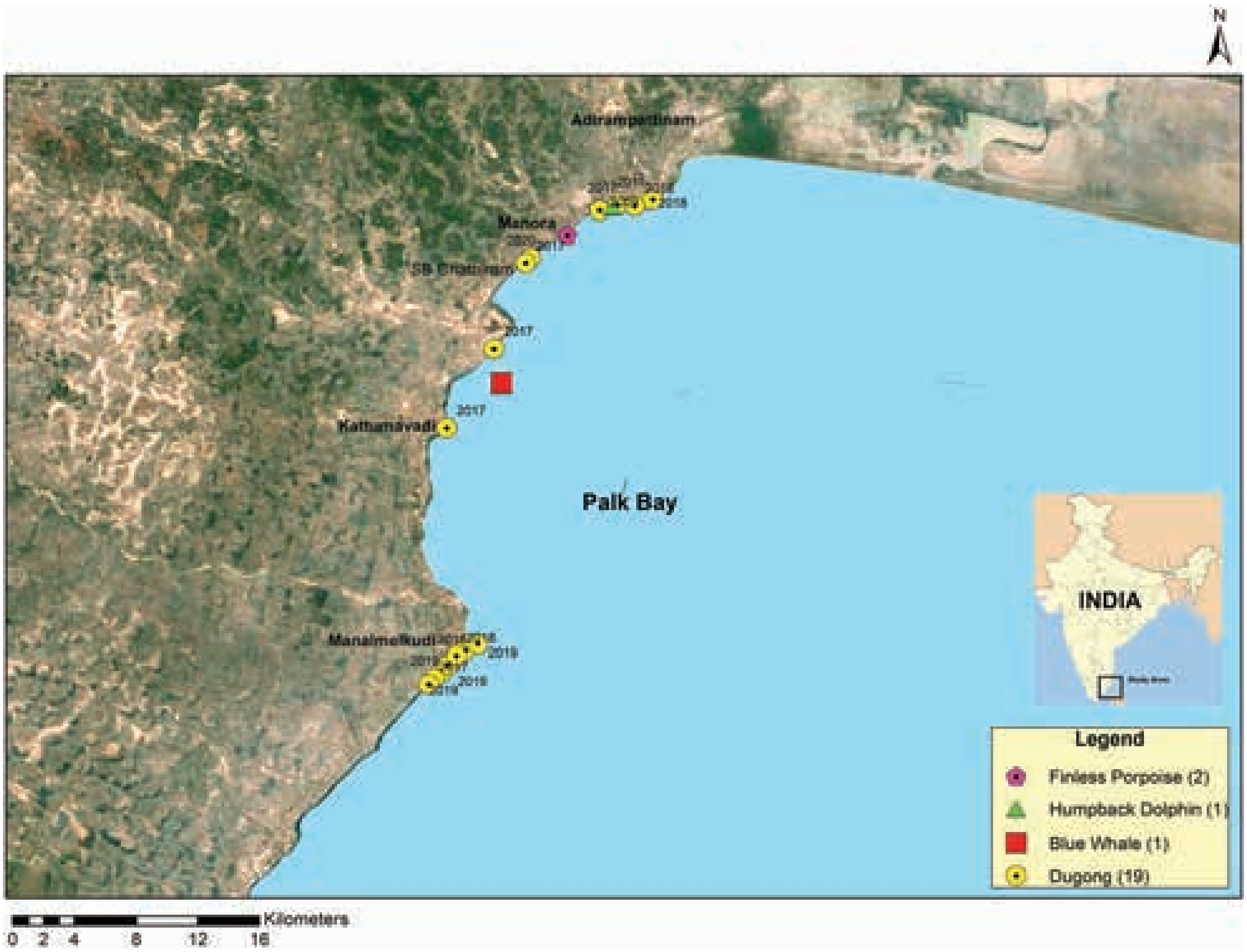

Figure 1. Marine mammal stranding in northern Palk Bay (2009–2020).

and hints to the government to consider for developing policy and guidelines, which is crucial to protect these taxa as per Wildlife Protection Act, 1972. This study is based on the data obtained by working with Tamil Nadu Forest Department and grassroot conservation volunteer groups in the northern part of Palk Bay, Tamil Nadu, India.

Materials and Methods

The study area in the northern part of Palk Bay falls in Thanjavur and Pudukkottai districts of Tamil Nadu (Figure 1). We received intimations about marine mammal strandings from local forest officials, fishermen, and marine police. Upon hearing about such an incident, we reached the stranding site, marked GPS coordinates of the site using Garmin Etrex GPS, and with due permission from the field-officials of the forest department measurements of the carcass were taken and the state of the specimen and other information were collected.

Results

In total, 21 marine mammal stranding events consisting of 23 animals were recorded between 2009 and 2020 (Figure 1). The stranded animals included two Finless Porpoises (Image 1 & 12), a Humpback Dolphin (Image 3), a Blue Whale (Image 4), and 19 Dugongs (Image 2, and 5–11). Other than the 14 dead Dugongs, five Dugongs were rescued from shore seine nets and released back into the sea during the four years from 2016 to 2019 jointly by Thanjavur and Pudukkottai divisions of Tamil Nadu Forest Department, Wildlife Institute of India, Coastal Security Group of Tamil Nadu Police Department, OMCAR Foundation and volunteers from the local community.

Discussion

The 12-year observations of this study were made through participatory conservation efforts by Tamil Nadu forest Department along with other inline departments and Friends of Dugongs in Thanjavur and Pudukkottai

Image 1. Finless Porpoise *Neophocaena phocaenoides* washed ashore at Mallipattinam, Thanjavur District, northern Palk Bay in 2010.

Image 2. A female Dugong washed ashore at Keezhathottam Village, Thanjavur District in northern Palk Bay in 2011.

Image 3. Humpback Dolphin washed ashore at Velivayal Village, Thanjavur District, Palk Bay in 2013.

Image 4. A 35-foot Blue Whale washed ashore at Kattumavadi, Thanjavur District, Palk Bay in 2015.

Image 5. Dugong calf washed ashore at Manalmelkudi, Pudukkottai District in 2016.

Image 6. Dead Dugong washed ashore at Adaikkathevan, Thanjavur District in April 2017.

districts.

Online database of Marine Mammal Research and Conservation Network of India (MMRCNI) listed 30 marine mammal stranding records in 120 years from Palk Bay between 1888 to 2009. Most of the records were from southern Palk Bay, listed for more than a century. This study focused only on a small part of Palk Bay, which documented a total number 21 observations in 12 years.

Monitoring of marine mammal stranding is one of the building blocks of 15 years of rapport building with local stakeholders by OMCAR, through participatory conservation approach. This is achieved by serving the basic needs of local stakeholders including conservation-oriented livelihood support to fishing communities, and integration of management-oriented restoration and baseline research in coastal habitats to support government conservation policy. As marine mammals are scheduled species in the Wildlife Protection Act, 1972, no parts of the specimen were collected during this study. Poaching, entanglement in fishing gear, boat accidents, and habitat destruction are the key factors that threaten the marine mammals of Palk Bay. The Finless Porpoises, recorded in 2010 and 2020, washed ashore in Mallipattinam (Image 2 and 13). This record shows the vulnerability of such animals in the fishing grounds of Palk Bay. Out of the 23 marine mammals reported in this study, only one animal, the Humpback Dolphin, had died due to natural causes. Veterinary doctors reported that a catfish spine had penetrated the oesophagus of the dolphin when the fish was being swallowed. The Blue Whale that washed ashore in 2015 might have drifted from the Bay of Bengal through the Palk Strait. It might have died due to collision with ships in Bay of Bengal, as such large marine mammals may not prefer to swim into the shallow Palk Bay away from their migration route (Randage et al. 2014). Most dugong strandings occurred in summer (Table 1), which may be due to high seagrass growth in summer. Dugongs graze on seagrass (Heinsohn & Birch 1972; Marsh et al. 1982) and Thanjavur District coast of Palk Bay has 12,243ha of seagrass beds as determined through an acoustic survey (Balaji 2018). Fourteen species of seagrass have been reported in this region (Kannan et al. 1999). The biggest threats to the Dugongs and seagrasses are from unsustainable fishing methods, eutrophication, and poor waste management. The seagrass ecosystem does not recover fast once destroyed (Kirkman 1997). It is estimated that about 75 to 100 Dugongs occur in Palk Bay based on the interviews of fishers (Yashpal et al. 2015). This study observed 19 dead Dugongs in 12 years along the coast of Thanjavur and Pudukkottai districts, which covers only 20% of total length of Palk Bay coast. Of the 19 dead Dugongs recorded during this study, 17 animals were recorded only after 2015. By comparing the Dugong population reported by Yashpal et al. (2015) with the observations made during this study, it is assumed that atleast 22 percentage of Dugongs in Palk Bay might have died in 12 years between 2009–2020. The percentage may increase if the total number of

Image 7. Decomposed Dugong calf without head washed ashore in March 2018.

Image 8. Heavily decomposed Dugong washed ashore, April 2018.

Dugong deaths are counted in remaining coastal areas of Palk Bay, or it may decrease if the total number of dugongs in Palk Bay is more than the estimated population by Yashpal et al. (2015).

The number of marine mammals stranded in the area recommends establishing Dugong habitat protected sites as conservation reserve in Palk Bay and marine mammal stranding response units in each district, namely Nagapattinam, Tiruvarur, Thanjavur, Pudukkottai, and Ramanathapuram. These grassroots-level units need to include fishers and line department personnel and have to be provided with appropriate technical training through periodical workshops on marine mammal rescue and release and also collection of data from carcasses. The units also need to be provided with the required equipment and infrastructure to respond to marine mammal strandings.

Table 1. Marine mammal strandings in the northern Palk Bay from 2009 to 2020.

	Date	Common name	Condition	Sex	Total length (feet)	Season	Nos.	Reason for Stranding	Place
1	23.v.2009	Dugong (*Dugong dugon*)	Dead	Unknown	9.7	Summer	1	Highly decomposed body, reason not known	Pudupattinam, Thanjavur District,
2	11.vi.2011	Dugong (*Dugong dugon*)	Dead	Female	12.2	Pre-monsoon	1	Drowning in a fishing net	Keezhathottam, Thanjavur District,
3	17.iv.2010	Finless Porpoise (*Neophocaena phocaenoides*)	Dead	Unknown	3.9	Summer	1	Accidental capture in a trawl net	Mallipattinam, Thanjavur District
4	22.iv.2013	Humpback Dolphin (*Sousa chinensis*)	Dead	Unknown	8.4	Summer	1	Oesophagus punctured by catfish spine	Velivayal, Thanjavur District
5	23.x.2015	Blue Whale (*Balaenoptera musculus*)	Dead	Unknown	45	Monsoon	1	Unknown	Kattumavadi, Pudukkottai District
6	05.iv.2016	Dugong (*Dugong dugon*)	Dead	Unknown	4	Summer	1	Drowning in a fishing net	Ponnagaram, Pudukottai District
7	15.ix.2017	Dugong (*Dugong dugon*)	Dead	Unknown	11	Monsoon	1	Drowning in a fishing net	Sethubhavachatram, Thanjavur District
8	01.vi.2017	Dugong (*Dugong dugon*)	Dead	Unknown	-	Pre-monsoon	1	Unknown	Velivayal
9	21.iv.2017	Dugong (*Dugong dugon*)	Dead	Unknown	10.5	Summer	1	Drowning in gill net (*kattavalai*)	Therku Pudukkudi, Pudukkotai District
10	02.iv.2017	Dugong (*Dugong dugon*)	Dead	Male	10	Summer	1	Drowning in a fishing net	Adaikalathevan, Thanjavur District
11	30.i.2017	Dugong (*Dugong dugon*)	Live	Female and calf	11.5	Post monsoon	2	Rescued and released from Shore seine net	Kattumavadi
12	29.iv.2018	Dugong (*Dugong dugon*)	Dead	Calf	4	Summer	1	Without head washed ashore	Vadakku Ammapattinam, Thanjavur District
13	05.iv.2018	Dugong (*Dugong dugon*)	Dead	Female	9.7	Summer	1	Unknown	Vadakku Ammapattinam
14	06.vii.2018	Dugong (*Dugong dugon*)	Live	Female	12	Pre-monsoon	1	Rescued and released from the shore seine net	Keezhathoddam, Thanjavur District
15	12.xi.2018	Dugong (*Dugong dugon*)	Live	Male	9.5	Monsoon	1	Rescued and released from the shore seine net	Keezhathoddam, Thanjavur District
16	07.ii.2019	Dugong (*Dugong dugon*)	Dead	Male	11	Post monsoon	1	Animal cut into two pieces due to unknown reasons.	Kodimunai, Manalmelkudi, Pudukottai District
17	02.iii.2019	Dugong (*Dugong dugon*)	Dead	-	-	Summer	1	Decayed dugong body washed ashore	Ammapattinam, Pudukkottai District
18	03.iii.2019	Dugong (*Dugong dugon*)	Dead	-	5	Summer	1	Head was damaged by boat accident	Ayyanpattinam, Pudukkottai District
19	02.iv.2019	Dugong (*Dugong dugon*)	Live	Male and female	10	Summer	2	The male was rescued, and the female died while rescue operation from the shore seine net	Ammapattinam, Pudukottai District
20	16.ii.2020	Dugong (*Dugong dugon*)	Dead	Female	12.8	Summer	1	Drowning in a fishing net	Sethubavachatthiram, Thanjavur District
21	16.x.2020	Finless Porpoise (*Neophocaena phocaenoides*)	Dead	-	4	Monsoon	1	Accidental capture in fishing net.	Mallipattinam, Thanjavur District

Image 9. A Dugong body cut into two pieces due to unknown reason in February 2019.

Image 10. A female pregnant Dugong accidentally captured in shore seine died during rescue attempt in April 2019. Volunteers try to save the Dugong from the fishing net.

Image 11. A female Dugong washed ashore at Sethubavachatthiram fish landing in February 2020.

Image 12. Finless Porpoise *Neophocaena phocaenoides* washed ashore at Mallipattinam, Thanjavur District, northern Palk Bay in October 2020.

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SHORT COMMUNICATION

First distribution record of the Asiatic Toad *Bufo gargarizans* Cantor, 1842 from India — Dibang Valley in Arunachal Pradesh

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Abstract: *Bufo gargarizans*, a species complex, has a wide distribution ranging from Japan to south-western China, Vietnam, and Russia but was not previously reported from India. Surveys conducted in Dibang Valley district of Arunachal Pradesh near the Indo-Tibetan border with China in 2014–15 revealed previously unreported specimens of the toad genus *Bufo*. Based on photographic comparisons with morphological characteristics obtained from published literature, we have identified the *Bufo* from Dibang Valley as the Asiatic Toad *Bufo gargarizans* Cantor, 1842. Individuals of the species reported from Dibang have a wide mid dorsal line in the dorsum, rarely observed in *Bufo gargarizans* except in the sub-populations on the Tibetan Plateau.

Keywords: Arunachal Pradesh, *Bufo gargarizans*, Dibang Wildlife Sanctuary, new country record, new distribution.

Bufo gargarizans Cantor, 1842 is a large-sized terrestrial toad (SVL males: 62–106 mm; females: 70–121 mm) distributed in eastern Asia, known to occur up to 4,300m (Fei et al. 2012). The populations on the Tibetan Plateau are some of the highest known records of any toad species (Fei et al. 2009; Zhan & Fu 2011). This species complex has a wide distribution range spanning most of central, southeastern, and northeastern China, the Russian far-east up to the Amur River Valley, throughout the Korean Peninsula, Japan, and Vietnam (IUCN SSC Amphibian Specialist Group 2019; Frost 2021 but see Che et al. 2020 for suggestions for a new taxonomic split for populations in Tibet). No records of the *Bufo gargarizans* species complex had been previously reported from India (Dinesh et al. 2020). In this paper, we report the first and the only known occurrence of *Bufo gargarizans* from the Indian subcontinent.

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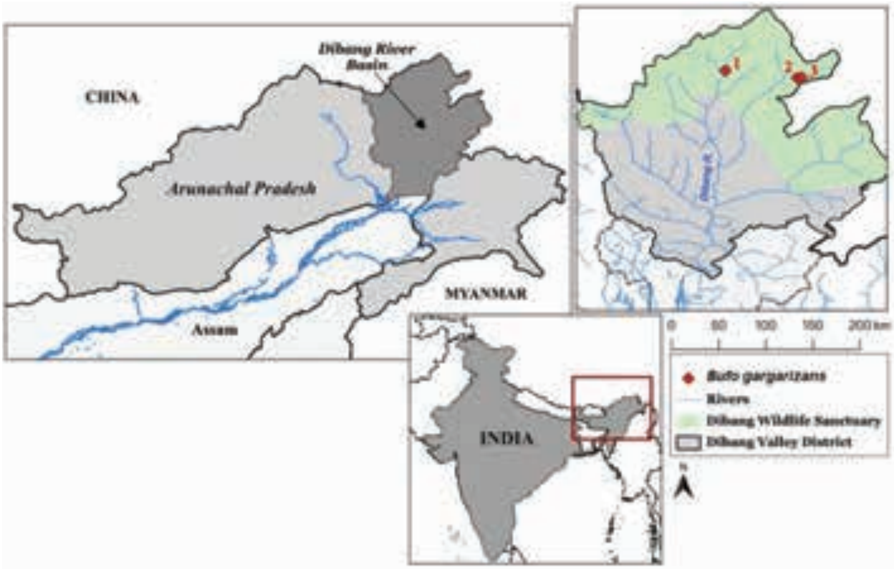

Figure 1. Locations 1 (29.198^{0}N; 95.895^{0}E), 2 (29.166^{0}N; 96.209^{0}E), 3 (29.168^{0}N; 96.229^{0}E) in Dibang Valley District where *Bufo gargarizans* specimens were recorded during field surveys.

From July to October of 2014 and 2015, while conducting mammalian surveys in Dibang Valley district of Arunachal Pradesh, India, we opportunistically encountered several individuals of a previously unreported *Bufo* species in the high-altitude marshlands near the Tibetan border. As we walked through the marshes, many toads jumped out of the grass in front of us drawing our attention. While no specimens were collected, a few different individuals were photographed and only one individual was measured for its SVL (Image 1). Based on preliminary photographic comparisons with the morphologically similar Asian Toad *Bufo gargarizans* Cantor, 184*,* known to occur in similar elevation range in southeastern Tibet (Frost 2021), we have identified the *Bufo* species from Dibang as *Bufo gargarizans*. Here, we present a detailed description of the Dibang specimens including the microhabitats where they were encountered. Though we suggest that the Dibang specimens are likely to be *Bufo gargarizans,* we call for further morphological and molecular work to confirm the taxonomy of this newly recorded toad from India.

Dibang Valley district (9,129km^2) is located between $27.133–28.783^{0}$N and $94.1–95.9^{0}$E along the Indian border with Tibet (China) in the state of Arunachal Pradesh. The northern part of the district falls within the Dibang Wildlife Sanctuary (4,149km^2). The region receives a mean annual rainfall of 1932–4442 mm (Guhathakurta et al. 2020). It is a heavily mountainous landscape with altitude ranging from 300m in the river valleys to 5,300m at the high peaks along the Indo-Tibetan border. This vast altitudinal range supports diverse habitats from tropical and subtropical wet forests in low-lying areas through temperate wet forest in mid elevations to alpine scrub and bare rock over 4,100m. Lying at the juncture of two biogeographical realms (Indomalayan and Palearctic), Dibang Valley forms part of the eastern Himalaya biodiversity hotspot and supports an exceptionally high species diversity across all floral and faunal groups (Sheth et al. 2020).

Bufo gargarizans from Dibang Valley

Morphologically*,* the toad species reported from Dibang Valley (Image 1) share the following significant similarities with *Bufo gargarizans* (see Fei Liang et al. 2012 for morphological details of the species). The specimens from Dibang Valley were dorsally dark gray to olive-brownish in color with a wide mid-dorsal line. The dorsal surface and flanks were rough with large warts. The ventral side from snout to vent was granular, grayish-yellow or light yellow in colour; belly smooth, and granular. Irregular dark spots or stripes were present on the ventral surface of the body and the flanks extending from the dorsal surface of the parotid gland to the thigh. There were 2–3 larger warts on the inner side of the upper eyelid. The head was triangular, tympanum large and distinct, parotid glands were bean-shaped. The tip of fingers and toes were soft and round. The SVL of the only individual of unknown sex measured was 62mm (n= 1).

We recorded abundant breeding populations of *Bufo gargarizans* at three different locations in two river valley systems inside Dibang Wildlife Sanctuary (Figure 1). All observations were made in the altitudes of 2,250–3,200 m near the Tibetan border. No specimens were recorded

Image 1. Adult *Bufo gargarizans* from Dibang Valley, Arunachal Pradesh, India: a—dorso-lateral view | b—dorsal view | c—ventral view | d—lateral view. © Sahil Nijhawan.

outside this altitudinal range. The microhabitat for all three breeding populations was similar—flat wetlands and marshes with stagnant water, covered with thick aquatic vegetation (Image 2). A few individuals were also encountered in small rainfed puddles and pools along human trails inside the forest, within close proximity to the marshlands. We also observed calls of the species between 14.00h and 16.30h. The toads were encountered only during surveys conducted in the summer and monsoon period from June until late September and not in surveys carried out in winter and spring—late January to early April.

These substantive morphological similarities and the proximity of the location of the specimens to the known distribution range of *Bufo gargarizans* indicate that the specimens from Dibang Valley likely belong to the *Bufo gargarizans* species complex.

Bufo gargarizans is locally known as 'Pambo'. The toad holds special importance for the animistic Idu Mishmi people of the Dibang Valley. According to an Idu Mishmi tale, the supreme spirit of the high mountains, 'Gõlõ', once lived as a toad. Since the Idu fear and respect Gõlõ, harming the toads is a strict taboo. The Idu Mishmi do not touch, kill or consume the toad, simply moving away when the toads are seen so as to not step on them accidently.

Discussion and Conclusions

Given the opportunistic nature of this study based on photographic comparisons and the taxonomic ambiguities around this species complex, our findings should be seen as preliminary and warrant further investigation. In this vein, we highlight three notable observations.

Firstly, the distribution and taxonomic classification of the *Bufo gargarizans* species complex has historically been a matter of much discussion and disagreement (Zhan & Fu, 2011). Zarevskij (1926) reclassified the populations on the Tibetan plateau as *Bufo tibetanus* based on some morphological differences, in particular

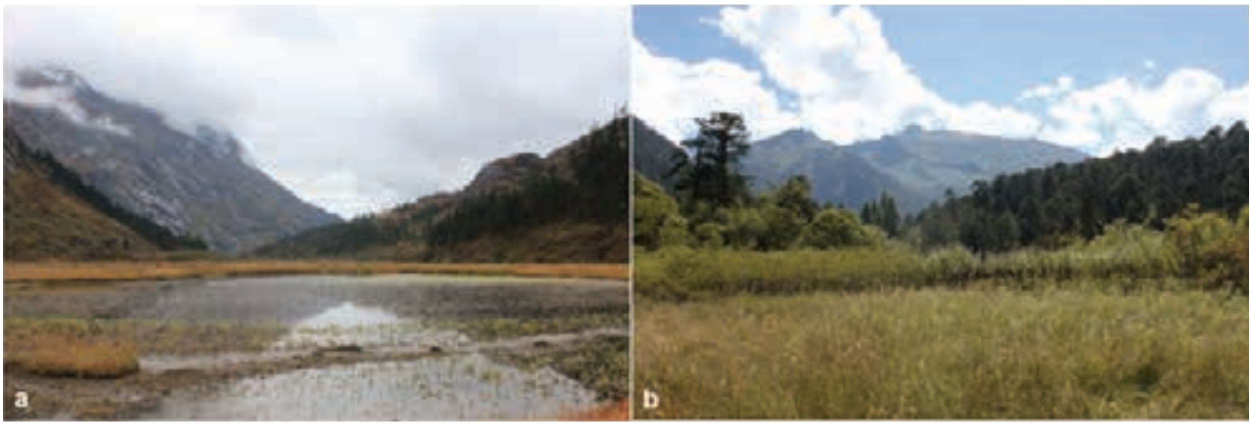

Image 2 . The microhabitat observed for three breeding populations of *Bufo gargarizans* in Dibang Valley, Arunachal Pradesh, India: a—riverine marshes covered in grass and other aquatic vegetation | b—bogs covered in tall thick grass. © Sahil Nijhawan.

a wide mid dorsal line in the dorsum of *Bufo tibetanus* which is less prominent in *Bufo gargarizans* found elsewhere (Liu & Hu 1961), gaining the support of a number of scientists later on (e.g., Borkin & Matsui 1987; Fei et al. 2009, 2012). The Dibang specimens, too, had a wide mid dorsal line akin to that reported from the Tibetan Plateau; however, despite significant morphological differences, a molecular study by Zhan & Fu (2011) did not find any support for the separation of *B. tibetanus* and *B. gargarizans* into distinct species. In 2019, the IUCN Amphibian Specialist Group recognized all previously thought species within the Asian Toad complex as a single species *Bufo gargarizans* (IUCN Amphibian Specialist Group 2019). Recently, Che et al. (2020) suggested that *Bufo gargarizans* from Tibet be reclassified as *Bufo* cf. *andrewsi* Schmidt, 1925 and predicted that the taxonomically widespread *Bufo gargarizans* will be partitioned into distinct species. Thus, the taxonomy of this species complex continues to be a matter of doubt and debate.

Secondly, in Dibang Valley, we observed the species exclusively during the peak monsoon months from July to September, with no individuals observed in field surveys conducted between January and April. Fei et al. (2012), on the other hand, reported January to June as the breeding season for *Bufo gargarizans* species complex. We believe that this difference could be due to a longer and colder winter in the high-elevation wetlands of Dibang Valley.

Lastly, and importantly, the species was not recorded in an earlier amphibian survey conducted across the Dibang River basin over an altitudinal gradient of 200–3,500m (Roy et al. 2018). While the high-altitude marshland habitats from where we report *Bufo gargarizans* were not surveyed during Roy et al.'s (2018) study, they sampled comparable elevations in the region during the monsoon season but did not encounter the species. This may indicate a narrow distribution of the species in Dibang Valley, restricted to areas with a specific habitat type (i.e., seasonal marshlands) within a small elevation range (2,250–3,200m). This is particularly interesting as studies from other parts of *Bufo gargarizans'* range have reported a wide altitudinal distribution (120–4,300m) for the species, spanning a variety of habitats including flood plains, river valleys, coniferous, mixed and deciduous forests, grasslands, and meadows (IUCN SSC Amphibian Specialist Group 2019).

In light of the ambiguous taxonomic classification of this species complex, we recommend that future research employ molecular techniques to conclusively ascertain the taxonomy of the specimens found in the upper reaches of the Dibang River basin. Future research should also explore the species' distribution and ecological correlates in other river valleys of the Dibang basin and across the Indo-Chinese borderlands in Arunachal Pradesh, particularly in the neighboring river basins of Subansiri, Siang, and Lohit, which are also likely to host high-altitude wetland habitats similar to those where *Bufo gargarizans* was encountered in the Dibang Valley. Finally, since *Bufo gargarizans* had not been previously reported from India (Dinesh et al. 2020), our present documentation from Arunachal Pradesh forms the first record of the species from India, throwing open prospects to better understand its geographic range.

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SHORT COMMUNICATION

A checklist of fishes of Telangana State, India

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Abstract: A checklist of freshwater fishes of Telangana State, India including accepted common name, vernacular name, IUCN status, and endemicity is presented. Freshwater fish diversity of Telangana State is represented by 143 species belonging to 14 orders and 34 families. Two species, *Rita bakalu* and *Indoreonectes telanganaensis* are endemic to Telangana State.

Keywords: Freshwater fish, ichthyofauna, Godavari River basin, Krishna River basin.

Telangana State (15.835–19.917 ^{0}N, 77.238–81.307 ^{0}E), located on the Deccan Plateau in the south central part of peninsular India, was part of the erstwhile united Andhra Pradesh (1956–2014). Before this the region contributed to the major land area of Hyderabad State (1948–1956) and the erstwhile Princely State of Hyderabad (1724–1948). It encompasses an area of 1,12,077km^2, and is drained by two major rivers, namely the Godavari and the Krishna along with their major and minor tributaries. Some important minor rivers include Dhundhubhi, Dindi, Haridra, Indravati, Kadam, Kagna, Kinnerasani, Manair, Manjeera, Munneru, Musi, Paleru, Peddavagu, Taliperu, Tungabhadra, Wainganga, and Wyra. Numerous natural and man-made water bodies also dot the landscape among which the major ones include Alisagar Reservoir, Annaram Barrage, Chelmelavagu Project, Devadula, Dindi, Dummugudem, Gollavagu, Gundrevula, Himayath Sagar, Icchampally, Jonnalaboguda, Jurala, Kadam, Kanthapally, Kinnerasani, Koilsagar, Laknavaram, Lendi, Lower Jurala Lower Manair, Manjeera, Medigadda, Mid Manair, Musi Reservoir, Mylaram Reservoir, Nagarjuna Sagar Reservoir, Nawabpet, Neelwai, Nizam Sagar, Osman Sagar, Pakhala, Palair, Palakurthy, Pedavagu, Pocharam, Pranahita Chevella, Rajolibanda, Ralevagu, Ramanpad, Rangaiah-Yerraiah, Sadarmat, Salivagu, Sathnala, Shanigaram, Shankara Samudram Balancing Reservoir, Singotam, Singur, Sriram Sagar, Tapaspalli Reservoir, Thotapally Reservoir, Udaya Samudram, Upper Manair

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Dam, Vattivagu, Wyra, and Yellampalli.

Studies on the freshwater fish diversity of Telengana State dates back to late 19th century (Day 1876). This was followed by the work of Das (1924, 1944) who presented and published accounts of fishes in Hyderabad in the proceedings of the Indian Science Congress, and later by Rahimullah & Das (1935, 1936) in 12th volume of Bulletin de la Société Portugaise des Sciences Naturelles. Comprehensive research on fishes of the erstwhile Hyderabad State was initiated by Rahimullah (1943a,b, 1944) and Mahmood & Rahimullah (1947). Other significant literature on the fishes of Godavari and Krishna river basins in the erstwhile Hyderabad State, Madras Presidency, and united Andhra Pradesh include those by David (1963a,b), Jhingran (1983), Rao & Reddy (1984), Talwar & Jhingran (1991a,b), Menon (1999, 2004), and Jayaram (1981, 1995, 1999, 2010).

Freshwater fish diversity of united Andhra Pradesh was studied and documented by Barman (1993) who reported the occurrence of 158 species belonging to 68 genera in 27 families and 10 orders. Later, Barman (2003) reported 39 species belonging to 26 genera, 12 families, and five orders occurring in the Koil Sagar, Mahabubnagar District. Chandrasekhar (2004) reported 65 species belonging to 36 genera spread over 13 families and five orders from tanks, lakes, and reservoirs in Hyderabad and environs. Recently, Rao et al. (2010, 2011) reported 24 species of fish belonging to 12 families and six orders from Pocharam Lake, and 22 species under 11 families and six orders from Wyra Lake, respectively.

Over the last few years, several new species of fish were described from this region. This includes a new species of bagrid catfish *Rita bakalu* from Pranahita River (Lal et al. 2017) and a new species of hillstream loach *Indoreonectes telanganaensis* (Prasad et al. 2020b). Prasad & Srinivasulu (2019a,b) provided new records of fishes from Telangana State, while Shyamsundar et al. (2017) and Prasad et al. (2020a) reported the checklist of freshwater fish fauna in the Udayasamudram and Manjeera reservoirs, respectively.

In recent years, numerous research papers in conference proceedings, theses, and predatory journals have been published on fish diversity of various lakes, reservoirs and rivers of Telengana State. Attempts have also been made to provide a comprehensive list of fishes known to occur in water bodies in Telangana State, including two such compilations by Srivastava et al. (2017), and Khartade et al. (2019).

Methods

For the present checklist, we researched and critically analysed all published (both peer-reviewed and non peer-reviewed) literature and also relied on field surveys conducted since 2010 in various parts of Telangana State. We have also provided explanation for deletion of the taxa earlier recorded in literarture, and appeal to future workers to collect voucher specimens to report additions to the fish diversity of Telangana State.

Results and Discussion

In this checklist, 143 species of freshwater fishes in 14 orders and 34 families are listed (Table 1; Images 1–86), of which two species (*Rita bakalu* Lal et al., 2017 and *Indoreonectes telanganaensis* Prasad et al., 2020) are endemic to Telangana State, while 39 are endemic to India (30 to peninsular India), 11 species endemic to southern Asia (eight species from India and Sri Lanka, three species from peninsular India, three species from Bangladesh and India), and one species from India and Myanmar. As per the IUCN Red List of Threatened Species, the fish diversity of Telangana State includes 12 threatened species (including seven endangered species, namely, *Bangana nukta*, *Clarias magur*, *Hypselobarbus curmuca*, *Hypselobarbus mussullah*, *Labeo potail*, *Thynnichthys sandkhol* and *Silonia childreni*, and five vulnerable species, namely, *Cirrhinus cirrhosus*, *Gagata itchkeea*, *Hypselobarbus kolus*, *Salmostoma horai* and *Wallago attu*). As many as 13 species (*Clarias gariepinus*, *Ctenopharyngodon idella*, *Cyprinus carpio*, *Gambusia affinis*, *Hypophthalmichthys molitrix*, *H. nobilis*, *Oreochromis mossambicus*, *O. niloticus*, *Osphronemus goramy*, *Pangasianodon hypophthalmus*, *Piaractus brachypomus*, *Poecilia reticulata*, and *Pterygoplichthys pardalis*) are introduced or exotic species, some of which have negative impacts on native fish fauna.

While compiling this list 43 species which were included in earlier publications and checklist have been removed due to taxonomic reasons and / or distribution mismatch (Table 2).

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Table 1. Checklist of fishes of Telangana State, India

	English name	Species	Authority	Vernacular name	IUCN RL	Endemicity
I. ORDER ANGUILLIFORMES						
1. Family Ophichthidae						
1	Rice-paddy Eel[1]	*Pisodonophis boro*	(Hamilton, 1822)		LC	
2. Family Anguillidae						
2	Indian Mottled Eel	*Anguilla bengalensis*	(Gray, 1831)	Dungoo Maigoo	NT	
II. ORDER OSTEOGLOSSIFORMES						
3. Family Notopteridae						
3	Bronze Featherback	*Notopterus synurus*	(Bloch & Schneider, 1801)	Mangalikatti	LC	
4	Knifefish[2]	*Chitala chitala*	(Hamilton, 1822)	Mangalikatti	NT	
III. ORDER CLUPEIFORMES						
4. Family Clupeidae						
5	Ganges River Sprat[3]	*Corica soborna*	Hamilton, 1822		LC	
6	Ilisha	*Tenualosa ilisha*	(Hamilton, 1822)	Pulasa	LC	
IV. ORDER CYPRINIFORMES						
5. Family Cobitidae						
7	Guntia Loach	*Lepidocephalichthys guntea*	(Hamilton, 1822)	Ulchal	LC	
8	Common Spiny Loach	*Lepidocephalichthys thermalis*	(Valenciennes, 1846)	Asira	LC	PI & SL
6. Family Nemacheilidae						
9	Telangana Loach[4]	*Indoreonectes telanganaensis*	Prasad et al., 2020	Sanna ulshalu	NE	TS
10	Mottled Loach	*Paracanthocobitis* cf. *botia*	(Hamilton, 1822)	Buddulche	LC	
11	Murangi	*Paracanthocobitis mooreh*	(Sykes, 1839)	Jerri chepa	LC	PI
12	Denison's Loach	*Schistura denisoni*	(Day, 1867)	Ulsha	LC	IN
7. Family Cyprinidae						
13	Nukta[5]	*Bangana nukta*	(Sykes, 1839)	Mukkidichepa	EN	PI
14	Carnatic Carp[6]	*Barbodes carnaticus*	(Jerdon, 1849)		LC	PI
15	Mrigal Carp	*Cirrhinus cirrhosus*	(Bloch, 1795)	Aruzu	VU	
16	Mrigal Carp	*Cirrhinus mrigala*	(Hamilton, 1822)	Yerra Mosu	LC	
17	Reba Carp	*Cirrhinus reba*	(Hamilton, 1822)	Eele Mosu	LC	
18	Common Carp	*Cyprinus carpio**	Linnaeus, 1758	Bangaru Teega		
19	Blackspot Barb	*Dawkinsia filamentosa*	(Valenciennes, 1844)	Chevalle-sevvali	LC	PI
20	Sucker Head	*Garra gotyla*	(Gray 1830)	Banda Pakiri	LC	
21	Sucker Fish	*Garra mullya*	(Sykes, 1839)	Banda Pakiri	LC	PI
22	Nilgiris Garra	*Garra stenorhynchus*	(Jerdon, 1849)	Kalgawa	LC	PI
23	Reba	*Gymnostomus ariza*	(Hamilton, 1807)	Arju	LC	
24	Deccan White Carp	*Gymnostomus fulungee*	(Sykes, 1839)	Mosu	LC	PI
25	Curmuca Barb[7]	*Hypselobarbus curmuca*	(Hamilton, 1807)	Curmuca	EN	PI
26	Jerdon's Carp	*Hypselobarbus jerdoni*	(Day, 1870)	Cha-meen	LC	PI
27	Kolus	*Hypselobarbus kolus*	(Sykes, 1839)	Nilusu	VU	PI
28	Humpback Mahseer	*Hypselobarbus mussullah*	(Sykes, 1839)	Goonimansoor	EN	PI
29	Bata	*Labeo bata*	(Hamilton, 1822)	Kangu	LC	
30	Boga Labeo	*Labeo boga*	(Hamilton, 1822)	Ariza	LC	

	English name	Species	Authority	Vernacular name	IUCN RL	Endemicity
31	Boggut Labeo	*Labeo boggut*	(Sykes, 1839)	Nusigadu	LC	
32	Orangefin Labeo	*Labeo calbasu*	(Hamilton, 1822)	Kaki-bocha	LC	
33	Catla	*Labeo catla*	(Hamilton, 1822)	Bocha	LC	
34	Fringed-lipped Peninsula Carp	*Labeo fimbriatus*	(Bloch, 1795)	Chitra	LC	
35	Kuria Labeo[8]	*Labeo gonius*	(Hamilton, 1822)	Mosoo	LC	
36	Deccan Labeo	*Labeo kawrus*	(Sykes, 1839)		LC	PI
37	Pangusia Labeo	*Labeo pangusia*	(Hamilton, 1822)	Done-chepa	NT	
38	Bombay Labeo	*Labeo porcellus*	(Heckel, 1844)	Moyya	LC	PI
39	Deccan Labeo	*Labeo potail*	(Sykes, 1839)	Baman-chapra	EN	PI
40	Roho Labeo	*Labeo rohita*	(Hamilton, 1822)	Routa	LC	
41	Peninsular Osteobrama	*Osteobrama peninsularis*	Silas, 1952	Dammisa	NE	PI
42	Nilgiri Osteobrama	*Osteobrama neilli*	(Day, 1873)		LC	PI
43	Godavari Osteobrama	*Osteobrama vigorsii*	(Sykes, 1839)	Kaydam-chepa	LC	PI
44	Konti Barb[9]	*Osteochilichthys thomassi*	(Day, 1877)	Pedda Parka	LC	PI
45	Rosy Barb	*Pethia conchonius*	(Hamilton, 1822)	Perka-chepa	LC	
46	Golden Barb[10]	*Pethia gelius*	(Hamilton, 1822)		LC	BD & IN
47	Ticto Barb	*Pethia ticto*	(Hamilton, 1822)	Parigi	LC	
48	Scarlet-banded Barb	*Puntius amphibius*	(Valenciennes, 1842)	Perka-chepa	DD	IN
49	Redside Barb	*Puntius bimaculatus*	(Bleeker, 1863)		LC	IN & SL
50	Swamp Barb	*Puntius chola*	(Hamilton, 1822)	Pakki	LC	
51	Long snouted Barb	*Puntius dorsalis*	(Jerdon, 1849)	Perka	LC	IN & SL
52	Wynaad Barb[11]	*Puntius melanostigma*	(Day, 1878)	Perka	NE	IN
53	Pool Barb	*Puntius sophore*	(Hamilton, 1822)	Chedu Parigi	LC	
54	Greenstripe Barb	*Puntius vittatus*	Day,1865	Parigi chepa	LC	IN & SL
55	Vatani Rohtee	*Rohtee ogilbii*	Sykes, 1839	Aku chepa	LC	PI
56	Olive Barb	*Systomus sarana*	(Hamilton, 1822)	Kanugu	LC	
57	Stone Roller[12]	*Tariqilabeo latius*	(Hamilton, 1822)		LC	
58	Sandkhol Carp	*Thynnichthys sandkhol*	(Sykes, 1839)	Thalasigadu	EN	PI
59	Deccan Mahseer	*Tor khudree*	(Sykes, 1839)	Kudis	LC	IN & SL
8. Family Danionidae						
60	Mola Carplet	*Amblypharyngodon mola*	(Hamilton, 1822)	Alan Chepa	LC	
61	Barred Baril	*Barilius barila*	(Hamilton, 1822)	Kodipe	LC	
62	Morari	*Cabdio morar*	(Hamilton, 1822)	Gitsu	LC	
63	Silver Hatchet Chela	*Chela cachius*	(Hamilton, 1822)	Getchu	LC	
64	Zebra Danio	*Danio rerio*	(Hamilton, 1822)	Chintaku-parega	LC	
65	Giant Danio	*Devario aequipinnatus*	(McClelland, 1839)	Nooltu	LC	
66	Sind Danio	*Devario devario*	(Hamilton, 1822)	Nooltu	LC	
67	Indian Flying Barb	*Esomus danrica*	(Hamilton, 1822)	Meesagadu	LC	
68	Flying Barb[13]	*Esomus thermoicos*	(Valenciennes, 1842)	Meesagadu	LC	PI & SL
69	Indian Glass Barb	*Laubuka laubuca*	(Hamilton, 1822)	Getchu	LC	
70	Barna Baril	*Opsarius barna*	(Hamilton, 1822)	Kodipe	LC	
71	Hamilton's Baril	*Opsarius bendelisis*	(Hamilton, 1807)	Kodipe	LC	

	English name	Species	Authority	Vernacular name	IUCN RL	Endemicity
72	Slender Rasbora	*Rasbora daniconius*	(Hamilton, 1822)	Narangi	LC	
73	Gangetic Scissortail Rasbora	*Rasbora rasbora*	(Hamilton, 1822)	Kodipe-chepa	LC	
74	Silver Razorbelly Minnow	*Salmostoma acinaces*	(Valenciennes, 1844)		LC	PI
75	Large Razorbelly Minnow	*Salmostoma bacaila*	(Hamilton, 1822)	Chandamama	LC	
76	Bloch Razorbelly Minnow	*Salmostoma balookee*	(Sykes, 1839)	Ichkey	LC	PI
77	Boopis Razorbelly Minnow	*Salmostoma boopis*	(Day, 1874)	Chela	LC	PI
78	Hora Razorbelly Minnow	*Salmostoma horai*	(Silas, 1951)	Chela	VU	IN
79	Novacula Razorbelly Minnow	*Salmostoma novacula*	(Valenciennes, 1838)	Chandamama	LC	PI
80	Finescale Razorbelly Minnow	*Salmostoma phulo*	(Hamilton, 1822)	Blancha	LC	
81	Mahanadi Razorbelly Minnow	*Salmostoma untrahi*	(Day, 1869)	Chela	LC	IN
9. Family Xenocyprididae						
82	Grass Carp	*Ctenopharyngodon idella**	(Valenciennes, 1844)	Ela-mosa		
83	Silver Carp	*Hypophthalmichthys molitrix**	(Valenciennes, 1844)	Vendi chepa		
84	Big-head Carp	*Hypophthalmichthys nobilis**	(Richardson, 1845)			
V. ORDER CHARACIFORMES						
10. Family Characidae						
85	Red-bellied Pacu	*Piaractus brachypomus**	(Cuvier, 1818)	Pacu		
VI. ORDER SILURIFORMES						
11. Family Loricariidae						
86	Amazon Sailfin Catfish	*Pterygoplichthys pardalis**	(Castelnau, 1855)	Dayyam-chepa		
12. Family Ailiidae						
87	Goongwaree Vacha	*Eutropiichthys goongwaree*	(Sykes, 1839)	Gaddamsiluva	DD	IN & MM
88	Indian Taakree	*Proeutropiichthys taakree*	(Sykes, 1839)	Siriva-jella	LC	IN
89	Schilbid Catfish	*Silonia childreni*	(Sykes, 1839)	Pedda-jella	EN	PI
13. Family Horabagridae						
90	Khavalchor Catfish[14]	*Pachypterus khavalchor*	(Kulkarni, 1952)		DD	PI
14. Family Bagridae						
91	Krishna Mystus	*Hemibagrus maydelli*	(Rössel, 1964)	Ponduga	LC	PI
92	Day's Mystus	*Mystus bleekeri*	(Day, 1877)	Narjella	LC	
93	Gangetic Mystus	*Mystus cavasius*	(Hamilton, 1822)	Thella-jella	LC	
94	Long Whiskers Catfish	*Mystus gulio*	(Hamilton, 1822)	Jella	LC	
95	Tengara Catfish	*Mystus tengara*	(Hamilton, 1822)	Jella	LC	BD & IN
96	Striped Dwarf Catfish	*Mystus vittatus*	(Bloch, 1794)	Erra-jella	LC	
97	Gogra Rita	*Rita gogra*	(Sykes, 1839)	Banki-yeddu	LC	IN
98	Deccan Rita	*Rita kuturnee*	(Sykes, 1839)	Bondu	LC	PI
99	Bakalu Rita[15]	*Rita bakalu*	Lal et al., 2017	Bakalu	NE	TS
100	Long Whiskered Cat-fish	*Sperata aor*	(Hamilton, 1822)	Mukkul-jella	LC	
101	Giant River-catfish	*Sperata seenghala*	(Sykes, 1839)	Nara-jella	LC	

	English name	Species	Authority	Vernacular name	IUCN RL	Endemicity
15. Family Sisoridae						
102	Goonch	*Bagarius bagarius*	(Hamilton, 1822)	Raati jella	NT	
103	Deccan Nangra	*Gagata itchkeea*	(Sykes, 1839)	Menamama Bakkalu	VU	PI
104	Mountain Catfish	*Glyptothorax lonah*	(Sykes, 1839)		LC	IN
16. Family Pangasiidae						
105	Pangas Catfish	*Pangasius pangasius*	(Hamilton, 1822)	Banka-jella	LC	
106	Sutchi Catfish	*Pangasianodon hypophthalmus**	(Sauvage, 1878)	Choluva-jella		
107	Silas' Catfish[16]	*Pangasius silasi*	Dwivedi et al. 2017	Banka-jella	NE	PI
17. Family Siluridae						
108	Butter Catfish	*Ompok bimaculatus*	(Bloch, 1794)	Theenuva	NT	
109	Pabdah Catfish	*Ompok pabda*	(Hamilton, 1822)	Gogli	NT	BD & IN
110	Pabo Catfish	*Ompok pabo*	(Hamilton, 1822)	Theduva	NT	
111	Wallago	*Wallago attu*	(Bloch & Schneider, 1801)	Valuga	VU	
18. Family Clariidae						
112	Magur	*Clarias magur*	(Hamilton, 1822)	Marpoo	EN	
113	African Catfish	*Clarias gariepinus**	(Burchell, 1822)			
19. Family Heteropneustidae						
114	Stinging Catfish	*Heteropneustes fossilis*	(Bloch, 1794)	Mapu-jella	LC	
VII. ORDER GOBIIFORMES						
20. Family Gobiidae						
115	Tank goby	*Glossogobius giuris*	(Hamilton, 1822)	Bullee-kokah	LC	
VIII. ORDER SYNBRANCHIFORMES						
21. Family Mastacembelidae						
116	Lesser Spiny Eel[17]	*Macrognathus aral*	(Bloch & Schneider, 1801)	Bommidai	LC	
117	Barred Spiny Eel	*Macrognathus pancalus*	Hamilton, 1822	Parparaal	LC	
118	Zig-zag Eel	*Mastacembelus armatus*	(Lacepède, 1800)	Kontemukku	LC	
IX. ORDER ANABANTIFORMES						
22. Family Anabantidae						
119	Climbing Perch	*Anabas testudineus*	(Bloch, 1792)	Goraka Chepa	LC	
23. Family Osphronemidae						
120	Giant Gourami	*Osphronemus goramy**	Lacepède, 1801	Gourami		
121	Dwarf Gourami[18]	*Trichogaster lalius*	(Hamilton, 1822)	Chinna Gourami	LC	
122	Banded Gourami	*Trichogaster fasciata*	Bloch & Schneider, 1801	Raika-punjee	LC	
24. Family Channidae						
123	Dwarf Snakehead	*Channa gachua*	(Hamilton, 1822)	Erra Matta	LC	
124	Great Snakehead	*Channa marulius*	(Hamilton, 1822)	Poola Matta	LC	
125	Spotted Snakehead	*Channa punctata*	(Bloch, 1793)	Matta	LC	
126	Striped Snakehead	*Channa striata*	(Bloch, 1793)	Koramata	LC	
25. Family Nandidae						
127	Gangetic Leaffish	*Nandus nandus*	(Hamilton, 1822)	Pindiperka	LC	
26. Family Badidae						
128	Badis[19]	*Badis badis*	(Hamilton, 1822)	Kundala	LC	

	English name	Species	Authority	Vernacular name	IUCN RL	Endemicity
X. ORDER CICHLIFORMES						
27. Family Cichlidae`						
129	Pearlspot	*Etroplus suratensis*	(Bloch, 1790)	Duvvena-chepa	LC	IN & SL
130	Mozambique Tilapia	*Oreochromis mossambicus**	(Peters, 1852)	Jilebi		
131	Nile Tilapia	*Oreochromis niloticus**	(Linnaeus, 1758)	Tilapia		
132	Orange Chromide	*Pseudetroplus maculatus*	(Bloch, 1795)	Burakasu	LC	PI & SL
XI. ORDER CYPRINODONTIFORMES						
28. Family Aplocheilidae						
133	Striped Panchax	*Aplocheilus lineatus*	(Valenciennes, 1846)	Minnow Chepa	LC	IN
134	Blue Panchax	*Aplocheilus panchax*	(Hamilton, 1822)	Minnow Chepa	LC	
29. Family Poeciliidae						
135	Mosquito Fish	*Gambusia affinis**	(Baird & Girard, 1853)	Gambusia		
136	Guppy	*Poecilia reticulata**	Peters, 1859	Guppy Cheppa		
XII. ORDER BELONIFORMES						
30. Family Belonidae						
137	Freshwater Garfish	*Xenentodon cancila*	(Hamilton, 1822)	Vadla-mukku	LC	
31. Family Hemiramphidae						
138	Congaturi Halfbeak	*Hyporhamphus limbatus*	(Valenciennes, 1847)	Konga-mukku	LC	
32. Family Adrianichthyidae						
139	Rice Fish	*Oryzias dancena*	(Hamilton, 1822)	Chukku-chepa	LC	
XIII. ORDER MUGILIFORMES						
33. Family Mugilidae						
140	Corsula	*Rhinomugil corsula*	(Hamilton, 1822)	Pai-kalla Chepa	LC	
XIV. ORDER PERCIFORMES						
34. Family Ambassidae						
141	Elongate Glass-perchlet	*Chanda nama*	Hamilton, 1822	Sarawara	LC	
142	Highfin Glassy-perchlet	*Parambassis lala*	(Hamilton, 1822)		NT	
143	Indian Glassy Fish	*Parambassis ranga*	(Hamilton, 1822)	Sarawa	LC	

DD—Data Deficient | EN—Endangered | LC—Least Concern | NE—Not Evaluated | NT—Near Threatened | VU—Vulnerable | BD—Bangladesh | IN—India | MM—Myanmar | PI—Peninsular India | SL—Sri Lanka | TS—Telangana State | *—Introduced / exotic species

[1]Known from Udayasamudram Reservoir, Nalgonda District (R. Shyamsundar pers. comm.)
[2]Known from Talai near Bejjur, Komaram Bheem Asifabad District (present study)
[3]Known from Komaram Bheem Asifabad District (Prasad et al. 2020c)
[4]Known from the type locality- Maisamma Loddi, In Kawal Tiger Reserve, Mancheriyal District (Prasad et al. 2020b)
[5]Known from Srisailam Reservoir, Nagarkurnool District (Jayaram 1995)
[6]Known from Jamkhandi to Lingalagattu and up to Nagarjunasagar Reservoir (Jayaram 1995)
[7]Known from Nizam Sagar Reservoir, Kamareddy District (Barman 1993)
[8]Known from Godavari River flowing through Bhadradri Kothagudem District (Barman 1993)
[9]Known from Krishna River between Rekulampally to Nagarjunasagar Dam (Jayaram 1995)
[10]Known from Godavari River, Peddapalli district and Nizam Sagar Reservoir, Kamareddy District (Barman 1993)
[11]Known from Krishna River (no exact location known, vide David 1963a), and Bejjur, Komaram Bheem Asifabad District (present study)
[12]Known from Krishna River between Rekulampally to Srisailam Dam (Jayaram 1995), and Hyderabad environs (Chandrasekhar 2004)
[13]Known from Janampeta and Koil Sagar Reservoir in Mahbubnagar District (Barman 1993, 2003)
[14]Known from Krishna River between Jamkhandi to Lingalagattu (Jayaram 1995)
[15]Known from type locality - Talai near Bejjur, Komaram Bheem Asifabad District (Lal et al. 2017; present study)
[16]Known from Nagarjunasagar Reservoir, Krishna River in Nalgonda District (Dwivedi et al. 2017)
[17]Known from Phulang River, Nizamabad District (Barman 1993)
[18]Known from Pocharam Lake, Medak district and Molachintalpally, Nagarkurnool District (present study)
[19]Known only from Manjeera Reservoir (Prasad & Srinivasulu 2019b, Prasad et al. 2020a), and Wardha River, Komaram Bheem Asifabad District (present study)

Table 2. Doubtful species removed from the final list of fishes known from Telangana State, India.

Family	Order	Species	Reason	Reference
Anguilliformes	Anguillidae	*Anguilla bicolor* McClelland, 1844	On the eastern side of Indian peninsula, this species is known only from the coastal areas	Pike et al. (2019)
Beloniformes	Adrianichthyidae	*Oryzias melastigma* (McClelland, 1839)	This species is known only from Wyanad in Kerala and along east coast of India from Tamil Nadu to West Bengal	Abraham (2011d)
Cypriniformes	Hemiraphidae	*Hyporhamphus xanthopterus* (Valenciennes, 1847)	This species is endemic to the lakes of southern Kerala, Western Ghats	Shaji (2011)
	Cobitidae	*Lepidocephalichthys berdmorei* (Blyth, 1860)	This species is known only from Irrawaddy drainage in Manipur	Daniels & Dahanukar (2020)
		Bangana diplostomus (Heckel, 1838)	This species is known from Indus & Gangetic drainages in northern India and Pakistan	Vishwanath (2010a)
	Cyprinidae	*Garra lamta* (Hamilton, 1822)	Reports of this species from southern India needs verification	Singh (2010)
		Garra mcclellandi (Jerdon, 1849)	This species is endemic to Western Ghats, known from Tamil Nadu, Kerala, and Karnataka	Dahanukar (2011b)
		Haludaria melanampyx (Day, 1865)	This species is endemic to Western Ghats, known from Kerala and Karnataka	Abraham (2015)
		Hypselobarbus dobsoni (Day, 1876)	Taxonomic uncertainty. This species is endemic to Western Ghats, known from Tamil Nadu, Kerala, Maharashtra, and Karnataka	Devi et al. (2005), Raghavan & Ali (2011b)
		Labeo dussumieri (Valenciennes, 1842)	This species is endemic to Western Ghats, known from southern Kerala	Raghavan & Ali (2011c)
		Labeo dyocheilus (McClelland, 1839)	This species is restricted to the Gangetic Plains and along the Himalayas in Assam, Uttar Pradesh, Uttarakhand, West Bengal, and Bihar	Dahanukar (2010b)
		Labeo kontius (Jerdon, 1849)	This species is restricted to the Cauveri river and its tributaries	Manimekalan (2011)
		Labeo microphthalmus Day, 1877	This species is restricted to Punjab, Uttar Pradesh, and Uttarakhand	Dahanukar (2010c)
		Labeo nigrescens Day, 1870	This species is restricted to Kerala and Karnataka	John & John (2004)
		Osteobrama belangeri (Valenciennes, 1844)	Presently *O. belangeri* is known only from Myanmar	Vishwanath (2010b)
		Osteobrama cotio (Hamilton, 1822)	All earlier records (Rahimullah 1943a,b, 1944; Mahmood & Rahimullah 1947; Barman 1993; Jayaram 1995; Prasad et al. 2020) assigned to this taxon are considered as *Osteobrama peninsularis* due to recent taxonomic changes recognizing specific status of taxa *cunma* and *peninsularis*, earlier considered subspecies of *Osteobrama cotio*	Rahman et al. (2018)
		Osteobrama cunma (Day, 1888)	See above remarks. All earlier records (Rahimullah 1943a,b, 1944; Mahmood & Rahimullah 1947; Barman 1993; Jayaram 1995) assigned to *O. peninsularis*. Presently *O. cunma* is known only from northeast India and Myanmar	Vishwanath (2010c)
		Osteochilus nashii	This species is restricted to Maharashtra, Karnataka, Kerala and Tamil Nadu. Earlier records of this taxon from Godavari and Krishna river basins could possibly represent *Osteochilichthys godavariensis* Babu Rao, 1977	Ali et al. (2011)
		Pethia stoliczkana (Day, 1871)	This species is currently treated as restricted to Chindwin in Manipur, India and Myanmar and extends in range to Thailand and Laos	Dahanukar (2015)
		Puntius parrah Day, 1865	This species is restricted to Maharashtra, Karnataka, Kerala and Tamil Nadu.	Abraham (2011e)
		Puntius terio (Hamilton 1822)	This species' occurrence in Hyderabad needs validation, as this species occurs in Uttar Pradesh, Orissa, Assam, Meghalaya, West Bengal, Bihar, and Manipur	Dahanukar (2010a)
	Danionidae	*Amblypharyngodon microlepis* (Bleeker, 1853)	The records of this species from Andhra Pradesh comes from literature that reports its presence from Kadapa district with no exact location mentioned.	Barman (1993)

Family	Order	Species	Reason	Reference
Cypriniformes		*Amblypharyngodon melettinus* (Valenciennes, 1844)	This species is distributed along the coastal water bodies in Karnataka, Kerala, and Tamil Nadu	Abraham (2011a)
		Bengala elanga (Hamilton, 1822)	This species is restricted to West Bengal, Bihar, Assam, and Arunachal Pradesh	Vishwanath (2018)
		Devario malabaricus (Jerdon, 1849)	This species is restricted to Western Ghats, known from Karnataka, Goa, Tamil Nadu, Maharashtra, and Kerala, and Sri Lanka	Raghavan et al. (2019)
		Opsarius bakeri (Day, 1865)	This species is restricted to Western Ghats, known from Karnataka, Tamil Nadu, and Kerala	Dahanukar (2011a)
		Rasbora caverii (Jerdon, 1849)	Although, Barman (1993) mention collection of this taxon from Kalwala Reservoir, Karimnagar district, we discount this record as it could be misidentified *Rasbora* species, as the lateral line scales of the specimens are mentioned as 32, while *Rasbora caverii* has 36 to 37 lateral line scales	
	Nemacheilidae	*Nemacheilus anguilla* Annandale, 1919	This species is restricted to Western Ghats, known from Karnataka, Maharashtra, and Kerala	Ali & Raghavan (2011)
		Schistura striata (Day, 1867)	This species is restricted to Western Ghats, known from Karnataka, Tamil Nadu, and Kerala	Abraham (2011b)
Gobiiformes	Gobiidae	*Awaous grammepomus* (Bleeker, 1849)	This species is known from the coastal areas of India	Larson (2019)
Siluriformes	Ailiidae	*Ailia coila* (Hamilton, 1822)	This species does not occur in Godavari and Krishna river drainages, and occurs in northern river drainages in India	Ng & Dahanukar (2011)
		Eutropiichthys vacha (Hamilton, 1822)	This species does not occur in Godavari and Krishna river drainages, and occurs in Ganges and Mahanadi river drainages	Ng (2010a)
	Bagridae	*Hemibagrus menoda* (Hamilton, 1822)	This species is known from the Brahmaputra, Ganges and Mahanadi river drainages in India, Nepal, and Bangladesh	Ng (2010b)
		Hemibagrus microphthalmus (Day, 1877)	This species is known from the Irrawaddy, Sittang, and Salween river drainages in northeast India	Ng (2010c)
		Hemibagrus punctatus (Jerdon, 1849)	This species is endemic to Western Ghats, known from Tamil Nadu, Kerala, and Karnataka	Raghavan & Ali (2011a)
		Mystus malabaricus (Jerdon, 1849)	This species is endemic to Western Ghats, known from Tamil Nadu, Kerala, Maharashtra, and Karnataka	Abraham (2011c)
		Mystus montanus (Jerdon, 1849)	This species is endemic to Western Ghats, known from Tamil Nadu, Kerala, and Karnataka	Dahanukar (2011c)
		Rita chrysea Day, 1877	This species is restricted to Mahanadi river drainage, known from Odisha and Chhattisgarh	Dahanukar (2010d)
	Clariidae	*Clarias batrachus* (Linnaeus, 1758)	Due to recent taxonomic change this species has been restricted in distribution to Java, Indonesia, while the nomen *Clarias magur* (Hamilton, 1822) has been applied to this taxon occurring in Indian subcontinent. Hence, the nomen is not applicable to India	Ng & Kottelat (2008)
	Horabagridae	*Pachypterus atherinoides* (Bloch, 1794)	Although it is opined that the species may be probably extant in Telangana State, no confirmed record exists	Ng (2010d)
	Siluridae	*Ompok malabaricus* (Valenciennes, 1840)	This species is endemic to the Indian peninsula with its distribution ranging in Maharashtra, Goa and Karnataka and Kerala along the Western Ghats mountain range	Jayaram (2010)
		Gogangra viridescens (Hamilton, 1822)	This species is known from the Ganges and Brahmaputra river drainages in India and Nepal	Ng (2010e)
Synbranchiformes	Mastacembelidae	*Macrognathus guentheri* (Day, 1865)	This species is endemic to Western Ghats, known from Kerala	Dahanukar (2011d)

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

Image 2. *Notopterus synurus* (Bloch & Schneider, 1801)

Image 3. *Chitala chitala* (Hamilton, 1822)

Image 4. *Corica soborna* Hamilton, 1822

Image 5. *Lepidocephalichthys guntea* (Hamilton, 1822)

Image 6. *Lepidocephalichthys thermalis* (Valenciennes, 1846)

Image 7. *Indoreonectes telanganaensis* Prasad et al., 2020

Image 8. *Paracanthocobitis* cf *botia* (Hamilton, 1822)

Image 9. *Paracanthocobitis* cf. *mooreh* (Sykes, 1839)

Image 10. *Schistura denisoni* (Day, 1867)

Image 11. *Cirrhinus reba* (Hamilton, 1822)

Image 12. *Cyprinus carpio* Linnaeus, 1758

Image 13. *Dawkinsia filamentosa* (Valenciennes, 1844)

Image 14. *Garra mullya* (Sykes, 1839)

Image 15. *Gymnostomus ariza* (Hamilton, 1807)

Image 16. *Hypselobarbus kolus* (Sykes, 1839)

Image 17. *Labeo calbasu* (Hamilton, 1822)

Image 18. *Labeo catla* (Hamilton, 1822)

Image 19. *Labeo porcellus* (Heckel, 1844)

Image 20. *Labeo rohita* (Hamilton, 1822)

Image 21. *Osteobrama peninsularis* Silas, 1952

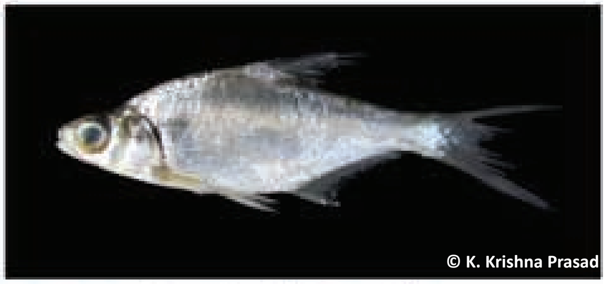

Image 22. *Osteobrama vigorsii* (Sykes, 1839)

Image 23. *Pethia conchonius* (Hamilton, 1822)

Image 24. *Pethia gelius* (Hamilton, 1822)

Image 25. *Pethia ticto* (Hamilton, 1822)

Image 26. *Puntius amphibius* (Valenciennes, 1842)

Image 27. *Puntius bimaculatus* (Bleeker, 1863)

Image 28. *Puntius chola* (Hamilton, 1822)

Image 29. *Puntius sophore* (Hamilton, 1822)

Image 30. *Puntius vittatus* Day, 1865

Image 31. *Systomus sarana* (Hamilton, 1822)

Image 32. *Amblypharyngodon mola* (Hamilton, 1822)

Image 33. *Barilius barila* (Hamilton, 1822)

Image 34. *Danio rerio* (Hamilton, 1822)

Image 35. *Devario aequipinnatus* (McClelland, 1839)

Image 36. *Devario devario* (Hamilton, 1822)

Image 37. *Esomus danrica* (Hamilton, 1822)

Image 38. *Laubuka laubuca* (Hamilton, 1822)

Image 39. *Opsarius bendelisis* (Hamilton, 1807)

Image 40. *Rasbora daniconius* (Hamilton, 1822)

Image 41. *Salmostoma bacaila* (Hamilton, 1822)

Image 42. *Salmostoma balookee* (Sykes, 1839)

Image 43. *Salmostoma phulo* (Hamilton, 1822)

Image 44. *Ctenopharyngodon idella* (Valenciennes, 1844)

Image 45. *Hypophthalmichthys molitrix* (Valenciennes, 1844)

Image 46. *Piaractus brachypomus* (Cuvier, 1818)

Image 47. *Proeutropiichthys taakree* (Sykes, 1839)

Image 48. *Mystus bleekeri* (Day, 1877)

Image 49. *Mystus cavasius* (Hamilton, 1822)

Image 50. *Mystus* cf. *vittatus* (Bloch, 1794)

Image 51. *Rita gogra* (Sykes, 1839)

Image 52. *Rita kuturnee* (Sykes, 1839)

Image 53. *Sperata aor* (Hamilton, 1822)

Image 54. *Sperata seenghala* (Sykes, 1839)

Image 55. *Bagarius bagarius* (Hamilton, 1822)

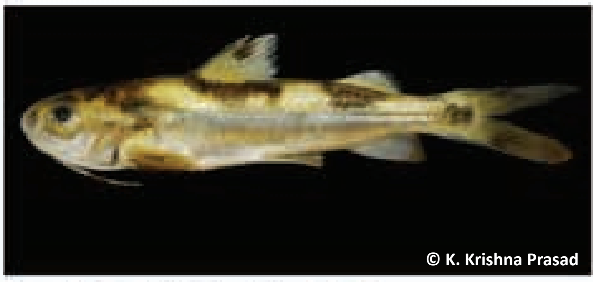

Image 56. *Gagata itchkeea* (Sykes, 1839)

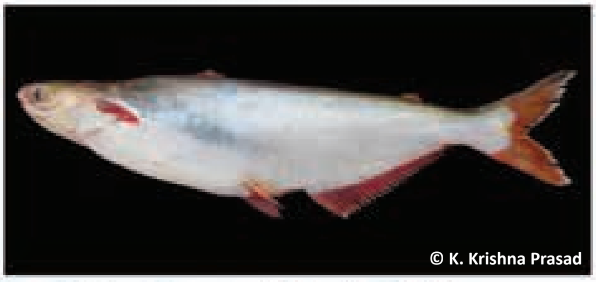

Image 57. *Pangasius pangasius* (Hamilton, 1822)

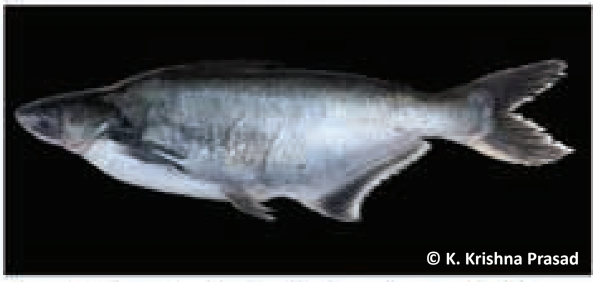

Image 58. *Pangasianodon hypophthalmus* (Sauvage, 1878)

Image 59. *Ompok bimaculatus* (Bloch, 1794)

Image 60. *Wallago attu* (Bloch & Schneider, 1801)

Image 61. *Clarias magur* (Hamilton, 1822)

Image 62. *Heteropneustes fossilis* (Bloch, 1794)

Image 63. *Glossogobius giuris* (Hamilton, 1822)

Image 64. *Macrognathus pancalus* Hamilton, 1822

Image 65. *Mastacembelus armatus* (Lacepède, 1800)

Image 66. *Trichogaster lalius* (Hamilton, 1822)

Image 67. *Trichogaster fasciata* Bloch & Schneider, 1801

Image 68. *Channa gachua* (Hamilton, 1822)

Image 69. *Channa marulius* (Hamilton, 1822)

Image 70. *Channa punctata* (Bloch, 1793)

Image 71. *Channa striata* (Bloch, 1793)

Image 72. *Badis badis* (Hamilton, 1822)

Image 73. *Etroplus suratensis* (Bloch, 1790)

Image 74. *Oreochromis mossambicus* (Peters, 1852)

Image 75. *Oreochromis niloticus* (Linnaeus, 1758)

Image 76. *Pseudetroplus maculatus* (Bloch, 1795)

Image 77. *Aplocheilus panchax* (Hamilton, 1822)

Image 78. *Gambusia affinis* (Baird & Girard, 1853)

Image 79. *Poecilia reticulata* Peters, 1859

Image 80. *Xenentodon cancila* (Hamilton, 1822)

Image 81. *Hyporhamphus limbatus* (Valenciennes, 1847)

Image 82. *Oryzias dancena* (Hamilton, 1822)

Image 83. *Rhinomugil corsula* (Hamilton, 1822)

Image 84. *Chanda nama* Hamilton, 1822

Image 85. *Parambassis lala* (Hamilton, 1822)

Image 86. *Parambassis ranga* (Hamilton, 1822)

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SHORT COMMUNICATION

Report on the stingless bees of Bhutan (Hymenoptera: Apidae: Meliponini)

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Abstract: Two species of stingless bees, *Tetragonula gressitti* (Sakagami) and *Lepidotrigona arcifera* (Cockerell), are reported from Bhutan for the first time. The nest description and meliponiculture are described. This is the gross underestimation of Meliponini diversity in Bhutan and summons more study on the diversity, biology, and meliponiculture.

Keywords: Diversity, meliponiculture, *Lepidotrigona arcifera*, *Tetragonula gressitti*

Abbreviation: NBCB—National Biodiversity Center, Bhutan.

Stingless bee keeping is known as meliponiculture (Cortopassi-Laurino et al. 2006) and is a rare activity in Bhutan, where it is considered a sin to taste even a tiny drop of honey, from a Buddhist perspective. Perhaps this explains its uncommonness in the country. Although a very few people in southern Bhutan rear stingless bees for domestic consumption nevertheless there is no published record of stingless bee species in Bhutan. Stingless bee honey and propolis are known to have high medicinal value (Choudhari et al. 2012; Vit et al. 2004). Stingless bees not only produce high-priced honey, but also help in pollination of crops, though they are facing various threats at present (Slaa et al. 2006). Therefore, a huge opportunity for meliponiculture exists in Bhutan, with 72% of the country under forest cover with rich and diverse flora, and chemical use in agriculture almost nonexistent, making the country attractive for large-scale organic meliponiculture (Gupta et al. 2014).

There are about 600 species of Meliponini in global tropical and subtropical areas (Cortopassi-Laurino et al. 2006). The Indo-Malayan region has 89 recognized stingless bee species, 43 in Asia and eight in the Indian subcontinent (Michener 2007; Rasmussen 2008; Rasmussen 2013). Two local types (white and black) of stingless bees were collected from different localities of Bhutan. They are locally known as “Putkha” in Nepali (Rasmussen 2013) but they are unambiguously named as “Kalo putka” (=black putka) and Shayto putka (=white putka) in Bhutan. Locally it is said that the honey of the black species has a higher medicinal value than the white (Deo K. Rai pers. comm. 10.xi.2017) though it is yet to be proven.

Materials and methods

Specimens were collected with a sweep net. Collected specimens were pinned, dried and stored. Identifications were based on Sakagami (1978), Smith (unpublished), Rasmussen (2013), and Rathor et al. (2013). Measurements were made with digital Vernier

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caliper under a stereo microscope. The specimens were deposited in the National Biodiversity Centre, Serbithang, Thimphu, Bhutan and a registered reference number is provided for each specimen as provided in the materials examined. Identifications were based on worker specimens collected during the invertebrate inventory project field work in 2014–2017 that focused on Hymenoptera (bees and wasps), Lepidoptera (moths and butterflies), Coleoptera (beetles), Odonata (dragonflies and damselflies), and Mollusca (snails and slugs). The project was funded by the Bhutan Trust Fund for Environmental Conservation (BTFEC) and coordinated by National Biodiversity Center, Bhutan. The surveys were conducted by the experts from Sherubtse College and College of Natural Resources, Royal University of Bhutan, Ugyen Wangchuck Institute for Conservation and Environmental Research (UWICER), National Plant Protection Centre (NPPC) and Naturalis Biodiversity Center, The Netherlands. Distribution within Bhutan is provided with Districts followed by localities in parenthesis.

Image 1. *Tetragonula gressitti*: A—facial view | B—malar space | C—body color.

Results and discussion

Genus Tetragonula Moure, 1961

The genus *Tetragonula* Moure is differentiated by the combination of the following characters: small size, body smooth, shiny with minute punctation; scutellum projecting backward, over-arching almost the whole propodeum; basal area of propodeum smooth, shiny and hairless; five hammuli per hind wing, hind basitarsus narrower than tibia with large sericeous patch; metasoma narrower than thorax; mesopleural hairs silvery white; clypeus with microscopic appressed silvery-white hairs; malar space not well developed; mandible with 2 teeth; wings uniformly clear.

Tetragonula gressitti (Sakagami, 1978) (Image 1A,B,C, 2, 3)

Trigona (*Tetragonula*) *gressitti* Sakagami 1978: 214–216; Holotype: worker; Type locality: Vietnam, Lâm Đồng province in the central Highlands. Diagnosis: highly melanic; body, scape, alveolus, flagella, hairs, corbicular bristles clypeus, tegula, legs and metasoma black; scape long; mesoscutal hairs do not form distinct bands; mesosoma and metasoma glossy. In Nepali it is known as "*kalo putka"* corresponding to its melanic body.

Measurements: Seven workers; total body length: 4.39–5.59 mm (mean 5.14mm); Forewing length excluding tegula: 4.31–4.89 mm (mean 4.62mm); Hind tibia length: 1.67–1.78 mm (mean: 1.73mm).

Image 2. Nest entrance of *Tetragonula gressitti*.

Materials examined: NBCB00282, NBCB00283, NBCB00284, NBCB00285, NBCB00286, NBCB00287, NBCB00288, 29.vii.2016, 7 females, Khengpagang, Sarpang (26.848N & 89.396E, 461m), coll. Deo Kumar Rai & Bishal Rai from a reared colony.

Remark: This species is reported for the first time from Bhutan and known only from a reared colony in

Image 3. Log with the nest of *Tetragonula gressitti* for rearing.

Image 4. *Lepidotrigona arcifera* (Cockerell): A—tessellation on thorax | B—hind leg showing tibia and the basitarsus | C—showing semi-circular dark band on first metasomal segment.

Image 5. *Lepidotrigona arcifera* feeding on flower of *Cynoglossum furcatum*.

Sarpang District and warrants further exploration.

Distribution: Vietnam (Sakagami 1978), India (Rathor et al. 2013), Bhutan.

Genus *Lepidotrigona* Schwarz, 1939

This genus is distinguished by having six hamuli and dense tesselation on head and thorax; mesonotum with a border of thick, scale-like yellow or whitish hairs. Basitarsis is without sericeous patch on inner face of basitarsus which is rather uniformly setose.

***Lepidotrigona arcifera* (Cockerell, 1929) (Image 4, A & B; Image 5, 6 & 7)**

Trigona arcifera Cockerell 1929: 591–592: Holotype: worker (BMNH 17b.1081); Type locality: India, Sikkim, Teesta bridge.

Diagnosis: Generally black; complete semicircular dark band on the pale first metasomal tergum partly enclosing the basal depression; yellowish apical metasomal terga; densely plumose ("scale-like") hairs on margin of mesoscutum; body and wing each more than or equal to 4mm in length.

Measurements: 12 workers; total body length: 4–4.60 mm (mean: 4.14mm); forewing length excluding tegula: 3.99–4.91 mm (mean: 4.49mm).

Materials examined: NBCB00268, NBCB00269, NBCB00270, 29.vii.2016, 3 females, Rinchending, Chhukha, (26.848N & 89.396E, 461m), coll. Tshering Nidup; NBCB00271, NBCB00272, NBCB00273, 23.x.2015, 3 females Yongkola, Monggar (27.306N & 91.164E, 1,553m), coll. Phurpa Dorji & Wim Klein; NBCB00274, NBCB00275, NBCB00276, NBCB00277, NBCB00278, NBCB00279, NBCB00280, NBCB00281, 29.vii.2016, 8 females, Khengpagang, Sarpang (26.848N & 89.396E, 461m), coll. Deo Kumar Rai & Bishal Rai.

Remark: This species seems to be widely distributed and recorded at the altitude range of 461–1,553m. It is reported from the seven districts of Chhukha, Dagana, Mongar, Zhemgang, Samdrup Jongkhar, Trashigang, Tsirang and Sarpang however, the nest entrance were examined only in Serzhong (Mongar), Dorona (Dagana), Shumar & Nganglam (Pemagatshel), Mantar & Pemathang (Samdrup Jongkhar), Dovan & Goang (Sarpang), Tsholingkhar (Tsirang), and Panbang (Zhemgang).

Distribution: India (Rasmussen 2008, 2013) Bhutan.

Image 6. Nest entrance of *Lepidotrigona arcifera* on the tree *Quercus griffithii.*

Image 7. Nest entrance of reared *Lepidotrigona arcifera*.

Nest description and meliponiculture

A nest of *L. arcifera* was observed under natural conditions in the oak forest in Pemagatshel (Image 6). It was nesting in the trunk of an oak tree, ca. 4m above ground on the bulging side of the trunk. The area was sloping and the ground was clear without much undergrowth. The nest entrance varies from broadly funnel-like to round and little narrow at the base but in some the base can be bulging. The color of the entrance is lighter at the tip and darker to reddish-brown at the base. The entrance is bit angled downward and the rim appears as though sliced angularly. It is guarded by 5–12 adults based on a series of the nest photographs. The nest entrance measures about 1.6cm in width (opening), 2cm in length (opening), 7.5cm dorsally from tip to base and 6.5cm ventrally. *T. gressitti* do not make any nest entrance like *L. arcifera*; however, it coats the nest tunnel with yellowish substances (likely resin or resin mixed with wax) (Image 2).

According to one informant, honey is extracted in winter and each *L. arcifera* colony provides approximately 750 ml/year. *T. gressitti* is thought to produce slightly more than 750 ml/year. Honey of *T. gressitti* is sold at Nu. 6000 (=100 US Dollars) and honey of *L. arcifera* at Nu. 3000 (=50 US Dollars), per 750 ml. Currently 20 households rear *L. arcifera* in Khengpagang village in Sarpang District but only one household rears *T. gressitti*. The first author also saw one household rearing *L. arcifera* at Tsholingkhar Village in Tsirang.

These bees are brought to the village from the forest with an undisturbed nest after cutting the trunk of the tree they were nesting in. They are then placed around the house in any position in case of *L. arcifera*, but in upright position in case of *T. gressitti* (Image 3). It is said that *T. gressitti* colony leaves the nest if kept in other positions. They are reared in a natural way and it was never observed that the bees were kept in rational hives or that the keepers knew how to perform divisions of the colonies or artificial feeding.

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SHORT COMMUNICATION

New records of six termite (Blattodea: Termitidae) species from Kerala, India

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Abstract: The present paper reports new records of six species of termites (Blattodea: Termitidae), viz., *Angulitermes acutus* Mathur & Sen-Sarma, *Dicuspiditermes obtusus* (Silvestri), *Pericapritermes dunensis* (Roonwal & Sen-Sarma), *Pericapritermes topslipensis* Thakur, *Nasutitermes cherraensis* Roonwal & Chhotani, and *Nasutitermes kali* Roonwal & Chhotani from Kerala. Three species *P. dunensis*, *N. cherraensis* and *N. kali* are reported for the first time from the Western Ghats. The details of materials collected, diagnostic characters and distribution data in India are provided.

Keywords: *Angulitermes acutus*, *Dicuspiditermes obtusus*, *Pericapritermes dunensis*, *Pericapritermes topslipensis*, *Nasutitermes cherraensis*, *Nasutitermes kali.*

Termites are fully social insects, with an extraordinary range of morphological forms (Eggleton 2011). They are a familiar group to common man, directly or indirectly due to their abundance, fascinating characteristic features and due to their pest status. Being decomposers and recyclers, they are also ecologically important (Wood & Sands 1972).

The family Termitidae is the most highly evolved of all the families of Isoptera and are known to occur in all zoogeographical regions of the world. It is the largest family in termites. Among the total 2,937 living species of the world, 2,072 (nearly 71%) belong to this single family under 238 genera (Krishna et al. 2013). In India, there are 208 species under 35 genera belonging to four subfamilies of Termitidae (71%) (Amina et al. 2013; Amina & Rajmohana 2013; Krishna et al. 2013).

As a part of our taxonomic studies on the termites of Kerala (Amina & Rajmohana 2013, 2016; Amina et al. 2013, 2016a,b), six species under four genera *Angulitermes acutus* Mathur & Sen-Sarma, *Dicuspiditermes obtusus* (Silvestri), *Pericapritermes dunensis* (Roonwal & Sen-Sarma), *Pericapritermes topslipensis* Thakur *Nasutitermes cherraensis* Roonwal & Chhotani, and *Nasutitermes kali* Roonwal & Chhotani (Family: Termitidae) are hereby reported as new records from Kerala. Three species namely *N. cherraensis*, *N. kali*, and *P. dunensis* are reported for the first time from the Western Ghat segment of Kerala.

Termites in particular have a very strong impact on soil environment with a significant role in maintenance of soil fertility and productivity of ecosystem. Among them, soil feeders have a positive impact on overall organic matter cycling (Brauman 2000). In termite groups, soil feeding termites are a less studied group. More taxonomic explorations are needed to understand the diversity and as well as the bioecological features of this group. In the above six species, *A. acutus*, *D. obtusus*, *P. dunensis*, and *P. topslipensis* are soil feeders and *N. cherraensis* and *N. kali*

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are wood feeders.

Materials and Methods

All the specimens were collected from the part of colonies, during field surveys undertaken in the Kerala part of the Western Ghats from 2013 to 2016. This southwestern state of India, has a very pleasant and equable climate throughout the year. The normal temperature of Kerala ranges from 28–32 ^{0}C on the plains, but in the highlands it drops to a low level. The average annual rainfall is 3,000mm, 70% of it is received during June to August (the period of the south-west monsoon), 20% during October to December (the north-east monsoon) and 10% during pre-monsoon period, i.e., April and May. The mean relative humidity value ranges from 60–90 % and the maximum being during the rainy season (June–September).

The specimens were preserved in 80% alcohol. Measurements were made in 80% alcohol under a stereozoom microscope, Leica EZ4HD, at magnifications between 8–35×. Images were taken using Leica 205-A stereomicroscope fitted with a DFC 500 camera, and processed with the help of extended focus software, LAS version 3.6.

The species identifications were made using Chhotani (1997). All specimens are deposited in the national zoological collections of the Zoological Survey of India (ZSI), at Kozhikode, Kerala, India.

Result and Discussion

As a part of the inventory on the termite fauna of Kerala, Amina & Rajmohana (2014) reported 60 species of termites from Kerala under 28 genera and three families. In addition to this, nine more species were reported (Amina & Rajmohana 2016; Amina et al. 2016a,b; Ipe & Mathew 2019). With the present report, an additional six species, within four genera under the family Termitidae are hereby documented as new records from the state.

New reports:
Family: Termitidae
Subfamily: Nasutitermitinae

1. Nasutitermes cherraensis **Roonwal & Chhotani, 1962**

Material examined: ZSI/WGRC/IR/INV/5474, 11-ii-1988, one colony, India, Kerala, Palakkad (Silent Valley), coll. ZSI collection. ZSI/WGRC/IR/INV/5475, 24-ii-2013, one colony, India, Kerala, Palakkad (Keralamedu) 10.6467N, 76.8072E, coll. Sureshan & party. ZSI/WGRC/IR/INV/5476, 22-ii-2013, one colony, India, Kerala, Palakkad (Poochippara), 10.7867N, 76.6548E, coll. Sureshan and team. ZSI/WGRC/IR/INV/5477, 22-ii-2013, one colony, India, Kerala, Palakkad (Varadimala), 10.7867N, 76.6546E, coll. Sureshan & team.

Distribution in India: Arunachal Pradesh, Meghalaya (Krishna et al. 2013), Kerala (Palakkad) (present study),

Diagnostic features: Soldier Caste (Image 1). Dimorphic. *Major soldier*: Total body length 3.50–4.60 mm. Head capsule without nasus pear shaped (head length with nasus 1.50–1.80 mm, head length without nasus 0.90–1.13 mm, head width 0.80–1.07 mm, head width index 0.87–0.93). Head in profile incurved behind nasus, nasus long (nasus length 0.60–0.77 mm, nasus/head length index 0.65–0.79) narrow, thin and cylindrical. Antennae 12–14 (mostly 12) segmented, segment 3 longer than (1.5 times) 2 in 12 segmented conditions and shorter in 14 segmented condition. Mandible without or with a very small spine like process. Pronotum saddle shaped. *Minor Soldier*: (Adapted from Chhotani 1997). Rare occurrence. Small. Head narrow (head length with nasus

Image 1. *Nasutitermes cherraensis* Roonwal & Chhotani: A—Soldier | B—Dorsal view of mandibular region. © Authors

1.25–1.40 mm; head length without nasus 0.68–0.80 mm; maximum head width 0.60–0.67 mm; head width index is 0.84–0.88). Head behind antennae constricted. Antennae 11–12 segmented. *Worker*: monomorphic. Total body length 4.30–5.90 mm, head capsule subcircular (length to tip of labrum 1.30–1.40 mm, length to base of mandible 0.92–1.20 mm and maximum width 1.00–1.33 mm). Antennae 13–15 segmented, segment 3 shortest in 13 segmented conditions and segment 4 shortest in 14 segmented antennae.

Remarks: Of the total 250 world species of *Nasutitermes*, 23 species are reported from India (among them 18 species are endemic to India) and three are known from Kerala. *N. cherraensis* is a species endemic to India and has a limited distribution, known hitherto only from northeastern India. This species is documented for the first time from the Western ghats of Kerala. As per Chhotani (1997), the worker caste is with 14–15 antennal segments and pronotum with a prominent notch at anterior margin. In the present collections, workers with 13 segmented antennae were also present. Soldier minor was not represented in the present collection, hence the attributes of the soldier minors given above are from Chhotani (1997).

2. Nasutitermes kali **Roonwal & Chhotani, 1962**

Material examined: ZSI/WGRC/IR/INV/5537, ZSI/WGRC/IR/INV/5538, ZSI/WGRC/IR/INV/5539, 06-i-2015, three colony, India, Kerala, Ernakulum: Thattekad (Urulamthanni) 10.1281N, 76.7552E, coll. Amina Poovoli.

Distribution in India: Assam, Meghalaya (Krishna et al. 2013), Kerala (Ernakulum) (present study)

Diagnostic features: Soldier (Image 2): Monomorphic. Head capsule without nasus pear shaped; head length without nasus a little longer than head width (head length with nasus 1.30–1.58 mm, head length without nasus, 0.78–0.86 mm, head width 0.73–0.90 mm, head width index 0.93–0.97, nasus length 0.50–0.55 mm, nasus/head length index 0.60–0.63). Head in profile straight with a weak hump behind nasus. Nasus short and conical. Antennae 11–12 segmented, segment 3 slightly shorter and narrower than 2 in 12 segmented antennae and subdivided in 11-segmented antennae. Mandibles with long prominent spine. Pronotum saddle shaped. Cerci short; 2 segmented. *Worker*. Dimorphic. *Major worker*: Total body length 3.4–3.70 mm. In dorsal view, head capsule subcircular, epicranial suture distinct. Antennae 13 segmented, 3 shortest. Post clypeus slightly swollen, length less than half of width (length 0.18–0.22 mm, width 0.43–0.46 mm). *Minor worker*: Similar to major worker, varying in their size and slightly in their colour. Total body length 2.60–3.00 mm.

Remarks: *N. kali* is an Indian endemic species and they were confined to the northeastern part of India and now this species is reported from Kerala, from Western Ghats. The samples were collected from trees.

Subfamily: Termitinae

3. Angulitermes acutus **Mathur & Sen-Sarma, 1961**

Material examined: ZSI/WGRC/IR/4652, 18-ix-2013, India: Kerala: Palakkad (Walayar Deer Park) 10.834N, 76.8461E, coll. Amina Poovoli.

Distribution in India: Tamil Nadu, Uttar Pradesh (Krishna et al. 2013), Kerala (Palakkad) (Present study)

Diagnostic features: Soldier (Image 3). Head capsule subrectangular with wavy sides; maximum width at anterior part Head capsule comparatively large and more wide (head length to the base of mandibles 1.20–1.35 mm; head length to tip of frontal projection 1.35–1.45 mm; maximum head width 0.95–1.00 mm); antero-lateral point of head not prominent. Left mandible comparatively longer than head length to base of mandible (1.35–1.40

Image 2. *Nasutitermes kali* Roonwal & Chhotani: A—Soldier | B—Dorsal view of mandibular spine. © Authors

Image 3. *Angulitermes acutus* Mathur & Sen-Sarma: A—Soldier | B—Dorsal view of head. © Authors

mm). Frontal projection short and pointed, with slightly raised tip, extending beyond the base of mandibles and covering part of labrum. Antennae 14 segmented; segment 3 a little longer than 2; 4 shortest or sometimes subequal to 2. Labrum asymmetrical, mandibles slightly snapping type; slender, long and rode-like. Postmentum short and club shaped, pronotum saddle shaped. *Worker:* Total body length 3.00–4.10 mm, head subcircular, antennae 14 segmented, segment 3 shorter than 2; 4 shortest.

Remarks: *A. acutus* is an Indian endemic species and it was formerly reported only from Tamil Nadu and Uttar Pradesh. Now the species is reported from Kerala for the first time. The colonies of this species have been collected from under boulders.

4. ***Dicuspiditermes obtusus* (Silvestri, 1923)**

Material examined: ZSI/WGRC/IR/5616, 18-ix-2013, one colony, India: Kerala: Palakkad (Walayar) 10.834N, 76.8461E, coll. Amina Poovoli. ZSI/WGRC/IR/5617, 17-v-2013, one colony, India, Kerala, Wayanad (Kuruva Dweep), 11.8217N, 76.0922E, coll. Amina Poovoli. ZSI/WGRC/IR/5618, 26-xi-2014, one colony, India, Kerala, Ernakulum (Thoppimudi-Thattekkad), 10.1319N, 76.7071E, coll. Jafer Palot. ZSI/WGRC/IR/5619, 27-xi-2014, one colony, India, Kerala, Ernakulum (Kolumba-Thattekad), 10.1039N, 76.7004E, coll. Jafer Palot. ZSI/WGRC/IR/5620, 5-i-2015, one colony, India, Kerala, Ernakulum (Kootikkal-Thattekad), 10.075N, 76.7495E, coll. Amina Poovoli.

Distribution in India: Karnataka, Madhya Pradesh, Orissa (Krishna et al. 2013), Kerala (Palakkad, Wayanad, Ernakulum) (present study)

Diagnostic features: Soldier (Image 4). Head capsule subrectangular, Frons inclined at angle of 45^{0}, antero-lateral tubercle of head short and blunt; median suture of head extending up to half of head length, fontanelle transverse, situated at frontal inclination. Antennae 14 segmented; segment 2–4 subequals, sometimes 3 slightly longer than 2 or 4. Labrum asymmetrical, anterior margin deeply incurved; lateral margin produced into long, thin spine like processes and with a few serrations on antero-lateral margin at the base of spines. Mandibles asymmetrical; left mandible strongly twisted at middle and with beak at tip; sometimes point-tip seen damaged. Right mandible blade like, apical blade elongate and highly incurved on inner margin, postmentum club shaped, waist narrow and long, lying at posterior end, pronotum saddle shaped. *Worker*: Total body length 4.00–5.10 mm, head capsule subcircular and wider than head length, antennae 14 segmented, segment 3 and 4 subequal and segment 2 slightly longer than 3 and 4.

Remarks: Of the 20 known species of *Dicuspiditermes*, *D. obtusus* has very distinctive characters from other species. They have very short and blunt antero-lateral processes on head. This species is recorded for the first time from Kerala and were collected from the soil underneath boulders

*5. **Pericapritermes dunensis*** **(Roonwal & Sen-Sarma, 1960)**

Material examined: ZSI/WGRC/IR/INV/5717, 21-ix-2014, one colony, India: Kerala: Idukki (Chinnar WS), 10.3068N, 77.2060E, coll. Emiliyamma & party. ZSI/WGRC/IR/INV/5715, 10-iv-2013, one colony, India, Kerala, Pathanamthitta (Gavi) 9.4358N, 77.1657E, coll. Rajmohana & party. ZSI/WGRC/IR/INV/5718, 23-ix-2014, one colony, India, Kerala, Idukki (Erachipara-Munnar), 9.8479N, 77.1464E, coll. Emiliyamma & party. ZSI/WGRC/IR/INV/5719, 7-i-2015, one colony, India, Kerala, Ernakulam (Thattekadu Bird Sanctuary- Kallippara), 10.0749N, 76.4551E coll. Amina Poovoli. ZSI/WGRC/IR/INV/5716,

Image 4. ***Dicuspiditermes obtusus*** **(Silvestri): A—Soldier | B—Dorsal view of head. © Authors**

Image 5. ***Pericapritermes dunensis*** **(Roonwal & Sen-Sarma): A—Soldier | B—Dorsal view of head. © Authors**

23-i-2014, one colony, India, Kerala, Pathanamthitta (Pekkavu), 9.4916N, 76.666E, coll. Sureshan & party. ZSI/WGRC/IR/INV/5720, 10-ix-2015, one colony, India, Kerala, Idukki (Uppupara-PTR), 9.5262N, 77.2368E, coll. Sureshan & party.

Distribution in India: Arunachal Pradesh, Meghalaya, Uttarakhand, Uttar Pradesh and West Bengal (Krishna et al. 2013), Kerala (Ernakulam, Idukki, and Pathanamthitta) (present study)

Diagnostic features: Soldier (Image 5). Head capsule elongate, subrectangular, sides slightly narrowing anteriorly (head length with mandibles 3.95–4.25 mm, head length to base of mandibles 2.30–2.50 mm, maximum head width 1.28–1.48 mm), frons weakly inclined in front; median suture of head distinct, extending from posterior margin to fontanelle, fontanelle small, circular, fontanelle gland small in size, sometimes indistinct. Antennae 14 segmented; segment 3 a little longer than 2 or 4, segment 4-shortest, labrum asymmetrical; anterior margin weakly incurved, with short, horn-like antero-lateral points, mandibles strongly asymmetrical, shorter than head length (left mandible length 1.43–1.70 mm, right mandible length 1.37–1.50 mm), postmentum long and club shaped, narrowed at waist. *Worker:* Total body length 3.2–4.00 mm, head capsule subcircular, broader than long. Antennae 14 segmented, segment 3 shorter than 2 and a little longer than 4, segment 4 shortest.

Remarks: This species is documented for the first time from Kerala as well as from Western Ghats. The colonies of this species have been collected from under boulders.

6. Pericapritermes topslipensis Thakur, 1976

Material examined: ZSI/WGRC/IR/INV/5721, ZSI/WGRC/IR/INV/5728, 11-ix-2013, 2 colonies, India: Kerala: Wayanad (Muneeswarankunnu), 11.7032N, 76.0834E, coll. Bhavana. ZSI/WGRC/IR/INV/5733, 31-vii-2015, one colony, India: Kerala: Wayanad (Thalappuzha), 11.8403N, 75.9492E, coll. Shili. ZSI/WGRC/IR/INV/5734, 15-vii-2015, India: Kerala: Wayanad (Vythiri), 11.5516N, 76.0403E, coll. Shili.

Distribution in India: Karnataka, Tamil Nadu (Krishna et al. 2013), Kerala (Wayanad) (present study)

Image 6. *Pericapritermes topslipensis* Thakur: A—Soldier | B—Dorsal view of head. © Authors

Diagnostic features: Soldier (Image 6). Head capsule elongated subrectangular, sides substraight (head length with mandibles 4.00–4.25 mm, head length to base of mandibles 2.50–2.70 mm, maximum head width 1.30–1.45 mm) frons weakly inclined in front; median suture of head distinct, extending from posterior margin to almost up to fontanelle, fontanelle small, circular, fontanelle gland small in size, antennae 14 segmented; segment 3 subequal to slightly longer than 2; segment 4-shortest, labrum asymmetrical; anterior margin substraight, with very short antero-lateral points, mandibles asymmetrical, shorter than head length (left mandible length 1.39–1.48 mm, right mandible length 1.36–1.45 mm), postmentum long and club shaped, pronotum strongly saddle shaped. *Worker*. Total body length 4.00–4.60 mm, head capsule subcircular, broader than long, antennae 14 segmented, segment 3 shorter than 2 and a little longer than 4, segment 4 shortest.

Remarks: The median suture of Y-arm is well distinct in some specimens and in some it is indistinct. *P. topslipensis* is a southern Indian endemic species from Kerala. It is reported only from the high elevation zones.

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SHORT COMMUNICATION

Status, abundance, and seasonality of butterfly fauna at Kuvempu University Campus, Karnataka, India

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Abstract: A survey was conducted to record the diversity, status, and occurrence of butterfly species in the Kuvempu University Campus, Jnana Sahyadri, Shivamogga District, Karnataka during February 2010 to January 2011. A total of 115 species of butterflies in 77 genera, belonging to five families were recorded. Nymphalidae comprised the highest number of species, followed by Lycaenidae, Pieridae, Papilionidae, and Hesperiidae. The study area hosts 14 species of butterflies protected under various schedules of the Indian Wildlife Protection Act, 1972. Nine species recorded are endemic to the Western Ghats of peninsular India and Sri Lanka. Hence there is an urgent need to protect this habitat by adapting long-term monitoring programs to manage and conserve the butterfly diversity.

Keywords: Diversity, Jnana Sahyadri, Lepidoptera, Seasonality, Shivamogga District, Western Ghats.

Butterflies are good indicators of habitat quality, climatic conditions, seasonal, and ecological changes; butterfly studies can be used to formulate conservation strategies (Beccaloni & Gaston 1995). India has 1,800 species and subspecies of butterflies (Kunte et al. 2018), and peninsular India hosts 350 species including many endemics, most found in the Western Ghats (Kunte 2008). Three-hundred-and-seventeen species have been recorded from the southern Western Ghats, 316 from the central Western Ghats and 200 from the northern Western Ghats (Gaonkar 1996).

The diversity of butterflies in a given area reflects the overall plant diversity and the presence of suitable habitats (Kakati 2006), making them good indicators of health of the ecosystems (Padhye et al. 2006) that can be used to assess the impact of various threats (Gaonkar 1996; Kunte 2000, 2008; Kehimkar 2008) and formulating conservation priorities for management of biodiversity. Thus, there is a need for studies of butterfly community structure and dynamic group structure in different regions to assess the impact of changing natural habitats on the diversity and distribution of butterflies.

Material and Methods

Study Area

Kuvempu University Campus is located between 13.7359° N and 75.6324° E at an elevation of 680–720m. The campus is situated 24km south-east of Shivamogga City and 4km north of Bhadra Reservoir amidst dry deciduous forest, and is located on the edge of Bhadra Tiger Reserve and Bhadra Wildlife Sanctuary. The campus covers an area of 326 acres, with 56% of the land being under forest (undisturbed area) and the remaining 44% occupied by buildings and associated landscaping

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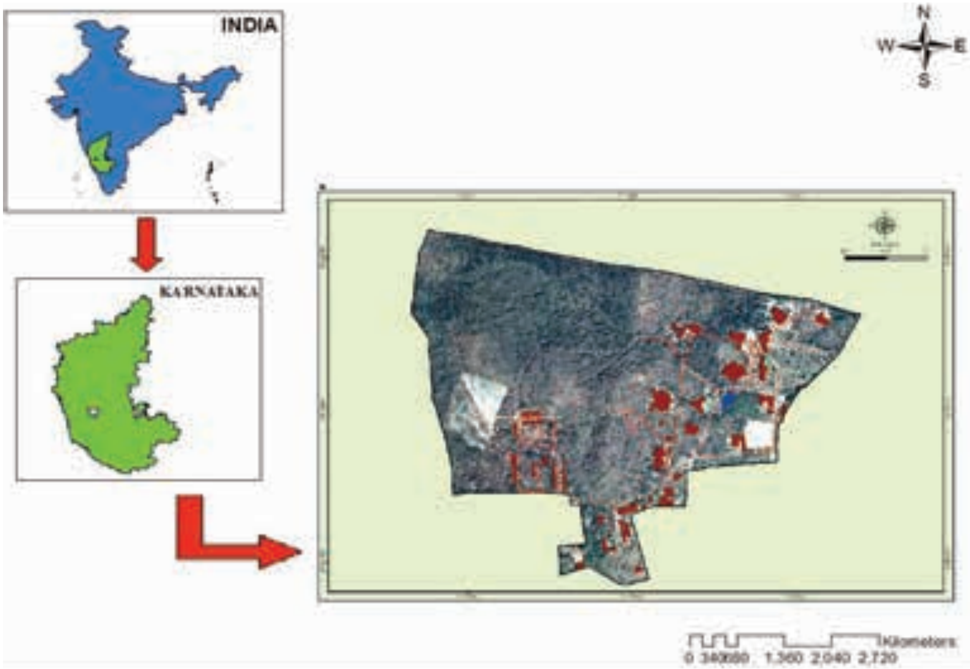

Figure 1. Location map of Kuvempu University Campus.

(Fig. 1). The predominant vegetation is typically dry deciduous forest having considerable similarity with the wildlife sanctuary.

Sampling method

The line transect method developed by the Institution of Terrestrial Ecology (Pollard 1979) was followed to monitor the diversity. Three line transects were set up, which were approximately 500m long and 10m wide, passing through different landscape element types. The transect lines were walked at a constant pace for approximately half an hour. Transects were walked from 07.30 to 11.00 h when butterflies are most active. Transects were walked every month for a period of one year from February 2010 to January 2011. Butterflies were identified with the help of field guide (Kunte 2000). Specimen collection was strictly avoided. The taxonomic status of butterflies is adopted from Kunte (2000). The status was scored using presence-absence scoring method and then percentage of abundance was calculated to determine the status. On the basis of abundance, butterflies were categorized under different score classes such as 80–100% as very common (VC), 60–80% as common (C), 40–60% as occasional (O), 20–40% as rare (R), and below 20% as very rare (VR) (Aneesh et al. 2013).

The seasonality of butterflies in the campus was then compared with trends available in other studies of Western Ghats, from Peringome Vayakkara Panchayath, Kerala (Sneha 2018) to see the variation in this forest type.

Results and Discussion

During the study a total of 115 species of butterflies in 77 genera, belonging to five families were recorded (Table 1, Images 1–16). The family Nymphalidae dominated with 38 species (33% of total species) recorded, followed by Lycaenidae with 28 species (24%), Pieridae with 23 species (20%), Papilionidae with 15 species (13%), and Hesperiidae with 11 species (10%) (see Tables 1,2). The status of butterflies based on frequency of occurrence revealed that 52 species were common (45% of total), 23 rare (20%), 22 very common (19%), 11 very rare (10%), and 7 occasional (6%) (Tables 1,2).

Butterflies are seasonal in their occurrence. They are common for only a few months and rare or absent in other parts of the year (Kunte 2000). During the study, the seasonality in the occurrence of different butterfly species was also recorded (Table 1). Figure 2 represents seasonal wise variations in the abundance and distribution of butterfly species. The number of species encountered was highest during winter at 102 species, and decreased to 85 in summer and 64 during the monsoon; 39 species were sighted throughout the year.

Butterflies are sensitive to changes in habitat and climate, which influence their distribution and

Table 1. Checklist of butterflies of Kuvempu University Campus along with legal status, status, and seasonality.

	Common name	Scientific name	Legal status (IWPA 1972)	Status	Seasonality
	Papilionidae				
1	Crimson Rose	*Pachliopta hector* (Linnaeus, 1758)	Sch. I	VC	M
2	Common Rose	*Pachliopta aristolochiae* (Fabricius, 1775)		R	S, M
3	Malabar Rose*	*Pachliopta pandiyana* (Moore, 1881)		VR	W
4	Common Mime	*Papilio clytia* (Linnaeus, 1758)	Sch. I	R	W, S, M
5	Common Mormon	*Papilio polytes* (Linnaeus, 1758)		C	W, S, M
6	Blue Mormon**	*Papilio polymnestor* (Cramer, 1775)		R	W, S, M
7	Lime Swallowtail	*Papilio demoleus* (Linnaeus, 1758)		VC	W, S
8	Common-banded Peacock	*Papilio crino* (Fabricius, 1793)		VR	W, S
9	Malabar Raven*	*Papilio dravidarum* (Wood-Mason, 1880)		R	W, S
10	Red Helen	Papilio helenus (Linnaeus, 1758)		O	W, M
11	Common Bluebottle	*Graphium sarpedon* (Linnaeus, 1758)		R	W, M
12	Tailed Jay	*Graphium agamemnon* (Linnaeus, 1758)		VC	W, S, M
13	Common Jay	*Graphium doson* (C. & R. Felder, 1864)		C	W
14	Spot Swordtail	*Graphium nomius* (Esper, 1799)		C	S
15	Sahyadri Birdwing*	*Troides minos* (Cramer, 1779)		R	W, S, M
	Lycaenidae				
16	Common Silverline	*Spindasis vulcanus* (Fabricius, 1775)		C	W, S
17	Common Pierrot	*Castalius rosimon* (Fabricius, 1775)	Sch. I	VC	W, S, M
18	Red Pierrot	*Talicada nyseus* (Guerin-Meneville, 1843)		C	W, S
19	Dark Pierrot	*Tarucus ananda* (de Nicéville, 1884)	Sch. IV	C	W, S
20	Angled Pierrot	*Caleta decidia* (Hewitson, 1876)		C	W, S, M
21	Banded Blue Pierrot	*Discolampa ethion* (Westwood, 1851)		C	W, S, M
22	Common Cerulean	*Jamides celeno* (Cramer, 1775)		VC	W, S, M
23	Dark Cerulean	*Jamides bochus* (Stoll, 1782)		C	W, S, M
24	Gram Blue	*Euchrysops cnejus* (Fabricius, 1798)	Sch. II	C	W, S
25	Zebra Blue	*Leptotes plinius* (Fabricius, 1793)		C	W
26	Pea Blue	*Lampides boeticus* (Linnaeus, 1767)	Sch. II	C	S, M
27	Lime Blue	*Chilades lajus* (Stoll, 1780)		C	S, M
28	Dark Grass Blue	*Zizeeria karsandra* (Moore, 1865)		VC	W, S, M
29	Lesser Grass Blue	*Zizina otis* (Fabricius, 1787)		C	W, S
30	Tiny Grass Blue	*Zizula hylax* (Fabricius, 1775)		VR	S, M
31	Common Lineblue	*Prosotas nora* (C. Felder, 1860)	Sch. II	VC	W, S, M
32	Common Hedge Blue	*Acytolepis puspa* (Horsfield, 1828)		C	W, M
33	Plain Hedge Blue	*Celastrina lavendularis* (Moore, 1877)		C	M
34	Orange-spotted Grass Jewel	*Freyeria trochylus* (Freyer, 1845)		VC	W
35	Forget-me-not	*Catochrysops strabo* (Fabricius, 1793)		C	M
36	Large Oakblue	*Arhopala amantes* (Hewitson, 1862)		O	W, M
37	Indian Oakblue	*Arhopala atrax* (Hewitson, 1862)		O	S
38	Monkey Puzzle	*Rathinda amor* (Fabricius, 1775)		C	W, S
39	Apefly	*Spalgis epius* (Westwood, 1851)		R	W, S
40	Yamfly	*Loxura atymnus* (Stoll, 1780)		O	S, M
41	Plum Judy	*Abisara echerius* (Stoll, 1790)		C	W, S, M
42	Plains Cupid	*Chilades pandava* (Horsfield, 1829)		C	W, S, M

	Common name	Scientific name	Legal status (IWPA 1972)	Status	Seasonality
43	Indigo Flash	*Rapala varuna* (Horsfield, 1829)	Sch. II	R	W, M
	Nymphalidae				
44	Common Castor	*Ariadne merione* (Cramer, 1777)		C	W, S
45	Tawny Coster	*Acraea terpsicore* (Linnaeus, 1758)		VC	W, S
46	Blue Tiger	*Tirumala limniace* (Cramer, 1775)		VC	W, S
47	Dark Blue Tiger	*Tirumala septentrionis* (Butler, 1874)		C	W, S
48	Glassy Tiger	*Parantica aglea* (Stoll, 1782)		VR	W, S
49	Plain Tiger	*Danaus chrysippus* (Linnaeus, 1758)		R	W, S
50	Striped Tiger	*Danaus genutia* (Cramer, 1779)		C	W, S
51	Common Leopard	*Phalanta phalantha* (Drury, 1773)		VC	W, S
52	Grey Count	*Tanaecia lepidea* (Butler, 1868)	Sch. II	R	W, S, M
53	Indian Common Crow	*Euploea core* (Cramer, 1780)		VC	W, S, M
54	Danaid Eggfly	*Hypolimnas misippus* (Linnaeus, 1764)	Sch. I	C	W, S, M
55	Great Eggfly	*Hypolimnas bolina* (Linnaeus, 1758)		C	W, S, M
56	Lemon Pansy	*Junonia lemonias* (Linnaeus, 1758)		VC	W, S
57	Peacock Pansy	*Junonia almana* (Linnaeus, 1758)		C	W, S
58	Yellow Pansy	*Junonia hierta* (Fabricius, 1798)		C	W, S
59	Chocolate Pansy	*Junonia iphita* (Cramer, 1779)		C	W, S, M
60	Grey Pansy	*Junonia atlites* (Linnaeus, 1763)		R	W, S
61	Blue Pansy	*Junonia orithya* (Linnaeus, 1758)		VC	W
62	Common Evening Brown	*Melanitis leda* (Linnaeus, 1758)		VC	W, S, M
63	Dark Evening Brown	*Melanitis phedima* (Cramer, 1780)		C	W, M
64	Common Bushbrown	*Mycalesis perseus* (Fabricius, 1775)		C	W, S, M
65	Dark-branded Bushbrown	*Mycalesis mineus* (Linnaeus, 1758)		C	W
66	Malabar Glad-eye Boshbrown***	*Mycalesis junonia* (Butler, 1868)		C	W
67	Bamboo Treebrown	*Lethe europa* (Fabricius, 1775)		C	W, S, M
68	Common Five-ring	*Ypthima baldus* (Fabricius, 1775)		VC	W, S, M
69	Common Four-ring	*Ypthima huebneri* (Kirby, 1871)		VC	W, S, M
70	Common Baron	*Euthalia aconthea* (Cramer, 1777)		C	W, S, M
71	Common Lascar	*Pantoporia hordonia* (Stoll, 1790)		R	W, S, M
72	Indian Nawab	*Charaxes bharata* (C. & R. Felder, 1867)		R	W, S
73	Tamil Yeoman***	*Cirrochroa thais* (Fabricius, 1787)		VR	W, S
74	Common Palmfly	*Elymnias hypermnestra* (Linnaeus, 1763)		C	W, S, M
75	Indian Red Admiral	*Vanessa indica* (Herbst, 1794)		VR	W, S
76	Painted Lady	*Vanessa cardui* (Linnaeus, 1758)		R	W, S
77	Rustic	*Cupha erymanthis* (Drury, 1773)		C	W, S
78	Baronet	*Symphaedra nais* (Forster, 1771)		R	W, S
79	Commander	*Moduza procris* (Cramer, 1777)		R	W, S
80	Common Sailer	*Neptis hylas* (Linnaeus, 1758)		VC	W, S, M
81	Nigger or Medus Brown	*Orsotriaena medus* (Fabricius, 1775)		VR	W, M
	Pieridae				
82	Common or Lemon Emigrant	*Catopsilia pomona* (Fabricius, 1775)		VC	W, S
83	Mottled Emigrant	*Catopsilia pyranthe* (Linnaeus, 1758)		C	W, S
84	Sahyadri Cabbage White	*Pieris canidia* (Linnaeus, 1768)		C	W, S
85	Common Albatross	*Appias albina* (Boisduval, 1836)	Sch. II	R	W, M

	Common name	Scientific name	Legal status (IWPA 1972)	Status	Seasonality
86	Indian Wanderer	*Pareronia hippia* (Fabricius, 1787)		C	W
87	Indian Jezebel	*Delias eucharis* (Drury, 1773)		C	W, S
88	Painted Sawtooth**	*Prioneris sita* (C. & R. Felder, 1865)	Sch. IV	VR	W
89	Common Grass Yellow	*Eurema hecabe* (Linnaeus, 1758)		VC	W, S, M
90	Small Grass Yellow	*Eurema brigitta* (Stoll, 1780)		C	W, S, M
91	One-spot Grass Yellow	*Eurema andersoni* (Moore, 1886)		C	W, M
92	Three-spot Grass Yellow	*Eurema blanda* (Boisduval, 1836)		C	W, M
93	Common Gull	*Cepora nerissa* (Fabricius, 1775)	Sch. II	O	W
94	Lesser Gull	*Cepora nadina* (Lucas, 1852)	Sch. II	VR	W, M
95	Crimson-tip	*Colotis danae* (Fabricius, 1775)		C	S
96	Little Orange-tip	*Colotis etrida* (Boisduval, 1836)		C	W, S
97	Plain Orange-tip	*Colotis aurora* (Cramer, 1780)		C	W, S
98	Small Salmon Arab	*Colotis amata* (Fabricius, 1775)		R	W, S, M
99	Large Salmon Arab	*Colotis fausta* (Olivier, 1804)		R	W, S, M
100	Yellow Orange-tip	*Ixias pyrene* (Linnaeus, 1764)		R	W, S
101	White Orange-tip	*Ixias marianne* (Cramer, 1779)		R	S
102	Great Orange-tip	*Hebomoia glaucippe* (Linnaeus, 1758)		VR	W, M
103	Pioneer	*Belenois aurota* (Fabricius, 1793)		VC	S
104	Psyche	*Leptosia nina* (Fabricius, 1793)		O	W, S, M
	Hesperiidae				
105	Indian Grizzled Skipper	*Spialia galba* (Fabricius, 1793)		R	W, S, M
106	Grass Demon	*Udaspes folus* (Cramer, 1775)		C	W, S, M
107	Dark Palm-Dart	*Telicota bambusae* (Moore, 1878)		C	W, S, M
108	Oriental or Common Grass Dart	*Taractrocera maevius* (Fabricius, 1793)		R	W, S, M
109	Tawny-spotted or Tamil Grass Dart	*Taractrocera ceramas ceramas* (Hewitson, 1868)		VR	W, M
110	Rice Swift	*Borbo cinnara* (Wallace, 1866)		C	W, S, M
111	Chestnut Bob	*Iambrix salsala* (Moore, 1866)		VC	W, S, M
112	Common Banded Awl	*Hasora chromus* (Cramer, 1780)		C	W, M
113	White-banded Awl	*Hasora taminatus* (Hübner, 1818)		O	W, M
114	Common Snow Flat	*Tagiades japetus* (Stoll, 1781)		C	W, M
115	Sahyadri Banded Ace	*Halpe hindu* (Evans, 1937)		C	W, M

*—Endemic to Western Ghats | **—Endemic to peninsular India & Sri Lanka | ***—Endemic to Western Ghats & Sri Lanka | VC—Very common | C—Common | O—Occasional | R—Rare | W—Winter | S—Summer | M—Monsoon.

Table 2. Community structure, composition, and frequency of butterflies in Jnana Sahyadri Campus, Kuvempu University.

		Relative abundance					
	Family	**No. of species**	**VC**	**C**	**O**	**R**	**VR**
1	Papilionidae	15 (13%)	3	3	1	6	2
2	Lycaenidae	28 (24%)	5	17	3	2	1
3	Nymphalidae	38 (33%)	10	16	0	8	4
4	Pieridae	23 (20%)	3	10	2	5	3
5	Hesperiidae	11 (10%)	1	6	1	2	1
		115 (100%)	**22 (19%)**	**52 (45%)**	**7 (6%)**	**23 (20%)**	**11(10%)**

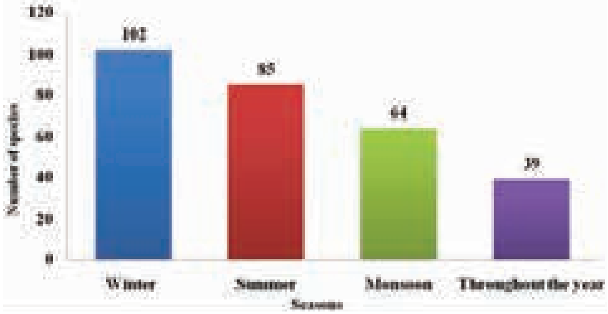

Figure 2. Seasonal wise variations in the abundance of butterfly species at Kuvempu University Campus.

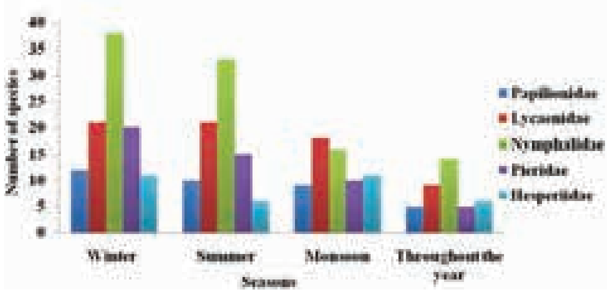

Figure 3. Family wise, seasonal distribution and occurrence of butterfly species at Kuvempu University Campus.

abundance (Wynter-Blyth 1957). Variations in the abundance and distribution of butterfly species (Fig. 3) were found to be consistently highest among the Nymphalidae in winter and summer and throughout the year. Among the Lycaenidae variation was equal in winter and summer, high in the monsoon and lower throughout the year. Among the Pieridae and Papilionidae it was persistently decreasing from winter, summer and monsoon throughout the year and among the Hesperiidae variation was inconsistent across seasons, being high in winter and monsoon, and low in summer and throughout the year.

The level of endemism varies within India depending upon the accessibility of larval as well as adult food resources, which determine the occurrence and migration of butterflies (Gilbert & Singer 1975). Forty-five species are endemic to southern India (Thomas 1966), of which seven were recorded from the study area: Malabar Rose *Pachliopta pandiyana* Moore, 1881, Malabar Raven *Papilio dravidarum* Wood-Mason, 1880 & Southern Birdwing *Triodes minos* Cramer, 1779, endemic to the Western Ghats (Kunte 2008), Glad-eye Bushbrown *Mycalesis patnia* Butler, 1868 & Tamil Yeoman *Cirrochroa thais* Fabricius, 1787 endemic to the Western Ghats & Sri Lanka (Kunte 2008; Kasambe 2018), and the Blue Mormon *Papilio polymnestor* Cramer, 1775 & Painted Sawtooth *Prioneris sita* C. & R. Felder, 1865 endemic to peninsular India & Sri Lanka (Kunte 2008).

Conservation activities such as monitoring and mapping biodiversity have played a key role in determining diversity status (Margules & Pressey 2000). When compared to other habitats of the Western Ghats, overall species diversity in the study area was very low. The diversity and abundance of butterfly species is greatly associated with the availability of food plants in the surrounding habitat (Kunte et al. 1999). From this study, it was found that there was frequent clearing in the study area of weeds, which provided nectar as well as larval host plants, resulting in low floral diversity that supported low butterfly diversity (Image 17).

The study also revealed the impacts of factors such as habitat alterations and improper drainage system (Image 18). The study area is a dry deciduous forest type with hilly terrains, which during the monsoon receives sufficient rainfall, but the drainage system carries water out of the area by flowing down towards the low lying areas, instead of allowing it to percolate into the forest soil. Consequently, there is low water retention for the plants to grow leaving the campus dry at the end of winter and during summer, providing poor habitat for butterflies. Also, the elimination of grasses, shrubs and trees during landscaping has resulted in loss of habitats for plants and butterflies, leading to local extinctions of species (Balmer & Erhardt 2000) (Images 19, 20).

Our results emphasize the importance of campus estates as habitats for butterflies. If landscaping is carefully planned and campus gardens are properly maintained, the diversity of butterfly fauna may increase on the campus, providing a rich ground for butterfly conservation as well as for research. Occurrence of scheduled and endemic species in the study area indicates an urgent need to protect this habitat by adapting long-term monitoring programs to manage and conserve the butterfly diversity of Kuvempu University Campus, Shivamogga District.

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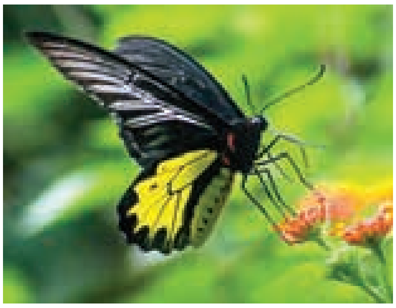

Image 1. Southern Birdwing, *Troides minos* ©MNH

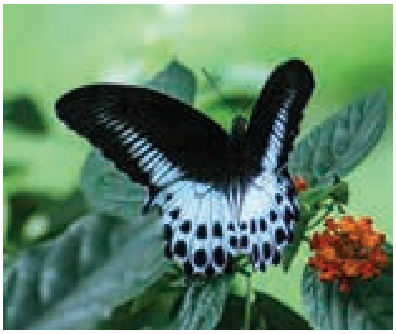

Image 2. Blue Mormon, *Papilio polymnestor* ©MNH

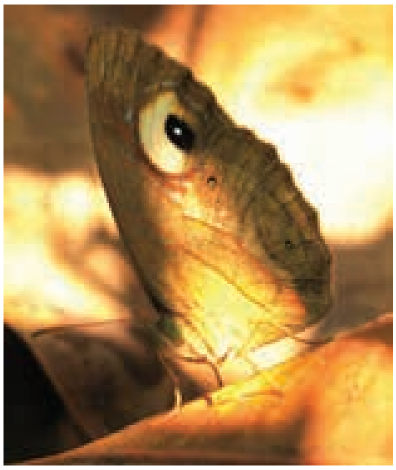

Image 3. Glad-eye Boshbrown, *Mycalesis patnia* ©HP

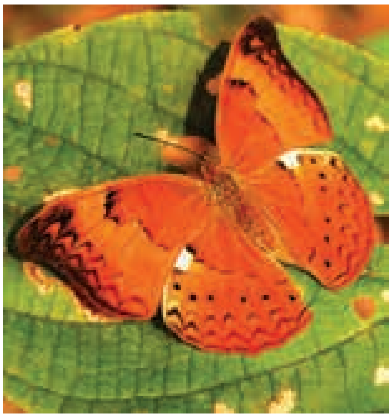

Image 4. Tamil Yeoman, *Cirrochroa thais* ©HP

Image 5. Common Baron, *Euthalia aconthea* ©MNH

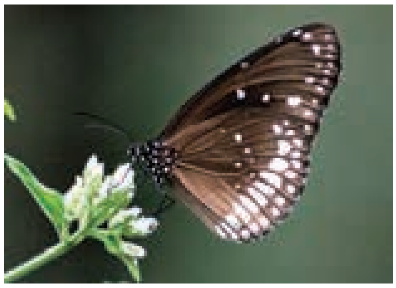

Image 6. Common Crow, *Euploea core* ©MNH

Image 7. Crimson Rose, *Pachliopta hector* ©MNH

Image 8. Danaid Eggfly, *Hypolimnas misippus* ©MNH

Image 9. Great Eggfly, *Hypolimnas bolina* ©MNH

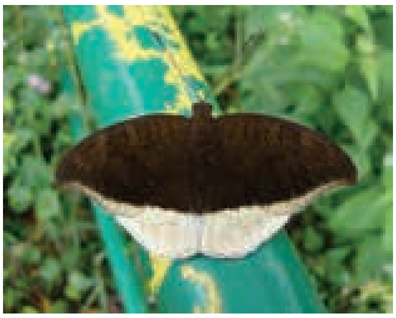

Image 10. Grey Count *Tanaecia lepidea* ©MNH

Image 11. Common Hedge Blue, *Acytolepis puspa* ©MNH

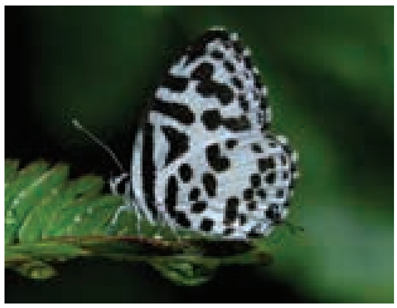

Image 12. Common Pierrot, *Castalius rosimon* ©MNH


Image 13. Dark Pierrot, *Tarucus ananda* ©MNH


Image 14. Gram Blue, *Euchrysops cnejus* ©MNH


Image 15. Indigo Flash, *Rapala varuna* ©MNH


Image 16. Pea Blue, *Lampides boeticus* ©MNH


Image 17. Forest patch with weeds cleared or uprooted ©MNH


Image 18. Drainage trench in the forest patch of KU Campus ©MNH

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Image 19. Anthropogenic activities in the forest area of campus ©MNH

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SHORT COMMUNICATION

Observations on butterflies of non-protected areas of Titabar, Assam, India

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Abstract: This paper depicts the result of two years study from 2014 to 2016 in non-protected areas on butterflies of Titabar (26.588 N & 94.187 E), Assam, India. During the study period, a total of 158 species of butterflies distributed in six families were recorded, out of which 29 belong to the family Hesperiidae, 17 to Pieridae, 11 to Papilionidae, 38 to Lycaenidae, two to Riodinidae, and 61 to Nymphalidae. Fourteen 'rare' species were recorded during the survey as per Evans (1932) such as *Athyma ranga, Arhopala paraganesa, Caltoris cormasa,* and *Appias nero*. This indicates the importance of the study and the need for conservation of butterflies of non-protected area of Titabar subdivision in upper Assam.

Keywords: Conservation, diversity, Jorhat District, Lepidoptera, northeastern India, species.

Upper Assam, a biodiversity rich zone of the northeastern region is well known for butterflies, having over 400 species of which 1/3rd are endemic and 1/7th are protected under various schedules of the Wildlife (Protection) Act 1972 in India (Singh 2017). Notable works have been done in Panbari Reserve Forest (RF), Kaziranga-Karbi hills (Gogoi 2013b, 2015), Jeypore RF, Dehing-Patkai (Gogoi 2013), Gibbon Wildlife Sanctuary (WS) (Singh et al. 2015), Dangori RF (Boruah & Das 2017), and floodplains of Dibru Soikhuwa NP (Das et al. 2017) in upper Assam. Along with the protected areas (PA), other non PAs like different forests and village woodlands of Assam also provide habitat for different butterfly species. But due to anthropogenic pressures these non PAs are declining in number thus affecting tiny creatures like butterflies.

Doubleday (1865) worked on the butterflies of Jorhat District. Recently, Singh et al. (2015) and Neog (2015) listed the butterflies of Gibbon WS which is the only PA of Titabar subdivision, and Bhuyan et al. (2005) documented the butterflies of the Regional Research Laboratory Campus of Jorhat. Again Saikia et al. (2014) studied the butterfly diversity of the Sericultural Training Institute Campus of Titabar and Dutta (2013) recorded 40 species from Titabar Town area. Our study hasn't included the Gibbon WS. Emphasis has been made to document the butterfly diversity of non PAs of Titabar subdivision to show the significance of non PAs especially in upper Assam and their importance in butterfly conservation in the region.

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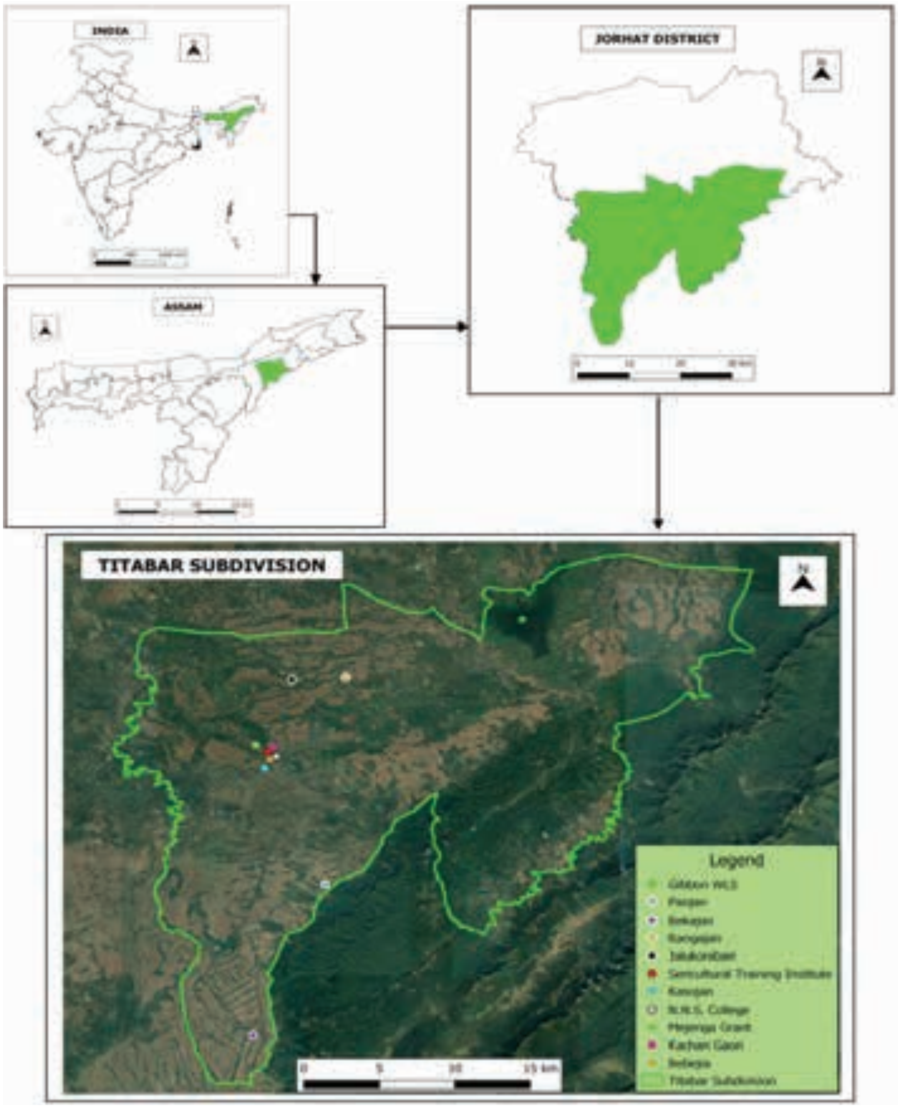

Figure 1. Map of Titabar subdivision showing the study locations.

Methods
Study Area

Titabar subdivision (26.588 N & 94.187 E) is located in Jorhat District of Upper Assam. To the north of Titabar lies the Jorhat subdivision, the south is bordered by Nagaland, Sivasagar District is located in the east, and the west is bordered by Golaghat District. Titabar subdivision consists of two revenue circles: Titabar and Mariani. The altitude of Titabar is 172m above sea level, while the average temperature ranges from 17–28°C, the average humidity is in the range of 66.5–89.9% and the annual rainfall of the study area is 250cm. The climate here is humid in summer and dry and cold in winter. Titabar has one wildlife sanctuary, the Hollongapar Gibbon WS under Mariani revenue circle. The survey was conducted in 10 different places in Titabar-Nanda Nath Saikia College Campus (26.588 N & 94.177 E), Sericultural Training Institute (26.592 N & 94.172 E), Bebejia (26.586 N & 94.173 E), Kachari Gaon (26.595 N & 94.175 E), Kasojan (26.58 N & 94.17 E), Mejenga Grant (26.597 N & 94.164 E), Bekajan (26.384 N & 94.162 E), Panjan (26.495 N & 94.21 E), Jalukonibari (26.645 N & 94.188 E), Rangajan (26.646 N & 94.223 E).

Survey methods

The survey of butterfly species was conducted in all the major seasons, i.e., pre-monsoon, monsoon, post-monsoon, and winter. The survey involved walking through different sites and visual search and photography were conducted on different forest trails, hill streams, village woodlands, grasslands, croplands, and tea gardens between 08.00 and 14.00 hr from May 2014 to June 2016. Some species were also recorded in the early mornings and evenings. The species were photographed with a digital camera whenever possible.

Identification of all encountered butterflies was done to the species level. Though a few species were identified in the field, most of the species were identified from digital images taken with the camera in the field. The identification of butterflies was done by using the identification guides of Watson (1897), Evans (1932), Kehimkar (2008), research papers of Gogoi (2013b), Gogoi (2015), and Singh et al. (2015). No butterflies were caught with net or other equipment for identification.

Results and Observations

During the study period, a total of 158 species of butterflies were identified belonging to six families from the non PAs of Titabar subdivision. Out of the 158 species identified, Nymphalidae showed the maximum species richness, comprising 38.60% with 61 species, followed by Lycaenidae 24.05% with 38, Hesperiidae 18.35% with 29, Pieridae 10.75% with 17, Papilionidae 6.96% with 11, and Riodinidae 1.26% with two species (Table 1, 2).

Twenty species found during the survey are new records for Titabar subdivision as they have not been recorded earlier by either Singh et al. (2015) or Neog (2015) from Gibbon WS. These are *Tirumala septentrionis, Elymnias malelas*, *Lexias pardalis, Pseudergolis wedah, Eurema brigitta, Appias nero, Curetis saronis, Iraota timoleon, Charana mandarinus, Arhopala paraganesa, Arhopala oenea, Caleta roxus, Taraka hamada, Bibasis jaina, Tagiades menaka, Pseudoborbo bevani*, *Halpe porus, Potanthus ganda*, *Telicota colon*, and *Caltoris cormasa.*

The species which have not been recorded by Singh et al. (2017) from eastern Assam found during the survey are *Elymnias malelas, Lexias pardalis, Pseudergolis wedah, Eurema brigitta, Appias nero, Charana mandarinus, Iraota timoleon, Arhopala paraganesa, Arhopala oenea, Caleta roxus, Tagiades menaka*, and *Telicota colon.*

Findings like *Arhopala oenea, Arhopala paraganesa, Appias nero*, and *Telicota colon* are significant as these species have not been recorded in recent times from the PAs of upper Assam by Gogoi (2013b, 2015), Neog (2015), Singh et al. (2015), Baruah & Das (2017), Singh (2017), and Das et al. (2017).

Fourteen species found during the survey are "rare" in occurrence as per Evans (1932). These are *Mycalesis malasarida, Athyma ranga, Neptis namba, Euthalia anosia, Appias albino, Appias libythea, Appias nero, Arhopala silhetensis, Arhopala bazaloises, Arhopala paraganesa, Arhopala oenea, Caltoris cormasa, Doleschallia bisaltide*, and *Iraota timoleon.* Twenty-two species found during the study are protected under various schedules of the Indian Wildlife (Protection) Act, 1972 (Schedule I—1 species, Schedule II—17 species, Schedule IV—4 species); however, results indicate poor habitat of butterflies in non PAs of Titabar as only 11 papilionids were recorded during the survey whereas 19 species of papilionids were recorded by Singh et al. (2015) from Gibbon WS.

Table 1. Overview of taxonomic diversity of butterflies of the Titabar subdivision.

Family	Number of subfamily	Number of genera	Number of species
Nymphalidae	10 (43.47%)	38 (35.18%)	61 (38.60%)
Papilionidae	1 (4.34%)	4 (3.70%)	11 (6.96%)
Pieridae	2 (8.69%)	9 (8.33%)	17 (10.75%)
Lycaenidae	6 (26.08%)	30 (27.77%)	38 (24.05%)
Riodinidae	1 (4.34%)	2 (1.85%)	2 (1.26%)
Hesperiidae	3 (13.04%)	25 (23.14%)	29 (18.35%)
TOTAL: 6	**23 (100%)**	**108 (100%)**	**158 (100%)**

Notes on 'rare' (Evans 1932) occurrence of the species

Plain Bushbrown *Mycalesis malsarida* Butler, 1868 One individual was encountered in a dense woodland in Bebejia on 28 October 2014 in the morning. In India, it is found only in the northeastern region. Except India it is recorded from Bangladesh (Larsen 2004), Bhutan, and Myanmar (Kehimkar 2016). We also encountered one individual from Gibbon WS in September, 2015. The species is protected under Schedule II of IWPA, 1972.

Yellow Sailer *Neptis namba* Moore, 1858: Two individuals were encountered during the study period. One was recorded from Bebejia on 26 August 2014 in the morning and the other from Rangajan on 10 July 2015 in the afternoon. Both the individuals were encountered on a village road.

Blackvein Sergeant *Athyma ranga* Moore, 1858: One individual of this species was encountered from the Sericulture Training Institute campus on 15 March 2015 in the morning. The species ranges from Nepal to northeastern India, northeastern Bangladesh, and Myanmar. It is protected under Schedule II of IWPA, 1972.

Grey Baron *Euthalia anosia* Moore, 1858: One individual was encountered mud puddling on a road surrounded by woodland in Jalukonibari on 28 October 2014. Protected under Schedule II of IWPA, 1972. In India the species is restricted to the northeastern region

Table 2. List of butterflies recorded in Titabar, Jorhat, Assam during the study period (May 2014–June 2016).

Common name	Scientific name	Status (Evans, 1932)	IWPA, 1972
Family Nymphalidae			
Subfamily Danainae			
1. Striped Tiger	*Danaus genutia* Cramer, 1779	VC	
2. Plain Tiger	*Danaus chrysippus* Linnaeus, 1758	VC	
3. Glassy Tiger	*Parantica aglea* Stoll, 1782	C	
4. Common Crow	*Euploea core* Cramer, 1780	C	
5. Dark Blue Tiger	*Tirumala septentrionis* Butler, 1874	NR	
6. Striped Blue Crow	*Euploea mulciber* Cramer, 1777	C	Schedule IV
7. Magpie Crow	*Euploea radamanthus* Fabricius, 1793	NR	
Subfamily Morphinae			
8. Common Duffer	*Discophora sondaica* Boisduval, 1836	C	
9. Common Faun	*Faunis canens* Huebner, 1826	C	
10. Jungle Glory	*Thaumantis diores* Doubleday, 1845	NR	
Subfamily Charaxinae			
11. Tawny Rajah	*Charaxes bernardus* Fabricius, 1793	C	
12. Common Nawab	*Polyura athamas* Drury, 1773	C	
Subfamily Satyrinae			
13. Angled Red Forester	*Lethe chandica* Moore, 1858	NR	
14. Bamboo Treebrown	*Lethe europa* Fabricius, 1775	NR	
15. Common Fivering	*Ypthima baldus* Fabricius, 1775	VC	
16. Common Bushbrown	*Mycalesis perseus* Fabricius, 1775	VC	
17. Plain Bushbrown	*Mycalesis malsarida* Butler, 1868	R	Schedule II
18. Whitebar Bushbrown	*Mycalesis anaxias* Hewitson, 1862	NR	Schedule II
19. Dark Brand Bushbrown	*Mycalesis mineus* Linnaeus, 1758	VC	
20. Common Evening Brown	*Melanitis leda* Linnaeus, 1758	VC	
21. Dark Evening Brown	*Melanitis phedima* Cramer, 1780	C	
22. Common Palmfly	*Elymnias hypermnestra* Linnaeus, 1763	C	
23. Spotted Palmfly	*Elymnias malelas* Hewitson, 1863	NR	
24. Tiger Palmfly	*Elymnias nesae* Linnaeus, 1764	NR	
Subfamily Heliconinae			
25. Common Leopard	*Phalanta phalantha* Drury, 1773	C	
26. Cruiser	*Vindula erota* Fabricius, 1793	NR	
27. Large Yeoman	*Cirrochroa aoris* Doubleday, 1847	NR	
28. Vagrant	*Vagrans egista* Cramer, 1780	NR	
Subfamily Acraeinae			
29. Leopard Lacewing	*Cethosia cyane* Drury, 1773	NR	
30. Tawny Coster	*Acraea violae* Fabricius, 1793	C	
Subfamily Limenitinae			
31. Common Sailer	*Neptis hylas* Linnaeus, 1758	VC	
32. Yellow Sailer	*Neptis namba* Tytler, 1915	R	
33. Grey Count	*Tanaecia lepidea* Butler, 1868	NR	Schedule II
34. Commander	*Moduza procris* Cramer, 1777	NR	
35. Knight	*Lebadea martha* Fabricius, 1787	NR	
36. Common Sergeant	*Athyma perius* Linnaeus, 1758	C	

Common name	Scientific name	Status (Evans, 1932)	IWPA, 1972
37. Blackvein Sergeant	*Athyma ranga* Moore, 1858	R	Schedule II
38. Staff Sergeant	*Athyma selenophora* Kollar, 1844	NR	
39. Colour Sergeant	*Athyma nefte* Cramer, 1780	NR	
40. Common Lascar	*Pantoporia hordonia* Stoll, 1790	C	
41. Archduke	*Lexias pardalis* Moore, 1878	NR	
42. Dark Archduke	*Lexias dirtea* Fabricius, 1793	NR	Schedule II
43. Gaudy Baron	*Euthalia lubentina* Cramer, 1777	C	Schedule IV
44. Powdered Baron	*Euthalia monina* Fabricius, 1787	NR	
45. Common Baron	*Euthalia aconthea* Cramer, 1777	NR	Schedule II
46. Grey Baron	*Euthalia anosia* Moore, 1858	R	Schedule II
47. Common Earl	*Tanaecia julii* Lesson, 1837	C	
Subfamily Cyrestinae			
48. Common Map	*Cyrestis thyodamas* Boisduval, 1846	C	
49. Common Maplet	*Chersonesia risa* Doubleday, 1848	NR	
50. Tabby	*Pseudergolis wedah* Kollar, 1848	C	
Subfamily Biblidinae			
51. Common Castor	*Ariadne merione* Cramer, 1777	C	
52. Angled Castor	*Ariadne ariadne* Linnaeus, 1763	C	
Subfamily Nymphalinae			
53. Peacock Pansy	*Junonia almana* Linnaeus, 1758	C	
54. Yellow Pansy	*Junonia hierta* Fabricius, 1798	C	
55. Grey Pansy	*Junonia atlites* Linnaeus, 1763	NR	
56. Lemon Pansy	*Junonia lemonias* Linnaeus, 1758	C	
57. Chocolate Pansy	*Junonia iphita* Cramer, 1779	C	
58. Great Eggfly	*Hypolimnas bolina* Linnaeus, 1758	C	
59. Orange Oakleaf	*Kallima inachus* Boisduval, 1846	NR	
60. Common Jester	*Symbrenthia lilaea* Moore, 1875	C	
61. Autumn Leaf	*Doleschallia bisaltide* Cramer, 1777	R	
Family Papilionidae			
Subfamily Papilioninae			
62. Common Jay	*Graphium doson* C.&R. Felder, 1864	C	
63. Tailed Jay	*Graphium agamemnon* Linnaeus, 1758	C	
64. Common Mormon	*Papilio polytes* Linnaeus, 1758	VC	
65. Great Mormon	*Papilio memnon* Linnaeus, 1758	C	
66. Lime Butterfly	*Papilio demoleus* Linnaeus, 1758	VC	
67. Common Bluebottle	*Graphium sarpedon* Linnaeus, 1758	C	Schedule II
68. Common Mime	*Papilio clytia* Linnaeus, 1758	NR	
69. Yellow Helen	*Papilio nephelus* Boisduval, 1836	NR	Schedule II
70. Red Helen	*Papilio helenus* Linneaus, 1758	C	
71. Common Raven	*Papilio castor* Westwood, 1842	NR	
72. Golden Birdwing	*Troides aeacus* C.&R. Felder, 1860	NR	
Family Pieridae			
Subfamily Coliadinae			
73. Small Grass Yellow	*Eurema brigitta* Stoll, 1780	VC	
74. Common Grass Yellow	*Eurema hecabe* Linnaeus, 1758	VC	

Common name	Scientific name	Status (Evans, 1932)	IWPA, 1972
75. Three Spot Grass Yellow	*Eurema blanda* Boisduval, 1836	C	
76. Tree yellow	*Gandaca harina* Horsfield, 1829	NR	
77. Common Emigrant	*Catopsilia pomona* Fabricius, 1775	C	
78. Mottled Emigrant	*Catopsilia pyranthe* Linnaeus, 1758	C	
Subfamily Pierinae			
79. Indian Cabbage White	*Pieris canidia* Linnaeus, 1768	VC	
80. Green Veined White	*Pieris melete* Menetries, 1857	NR	
81. Common Albatross	*Appias albina* Boisduval, 1836	R	Schedule II
82. Chocolate Albatross	*Appias lyncida* Cramer, 1777	C	
83. Striped Albatross	*Appias libythea* Fabricius, 1775	R	Schedule IV
84. Orange Albatross	*Appias nero* Fabricius, 1793	R	Schedule IV
85. Red-Base Jezebel	*Delias pasithoe* Linnaeus, 1767	NR	
86. Red-Spot Jezebel	*Delias descombesi* Boisduval, 1836	NR	
87. Lesser Gull	*Cepora nadina* Lucas, 1852	NR	
88. Great Orange Tip	*Hebomoia glaucippe* Linnaeus, 1758	C	
89. Psyche	*Leptosia nina* Fabricius, 1793	C	
Family Lycaenidae			
Subfamily Poritiinae			
90. Common Gem	*Poritia hewitsoni* Moore, 1866	NR	Schedule II
Subfamily Miletinae			
91. Apefly	*Spalgis epius* Westwood, 1852	NR	
Subfamily Curetinae			
92. Burmese Sunbeam	*Curetis saronis* Moore, 1877	NR	
Subfamily Lycaeninae			
93. Purple Saphire	*Heliophorus epicles* Godart, 1824	C	
Subfamily Theclinae			
94. Fluffy Tit	*Zeltus amasa* Hewitson, 1865	NR	
95. Common Tit	*Hypolycaena erylus* Godart, 1824	C	
96. Orchid Tit	*Chliaria othona* Hewitson, 1865	NR	Schedule I
97. Yamfly	*Loxura atymnus* Stoll, 1780	C	
98. Common Imperial	*Cheritra freja* Fabricius, 1793	NR	
99. Common Acacia Blue	*Surendra quercetorum* Moore, 1858	C	
100. Common Onyx	*Horaga onyx* Moore, 1858	NR	Schedule II
101. Copper Flash	*Rapala pheretima* Hewitson, 1863	NR	
102. Sylhet Oakblue	*Arhopala silhetensis* Hewitson, 1862	R	Schedule II
103. Tamil Oakblue	*Arhopala bazaloides* Hewitson, 1878	R	Schedule II
104. Yellow Disc Tailless Oakblue	*Arhopala perimuta* Moore, 1858	NR	
105. Silverstreak Blue	*Iraota timoleon* Stoll, 1790	R	
106. Mandarin Blue	*Charana mandarinus* Hewitson, 1863	NR	
107. Dusky Bush Blue	*Arhopala paraganesa* de Niceville, 1882	R	Schedule II
108. Centaur Oakblue	*Arhopala centaurus* Fabricius, 1775	NR	
109. Hewitson's Dull Oakblue	*Arhopala oenea* Hewitson, 1869	R	Schedule II
Subfamily Polyommatinae			
110. Common Hedge Blue	*Acytolepis puspa* Horsfield, 1828	C	

Common name	Scientific name	Status (Evans, 1932)	IWPA, 1972
111. Plain Hedge Blue	*Celastrina lavendularis* Moore, 1877	NR	
112. Malayan	*Megisba malaya* Horsfield, 1828	NR	
113. Common Cerulean	*Jamides celeno* Cramer, 1775	C	
114. Dark Cerulean	*Jamides bochus* Stoll, 1782	C	
115. Pale Grass Blue	*Pseudozizeeria maha* Kollar, 1844	VC	
116. Lesser Grass Blue	*Zizina otis* Fabricius, 1787	C	
117. Lime Blue	*Chilades lajus* Stoll, 1780	C	
118. Tailless Lineblue	*Prosotas dubiosa* Semper, 1879	C	
119. Common Lineblue	*Prosotas nora* C.Felder, 1860	C	
120. Common Ciliate Blue	*Anthene emolus* Godart, 1824	C	
121. Zebra Blue	*Leptotes plinius* Fabricius, 1793	C	
122. Pea Blue	*Lampides boeticus* Linnaeus, 1767	C	Schedule II
123. Common Pierrot	*Castalius rosimon* Fabricius, 1775	C	
124. Elbowed Pierrot	*Caleta elna* Hewitson, 1876	NR	
125. Straight Pierrot	*Caleta roxus* Godart, 1824	NR	
126. Forest Pierrot	*Taraka hamada* Druce, 1875	NR	
127. Quaker	*Nepoithecops zalmora* Butler, 1870	C	
Family Riodinidae			
Subfamily Riodininae			
128. Punchinello	*Zemeros flegyas* Cramer, 1780	VC	
129. Tailed Judy	*Abisara neophron* Hewiton, 1861	NR	
Family Hesperiidae			
Subfamily Coeliadinae			
130. Common Awl	*Hasora badra* Moore, 1858	NR	
131. Common Banded Awl	*Hasora chromus* Cramer, 1780	NR	
132. Orange Awlet	*Bibasis jaina* Moore, 1866	NR	
Subfamily Pyrginae			
133. Common Small Flat	*Sarangesa dasahara* Moore, 1866	C	
134. Fulvous Pied Flat	*Pseudocoladenia dan* Fabricius, 1787	C	
135. Indian Skipper	*Spialia galba* Fabricius, 1793	C	
136. Common Spotted Flat	*Celaenorrhinus leucocera* Kollar, 1844	C	
137. Suffused Snow Flat	*Tagiades japetus* Stoll, 1781	NR	
138. Spotted Snow Flat	*Tagiades menaka* Moore, 1866	C	
139. Common Snow Flat	*Tagiades parra* Fruhstorfer, 1910	C	
Subfamily Hesperiinae			
140. Tiger Hopper	*Ochus subvittatus* Moore, 1878	C	
141. Common Redeye	*Matapa aria* Moore, 1866	C	
142. Giant Redeye	*Gangara thyrsis* Fabricius, 1775	NR	
143. Grass Demon	*Udaspes folus* Cramer, 1775	C	
144. Chocolate Demon	*Ancistroides nigrita* Latreille, 1824	C	
145. Restricted Demon	*Notocrypta curvifascia* C.&R. Felder, 1862	C	
146. Bevan's Swift	*Pseudoborbo bevani* Moore, 1878	NR	
147. Small Branded Swift	*Pelopidas mathias* Fabricius, 1798	C	
148. Moore's Ace	*Halpe porus* Mabille, 1877	NR	

Common name	Scientific name	Status (Evans, 1932)	IWPA, 1972
149. Pigmy Scrub Hopper	*Aeromachus pygmaeus* Fabricius, 1775	NR	
150. Tufted Swift	*Caltoris plebeian* de Niceville, 1887	NR	
151. Grass Bob	*Suada swerga* de Niceville, 1884	NR	
152. Sumatran Dart	*Potanthus ganda* Fruhstorfer, 1911	_	
153. Common Dartlet	*Oriens gola* Moore, 1877	NR	
154. Common Palm Dart	*Telicota colon* Linnaeus, 1763	NR	
155. Chestnut Bob	*Iambrix salsala* Moore, 1866	C	
156. Coon	*Psolos fuligo* Mabille, 1876	C	
157. Bush Hopper	*Ampittia dioscorides* Fabricius, 1793	C	
158. Full Stop Swift	*Caltoris cormasa* Hewitson, 1876	R	

VC—Very Common | C—Common | NR—Not Rare | R—Rare | IWPA—Indian Wildlife (Protection) Act, 1972.

only.

Orange Albatross *Appias nero* Fabricius, 1793: One Individual was encountered on the bank of Kasojan sub-tributary in Kasojan Village on 10 August 2014 in the afternoon. The right forewing of the individual recorded was worn off (Image 66). The species is found in northeastern India and Myanmar. The species was recorded from Lumding, upper Assam by Parsons & Cantile (1948) and protected under Schedule IV of IWPA, 1972.

Common Albatross *Appias albina* Boisduval, 1836: One individual was encountered in a muddy patch on the boundary between Nanda Nath Saikia College and Kachari Gaon on 11 June 2014 in the morning. The species is protected under Schedule II of IWPA, 1972.

Striped Albatross *Appias libythea* Fabricius, 1775: Two individuals were encountered during the study period. One was from a roadside in Bebejia feeding on the nectar of *Lantena camera* on 09 July 2014 and the other individual was encountered in the flower garden of Nanda Nath Saikia College on 12 August 2014. This species is protected under Schedule IV of IWPA, 1972.

Sylhet Oakblue *Arhopala silhetensis* Hewitson, 1862: Two individuals were encountered on 14 March 2015 and 09 July 2015 in a forest in Rangajan. This species is distributed in the northeastern region of India, Bangladesh, and Myanmar. It is protected under Schedule II of IWPA, 1972.

Tamil Oakblue *Arhopala bazaloides* Hewitson, 1878: Two individuals were encountered during the study period. One was encountered from Rangajan on 15 March 2015 and the other from Bebejia on 02 August 2015. Both the individuals were encountered in a woodland in the morning. The species is protected under Schedule II of IWPA, 1972.

Centaur Oakblue *Arhopala centaurus* Fabricius, 1775: Two individuals were encountered during the survey, one from Bebejia on 12 June 2015 and the other from Kachari Gaon on 30 May 2016. Both the individuals were encountered from village woodlands. In India this species is found in Uttarakhand, Western Ghats, north-east, and West Bengal. The status of occurrence of this species is not rare (Evans 1932).

Hewitson's Dull Oakblue *Arhopala oenea* Hewitson, 1869: The species was encountered four times in a woodland in Bebejia Gaon on 30 May, 02, 09, & 18 June 2016. One individual was found laying eggs on *Castanopsis indica* plant and most probably it is the first record of its egg laying on this plant. The species is distributed from Garhwal to northeastern India (Khasi Hills and Nagaland), northeastern Bangladesh, and Myanmar. It is protected under Schedule II of IPWA, 1972.

Dusky Bushblue *Arhopala paraganesa* de Niceville, 1882: Only one individual was encountered in a woodland in Bebejia on 18 June 2016 in the morning. The species is restricted to the northeastern region in India. It's protected under Schedule II of IWPA, 1972. Except for this species and *A. oenea,* we observed all other *Arhopala* spp. recorded during the study period in Gibbon WS.

Autumn Leaf *Doleschallia bisaltide* Cramer, 1777: This species was encountered two times during the study period. One individual from Bebejia on 14 July 2015 and the other from Jalukonibari on 13 April 2016. Both the individuals were encountered near a bamboo patch puddling on stone and sand.

Full Stop Swift *Caltoris cormasa* Hewitson, 1876: One individual of this species was encountered in Bebejia on 05 April 2016 puddling on bird droppings in a small open area between a bamboo patch and a woodland. It is restricted to the northeastern region of India.

Silverstreak Blue *Iraota timoleon* Stoll, 1790: One individual was encountered sitting on a dry leaf of *Dioscorea* sp. in a vegetable garden surrounded by a woodland in Bebejia on 25 February 2015.

Tabby *Pseudergolis wedah* Kollar, 1848: Though a common species as per Evans (1932), it was encountered only once in Panjan on 24 December 2014, found puddling on stones near a hill stream. The species is found in the north-east, Uttarakhand, and Himachal in India.

Forest Pierrot *Taraka hamada* Druce, 1875: One individual was encountered in a tea garden surrounded by village woodland in Mejenga Grant on 05 January 2015. The species is distributed from eastern Nepal to northeastern India, southeastern Bangladesh, and Myanmar. It is not rare as per Evans (1932).

Straight Pierrot *Caleta roxus* Godart, 1824: One individual was encountered near a hill stream in Bekajan on 18 January 2015 in the morning. The surrounding area of the spot where the individual was encountered was heavily disturbed by illegal coal mining and saw mills. The species is not rare as per Evans (1932).

Sumatran Dart *Potanthus ganda* Fruhstorfer, 1911: One individual of this species was encountered in a woodland in Rangajan on 15 March 2015 sitting on a fern in the morning. The species is considered extralimital in Evans (1932). It was identified on the basis of subapical spot. The subapical spot in space 8 is slightly smaller than that of the space 7 and 6 (Corbet et al. 1992; Ek-Amnuay 2012). It is distributed in the northeastern region in India and in Myanmar, Thailand, Laos, Vietnam, Malaysia, Sumatra and Java.

Discussion

Titabar subdivision is rich in its biodiversity due to the edge effect of both plain and hilly areas and being located at the foothills of Nagaland. Gibbon WS is already well known for its floral and faunal diversity including butterflies. Singh (2015) recorded 211 species of butterflies from the sanctuary. Our study added 20 more species of butterflies from the non PAs to the total butterfly diversity of Titabar subdivision. The village woodlands with rich bamboo plantations serve as ideal habitat for the majority of animals, including butterflies. Though during the present survey a total of 158 species were recorded in the non PAs of Titabar subdivision, the final number of butterfly species occurring in the non PAs is more likely to be between 200–250 as some places of Titabar are still unexplored.

The significance of the area from the lepidopteran viewpoint lies in the fact that it harbors one species belonging to Schedule I, 17 species to Schedule II, and four species to Schedule IV of IWPA, 1972. Fourteen rare species, according to Evans (1932) were also recorded here. Again, many species listed as common by Evans (1932) were actually found to be uncommon or rare in this survey. This is probably because of different anthropogenic pressures. The major threat to the butterfly population in this area is the conversion of village woodlands to small and micro tea gardens. Pesticides, herbicides, and other chemicals used in these tea gardens may directly affect the number of butterflies by reducing their habitats. A number of illegal coal mining stations and saw mills in the Titabar-Nagaland border pose a big threat to the biodiversity, as well as the butterfly diversity of this area.

Still more work on the butterflies of this area regarding the host plants, habitat, and ecology are required. The results of our study form a baseline for future work on the diversity and conservation of butterflies in Titabar subdivision.

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Image 1. *Cethosia cyane*


Image 2. *Mycalesis anaxias*


Image 3. *Euthalia lubentina*


Image 4. *Euthalia monina*


Image 5. *Athyma nefte*


Image 6. *Moduza procris*


Image 7. *Chersonesia risa*


Image 8. *Danaus chrysippus*


Image 9. *Discophora sondaica*


Image 10. *Lebadea martha*


Image 11. *Doleschallia bisaltide*


Image 12. *Tanaecia julii*


Image 13. *Phalanta phalantha*


Image 14. *Neptis hylas*


Image 15. *Vindula erota*


Image 16. *Tirumala septentrionis*


Image 17. *Parantica aglea*


Image 18. *Mycalesis mineus*


Image 19. *Acraea violae*


Image 20. *Cirrochroa aoris*


Image 21. *Kallima inachus*


Image 22. *Pseudergolis wedah*


Image 23. *Neptis ananta*


Image 24. *Euthalia anosia*


Image 25. *Mycalesis malasarida*


Image 26. *Cyrestis thyodamas*


Image 27. *Elymnias malelas*


Image 28. *Caleta elna*


Image 29. *Castalius rosimon*


Image 30. *Caleta roxus*


Image 31. *Taraka Hamada*


Image 32. *Lampides boeticus*


Image 33. *Spalgis epius*


Image 34. *Curetis thetis*


35. *Acytolepis puspa*l


Image 36. *Prosotas dubiosa*


Image 37. *Charana mandarinus*


Image 38. *Zeltus amasa*


Image 39. *Loxura atymnus*


Image 40. *Iraota timoleon*


Image 41. *Chliaria othona*


Image 42. *Rapala pheretima*


Image 43. *Arhopala silhetensis*


Image 44. *Arhopala perimuta*


Image 45. *Arhopala centaurus*


Image 46. *Arhopala oenea*


Image 47. *Arhopala paraganesa*


Image 48. *Heliophorus epicles*

Image 49. *Cheritra freja*

Image 50. *Surendra quercetorum*UP

Image 51. *S. quercetorum* UN

Image 52. *Horaga onyx*

Image 53. *Leptotes plinius* UN

Image 54. *L. plinius* UP

Image 55. *Abisara neophron*

Image 56. *Zemeros flegyas*

Image 57. *Graphium doson*

Image 58. *Graphium agamemnon*

Image 59. *Papilio helenus*

Image 60. *Papilio memnon*

Image 61. *Papilio nephelus*

Image 62. *Troides aeacus*

Image 63. *Eurema brigitta*

Image 64. *Eurema blanda*

Image 65. *Gandaca harina*

Image 66. *Appias nero*

Image 67. *Appias libythea*

Image 68. *Appias lyncida*

Image 69. *Cepora nadina*

Image 70. *Pieris melete*

Image 71. *Hebomoia glaucippe*

Image 72. *Delias pasithoe*


Image 73. *Delias descombesi*


Image 74. *Catopsilia Pomona*


Image 75. *Hasora badra*


Image 76. *Hasora chromus*


Image 77. *Halpe porus*


Image 78. *Telicota colon*


Image 79. *Potanthus ganda*


Image 80. *Oriens goloides*


Image 81. *Tagiades gana*


Image 82. *Tagiades japetus*


Image 83. *Tagiades menaka*


Image 84. *Suada swerga*


Image 85. *Iambrix salsala*


Image 86. *Notocrypta curvifascia*


Image 87. *Ochus subvittatus*


Image 88. *Ampittia dioscorides*


Image 89. *Gangara thyrsis*


Image 90. *Aeromachus pygmaeus*


Image 91. *Udaspes folus*


Image 92. *Ancistroides nigrita*

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SHORT COMMUNICATION

Three new distribution records of Conidae (Gastropoda: Neogastropoda: Conoidea) from the Andaman Islands, India

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Abstract: This study documents new distribution records of three species of the family Conidae in the Andaman Islands: *Conus augur* [Lightfoot], 1786, *C. sponsalis* Hwass in Bruguière, 1792, and *C. varius* Linnaeus, 1758. The latter two records are first reports for India.

Keywords: Andaman Islands, cone snails, *Conus augur, Conus sponsalis, Conus varius,* new records.

Abbreviations: BNHS—Bombay Natural History Society, Hornbill House, Mumbai, India | CBW—*Conus* Biodiversity Website | ZSI—Zoological Survey of India, Calcutta, India | ZSI/ANRC—Zoological Survey of India/Andaman & Nicobar Regional Centre, Port Blair, India | LSL—Linnaean Collection, Linnaean Society, London, United Kingdom | NHMUK—The Natural History Museum, London, United Kingdom | MNHN—Muséum national d'Histoire naturelle, Paris, France | SL—Shell length | SW—Shell width.

Conidae is a large family of marine gastropod molluscs with more than 800 extant species worldwide (MolluscaBase eds. 2020). They occur throughout the tropical and subtropical oceans and are most diverse in the Indo-West Pacific region (Filmer 2001). The members of Conidae contribute substantially to high molluscan diversity, especially in the inter-tropical zone and are important ecologically, because a maximum of 36 species co-occur on a single reef platform (Kohn 2001); evolutionarily, since its diversification rate is high among gastropods (Stanley 2007); and medically, as the venom produced by these snails promise new drug discoveries (Puillandre et al. 2011). In addition, each species count (biodiversity) adds knowledge of 100–200 venom peptides (chemical diversity) with potential applications in human health (Franklin et al. 2009).

In India, Kohn (1978) reported 48 species and then increased to 77 species with 29 new records (Kohn 2001). Later, Franklin et al. (2009) recorded 60 species from Tamil Nadu (south-east) coast of India that increased the number of Indian Conidae species from 77 to 81. Towards the west sea, 78 species are so far known from the Lakshadweep Islands (Smith 1906; Hornell 1921; Nagabhushanam & Rao 1972; Appukuttan et al. 1989; Rao & Rao 1991; Apte 1998; Rao 2003; Ravinesh & Bijukumar 2015). Of the 78 species, Ravinesh et al. (2018) recently confirmed the presence of 48 species from the seas around 10 inhabited Islands of Lakshadweep Islands.

Similarly, in the Andaman & Nicobar Islands, Smith (1878) followed by Melvill & Sykes (1898) and Preston (1908) reported 10 species of Conidae. Rao

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(1980) studied this group during three oceanic surveys conducted between 1970 and 1972 and that includes 51 species compiled after going through the named and unnamed collections of Conidae present in the Zoological Survey of India and also from the literature. Of this, 49 species were newly recorded from the Andaman & Nicobar Islands. Subsequently, Rao & Dey (2000) and Rao (2003) updated the number of species to 53. Franklin et al. (2013) added the records of four species to the Conidae of the Andaman & Nicobar Islands.

This study documents new distribution records of three species (*Conus augur* [Lightfoot], 1786, *C. sponsalis* Hwass in Bruguière, 1792, and *C. varius* Linnaeus, 1758) of the family Conidae from the Andaman Islands.

Materials and methods

Specimens were collected from the shoreline to a depth of approximately five meters from two sites of South Andaman District of Andaman & Nicobar Islands by hand picking and snorkeling during regular field visits. Details of shell size, date of collection, voucher numbers, habitats, localities (coordinates) of collection sites, type & material, and type locality information are presented in materials examined section of each species account. Documented distributions of species globally and in India and shell description are given. Morphological measurements, viz., shell length (SL) and shell width (SW) are recorded to the nearest millimeter. One or more specimens of each species were deposited in institutional repositories as indicated and voucher numbers are provided. Color photographs of the shells deposited in the institutional repositories are provided.

Results

Systematic account

Order: Neogastropoda Wenz, 1938
Superfamily: Conoidea Fleming, 1822
Family: Conidae Fleming, 1822
Genus: *Conus* Linnaeus, 1758

Conus augur [Lightfoot], 1786 (Common name: Augur Snail) (Images 1, 2)

Type material: Specimen illustrated by Knorr (1772, pl. 13, fig. 6); size: 65.5 x 35 mm; selected as lectotype by Kohn (1964a).

Type locality: Unknown, Coomans et al. (1981) designated as "Island of Ceylon" (Sri Lanka).

IUCN Red List status: Least Concern.

Materials examined: BNHS-GASTRO-2074 (Images 1 and 2), 8.ii.2020, 3 (1 living, 2 shells) specimens, SL 50×28 SW mm, intertidal, Burmanallah (11.574N, 92.737E), South Andaman, Andaman & Nicobar Islands, coll. J.B. Franklin.

Distribution: *Conus augur* occur in shallow waters and is widely distributed across the Indian Ocean; from the southern coast of Natal along eastern Africa to western Thailand, probably Moluccas (Röckel et al. 1995; Franklin et al. 2009; CBW 2020). Coomans et al. (1981) reported its distribution from eastern Africa to western Indonesia.

Documented distributions are from Sri Lanka (Kohn 1960; from the records of previous authors, Hanley 1859; Standen & leicester 1906), Tanzania (Spry 1961), Aldabra Atoll (Taylor 1973), Thailand (da Motta & Lenavat 1979), Zanzibar, Mozambique, Tanzania (Dar es Salaam), Kenya, Madagascar (Tulear), the Andaman Sea (western Thailand) (Coomans et al. 1981), Mayotte (Deuss et al. 2013), and southern Madagascar (Monnier et al. 2018).

In India, previous reports are from Vellapatti, Gulf of Mannar (Kohn 2001; Hylleberg & Kilburn 2002). Yerwadi, Keelakarai, and Vembar (Franklin et al. 2009) of Gulf of Mannar. Venkitesan et al. (2019) reported its occurrence from Tamil Nadu and Karnataka based on the materials present in National Zoological Collections of ZSI without precise locality data or catalog numbers.

Description: Shell moderately large (55–80 mm). Body whorl broadly conical; sides nearly straight. Shoulder sub-angulate, weakly tuberculate. Spire of moderate height (0.12–0.23 mm); outline convex. Body whorl with weak spiral ribs at base in small specimens, ribs granulose in moderately large specimens.

Ground colour white. Body whorl with numerous spiral rows of fine reddish-brown dots from base to shoulder, with two interrupted reddish-brown transverse bands on either side of the centre. The posterior band extends irregularly towards the shoulder. Aperture white, outer lip thick.

Habitat: In the Andaman Islands, this species inhabits sand substrates and lives beneath rocks on intertidal benches. Röckel et al. (1995) and Franklin et al. (2009) have reported this species from similar habitats; the latter collected specimens from sand at depths of 8–15 m in the Gulf of Mannar. In Mayotte, specimens were observed at 0–5 m in the intertidal region on sand, mud and sea grass associated habitats (Deuss et al. 2013). In Madagascar, the specimens were collected from intertidal zones and depths up to 18m (Monnier et al. 2018).

Habit: No observation on feeding has been reported to date and thus necessitates further study. Nevertheless, the teeth morphology supports this species as a worm eater (Franklin et al. 2007).

Remarks: Uncommon in the Andaman Islands. Shell pattern similar between specimens of mainland India and the Andaman Islands. Coomans et al. (1981) reported the distribution of this species (from the collections of Saesen, Wils) from eastern Africa to western Thailand and Indonesia that includes Andaman Sea. Yet, there have been no reports on the occurrence of *C. augur* from the Andaman & Nicobar Islands. This is the first report from the Andaman Islands.

***Conus sponsalis* Hwass in Bruguière, 1792 (Common name: Sponsal Cone) (Images 3–7)**

Type material: Specimen illustrated by Bruguière (1792: pl. 322, fig. 1), selected as lectotype by Kohn (1968); size: 29 x 20 mm.

Type locality: "Iles Saint-George" [said by Hwass to be in the Pacific Ocean; present name of the island unknown]. Nevertheless, Lee & Park (2014) mentioned as 'Indo-West Pacific; Rowley Shoals, New South Wales'.

IUCN Red List Status: Least Concern.

Materials examined: BNHS-GASTRO-2075 (wet preservation), 8.ii.2020, 4 (3 living, 1 shell) specimens, size range—SL 17×10 SW (Images 3, 4); SL 15×10 SW to SL 20×15 SW mm; (SL 20×15 SW mm; Images 5, 6), Burmanallah (11.523N, 92.740E), South Andaman, Andaman & Nicobar Islands, coll. J.B. Franklin.

Distribution: *Conus sponsalis* occurs throughout the Indo-Pacific (Kohn 1968).

Documented distributions are from Dar es Salaam, Tanzania (Spry 1961), Hawaii (Kohn 1959a,b, 1966; Kohn & Weaver 1962), Maldives (Kohn & Robertson 1966), Chaos Archipelago (Liénard 1877; Kohn & Robertson 1966), Eilat, Gulf of Aquba & Sinai Peninsula (Kohn 1964b), Aldabra Atoll (Taylor 1973), Thailand (da Motta & Lenavat 1979), Mascarene Basin (Drivas & Jay 1987), Rottnest Island, western Australia (Kohn 1993), New Caledonia (Héros et al. 2007), Moreton Bay, Queensland (Healy et al. 2007), Philippines (Massilia 2008), Australia, Papua New Guinea, Philippines, China, Japan, & Korea (Jeju-do) (Lee & Park 2014), Christmas Island & the Cocos (Keeling) Islands (Abbott 1950; Maes 1967; Wells et al. 1990; Wells 1994; Wells & Slack-Smith 2000; Tan & Low 2014), American Samoa, Fiji, French Polynesia, Guam, Palau, Papua New Guinea, & Reunion (Duda et al. 2008), Mayotte (Deuss et al. 2013), Mauritius (de Billot & Touitou 2014), Seychelles Island (Kohn 2015), and Mozambique, Papua New Guinea, & southern Madagascar (Monnier et al. 2018). Pleistocene fossils are also known from the Oahu and Molokai (Kohn 1959a).

This is the first report of *C. sponsalis* for India from the Andaman Islands.

Description: Shell small, thick and solid. Body whorl conical; outline convex at adapical half and straight below. Body whorl with fine granulose ribs; pronounced basally. Shoulder coronated with small tubercles. Spire low, eroded; inner whorls looks like coronated, outline convex. Spire low, outline convex. Aperture narrow.

Ground colour white with blue shade. Body whorl with brown reduced axial flames arranged in rows; above and below center. Basal part of columella purplish-blue. Aperture ivory in color, interior purplish-blue; inner lip brown spot on white, outer lip yellowish to white. Periostracum yellow, thin, translucent, and smooth.

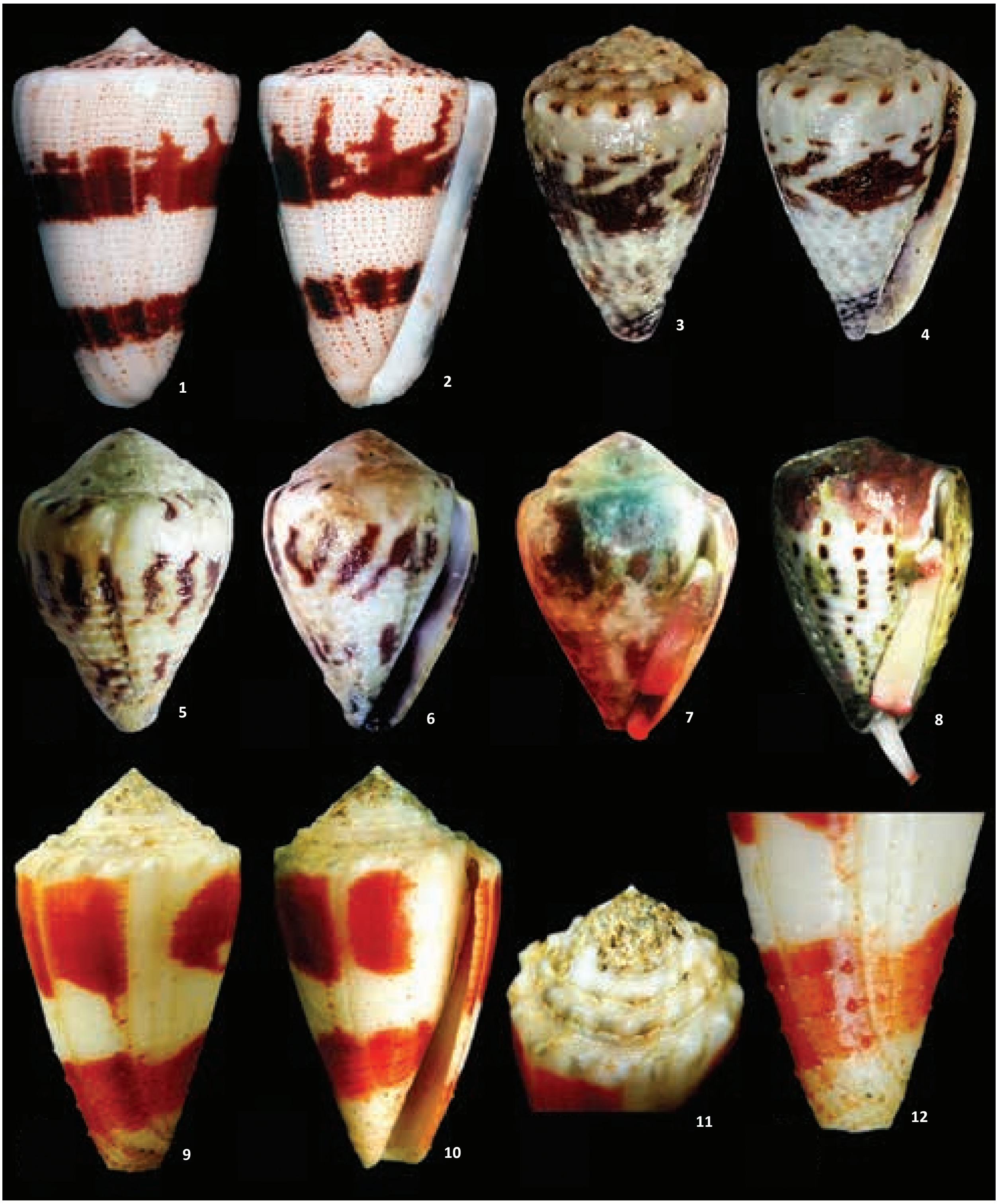
Living animal: Foot narrow and sole of foot pink; dorsum pale pink. Tentacles red, siphon pink (Fig. 7).

Habitat: In the Andaman Islands; collected beneath rock on intertidal bench.

Elsewhere, this species is common on intertidal benches; some specimens dredged in 100m depths (CBW 2020). Usually found in protected and exposed sites; on beach rock and limestone benches, in sand, sand-filled depressions, coral rubble, & rock crevices (Röckel et al. 1995), and on rocks & pebbles (Lee & Park 2014). Sub tidally, on reef flats, lagoon pinnacles and deeper reef habitats up to 18m depth, inhabiting sand or limestone with algal turf, coral rubble, and crevices of dead coral (Röckel et al. 1995; Lee & Park 2014). *Conus sponsalis* is common on the intertidal and shallow waters in the lagoon, reefs, and shore reefs in Mayotte (Deuss et al. 2013). This species is very common in shallow waters of lagoons in Mauritius (Billot & Touitou 2014). In Seychelles on main and coralline island reefs on thin layer of sand on limestone bench (Kohn 2015). Monnier et al. (2018) reported it in 0–14 m depths from Mozambique, Papua New Guinea, and southern Madagascar.

Habit: *Conus sponsalis* feeds exclusively on errant polychaetes (Ragworms) (Kohn 1959b; Kohn & Nybakken 1975; Reichelt & Kohn 1985; Kohn & Almasi 1993) nereids, and eunicids (Duda et al. 2001).

Remarks: Uncommon in Andaman Islands. *Conus sponsalis* resembles *C. parvatus* (Walls, 1979) in size, but differs in shell colour pattern; the former has axial flames while the latter has a distinct small dotted pattern in the body whorl. Further, the shell shape in *C. parvatus* is almost conical with a flat spire (Fig. 8) and the outline of the body whorl is almost straight. However, the outline of the body whorl is convex in *C. sponsalis*. The anterior and posterior tips of the foot and siphon in *C. parvatus* is tinged with pink, sole ivory (Fig. 8); in *C. sponsalis* the



Images 1–12. 1 & 2—*Conus augur* [Lightfoot], 1786 (BNHS-GASTRO-2074; 45×24 mm) | 3 & 4—*Conus sponsalis* Hwass in Bruguière, 1792 (17×10 mm) | 5 & 6—*Conus sponsalis* Hwass in Bruguière, 1792 (BNHS-GASTRO-2075; 20×15 mm) | 7—*Conus sponsalis* Hwass in Bruguière, 1792 (18 ×15 mm); shows foot sole and siphon colour | 8—*Conus parvatus* (20 ×14 mm); shows foot sole and siphon colour | 9 & 10—*Conus varius* Linnaeus, 1758 (ZSI/ANRC-11274; 48×25 mm) | 11—*Conus varius* Linnaeus, 1758; shows shell granulose in abapical third | 12—*Conus varius* Linnaeus, 1758; shows tuberculate shoulder & spire. © J.B. Franklin

entire sole pink or red (Fig. 7). Similarly, *Conus musicus* Hwass in Bruguière, 1792 (= *Conus ceylanensis* Hwass in Bruguière, 1792) resembles *C. sponsalis* in the shell characters. But it could be differentiated. The colour pattern of *C. sponsalis* lacks dotted spiral lines and the markings between the tubercles in *C. musicus* are blackish-brown; spiral rows of brown dots and dashes extend from base to shoulder, varying in number and arrangement. Dark dots may alternate with white dashes or dots. The pronounced double row of red-brown axial flames in *C. sponsalis* is absent in *C. musicus.*

***Conus varius* Linnaeus, 1758 (Common name: Freckled Cone) (Images 9–12)**

Type material: Lectotype selected by Kohn (1963a) in LSL; size: 33.5 x 16 mm (Cat. no: 312).

Type locality: Banda, Moluccas, Indonesia; Kohn (1963a).

IUCN Red List status: Least Concern.

Materials examined: ZSI/ANRC-11274, 9.x.2014, 3 (2 living, 1 shell) specimens; size range from SL 48×25 SW mm to SL 50× 25 SW mm, (Images 9, 10; SL 48×25 SW mm), Aberdeen Bay (11.669N, 92.749E), South Andaman, Andaman & Nicobar Islands, coll. J.B. Franklin.

Distribution: *Conus varius* is believed to be from southern and eastern Africa to Marshall Islands and Tuamotu Archipelago; absent from Red Sea, India, and Sri Lanka (Röckel et al. 1995).

Documented distributions are from Dar es Salaam, Tanzania (Spry 1961), Maldives (Kohn & Robertson 1966), Chaos Archipelago (Liénard 1877; Kohn & Robertson 1966), Aldabra Atoll (Taylor 1973), Thailand (da Motta 1979), Mascarene Basin (Drivas & Jay 1987), Philippines (Massilia 2008), Christmas Island, Cocos (Keeling) Island (as *C. hevassii*; Maes, 1967; Wells et al. 1990; Wells 1994; Wells & Slack-Smith 2000; Tan & Low 2014), New Caledonia (Héros et al. 2007), Moreton Bay, Queensland (Healy et al. 2007), Mayotte (Deuss et al. 2013), Mauritius (Billot & Touitou 2014), and southern Madagascar (Monnier et al. 2018).

This is the first report of *C. varius* from India (A.J. Kohn pers. comm.).

Description: Shell moderately large (55–80 mm), thick and solid (0.30–0.80 g/mm). Body whorl slightly conical; outline evenly convex. Shoulder angulate, strongly tuberculate. Spire of moderate height (0.12–0.23 mm), outline slightly convex (Fig. 11). Last whorl with evenly spaced ribs, heavily granulose in abapical third (Fig. 12), weak granulose ribs around abapical fourth of last whorl.

Ground colour white. Last whorl tinged with brown, irregularly-shaped or axial blotches within adapical and abapical third. Blotches variable in size and number, fusing into two spiral bands. Evenly spaced spiral rows of dark brown dashes extend from base to shoulder. Larval whorls white. Aperture white, pale orange behind a white marginal zone. Periostracum yellowish-brown, thin, translucent, and smooth.

Habitat: *Conus varius* occurs on coral reef platforms and fore-reefs in or under dead corals, on limestone benches and in sand often beneath coral rocks (CBW 2020).

In the Andaman Islands, it is found on coral reef platforms under dead corals in sand. *T*his species occurs in the intertidal zones up to about 30m depth and there's a note on a specimen dredged up from about 240m depth in the Philippines (Röckel et al. 1995). Specimens were observed in lagoons, reefs, lagoon pinnacles, and shore reefs in the intertidal region (0–5 m depth) in sand, mud, and sea grass (Deuss et al. 2013). They occur on coral debris in the lagoon in Mauritius (Billot & Touitou 2014). Monnier et al. (2018) reported this species at 19–20 m depth in southern Madagascar.

Habit: *Conus varius* is known to feed on polychaete worms (Duda et al. 2001).

Living animal: Dorsum of foot pale yellow; a small black fleck in anterior part beneath the operculum; sole of foot pale yellow to white. Siphon pale yellow with a brown ring just behind the tip (Röckel et al. 1995).

Remarks: The shell of *C. varius* is very unique from other species of family Conidae. Röckel et al. (1995) stated this species as 'absent from India'. Nevertheless, this study reports *C. varius* for the first time from India.

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SHORT COMMUNICATION

A new record of an endangered and endemic rare Rein Orchid *Habenaria rariflora* from Gujarat, India

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Abstract: *Habenaria rariflora* A.Rich., a species endemic to the southern and western parts of India, is reported for the first time from Gujarat State, western India. A detailed description and photographs are provided here for easy recognition in the field. Further, morphology, distribution, habitat, ecology, anatomy of leaf, rarity index, and conservation status of the species are provided.

Keywords: Anatomy, conservation, rarity Index, taxonomy.

The genus *Habenaria,* belonging to the family Orchidaceae, subfamily Orchidoideae, tribe Orchideae, and subtribe Orchidiinae was described by Willdenow (1805). The generic name is derived from the Latin word "*habena*" means 'a strap, holder, or rein', probably attributed to the thread-like fringes of the lip in the flowers. It is one of the largest terrestrial orchid genera with c. 885 species worldwide (Govaerts et al. 2020). *Habenaria* species are distributed in both the New and Old World tropics and subtropics, with a few species in temperate areas, particularly in eastern India (Pridgeon et al. 2001). The genus is terrestrial, characterised by undivided tubers, spurred lip, short column, small & minute caudicle & viscidium, and long & free stigma drawn out at the entrance of spur (King & Pantling 1898; Pridgeon et al. 2001; Dangat 2015). *Habenaria* is represented by c. 62 species in India (Singh et al. 2019). So far, six species have been recorded from Gujarat, making it the largest terrestrial genus of the family for the state (Shah 1978; Anonymous 1996). During the orchid survey, a remarkable species of *Habenaria* was collected from Chinchali Village of Dang District. Various morphological characters of this species did not match with the previously documented species from Gujarat State (Suryanarayana 1968; Desai 1976; Shah 1978, 1983; Vora 1980; Raghavan et al. 1981; Reddy 1987; Bole & Pathak 1988; Anonymous 1996; Tadvi 2014). Hence, the systematic treatment of this taxon along with a detailed description, morphology, anatomy, photographs, ecological notes, rarity index, and conservation status has been provided here.

Materials and Methods

Field survey and collection

In the course of ongoing taxonomic studies on the family Orchidaceae in Gujarat State, an interesting but unknown species of *Habenaria* was collected from Chinchali Village of the Dang District in September 2017. The district is located in the southeastern part of Gujarat and is part of the Western Ghats. It lies between 20.561–21.086N & 73.466–73.943E. The species was collected during the flowering stage and was photographed in its

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Figure 1. Distribution of *Habenaria rariflora* in India.

natural habitat as well as in the laboratory using various digital cameras (Nikon Coolpix P600, Nikon 5300). Details on habit, habitat, flowering, and fruiting period were recorded at the time of collection.

Herbarium preparation and identification

The species was studied for its gross morphological characters during the collection and critically examined under stereo zoom microscope for its detailed taxonomic identification. After a meticulous examination of its morphology and perusal of the relevant literature, the species was identified as *Habenaria rariflora* A. Rich. (Hooker 1890; Santapau & Kapadia 1964; Abraham & Vatsala 1981; Misra 2007). The description of vegetative and reproductive characters is based on live plants. All the representative parts for identification of orchids were collected and used for herbarium preparation. The prepared herbarium specimens were deposited at the Herbarium of The Maharaja Sayajirao University of Baroda (BARO) and Botanical Survey of India, Arid Zone Regional Centre, Jodhpur (BSJO).

Anatomical study

The matured and fresh young leaf samples of *H. rariflora* were fixed in FAA (Formaldehyde: acetic acid: ethanol 10: 5: 50, v/v/v) for preservation (Berlyn et al. 1976). The fixed samples were dehydrated with a graded series of TBA and processed for paraffin embedding (Johansen 1940; Ruzin 1999). Transverse sections of 15–20 µm thickness were taken using Leica rotary microtome (Leica RM 2035). The sections were stained with Safranin-Astra blue stain combination and mounted with DPX for permanent slide. The permanently mounted sectors on slides were observed and all the important features were photographed using a Leica DM1200 microscope coupled to an image capture system.

Rarity status analysis

Rarity index was calculated to assign a status to the species at the regional level (Jalal 2012). A statistical formula was developed considering five quantification parameters (Table 1). The rarity value of the species depends on all the five quantifiable parameters as mentioned in the below formula. The data were entered into an excel spreadsheet and summarized using descriptive statistics.

$$R = \frac{h^1+s^1+p^1+p^2+p^3}{5}$$

Where, h^1 = a number of habitats, s^1 = a number of sites in Gujarat, p^1 = distribution in India, p^2 = phytogeographical distribution within the Indian subcontinent, p^3 = phytogeographical distribution globally.

The scale of rarity index ranges from 1 to 5. Rarity ranking (Very Rare: 0.5–1; Sparse: 1.1–2; Occasional 2.1–3; Common: >3).

Results

Taxonomic treatment

Habenaria rariflora A. Rich. in Ann. Sci. Nat., Bot. ser. 2, 15: 70, t. 2D. 1841; Hook.f., Fl. Brit. India 6: 136. 1890; T. Cooke, Fl. Bombay 2: 716. 1907; Santapau and Kapadia, Orchids Bombay 15, t. 3, f. 9, 10. 1966; Abraham & Vatsala, Introd. Orchids 216. 1981; Lakshmin. in B.D. Sharma et al., Fl. Maharashtra 2: 43. 1996.

Lithophytic or terrestrial herb, 13.0–15.0 cm high with inflorescence. Tubers 1 or 2, small, ovoid or oblong. Leaves 3.0–5.0 × 1.1–1.8 cm, radical, oblong to lanceolate, broadly oblong, ovate to elliptic, or even ovate. Inflorescence 10–12 cm long, 1–4-flowered terminal racemes. Flowers 2.0–2.5 cm long, white,

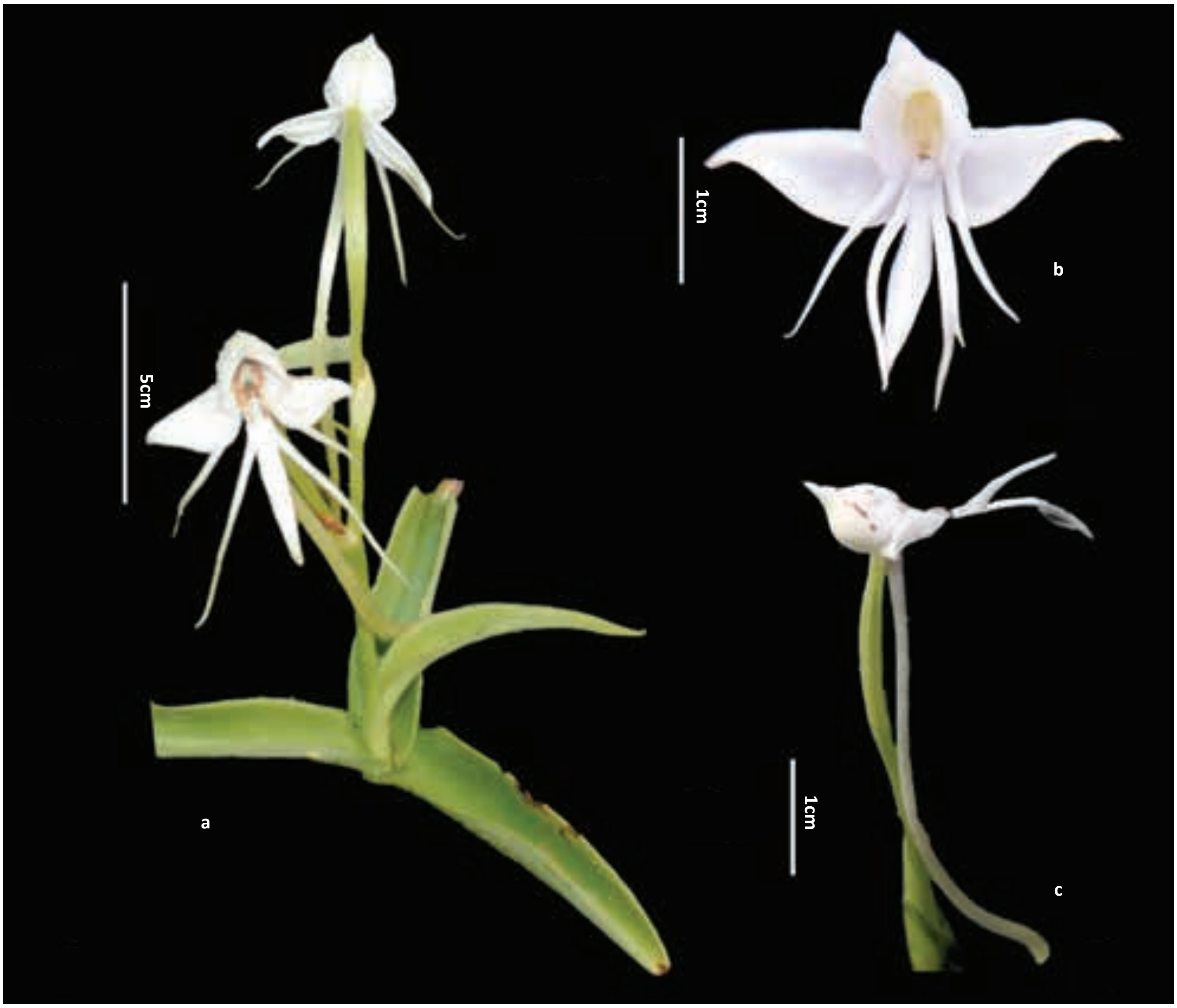

Image 1. *Habenaria rariflora* A. Rich. a—habit | b—front view of flower | c—side view of flower. © Vinod Gosavi

pedicellate, bracteate. Bracts 1.9–2.2 × 0.7–0.8 cm, ovate to lanceolate, acute. Pedicel with ovary c 4.0cm long. Sepals subequal, subacute; dorsal sepal c 1.0 × 0.6–7.0 cm, broadly ovate; lateral sepals c 1.1 × 0.6 cm, obliquely ovate, spreading, apical portions slightly decurved. Petals 2-partite; upper segment 0.8–1.0 × 0.4–0.6 cm, obliquely triangular–ovate; lower segment 1.0–1.3 cm long, filiform, acute. Lip c 1.5cm long, tripartite from a little below middle; lateral segments scarcely 0.8–1.0 cm long, filiform or narrowly linear to subulate; mid segment 0.8–0.9 × c 0.2 cm, linear, subobtuse. Spur 4.5–4.6 cm long, curved, white. Column c 0.5 × 0.3 cm, oblong, rounded, greenish-white. Pollinia yellow, ovoid to oblong, caudicle slender. Capsules 2.0–3.0 cm long, strongly ribbed, beaked (Image 1).

Specimen Examined: 0208 (BSJO), 10.ix.2017, Chinchali ((20.749N & 73.933E, 1,000m), Ahwa, Dangs, Gujarat, India, coll. Mital R. Bhatt (Image 2).

Phenology: August (flowering) and September–October (fruiting).

Distribution: This endemic species is reported to occur in Andhra Pradesh, Goa, Gujarat (present report), Karnataka, Kerala, Maharashtra, and Tamil Nadu (Figure 1).

Habitat and Ecology: The habitat is dominated by tropical moist deciduous vegetation with an average rainfall of 2,000mm. The species was found growing on vertical rocks and old walls along with grasses up to an elevation of 1,000m.

Only a few individuals were located from the site.

Anatomical study

In the transverse section, the leaf shows a crescent shape with a minor abaxial groove in the middle section.

Table 1. Quantification parameters of rarity (Jalal 2012).

	Parameters	Documentation	Scoring (Quantification)
1	Number of habitats (h^1)	A number of habitats in which each orchid species found were recorded.	Three habitats depending on how many habitats, a particular orchid occurred in.
2	Number of sites (s^1)	A number of sites in which each orchid found were recorded.	"1" for single site; "2" for < 5 sites; "3" for < 10 sites; "4" for < 15 sites and "5" for > 15 sites.
3	Distribution in India (p^1)	Divided into six divisions 1. Andaman & Nicobar Islands 2. Northeastern India 3. Western Himalaya 4. Western Ghats 5. Eastern Ghats 6. Central India	1 to 4 divisions depending on the occurrence of species in a particular division.
4	Phytogeographical distribution (p^2)	Indian subcontinent (Bangladesh, Bhutan, Nepal, Pakistan, Sri Lanka)	Depending on how many species are spread in a particular region.
5	Phytogeographical distribution (p^3)	Europe, Sino-Japan, China, Indo-Malaya, Africa, Australia, and North & South America	Depending on how many species are spread in a particular region.

Image 2. Herbarium sheet of *Habenaria rariflora* A. Rich.

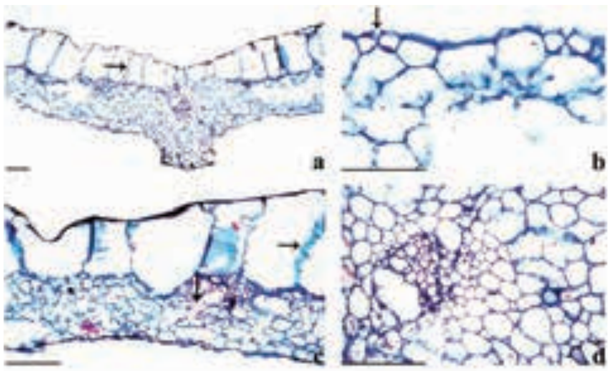

Image 3. Photomicrographs of a sector of leaf blade of *H. rariflora*: a—transverse section | b—hypostomatic stomata showing cuticular projection and sub-stomatal cavity | c—starch grains and undulating anticlinal walls of adaxial epidermis | d—midvein vascular bundle. Scale bars = 100µm.

The cuticle is thin and smooth followed by epidermis, ground tissues and vasculature (Image 3a). The leaf shows a single-layered epidermis with thin-walled cells. The abaxial epidermal layer is interrupted by superficial stomata (hypostomatic) having a cuticular extension and sub-stomatal cavity (Image 3b). Adaxial cells are usually larger than abaxial ones occupying half the volume of leaf (Image 3a,c). The anticlinal walls of adaxial cells are undulating (Image 3c). The outer cell wall is thicker compared to other cell walls which are generally flat to slightly round. Hypodermis and fibre bundles are absent in this species. The mesophyll layer comprises homogenous, thin-walled parenchymatous cells. It is 4–6 cells wide with comparatively smaller intercellular spaces. Raphide bundles are absent. Starch grains are the most common cellular inclusion (Image 3c). Vascular bundles are conjoint, collateral and closed with a larger one in the midrib and smaller in the side vein region. They are arranged in a single series across the blade. The vascular sclerenchyma is absent (Image 3a, d).

Identification Key to the Habenaria of Gujarat

1a. Petals divided 2
2a. Plants with inflorescence up to 45cm tall, leaves spreading all along the stem, flowers greenish white .... *H. gibsonii*
2b. Plants with inflorescence up to 12–55 cm tall, leaves radical, flowers white 3
3a. Leaf solitary or occasionally two, cordate, appressed to the ground .... *H. grandifloriformis*
3b. Leaves few, oblong-lanceolate, not appressed to the ground .... *H. rariflora*
1b. Petals undivided 4
4a. Flowers white 5
5a. Plants reaching up to 45cm height, leaves 1–5, radical, spur equal to the length of ovary .... *H. plantaginea*
5b. Plants reaching up to 80–120 cm height, leaves many, cauline, neither spreading nor flat on the ground, spur much longer than the length of ovary .... *H. longicorniculata*
4b. Flowers green or yellow 6
6a. Leaves radical, clustered at base of stem, with narrow pale yellow margins, flowers yellow, spur geniculate, clavate at apex .... *H. marginata*
6b. Leaves clustered about middle of the stem, not margined, spur linear, incurved .... *H. furcifera*

Rarity status

As per the present study and rarity status analysis, the species is considered as very rare as the rarity index value is 0.8 and the species is located only from the single locality.

Conservation status

Habenaria rariflora is an endemic terrestrial orchid of peninsular India. Based on the current survey and literature study it is revealed that the species is reported from seven different states of India (Figure 1). In the present study, only a few individuals were located from Chinchali Village of Dangs District in Gujarat State. The particular site is prone to soil erosion due to agricultural invasion and grazing. The ex situ conservation for this species have been made at Wagahi Botanical Garden, Dangs and Maharaja Sayajirao University of Baroda, Vadodara. The species has not been evaluated for its threat status till date.

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SHORT COMMUNICATION

Glimpse of climber diversity in Saharanpur District, Uttar Pradesh, India

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Abstract: The present paper focuses on the herbaceous and woody climbers of Saharanpur District. A total of 66 species of herbaceous climbers, 33 species of woody climbers, 15 species of climbing shrubs, and two species of parasitic climbers belonging 27 different families have been recorded. Climbers belonging to the families such as Convolvulaceae, Cucurbitaceae, Fabaceae, and Apocynaceae were found to be dominant in this region. This study also records the occurrence of 14 species of threatened climbers.

Keywords: Apocynaceae, Convolvulaceae, Cucurbitaceae, Fabaceae, threatened.

A climber starts its life on the forest floor and spends almost one-fourth of its life on forest surface. After this phase the adhering, anchoring, and leaning starts on other plants to achieve immense stature (Jongkind & Hawthorne 2005). Families such as Cucurbitaceae, Convolvulaceae, and Dioscoreaceae are considered to be climber rich. Amongst the climber-rich families, Apocynaceae, Rubiaceae, Celastraceae, and Leguminosae have more than 50 species (Gentry 1991; Schnitzer & Bongers 2002). Diversity is also found in the climbing mechanism in the form of branch twiners, stem twiners, tendril climbers, root adhesive climbers, hook climbers, and scramblers (Bongers et al. 2005; Jongking & Hawthorne 2005). Climbers are rooted plants in the ground but necessitate hold up for their growth and these may be root climbers, scramblers, tendril climbers, and twiners. Climbers mostly occur in woody plant ecosystem, although diversity is found in subtropical and tropical forests (Richards 1952; Schimper 1903; Bongers et al. 2005). Tropical rain forest has a high diversity of climbers up to 30% of vegetation (Schnitzer & Bongers 2002). Climbing plant species are more abundantly associated to tropical forest than temperate forest (Putz 1984; Richard 1996).

Climber is defined as plant species that require mechanical support for its growth (Putz & Windsor 1987). It includes herbaceous and woody lianas (Gentry 1991). According to an estimate, climbers are one half of vascular plant species. Hippocrataeceae, Vitaceae, and Smilacaceae families have lianas or vines (Putz 1984; Gentry 1991). A climber floristically plays an important role in tropical forest and considered to be a structural component that affects the physiognomy of the forest (Gentry 1991). A climber plant species plays a vital role in forest ecosystem as it provides habitat and food for animals (Hladik 1978; Emmons & Gentry 1983; Gentry 1991; Gelatti & Padroni 1994). Climbers are almost neglected in all floristic studies but this group represents one of the major part of plant collections (Gentry 1991). A review of the literature reveals that several workers did comprehensive work on climbers

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Figure 1. Study area

and related taxa (DeWalt et al. 2000; Muthuramkumar & Parthasarathy 2001; Pérez-Salicrup et al. 2001; Reddy & Parthasarathy 2003; Kouamé et al. 2004; Parthasarathy et al. 2004; DeWalt et al. 2006; Mukherjee 2006; Prasad et al. 2009; Ghosh & Pandey 2014). During the present study, an attempt was made to enumerate and list all native, exotic, and threatened climbers of Saharanpur forest division of Uttar Pradesh, India. During fields surveys and floristic study, the authors collected many plant species and recorded 116 climbers (Table 1).

Material and Methods

Saharanpur lies between 29^{0}34'45"–30^{0}21'30"N & 77^{0}9'46"–78^{0}14'45"E with the average 269m elevation and covers 3,689km^2 area. Most part of the Saharanpur District is plain except the northern frontier which includes Shivalik Hills. While inventorying the flora of Saharanpur, the authors conducted several field trips in different seasons and collected hundreds of plant species. During the field survey many climber specimens were collected, processed, preserved, and mounted on herbarium sheets following the standard herbarium techniques (Jain & Rao 1977). The dried and fresh specimens were identified using floras published by Hooker (1872–1897), Duthie (1903–1929), Brandis (1906), Kanjilal (1928), Maheshwari (1963), and Delta software. The herbarium sheets are preserved in the Department of Botany, C.C.S. University, and Meerut.

Result and Discussion

During field surveys, the authors collected many plant and recorded 116 species (98 native and 18 non-native) of climbers, of which 66 were herbaceous climbers, 33 woody climbers or lianas and 15 climbing shrubs, and two parasite climbers (Images 1–22). We also observed diversity in the nature of climbing organs. It was reported that out of 116 climber species 70 are twiners, 24 are tendril climbers, 15 are climbing shrubs, four are root climbers and three are hook climbers.

Threatened climbers of Saharanpur District

Abrus precatorius, Aspidopterys cordata, Asparagus racemosus, Cryptostegia grandiflora, Brachypterum scandens, Dioscorea alata, D. bulbifera, Ipomoea dichroa, Mucuna pruriens, Operculina terpethum, Paederia foetida, Pueraria tuberosa, Trichosanthes cucumerina, and *Vincetoxicum indicum* are some of the threatened climbers found in Saharanpur District. These findings are in accordance to the work done by previous explorers (Malik 2016; Barik et al. 2018).

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Table 1. Enumeration of different climbing plant of district Saharanpur.

	Binomial	Family	Climber type	Climbing mode	Nature of climbing organ
1	*Abrus melanospermus* Hassk.	Leguminosae-Papilionoideae	Herbaceous climber	Twiner	Stem
2	*Abrus precatorius* L.	Leguminosae-Papilionoideae	Herbaceous climber	Twiner	Stem
3	*Allamanda cathartica* L.	Apocynaceae	Herbaceous climber	Twiner	Stem
4	*Ampelocissus latifolia* (Roxb.) Planch.	Vitaceae	Woody climber	Tendril climber	Stem
5	*Antigonon leptopus* Hook. & Arn.	Polygonaceae	Herbaceous climber	Tendril climber	Inflorescence axis
6	*Argyreia nervosa* (Burm.f.) Bojer	Convolvulaceae	Herbaceous climber	Twiner	Stem
7	*Aristolochia littoralis* Parodi	Aristolochiaceae	Herbaceous climber	Tendril climber	Modified axillary bud
8	*Asparagus racemosus* Willd.	Asparagaceae	Herbaceous climber	Twiner	Stem
9	*Asparagus setaceus* (Kunth) Jessop	Asparagaceae	Herbaceous climber	Twiner	Stem
10	*Aspidopterys cordata* (B. Heyne ex Wall.) A.Juss.	Malpighiaceae	Climbing shrub	Climbing shrub	Stem
11	*Aspidopterys wallichii* Hook.f.	Malpighiaceae	Climbing shrub	Climbing shrub	Stem
12	*Basella alba* L.	Basellaceae	Herbaceous climber	Twiner	Stem
13	*Bougainvillea spectabilis* Willd.	Nyctaginaceae	Woody climber	Hook climber	Stem
14	*Brachypterum scandens* (Roxb.) Miq.	Leguminosae-Papilionoideae	Climbing shrub	Twiner	Stem
15	*Cajanus crassus* (Prain ex King) Maesen	Fabaceae	Climbing shrub	Climbing shrub	Stem
16	*Cajanus scarabaeoides* (L.) Thouars	Leguminosae-Papilionoideae	Herbaceous climber	Twiner	Stem
17	*Campsis radicans* (L.) Bureau	Bignoniaceae	Woody climber	Twiner	Stem
18	*Cardiospermum halicacabum* L.	Sapindaceae	Herbaceous climber	Tendril climber	Inflorescence axis
19	*Causonis trifolia* (L.) Mabb. & J.Wen	Vitaceae	Herbaceous Climber	Tendril climber	Stem
20	*Celastrus orbiculatus* Thunb.	Celastraceae	Woody climber	Twiner	Stem
21	*Celastrus paniculatus* Willd.	Celastraceae	Woody climber	Twiner	Stem
22	*Cissampelos pareira* L.	Menispermaceae	Herbaceous climber	Twiner	Modified auxiliary bud
23	*Cissus repanda* (Wight & Arn.) Vahl	Vitaceae	Woody climber	Twiner	Stem
24	*Citrullus lanatus* (Thunb.) Matsum. & Nakai	Cucurbitaceae	Herbaceous climber	Twiner	Stem
25	*Clerodendrum splendens* G.Don	Lamiaceae	Woody climber	Twiner	Stem
26	*Clerodendrum thomsoniae* Balf.f.	Lamiaceae	Woody climber	Twiner	Stem
27	*Clitoria ternatea L.*	Leguminosae-Papilionoideae	Herbaceous climber	Twiner	Stem
28	*Coccinia grandis* (L.) Voigt	Cucurbitaceae	Herbaceous climber	Tendril climber	Modified axillary bud
29	*Cocculus hirsutus* (L.) W.Theob.	Menispermaceae	Herbaceous climber	Twiner	Stem
30	*Combretum indicum* (L.) DeFilipps	Combretaceae	Woody climber	Twiner	Stem
31	*Convolvulus arvensis* L.	Convolvulaceae	Herbaceous climber	Twiner	Stem
32	*Cryptolepis buchananii* R.Br. ex Roem. & Schult.	Apocynaceae	Climbing shrub	Climbing shrub	Stem
33	*Cryptostegia grandiflora* Roxb. ex R.Br.	Apocynaceae	Woody climber	Twiner	Stem
34	*Cucumis maderaspatanus* L.	Cucurbitaceae	Herbaceous climber	Tendril climber	Modified auxiliary bud
35	*Cucumis melo* L.	Cucurbitaceae	Herbaceous climber	Tendril climber	Modified auxiliary bud
36	*Cucumis sativus* L.	Cucurbitaceae	Herbaceous climber	Tendril climber	Modified axillary bud
37	*Cucurbita maxima* Duchesne	Cucurbitaceae	Herbaceous climber	Tendril climber	Modified axillary bud
38	*Cuscuta campestris* Yunck.	Convolvulaceae	Parasite climber	Twiner	Stem
39	*Cuscuta reflexa* Roxb.	Convolvulaceae	Parasite climber	Twiner	Stem
40	*Dioscorea alata* L.	Dioscoreaceae	Herbaceous climber	Twiner	Stem

	Binomial	Family	Climber type	Climbing mode	Nature of climbing organ
41	*Dioscorea bulbifera* L.	Dioscoreaceae	Herbaceous climber	Twiner	Stem
42	*Diplocyclos palmatus* (L.) C.Jeffrey	Cucurbitaceae	Herbaceous climber	Tendril climber	Leader axis of main stem
43	*Distimake aegyptius* (L.) A.R.Simões & Staples	Convolvulaceae	Herbaceous climber	Twiner	Modified auxiliary bud
44	*Distimake dissectus* (Jacq.) A.R.Simões & Staples	Convolvulaceae	Herbaceous climber	Twiner	Modified auxiliary bud
45	*Dolichandra unguis-cati* (L.) L.G.Lohmann	Bignoniaceae	Woody climber	Tendril climber	Stem
46	*Epipremnum aureum* (Linden & André) G.S.Bunting	Araceae	Herbaceous climber	Root climber	Arial adventitious root
47	*Epipremnum pinnatum* (L.) Engl.	Araceae	Herbaceous climber	Root climber	Arial adventitious root`
48	*Ficus pumila* L.	Moraceae	Woody climber	Root climber	Root
49	*Guilandina bonduc* L.	Leguminosae-Caesalpinioideae	Woody climber	Hook climber	Prickles on stem & leaf rachis
50	*Helinus lanceolatus* Brandis	Rhamnaceae	Climbing shrub	Climbing shrub	Stem
51	*Hiptage benghalensis* (L.) Kurz	Malpighiaceae	Woody climber	Twiner	Stem
52	*Holmskioldia sanguinea* Retz.	Lamiaceae	Climbing shrub	Climbing shrub	Stem
53	*Ichnocarpus frutescens* (L.) W.T. Aiton	Apocynaceae	Woody climber	Twiner	Stem
54	*Ipomoea aquatica* Forssk.	Convolvulaceae	Herbaceous climber	Twiner	Stem
55	*Ipomoea batatas* (L.) Lam.	Convolvulaceae	Herbaceous climber	Twiner	Stem
56	*Ipomoea cairica* (L.) Sweet	Convolvulaceae	Herbaceous climber	Twiner	Stem
57	*Ipomoea cheirophylla* O' Donell	Convolvulaceae	Herbaceous climber	Twiner	Stem
58	*Ipomoea dichroa* Hochst. ex Choisy	Convolvulaceae	Herbaceous climber	Twiner	Stem
59	*Ipomoea hederifolia* L.	Convolvulaceae	Herbaceous climber	Twiner	Stem
60	*Ipomoea muricata* (L.) Jacq.	Convolvulaceae	Herbaceous climber	Twiner	Stem
61	*Ipomoea nil* (L.) Roth	Convolvulaceae	Herbaceous climber	Twiner	Stem
62	*Ipomoea obscura* (L.) Ker Gawl.	Convolvulaceae	Herbaceous climber	Twiner	Stem
63	*Ipomoea pes-caprae* (L.) R.Br.	Convolvulaceae	Herbaceous climber	Twiner	Stem
64	*Ipomoea quamoclit* L.	Convolvulaceae	Herbaceous climber	Twiner	Stem
65	*Ipomoea triloba* L.	Convolvulaceae	Herbaceous climber	Twiner	Stem
66	*Jasminum laurifolium* Roxb. ex Hornem.	Oleaceae	Woody Climber	Twiner	Stem
67	*Jasminum multiflorum* (Burm.f.) Andrews	Oleaceae	Woody Climber	Twiner	Stem
68	*Lablab purpureus* (L.) Sweet	Fabaceae	Herbaceous climber	Twiner	Modified stem
69	*Lagenaria siceraria* (Molina) Standl.	Cucurbitaceae	Herbaceous climber	Tendril climber	Modified auxiliary bud
70	*Leptadenia reticulata* (Retz.) Wight & Arn.	Apocynaceae	Woody Climber	Twiner	Stem
71	*Luffa acutangula* (L.) Roxb.	Cucurbitaceae	Herbaceous climber	Tendril climber	Modified auxiliary bud
72	*Mansoa alliacea* (Lam.) A.H.Gentry	Bignoniaceae	Woody Climber	Twiner	Modified auxiliary bud
73	*Merremia hederacea* (Burm.f.) Hallier f.	Convolvulaceae	Herbaceous climber	Twiner	Modified auxiliary bud
74	*Millettia extensa* (Benth.) Benth. ex Baker	Leguminosae-Papilionoideae	Woody climber	Twiner	Stem
75	*Mimosa pudica* L.	Leguminosae-Mimosoideae	Herbaceous climber	Twiner	Prickles on stem
76	*Momordica charantia* L.	Cucurbitaceae	Herbaceous climber	Tendril climber	Modified auxiliary bud
77	*Monstera deliciosa* Liebm.	Araceae	Herbaceous climber	Root climber	Arial adventitious root
78	*Mucuna hainanensis* Hayata	Leguminosae-Papilionoideae	Woody climber	Twiner	Stem
79	*Mucuna imbricata* (Roxb. ex Lindl.) D C. *ex Baker*	Leguminosae-Papilionoideae	Woody climber	Twiner	Stem

	Binomial	Family	Climber type	Climbing mode	Nature of climbing organ
80	*Mucuna monosperma* Roxb. ex Wight	Leguminosae-Papilionoideae	Woody climber	Twiner	Stem
81	*Mucuna pruriens* (L.) DC.	Leguminosae-Papilionoideae	Woody climber	Twiner	Modified stem
82	*Operculina turpethum* (L.) Silva Manso	Convolvulaceae	Herbaceous climber	Twiner	Modified auxiliary bud
83	*Oxystelma esculentum* (L.f.) Sm.	Apocynaceae	Herbaceous Climber	Twiner	Stem
84	*Paederia foetida* L.	Rubiaceae	Herbaceous Climber	Twiner	Leader axis of branch
85	*Passiflora foetida* L.	Passifloraceae	Herbaceous climber	Tendril climber	Modified axillary bud
86	*Passiflora suberosa* L.	Passifloraceae	Herbaceous climber	Tendril climber	Modified axillary bud
87	*Passiflora vitifolia* Kunth	Passifloraceae	Herbaceous climber	Tendril climber	Modified axillary bud
88	*Pentalinon luteum* (L.) B.F. Hansen & Wunderlin	Apocynaceae	Climbing shrub	Climbing shrub	Stem
89	*Petrea volubilis* L.	Verbenaceae	Woody climber	Twiner	Stem
90	*Phanera vahlii* (Wight & Arn.) Benth.	Leguminosae-Caesalpinioideae	Woody climber	Twiner	Stem
91	*Poranopsis paniculata* (Roxb.) Roberty	Convolvulaceae	Woody Climber	Twiner	Stem
92	*Pueraria tuberosa* (Roxb. ex Willd.) DC.	Leguminosae-Papilionoideae	Woody Climber	Twiner	Stem
93	*Pyrostegia venusta* (Ker Gawl.) Miers	Bignoniaceae	Herbaceous Climber	Tendril climber	Stem
94	*Rivea hypocrateriformis* (Desr.) Choisy	Convolvulaceae	Climbing shrub	Climbing shrub	Stem
95	*Senegalia gageana* (Craib) Maslin, Seigler & Ebinger	Leguminosae-Mimosoideae	Climbing shrub	Climbing shrub	Stem
96	*Senegalia pennata* (L.) Maslin	Leguminosae-Mimosoideae	Climbing shrub	Climbing shrub	Stem
97	*Senegalia torta* (Roxb.) Maslin, Seigler & Ebinger	Leguminosae-Mimosoideae	Climbing shrub	Climbing shrub	Stem
98	*Spatholobus parviflorus* (Roxb. ex G.Don) Kuntze	Leguminosae-Papilionoideae	Woody Climber	Twiner	Stem
99	*Stephanotis floribunda* Jacques	Apocynaceae	Woody Climber	Twiner	Stem
100	*Syngonium podophyllum* Schott	Araceae	Herbaceous Climber	Root climber	Arial adventitious root
101	*Tarlmounia elliptica* (DC.) H.Rob, S.C.Keeley, Skvarla & R.Chan	Asteraceae	Herbaceous Climber	Twiner	Stem
102	*Telosma pallida* (Roxb.) W.G.Craib	Apocynaceae	Woody Climber	Twiner	Stem
103	*Teramnus labialis* (L.f.) Spreng.	Leguminosae-Papilionoideae	Herbaceous Climber	Tendril climber	Stem
104	*Thunbergia coccinea* Wall. ex D.Don	Acanthaceae	Herbaceous Climber	Twiner	Stem
105	*Tiliacora racemosa* Colebr.	Menispermaceae	Climbing shrub	Climbing shrub	Stem
106	*Tinospora cordifolia* (Willd.) Hook. f. & *Thomson*	Menispermaceae	Woody Climber	Twiner	Stem
107	*Trachelospermum jasminoides* (Lindl.) Lem.	Apocynaceae	Woody Climber	Twiner	Stem
108	*Trichosanthes cucumerina* L.	Cucurbitaceae	Herbaceous Climber	Tendril climber	Leaf auxiliary bud
109	*Trichosanthes dioica* Roxb.	Cucurbitaceae	Herbaceous Climber	Tendril climber	Leaf auxiliary bud
110	*Vallaris solanacea* (Roth) Kuntze	Apocynaceae	Climbing shrub	Climbing shrub	Stem
111	*Vigna unguiculata* (L.) Walp.	Leguminosae-Papilionoideae	Herbaceous climber	Twiner	Stem
112	*Vincetoxicum indicum* (Burm.f.) Mabb.	Apocynaceae	Herbaceous Climber	Twiner	Stem
113	*Vitis vinifera* L.	Vitaceae	Woody climber	Tendril climber	Stem
114	*Wattakaka volubilis* (L.f.) Stapf	Apocynaceae	Woody climber	Twiner	Stem
115	*Wisteria sinensis* (Sims) DC.	Fabaceae	Woody climber	Twiner	Stem
116	*Ziziphus oenoplia* (L.) Mill.	Rhamnaceae	Woody climber	Hook climber	Stem and thorns

Image 1. *Basella alba*

Image 2. *Diplocyclos palmatus*

Image 3. *Oxystelma esculenta*

Image 4. *Holmskioldia sanguinea*

Image 5. *Clitoria ternatea*

Image 6. *Stephanotis floribunda*

Image 7. *Pueraria tuberosa*

Image 8. *Wattakaka volubilis* (L.f.) Stapf

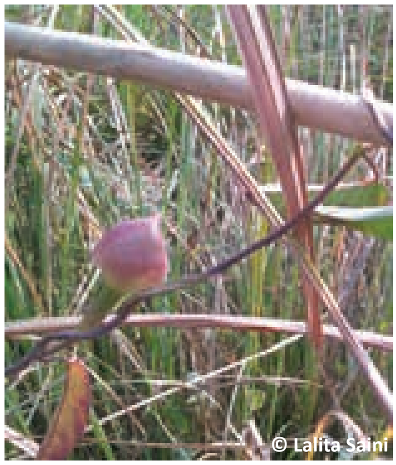

Image 9. *Operculina turpethum*

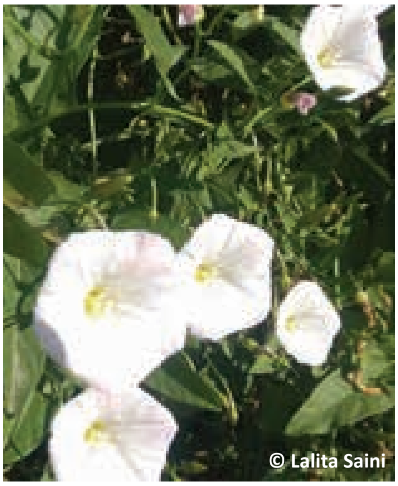

Image 10. *Convolvulus arvensis*

Image 11. *Vallaris solanacea*

Image 12. *Ichnocarpus frutescens*

Image 13. *Paederia foetida*

Image 14. *Cajanus scarabaeoides*

Image 15. *Abrus pulchellus*

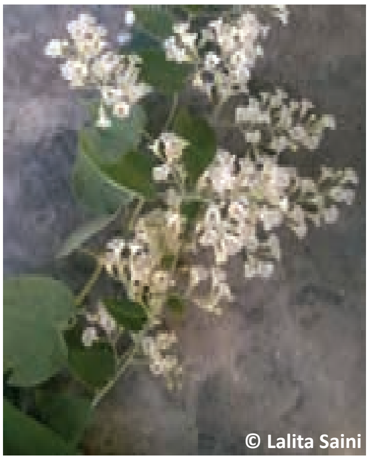

Image 16. *Poranopsis paniculata*

Image 17. *Ipomoea obscura*

Image 18. *Telosma pallida*

Image 19. *Cissus repanda*

Image 20. *Clerodendrum thomsoniae*

Image 21. *Aspidopterys cordata*

Image 22. *Cardiospermum halicacabum*

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SHORT COMMUNICATION

First report of the fleshy mushroom *Trichaleurina javanica* (Rehm) M. Carbone et al. (Ascomycota: Pezizales: Chorioactidaceae) from southern India

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Abstract: *Trichaleurina javanica* was collected from tropical dry evergreen forests, located in the southeastern coastal belt of India. This is the first report of the species from southern India. *Trichaleurina javanica* is a fleshy and rubbery cup-like mushroom, brownish-grey in colour with a brilliant yellowish-orange disc. The identification is supported using morphological and microscopical characters. It is one of the less known wild edible mushrooms belonging to Ascomycota.

Keywords: Ascomycetous mushroom, Ice Apple Mushroom, rubbery cup, tropical dry evergreen forests, wild edible mushroom.

Trichaleurina javanica, an ascomycetous mushroom, called Ice Apple Mushroom is a fleshy and rubbery cup like mushroom which is brownish-grey in colour with a brilliant yellowish-orange disc. *Trichaleurina* is a tropical and subtropical species which is complex and was not well resolved for its identity using well supported classical data until recently. It was separated recently from its allies *Sarcosoma* and *Galiella* and re-established as a separate genus recently (Carbone et al. 2013a,b) based on the phylogenetic evidence.

The most close allies *Galiella* with type *Galiella rufa* (Schwein.) Nannf. & Korf., is an American species (Carbone et al. 2015) but also reported from China (Cao et al. 1992), Malaysia (Chong et al. 2007; Abdullah & Rusea 2009) but poorly known from India (Pant & Prasad 2008). Sharma and Rawla (1982) reported *G. rufa* from India but due to unavailability of the specimen, identity remained doubtful and it is later mentioned as not recorded in India (Pant & Prasad 2008). Whereas, other species of *Galiella* namely *G. celebica* is reported from India (Pant & Prasad 2008) and was later mentioned as *Trichaleurina javanica* by Patel et al. (2019).

The genera *Galiella* is considered a synonym of *Sarcosoma* Casp. by Le Gal (1958, 1960) and Boedijn (1959) while many other mycologists from Korf (1957) to Pant & Prasad (2008) considered it as a separate genus. Recently, Carbone et al. (2013a,b, 2015) proved *Galiella* is an independent genus in the family Sarcosomataceae Kobayasi with at least two species *G. javanica* and *G. celebica* which were formerly included in the same genus.

Later, the phylogentic studies on Sacrocosomataceae revealed that *G. javanica* and *G. celebica* cannot be grouped under the genera and were therefore shifted to the genera *Trichaleurina* (Carbone et al. 2013a). Although, the name *Trichaleurina* was first used by Rehm

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(1903) as an infrageneric rank within *Aleurina* Massee., it was later raised to the genus level (Rehm 1914) by validating it with the new (and only) species *Trichaleurina polytricha* collected from the Philippines. But much later (Carbone et al. 2013b), the genus *Trichaleurina* was established with well supported morphological and molecular evidence with at least two clearly defined species—*T. javanica* and *T. tenuispora*. Moreover, Carbone et al. (2015) also clearly distinguished *G. rufa* by giving a detailed description of the micro-morphological characters for clear identification in future.

This *Galiella* complex (until recently) mushroom which is mustard yellow to light tan in colour is known as 'Mata Rusa' (deer eyes) in Sabah, by Dusuns and 'Mata Kerbau' (buffalo eyes) in Sarawak, Malaysia (Abdullah & Rusea 2009) was consumed and prized in the market. In India, we found the same mushroom is consumed raw by the Oorali tribe of Sathyamangalam forest (not reported earlier). This is not reported as an edible fungi from any other part of India.

Mushroom diversity of tropical dry evergreen forests (TDEF) vegetation is poorly reported (Kumar 2020). The actual diversity of these regions is much more than what is known, because TDEFs are among the highly neglected region for mushroom biodiversity studies. The species reported in this study was collected during mushroom biodiversity studies in the TDEF region of southern India being done for the past seven years (2012–2019).

Materials & Methods

The specimens were found on dead and decaying wood (*Delonix*) and collected from Madras Christian College campus, Chennai, India. The campus is a green, extended over 365 acres with TDEF vegetation. The specimens were cut from the stump in all stages starting from initial fruiting to mature stage. Specimens from the field were wrapped in paper covers. They were dried at 70°C for 24 hours and sealed in polythene covers along with their label and naphthalene balls for further examination (Kaviyarasan et al. 2009). The microscopic structures were examined in the dried specimens which were as revived in 5% KOH. Stains such as phloxine and Melzer's reagent were used to study other details (Largent 1986). The specimens were deposited in the Madras Christian College Herbarium (MCCH) with accession MCCHF1601, MCCHF1920 for future reference. They were identified with proper keys and manuals (Cao et al. 1992; Pant & Prasad 2008; Carbone et al. 2013a,b, 2015; Patel etal. 2019).

Results & Discussion

In the present study the fruit bodies of *Trichaleurina javanica* were collected throughout the Madras Christian College Campus. They were always collected on dead and decaying wood.

Trichaleurina javanica (Rehm) M. Carbone, Agnello & P. Alvarado (2013) (Image 1; Figure 1)

≡ *Sarcosoma javanicum* Rehm, Hedwigia 32: 226 (1893)

≡ *Galiella javanica* (Rehm) Nannf. & Korf, Mycologia 49 (1): 108 (1957)

= *Urnula philippinarum* Rehm, Leaflets of Philippine Botany 6: 2281 (1914)

= *Trichaleurina polytricha* Rehm, Leaflets of Philippine Botany 6: 2234 (1914)

= *Sarcosoma novoguineense* Ramsb.: 186 (1917), fide Boedijn (1932) and Le Gal (1959)

= *Sarcosoma decaryi* Pat., Mémoirs de l´Académie Malgache 6: 37 (1928), fide Le Gal (1953)

Macroscopic features

Sporocarps occur in troops, clusters, or singly. Fruiting body cup-shaped, cup curved inwards during initial stage, leathery. Inner tissue gelatinous, jelly like, translucent and rubbery, smooth, outer surface blackish-brown to grey brown in colour, rough, velvety, smooth or wrinkled, 5.2–7.8 cm wide and 5.5–6.5 cm high, cylindric or tapering downwards, hairs sparse throughout the surface, more hirsute hairs along the rim of the cup, at maturity the hairs not significant, hymenial portion reddish-orange to yellowish-orange, concave when young, at maturity the hymenial region prominent, plane, convex and slightly decurving . Margin entire, at maturity sparsely folded. Inside the cup below the hymenial region cavity present, cavity may be partitioned with two locule, gelatinous tissue getting reduced towards the base. Cavity filled with mild gelatinous fluid, fluid colourless and odourless. As much as 20ml of fluid accumulate in the cavity. At initial stage and also at maturity the fluid may not be present.

Microscopic features

Hymenium thick, ascospores large, thin walled, with prominent oil guttules, spores hyaline, inamyloid, elliptical, 30.9–35.8, 12.7–15.2 mm, tilted towards right with two to three large prominent oil guttules and few smaller guttules, ascospores at the tip are smaller than those at the bottom. Asci narrow, long, cylindrical, operculate, unitunicate, wall thick up to

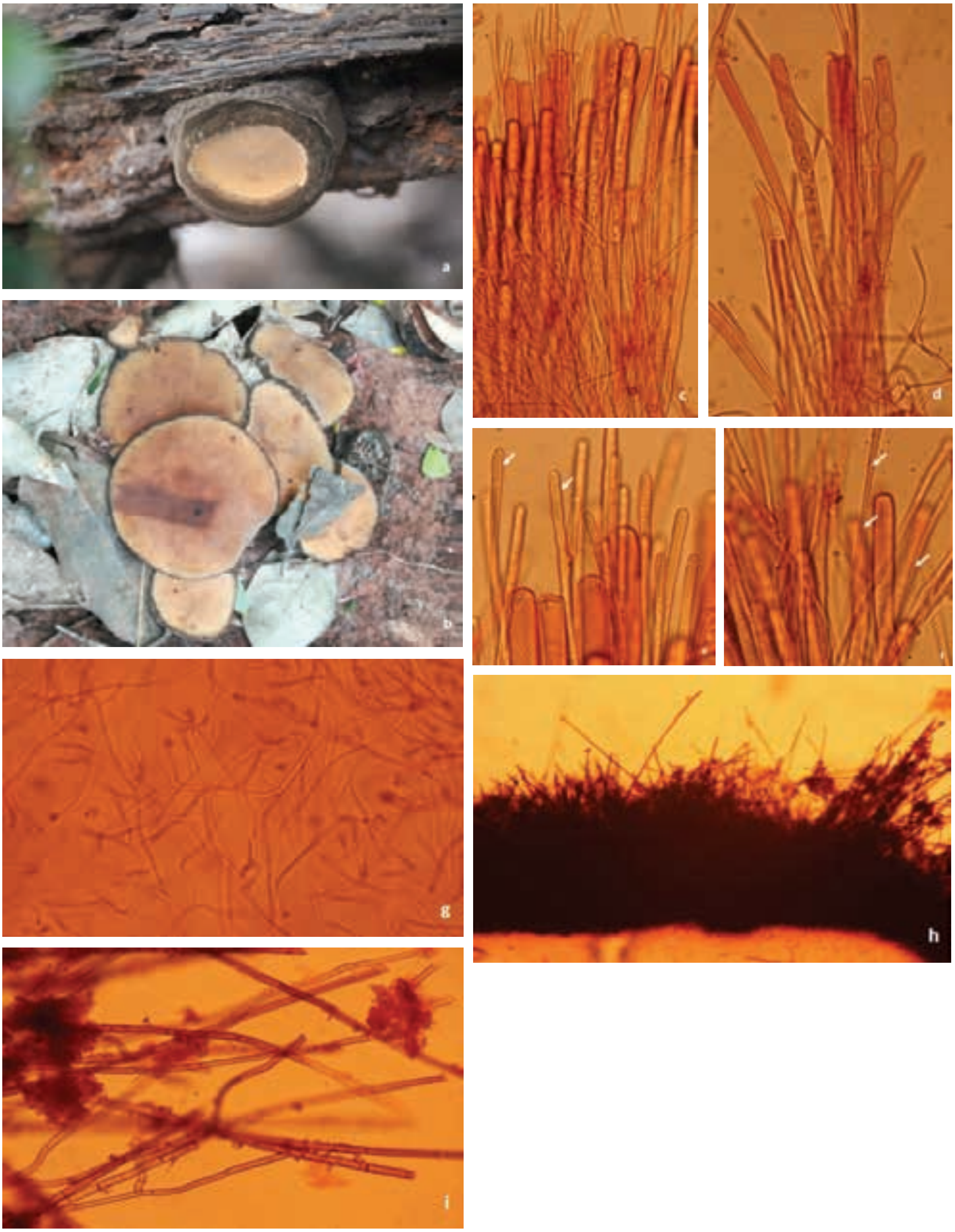

Image 1. *Trichaleurina javanica*: a—habit – young | b—habit – mature | c—v.s. of apothecium showing the hymenium | d—ascus with ascospore and showing operculum | e—paraphyses showing uneven wall layer | f—paraphyses showing septum | g—gelatinized hyphae of hypothecium | h—excipulum region of ascocarp | i—septate hyphae of the excipulum. © M. Kumar.

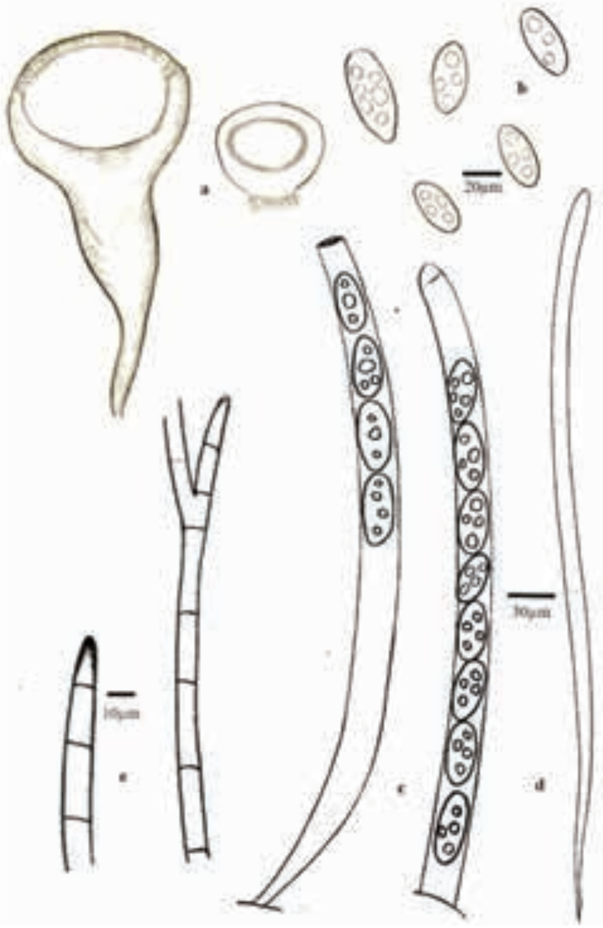

Figure 1. *Trichaleurina javanica*: a—habit | b—spores | c—asci with operculum | d—paraphyses | e—gelatinized hyphae.

1.5mm, spores vertically arranged to the length of the asci, 374–388 ´ 8.1–8.3 mm, callose depositions found on the wall. Paraphyses filiform, extending beyond asci, 4–8 mm diameter, gradually tapering downwards, septate, septum not prominent, septal wall thin, depositions present on the tip portion, wall not smooth, uneven. Subhymenium, pale or creamy, appears pseudoparanchymatous and partially with gelatinized hyphae.

Hypothecium with gelatined hyphae with watery cavity, all hyphae septate with visibly dark septum, thin, 3–6 mm diameter, sparsely branched, wall layer are hyaline and has some warty ornamentation. Hypothecium and excipulum separated with cavity. Excipulum rubbery with gelatinized hyphae and towards outer dark brown hyphal aggregation present, some dark deposition on the walls, wall layer dark, hyphae erect and septate with prominent dark septum, tip blunt.

Specimen examined: MCCHF1601, MCCHF1920, 19.viii.2016 and 29.x.2019, India, Tamil Nadu, Chennai, Madras Christian College Campus, in troops (15–20 sporocarps), around MacPhail art center ($12^0$55'10.96"N $80^0$7'18.91"E), coll. M. Kumar.

The specimen examined shows similarity with the previously reported species mentioned from China, Taiwan, Thailand, and Seychelles (Cao et al. 1992; Carbone et al. 2013b) with slight variation in the morphological and microscopical dimensions. It was unable to compare with the Indian species (Patel et al. 2019) because the report from Gujarat was not described using micromorphological characters rather identified only by molecular analysis.

The morpho-microscopic examination in the present study includes the notable characters such as gelatinous liquid: its presence and absence, quantity and taste, presence of two locules in the fluid cavity, septate hyphae of gelatinous excipulum, which were not recorded in the previous reports (Cao et al. 1992; Pant & Prasad 2008; Carbone et al. 2013a,b, 2015).

Trichaleurina javanica contains a mild salty sweet liquid which is similar to that of the liquid found in palmyra palm fruit. During our collection it was also observed that the sporocarp is vigorously fed by few larvae and common snail of this region.

Since the species was already reported by Pant & Prasad (2008) from the Kumoun hills, Uttarakhand as *Galiella celebica* and by Patel et al. (2019) from Gujarat as *Trichaleurina javanica,* this will be the first report for southern India.

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NOTE

Photographic record of Temminck's Tragopan *Tragopan temminckii* (Gray, 1831) (Aves: Galliformes: Phasianidae) from eastern Bhutan: an evidence of its westward range expansion

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Inhabiting temperate forest and shrublands, Temminck's Tragopan *Tragopan temminckii* is distributed across the eastern Himalaya in China, India, Myanmar, and Vietnam above 2,500m (Grewal et al. 2011; BirdLife International 2016). In India, the bird has been observed along Mishmi Hills, Dibang and Tsangpo valleys in Arunachal Pradesh (Ali et al. 1995; Ali 1999), a state neighboring eastern Bhutan. With estimated global population of over 100,000 individuals, Temminck's Tragopan is listed as Least Concern species in its assessment by the IUCN Red List (BirdLife International 2016). The species is declining over much of its distribution range owing to habitat degradation caused by under storey cutting, over grazing, over hunting, and collection of eggs (Del Hoyo et al. 1994). Further, BirdLife International (2016) claimed that the most emerging threats identified in its range were habitat deterioration, hunting, and trapping.

Temmincks Tragopan is one of the three tragopan species found in Bhutan, the other two being Blyth's Tragopan *Tragopan blythii* and Satyr Tragopan *Tragopan satyra* (Grimmett et al. 2019).

The presence of Temminck's Tragopan in Bhutan was first reported in 2016 based on a camera trap image captured in 2014 from Samdrup Jongkhar District, near the Jomotsangkha Wildlife Sanctuary in eastern Bhutan (Kuensel Corporation Ltd 2016). After six years of its first discovery, we have captured an image of a male Temminck's Tragopan on 20 April 2020, which makes it the second photographic record of species from Bhutan. The current observation was made at an elevation of 2,952m at a place called Kharungla (27.180^{0}N & 91.533^{0}E) under Lumang block of Trashigang District. It was captured in one of the camera traps kept for monitoring mammals under Trashigang Forest Division.

The present observation site for the species is about 50km westward as compared to the first record of 2014, and approximately 170km away from the occurrence

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Figure 1. Global distribution of Temminck's Tragopan

Image 1. Camera trap of a male Temmincks Tragopan *Tragopan temminckii*.

range updated by IUCN indicating a westward range expansion of its habitat from the earlier known distribution (Figure 1). The vegetation type at the observation area is evergreen broadleaf forest mixed with bamboo species. The dominant species found at the location were *Rhododendron* sp., *Borinda grossa*, and other smaller bamboo species (*Arundinaria racemosa* & *Drepanostachyum* spp.) with dense undergrowth. The geographical aspect where the bird was photographed is south-east facing slope. The habitat inhabited is very similar to those reported earlier by Shi et al. (1996) in China and Ali (1999) in neighboring India. The image has been confirmed as that of a male Temminck's Tragopanon consulting references, e.g., Grewal et al. (2011) and Ali & Ripley (1995) for plumage description. According to them the male Temminck's Tragopan is characterized by the presence of bright flame-orange overall with bright blue face surrounded by black and red under parts. It also has black and white-spotted brown wings with upper tail and darker tail coverts as we can see in the image (Image 1). Both records from Bhutan were made through motion sensored, remotely triggered camera traps in the primary forests, indicating that the species prefers forested habitat, away from human disturbances. The fact that the species was recorded only in one camera trap station in the recent monitoring program indicates it is rare as well as elusive. Therefore, further detailed study is recommended in the region to document the extent of distribution and associated threats in Bhutan, which are lacking for now. Information from such studies will help Department of Forest and Park Services for conservation planning and IUCN in updating the species factsheet.

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NOTE

The Malay Cardamom *Meistera aculeata* (Roxb.) Škorničk. & M.F. Newman (Zingiberaceae: Alpinioideae) from the Palghat gap: a new record to Kerala, India

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Zingiberaceae, the ginger family, comprises 53 genera and more than 1,375 species widely distributed throughout tropical Africa, Asia, and America (Kress et al. 2002; Kong et al. 2010). *Amomum* Roxb s.l. is the second largest genus in the family Zingiberaceae with about 150–180 species (Xia et al. 2004). The distribution of the genus in India is concentrated in northeastern India, peninsular India, and the Andaman & Nicobar Islands with 22 species (Thomas & Sabu 2012). *Amomum* is reported to have 48 species in the Flora of British India (Hooker 1894), while five species were reported by Fischer (1928) in the Flora of Presidency of Madras. Recent taxonomic studies have resulted in the discovery of 12 taxa under the genus *Amomum* (Thomas et al. 2010, 2012a,b, 2014, 2015, 2016; Thomas & Sabu 2012; Hareesh & Sabu 2018).

Presently *Amomum* is circumscribed to a monophyletic genus based on multi-marker phylogenetic framework using matK and nrITS as markers. The targeted sampling combined with the molecular data, phylogenetic analysis and morphological characters allowed the re-circumscription of 10 clades of the genus *Amomum* as separate genera (De Boer et al. 2018). Accordingly, certain species in the genus *Amomum* are either resurrected or transferred to the genus *Meistera* Giseke.

Meistera is characterized by semi-lunar anther crest, echinate fruit and solitary flower in each fertile bract (Thomas & Sabu 2018). The genus comprises 42 species and three varieties, and is distributed from Sri Lanka and India, throughout the Indo-Chinese region to Sundaland (De Boer et al. 2018).

During the exploratory studies on the floristic diversity in the Walayar forest range of the southern Western Ghats, the authors collected specimens belonging to the genus *Meistera* growing on the foothills of Jamanthimala coming under Pudussery North Section (10.863°N & 76.789°E) near the Palakkad Gap region in June 2019. The specimens were preserved as herbarium using standard herbarium procedures. The specimen was identified as *Meistera aculeata* (Roxb.) Skornick. & M.F. Newman after consulting relevant taxonomic

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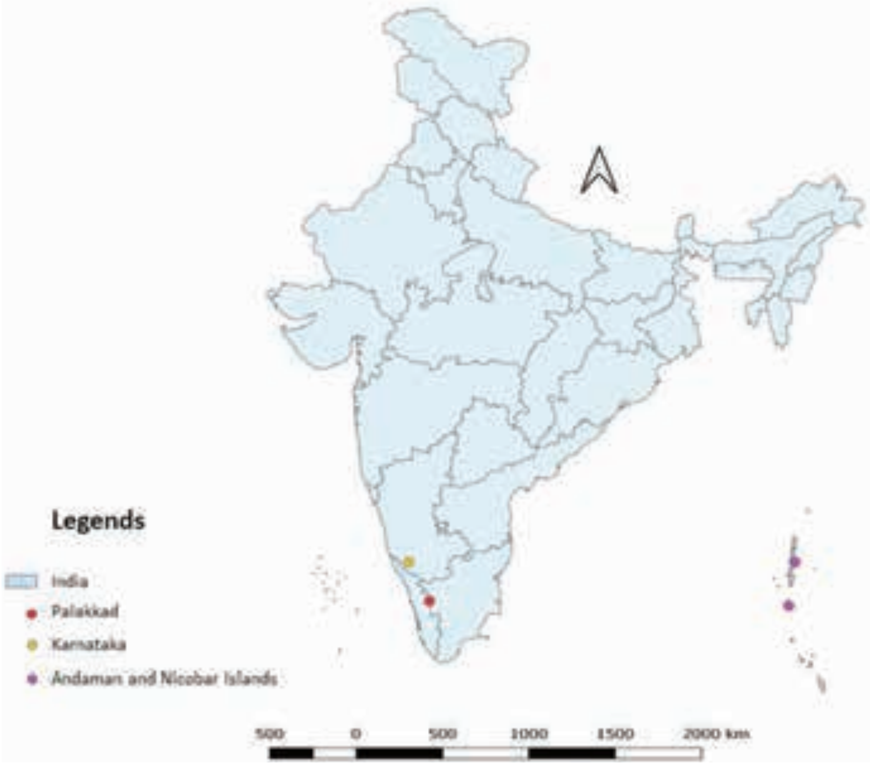

Figure 1. Known locations of the Malay Cardamom *Meistera aculeata* (Roxb.) Škorničk. & M.F. Newman in India. Map by V.J. Aswani.

literature and the type specimen housed at the Natural History Museum (BM).

Balakrishnan & Nair (1979) reported this species from the Andaman & Nicobar islands and recently, this was reported from Kodagu in Karnataka (Patil & Lakshminarasimhan 2018) as a new addition to its distribution in mainland India. Our collection from the foothills of Jamanthimala forms a new record to the flora of Kerala as this taxon has not been included in any of the literature pertaining to the flowering plants of Kerala (Vajravelu 1990; Sasidharan 2002, 2011; Nayar et al. 2006, 2014) as well as the revisionary studies on *Amomum* s.l. (Sabu 2006; Thomas 2011). A detailed description of the taxon along with photographs and distribution map is provided. The specimens are deposited at Madras Herbarium (MH), Calicut University Herbarium (CALI), and Government Victoria College Herbarium (GVCH).

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Type: Ind. Orient., India, *William Roxburgh* s.n. (BM000958151, Image!)

Perennial herb, 2–3.5 m tall with distichous leaves. Root stock rhizomatous, branched and creamy brown within. Leafy shoots elongated, 2–3 cm thick, reddish brown towards base. Leaves sessile or shortly petiolate; lamina 30–60 cm long and 5–9 cm broad, oblong-lanceolate, acuminate at apex, cuneate at base, margins entire, glabrous on both surfaces, midrib yellowish-green, glabrous; petioles 0–3 mm long. Ligules bifid or subentire, longer than petiole, 1–1.5 cm long. Spikes many flowered borne directly from root stock, peduncles 10–15 cm long, 1–1.25 cm thick, glabrous. Bracts many, imbricate, very closely sheathing and spirally arranged, ovate, reddish-brown, cuspidate at apex, 4–6 cm long, 2.5–3.5 cm broad, glabrous inside and puberulous outside. Fertile bracts pinkish-red, ovate, cuspidate at apex, 4–5 cm long and 2–2.5 cm wide, puberulous towards base inside, glabrous towards apex on both surfaces. Each floral bract subtends a single flower. Bracteole tubular, abruptly 3 lobed, 1.4–1.6 cm long, membranous towards apex, glabrous on both surfaces. Flowers 1–4, open simultaneously in a head pattern with older flowers beneath which appears brown and slimy, 4–4.5 cm long. Calyx tubular, 2–2.5 cm long, 1.2–1.6 cm wide, 3 lobed from middle,

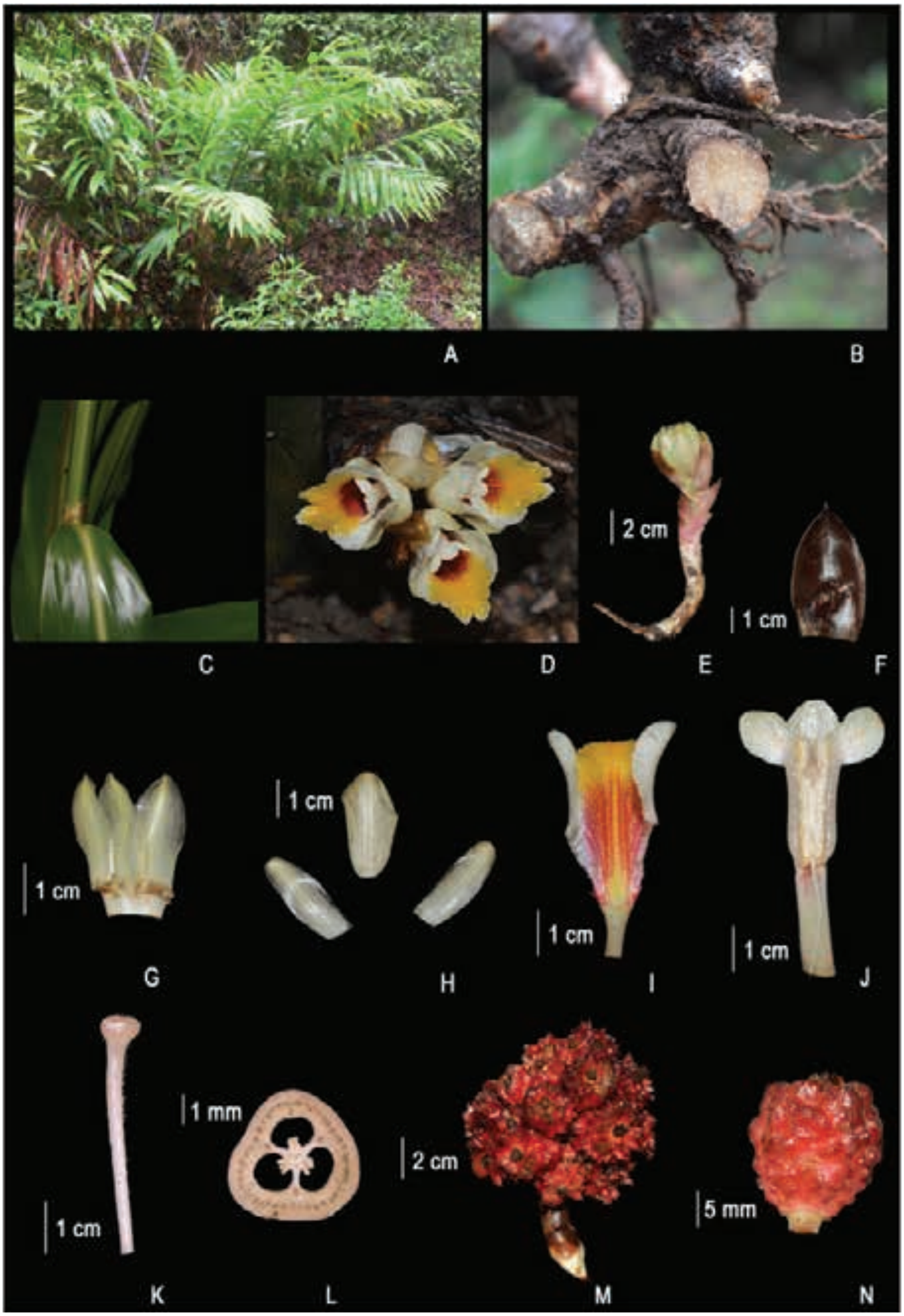

Image 1. *Meistera aculeata* (Roxb.) Škorničk. & M.F.Newman. A—Habit | B—Rhizome | C—Ligule | D—Flowers | E—Inflorescence at bud stage | F—Floral bract | G—Calyx | H—Petals | I—Labellum | J—Stamen with petaloid anther crest | K—A portion of style with stigma | L—C.S of Ovary | M—Fruit cluster | N—Single fruit. © Aswani, V.J. & Jabeena M.K.

apex mucronate, margins ciliate. Corolla tube 1.8–2.8 cm long, white, glabrous. Dorsal corolla lobe obovate, broader than lateral lobes, 2–2.8 cm long, rounded at apex, margins ciliate and slightly wavy. Lateral corolla lobes oblong, 1.2–1.5 x 1–1.5 cm long, rounded at apex, margins ciliate. Labellum obovate, trilobed, 3.5–3.6 cm wide, margins slightly undulate, glabrous. Median lobe truncate, clefted, white with yellow along with red streaks towards base and lateral lobes orbicular, lateral staminodes 2, subulate at base, red, 0.2–0.3 cm long, glabrous; anther one, oblong, 1.2–1.5 cm long, 0.3–0.4 cm broad furnished with a white petaloid anther crest; anther crest tri–lobed, middle lobe truncate or rounded and lateral lobes orbicular; thecae oblong, 1.2–1.5 cm long, white with irregular pink spots, apex rounded, base slightly acute, glabrous dehiscing throughout length. Gynoecium 4.8–5 cm, ovary 0.3–0.5 cm long, minutely pubescent, three celled with many ovules in each cell; style 3.8–4 cm long, glabrous except for ciliate hairs on one side half way long; stigma cup shaped, 0.1cm long and 0.15cm wide, creamy yellow with ciliate hairs in mouth region. Fruits 1.5–1.8 x 1.3 cm, echinate in clusters, glabrous, deep red when mature, many seeded.

Specimen examined: 177854 (MH) 23.vi.2019, INDIA: Kerala: Palakkad District, Walayar forest range, Pudussery North Section, Jamanthimala, 10.863°N & 76.789°E, 559.2m, coll. Aswani & Maya; 7005 (CALI) 23.vi.2019, Palakkad District, Walayar forest range, Pudussery North Section, Jamanthimala, 10.863°N & 76.789°E, 559.2m, coll. Aswani & Maya; 4078 (GVCH), 23.vi.2019, Palakkad District, Walayar forest range, Pudussery North Section, Jamanthimala, 10.863°N & 76.789°E, 559.2m, coll. Aswani & Maya; 4153 (GVCH) 01.vii.2019, Palakkad District, Walayar range, Pudussery North Section, Jamanthimala, 10.864°N & 76.788°E, 561.8m coll. Aswani; 4385 (GVCH) 19.vii.2019, Palakkad District, Walayar range, Akamalavaram section, Malampuzha (Moochikadavu), 10.880°N & 76.703°E, 500.5m, coll. Aswani & Maya.

Flowering: May–July; Fruiting: July–August.

Distribution: India (Karnataka: Kodagu – Pushpagiri Wildlife Sanctuary; Kerala: Palakkad, Walayar, Pudussery North, Jamanthimala; Andaman Islands: Figure 1), Myanmar, Thailand, Vietnam, Indonesia, Malay Archipelago, Malaysia, also extending across Wallace's Line to Sulawesi, New Guinea, and Australia.

Ecology: This plant grows at an elevation of 500–600m in humus-covered semi-evergreen forest floor. Small populations at an average of 20–30 mature plants were observed within a distance of 100m. The taxon was found growing in some restricted localities of Walayar forest range along with *Ancistrocladus heyneanus* Wall. ex J. Graham, *Atalantia monophylla* D.C., *Dioscorea oppositifolia* L., *Cyclea peltata* (Lam.) Hook.f. & Thomson and *Anamirta cocculus* (L.) Wight & Arn.

Discussion

In the Palghat Gap region, exhaustive surveys covering the nearby forest ranges could not locate this species. Recently, this species was reported from Pushpagiri Wildlife sanctuary, Kodagu, Karnataka (Patil & Lakshminarasimhan 2018) and earlier from Andaman & Nicobar Islands (Balakrishnan & Nair 1979). Further, the threat status of the taxon is designated as Least Concern on the IUCN Red List (Olander 2020). As the population is discrete and discontinuous, the most appropriate causes for these disjunctions need to be studied and exhaustive explorations are required to fix the threat status of this taxon.

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