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No. 12, Thiruvannamalai Nagar, Saravanampatti - Kalapatti Road, Saravanampatti,
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Cover (front & back) — Red Panda *Ailurus fulgens* in Anji Bamboo Expo Park at Huzhou City of Zhejiang Province of China. © Rishi Baral.

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ARTICLE

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ORNITHOPHONY IN THE SOUNDSCAPE OF ANAIKATTY HILLS, COIMBATORE, TAMIL NADU, INDIA

Chandrasekaran Divyapriya [1] & Padmanabhan Pramod [2]

[1,2] Nature Education Division, Sálim Ali Centre for Ornithology & Natural History (SACON), Anaikatty (P.O.), Coimbatore, Tamil Nadu 641108, India.
[1] Bharathiar University, Marudhamalai Road, Coimbatore, Tamil Nadu 641046, India.
[1] cdp08india@gmail.com (corresponding author), [2] neosacon@gmail.com

Abstract: An attempt has been made to understand the extent of ornithophony (vocalization of birds) in the soundscape of Anaikatty Hills. The study was limited to 13 hours of daylight from dawn to dusk (06.00–19.00 h) between January 2015 and October 2016. Six replicates of 5-minute bird call recordings were collected from each hour window in 24 recording spots of the study area. Each 5-minute recording was divided into 150 '2-sec' observation units for the detailed analysis of the soundscape. A total of 78 recordings amounting to 390 minutes of acoustic data allowed a preliminary analysis of the ornithophony of the area. A total of 62 bird species were heard vocalizing during the study period and contributed 8,629 units. A total of 73.75% acoustic space was occupied by birds, among which the eight dominant species alone contributed to 63.65% of ornithophony. The remaining 26% of acoustic space was occupied by other biophonies (12.60%), geophony (5.57%), indistinct sounds (7.66%), and anthropogenic noise (0.41%). Passerines dominated the vocalizations with 7,269 (84.24%) and non-passerines with 1,360 (15.76%) units. Birds vocalized in all 13 observation windows, with a peak in the first three hours of the day (06.00–09.00 h). Vocalizations of non-passerines were prominent in the dusk hours (18.00–19.00 h).

Keywords: Acoustic community, bird acoustics, bird vocalization, diurnal singing, ornithophony, soundscape analysis.

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INTRODUCTION

The biological sound produced by vocalizing animals (e.g., birds and stridulating insects (biophony)), non-biological sounds such as wind, rain, running stream (geophony) in a forest or any natural habitat (Hildebrand 2009) constitutes the soundscape of that area (Pijanowski et al. 2011; Gage & Axel 2014). The man-made sounds produced from automobile, machinery (technophony or anthrophony) that dominate in urban settings are rarely detected in forest habitats (Krause 1987; Pijanowski et al. 2011; Gage & Axel 2014). Vocalization of birds (ornithophony) of a terrestrial habitat varies due to the variations in the dominant vocalizers, number of species involved in vocal activity and the time specificity of the birds. It is well known that many species of birds are more vocally active during dawn and dusk hours as they are active in search of food and / or attracting a female partner (Slabbekoorn 2004; Brumm, 2006; Catchpole & Slater 2008; Ey & Fischer 2009). Leaving aside the functionality, ornithophony is observed as one of the dominant aspects of the soundscape of any natural ecosystem, especially in forests.

The vocal communication of the birds was well studied, experimented and the results give insights about the characteristics of avian vocal signals (Aylor 1971; Morton 1975; Wiley & Richards 1978; Brenowitz 1982). The environmental factors such as humidity, temperature, atmospheric turbulence, or vegetation cover influence the signal transfer through masking, absorption, attenuation, reverberation or signal scattering effect (Wiley & Richards 1978). Birds prefer a suitable environmental condition for the effective long-distant signal transfer (Morton 1975; Kroodsma 1977; Brenowitz 1982). As the vocal communication consumes significant energy and time (Prestwich 1994; Oberweger & Goller 2001), animals adapt their vocal signals spectrally, by altering their syllable structure and usage; or temporally, by opting for a better daytime hour for signal transfer (Ficken et al. 1974; Nelson & Marler 1990; Boncoraglio & Saino 2007; Planque & Slabbekoorn 2008; Ey & Fischer 2009; Velásquez et al. 2018). Birds reduce the interference and masking effect of other animal signals such as insects (Stanley et al. 2016), and abiotic noise like wind and water (Klump 1996). Hence, birds have vocal partitioning or an 'acoustic niche' (Brumm 2006; Planque & Slabbekoorn 2008; Luther 2009; Hart et al. 2015). As dawn and dusk hours have a favourable environmental conditions (Morton 1975; Slagsvold 1996; Hutchinson 2002) and enhance long-distant signal transfer (Henwood & Fabrick 1979; Dabelsteen & Mathevon 2002; Brown & Handford 2003), birds probably prefer those hours for consistent signal transfer.

The interaction of biological and non-biological sounds provides the overall framework of the acoustic ecology of a landscape (Pijanowski et al. 2011). Spectral frequency (Hz) analysis is a valid method for interpreting the terrestrial soundscape (Irwin 1990; Nowicki & Nelson 1990; Cardoso 2010; Cardoso & Atwell 2011). Overlapping of sound frequencies of geophony (such as wind, rain) or technophony (automobiles) may mask the biophony signals (Qi et al. 2008; Mullet 2017). Most of the technophony and a few biophonic sounds (birds) occur in lower frequency range 1–2 kHz. Passerines species' frequency ranges between 3 and 6 kHz, whereas insects occupy a higher range, > 6kHz, and all the geophony are of low frequency ranging from 1–11 kHz (Napoletano 2004; Qi et al. 2008; Joo et al. 2011; Kasten et al. 2012; Gage & Axel 2014).

Biophony of the soundscape can be comprehended by examining the temporal framework across the daytime from dawn to dusk (Joo 2008; Joo et al. 2011). It also provides valuable insights on species diversity (Napoletano 2004; Sueur et al. 2008) and ecosystem (Qi et al. 2008). This study is a first step to understand the biophony in the soundscape of Anaikatty Hills through a community acoustics' approach on the ornithophony across daylight hours.

METHODS

Study area

The study area is Anaikatty Hills (11.090–11.097 ^{0}N & 76.778–76.792 ^{0}E; Fig. 1), in Coimbatore District, Tamil Nadu, India, is a part of the Nilgiri Biosphere Reserve (NBR), approximately 500 to 600 m, lies on the leeward side of the Western Ghats. It receives an annual rainfall of about 700mm, which is mainly contributed by the north-east monsoon. The temperature varies from 17˚ C to 36˚ C (Mukherjee & Bhupathy 2007). It is a secondary forest area surrounded by dry deciduous forests rich in biodiversity and forms a part of the Western Ghats, which is one among the 35 biodiversity hotspots of the world (Noss et al. 2015). The study site is dominated by trees such as Ceylon Tea *Cassine glauca*, Woolly-leaved Fire-brand Teak *Premna tomentosa*, Umbrella Thorn *Acacia planifrons*, Neem *Azadirachta indica*, Ceylon Boxwood *Psydrax dicoccos*, Krishna Siris *Albizia amara*, Bidi Leaf Tree *Bauhinia racemosa*, Algaroba *Prosopis juliflora*, and shrubs such as Orangeberry *Glycosmis*

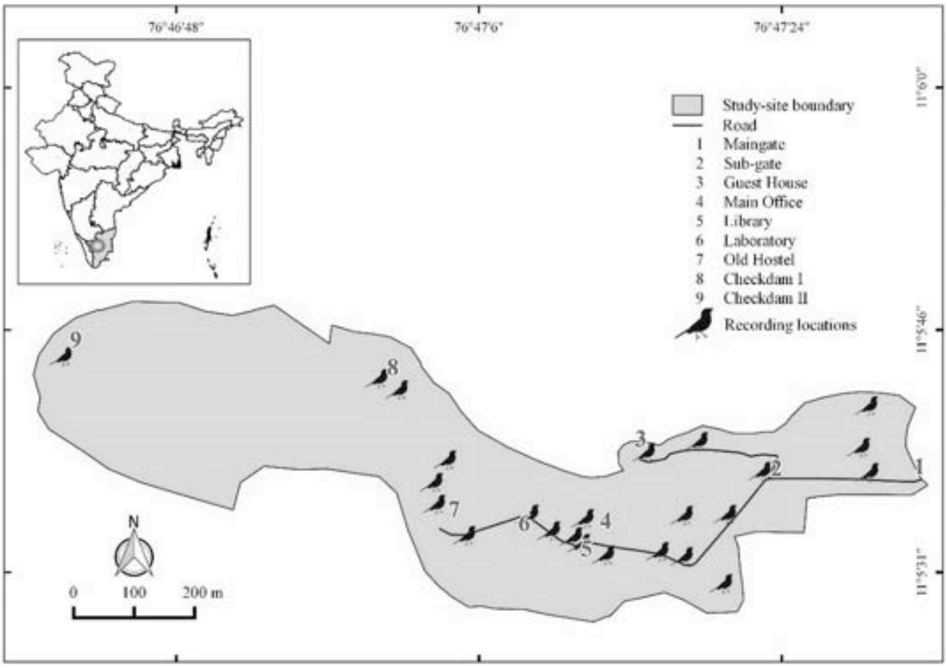

Figure 1. The study location of Anaikatty Hills in India (inset). Map showing the study area with Tamil Nadu State boundary.

mauritiana, *Clausena dentata*, Cat Thorn *Scutia myrtina*, Siam Weed *Chromolaena odorata*, and Lantana *Lantana camara* (Balasubramanian et al. 2017). A total of 145 bird species, from 48 families with 52% of passerine species has been reported from the study site (Ali et al. 2013).

Field methods

The acoustic signals were recorded from 24 different recording spots (Fig. 1) of the landscape to capture the soundscape from the maximum microhabitats from January 2015 to October 2016. The study area is a scrub jungle with dry deciduous forest patches (Ali et al. 2013). Acoustic data was recorded using Sony PCM-M10 portable linear PCM handheld audio recorder (2009), with an Audio-Technica ATR-6550 condenser shotgun microphone in .WAV format with 44.1kHz sampling frequency and 24-bit accuracy rate. The diel pattern of acoustic behavior of birds was observed and calls were recorded from 06.00h to 19.00h spanning 13 hours of a day. The daylight period is segmented into 13 one-hour slots (from henceforth mentioned as 'observation window'). Six replicates of 5-minute bird call recordings were collected from each window, of which each 5-minute call recording is considered as 'a sampling unit'. The first author held the microphone for one minute in each direction to capture the soundscape. The sampling effort is six replications of 13h, makes 78 recordings. The average sampling effort per location was 3.0. The sampling effort is presented in Table 1. The recording date, time and location were noted during the recording period. Recordings were not collected during rainy days. The sunrise and sunset time was 06.00–06.48 h and 17.57–18:51 h, respectively. The sunrise and sunset data were obtained from the official website of Indian Meteorological Department, Government of India.

Data analysis

Each 5-min recording was analysed by dividing it into 150 '2-sec' parts (henceforth mentioned as 'observation unit(s)'). The first author manually investigated each 2-sec unit for capturing the dominant vocalizing bird species. It was a challenging and time-consuming task, however, it helped to understand the soundscape in a much finer resolution. About 90% of the species were identified and the remaining were documented as unidentified species. One second would be too short, whereas 3-sec part would miss out the short vocal signals, hence, 2-sec unit analysis was preferred. The term 'vocal unit' is used to refer to any biophony (animal vocalizations) present in it. The calls/audio signals of (i) individual birds, (ii) unidentified birds, (iii) birds which were identified to their genus category, (iv) gap during the absence of any vocal signal of bird, (v) wind, (vi) vehicle noise, (vii) sound of other animals like Spotted Deer, Indian Palm Squirrel, goat, and (viii) other

Table 1. Sampling effort of the study in Anaikatty Hills.

13 hrs/ 24 loc	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
6–7 h		🟩											🟩			🟩	🟩		🟩					
7-8 h				🟩		🟩						🟩	🟩				🟩							
8–9 h			🟩	🟩						🟩			🟩											
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14–15 h				🟩									🟩	🟩					🟩			🟩	🟩	
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16–17 h		🟩					🟩							🟩					🟩			🟩		
17–18 h		🟩								🟩				🟩							🟩	🟩		
18–19 h											🟩		🟩				🟩		🟩		🟩			

The sampling effort was distributed across 13 hours in 24 locations to capture the soundscape of the study area.

indistinct sounds were also noted in each observation unit. The loud and vocally dominant species in each observation unit was visually classified and considered for further analysis. The vocalizations identified to group level were also considered as separate taxa for broad level classifications, however, they are not included as separate species while accounting for the total number of species vocalized.

The 13 daytime hours were classified into morning (06.00–09.00 h), mid-day (09.00–12.00 h), afternoon (12.00–16.00 h), and evening (16.00–19.00 h) hours. To study the variation on the number of bird species and vocal units across 13 observation windows, ANOVA test (Fisher 1925) with random effect was performed. Kruskal-Wallis test (Kruskal & Wallis 1952) was performed to show statistical proof for significant variation between morning and evening hours against mid-day and afternoon hours. All the statistical tests were performed using SPSS v.16.0 (SPSS Inc. 2007). The sound recordings were analyzed for spectrogram views with the aid of sound analysis software Raven Pro 1.4 (Bioacoustics Research Program 2011) and audio signals were edited using Audacity 2.0.6. software. The spectrogram settings in Raven Pro 1.4 (2011) were as follows: Hann 512, 3dB filter Bandwidth 124Hz, 50% overlap, grid spacing 86.1Hz. The frequency values of bird vocalizations were measured by visual inspection method (Irwin 1990; Nowicki & Nelson 1990; Baker & Boylan 1995; Cardoso & Atwell 2011; Singh & Price 2015).

RESULTS

Soundscape analysis

The acoustic data collected from the field had 78 recordings with a total duration of 390 minutes sampled from multiple locations (24) of the same landscape evenly spread along the 13 different observation windows. This gives 900 observation units per window adding to 11,700 units in total. Visual classification of these observation units yielded a total of 62 bird species' calls (Tables 2, 3). The checklist of species was prepared following Praveen et al. (2019). Passerines dominated all through the 13 day-hours and non-passerines were more vocalizing during 18.00h to 19.00h. Especially, the first three hours had 19, 22, and 20 passerine species (Fig. 2). Thirty-nine passerine species (62.90%) and 23 (37.09%) non-passerine species (Tables 2, 3) were recorded as the vocalizers of the Anaikatty soundscape. Among the total 11,700 observation units, birds occupied 8,629 (74%); of these, passerines occupied 7,269 (84.24%), and non-passerines only 1,360 (15.76%) vocal units (Fig. 3). Of the remaining 26% of the sample, 12.60% was contributed by biophony of other creature such as insects and 5.57% by geophony (wind, indistinct noise). Undetectable or indistinct sounds were 7.66%, and the remaining negligible 0.41% by anthropogenic noise. ANOVA (Fisher 1925) showed that the bird species and vocal units significantly varied across the 13 observation windows, i.e., $F_{12,65} = 4.220$, $p < 0.01$ and $F_{12,65} = 2.251$, $p = 0.019$, respectively. ANOVA (Fisher 1925) showed that the vocalization number of bird species were significantly varied across 13 hours (random effect in ANOVA).

Bird vocalizations across diurnal hours

The number of species recorded vocalizing was high in the initial three hours of the day (Fig. 2). In the first hour of observation, i.e., 06.00–07.00 h, 95% of the time was occupied by bird calls (858 out of 900 observation units), 10.00–11.00 h window received the next maxima with 763 bird vocal units, and in the evening just before the sunset, i.e., 17.00–18.00 h had the next peak with 647 vocal units. (Fig. 3, 4).

The Kruskal-Wallis test showed no significant difference across the bird species between mid-day–afternoon hours against morning–evening hours, χ2 = 3.47, df = 1, p = 0.063 (N = 13). There was no significant variation in vocal units among the tested groups χ2 = 0.73, df = 1, p = 0.39 (N = 13). In any one-hour observational window, a minimum of 16 species was recorded to be vocally active.

Non-passerines were higher at 06.00–07.00 h and declined as the day progressed. There was a peak in their vocalizations during 18.00–19.00 h (Fig. 2). It is to be noted that non-passerine vocal contribution increased from 15.00h onwards (Fig. 3). Among the 13 hours, Indian Pitta was more vocal during 18.00–19.00 h. The 15 species that contributed to dusk calls were either producers of low-frequency calls or harmonics. Totally, 10 species (Yellow-billed Babbler, Jungle Crow, Common Tailorbird, Indian Peafowl, Indian Robin, White-browed Bulbul, Spotted Dove, Red-vented Bulbul, Grey Jungle fowl, and Common Hawk Cuckoo) were observed to be vocalizing both in dawn and dusk time. The low and high frequency values of the 62 species are given in Tables 2 and 3.

Dominance in vocalization

Eight species dominated the ornithophony with 63.65% of vocal units' contribution (Fig. 5 and their statistical analysis is provided in Table 4). Of these, Common Tailorbird, Red-vented Bulbul, Yellow-billed Babbler, Indian Robin, and White-browed Bulbul had vocalized in all 13-hour observation windows (Fig. 5), whereas Purple-rumped Sunbird, Grey-breasted Prinia,

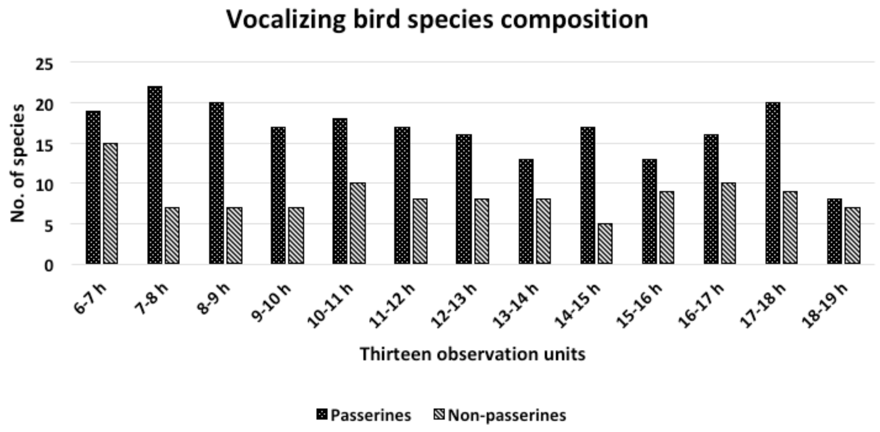

Figure 2. Bird species composition of vocalizing passerines and non-passerines in 13 observation windows.

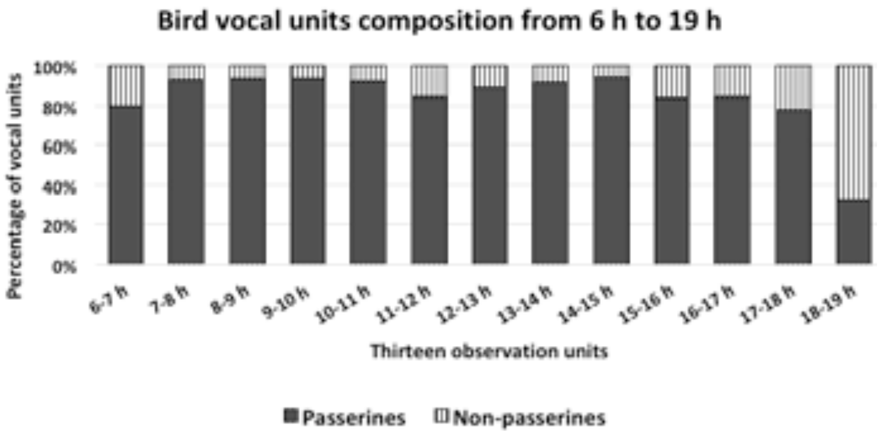

Figure 3. Vocal units of birds across 13 observation windows. Passerines are more in morning 07.00–08.00 h onwards. Non-passerines are more 18.00–19.00 h.

Table 2. List of passerine species of Anaikatty Hills recorded during the study. Birds with harmonics are marked with an asterisk (*). Sample size of the low and high frequencies are 10, except # - sample size 5; ^ - sample size 4.

	Bird species /Family	Scientific name	Low-frequency values (in Hz) (Mean ± S.D.)	High-frequency values (in Hz) (Mean ± S.D.)
	Pittidae			
1	Indian Pitta	*Pitta brachyura*	1662.5 ± 289.5	4662.9 ±3353.1
	Oriolidae			
2	Black-hooded Oriole	*Oriolus xanthornus*	1465.97 ± 798.58	2229.97 ± 564.44
3	Eurasian Golden Oriole	*Oriolus oriolus*	1099.7 ± 408.8	7825.8 ± 6266.1
	Aegithinidae			
4	Common Iora	*Aegithina tiphia*	1589.54 ± 301.49	3432.68 ± 682.08
	Dicruridae			
5	Ashy Drongo*	*Dicrurus leucophaeus*	1661.9 ± 329.3	10420.0 ± 3202.1
6	Greater Racket-tailed Drongo	*Dicrurus paradiseus*	1673.6 ± 118.9	2741.6 ± 53.9
	Laniidae			
7	Brown Shrike*	*Lanius cristatus*	2166.9 ± 504.1	10701.9 ±1479.1
	Corvidae			
8	Rufous Treepie*	*Dendrocitta vagabunda*	815.2 ± 272.5	18059.0 ± 1996.3
9	House Crow*	*Corvus splendens*	1205.1 ± 955.5	3136.6 ± 1317.2
10	Large-billed Crow*	*Corvus macrorhynchos*	1193.6 ± 690.6	2298.2 ± 658.7
	Monarchidae			
11	Indian Paradise-flycatcher*	*Terpsiphone paradisi*	1231.56 ± 262.78	13764.35 ± 1550.62
	Dicaeidae			
12	Thick-billed Flowerpecker	*Dicaeum agile*	2562.6 ± 602.4	14147.4 ± 592.3
13	Pale-billed Flowerpecker	*Dicaeum erythrorhynchos*	3721.5 ± 549.8	11403.5 ± 567.2
	Nectariniidae			
14	Purple-rumped Sunbird	*Leptocoma zeylonica*	3581.8 ± 461.5	6273.3 ± 1006.4
15	Purple Sunbird	*Cinnyris asiaticus*	4145.5 ± 1099.1	7016 ± 734.1
16	Loten's Sunbird	*Cinnyris lotenius*	4145.5 ± 662.3	6643.9 ±1530.6
	Chloropseidae			
17	Jerdon's Leafbird*	*Chloropsis jerdoni*	1844.6 ± 460.3	7736.8 ± 5421.0
	Fringillidae			
18	Common Rosefinch#	*Carpodacus erythrinus*	2060.1 ± 146.1	6003.3 ± 166.8
	Paridae			
19	Cinereous Tit	*Parus cinereus*	2835.5 ± 350.4	8553.6 ± 427.4
	Cisticolidae			
20	Grey-breasted Prinia	*Prinia hodgsonii*	3002.7 ± 329.6	7107.9 ± 325.6
21	Jungle Prinia	*Prinia sylvatica*	2705.6 ± 244.5	6545.5 ± 600.1
22	Ashy Prinia	*Prinia socialis*	2821.5 ± 530.2	6394.2 ± 611.4
23	Common Tailorbird	*Orthotomus sutorius*	2604.27 ± 1153.85	5840.91 ± 833.58
	Acrocephalidae			
24	Blyth's Reed Warbler	*Acrocephalus dumetorum*	2663.7 ± 505.34	7379.51 ± 335.14
	Hirundinidae			
25	Red-rumped Swallow*	*Cecropis daurica*	2719.4 ± 196.9	7807.4 ± 1334.1
26	Barn Swallow*	*Hirundo rustica*	2587.8 ± 597.3	8021.2 ± 2566.4
	Pycnonotidae			
27	Red-whiskered Bulbul	*Pycnonotus jocosus*	1703.8 ± 509.9	3667.3 ± 488.7

	Bird species /Family	Scientific name	Low-frequency values (in Hz) (Mean ± S.D.)	High-frequency values (in Hz) (Mean ± S.D.)
28	Red-vented Bulbul	*Pycnonotus cafer*	1562.8 ± 194.1	3062.5 ± 393.1
29	White-browed Bulbul	*Pycnonotus luteolus*	1256.8 ± 227.8	3707.7 ± 504.8
	Phylloscopidae			
30	Greenish Leaf Warbler	*Phylloscopus trochiloides*	3438.2 ± 716.6	7505.9 ± 1717.6
	Timaliidae			
31	Indian Scimitar Babbler*^	*Pomatorhinus horsfieldii*	622.7 ± 116.9	1300.2 ± 248.2
32	Tawny-bellied Babbler	*Dumetia hyperythra*	3475.0 ± 554.3	6443.7 ± 193.6
	Leiothrichidae			
33	Yellow-billed Babbler*	*Turdoides affinis*	3702.7 ± 518.8	9946.6 ± 2710.5
	Sturnidae			
34	Common Myna*	*Acridotheres tristis*	1399.8 ± 393.8	10244.5 ±3148.6
35	Jungle Myna*	*Acridotheres fuscus*	1368.7 ± 204.5	9803.4 ± 3469.0
	Muscicapidae			
36	Indian Robin	*Saxicoloides fulicatus*	5034.9 ± 1375.7	7261.5 ± 642.1
37	Oriental Magpie Robin*	*Copsychus saularis*	2399.4 ± 320.9	6770.0 ± 2349.3
38	Tickell's Blue flycatcher	*Cyornis tickelliae*	3095.0 ± 206.8	7318.3 ± 1788.8
39	Pied Bushchat	*Saxicola caprata*	2037.4 ± 349.7	5089.6 ± 849.5

Figure 4. Distribution of bird vocal units in the study area shows that the early hours have more vocal units with second peak at 10.00–11.00 h and a third maxima at 17.00–18.00 h.

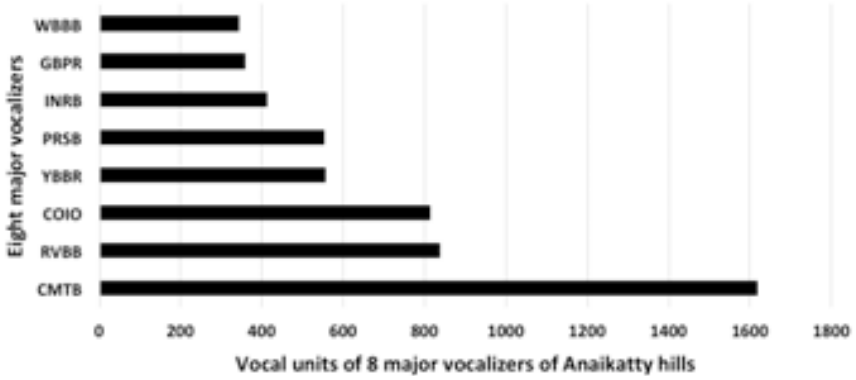

Figure 5. Vocal units of the eight most vocalizing resident passerines of Anaikatty Hills. CMTB—Common Tailorbird | RVBB—Red-vented Bulbul | COIO—Common Iora | YBBR—Yellow-billed Babbler | PRSB—Purple-rumped Sunbird | INRB—Indian Robin | GBPR—Grey-breasted Prinia | WBBB—White-browed Bulbul. These common vocalizers together occupied 63.65% of total birds' vocal participation of Anaikatty Hills.

and Common Iora were absent in the 18.00–19.00 h window. Common Tailorbird dominated the soundscape of the study area with 1,619 vocal units (Fig. 5), i.e., 18.76% vocal signal contribution and was present in 74 out of 78 recordings. White-browed Bulbul's vocal signals were present in 66 recordings, occupied just 3.97% of total ornithophony (Table 4). Indian Paradise-flycatcher was found only in a 5-min recording. They produce several quick high-pitched notes and hence, occupy several observation units (40) in a single utterance. The Common Rose-finch, Blue-bearded Bee-eater, Rose-ringed Parakeet, Indian Golden Oriole, Ashy Drongo, Plum-headed Parakeet, Tawny-bellied Babbler, Greater Racket-tailed Drongo, and Barn Swallow were observed in only one of the recordings.

Fifteen non-passerines were recorded vocalizing during the dawn hour (06.00–07.00 h), after that non-passerine composition declined in the subsequent hours (Fig. 2). It is to be noted that non-passerines vocal contribution slightly increased from 15.00h onwards (Fig. 3). Indian Peafowl, Grey Francolin, Grey Junglefowl, Red-wattled Lapwing, Jerdon's Nightjar, and Common Hawk Cuckoo were the dominant non-passerines during the 18.00–19.00 h window and were at low ebb or almost nil during other hours. Indian Peafowl was the only non-passerine to be vocally active in all 13 observation windows, the Grey Francolins were present in seven out of 13 observation windows, and the Grey Junglefowl calls were recorded in six observation windows. Indian Pitta being a winter visitor and lower song rate species had fewer vocal units in the present study. Figure 6 shows the number of bird species' spread in each observation window. The 06.00–08.00 h window had more bird species, whereas, 18.00–19.00 h had the least. Figure 7 depicts the vocal units' data spread. Vocal units at 09.00–10.00 h, 12.00–13.00 h, and 18.00–19.00 h were relatively more variable than other observation hours.

DISCUSSION

Soundscape analysis

The study area, a scrub jungle in a dry deciduous landscape, had more of sound than silence in day hours. The sounds of birds dominated 74% of the time in the study area, especially in the initial three hours. We have recorded other biophony and indistinct, undetectable sound sources from the study area. The indistinct sounds in the study area could be relatively short-bursts of wind or sound produced by any other vocalizing animal. Earlier studies say that the forest environment has lesser decibel (Aylor 1971; Marten & Marler 1977; Marten et al. 1977) as background sound than in urban areas (Brumm & Slabbekoorn 2005; Brumm 2006). The terrestrial habitats are prone to low-frequency noise caused by air turbulence, rain, running water (Brumm & Slabbekoorn 2005) and other biotic noises (Slabbekoorn 2004). The omnipresent cicadas and their concert produce a constant spectrum of background noise (Slabbekoorn 2004). Therein, the biophony generally ranges between 2kHz and 11kHz (Napoletano 2004; Qi et al. 2008; Joo et al. 2011; Kasten et al. 2012; Gage & Axel 2014). Mullet et al. (2016) clarify that the high-frequency vocalizing passerines can be effectively distinguished from low-frequency producers through a spectrogram analysis. To avoid the biological or non-biological sound frequency overlap, birds utilize different acoustic niches to broadcast the information (Krause 1987; Qi et al. 2008; Luther 2009).

This acoustic diversity study assessed the ornithophony distribution across day hours. Anaikatty soundscape has 86.60% of biophony. Gage & Axel's (2014) soundscape power analysis study of Cheboygan County soundscape showed that the biological sounds attributed to 80% of total eco-acoustics. The frequency-dependent acoustic analysis corroborates that ornithophony occupies the 2–8 kHz of spectral bandwidth (Napoletano 2004; Qi et al. 2008; Gage & Axel 2014). Thus, acoustic diversity study across the day hours will assess the ornithophony distribution and assess the soundscape framework of a habitat.

Bird vocalizations across diurnal hours

More number of species showed acoustic activity in dawn and dusk hours; however, the vocal units were not significantly different across 13 hours. The soundscape of the study area had higher bird vocalizations in the early three hours (0600–09.00 h). The temperature, wind, humidity is more advantageous with least atmospheric turbulence and less background noise during dawn, thus enhancing the signal transmission (Morton 1975; Kroodsma 1977; Krebs & Davies 1981; Slagsvold 1996; Hutchinson 2002; Luther 2009; Hart et al. 2015). Early hour bird vocalizations were observed in Arizona and in Kutai Nature Reserve, Borneo (Henwood & Fabrick 1979), deciduous forest in Denmark (Dabelsteen & Mathevon 2002), open grassland and closed forest habitat in Ontario (Brown & Handford 2003), and upland pasture at New York (Brenowitz 1982). Moreover, the dawn (and dusk) chorus gives the advantage to use the energy reserve unused since the previous night (McNamara et al. 1987; Hutchinson 2002). Dawn

Table 3. List of non-passerine species of Anaikatty Hills recorded during the study. Birds with harmonics are marked with an asterisk (*). The sample size for low and frequencies of the species are ten, except ^ - sample size is 8.

	Bird species /Family	Scientific name	Low-frequency values (in Hz) (Mean ± S.D.)	High-frequency values (in Hz) (Mean ± S.D.)
	Phasianidae			
1	Indian Peafowl*	*Pavo cristatus*	551.36 ± 84.9	10284.2 ± 891.5
2	Grey Francolin*	*Francolinus pondicerianus*	1908.2 ± 106.1	6700.1 ± 1873.2
3	Grey Junglefowl*	*Gallus sonneratii*	763.5 ± 647.6	8009.7 ± 4212.4
	Columbidae			
4	Spotted Dove	*Streptopelia chinensis*	569.0 ± 44.2	837.9 ± 39.6
5	Laughing Dove	*Streptopelia senegalensis*	640.8 ± 26.4	886.1 ± 22.9
	Caprimulgidae			
6	Jerdon's Nightjar	*Caprimulgus atripennis*	574.9 ± 41.2	1476.0 ± 30.8
	Cuculidae			
7	Greater Coucal	*Centropus sinensis*	398.0 ± 102.5	870.5 ± 233.4
8	Asian Koel*	*Eudynamys scolopaceus*	982.3 ± 75.49	10473.3 ± 4694.39
9	Common Hawk Cuckoo	*Hierococcyx varius*	1510.81 ± 357.50	2225.95 ± 280.65
	Charadriidae			
10	Red-wattled Lapwing*	*Vanellus indicus*	1490.9 ± 431.3	8282.1 ± 4678.9
	Accipitridae			
11	Crested Serpent Eagle*	*Spilornis cheela*	1806.7 ± 91.9	6317.6 + 1242.54
12	Shikra*	*Accipiter badius*	1472.9 ± 453.0	13709.4 ± 1980.1
	Upupidae			
13	Common Hoopoe	*Upupa epops*	795.0 ± 410.2	1621.1 ± 1052.1
	Megalaimidae			
14	White-cheeked Barbet	*Psilopogon viridis*	940.8 ± 61.7	1307.6 ± 40.2
15	Coppersmith Barbet	*Psilopogon haemacephalus*	633.8 ± 25.1	898.1 ± 25.4
	Meropidae			
16	Blue-bearded Bee-eater	*Nyctyornis athertoni*	586.17 ± 80.15	3740.23 ± 695.06
17	Green Bee-eater	*Merops orientalis*	2781.7 ± 219.5	4373.6 ± 241.5
18	Chestnut-headed Bee-eater	*Merops leschenaulti*	2538.88 ± 113.84	3590.01 ± 215.33
	Alcedinidae			
19	White-throated Kingfisher*	*Halcyon smyrnensis*	2436.2 ± 105.3	7272.7 ± 2739.7
	Psittaculidae			
20	Plum-headed Parakeet*^	*Psittacula cyanocephala*	1828.0 ± 468.1	6735.8 ± 1347.2
21	Malabar Parakeet*	*Psittacula columboides*	2571.6 ± 165.1	4199.9 ± 277.9
22	Rose-ringed Parakeet*	*Psittacula krameri*	2047.4 ± 798.9	8566.3 ± 1257.9
23	Vernal Hanging Parrot*	*Loriculus vernalis*	6261.7 ± 571.0	7948.1 ± 179.5

chorus also has reproductive benefits such as attracting a mate and deter other potent males to get access to the partner (Slagsvold 1996; Catchpole & Slater 2008), to defend territory and nest site from conspecific males (Slagsvold 1996).

Low frequency and/or harmonic producing birds' vocalizations dominated the dusk hour (18.00–19.00 h; Tables 2,3). Low frequency vocalizations of birds and amphibians dominated during the night at Cheboygan County, Michigan (Gage & Axel 2014). Harmonics increases the difficulty in locating the calling bird (Blindfolded birdwatching 2010), thus avoiding predatory attacks. As the visual cues are undependable during the sunset hour (Kacelnik 1979), low frequency gives an advantage for long-distance signal propagation (Aylor 1971; Morton 1975; Marten & Marler 1977;

Table 4. Descriptive statistics of the eight most vocalizing passerines of the study area.

Bird sp.	Mean	Std. Dev.	Co-efficient of Variation (CV)	Min	Max	No. of presence among 78 recordings	No. of vocal units
Common Tailorbird	20.76	15.43	74.32	1.00	61.00	74	1619
Red-vented Bulbul	10.73	10.36	96.53	1.00	45.00	69	837
Common Iora	10.42	16.47	158.06	1.00	63.00	52	813
Yellow-billed Babbler	7.13	10.47	146.83	1.00	58.00	54	556
Purple-rumped Sunbird	7.09	11.61	163.72	1.00	68.00	52	553
Indian Robin	5.31	7.99	150.55	1.00	36.00	55	414
Grey-breasted Prinia	4.59	9.60	209.14	1.00	41.00	29	358
White-browed Bulbul	4.40	4.19	95.38	1.00	18.00	66	343

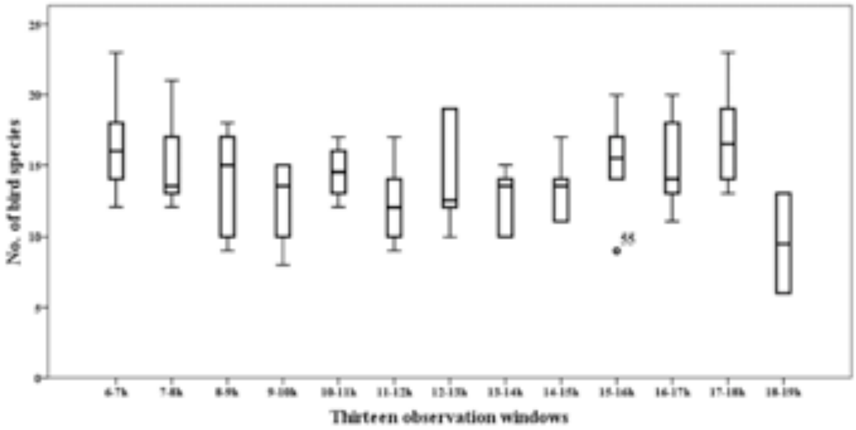

Figure 6. Vocalizing bird species per sampling unit of 13 observation windows.

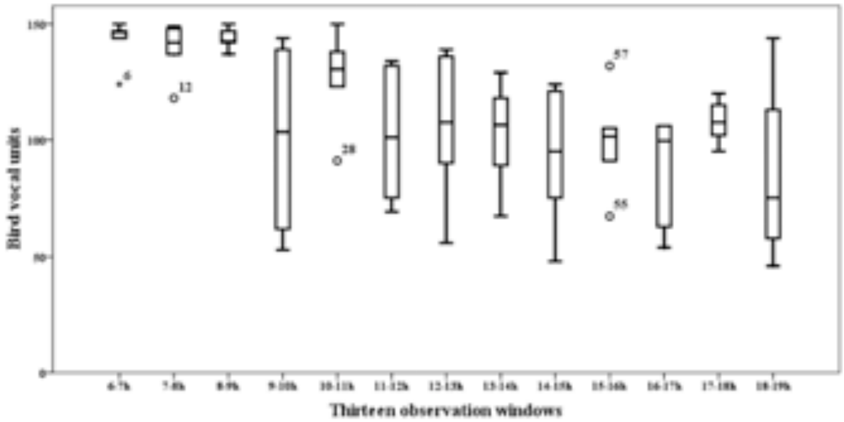

Figure 7. Bird vocal units per sampling units of 13 observation windows.

Martenet al. 1977; Wiley & Richards 1982; Wiley 1991). Song activity at dusk increases the pair-bonding behavior in American Robins (Slagsvold 1996), and in Blackbird (Cuthill & Macdonald 1990). A peak in dawn and dusk vocal activity suggest that these hours are important for a male to guard the mate and nest site (Sturkie 1976; Mace 1986, 1987; Cuthill & Macdonald 1990). Soundscape peaked at dawn chorus (06.00–07.00 h), then dropped shortly after sunrise, till evening and once again raised during dusk hours and reached second maxima at 20.00h in Cheboygan County, Michigan (Gage & Axel 2014).

Dominance in vocalization

The Common Tailorbird was the most dominant vocalizer of the landscape as their calls were louder and have a higher song rate, i.e., the number of call syllables produced in a minute. All the eight dominant species vocalize continuously. The passerines are louder and are continuous vocalizers (Garamszegi & Møller 2004; Catchpole & Slater 2008; Cardoso 2010). Seven of the dominant species are forage generalists and were vocally active all through the day yielding a higher vocal unit. The early hours had uniform vocal units' contribution per observation window. Increased variability of vocal units during 09.00–10.00 h, 12.00–13.00 h, 14.00–15.00 h, and 18.00–19.00 h could be attributed to relatively variable number of vocalizers (Fig. 7). This might also show the need of more sampling efforts.

The 16.00–17.00 h observation window had more non-passerines (11 species) yielding fewer vocal units, whereas, passerines were predominant in the study area with more vocal units. More vocal units and complexity exhibits the versatility of passerine birds (Garamszegi & Møller 2004; Boncaraglio & Saino 2007; Catchpole & Slater 2008; Cardoso 2010), as they are louder (Calder 1990; Cardoso & Mota 2009; Cardoso 2010) and are continuous vocalizers (Hartley & Suthers 1989; Irwin 1990; Podos 1997; Forstmeier et al. 2002). This makes passerines to occupy a larger portion of the soundscape of Anaikatty Hills in general.

Song rate analysis is beyond the scope of this present study, however, any trained ears could relatively understand the song rate of bird calls. The study which aimed at understanding the vocal activity pattern of diurnal birds illustrates that the soundscape of Anaikatty is largely occupied by birds in those hours.

CONCLUSIONS

Birds occupy 73.75% of acoustic space in the soundscape of Anaikatty Hills and the remaining 26.25% includes the vocal activity of insects, other indistinct sounds or complete silence. Thirty-nine passerine species (62.90%) and 23 non-passerine species (37.09%) vocalized in the sampled soundscape of the study area. The eight dominant species constitutes 63.65% of ornithophony of the study area. Out of the total sampled ornithophony, passerines occupied 84.35% and non-passerines 14.74% of the vocal units. Birds vocalized in all 13 daylight hours, with a peak in the first three hours of the day (06.00–09.00 h). Passerines dominated the soundscape in all hours except the dusk 18.00–19.00 h.

Limitation of the study

The sampling effort was done to answer the preliminary account of ornithophony of the soundscape of the region. Though the researcher intentionally did not direct the microphone towards the vocalizing bird, the usage of shotgun microphone might have had an effect on the calling bird. Though the researcher had sampled the 5-min by directing the microphone in all directions, the shotgun microphone was a limitation for the soundscape study compared to the omnidirectional microphone.

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A case study on the public knowledge and awareness of the Philippine Pangolin *Manis culionensis* (Mammalia: Pholidota: Manidae)

Frances Mae Tenorio [1] & **Joselito Baril** [2]

[1,2] Institute of Biological Sciences, College of Science, University of the Philippines Los Banos, Batong Malake,
Los Baños Laguna 4031, Philippines.
[1] fbtenorio@up.edu.ph (corresponding author), [2] joeybaril@yahoo.com.ph

Abstract: Pangolins are poorly known species despite their high demand in the illegal international trade. This study has been conducted to analyze the awareness of Filipinos towards the endemic Philippine Pangolin *Manis culionensis* and how much they would be willing to contribute to its conservation. The respondents were selected from the social media reach of the researchers. The results showed that most of the respondents know about the pangolin from mass media such as news from television. Social media is also a factor in their awareness of the animal. They unanimously agreed that pangolins are important ecologically rather than its medicinal value in the illegal market trade. Overall, the respondents showed a high degree of knowledge of pangolins and have favorable attitudes towards its conservation.

Keywords: Conservation, *Manis*, social media, trade.

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Author details: Frances Mae Tenorio is currently an MS in wildlife studies student. Her researchinterests are animal behavior, behavioral ecology, anthrozoology, and environmental psychology. Joselito Baril is currently an Assistant Professor in the Animal Biology Division. He specializes in conservation biology, genetics, vertebrate biology and environmental science. His research interests include conservation genetics and behavioral ecology.

Author contribution: FMT conceptualized and designed the study, gathered data, performed statistical analysis and interpretation, wrote the draft and revisions of the manuscript. JB provided revisions to the scientific content and is the adviser of the study.

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INTRODUCTION

There are only eight extant species of pangolins in the world (Lim & Ng 2007). Unfortunately, all pangolin species are in high demand for international illegal trade, most especially in China, making them the most visible and most voluminous mammals in trade. They are traded for skin (leather goods like boots and shoes), scales (traditional medicine), and meat (food and traditional medicine) (Schoppe & Cruz 2009).

Among the eight species, only one species is found in the Philippines. The Philippine Pangolin *Manis culionensis*, locally known as Balintong, is endemic to the Palawan faunal region (Lagrada et al. 2015). It occurs in lowland primary and secondary forests, grassland/secondary growth mosaics and mixed mosaics of agricultural lands and scrubland adjacent to secondary forests (Esselstyn et al. 2004; Heaney et al. 1998). It is currently classified as Endangered by the IUCN Red List (2015) and under Appendix I of the Convention on the International Trade of Endangered Species of Flora and Fauna (2016) (CITES). Currently, there is an increase in the demand in the local trade for live pangolins. In November 2017, two individuals were found in Manila and taken into custody by the Biodiversity Management Bureau (BMB). This year, five individuals were found again in Manila and were surrendered to BMB. All individuals were allegedly caught to be sold as delicacy for private individuals (Sy pers. comm. 05 March 2018).

Conservation in the Philippines is inextricably linked to social and political issues. The country was long under colonial rule, and its natural resources were traditionally controlled by the elite and powerful, whose unsustainable and inequitable exploitation devastated the environment and marginalized the poor (Broad & Cavanagh 1993; Pineda-Ofreneo 1993). But considerable progress in environmental protection legislation has been made, driven in part by public advocacy. Of significance to biodiversity conservation are the National Integrated Protected Areas System (NIPAS) Act of 1992, the establishment of protected areas, and the 2002 Wildlife Resources Conservation and Protection Act. At the international level, Philippines is one among the signatories to the Convention on Biological Diversity and other agreements such as CITES, and the Ramsar Convention on Wetlands (Posa et al. 2008). With the on-going efforts of the government and conservation groups, public interest in biodiversity conservation has increased.

In 2017, Gamalo et al. conducted a case study on the Philippine Wildlife and wildlife laws' awareness in tertiary education. In the study, it was found that the Philippine Pangolin is among the endemic wildlife which were poorly known to the students. Since the decline of pangolin populations is due to anthropogenic pressures such as illegal trade, poaching, and deforestation, it is important to determine the public knowledge and perception towards the animal. Thus, this study is aimed at determining the public knowledge on the Philippine Pangolin and their awareness of the plight of this poorly studied species. It is also aimed to identify the willingness of the public to participate in the conservation of pangolins. The data collected will help in creating a suitable campaign and awareness programs for the Philippine Pangolin.

METHODS

An online survey, created through Google forms, was used for the collection of data. Google forms was selected since it is easy to operate, and the survey generated can be easily answered by the respondents. The survey was disseminated via Facebook and Twitter. The survey was opened online and shared for one month to allow a large number of respondents to access the survey. A total of 169 respondents from various regions all over the Philippines answered the survey. These respondents were from regions where no pangolin is found. It should be noted, however, that the respondents from this survey were selected from the researchers' social media reach and does not reflect the general populations' knowledge and awareness about the Philippine Pangolin.

The survey questionnaire is composed of 14 questions which is divided into three sections: knowledge on pangolins, awareness on laws protecting the pangolin, and willingness to participate in conservation activities related to the Philippine Pangolin.

All statistical analyses were done using R Studio version 3.4.3 (R Core Team, 2018). Percentage was taken using package 'prettyR' (Lemon & Grosjean 2018).

RESULTS

Out of the 169 respondents, a total of 83 males and 86 females answered the online survey on pangolins (Table 1). Most of the respondents were aged 21–30 years. Majority of the respondents had attained tertiary level education (66.3%). Based on location, 49.1% are from National Capital Region (NCR), while 23.1% are

Table 1. Demographic characteristics of respondents (n=169).

	Category	Overall %
Gender	Male	49.11
	Female	50.89
Age	12–20	28.67
	21–30	51.48
	31–40	14.2
	41–50	2.96
	51 and above	2.37
Educational Attainment	Secondary	12.13
	Tertiary	66.27
	Post graduate (MS)	18.24
	Post graduate (PhD)	2.37
Region	NCR	49.11
	Region IV-A	23.08
	Region III	10.06
	Region IV-B	4.14
	Region V	2.37
	Region VI	2.37
	Region XIII	2.37
	Region VII	1.78
	Region XI	1.78
	Region XII	1.18
	CAR	0.59
	Region IX	0.59
	Region X	0.59
Monthly income	Not applicable	40.24
	10,000 PHP and below	10.65
	11,000 – 20,000 PHP	17.75
	21,000 – 30,000 PHP	15.98
	31,000 – 40,000 PHP	6.51
	41,000 – 50,000 PHP	2.96
	51,000 and above	5.92

Table 2. Respondents' answers to whether they know the animal in the photo or not (N=169).

	Overall %
Yes	74.56
No	25.44
Pangolin	63.90
Armadillo	11.24
Philippine pangolin	7.69
Palawan pangolin	3.55
Anteater	2.96
Porcupine	1.18
Balintong	0.59
I don't know	2.37

Table 3. Respondents' answers to whether they think a pangolin is beneficial or harmful (N=169).

	Overall %
Yes, it is beneficial	99.41
No, it is harmful	0.59
Ecological	87.57
Cultural	4.14
Medicinal	1.18
Don't know	7.1

from Region IV-A (CALABARZON) and 10.1% are from Region III (central Luzon).

Knowledge of pangolins

Majority of the respondents (74.56%) claimed to know the animal shown in the survey; the popular answers included the pangolin and armadillo (Table 2). The respondents were also asked whether they knew what the animal in the photo ate. Many of the answers included insects, ants, and termites. In terms of encounter, the respondents were more likely to encounter a pangolin on the internet, television, educational materials, and through Facebook.

Many stories and myths generated from the relationships between animals and man had been passed on from generation to generation (Setlalekgomo 2014). Based on the responses, it was found that medicinal use is the most widely known belief associated with pangolins. Setlalekgomo (2014) noted that pangolins were used as bush meat and different body parts of pangolins were used in traditional medicine by indigenous people. Pangolins were used in traditional medicine to cure several human ailments as well as being used in charm making. The respondents, however, unanimously agreed (99.41%) that the pangolin is beneficial due to its ecological role in the environment (87.57%) (Table 3).

Awareness on laws protecting pangolins

Several of the respondents have noted that they have seen a pangolin being traded (19.53%) by adults. It was made clear in this study that the respondents know that this animal is protected by law (85.8%) through their educational background and knowledge of the laws on wildlife and its trade (68.64%).

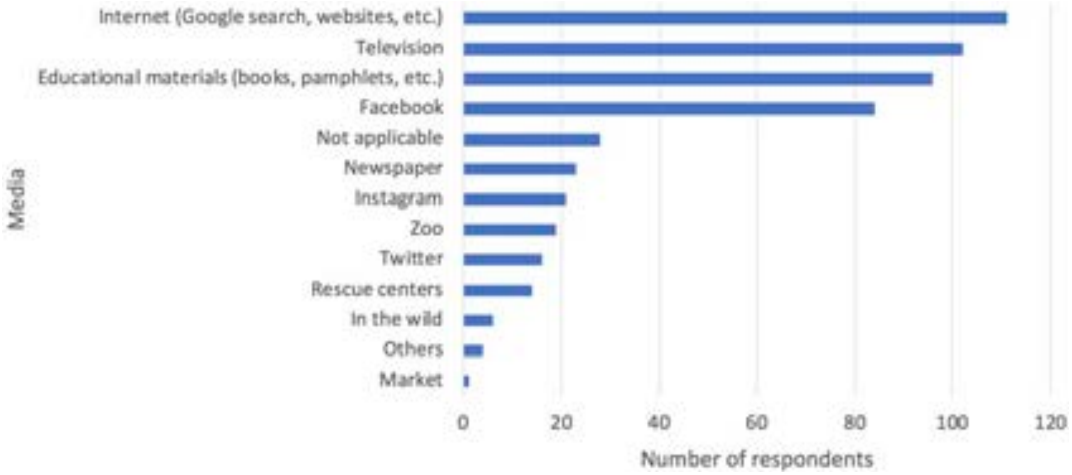

Figure 1. Media where the respondents saw a pangolin

Table 4. Respondents' answers to participate in conservation activities (N=169).

		Overall %
Willingness to donate	Yes	91.7
	No	8.3
	In kind	68.6
	Monetary	31.4
Willingness to volunteer	Yes	94.08
	No	5.92
	Awareness through social media	78.1
	Educational campaigns	60.9
	Research	59.2

Willingness to participate in conservation of pangolins

The respondents were willing to donate in kind to the conservation of pangolins. Majority of the respondents were willing to volunteer to conserve pangolins (94.1%) through awareness on social media platforms, educational campaigns, and research (Fig. 1).

DISCUSSION

Communication has been used throughout human history to impart information, teach skills, influence attitudes and perceptions, moderate debate and disagreement, create connections between individuals and groups, inspire new ideas, and facilitate cultural and behavioral changes (Anderson-Wilk 2009). It is often cited for its role in creating change (King 2003; Rogers 2003). At the core of a conservation movement is a communication movement. This is primarily because conservation requires change, and change requires communication (Anderson-Wilk 2009). Communication can be channeled through mass media such as television and radio, literature such as articles and books, and social media. Media particularly television has the largest impact on the familiarity of respondents with wildlife. Television shows on channels such as National Geographic, Discovery Channel, Animal Planet, BBC Earth, Born to be Wild and local and international news feature wildlife. Mass media often targets a wide range of audience and is effective at creating initial awareness and interest (FAO 2006).

The high degree of knowledge of the respondents shows that the use and influence of electronic media such as television and internet have a positive impact on the knowledge on pangolins. According to Brossard & Scheufele (2013), the news media portrayal of wildlife is related to public conservation awareness and shows good or positive content of intervention information. This may strengthen environmentally-favorable behavior, thereby increasing the public's knowledge on biological conservation (Shiffman 2012; Fauville et al. 2014; Bombaci et al. 2015; Minin et al. 2015). The news media have different types of coverage and portrayal of wildlife issues (Muter et al. 2013), which could direct the public's attitudes towards conservation (Wu et al. 2018). This is shown by the high number of respondents knowing that the pangolin is an animal that should be protected and conserved.

Creating a conservation education movement to connect between people with nature is not easy (Abd Mutalib et al. 2013). Finding a balance between monetary values with conservation value might be difficult, and requires an in-depth understanding of the aspects such as carrying capacity, demographic structures, and conservation interests (Humavindu & Stage 2014). Social demographics such as age, gender, level of education, monthly income and years at residence play an important role in the determination of the level of awareness towards wildlife, and often act as behavioral predictors (Thornton & Quinn 2009; Loyd & Miller 2010; Mahmood-ul-Hassan et al. 2011; Shumway et al. 2014). In this study, however, social demographics do not have any implications on the knowledge and awareness on pangolins based on the age, educational attainment and monthly income of the respondents.

Social media such as Facebook shows that social media is a great tool in spreading knowledge and awareness on pangolins. Currently, there are 47 million active users of Facebook in the Philippines. Convenient social platforms such as Facebook are believed to have a great power in impacting on public awareness on wildlife conservation. In fact, studies have shown that even conservation science information extracted from professional conferences can be delivered to more audience via social media forums such as Twitter (Shiffman 2012; Bombaci et al. 2015; Wu et al. 2018). The data on social media can potentially play an important role in conservation since it can be used to learn more about the spatio-temporal patterns, values, and activities related to biodiversity conservation of different groups of people. Moreover, social media can directly target specific citizen science campaigns (Minin et al. 2015).

Citizen science is defined as the practice of engaging the public in a scientific project – a project that produces reliable data and information usable by scientists, decisionmakers, or the public that is open to the same system of peer review that applies to conventional science (McKinley et al. 2017). Citizen scientists can spread knowledge among their friends, family, and colleagues by sharing their citizen science activities and discussing the issues (Nerbonne & Nelson 2004; Overdevest et al. 2004; Johnson et al. 2014; Forrester et al. 2016) on pangolins. The respondents were willing to volunteer out of moral obligation, gaining knowledge, passion and compassion towards animals, satisfaction, advocacy, and research background. They chose volunteering to raise awareness through social media because of its wider audience capacity, low-cost effectiveness, viability, and easy use.

Respondents were likely to conserve and protect pangolins due to its ecological importance, endemism, rarity, intrinsic value, inherent value, aesthetic value, economic benefits through ecotourism, cultural value, and conservation status. The respondents also believe that pangolins are needed to maintain biodiversity and are equally important species that needs conservation to prevent extinction.

According to the respondents, awareness through dissemination of information via social and mass media, and seminars and orientations, baseline research, protection of natural habitat, and strict enforcement of law are the programs needed to protect and conserve pangolins.

CONCLUSION

Public awareness on wildlife is essential to the effectiveness of wildlife conservation and protection. The respondents were well aware of the Philippine Pangolin and had favorable attitudes towards wildlife protection and conservation. The awareness on wildlife were most likely due to mass media and social media. This implies that these media should be used by conservationists and conservation groups to promote and disseminate information regarding wildlife.

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WINTER FOOD HABITS OF THE COMMON PALM CIVET *PARADOXURUS HERMAPHRODITUS* (MAMMALIA: CARNIVORA: VIVERRIDAE) IN PATNA BIRD SANCTUARY, INDIA

Khursid Alam Khan[1], **Jamal Ahmad Khan**[2], **Khursheed Ahmad**[3] & **Narendra Mohan**[4]

[1,2] Department of Wildlife Sciences, Near Sir Syed House, Aligarh Muslim University, Aligarh, Uttar Pradesh 202002, India.
[3] Division of Wildlife Science, Faculty of Forestry, Benihama, Sher-e-Kashmir University of Agriculture Science and Technology, Benihama , Ganderbal, Jammu & Kashmir 191201, India.
[1,4] Wildlife Institute of India, Chandrabani, Dehradun, Uttarakhand 248001, India.
[1] khursid.amu@gmail.com (corresponding author), [2] secretorywsi@gmail.com, [3] khursheed47@gmail.com, [4] narendrawls@gmail.com

Abstract: Food habits of the Common Palm Civet *Paradoxurus hermaphroditus* were investigated using scat analysis method, a technique widely used to study small and medium sized mammals. We analyzed 112 scats of Common Palm Civet between November 2012 and March 2013 from the Patna Bird Sanctuary and found a total of nine food items. Out of 112 scats, 32.09% scats contained three food items, 29.62% scats had two items, 24.69% scats contained four prey items, and 3.7% scats had seven prey items. The results show that the Common Palm Civet is more frugivorous (ca. 39.28%) than insectivores (ca. 29.46%). Percent frequency of occurrence showed that insects contributed maximum in the diet of Civet (29.46±2.29) followed by fruits of *Ficus religiosa* (19.64±1.13), *Prosopis juliflora* (11.60±0.18), and Date Palm (*Phoenix sylvestrix)* (8.03±0.23), while birds contributed 9.82±0.02 and rodents 6.25±0.44. Rufous-tailed Hare (*Lepus nigricollis ruficaudatus*) (1.78±0.96) contributed the minimum in the Common Palm Civet diet. PBS is an Important Bird Area site and it harbours thousands of migratory birds during winter. But the results show that birds are a less preferred diet item of the Common Palm Civet.

Keywords: Civet, diet, food preference, frugivorous, insectivores, scat analysis, Uttar Pradesh.

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Author details: MR. KHURSID ALAM KHAN is a PhD scholar in Department of Wildlife Sciences, Aligarh Muslim University, and currently working as a Project Associate in Wildlife Institute of India Dehradun. He has completed his masters and MPhil degree in Wildlife sciences Aligarh Muslim University, Aligarh. DR. JAMAL A. KHAN is a Chairman and Professor in Department of Wildlife Science, Aligarh Muslim University, Aligarh. DR. KHURSHEED AHMAD is a Head of Division in Division of Wildlife Science, Benihama, Ganderbal, SKUAST-K, Jammu & Kashmir, India. MR. NARENDRA MOHAN is field biologist in Wildlife Institute of India Dehradun.

Author contribution: The data was collected by KAK and NM, while the analysis and paper writing is done by KAK under the supervision of JAK and KA.

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INTRODUCTION

There are eight species of civets found in India (Prater 1971; Menon 2014). Among them, the Common Palm Civet *Paradoxurus hermaphroditus* (Viverridae) is a small size carnivore with widespread distribution in central, southern and southeastern Asian countries including Bangladesh, Bhutan, Brunei Darussalam, Cambodia, China, India, Indonesia, Lao People's Democratic Republic, Malaysia, Myanmar, Nepal, Philippines, Singapore, Sri Lanka, Thailand, and Vietnam (Pocock 1933; Duckworth et al. 2016). In India, the Common Palm Civet is distributed throughout except in the desert zone and Punjab and lives in tropical forests, plantations, fruit orchards and human-settlements, often residing in eaves of houses or outbuildings (Prater 1971; Menon 2014). Although widely distributed in Asia, the Common Palm Civet is a less studied animal in comparison to other carnivores (Joshi et al. 1995) and very little is known about its current status and ecology (Krishnakumar & Balakrishanan 2003). The Common Palm Civet is listed in Appendix III in the Convention on International Trade of Endangered Species (*CITES)*, and as Least Concern by the IUCN Red List, and Schedule II in Wildlife (Protection) Act 1972 of India.

The Common Palm Civet is an omnivorous and opportunistic forager. Its diet varies according to habitat and season (Jothish 2011). It is a nocturnal species and feeds on a variety of foods including fruits and flesh (Joshi et al. 1995; Grassman 1998; Krishnakumar & Balakrishanan 2003). In forested areas, it is primarily frugivorous, feeding on berries and pulpy fruits including those of figs and palms and is an effective seed disperser (Rabinowitz 1991; Corlett 1998; Nakashima et al. 2010). It is often considered a pest because of its raiding of coffee plantations, other fruit crops, and poultry (Prater 1971).

Direct observations of feeding behaviour are often difficult under field conditions. Scat analysis is one of the primary tools used to assess carnivore diets, especially when focusing on individual prey items. Scat analysis has been used to know the dietary composition of major carnivores throughout the world (Schaller 1967; Jethva & Jhala 2004; Giannatos *et al.* 2005).

Hairs are the most important part for identifying prey species consumed by predators. Different species have different kinds of shape, size and structure of medulla and cuticle (Teerink 1991). The present paper reports the winter food habits of the Common Palm Civet in the Patna Bird Sanctuary, Uttar Pradesh, India.

MATERIALS AND METHODS

Study Area

PBS is situated in Jalesar Tehsil of the Etah District of Uttar Pradesh. The bird sanctuary is situated at 27.526^{0}N–78.320^{0}E. The PBS has 109ha area which contains a small jheel along with a track of date palm trees (*Phoenix sylvestrix*). Patna Jheel is a typical rain-fed wetland. The wetland can be categorised as natural fresh water, shallow wetland or jheel (Rahmani & Daniel 1997). The eastern part of the sanctuary is covered with dense Date Palm trees (Fig. 1) while the boundary of the sanctuary and trails are covered with *Prosopis juliflora*.

More than 180 species of birds were reported from PBS (Ahmad & Javed 2000), and thousands of migratory birds visit every winter in this IBA site. The Golden Jackal *Canis aureus*, Jungle Cat *Felis chaus*, Fishing Cat *Prionailurus vivverinus*, Indian Fox *Vulpes bengalensis*, and Common Palm Civet *Paradoxurus hermaphrodites* are common meso-predators of the area. PBS has ample prey species like Indian Bush Rat *Golunda ellioti*, Rufous-tailed Hare *Lepus nigricollis ruficaudata*, and avian fauna. There is a variety of tree species found in the sanctuary including *Phoenix sylvestris, Prosopis juliflora, Ficus religiosa, Ficus recemosa*, *Acacia* spp., *Ziziphus* spp., *Pithecelobium dulce, Morus alba, Dalbergia sissoo, Azadiracta indica*. Beside these woody plant species, the sanctuary contains aquatic vegetation that consists of *Hydrilla verticillata*, *Salvinia*, *Azolla*, *Ceratophyllum demersum*, *Vallisneria spiralis*, *Potamogeton crispus*, and *Eichhornia crassipes*. On the outer reaches of the wetlands, *Ipomea carnea* and *I. aquatica* grow in excess (Ahmad & Javed 2000).

METHODS

It is very complex to find each prey item contributing to the diet of a carnivore species by direct observation in the field. Thus scat analysis method is broadly used to find out food habits of carnivores because of its non-invasive nature, easy collection and analysis (Korschgen 1980; Ackerman et al.1984; Reynolds & Aebischer 1991). To determine the food habits of Common Palm Civet, we used the scat analysis method. A total of 112 scats were randomly collected from the travel routes, trails, roosting sites (Image 1), and den sites which were present in different habitat types of the Sanctuary.

The scats of Common Palm Civet were identified based on their occurrence in more-or-less the same location as the roosting animal(s), elongated shape in

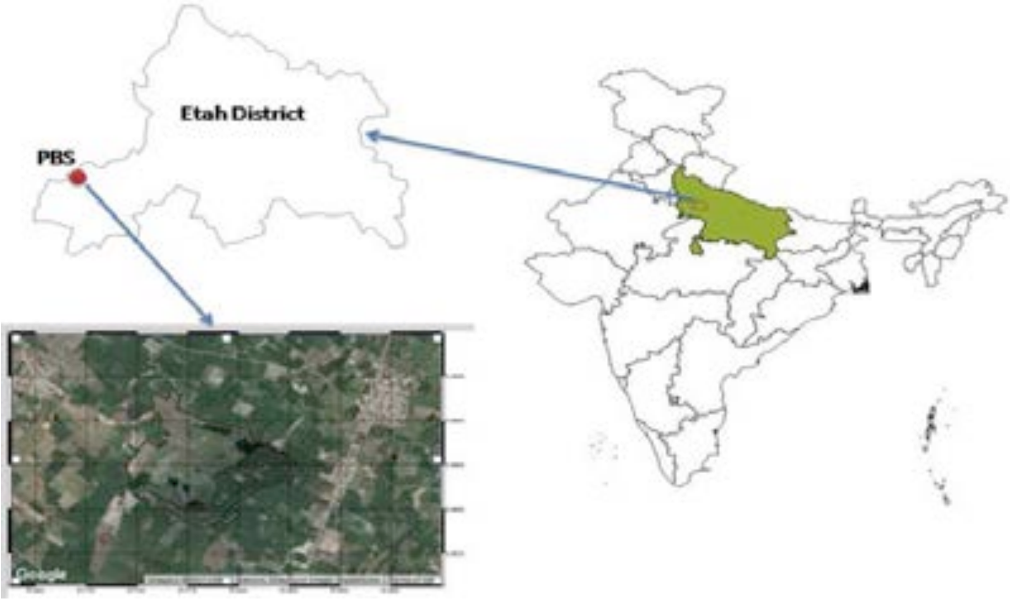

Image 1. Patna Bird Sanctuary, Etah, Uttar Pradesh, India.

Image 1. Common Palm Civet in Patna Bird Sanctuary.

nature and composition of undigested plant or animal matter; however, the ambiguous scats were not used in analysis. The scats were collected from November 2012 to March 2013. Scats were collected from identified dens of Common Palm Civets and stored in zipped polythene bags and additional information was recorded such as habitat, GPS coordinates, time and date of collection. The collected scats were sun dried, and washed in running tap water through a sieve. The remains, like hairs, feathers, seeds, bones, grasses were separated and sun dried for further identification of species and observation through microscope and macro lens. At least 20 hairs were picked randomly from each scat. The hairs were treated with xylene to see clear structure of medulla. These hairs were mounted on permanent slides and observed under microscope to identify the prey species. The hairs were compared with the already made reference slides and hair guard manual of Wildlife Institute of India (Bahuguna et al. 2010) made with the collected hairs during the study period from PBS. The seeds which were not identified during the scat analysis were sown in pots and after germination these were identified by a taxonomist to avoid any possible error.

The percentage of occurrence of a prey item was calculated as the numbers of items of a specific prey item that were found to occur in scat and expressed as a percentage of all prey occurrences (Floyd et al. 1978; Weaver & Fritts 1979; Ackerman et al. 1984). The frequency of occurrence of prey species in the scat was computed as the number of occurrence of each prey type divided by total number of scat analysed and expressed as percentage (Corbett 1989; Jethva & Jhala 2004).

RESULTS

In 112 scats, one to seven prey items were recorded (Table 1). The maximum numbers of prey items (seven) were found in 3.70% scats, followed by six prey items in 9.87% scats while three, two and four prey items were found in 32.09%, 29.62%, and 24.69% scats respectively. A single prey item was recorded in 8.73% of the scats. The decreasing order of frequency of occurrence found in the Common Palm Civet diet is presented in Fig. 2.

The maximum percent of occurrence was recorded for Insects (29.46±2.29) followed by *Ficus religiosa* seeds

Table 1. Percentage of scats containing different number of prey items.

Number of prey item	Number of scats	Percentage of scat
One	9	8.73
Two	26	29.62
Three	32	32.09
Four	21	24.69
Five	13	16.04
Six	8	9.87
Seven	3	3.70

Table 2. Percent frequency of occurrence with standard error and confidence level.

Prey Item	Percentage occurrence	Standard Error	Confidence Level (95%)
Prosopis juliflora	11.60	0.18	0.35
Ficus religiosa	19.64	1.13	2.21
Insects	29.46	2.29	4.48
Grass	4.46	0.65	1.27
Birds	9.82	0.02	0.03
Rodents	6.25	0.44	0.86
Jackal	3.57	0.75	1.47
Rufous-tailed Hare	1.78	0.96	1.88
Date Palm	8.03	0.23	0.45
Unidentified	5.35	0.54	1.05

Table 3. Percentage of food items according to the food habits of Common Palm Civet.

Food habit	Frugivorous	Insectivorous	Carnivorous	Other
No. of prey item	44	33	24	11
Percentage	39.28	29.46	21.42	9.82

Figure 2. Overall visualisation of the scat contents in Common Palm Civet diet in PBS. A—Insects | B—Fruit of *Ficus religiosa* | C—Fruit of *Prosopis juliflora* | D—Birds | E—Date Palm | F—Rodents | G—unidentified | H—Grass | I—Jackal | J— Rufous-tailed Hare.

(19.64±1.13), *Prosopis juliflora* seeds (11.60±0.18), and Date Palm seeds (8.03±0.23), while the birds contributed (9.82±0.02) in Palm Civet diet (Fig. 1; Table 2).

Over all the Palm Civet is more frugivorous than insectivorous and carnivorous as the fruits contribute 39.28% of its diet, followed by insects 29.46% and mammals 21.42% (Table 3). It is found that the Palm Civet scavenges on road killed jackal (3.57±0.75).

The seeds collected from the scat were sowed to identify the plant species and germination rate was found to be more than 90%. Undigested parts of *Ficus racemosa* were also observed in the scats of the Common Palm Civet but due its ambiguity it was recorded as unidentified. Among the insects termites encompassed the bulk in the Common Palm Civet diet. Plastics were also recorded in the scats of the Common Palm Civet.

DISCUSSION

The Common Palm Civet is among the more frugivorous viverrids (Corlett 1998). No systematic studies on its diet have been carried out in India (Singh 1982; Krishnakumar & Balakrishanan 2003); however, Krishnakumar & Balakrishanan (2003) and Jothish (2011) studied some aspects of food habit and diet composition of the Common Palm Civet and its role in seed dispersal. Fruits have been recorded as a major component in the diet of the Common Palm Civet in studies carried out in different countries including Nepal (Joshi et al. 1995), Thailand (Rabinowitz 1991; Grassman 1998), and Myanmar (SuSu & Sale 2007). Moreover, the study carried out in India also reviled that fruit is a predominant component (82% and 95%) in the Common Palm Civet diet (Krishnakumar & Balakrishnan 2003; Jothish 2011). The present study also shows that the Common Palm Civet is more frugivorous (39.28%) than insectivorous (29.46%). The fruit content is found less in the diet of the Common Palm Civet in comparison to earlier studies because of less availability of fruits in and around the PBS.

Bekele et al. (2008) observed a high rate of scavenging in human habitats by the African Civet *Civettictis civetta* in Ethopia. Balakrishnan & Sreedevi (2007) observed that faeces of Small Indian Civets *Viverricula indica* often contained cooked rice and fish bone; however, we did not find any evidence of fish or cooked rice in the present study. The high percentage of insects (29.46%) in the Common Palm Civet diet is perhaps because of their congregation habits around street lamps. Most faeces contained two, three and four food items in the scats of Common Palm Civet, showing that there was a scarcity of food items for the palm civet while (Jothish 2011) suggested that the civet(s) ate a single source in bulk at a particular feeding time. The frequent occurrence of grass leaves in the faeces (4.46±0.65 of total faeces) is consistent with other studies, pointing to a possible role of grass leaves in scouring the intestine and in the digestion process (Grassman 1998; Krishnakumar & Balakrishnan 2003; Balakrishnan & Sreedevi 2007; Mudappa et al. 2010).

Palm Civets ate at least 18 fruit species in Kerala (Jothish 2011), mostly from non-native plants (Nayar et al. 2006). Krishnakumar & Balakrishnan (2003) identified only 10 fruit species from Common Palm Civet faeces in two semi urban habitats in Thiruvananthapuram, Grassman (1998) found 13 fruit species in faeces pooled from Common and Masked Palm Civet *Paguma larvata* in Kaeng Krachan National Park (Thailand) and SuSu & Sale (2007) found 31 types of fruits in Common Palm Civet faeces analysed from Hlawga, Myanmar. In the present study eight fruit species were recorded from Common Palm Civet faeces.

The presence of jackal's hair in the scats of Common Palm Civet shows that it is an opportunistic feeder. The possibility of direct hunting on jackal is very rare but it may hunt on fawn of jackals as there is a good population of jackals in PBS. Birds consisted of 9.82% in the Common Palm Civet diet and this number is very low as the PBS is well known as a congregation site of migratory as well as residential birds. PBS is also an IBA site; however, birds contribute about 40% in the Golden Jackal diet in winter (Khan et al. 2017). Feathers and bones of babbler (n=2) were also recorded in the Common Palm Civet scats. A similar observation by Balakrishnan & Sreedevi (2007) on the stomach content of Small Indian Civets showed that only the head region of a babbler was chewed and feathers and body were left intact.

The civets are known for seed dispersal as the fleshy parts of fruits were digested by its digestive system but the seeds remained unaffected during this process. Frugivores and carnivores may disperse seeds (Herrera 1989; Nakashima et al. 2010). When an animal ingests fruits, the successful dispersal of the seeds depends on the feeding behaviour of the frugivores, after consumption and gut passage and the movement of animals. The seeds collected from the faeces were undamaged and did not lose their viability after the gut passage. When the seeds were sowed for the identification of species the germination rate was found about to be 90%. According to studies (Jothish 2011) civets are threats for the poultry as they raid and kill the fowls. But during this study we did not find any evidence of fowl hunting.

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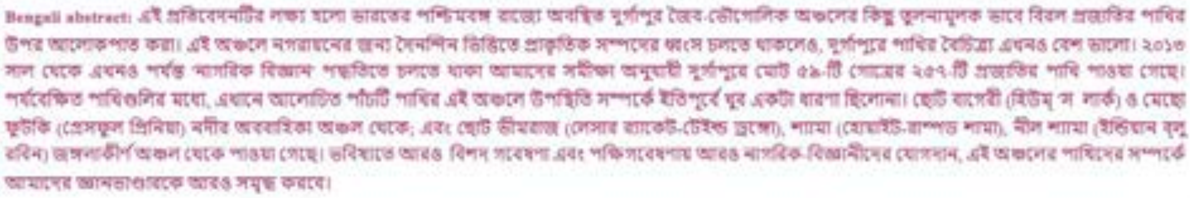
REPORT OF FIVE INTERESTING AVIAN SPECIES FROM DURGAPUR ECOREGION, WEST BENGAL, INDIA BY CITIZEN SCIENCE EFFORT

Sagar Adhurya[1] & **Shantanu Bhandary**[2]

[1] Department of Zoology, Visva-Bharati University, Santiniketan, Birbhum, West Bengal 731235, India.
[1,2] Durgapur Wildlife Information and Nature Guide Society, Fuljhore, Durgapur, Paschim Bardhaman, West Bengal 713206, India.
[1] sagaradhurya.rs@visva-bharati.ac.in (corresponding author), [2] shaanbhandary@gmail.com

Abstract: This study aimed to report a few lesser known species from Durgapur ecoregion, West Bengal, India. In spite of the anthropogenic pressure, Durgapur supports a high avian diversity. So far, 257 avian species belonging to 59 families were recorded with a citizen science effort during a period of more than five years (2013–present). Out of these, five species discussed here, are either not recorded previously or have few records: Hume's Lark and Graceful Prinia were recorded from riverine habitat; and Lesser Racket-tailed Drongo, White-rumped Shama, and Indian Blue-Robin were recorded from woodland habitat. More extensive exploration of this region with involvement of citizen scientists in this study will enrich our knowledge about bird diversity, their migration and distribution pattern in this region.

Keywords: Anthropogenic activity, birds, drongo, lark, prinia, robin, shama.



Bengali abstract: এই প্রতিবেদনটির লক্ষ্য হলো ভারতের পশ্চিমবঙ্গ রাজ্যে অবস্থিত দুর্গাপুর জৈব-ভৌগোলিক অঞ্চলের কিছু তুলনামূলক ভাবে বিরল প্রজাতির পাখির উপর আলোকপাত করা। এই অঞ্চলে নগরায়নের জন্য দৈনন্দিন ভিত্তিতে প্রাকৃতিক সম্পদের ধ্বংস চলতে থাকলেও, দুর্গাপুরে পাখির বৈচিত্র্য এখনও বেশ ভালো। ২০১৩ সাল থেকে এখনও পর্যন্ত নাগরিক বিজ্ঞান পদ্ধতিতে চলতে থাকা আমাদের সমীক্ষা অনুযায়ী দুর্গাপুরে মোট ৫৯-টি গোত্রের ২৫৭-টি প্রজাতির পাখি পাওয়া গেছে। পর্যবেক্ষিত পাখিগুলির মধ্যে, এখানে আলোচিত পাঁচটি পাখির এই অঞ্চলে উপস্থিতি সম্পর্কে ইতিপূর্বে খুব একটা ধারণা ছিলোনা। ছোট বাগেরী (হিউম্‌স লার্ক) ও মেঠো ফুটকি (গ্রেসফুল প্রিনিয়া) নদীর অববাহিকা অঞ্চল থেকে; এবং ছোট ভীমরাজ (লেসার র‍্যাকেট-টেইল্ড ড্রঙ্গো), শামা (হোয়াইট-র‍্যাম্পড শামা), নীল শামা (ইন্ডিয়ান ব্লু রবিন) জঙ্গলাকীর্ণ অঞ্চল থেকে পাওয়া গেছে। ভবিষ্যতে আরও বিশদ গবেষণা এবং পক্ষিগবেষণায় আরও নাগরিক-বিজ্ঞানীদের যোগদান, এই অঞ্চলের পাখিদের সম্পর্কে আমাদের জ্ঞানভাণ্ডারকে আরও সমৃদ্ধ করবে।

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Author details: Sagar Adhurya is Senior Research Fellow at Department of Zoology, Visva-Bharati University. SHANTANU BHANDARY is employee of Eastern Coalfield Limited. Both of the authors are member of Durgapur Wildlife Information and Nature Guide Society and working on its project on avian diversity study.

Author contribution: SA wrote the paper and performed all of the analysis. Both authors collected field data.

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Wildlife Information and Nature Guide Society
WINGS

INTRODUCTION

Durgapur is an industrial city in West Bengal, India. Geographically, it lies in the transitional zone between two ecoregions, Chotanagpur Plateau and Gangetic Plains. Complementing its unique geographical location, this region harbours exceptional biodiversity, having species from both the ecoregions mentioned earlier. Mention may be made that the Common Babbler *Argya caudata* and Striated Babbler *Argya earlei* are species of Chotanagpur Plateau and Gangetic Plains respectively, but then, the present study revealed that both these species are found in this ecoregion.

Avifaunal diversity of this region has been studied by various researchers, however, most of their studies focused on Damodar Valley (Gauntlett 1971, 1985; Chakraborty 2011; Hossain & Aditya 2016). Thus, it was felt necessary to undertake a holistic study to get an idea about the avifaunal diversity of the entire city and its outskirts. This was the primary motivation behind the present work where, for the first time, the whole area of Durgapur was taken into consideration for studying avifaunal diversity. We started a citizen science program namely 'Birding Durgapur' in 2013 to accomplish our job. With increasing citizen science involvement, we increased our area of work to the whole Paschim Bardhaman District in April 2017. In recent days, the citizen science program has become a potential tool for biodiversity monitoring (Cohn 2008; Silvertown 2009; Devictor et al. 2010; Theobald et al. 2015). Several web-based popular programs (such as eBird, CBMI, MigrantWatch etc.) rely on the power of citizen scientists. The volunteer citizen scientists minimize the difficulties of researchers to study a large region. Increase in a number of observers in an area, in turn, increases the frequency of sampling, resulting in better coverage and public awareness.

In present days, finding a bird outside of its range is not uncommon. It may occur due to three possible reasons. First, increase in the number of birds beyond carrying capacity, forcing excess individuals to go beyond the range to find suitable resources for their survival. Second, an increase in the number of observers helps to fill the gap in knowledge about the bird distribution pattern. Third, disturbances (possibly driven by unpredictable climate patterns and anthropogenic habitat alteration) beyond the tolerance limit in its range forcing the species to shift.

This article aims to report the five-interesting avifauna from Durgapur ecoregion, which are either not recorded or very little recorded from this geographical area.

MATERIALS AND METHODS

Study area

The present study was carried out in Durgapur subdivision (23.48^{0}N, 87.32°E) of Paschim Bardhaman District, West Bengal, India and adjoining Damodar Valley (Fig. 1). Durgapur is the 77th most populated city in India with 566,517 people (as per 2011 census of Government of India) and covers an area of about 154km^2. This industrial city is at approximately 65m above sea level and located in the transitional zone between the Chotanagpur Plateau and the Gangetic Plains. This ecoregion is surrounded by the river Damodar in the south and the river Ajoy in the north. Soil, in this region, is red laterite type. About 100 years ago, the total area was covered by dense Sal *Shorea robusta* forest, which was cleared gradually from the late 1950s to establish India's second planned city (Chakrabarti 1989).

Data collection

A citizen science program, 'Biodiversity of Paschim Bardhaman' (formerly known as 'Birding Durgapur') has been running since 2013 to create interest among the citizens of Durgapur and adjoining areas for nature watching by Durgapur Wildlife Information and Nature Guide Society. Nature-watchers use digital cameras for photography and field binoculars for birdwatching. Nature watchers regularly post their efforts (eBird checklists, photographs and call recordings) with date and place in the Facebook group. All observations are verified by the group experts. Species were identified by using suitable field guides (Grimmett et al. 2011; Ali 2012; Grewal et al. 2016) while suitable field guides (Grimmett et al. 2011; Baidya et al. 2017), online range maps and databases (eBird 2017) and publications (Gauntlett 1971, 1985; Chakraborty 2011; Hossain & Aditya 2014) on this region were followed to find out the distribution and occurrence of various bird species. A checklist of birds of Durgapur subdivision is continuously maintained by group members.

RESULTS

Since 2013, 257 species belonging to 59 families have been recorded with the cumulative effort of citizen scientists in Durgapur subdivision. Out of these, eight species did not have any previous records from this ecoregion before 2013. Of these, three species were reported recently (Gupta et al. 2013; Nayak et al. 2015; Maulick & Adhurya 2017). The remaining five avian

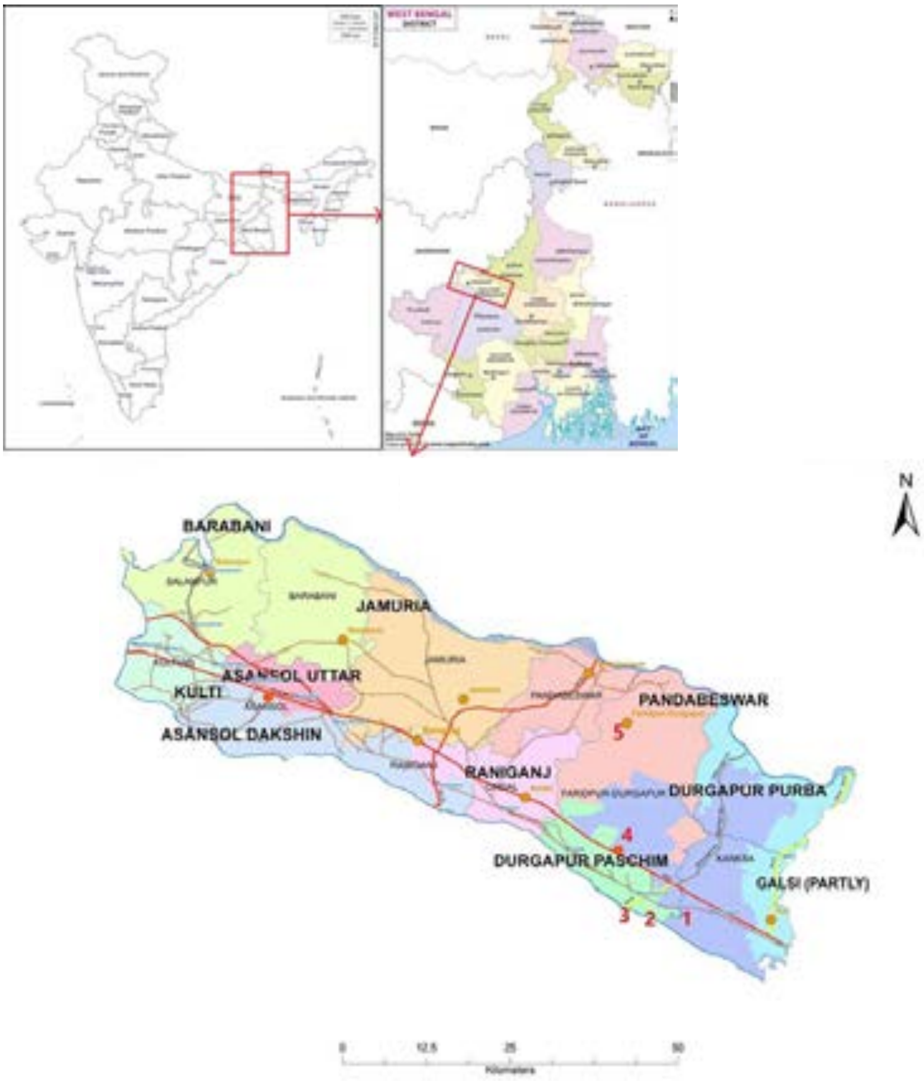

Figure 1. Location of the study sites in India, West Bengal and Paschim Bardhaman respectively. In the Paschim Bardhaman map (below): Beharpur marked as '1'; Krishnanagar marked as '2'; Durgapur Barrage marked as '3'; Kumar Mangalam Park marked as '4' and Tilabani forest marked as '5'. The map of Paschim Bardhaman district is modified from Assembly Constituency map downloaded from https://www.paschimbardhaman.co.in/for_citizen/maps.php on 23 January 2019.

species are discussed below (Table 1).

Family Alaudidae

1. Hume's Lark *Calandrella acutirostris*: This species was recorded three times: the first record from Beharpur (23.466˚N, 87.347˚E) on 10 February 2017, the second record from Krishna Nagar Village (23.460˚N,87.328˚E) on 26 March 2017, and the third record from Durgapur Barrage (23.476˚N, 87.308˚E) on 25 December 2017. This species was identified by its typical call pattern and its dark lore, pale ear coverts, yellowish bill with a dark spot at culmen, pale crescent below the eye and lightly streaked upperparts. Habitat was riverside agricultural land (Image 1).

Family Cisticolidae

2. Graceful Prinia *Prinia gracilis stevensi*: This species has been recorded regularly at Durgapur Barrage (23.468°N, 87.306°E) since 16 April 2017. This is a smaller prinia compared to other similar looking grassland prinia of this region. It is separated from other prinias by streaked upperparts and cross-barred tail with white tip. The dark grey brown upperparts indicated the subspecies *P. g. stevensi*. In addition, this species can be identified with its typical *zr-zr-zr* call which was heard during the field work. Habitat was river sand bed with sarpat grass (Image 2).

Image 1. Photograph and sonogram of Hume's Lark recorded on 10 February 2017 at Krishnanagar Village. © Sagar Adhurya.

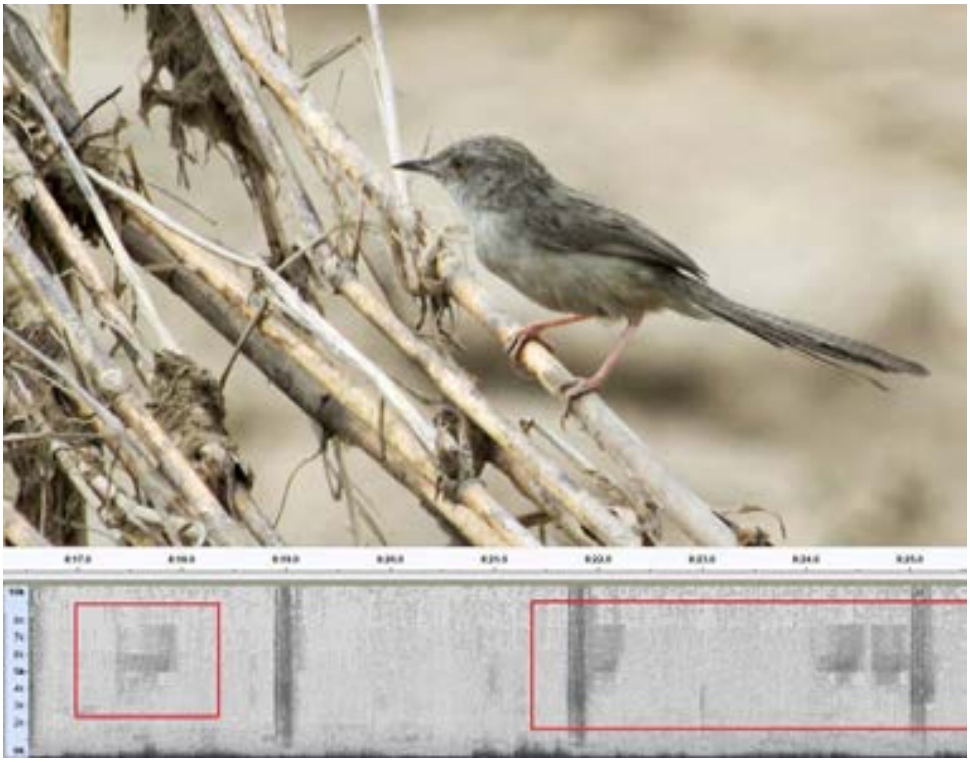

Image 2. Photograph and sonogram of Graceful Prinia recorded on 16 April 2017 at Durgapur Barrage. © Sagar Adhurya.

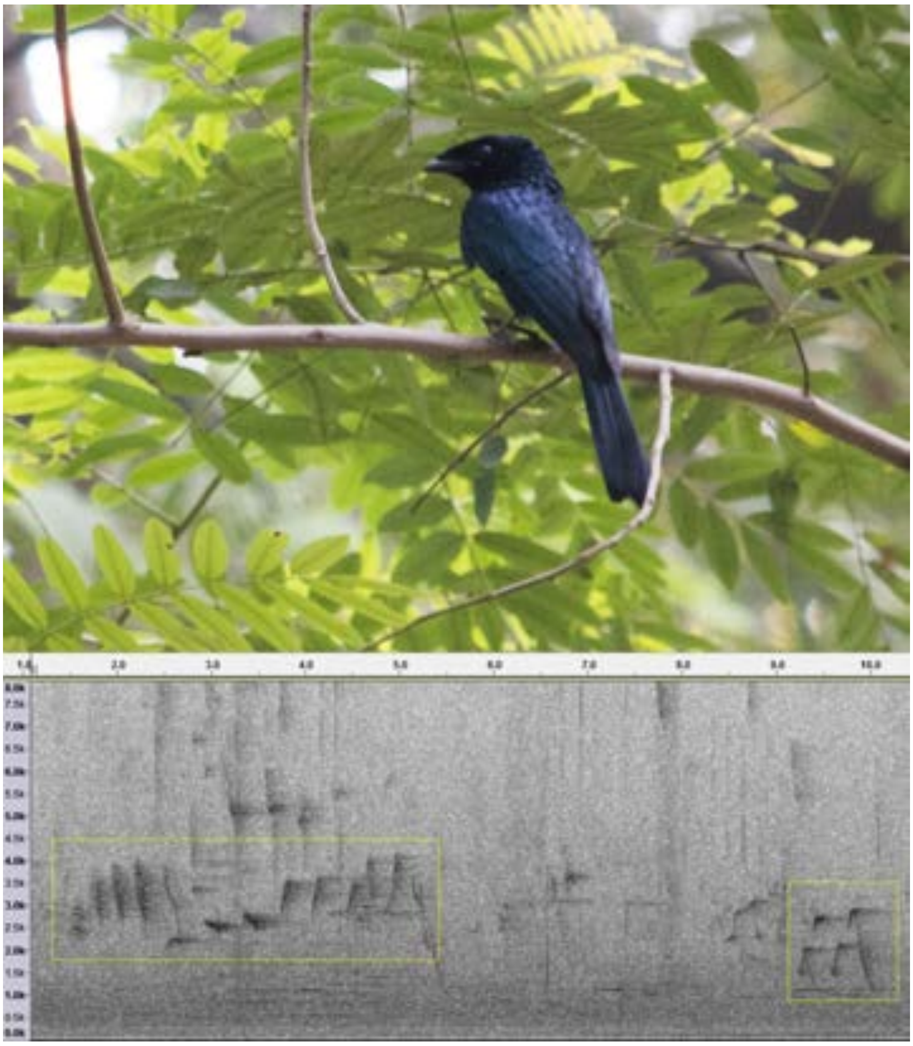

Image 3. Photograph and sonogram of Lesser Racket-tailed Drongo recorded on 10 November 2016 at Kumar Mangalam Park. © Sagar Adhurya.

Family Dicruridae

3. Lesser Racket-tailed Drongo *Dicrurus remifer*: One immature individual was spotted at Kumar Mangalam Park (23.563˚N, 87.303˚E) on 10 November 2016. The immature individual was differentiated from a similar looking species *D. aeneus* (Bronzed Drongo) by the lesser forked tail and shorter bill. The sound was variable, loud and musical. Habitat was woodland (Image 3).

Family Muscicapidae

4. White-rumped Shama *Copsychus malabaricus*: One female was found at Kumar Mangalam Park (23.563˚N, 87.303˚E) on 10 November 2016. The female was identified from similar-looking abundant *C. saularis* (Oriental Magpie-Robin) by its white rump, and orangish breast and whitish belly. Habitat was woodland (Image 4).

Table 1. Tabular presentation of five species and their occurrence pattern.

	Scientific name	**Common name**	**Period of occurrence**
1	*Calandrella acutirostris*	Hume's Lark	February, March, December
2	*Prinia gracilis stevensi*	Graceful Prinia	Throughout the year
3	*Dicrurus remifer*	Lesser Racket-tailed Drongo	November
4	*Copsychus malabaricus*	White-rumped Shama	November
5	*Larvivora brunnea*	Indian Blue-Robin	April

5. Indian Blue-Robin *Larvivora brunnea*: A male was observed at Tilabani forest (23.657˚N, 87.283˚E) on 19 April 2017. It was identified by bold white supercilium, black lore and cheek, bluish upperparts, chestnut throat, breast and flanks, white vent and undertail covert and short tail. Habitat was forest floor (Image 5).

Image 4. White-rumped Shama on 10 November 2016 at Kumar Mangalam Park. © Sagar Adhurya.

Image 5. Indian Blue-Robin on 19 April 2017 at Tilaboni Forest. © Shantanu Bhandary.

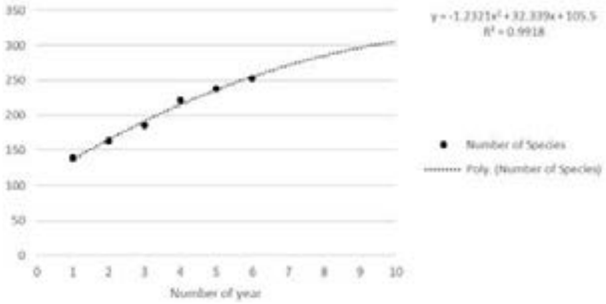

Figure 2. Species Accumulation Curve with a forecast using polynomial regression fit. [In the curve, year 1 = 2013].

DISCUSSION

All of the above-mentioned species are mostly unknown from Durgapur ecoregion and some of them have been only recently included in the literature (Baidya et al. 2017). The Hume's Lark and Lesser Racket-tailed Drongo may be the first record from the Paschim Bardhaman and adjoining Bankura District. The Hume's Lark mainly has distribution in northern West Bengal; up to upper edges of Birbhum District. Though the species has been recorded from Damodar Valley (Chakraborty et al. 2011), the location of the finding is unclear. In addition, Chakraborty (2011) marked the species as resident, while it is a well-known winter migrant (Grimmett et al. 2011; Grewal et al. 2016; Baidya et al. 2017). The Graceful Prinia is mainly found in the northern part of West Bengal up to the upper part of Birbhum District in the south. Recently, it has been also recorded at Damodar Valley of Asansol subdivision of Paschim Bardhaman District and Bardhaman, Purba Bardhaman district (Baidya et al. 2017), but no records have been made in between these two regions so far. The multiple record of Graceful Prinia between Asansol and Bardhaman suggests that the bird may have distribution throughout the Damodar Valley which was previously unknown. The Lesser Racket-tailed Drongo has distribution mainly in the Himalayan foothills of West Bengal (Darjeeling, Jalpaiguri and Alipurduar districts). But recently it has been recorded as a rare winter migrant to the Gangetic plains of West Bengal (Khan 2005; Roy et al. 2016; Baidya et al. 2017). In addition to these records, our record suggests that this species may also have a wintering range to Damodar Valley at the west. As Baidya et al. (2017) concluded in their book, there needs further investigation about the wintering activity of this bird. The White-rumped Shama is distributed up to the hilly region of the western part of West Midnapur, Purulia and Paschim Bardhaman district to the east (Baidya et al. 2017). But it has no earlier record from Durgapur ecoregion, which is not a hilly area. The present record suggests that this bird sometime visits the far east to plateau-plains transition areas like Durgapur. As per Baidya et al. (2017), the Indian Blue Robin is a passage migrant to the whole of West Bengal except the extreme eastern corner. This is actually a lesser-known bird from this region.

The number of avifaunal species in Durgapur subdivision is increasing day by day with increasing citizen involvement and more extensive exploration. At the end of 2013, 2014, 2015, 2016, 2017, and 2018 the total number of avifaunal species at Durgapur subdivision was 139, 163, 186, 221, 238, and 253, respectively (Adhurya, unpublished work) (Fig. 2). With the increasing number of avian species, finding of unreported avian species is also increasing due to the interesting geographical position. Records of these species are important because there are very few records of these species from this ecoregion in both existing range maps and literature. But most of the places in this region are still unexplored and need more citizen scientist involvement as a cost-effective method, which will help us to understand in more detail the spatial and temporal occurrence of different avian species.

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COMMUNICATION

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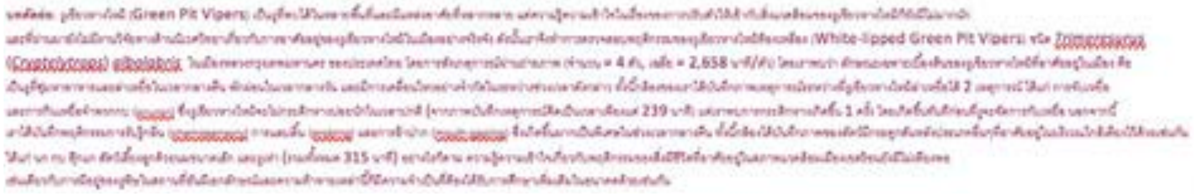
BRIEF INSIGHT INTO THE BEHAVIOR, ACTIVITY, AND INTERSPECIFIC INTERACTIONS OF URBAN *TRIMERESURUS* (*CRYPTELYTROPS*) *ALBOLABRIS* (REPTILIA: SQUAMATA: VIPERIDAE) VIPERS IN BANGKOK, THAILAND

Curt Hrad Barnes[1] & **Tyler Keith Knierim**[2]

[1,2] Suranaree University of Technology, School of Biology, Institute of Science, 111 Suranaree Subdistrict, Muang District, Nakhon-Ratchasima, 30000, Thailand.
[1] chradbarnes@gmail.com (corresponding author), [2] tyler.k.knierim@gmail.com

Abstract: Green Pit Vipers are a widely distributed, diverse group of snakes which occur across a variety of habitats. Little is known about their natural history in anthropogenically modified environments, and no ecological work has investigated their persistence in cities. We non-invasively photo-monitored White-lipped Green Pit Vipers *Trimeresurus* (*Cryptelytrops*) *albolabris* in the metropolis of Bangkok, Thailand (n = 4 individuals, mean = 2,658 minutes per individual). Subsequently, we preliminarily characterize urban green pit vipers as nocturnal predators, displaying ambush-foraging at night, sheltering during the day, and having limited movement in between temporal periods. We recorded two predation events of vipers capturing and ingesting anuran prey. Vipers infrequently displayed tail undulations (239 minutes total), with one event occurring immediately before a predation event. We also document chemosensory, probing, and mouth-gaping behaviors having occurred exclusively at night. Other vertebrates including birds, frogs, geckos, small mammals, and a cobra were photographed interacting with focal vipers or their immediate surroundings (315 minutes total). Knowledge of organisms in tropical urban environments is scarce, and the persistence of venomous snakes in these unique and challenging habitats requires further study.

Keywords: Activity, behavior, conservation, White-lipped Green Pit Viper.



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Author details: CURT HRAD BARNES is a PhD student in the Department of Biology at Suranaree University of Technology. His research and professional interests span a diverse range of topics and taxa, but his current focus is primarily venomous snake ecology and conservation. TYLER KEITH KNIERIM is completing his master's degree at Suranaree University of Technology in Thailand. Additionally, he instructs middle school science courses and has an interest in herpetofauna of Indochina and urban ecology.

Author contribution: Both CHB and TKK conceived and designed the study concept, while TKK designed and implemented monitoring and data collection in the field. CHB lead the writing of the manuscript with significant guidance and contribution from TKK.

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INTRODUCTION

White-lipped Green Pit Vipers (*Trimeresurus* (*Cryptelytrops*) *albolabris*) are a widely distributed arboreal pit viper belonging to the genus *Trimeresurus,* which is comprised of over 40 species inhabiting various regions in Asia (Uetz & Hallermann 2015). At least eight species are currently known to occur in Thailand (Cox et al. 2012), with some species, like the Phuket Pit Viper (*Trimerersurus* (*Popeia*) *phuketensis*) becoming described as recently as 2011 (Sumontha et al. 2011). While the taxonomy and phylogeny of the genus *Trimeresurus* has largely been resolved (Malhotra & Thorpe 2004), genera and nomenclature designation remains unclear (David et al. 2011). Two species of green pit vipers, the Big-eyed Green Pit Viper (*T. macrops*) and White-lipped Green Pit Viper, inhabit Thailand's large metropolitan capital Bangkok (Cox et al. 2012).

Both, White-lipped and Big-eyed Green Pit Vipers have been previously reported to be responsible for 95% of the envenomating snake bites in the Bangkok metropolitan area (Meemano et al. 1987; Mahasandana & Jintakune 1990) and 30–40 % throughout Thailand (Viravan et al. 1992; WHO 2010). Despite being widely distributed throughout southern and southeastern Asia, little research has investigated the in situ ecology of green pit vipers. Work has largely focused on the habitat use, basic biology, and spatial ecology of radio telemetered Big-eyed and White-lipped Green Pit Vipers in rural or forested habitats (Devan-Song et al. 2016, 2017; Barnes et al. 2017; Strine et al. 2018). These studies, however, did not report data on the predatory behavior or interspecific interactions of White-lipped Green Pit Vipers in highly urbanized study sites. To address this knowledge gap, we utilized a time lapse camera to investigate and provide preliminary study of White-lipped Green Pit Viper behavior and activity patterns in Bangkok, Thailand. We also provide observations of syntopic organisms that were accidently photographed while vipers were present (or within 12 hours of abandoning sites) within this highly disturbed landscape.

METHODS

We surveyed for green pit vipers from a public roadway (Bangna Trad 19, Yaek 12), visually scanning vegetation where the road bordered a densely vegetated 0.20ha vacant lot (Image 1A). The property is located at (676494 E / 1512069 N; 47 P) in the Bangna District of Bangkok, Thailand. Dominant vegetation cover along the roadside and adjacent vacant lot predominantly consisted of non-native trees (*Leucaena leucocephala*), and vines (*Antigonon leptopus)*. We opportunistically surveyed for vipers after dark, beginning our searches at 21.00h between 30 October–16 November 2018. When a viper was located, we positioned a Bushnell field camera (Trophy Cam HD Essential E3, Model: 119837) with infrared night capability on a tripod spaced 1–2 m from each focal viper. We programmed the camera using a combined setting, including field scan, which continuously captured one photo every minute, along with motion sensor, which took photos upon movement trigger outside of the regular 1-minute intervals.

Only photos taken at the 1-minute intervals were utilized in our activity pattern analysis. The remaining pictures taken by the motion trigger were intended to be used as supplements (for identification and context) in the case of interactions and observations of or with other organisms. Care was taken when placing cameras to minimize our disturbance to the vipers.

Herein we report observations from four individual adult White-lipped Green Pit Vipers that had not abandoned their position in their photo frames within an hour of us setting the cameras. We left cameras stationed at the viper locations from their initial spotting at approximately 21.00h on the first night to 21.00h on the third night of monitoring, allowing two days and one full night (with one partial night after setting and one partial night before retrieving the camera) of photo observation without a visit from us to the site. We did not handle vipers and attempted to limit our disturbance to the habitat during camera setting by avoiding contact with connective vegetation. Upon camera removal on the third night, we also attempted to capture close-up images of each viper using Nikon D7000 camera to determine their sex (larger body and head size for females, and presence of a postocular stripe for males; Devan-Song et al. 2017) later (Image 1B). We monitored one viper per each two-day photo monitoring period because we were limited to one trail camera for field use. We determined that each individual we monitored was unique through general visual appearance, size, coloration/markings, and presumed sex.

We classified each time-lapse image with a green pit viper from our trail camera into one of four primary behavior states, defined as: ambushing, moving, resting, and sheltering following classification used by Strine et al. (2018). States are behaviors of relatively long duration (2 or more frames in our study (Martin & Bateson 2007). Ambush behavior was defined as maintaining a stationary

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Image 1. A—Green Pit Viper habitat at survey site along Bangna 21 alleyway in Bangkok; B—an adult male White-lipped Green Pit Viper *Trimeresurus albolabris* (V3) ambushing towards a concrete wall within this environment.

foraging position, having a semi-coiled body with the head set in a bent neck, ready-to-strike position. Moving behavior was defined as a complete transference of the body of a viper from one site to another on camera frame or from a site on frame to off frame (or off camera to on camera). Resting was defined as having un-raised head settled on the body or habitat feature in what could best be described as a relaxed position. We classified a viper as being in a sheltering state only when it was not visible and other primary behaviors were not observable due to obstruction by vegetation or other habitat features. Additionally, we only defined behavior as sheltering if we could confirm both entrance and departure from the visually obstructing microhabitat feature on camera frame.

Other behavior states we observed, although infrequently, include feeding and tail undulation. Feeding was the behavior state used to collectively describe restraint and ingestion (until prey not visible and fully inside focal viper) processes of predation. We defined tail undulation similarly to Clark et al. (2016) as continuous, clear movement of the tail without pause for two or more consecutive time-lapse image scans (2 minutes).

Behavioral events (instantaneous behaviors, only observed for 1 frame in our study; Martin & Bateson 2007) irregularly observed in our study include mouth gaping and probing, which we defined similarly to Barbour & Clark (2012). A chemosensory probe (“probe”) was a clear (not blurred on camera, which could suggest a predatory strike towards prey) extension of the head beyond the body coil with a closed mouth towards a habitat feature. A mouth gape (“gape”) occurred when a viper opened its mouth at a ≥ 45˚ angle.

Behavioral events (probe and gape) and infrequently observed behavioral states (feeding and tail undulation) were recorded, but not included in our activity pattern analyses. We also attempt to document (but not analyse) all vertebrates observed on the cameras when vipers were present at or recently (within 12 hours) abandoned sites, so as to provide context for behaviors observed, potential prey and predators of green pit vipers, and general diversity in urban Bangkok; all of which have been scarcely studied prior.

We utilized the methodology developed by Ridout & Linkie (2009) to determine the daily activity patterns of vipers and quantify the amount of temporal overlap between active (ambush and movement) and inactive behaviors (resting and sheltering) using the 'overlap' package (Meredith & Ridout 2016) in program R (version 3.5.1; R Development Team 2018). First, a non-parametric circular kernel-density function was employed to assess comprehensively (summarized, since behaviors were discrete, i.e., only one behavior recorded at any given minute interval) daily activity patterns. Then a coefficient of overlap (Δ) was used to measure the extent of overlap between two kernel-density estimates, taking the minimum of the density functions from two sets of samples being compared at each point in time. Overlap was determined to be the area under both the density curves. The coefficient of overlap ranged from 0 (no overlap) to 1 (complete overlap) (Ridout & Linkie 2009; Linkie & Ridout 2011). We calculated the 95% confidence intervals of each overlap index using smoothed bootstrap with 999 resamples (Meredith & Ridout 2016).

RESULTS

In total, we set cameras for 10,628 minutes over the course of 11 days between 30 October and 16 November 2018 (mean 2,658 minutes per individual, n = 4, Table 1), which corresponds to the end of the rainy season in central Thailand (Singhrattna et al. 2005) and the end of the mating season for the species in Thailand (Chanhome et al. 2011). Vipers were positioned 10–50 cm above ground when recorded and generally moved out of frame when having left that height range.

We observed vipers ambushing for 2,872 minutes, sheltering for 467 minutes, and moving for 89 minutes. Ambush behavior was most frequently observed at night (18.00–06.00 h), sheltering during the day (under concrete buildings facing south and west, with about a 10cm opening with chunks of concrete wedged in), and movement occurring irregularly during both times (Fig. 1). Activity pattern overlap was minimal for active (ambush and movement) and inactive (sheltering) behaviors (Fig. 1, Δ = 0.05, CI = 0.08–0.10). Males were most frequently observed ambushing (77.0% of observations), then sheltering (20.3%), and moving least frequently (2.7%). Female vipers were most frequently observed ambushing (97.6%) and least frequently moving (2.4%), and never sheltering in frame (i.e., in immediate proximity to their camera location).

Table 1. Basic summary of our four focal White-lipped Green Pit Vipers *Trimeresurus albolabris* observed for 2,156–2,856 minutes each with proportion of active (ambush and movement behavior states) and inactive (resting and sheltering).

Viper ID	Sex	Time observed (in minutes)	Proportion active/inactive
V1	Female	2,156	1:0
V2	Female	2,803	1:0
V3	Male	2,817	0.67:0.33
V4	Male	2,856	1:0

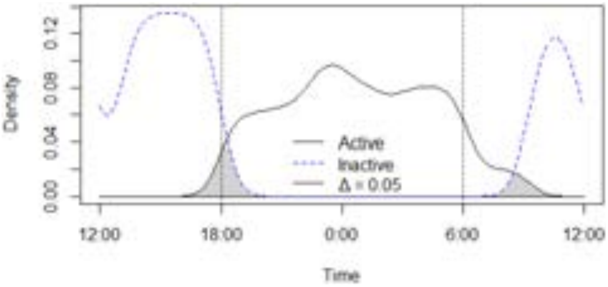

Figure 1. Density estimates of daily activity patterns of White-lipped Green Pit Vipers *Trimeresurus albolabris* in Bangkok, Thailand. Solid lines are kernel-density estimates for active behavior (ambushing and movement) observed, whereas dashed blue lines are inactive behavior (sheltering). Vertical dotted black lines indicate relative start of night (18.00h) and day time (06.00h). The overlapping coefficient (Δ) is represented by the shaded area.

Tail undulation was observed concurrently with ambush foraging behavior for 239 minutes by both females (176 minutes) and one male (V4, 63 minutes). It was observed in the presence of frogs (family: Microhylidae, likely genus *Microhyla*) for 17 minutes and in the presence of a single gecko (*Hemidactylus* sp.) for four minutes. One of the males (V4) was observed undulating for nine minutes (23.49–23.57 h) immediately preceding predation of one of the small frogs (at 23.58 h). The same male was also observed depredating a frog the following night (18.36–18.41 h, Fig. 2, 18 h 38 min between predation observations), although undulation was not observed immediately preceding the second predation event.

We observed 11 probing events by a single male (V4, 4min) and a single female (V2, 8min) viper, all of which were during the night time. Four mouth-gaping events were observed for a single male (V4, 3min) and a single female (V2, 1min), also all during the nocturnal hours.

Large rats (*Rattus* spp.) were visible on cameras for 10 minutes in the presence of two ambushing vipers (V1 & V3), both vipers appeared to react in response to the rat's activity. The rats were observed with refuse

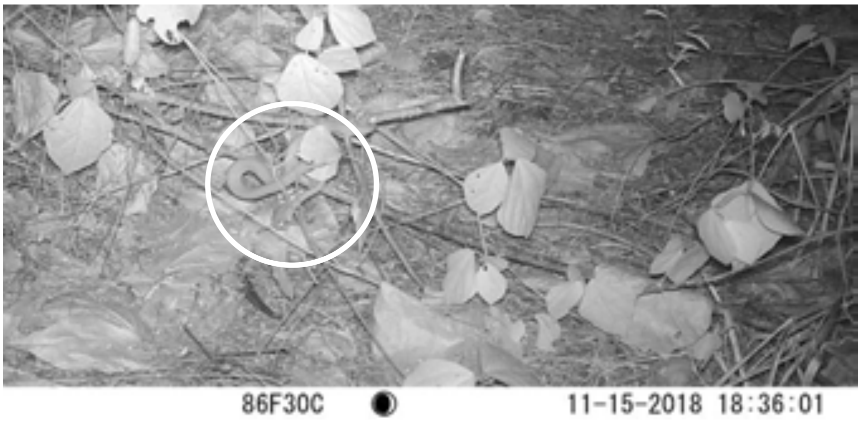

Figure 2. Adult male White-lipped Viper (V4, circled) successful predation of a small frog (likely family Microhylidae).

or food (indistinguishable on camera) in their mouths for seven minutes. Both vipers pulled their heads back towards their body coil in response to all rats passing within approximately 30cm of their location. The male (V3) temporarily abandoned his ambush site during one interaction when a rat ran in front of his ambush target location. An adult Tokay Gecko *Gekko gecko* was visible within 50cm of viper for five minutes, which did not elicit a response from the focal viper (V3). The adult rats and Tokays were likely too large prey for the vipers in our observations, however, White-lipped Green Vipers have been recorded previously to eat small mammals and geckos (including other *Gekko* spp.; Chanhome et al. 2011; Devan- Song et al. 2017). Small (prey-sized) geckos (likely genus *Hemidactylus* or *Gehyra*, 6min) and frogs (family Microhylidae, likely genus *Microhyla*, 38min) were observed in the frame while vipers were ambushing.

One type of small frog (family Microhylidae, likely genus *Microhyla*, 181min) and another type (likely genus *Hylarana*, 2min) were visible on camera during which vipers were not present at ambush or shelter sites. Small (prey-sized) geckos (likely genus *Hemidactylus* or *Gehyra*) were observed for nine minutes. Large skinks (genus *Eutropis*) were visible on camera for 10 minutes during the daytime. Small passerine birds were observed for 15 minutes during the daytime (Oriental Magpie-Robin *Copsychus saularis*, 1min; Streak-eared Bulbul *Pycnonotus blanfordi*, 12min; unidentifiable species, 2min), and of these observations one minute featured two birds which perhaps suggested a mated pair (*P. blanfordi*). Large rats were visible for 38 minutes when vipers were not visible, of which one minute featured a rat with food or refuse. A Monocled Cobra *Naja kaouthia* was observed crawling directly past a viper's previous ambush site (11.33h) five hours and 30 minutes after a viper (V4) was observed ambushing; the same viper returned and resumed ambushing at the same site after nightfall, six hours and 27 minutes following the cobra observation. Knowledge of *N. kaouthia* diet is largely unpublished, however, they have been documented as preying primarily on snakes (but not green pit vipers, 21.7% of total diet composition), bird eggs (11.3%), and rodents (65.7%) in central Thailand (Chaitae 2000; summarized in Chanhome et al. 2011).

DISCUSSION

Our observations revealed novel and interesting insight into the persistence of an ambush-foraging snake species in highly degraded and disturbed habitat. During 11 days of camera monitoring, we witnessed multiple interactions (including predation events) and gained insight into behaviors and activity periods of green pit vipers in a previously unstudied habitat type (urban). We were able to confirm similar general behavioral trends between our city vipers and radio-telemetered White-lipped and Big-eyed Green Pit Vipers in rural and forested habitats in another region of Thailand (Strine et al. 2018; Barnes et al. in preparation). These behaviors are characterized by nocturnal active foraging (ambushing), diurnal inactive (sheltering), and infrequent short distance (within camera frame, < 0.5 m) movement primarily between ambush and shelter sites. Overlap of active (ambush and movement) and inactive (sheltering) behaviors was minimal, primarily limited to early evening and mornings (Fig. 1). Infrequently observed behaviors of suspected chemosensory function (probing and mouth gaping; Clark et al. 2016) were only observed nocturnally. Similar observation of active and chemosensory behaviors primarily during the night and inactive behaviors during the day by rural, natural forest, and urban vipers may suggest limited plasticity of White-lipped Green Pit Viper activity patterns, although retention of similar habitat (functionally, with the non-native trees and vines in Bangkok) and prey may partially explain similar behavior observed between habitat types. Urban White-lipped Green Pit Viper resting and sheltering behavior expression differed from previous observation of green pit vipers in natural forest and rural habitat, however.

Interestingly, we did not observe resting behavior by the city vipers; however, resting behavior has been frequently documented from green pit vipers in rural and forested habitats (Strine et al. 2018; Barnes et al. in preparation). We postulate that the vipers at our highly urbanized study site may prefer to rest in hidden shelters, rather than in the open as was observed from the vipers in the forested and rural studies. Additionally, vipers in our study only utilized terrestrial shelter sites (beneath cover objects) which may be unusual for what is usually characterized as an arboreal species. Phenotypic plasticity of organisms in natural habitats and urban environments has been documented for many groups of organisms with regards to shelter sites, foraging, and reproduction within the context of behavior (summarized in Lowry et al. 2012).

The vertebrate abundance that we observed on camera appears surprisingly high for such a disturbed habitat. We were able to observe multiple species of birds, geckos, lizards, frogs, and even a cobra, all of which may serve as potential prey (geckos, lizards, and frogs), predators (cobra), or antagonists (birds) to green pit vipers. Remote time-lapse cameras may thus provide an additional tool for sampling diversity in urban habitats. While none of the vertebrates photographed in our study are classified as threatened by the IUCN Red List, our cobra observation was significant as common cobras (monocle and spitting, *N. kaouthia* and *N. siamensis*, respectively) inflict approximately 23% of all venomous snakebites in Thailand (Warrell 2010).

We did not observe human-viper interactions during our short study. While large and charismatic snake species are frequently killed in Thailand (Marshall et al. 2018), a previous radio telemetric study suggests people in rural areas are tolerant of green pit vipers so long as they do not come into direct interaction (Barnes et al. 2017). Similarly, both in this work and a previous study (Barnes et al. 2017), vipers appear tolerant to the presence of people so long as they do not make physical contact (i.e., touch) with the snakes. Green pit vipers are responsible for inflicting the majority of venomous snake bites in Bangkok (approximately 95% of all bites; Meemano et al. 1987; Mahasandana & Jintakune 1990).

We strongly discourage long distance mitigation translocation (moving a snake from a site of conflict with people, to a different site outside of their home range) (Sullivan et al. 2014) due to limited activity and movement we observed in our work. A previous study of White-lipped Green Pit Viper in Hong Kong suggests non-natural (increased and erratic) movement, decreased fecundity, and significantly increased mortality of individuals resulted from being translocated outside of their home ranges (Devan-Song et al. 2017). Short distance mitigation translocation (within home range (Brown et al. 2009); previously suggested to be < 0.5ha area for White-lipped Green Pit Vipers (Barnes et al. 2017; Devan-Song et al. 2017)) or soft releases (gradual release with a limited acclimation period (Tuberville et al. 2005; Kingsbury & Attum 2009)) may suffice as less detrimental alternatives.

Although observations of large rats were infrequent on our cameras (only 48min total), all interactions (10min when vipers were present) elicited visible reactions from focal vipers. Both vipers (one male and one female) which interacted with rats clearly pulled their heads out of ambush position, while the male focal viper even temporarily moved away from his ambush site. We were unable to definitively discern the rat species observed on camera, although three *Rattus* species are known to be abundant in Bangkok, *Rattus norvegicus*, *R. exulans*, and *R. rattus* (Chotelersak et al. 2015); the Brown Rat *R. norvegicus* is an introduced species (Ruedas 2016). Interestingly, rat species in Bangkok have been suggested to utilize different habitats and different habitat features (*R. norvegicus* being primarily terrestrial and *R. exulans* usually confined to smaller villages, for example; Chotelersak et al. 2015), suggesting niche partitioning which could subsequently interact with and influence the behavior of White-lipped Green Pit Vipers (generally considered habitat generalists) differently depending on habitat type. While small mammals have previously been recorded as prey for White-lipped Green Pit Vipers (Chanhome et al. 2011), our study also suggests the direct disturbance by rats may play an important role in ambush site selection of green pit vipers in urban habitats. Additionally, we observed rats on camera (8min) carrying what appeared to be refuse or food, which may have been anthropogenic in nature and subsequently suggested human support of local rat populations. The abundance and influence of these various rat species, both native and introduced, on green pit viper foraging and activity patterns in the urban interface requires further attention.

Many green pit viper species possess orange or red colored tails. While, the function has not been widely discussed but defense and caudal luring may certainly be speculated. We categorized the behavior as tail undulation so as to be conservative in our assessment; however, we suspect the behavior to be a form of caudal luring. Although primarily observed when potential prey was not visible (218min), we also observed tail undulation in the presence of prey species (geckos and frogs, 21min) and immediately preceded one of the two predation events (9min, followed immediately by predation in the next scan/minute). Our observations support the functionality of tail colorations in luring prey, while Greene & Campbell (1972) and Greene (1973) proposed tail colorations to function as defensive warnings when used by *T. gramineus*. One of us (C. Barnes) has observed both functions for Big-eyed Green Pit Vipers (Barnes & Tipprapatkul 2019), which is sympatric in Bangkok and thought to be closely related to the White-lipped Green Pit Viper. Interestingly, vipers (White-lipped, Big-eyed, and Vogels Green Pit Viper *T. vogeli*) were rarely observed displaying tail undulation behavior (only one Big-eyed Green Pit Viper out of 21 individuals of several species studied on camera) in rural and forested habitats in a previous study (Barnes et al. in preparation), contrasting to most urban (3 out of 4 individuals) White-lipped Green Pit Vipers in this current report. Tail undulation and chemosensory behaviors could be investigated further in ex situ (under controlled laboratory conditions) vipers, using prey type and viper age as variables (refer to Reiserer 2002 for example with multiple other species of viper).

Snake behavior in urban environments remains poorly understood, particularly within the overall context of ecology. Future research into the behavior of green pit vipers in urban areas would benefit from investigation of the effects of non-natural lighting (i.e., streetlights) and vibration (from vehicle traffic or construction). Concurrent habitat assessment (characterization) and use, both natural and anthropogenic would prove invaluable. Whether or not the green spaces we observed White-lipped Green Pit Vipers to persist in serve as islands, bottlenecks, or ecological traps for the species could be revealed by population and genetic analysis. Previous camera study has suggested increased interactions and change in species occurrence of mesocarnivores with increased urbanization intensity (Parsons et al. 2019); more intensive (larger sample size during multiple seasons) work should be conducted to understand interactions among conspecifics (between and within sexes, age classes of White-lipped Green Pit Vipers), co-occurring green pit vipers (Big-eyed Green Pit Vipers, in Bangkok), and other native and non-native animals in tropical urban environments.

While our current work revealed brief but valuable insight into green pit viper ecology in tropical urban habitat, much work remains to properly characterize persistence and natural history in this unique and challenging environment. Further time-lapse camera studies would provide novel conservation and ecological information on green pit vipers and syntopic organisms in urban areas in tropical southeastern Asia. We strongly caution extrapolation from our preliminary observations and encourage more intensive (larger sample size over multiple seasons) investigation.

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THE DISTRIBUTIONAL PATTERN OF BENTHIC MACROINVERTEBRATES IN A SPRING-FED FOOTHILL TRIBUTARY OF THE GANGA RIVER, WESTERN HIMALAYA, INDIA

Vijay Prakash Semwal[1] & **Asheesh Shivam Mishra**[2]

[1] Department of Zoology, Government Post Graduate College New Tehri, Tehri Garhwal, Uttarakhand 249001, India.
[2] Department of Zoology, Nehru Gram Bharati (Deemed to be University) Prayagraj, Uttar Pradesh 221505, India.
[1] vpsemwal75@gmail.com, [2] shivam_a2000@yahoo.co.in (corresponding author)

Abstract: Benthic macroinvertebrates play important ecosystem roles in the cycling and outflow of nutrients. The benthos transforms organic detritus from sedimentary storage into dissolved nutrients that can be mixed into overlying waters and used by rooted plants (macrophytes) and algae (phytoplankton) to enhance primary productivity. This study examined the distribution pattern of benthic macroinvertebrates in a lesser Himalayan foothill stream from the headwaters (2,200m) to mouth (375m). Five stations (S1 to S5) were established along the 43-km course of the stream. Samples were collected at bi-monthly intervals from January to December 2009. The total density of the benthic macroinvertebrate community increased with decreasing altitude and differed significantly among stations. Dominant orders were Diptera at S1 (Simulidae, 27%) & S5 (Chironomidae 24%), Trichoptera at S2 (Limnephilidae 16%) & S3 (Hydropsychidae 9.9%), and Ephemeroptera (Heptageniidae 9.2%) at S4. Principal component analysis revealed that the characteristic taxa were Simulidae at S1, Limnephildae at S2, Hydropsychiidae, Rhyacophilidae, Tipulidae, Perlodidae, Dryopidae & Notonectidae at S3, Heptageniidae at S4, and Chironomidae, Siphlonuridae, & Agrionidae at S5. Cluster analysis showed one large cluster comprising S1 and S2 as sub-groups with resemblance to S3-S4, and S5 as an outlier. The similarity between the stations S3-S4 was attributed to similar land-use pattern (agriculture) and stream order (II Order), while S1 and S2 were slightly similar due to partial similar forest type (oak forest at S1, pine-oak forest at S2) and stream order. At S5, however, the considerable change in forest type (mixed forest) land-use and stream order (III Order) caused S5 as an outlier in cluster. The variations in the abundant and characteristics taxon at different stations were attributed to change in substratum and land-use patterns.

Keywords*:* Ganga, lesser Himalaya, altitudinal variation, dominants, Diptera, Trichoptera.

बेन्थिक मैक्रोइनवेर्टेब्रेट पारिस्थितिकी तंत्र की साइकिल चलाने और पोषक तत्वों के बहिर्वाह में महत्वपूर्ण भूमिका निभाता है। बेन्थोस कार्बनिक डिट्रिटस को तलछटी भंडारण से विघटित पोषक तत्वों में बदल देता है जो प्राथमिक उत्पादकता को बढ़ाने के लिए जड़ वाले पौधों (मैक्रोफाइट्स) और शैवाल (फाइटोप्लांकटन) द्वारा पानी में मिलाया जा सकता है। इस अध्ययन में हेडवाटर्स (2,200m) से मुंह (375m) तक कम हिमालयी तलहटी की धारा में बेन्थिक मैक्रोइनवर्टेब्रेट के वितरण पैटर्न की जांच की गई। धारा के 43 किलोमीटर के रास्ते में पांच स्टेशन (S1 से S5) स्थापित किए गए थे। जनवरी से दिसंबर 2009 के बीच द्वि-मासिक अंतराल पर नमूने एकत्र किए गए थे। मैक्रोइनवर्टेब्रेट समुदाय की कुल घनत्व कम ऊंचाई के साथ बढ़ी और स्टेशनों के बीच काफी भिन्नता थी। S1 पर डिप्टेरा (27%) और एस 5 (चिरोनोमिडे 24%), एस 2 पर ट्राइकोप्टेरा (लिम्नेफिलिडे 16%) और एस 3 (हाइड्रोसाइकिडे 9.9%), और एफिमेरोप्टेरा (हेप्टेजेनिडे 9.2%) एस 4 प्रमुख टैक्सा थे। प्रधान घटक विश्लेषण से पता चला है कि एस 1 में सिमुलिडे, एस 2 में लिम्नेफिल्डे, हाइड्रोप्सिकिडे, रियाकोफिलिडे, टिपुलिडे, पेर्लोडिडे, ड्रायोपिडे और एस 3 में हेप्टेजेनिडे, चिरोनोमिड और सिफ्लोनुरिडे में विशेषता टैक्सा थे। क्लस्टर विश्लेषण में S1 और S2 के एक बड़े क्लस्टर को S3-S4, और S5 के एक समानता के साथ उप-समूह के रूप में दिखाया गया है। S3-S4 स्टेशनों के बीच समानता को समान भूमि-उपयोग पैटर्न (कृषि) और स्ट्रीम ऑर्डर (II ऑर्डर) के लिए जिम्मेदार ठहराया गया था, जबकि S1 और S2 आंशिक समान वन प्रकार (S1 में ओक वन, पाइन-ओक वन के कारण समान थे) S2 पर और स्ट्रीम ऑर्डर S5 में, हालांकि, वन प्रकार (मिश्रित वन) भूमि-उपयोग और धारा क्रम (III ऑर्डर) में काफी बदलाव से क्लस्टर में बाहरी रूप से S5 का कारण बना। विभिन्न स्टेशनों पर प्रचुर और विशेषताओं वाले टैक्सों में बदलाव को सब्सट्रेटम और भूमि-उपयोग पैटर्न में बदलाव के लिए जिम्मेदार ठहराया गया था।

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INTRODUCTION

Benthic macroinvertebrates are important components of aquatic communities, where they can be found in sediment and accumulated leaves, and in association with macrophytes between rocks, interacting with a wide range of environmental conditions (Moretti & Callisto 2005; Würdig et al. 2007). Community species distributions vary with water characteristics (Pereira & De Luca 2003; Silveira et al. 2006). Benthic organisms are sensitive to the habitat characteristics and substratum (Buss et al. 2004; Mishra & Nautiyal 2016), water temperature (Camargo & Voelz 1998; Mishra & Nautiyal 2011), pH (Sandin & Johnson 2004), electrical conductivity (Buss et al. 2002), riparian vegetation (Silveira et al. 2006), sedimentation (Smith & Lamp 2008), and land-use (Collier et al. 2000; Kratzer et al. 2006; Nautiyal et al. 2017). Thus they can be used as indicators of the functional status of rivers (Jiang et al. 2011; Mishra & Nautiyal 2013a).

In the lesser Himalayan region, benthic macroinvertebrates have been investigated in glacier and spring fed rivers/streams (Rundle et al. 1993; Ormerod et al. 1994; Singh et al. 1994; Nautiyal 1997; Julka et al. 1999; Kannel et al. 2007; Nesemann et al. 2011; Mishra et al. 2013c; Nautiyal et al. 2013; Nautiyal & Mishra 2014). Few studies have examined the foothill[1] region of western Himalaya, where streams often have springs as their source. We studied a spring-fed stream in the foothill region (Fig. 1a) that flows into the Ganga at Shivpuri, 15km upstream of Rishikesh. The rapids between Shivpuri and Rishikesh are a popular water-rafting zone, and the stream is under severe anthropogenic stress owing to extensive use of its banks for night camping. In the middle and upper reaches stress comes from water extraction for agriculture. Our study of benthic macroinvertebrate fauna is intended to help detect environmental changes in the stream due to human activity in the vicinity.

MATERIALS AND METHODS

Study Area

Most foothill streams that discharge into the Ganga between Shivpuri and Rishikesh are steep and short, and many dry up in summer. Hiyunl Nadi is a perennial stream with a 43km course that was chosen as a representative of a foothill stream. There are a number of streams of moderate length but in the Doon Valley and not the hills except for Song that drains eastern Doons. The Kho is one such like Hiyunl but not of this kind. The Hiyunl flows down from an elevation of 2,400m north-west direction and meets the Ganga River at 375m. By virtue of this it exhibits a rapid transition from alpine to sub-tropical conditions. Bemunda Gad, Pilri Gad, and Chamol Gad are its prominent tributaries. The Hiyunl basin lies between 30.258–30.440 ^{0}N and 78.708–75.084 ^{0}E, covering an area of 167.50km^2 (Table 1, Fig. 1b) that is rich in limestone (Kumar et al. 2017). There is some confusion regarding its name: Henval in headwaters (toposheet 53 J/7; https://zenodo.org/record/1216911) and Hiyunl in its lower stretch (toposheet 53 J/8; https://zenodo.org/record/1216913). Some studies carried out on the Ganga River between Devprayag and Haridwar have conveniently called it Henval, and another local name is Huinl (NH 44-5, Series U502).

Sampling

Five stations were selected in the stream on the basis of variation in land-use type (forest and/or agriculture). Sampling was performed at bi-monthly intervals from January 2010 to December 2010 (Table 1). Samples were taken from area of 0.09m^2 with respect to habitat type (20 samples per station). The standard methods for sampling (Singh & Nautiyal 1990; Nautiyal & Mishra 2013b) and identification (Burks 1953; Pennak 1953; Edmunds et al. 1976) were adopted. Family level counts were performed to obtain abundance (as %). Significant difference in density between stations was determined using the Mann–Whitney (U) test, and among the stations using the Kruskal–Wallis (H) test (PAST software http://nhm2.uio.no/norlex/past). Principal Component Analysis (PCA) was used to determine the characteristic taxa at each station (CANOCO ver 4.5; ter Braak & Smilauer 2002).

RESULTS AND DISCUSSION

Physicochemical characteristics varied among stations. The air (4–42^{o}C) and water temperature (3–25^{o}C) increased from S1 to S5 as did dissolved oxygen (7.4–12.5 mgl^{-1}), pH (6.8–7.3), conductivity (80–350 µS^{-1}), and current velocity (0.1–0.48msec^{-1}).

The total mean density of macroinvertebrates increased from S1 to S5, with significant differences observed between successive stations (Table 1). Singh &

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[1] The **foothills** of a mountain or a range of mountains are the lower hills or mountains around its base).

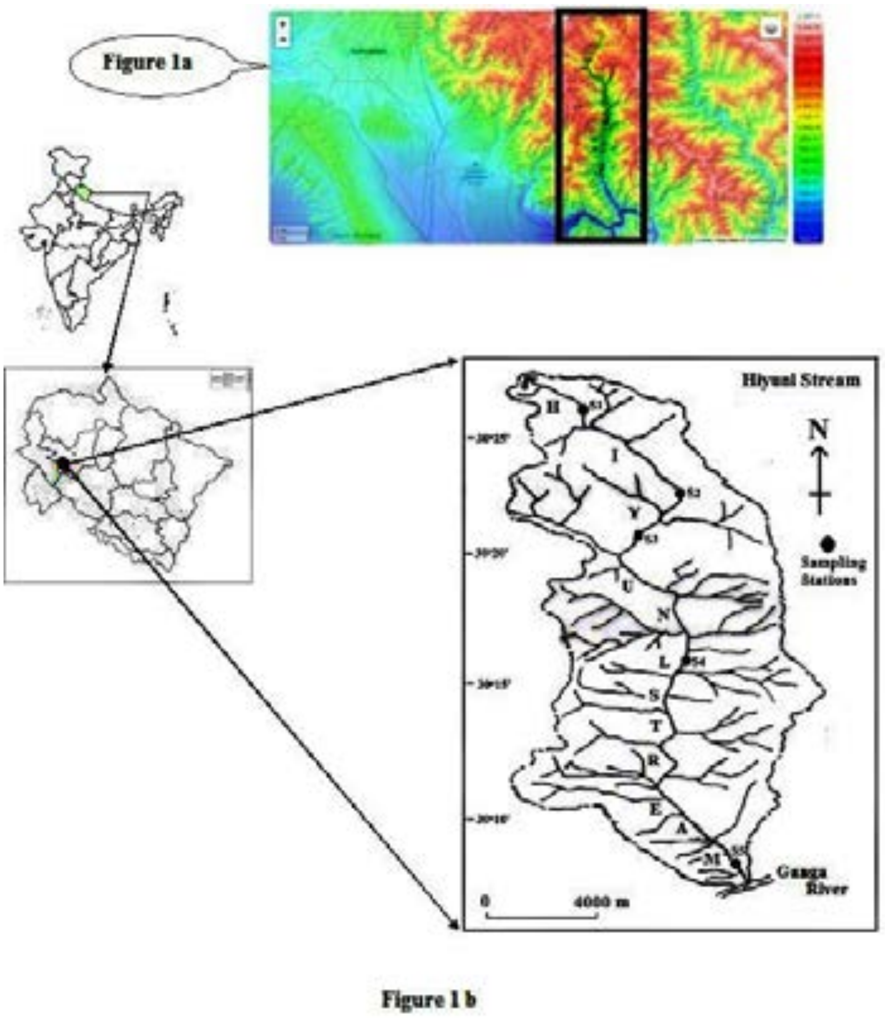

Figure 1a&b. a—Terrain map to show location of the Hiyunl Stream in foothills. Flat terrain at Rishikesh extending towards Haridwar and Dehradun while high rise lesser Himalayan mountains to right with elevation reaching over 2,400m even in foothills. b—Location of Uttrakhand in India and of Hiyunl Stream in Uttrakhand. The sampling stations (S1 to S5) are indicated in the map via black circle.

Nautiyal (1990) suggested that density increased in the mouth zone of the Himalayan river Bhagirathi. In central Indian rivers, the density also increased in the mouth zone of Paisuni River (Mishra & Nautiyal 2011) but decreased in Tons (Mishra & Nautiyal 2013b). The sudden decline of density at S4, however, was attributed to the dumping of waste materials into the river from road construction, which caused habitat loss and fragmentation resulting in a decline in the benthic macroinvertebrate community. The decline is also attributed to anthropogenic activity such as extraction of water for agriculture (Mishra & Nautiyal 2013b).

Taxonomic composition

Diptera (81%) was dominant at S1, Trichoptera at S2 (75%), S3 (80.7%) and S4 (54.5%). At S5 Ephemeroptera (69.3%) was dominant. The composition of other taxa varied at each station (Table 2). Diptera, Trichoptera and Ephemeroptera dominated the assemblages from S1 to S5. Odonates and annelids exhibited a similar profile, though their share was low in the community. Diptera declined abruptly from S1 to S2, and increased from S3 to S5. The communities differed structurally primarily on account of proximity to a snow line of approximately 150km aerial length, with high gradients in mountain streams. At the family level, Simulidae was the most abundant taxon at S1 followed by Limnephilidae, while Limnephilidae and Hydropsychidae were dominant at S2 and S3, respectively. Heptageniidae and Chironomidae were dominant at S4 and S5, respectively (Fig. 2). The share of Simulidae decreased from S1 to S5, while Chironomidae increased from S1 to S5. Trichopterans were dominant in the headwater section of the Garhwal Himalayan spring-fed streams (Nautiyal et al. 2015) and

Table 1. Geographical co-ordinates of the sampling station in different forest types in H Hiyunl Stream (nadi). Total density (mean, SE) at different stations in Henwal River. Density is calculated from 15 quadrants data at each station. Kruskal-Wallis test (H-test) and Mann-Whitney tests (U-test) determined significant differences in mean densities (indiv. m^{-2}) among and between the stations in the Hiyunl Stream.

Henwal Station	Khuret (S1)	Kurialgaon (S2)	Nagani (S3)	Jajal (S4)	Shivpuri (S5)
Forest	Oak Forest	Pine-Oak Forest	Agriculture	Agriculture	Mixed Forest
Stream Order	I	II	III	III	III
Distance from Source (Km)	6	11	21	29	43
Latitude (°N)	30.390	30.356	30.320	30.304	30.137
Longitude (°E)	78.325	78.336	78.325	78.344	78.391
Altitude (m)	2,200	1,571	1,400	1,200	375
Substrate type	C,P,PMB, St	LMB	C,PMB,St	LMB,C,P,G,St	C, P,G,St
Total Mean Density ±SE (Indiv.m^{-2})	542.36± 15.18	617.49± 15.31	649.62± 16.80	588.07 ±19.66	754.54± 39.88
Final p value (U-test)	S1-S2 0.003653	S2-S3 0.06448	S3-S4 0.02122	S4-S5 =0.0004915	S1-S5= 2.3E-05
Final p value (H-test)	S1-S5=2.312E-06				

C—Cobble | P—Pebble | PMB—Prismatic maturing boulder | LMB—Large maturing boulder | G—Gravel | St—Silt.

Table 2. Percentage composition of benthic macroinvertebrate community in Hiyunl Stream.

Station	E	T	D	P	C	O	N	L	M
S1	3.3	5.27	**81.43**	5.0	2.0	00	1.0	2.0	00
S2	11.05	**75.00**	10.52	3.43	00	00	00	00	00
S3	6.63	**80.79**	3.58	00	4.0	5.0	00	00	00
S4	18.79	**54.51**	20.69	00	3.5	1.5	1.1	00	00
S5	**69.29**	6.29	22.85	00	00	00	00	00	1.57

E—Ephemeroptera | T—Trichoptera | O—Odonata | L—Lepidoptera | D—Diptera | P—Plecoptera | C—Coleoptera | N—Neuroptera | M—Mollusca.

in headwater zone of Vindhyan spring-fed river Paisuni (Mishra & Nautiyal 2011). In the spring-fed Himalayan streams, Ephemeroptera was dominant taxon in the Khanda Gad (Kumar 1991) and the Gaula in the Kumaun region (Sunder 1997).

The benthic macroinvertebrate assemblages also varied at S1 (Simulidae-Limnephilidae), S2 (Limnephilidae-Hydropsychidae), S3 (Hydropsychidae-Baetidae), S4 (Heptageniidae-Hydropsychidae), and S5 (Chironomidae-Heptageniidae). This variation was attributed mainly to substratum, forest type and altitude. Simuliade was dominant in Oak forest at S1 while Limnephilidae was dominant in Pine-Oak forest at S2 (Table 1). Nautiyal et al. (2015) also observed similar pattern in the streams/rivers of Uttarakhand Himalaya. Corkum (1992) and Sivaramakrishnan (2005) also reported the impact of forest type on assemblage pattern. The dominance of Hydropsychidae, Heptageniidae, and Chironomidae at S3, S4, S5, respectively, indicated impact of agricultural land-use and substratum, also evident in central Highlands rivers (Mishra & Nautiyal 2013b, 2016).

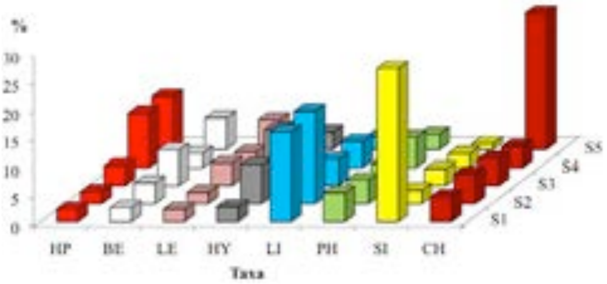

Figure 2. Taxonomic composition of the benthic macroinvertebrate fauna (>1%) at various stations in the Hiyunl Stream. CH—Chironomidae | HP—Heptageniidae | HY—Hydropsychidae | LP—Leptophlebiidae | LI—Limnephelidae | PH—Philopotamidae | SI—Simulidae.

Functionally, the river continuum concept (Vannote et al. 1980) also supports the distribution pattern of invertebrate fauna, as predators (Simulidae)

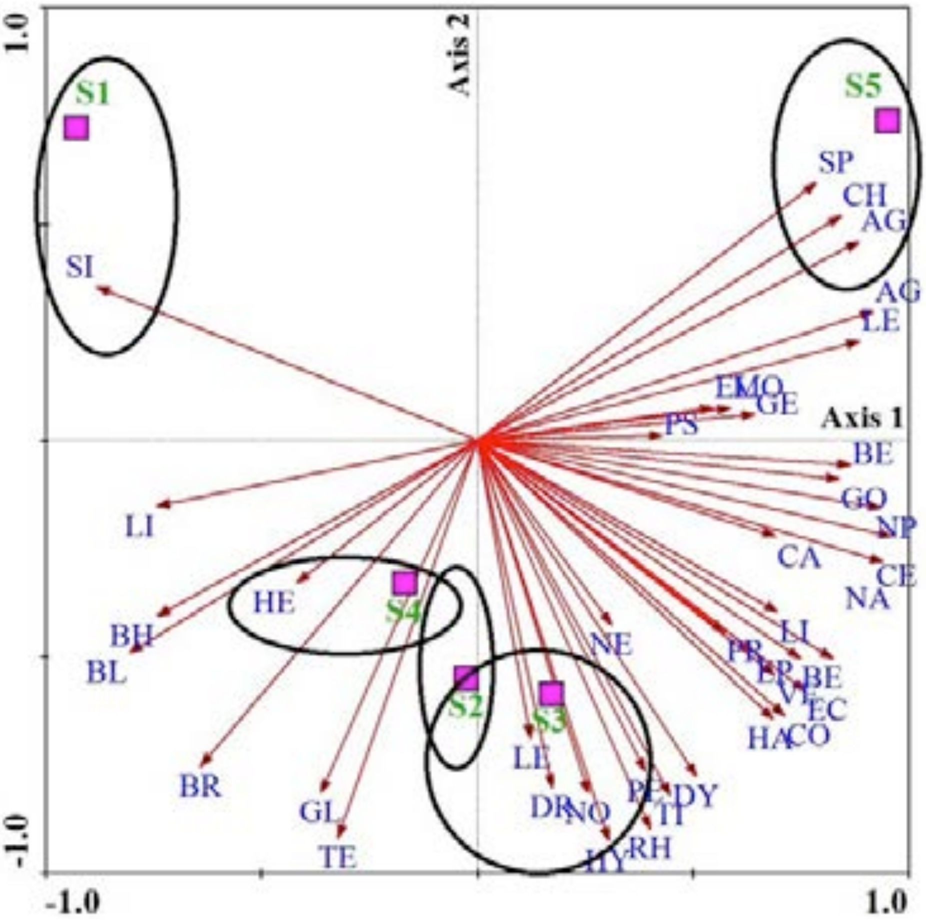

Figure 3. Principal component analysis (PCA): the ordination indicates the characteristic taxa (in circle) through graphical presentation between the taxon (arrows) and station (filled square) in the Hiyunl Stream. The taxa close to the station are characteristic of that station and encircled. HE—Heptageniidae | BA—Baetidae | EP—Ephemerellidae | LE—Leptophlebidae | CA—Caenidae | SP—Siphlonuridae | EC—Ecdyonuridae | HY—Hydroosychidae | LI—Limnephilidae | GL—Glossosomatidae | LP—Leptoceridae | PH—Philopotamidae | BR—Brachycentridae | PSY—Psychomyiidae | RH—Rhyacophilidae | SI—Simulidae | BL—Blepharoceridae | TE—Tendipedini | CH—Chironomidae | PY—Psychodidae | LT—Leptidae | TI—Tipulidae | PE—Perlodidae | PR—Perlidae | CHL—Chloroperlidae | NE—Nemouridae | DR—Dryopidae | HD—Hydrophilidae | EL—Elmidae | HA— Haliplidae | PS—Psephenidae | DY—Dytiscidae | SA—Sialidae | CO—Corixidae | NA—Naucoridae | GE—Gerridae | VE—Vellidae | NP—Nepidae | NO—Notonectidae | BE—Belostomatidae | AGN—Agrionidae | GO—Gomphdae | CE—Coenagridae | CHP—Chlorocyphidae | AG—Agridae | LD—Lipidoptera | MO—Mollusca.

were abundant at S1, followed by collectors at S2 (Limnephilidae) and S3 (Hydropsychidae), scrappers (Heptageniidae) at S4, and collectors (Chironomidae) at S5.

Cluster analysis revealed highest similarity between S3 and S4 as compared to other stations as both the stations were functionally similar (gathering collectors) because of common land-use pattern (agriculture) and stream order (Table 1). The distance between these two stations was c. 8km. These two stations were more similar to S2 and then S1. S5 was noticeably different from all of them (Fig. 3). The similarity among the stations in cluster analysis is also evident in the PCA (Fig. 4) as the circle of S2, S3 and S4 were close to each other and closer to S1 rather than S5.

Characteristic taxa: principal component analysis (PCA)

The eigen values for PCA axis 1 (λ_1=0.501) and 2 (λ_2=0.293) explained cumulative variance in taxonomic composition and taxon-environmental relationships in the stream and caused 5.01% and 29.3% variation in the taxon-site relationship, respectively. The characteristic benthic macroinvertebrate taxa differed at S1, S2, S3, S4 and S5, Simulidae was characteristic taxa at S1, while Limnephildae taxa at S2. Hydropsychiidae, Rhyacophilidae, Tipulidae, Perlodidae, Dryopidae, and Notonectidae were characteristic at S3. Heptageniidae was characteristics at S4, while Chironomidae, Siphlonuridae, and Agrionidae were characteristic taxa at S5 (Fig. 3). Functionally, filtering collector was dominant at S1, shredder at S2, gathering collectors-

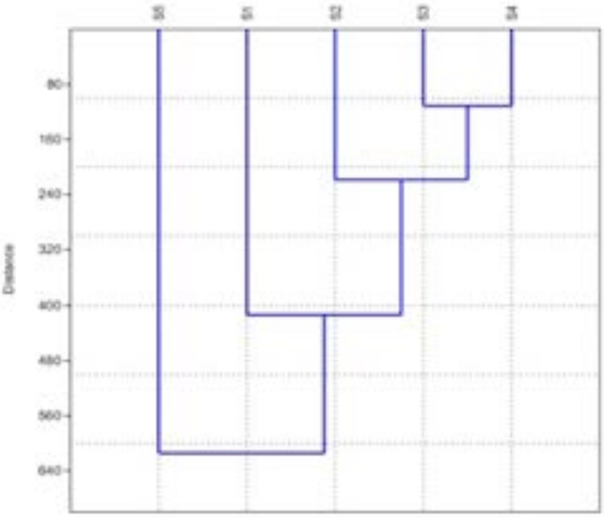

Figure 4. Cluster analysis indicated the similarity among the stations based on linkage distance among the stations.

predators at S3, scraper at S4, and gathering collectors-predators at S5.

The variation in the characteristic taxa at S1, S2, S3, S4, and S5 was attributed to difference in substrate heterogeneity (Table 1) and forest type (S1—oak forest, S2—oak-pine forest, S5—mixed forest). The land-use type (agriculture), however, was similar at S3 and S4. Functionally, the stream was heterotrophic as the gathering and filtering collectors prevailed, attributed to presence of fine particulate organic matter (FPOM) from agricultural land in the lower section of the stream as also observed in the central Indian rivers (Mishra & Nautiyal 2013a). Agriculture is both extensive and intensive in this lower stretch of the stream and anthropogenic influences hence become a prominent factor because of fertilizer and other inputs. The impact of agriculture and habitation was also observed on the distribution of benthic macroinvertebrate fauna in Himalayan rivers (Mishra et al. 2013; Nautiyal et al. 2015) and central Indian rivers (Mishra & Nautiyal 2013a). Vannote et al. (1980) suggested that the longitudinal or continuum models predict that invertebrate assemblages will change along the length of rivers as evident in the present study.

CONCLUSION

The present study indicated that the mean density of benthic macroinvertebrates increased along the stream (except S4), and differed significantly between and among the stations. The taxonomic composition and function of invertebrate fauna varied along the stream length indicated the impact of substrate heterogeneity and land-use type. At some stations, however, the functional composition was observed to be similar with other stations. Thus, the present study indicated the variations in the taxa along the stream.

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Author details: Dr. Vijay Prakash Semwal, Assistant Professor, Major contributions: Research on Benthic macroinvertebrate fauna in the Himalayan rivers/streams. Dr. Asheesh Shivam Mishra, Assistant Professor & Head, performing research on distribution and population ecology of diatom, benthic macroinvertebrate and fish in Central Highlands & Himalayan rivers/streams. Expertise on Environmental Flow studies on the river Ganga and its tributaries, Environmental Impact Assessment (HEP).

Author contribution: VPS data collection from the study area & identify the taxa. ASM worked on data analysis using various softwares and manuscript writing, graphs, and map preparation.

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SEASONAL VEGETATION SHIFT AND WETLAND DYNAMICS IN VULNERABLE GRANITIC ROCKY OUTCROPS OF PALGHAT GAP OF SOUTHERN WESTERN GHATS, KERALA, INDIA

Pathiyil Arabhi [1] & **Maya Chandrasekharan Nair** [2]

[1] Environmental Resources Research Centre (ERRC), NCC Road, P.B. No. 1230, P.O. Peroorkada, Thiruvananthapuram,
Kerala 695005, India.
[1] Department of Botany, Baselius College, K.K. Road, Kottayam, Kerala 686001, India.
[2] Post Graduate and Research Department of Botany, Govt. Victoria College (University of Calicut),
College Road, Palakkad, Kerala 678001, India.
[1] arabhip1@gmail.com (corresponding author), [2] drmayadhoni@gmail.com

Abstract: Low altitude granitic hillock systems prevalent in Palghat (Palakkad) Gap region of southern Western Ghats were analyzed for seasonal dynamics in wetland taxa associated with marshy ephemeral flush vegetation, small ephemeral pools and deep rock pools. Due to characteristic habitat features, such systems harbor a unique pattern of microhabitats and associated floristic components. Wet phase in rocky outcrops in the monsoon season establishes a hydro-geomorphic habitat that supports establishment of wetland taxa like *Eriocaulon, Drosera, Utricularia, Dopatrium*, and *Rotala*. Seasonal shift in the floral associations was evident in tune with wetland dynamics. Wet rocks support ephemeral flush vegetation which display some unique plant associations of species of *Eriocaulon, Utricularia, Drosera, Cyanotis, Murdannia*, and *Lindernia*. Small ephemeral pools displayed taxa like *Rotala malampuzhensis* R.V. Nair*, Dopatrium junceum* (Roxb.) Buch.-Ham. ex Benth.*, D. nudicaule* (Willd.) Benth.*, Monochoria vaginalis* (Burm.f.) C. Presl, and *Cyperus iria* L. Rocky pools are the habitats of aquatic angiosperms like *Nymphaea nouchali* Burm. f., *Ludwigia adscendens* (L.) H. Hara*, Utricularia aurea* Lour. and *Hydrilla verticillata* (L.f.) Royle. The study documented 121 plant taxa from 37 families during a wet phase from rocky outcrops of the study area. Gradual shift in vegetation is evident as water recedes from granitic hillocks. During the period from December to March, the rocky pools dry up which results in a shift in the vegetation pattern where Poaceae members form the dominant elements. As most of the rocky outcrops are exposed to extreme temperature and acute water shortage, the taxa inhabiting such ecosystems tend to evolve much faster than in other habitats. Moreover, the vicinity of these hillocks in the Palghat Gap region to human settlements, face threats like fire, grazing, quarrying, dumping of wastes etc. which may cause considerable loss to the very sensitive plant communities which are not yet fully documented.

Keywords: Granitic hillocks, Palakkad, vegetation shift, wetland dynamics.

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Author details: PATHIYIL ARABHI is working as Assistant Professor in Department of Botany, Baselius College, Kottayam. DR. MAYA CHANDRASEKHARAN NAIR is Assistant Professor and Head, Post Graduate and Research Department of Botany, Govt. Victoria College, Palakkad who is specialized in plant taxonomy and floristics.

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INTRODUCTION

Rocky outcrops, which rise abruptly from the surrounding landscape, have a patchy distribution, and represent centers of diversity and endemism for both animal and plant life (Hopper & Withers 1997). They support high levels of species diversity and endemism, have provided stable micro-climates for thousands of years and also provide important insights into our ecological past where they contain the remains of extinct species (Fitzsimons & Michael 2017). They exhibit extreme climatic and edaphic features strikingly different from the surrounding environment.

The Palghat Gap, a 32-km break in the hill ranges of the Western Ghats with an average elevation of 140m, is a peculiar geological feature in southern India along 10.750^{0}N latitude which divides the Western Ghats into Nilgiri Hills on the northern lip and Anamalai-Palani Hills on the southern lip. The gap area is characterized with gneissic, charnockite and amphibolite rock types (Cruz et al. 2000). Small and medium-sized rocky hillocks are common in the Gap area and most of them are covered with rich vegetation providing rich grazing areas for cattle. They perform significant ecosystem services, as the main repositories of water resources keeping the wells of nearby areas filled. In Kerala, lateritic and granitic hillocks occur with a prevalence of lateritic ones in northern and granitic hillocks in southern Kerala. Numerous low-altitude hillock systems which are characteristic to the Palghat Gap region of southern Western Ghats have their own unique manifestations of floral elements due to spatial and ecological isolation from the surrounding vegetation. These granitic outcrops provide suitable microhabitats for many rare and endemic plants. Floristic explorations on such low-altitude hillocks resulted in the discoveries of taxa new to science (Jose et al. 2013, 2015).

Low-altitude hillock systems exhibit seasonal wetland dynamics and periodical shifts in vegetation patterns in response to the onset and retreat of the monsoons. The wet phase in such hillock systems is characterized by unique associations of ephemeral herbaceous floral elements in specific microhabitats like seasonal pools (Pramod et al. 2014). Most of the hillocks in the Palghat Gap region are found in the neighborhood of human settlements and are facing various threats, including fire, grazing, quarrying and dumping of wastes, which cause considerable loss to the very sensitive plant communities which are not yet fully documented. With this background, the present paper summarizes the floristic diversity of ephemerals associated with the microhabitats of granitic hillocks in the Palghat Gap of southern Western Ghats.

MATERIALS AND METHODS

Study Area

Documentation of wetland taxa in selected granitic hillocks of seven different forest ranges, viz., Alathur, Kollengode, Nelliyampathy, Olavakkode, Ottappalam, Walayar, and Mannarkkad was carried out between June 2016 and May 2018. The sampling locations lie between 10.551–11.010 ^{0}N and 76.161–76.828 ^{0}E (Image 1). The plants were collected and identified using regional floras along with reference to local herbaria MH and CALI and enumerated based on APG IV (Chase et al. 2016). The nomenclature validation was carried out using IPNI (www.ipni.org), The Plant List (www.theplantlist.org) databases and Flowering Plants of Kerala (Sasidharan 2014). The plant diversity in different microhabitats during the wet phase were identified (Sreejith et al. 2016), documented and seasonal vegetation shift was observed. The threat assessment of the taxa was based on IUCN (2019) guidelines. The plants and habitats were photographed using digital cameras Nikon D 3200 and Sony Cyber shot DSC HX7V.

RESULTS AND DISCUSSION

Granitic hillock systems harbor unique microhabitats and associated floristic components. Seasonal shift in vegetation was apparent, which shows demarcating wet and dry phases based on the availability of moisture. The micro environment on the rock surface in these hillock systems varied between extremely hot and arid in dry seasons to water logged and slippery in the wet season. Microhabitat conditions present on the outcrops vary significantly from the adjoining areas and hence they can be referred to as terrestrial habitat islands.

Wet phase in granitic hillocks

The establishment of the wet phase in the rocky outcrops begins with the onset of the southwest monsoon and ends with the completion of the northeast monsoon. Occurrence of the wet phase in rocky outcrops in the form of different microhabitats in the monsoon season (June–November) establishes hydro-geomorphic habitats with significant microhabitats and floral associations (Image 2).

Image 1. Study area and sample hillocks: A—Wet phase in hillocks | B—Dry phase in hillocks | C—Vizhumala | D—Karadikunnu | E—Ayilamudichi mala | F—Mambram | G—Anangan mala | H—Koomachi mala | I—Vakkodan mala | J—Vamala | K—Athanad | L—Mallanpara. © Pathiyil Arabhi.

a) Ephemeral flush vegetation (EFV): This is the predominant vegetation type occurring in the microhabitats of granitic hillocks during the wet phase. The ephemeral herbaceous plants flourish in the open rocky slopes through which water flows slowly. This microhabitat harbors 11 species, viz., *Burmannia* *coelestis* D. Don*, Cyanotis papilionacea* (Burm. f.) Schult. & Schult. f., *Drosera indica* L., *D. burmanni* Vahl, *Eriocaulon pectinatum* Ruhland, *E. thwaitesii* Körn.*, E. xeranthemum* Mart.*, Lindernia ciliata* (Colsm.) Pennell, *Murdannia semiteres* (Dalzell) Santapau, *Utricularia lazulina* P. Taylor, and *U. graminifolia* Vahl; and of these, species of *Utricularia* are exclusive EFV endemics and the insectivorous taxa which prefer nutrient deficient soil, viz., *Drosera* spp. and *Utricularia* spp., were found to be well adapted to this habitat. This micro-eco-climate showed unique plant associations between *Eriocaulon-Utricularia-Drosera* and *Lindernia.*

b) Small ephemeral pools (SEP): Most of the rocky outcrops possess several shallow depressions which remain filled with water during the rainy season. They form unique microhabitats for some wet phase elements, such as, *Dopatrium junceum* (Roxb.) Buch.-Ham. ex Benth., *D. nudicaule* (Willd.) Benth., *Rotala indica* (Willd.) Koehne, *R. malampuzhensis* R. V. Nair, *Monochoria vaginalis* (Burm. f.) C. Presl, and *Cyperus iria* L. The study recorded 20 species (Table 1) from this microhabitat and the above six taxa were specifically confined to this microhabitat.

c) Rock pools (RP): Some hillocks possess deep water-filled pools mainly created as a result of quarrying which harbor aquatic taxa like *Nymphaea nouchali* Burm.f., *Hydrilla verticillata* (L.f.) Royle*, Ludwigia adscendens* (L.) H. Hara, *Utricularia aurea* Lour., *Ipomoea aquatica* Forssk., *Marsilea quadrifolia* L., and *Rotala mexicana* Schltdl. & Cham. This unique ecosystem recorded eight species, of which the first four members were recorded from this microhabitat only.

d) Exposed rock surfaces (ERS): These are flat or irregular rocky surfaces which were directly exposed to sunlight. These areas with poor soil deposition remain more or less wet during the rainy season. This survey recorded 35 taxa from this microhabitat, viz., *Burmannia coelestis* D.Don, *Centranthera indica* (L.) Gamble, *Geissaspis cristata* Wight & Arn., and *Lobelia alsinoides* Lam.*,* of which *Xyris pauciflora* Willd. was recorded specifically from this microhabitat.

e) Rocky crevices and fissures (RCF): Granitic outcrops possess several rock crevices and fissures with very thin soil deposition which act as ecological niche for some specific species like *Henckelia incana* (Vahl) Spreng. and *Cyanotis arachnoidea* C.B. Clarke, and about 14 species were recorded from this microhabitat and the above mentioned taxa were specifically confined to this habitat.

f) Soil-filled depressions (SFD): Rocky outcrops possess several depressions which accumulate water and soil during the rainy season and provide a marshy habitat. Around 81 species were recorded from this particular microhabitat of which *Alysicarpus monilifer* (L.) DC.*, Isoetes coromandeliana* L.f.*, Crotalaria linifolia* L.f., *Cyanotis burmanniana* Wight*, Ophioglossum nudicaule* L.f., *Lindernia anagallis* (Burm.f.) Pennell*, Ludwigia hyssopifolia* (G.Don) Exell, *Mitrasacme pygmaea* R.Br., etc. were some species found exclusively in this microhabitat.

g) Soil rich area (SRA): These microhabitats with good soil deposition having more than 20cm soil thickness, during the wet phase were frequently occupied by species like *Chrysopogon aciculatus* (Retz.) Trin, *Cyanotis cristata* (L.) D.Don, *Eclipta prostrata* (L.) L., *Spermacoce articularis* L.f., *Spermacoce hispida* L.*, Spermacoce alata* Aubl., *Commelina clavata* C.B. Clarke, *Commelina diffusa* Burm.f.*, Eragrostis unioloides* (Retz.) Nees ex Steud., and *Spermacoce ocymoides* Burm.f. Among them, the first six taxa were exclusively found in this microhabitat.

h) Boulders (B): These microhabitats consist of isolated rocks or large rocks in groups which were found to be inhabited with some mosses, pteridophytes like *Cheilanthes opposita* Kaulf., *Parahemionitis cordata* (Hook. & Grev.) Fraser-Jenk. and angiosperms like *Bulbostylis barbata* (Rottb.) C.B. Clarke, *Osbeckia muralis* Naudin, and *Oxalis corniculata* L. during the wet phase.

During the study 121 plant species belonging to 37 families (Table 1) were documented from different microhabitats in the wet phase (June–November). The most represented family were Fabaceae with 22 species followed by Cyperaceae with 16 species and Commelinaceae with 10 species.

Dry phase in granitic hillocks

A gradual shift in vegetation was evident as water receded from granitic hillocks after the retreat of the monsoon. During the period from December to April, the small ephemeral pools dry up, ephemeral flush vegetation disappears, water level in deep rock pools lowers, which results in a shift in wet vegetation to a drought-adaptive taxa. Dry phase is characterized by the complete absence of microhabitats like EFV and SEP and shift in plant associations in other microhabitats like ERS, RCF, SFD and SRA (Image 3).

During the dry phase, plant species like *Heliotropium marifolium* J. Koenig *ex* Retz. and *Cleome aspera* J. Koenig *ex* DC. dominate in exposed rock surfaces (ERS) and rock crevices and fissures (RCF) harbors plant taxa like *Anisochilus carnosus* (L.f.) Wall.*, Andrographis echioides* (L.) Nees, *Cleome viscosa* L., *Dimeria deccanensis* Bor,

Image 2. Wetphase microhabitats in rocky hillocks: A–C—Ephemeral flush vegetation (A–*Cyanotis papilionacea* (Burm.f.) Schult. & Schult.f.; B–*Eriocaulon pectinatum* Ruhland; C–*Utricularia lazulina* P. Taylor) | D—Rock pools | E&F—Small ephemeral pools | G—Exposed rock surfaces (*Sesamum prostratum* Retz.) | H—Soil filled depressions (*Cyperus* spp.) | I&J—Rocky crevices and fissures (I–*Cyperus maderaspatanus* Wild.,; J–*Cyanotis papilionacea* (Burm.f.) Schult. & Schult.f.)| K—Soil rich area | L—Boulders. © Pathiyil Arabhi.

Hyptis suaveolens (L.) Poit., and *Theriophonum fischeri* Sivad. Plant species like *Perotis indica* (L.) Kuntze, *Croton hirtus* L'Hér., *Ischaemum rugosum* Salisb., *Rhynchosia rufescens* (Willd.) DC., *Blumea virens* DC., *Richardia scabra* L., *Tephrosia villosa* (L.) Pers., *Merremia tridentata* (L.) Hallier f., and *Apluda mutica* L. were

Table 1. Distribution of wet phase floristic elements in different microhabitats.

	Botanical name	Family	Micro-habitats
1	*Aeschynomene indica* L.	Fabaceae	SEP, SFD
2	*Alysicarpus bupleurifolius* (L.) DC.	Fabaceae	SFD
3	*Alysicarpus heterophyllus* (Baker) Jafri & Ali	Fabaceae	SFD
4	*Alysicarpus monilifer* (L.) DC.	Fabaceae	SFD
5	*Alysicarpus vaginalis* (L.) DC.	Fabaceae	ERS, SFD
6	*Bulbostylis barbata* (Rottb.) C.B.Clarke	Cyperaceae	B, ERS, RCF
7	*Bulbostylis puberula* Kunth	Cyperaceae	SEP, RCF
8	*Burmannia coelestis* D.Don	Burmanniaceae	ERS, EFV
9	*Centranthera indica* (L.) Gamble	Orobanchaceae	ERS, SFD
10	*Centranthera tranquebarica* (Spreng.) Merr.	Orobanchaceae	SEP, SFD
11	*Chamaecrista absus* (L.) H.S.Irwin & Barneby	Fabaceae	SFD, SRA
12	*Chamaecrista kleinii* (Wight & Arn.) V.Singh	Fabaceae	SFD
13	*Chamaecrista mimosoides* (L.) Greene	Fabaceae	ERS, SFD
14	*Chamaecrista nictitans* subsp. *patellaria* (Collad.) H.S.Irwin & Barneby	Fabaceae	ERS, SFD
15	*Cheilanthes opposita* Kaulf.	Pteridaceae	B
16	*Chrysopogon aciculatus* (Retz.) Trin.	Poaceae	SRA
17	*Commelina clavata* C.B.Clarke	Commelinaceae	SFD, SRA
18	*Commelina diffusa* Burm.f.	Commelinaceae	SFD, SRA
19	*Commelina wightii* Raizada	Commelinaceae	ERS, SFD
20	*Crotalaria linifolia* L.f.	Fabaceae	SFD
21	*Crotalaria nana* Burm.f.	Fabaceae	SFD
22	*Cyanotis arachnoidea* C.B.Clarke	Commelinaceae	RCF
23	*Cyanotis axillaris* (L.) D.Don ex Sweet	Commelinaceae	ERS, SEP
24	*Cyanotis burmanniana* Wight	Commelinaceae	SFD
25	*Cyanotis cristata* (L.) D.Don	Commelinaceae	SRA
26	*Cyanotis papilionacea* (Burm.f.) Schult. & Schult.f.	Commelinaceae	EFV, ERS, RCF
27	*Cyperus clarkei* T.Cooke	Cyperaceae	SFD
28	*Cyperus compressus* L.	Cyperaceae	SFD
29	*Cyperus cyperinus* (Retz.) Suringar	Cyperaceae	SFD
30	*Cyperus dubius* Rottb.	Cyperaceae	SFD
31	*Cyperus iria* L.	Cyperaceae	SEP
32	*Cyperus maderaspatanus* Willd.	Cyperaceae	ERS, RCF
33	*Cyperus rotundus* L.	Cyperaceae	SFD
34	*Desmodium triflorum* (L.) DC.	Fabaceae	ERS, SFD
35	*Dipcadi montanum* (Dalzell) Baker	Asparagaceae	SFD
36	*Dopatrium junceum* (Roxb.) Buch.-Ham. ex Benth.	Plantaginaceae	SEP
37	*Dopatrium nudicaule* (Willd.) Benth.	Plantaginaceae	SEP
38	*Drosera burmanni* Vahl	Droseraceae	ERS, EFV
39	*Drosera indica* L.	Droseraceae	ERS, EFV
40	*Eclipta prostrata* (L.)L.	Asteraceae	SRA
41	*Eragrostis unioloides* (Retz.) Nees ex Steud.	Poaceae	ERS, SFD, SRA
42	*Eriocaulon pectinatum* Ruhland	Eriocaulaceae	EFV, ERS
43	*Eriocaulon thwaitesii* Körn.	Eriocaulaceae	EFV, ERS
44	*Eriocaulon xeranthemum* Mart.	Eriocaulaceae	EFV, ERS
45	*Fimbristylis aestivalis* Vahl	Cyperaceae	RCF, SFD
46	*Fimbristylis argentea* (Rottb.) Vahl	Cyperaceae	SFD
47	*Fimbristylis falcata* (Vahl) Kunth	Cyperaceae	SFD
48	*Fimbristylis littoralis* Gaudich.	Cyperaceae	SFD
49	*Fimbristylis microcarya* F.Muell.	Cyperaceae	SFD, SEP
50	*Fimbristylis polytrichoides* (Retz.) Vahl	Cyperaceae	RCF, SFD
51	*Fimbristylis schoenoides* (Retz.) Vahl	Cyperaceae	SEP, SFD
52	*Geissaspis cristata* Wight & Arn.	Fabaceae	ERS, SFD
53	*Geissaspis tenella* Benth.	Fabaceae	ERS, SFD
54	*Glinus oppositifolius* (L.) Aug. DC.	Molluginaceae	SFD
55	*Henckelia incana* (Vahl) Spreng.	Gesneriaceae	RCF
56	*Hoppea fastigiata* (Griseb.) C.B.Clarke	Gentianaceae	ERS, SFD
57	*Hydrilla verticillata* (L.f.) Royle	Hydrocharitaceae	RP
58	*Hygrophila ringens* (L.) R.Br. ex Spreng.	Acanthaceae	SFD
59	*Indigofera uniflora* Roxb.	Fabaceae	ERS, SFD
60	*Ipomoea aquatica* Forssk.	Convolvulaceae	SEP, RP
61	*Ipomoea marginata* (Desr.) Verdc.	Convolvulaceae	SFD, SEP
62	*Isoetes coromandeliana* L.f.	Isoetaceae	SFD
63	*Limnophila aromatica* (Lam.) Merr.	Plantaginaceae	SEP, SFD
64	*Limnophila heterophylla* (Roxb.) Benth.	Plantaginaceae	SEP, SFD
65	*Lindernia anagallis* (Burm.f.) Pennell	Linderniaceae	SFD
66	*Lindernia antipoda* (L.) Alston	Linderniaceae	SFD
67	*Lindernia caespitosa* (Blume) Panigrahi	Linderniaceae	SFD
68	*Lindernia ciliata* (Colsm.) Pennell	Linderniaceae	EFV, ERS, SFD
69	*Lindernia crustacea* (L.) F.Muell.	Linderniaceae	SFD
70	*Lindernia hyssopioides* (L.) Haines	Linderniaceae	SFD
71	*Lindernia nummulariifolia* (D.Don) Wettst.	Linderniaceae	SFD, SEP
72	*Lindernia rotundifolia* (L.) Alston	Linderniaceae	SFD, SEP
73	*Lobelia alsinoides* Lam.	Campanulaceae	ERS, SFD
74	*Ludwigia adscendens* (L.) H.Hara	Onagraceae	RP

	Botanical name	Family	Micro-habitats
75	*Ludwigia hyssopifolia* (G.Don) Exell	Onagraceae	SFD
76	*Marsilea quadrifolia* L.	Marsileaceae	SEP, RP
77	*Melochia corchorifolia* L.	Malvaceae	SFD, SRA
78	*Microcarpaea minima* (K.D.Koenig ex Retz.) Merr.	Plantaginaceae	SFD
79	*Mitrasacme indica* Wight	Loganiacaeae	SFD
80	*Mitrasacme pygmaea* R.Br.	Loganiacaeae	SFD
81	*Monochoria vaginalis* (Burm.f.) C.Presl	Pontederiaceae	SEP
82	*Murdannia semiteres* (Dalzell) Santapau	Commelinaceae	EFV, ERS
83	*Murdannia spirata* (L.) G.Brückn.	Commelinaceae	SFD
84	*Nymphaea nouchali* Burm.f.	Nymphaeaceae	RP
85	*Oldenlandia corymbosa* L.	Rubiaceae	SFD, RCF
86	*Oldenlandia diffusa* (Willd.) Roxb.	Rubiaceae	SFD
87	*Oldenlandia dineshii* Sojan & Suresh	Rubiaceae	ERS, SFD
88	*Ophioglossum nudicaule* L.f.	Ophioglossaceae	SFD
89	*Oryza rufipogon* Griff.	Poaceae	SFD
90	*Osbeckia muralis* Naudin	Melastomataceae	B, ERS, RCF, SFD
91	*Oxalis corniculata* L.	Oxalidaceae	B, SFD
92	*Pandanus canaranus* Warb.	Pandanaceae	RP
93	*Parahemionitis cordata* (Hook. & Grev.) Fraser-Jenk.	Pteridaceae	B
94	*Parasopubia delphiniifolia* (L.) H.-P.Hofm. & Eb.Fisch.	Orobanchaceae	ERS, SFD
95	*Polygala chinensis* L.	Polygalaceae	SFD
96	*Polygala persicariifolia* DC.	Polygalaceae	ERS, RCF
97	*Rhamphicarpa fistulosa* (Hochst.) Benth.	Orobanchaceae	ERS, SFD
98	*Rhynchosia rufescens* (Willd.) DC.	Fabaceae	RCF, SFD
99	*Rhynchosia suaveolens* (L.f.) DC.	Fabaceae	RCF, SFD
100	*Rotala indica* (Willd.) Koehne	Lythraceae	SEP
101	*Rotala malampuzhensis* R.VNair	Lythraceae	SEP
102	*Rotala mexicana* Schltdl. & Cham.	Lythraceae	SEP, RP
103	*Sesamum prostratum* Retz.	Pedaliaceae	ERS, SFD
104	*Setaria pumila* (Poir.) Roem. & Schult.	Poaceae	SFD, SRA
105	*Sida acuta* Burm.f.	Malvaceae	SFD, SRA
106	*Smithia blanda* Wall.	Fabaceae	SFD
107	*Smithia conferta* Sm.	Fabaceae	SFD
108	*Spermacoce alata* Aubl.	Rubiaceae	SRA
109	*Spermacoce articularis* L.f.	Rubiaceae	SRA
110	*Spermacoce hispida* L.	Rubiaceae	SRA
111	*Spermacoce ocymoides* Burm.f.	Rubiaceae	SFD, SRA
112	*Spermacoce pusilla* Wall.	Rubiaceae	RCF, SFD
113	*Striga angustifolia* (D.Don) C.J. Saldanha	Orobanchaceae	ERS, SFD
114	*Striga asiatica* (L.) Kuntze	Orobanchaceae	ERS, SFD
115	*Tephrosia maxima* (L.) Pers.	Fabaceae	SFD, SRA
116	*Tephrosia purpurea* (L.) Pers.	Fabaceae	ERS, SFD, SRA
117	*Utricularia aurea* Lour.	Lentibulariaceae	RP
118	*Utricularia lazulina* P.Taylor	Lentibulariaceae	EFV
119	*Utricularia graminifolia* Vahl	Lentibulariaceae	EFV
120	*Xyris pauciflora* Willd.	Xyridaceae	ERS
121	*Zornia gibbosa* Span.	Fabaceae	ERS, SFD

EFV—Ephemeral flush vegetation | SEP—Small ephemeral pool | RP—Rock pool | ERS—Exposed rock surface | RCF—Rocky crevice and fissure | SFD—Soil-filled depression | SRA—Soil rich area | B—Boulder.

mostly seen in soil-filled depressions (SFD) during the dry phase. Soil rich area (SRA) is dominated by plant taxa such as *Alternanthera bettzickiana* (Regel) G. Nicholson, *Achyranthes aspera* L., *Acalypha alnifolia* Klein ex Willd., *Sesamum radiatum* Schumach. & Thonn., *Sida cordata* (Burm.f.) Borss. Waalk., *Boerhavia diffusa L.*, *Ipomoea pes-tigridis* L., grasses like *Heteropogon contortus* (L.) P. Beauv. ex Roem. & Schult., *Arundinella mesophylla* Nees ex Steud., and *Garnotia tenella* (Arn. ex Miq.) Janowski during the dry phase. During the dry phase, the mosses and pteridophytes inhabited on boulders (B) dry up.

Both dry and wet phases in granitic outcrops share floristic elements of scrub jungles and tree cover and such vegetation provides isolated patches of greenery to these vulnerable habitats.

Scrub jungle elements

Some shrubs and climbers give a stunted forest appearance to the rocky hillocks. *Ziziphus jujuba* Mill., *Z. oenopolia* (L.) Mill., *Canthium coromandelicum* (Burm.f.) Alston*, C. rheedei* DC., *Euphorbia trigona* Mill., *Flacourtia indica* (Burm.f.) Merr., *Ehretia microphylla* Lam*.*, *Catunaregam spinosa* (Thunb.) Tirveng., *Casearia esculenta* Roxb., *C. wynadensis* Bedd., *Abrus precatorius* L*.*, *Getonia floribunda* Roxb., *Pterolobium hexapetalum* (Roth) Santapau & Wagh, and *Spatholobus parviflorus* (DC.) Kuntze. are some of the common scrub jungle elements found in rocky systems.

Tree cover

The extent of tree cover varies in different hillock systems from thick tree cover and associated shade loving shrub elements to hillock systems with sparsely

Image 3. Dryphase microhabitats in rocky hillocks: A—Exposed rock surfaces (*Heliotropium marifolium* J. Koenig ex Retz.) | B&C—Rocky crevices and fissures (B–*Anisochilus carnosus* (L.f.) Wall.,; C–*Theriophonum fischeri* Sivad.) | D—Soil filled depressions | E—Soil rich area | F&G—Tree cover | H—Scrub jungle elements (*Ziziphus oenopolia* (L.) Mill.). © Pathiyil Arabhi.

distributed tree species. This study documented 100 tree taxa from rocky hillocks and among them, *Cochlospermum religiosum* (L.) Alston, *Givotia moluccana* (L.) Sreem., *Firmiana simplex* (L.) W. Wight, *Phyllanthus emblica* L., *Strychnos nux-vomica* L., *S. potatorum* L.f., *Morinda pubescens* Sm., *Azadirachta indica* A. Juss., *Holarrhena pubescens* Wall. ex G. Don, *Cleistanthus collinus* (Roxb.) Benth. ex Hook.f., *Wrightia tinctoria* R.Br., *Ficus exasperata* Vahl, *Pterocarpus marsupium* Roxb., and *Terminalia paniculata* Roth. were common inhabitants of most of the rocky hillocks.

Threatened Taxa with conservation significance

The vulnerable habitats of granitic rocky outcrops of the Palghat Gap of the southern Western Ghats harbor taxa with conservation significance. The analysis revealed the presence of five taxa under threatened category (IUCN 2019). *Pterocarpus marsupium* Roxb. among tree cover element is classified as Near Threatened and *Cleistanthus collinus* (Roxb.) Benth. ex Hook.f. and

Santalum album L. are Vulnerable. The wet phase taxon, *Eriocaulon pectinatum* Ruhland and scrub jungle element, *Casearia wynadensis* Bedd. are also classified as Vulnerable as per IUCN Red List of Threatened Plants version 2019-2 (IUCN 2019). Conservation status of about 45% wetland taxa recorded from the study area are not yet assessed and as the habitats of these elements are facing serious threats, the future of these taxa inhabiting these niche is uncertain.

Threats to low altitude hillocks in Palghat Gap region

Rapid urbanization places anthropogenic pressures on low altitude granitic hillocks in the Gap region of the southern Western Ghats. Indiscriminate quarrying poses serious threats to the unique flora and fauna on the granitic hillocks. Some of the low altitude hillocks on either side of the national highways were destroyed for expansion of the highway. The hillocks near human settlements have become dumping grounds for disposal of wastes which adversely affects the soil quality and vegetation. Invasion of *Chromolaena odorata* (L.) R.M. King & H. Rob. and *Mimosa diplotricha* Sauvalle and promotion of monoculture plantations of *Tectona* and *Acacia* were found to retard the growth of indigenous flora of the hillocks. During the dry phase, most of the rocky outcrops were dominated by fire-indicating taxa like *Hyptis suaveolens* (L.) Poit. and grasses like *Apluda mutica* L. which easily catch fire and lead to the loss of natural vegetation. Some of these hillocks are susceptible to landslides owing to indiscriminate quarrying which in turn destroy entire flora and fauna of associated microhabitats.

CONCLUSIONS

All microhabitat categorizations are limited by factors such as soil depth, water content and other seasonal variations and there is no clear physical demarcation between the habitats. The onset of the monsoon season leads to dispersion of water in soil-filled depressions or even flat surfaces and hence overlay in species composition can be observed in these habitats. While some taxa were restricted to a single microhabitat, other species were able to grow in an array of closely similar microhabitats although their dominance levels varied with reference to specific habitat inclinations and niche.

The documentation of taxa during the wet phase alone could record 121 elements belonging to 37 families distributed in eight different microhabitats which are ephemeral and seasonal. The adaptive strategies provided by such microhabitats support taxa which have narrow ecological amplitude and share narrow ecological niches. Hence conservation of such microhabitats becomes inevitable as far as these vulnerable habitats are concerned as they are prone to many human-induced threats along with biological invasions. Natural calamities such as landslides and forest fires and anthropogenic activities including quarrying and urbanization reduce the natural vegetation of these unique habitats. Hence, conservation strategies have to be formulated for the maintenance of floristic diversity in these unique ecosystems.

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A comprehensive checklist of endemic flora of Meghalaya, India

Aabid Hussain Mir [1], Krishna Upadhaya [2], Dilip Kumar Roy [3], Chaya Deori [4] & Bikarma Singh [5]

[1] Department of Environmental Studies, North-Eastern Hill University, Shillong, Meghalaya 793022, India.
[2] Department of Basic Sciences and Social Sciences, North-Eastern Hill University, Shillong, Meghalaya 793022, India.
[3,4] Botanical Survey of India, Eastern Regional Centre, Shillong, Meghalaya 793003, India.
[5] CSIR - Indian Institute of Integrative Medicine, Canal Road, Jammu 180001, India.
[1] aabidm4@gmail.com, [2] upkri@yahoo.com (corresponding author), [3] dilipbsierc@gmail.com,
[4] drchayadeoribsi@gmail.com, [5] drbikarma@iiim.ac.in

Abstract: The geographical distribution of plants of Meghalaya show that a total of 548 plant taxa belonging to 302 genera and 100 families are endemic to northeastern India or Indo-Burma or the eastern Himalaya region. Of these, 115 species are exclusively endemic to the state of Meghalaya. The dominant life form is epiphytes (25.4%), followed by trees (25%), shrubs (21.7%), herbs (21%), climbers (6.6%) and parasites (0.4%). In terms of species richness, Orchidaceae is the largest family with 146 species and *Bulbophyllum* is the dominant genera represented by 15 species. The present investigation reveals that most species considered endemic to the state of Meghalaya has extended geographic distribution to neighbouring states and other countries. Majority of the endemic taxa are restricted to protected areas such as national parks, wildlife sanctuaries, conservation reserves, and small forest patches preserved in the form of community forests or sacred groves. Lesser known species with small populations outside the protected areas are on the verge of extinction due to a number of anthropogenic activities, hence warranting immediate conservation measures.

Keywords: Conservation, diversity, forest fragmentation, Indo-Burma hotspot, northeastern India, Orchidaceae.

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Author details: Dr. Aabid Hussain Mir worked extensively in community forests of Meghalaya for his PhD thesis and his interests include plant diversity and conservation biology. Dr. Krishna Upadhaya is a plant ecologist and actively involved in research dealing with plant diversity, ecosystem functioning and regeneration ecology of endemic and threatened species. Dr. Dilip Kumar Roy from Botanical Survey of India, Shillong is a plant taxonomist with interest in field botanical exploration and higher plant taxonomy. Dr. Chaya Deori working as Scientist D in Botanical Survey of India, Shillong is specialized in Orchidaceae. Dr. Bikarma Singh working as Scientist in CSIR-Indian Institute of Integrative Medicine, Jammu is higher plant taxonomist working on ethnobotany and plant natural products for value addition.

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INTRODUCTION

Population explosion and associated human driven major changes in land use have led to the rapid disappearance of forests and endangered many important plant species and their habitats (Defries 2010). It has also increased the risks of loss of many vital services on which human beings depend (Khandel et al. 2012). Anthropogenic disturbances and its related habitat fragmentation have been identified as a major cause of biodiversity loss (Pao & Upadhaya 2017). Of particular concern are those places with special biological features that comprise of high diversity and high levels of endemism. Such areas have caught the attention of conservation scientists, practitioners and planners (Margules & Pressey 2000; Myers et al. 2000). The degree of endemism for an area is cited as a measure of the uniqueness of the flora, and consequently is important for prioritizing sites for conservation (Young et al. 2002). Endemic species with limited geographical ranges are more susceptible to extinction than widely distributed species as the former is extremely vulnerable to environmental change and anthropogenic disturbances (Myers 1988). Given that endemism and extinction risks are closely coupled, actions to minimize global extinction needs to focus on patterns in endemism and range-restricted species (Pimm & Brooks 2000).

The state of Meghalaya (owing to the diverse ecological conditions such as wide variation in rainfall, temperature, altitude and edaphic conditions) supports luxuriant growth of different types of vegetation, viz: tropical evergreen, tropical semi evergreen, tropical moist and dry deciduous, subtropical broad leaved hill forests, subtropical pine forests, temperate forests, and grasslands (Champion & Seth 1968; Rao & Hajra 1986). The state, being a part of Indo-Burma hotspot, is rich in plant diversity with a high level of endemism (Khan et al. 1997). The floristic richness of the state has been recognised by several earlier workers (Hooker 1854, 1872−97, 1904; Brandis 1906; Kanjilal et al. 1934−40). Although a total of 3,334 plant species are known from the state (Khan et al. 1997), the information on endemic species is scarce and a complete checklist of endemic plants is still lacking. Though some studies have been carried out to enumerate endemic species (Khan et al. 1997; Lakadong & Barik 2006; Lakadong 2009), these studies are inadequate. Many new taxa have been described from the state in the recent past and several taxa which were earlier considered as endemic to the state have been reported from other parts of the world. Hence, it has become necessary to assess the current status of endemic plants of the state. The present study was conducted to assess the diversity of endemic plants in the state and provide base line information on their distribution. Such a study will help in taking effective measures for the conservation and management of the intended target species.

MATERIALS AND METHODS

Study area

The state of Meghalaya in northeastern India covers an area of 22,429km^2 with an altitudinal range of 50–1,990 m. Geographically, being a part of the Indo-Burma hotspot, it is also close to the eastern Himalaya. The vegetation of the state can be broadly categorized into tropical forests, subtropical broadleaved and pine forests, temperate forests and grasslands (Haridasan & Rao 1985−1987 (Images 1–6)). The climate of the area is monsoonal with distinct wet and dry seasons. The wet season extends from May and continues up to October, whereas the dry season extends from November to March. The western part of Meghalaya (Garo Hills) being relatively at a low elevation, experiences high temperatures, whereas Khasi and Jaintia hills have low temperatures. The average rainfall of the state ranges from 2,689mm to 4,000mm, except Cherrapunjee and Mawsynram that record the highest rainfall (12,000–13,000 mm) in the world. The state consists mainly of Archean rock formations, with rich deposits of valuable minerals like coal, limestone, uranium and sillimanite.

Data collection

The database of endemic species was prepared with the help of published literature (Kanjilal et al. 1934−1940; Myrthong 1980; Balakrishnan 1981−1983; Joseph 1982; Kumar 1984; Haridasan & Rao 1985−1987; Ahmedullah & Nayar 1986; Kataki 1986; Rao & Hajra 1986; Renuka 1996; Khan et al. 1997; Nayar & Sastry 1987, 1988, 1990; Seethalakshi & Kumar 1998; Walter & Gillett 1998; Jamir & Pandey 2003; Upadhaya et al. 2003, 2013; Pandey et al. 2005; Singh et al. 2015) and referring to the specimens deposited in the herbaria of the Botanical Survey of India, Eastern Regional Centre, Shillong (ASSAM) and Department of Botany, North-Eastern Hill University, Shillong (NEHU). This was followed by rapid field exploration in different parts of the state during 2012–2016. Collected plant materials were processed and herbarium specimens prepared following Jain & Rao (1977). Identification was confirmed with the help of available literature (Kanjilal

Image 1. An overview of dense forest at Nokrek Biosphere Reserve.

Image 2. An overview of Mawsynram area in Meghalaya.

Image 3. An overview of Sacred Grove at Mawnai.

Image 4. Land scape at Ranikor in West Khasi Hills of Meghalaya.

Image 5. Tropical forest in Balphakram National Park in Meghalaya.

Image 6. Subtropical forest at Garo Hills in Meghalaya.

et al. 1934–1940; Balakrishnan 1981–1983; Haridasan & Rao 1985–1987) and by comparing with the specimens, housed at ASSAM. Voucher specimens were deposited in the herbaria at ASSAM. The distribution of the species in the state and other parts of the world was thoroughly reviewed. The species whose distribution is restricted only to Meghalaya were considered as 'narrow endemic' and those that are distributed in northeastern India, Indo-Burma and/or eastern Himalaya hotspots were considered as endemic.

RESULTS AND DISCUSSION

In the database, a total of 548 species distributed in 100 families and 302 genera were recorded (Appendix 1). Of these, epiphytes were dominant with 139 species, followed by trees (137 species), shrubs (119) and herbs (115) (Images 7–64). Other life forms (climbers and parasites) were represented by <50 species (Fig. 1). Out of the total, 115 species were exclusively endemic to the state and the rest (433) were restricted to northeastern India or Indo-Burma or the eastern Himalayan region. In terms of species richness, Orchidaceae was the dominant family with 146 species, followed by Rubiaceae (27 species), Acanthaceae (23), Lauraceae and Poaceae (21 species each), Zingiberaceae (18), Ericaceae (14), Rosaceae (13), Euphorbiaceae (12), Fabaceae (10), Annonaceae and Myrsinaceae (9 species each), Arecaceae, Balsaminaceae and Elaeocarpaceae (8 species each), Magnoliaceae and Melastomataceae (7 species each), Araliaceae, Celastraceae, Gesneriaceae, Lamiaceae and Theaceae (6 species each), Anacardiaceae, Asclepiadaceae, Myrtaceae, Oleaceae and Primulaceae (5 each), Aquifoliaceae, Araceae, Asparagaceae, Begoniaceae, Clusiaceae, Ebenaceae, Menispermaceae, Piperaceae, Rutaceae and Sapotaceae (4 each), Thymelaeaceae, Boraginaceae, Eriocaulaceae, Loranthaceae, Malpighiaceae, Ranunculaceae, Sabiaceae and Salicaceae (3 each), Achariaceae, Apiaceae, Apocynaceae, Aspleniaceae, Asteraceae, Campanulaceae, Caprifoliaceae, Combretaceae, Convolvulaceae, Moraceae, Pentaphyllaceae, Phyllanthaceae, Putranjivaceae, Sterculiaceae and Vitaceae (2 species each), while the rest of the 40 families were monospecific (Fig. 2). The genus *Bulbophyllum* had the maximum number of species (15), followed by *Coelogyne* (14), *Eria* (13), *Dendrobium, Strobilanthes* and *Impatiens* (8 each), *Agapetes*, *Magnolia* and *Ardisia* (7 species each), *Elaeocarpus* (6), while the rest of the 292 genera had less than six species each.

The current study allowed the preparation of an exhaustive checklist of the endemic flora of Meghalaya, thus updating the previous works in which the endemic taxa of the state was analyzed. It was found that the region has a rich endemic floral diversity as evidenced by the presence of 548 species. The preponderance of species belonging to the family Orchidaceae might be attributed to the diverse nature of the family and habitat suitability. Morever, the higher number of *Bulbophyllum* species endemic to the region makes the family dominant. Series of plant diversity studies carried out in various parts of the state also showed Orchidaceae to be one of the families with the highest number of species representatives (Hooker 1872−1997; Jamir & Pandey 2003; Upadhaya et al. 2014). The presence of various primitive families (Magnoliaceae, Ranunculaceae, Annonaceae, Lauraceae, Piperaceae, Aristolochiaceae) provides an idea that endemism of the area is also attributed to primitiveness in terms of evolutionary age and affinities. Climatic factors including rainfall and temperature might also have contributed to high species richness and endemism of the area (Gentry 1982). Morever, geographic location of the region in the confluence of three biogeographic realms (Indian, Indo-Malayan, and Indo-Chinese) has probably led to the organization of taxa with unique biological properties. Since it is significant to conserve endemic flora, it is equally important to accurately identify them in order to accord them conservation priorities. Many of the endemic species play an

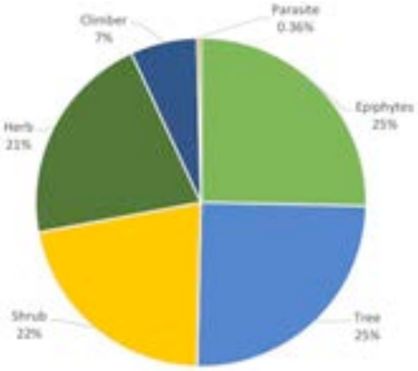

Figure 1. Distribution of life form of endemic plants of Meghalaya.

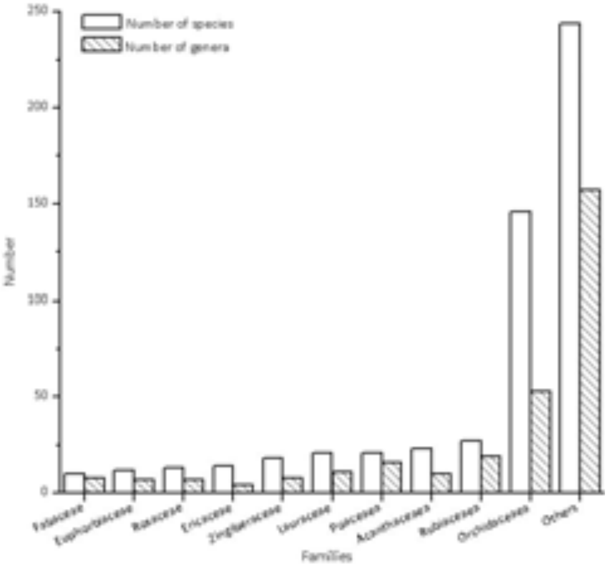

Figure 2. Top 10 families with their respective genera and species.

important role as they are used as timber (*Magnolia rabaniana* Hook.f. & Thomson*, M. lanuginosa* Wall.) (Mir et al. 2016, 2017), for fuel and firewood (*Schima khasiana* Dyer., *Viburnum foetidum* Wall.*, Elaeocarpus lancifolius* Roxb., *Glochidion thomsonii* Hook.f.*, Litsea laeta* (Wall. ex Nees) Hook.f., *Neolitsea umbrosa* (Nees) Gamble, *Ulmus lanceifolia* Roxb.)*,* as medicine in traditional herbalism (*Goniothalamus simonosii* Hook.f. & Thomson, *Trachyspermum khasianum* H.Wolff*, Ilex khasiana* Purkay.*, Ilex embelioides* Hook.f., *Euonymus lawsonii* C.B.Clarke ex Prain*, Nepenthes khasiana* Hook.f., *Citrus latipes* Hook.f. & Thomson) and heavily exploited (*Coelogyne flaccida* Lindl.*, Dendrobium hookerianum* Lindl.*, Micropera rostrata* (Roxb.) N.P.Balakr.*, Paphiopedilum insigne* (Wallich ex Lindley) Pfitzer) for ornamental purposes.

The present study reveals the presence of 548 species as endemic to the region, in contrast to 1,236 species reported by earlier workers (Khan et al. 1997; Jamir & Pandey 2003). Likewise, many species (e.g., *Acer laevigatum* Wall., *Aeschynanthes sikkimensis* (Clarke) Stapf., *Carpinus viminea* Wall.ex Lindl., *Cinnamomum bejolghota* (Buch-Ham.) Sweet., *Dendrobium devonianum* Paxton., *Hedera nepalensis* K. Koch, *Porana racemosa* Roxb., *Styrax hookeri* C.B. Clarke, *Turpinia nepalensis* Wall. ex Wight & Arn.*, Berchemia floribunda* (Wall.) Brongn., *Chirita hamosa* R.Br., *Calanthe puberula* Lindl.*, Drymycarpus racemosus* (Roxb.) Hook.f., *Trachelospermum axillare* Hook.f., *Ilex fragilis* Hook.f., *Euonymus bullatus* Wall. ex Lodd*, Cyathea gigantea* (Wall. ex Hook.) Holttum, *Anoectochilus roxburghii* (Wall.) Lindl., *Pholidota imbricata* Lindl.) which were among the reported endemic species (Khan et al. 1997; Jamir & Pandey 2003; Lakadong & Barik 2006; Upadhaya et al. 2013, 2014), have lost their endemic status as they have been reported from other parts of the world. Similar findings were observed from other parts of India, where 62 earlier reported endemic genera of angiosperms have been found in other countries, and some taxonomic changes to some genera have also affected their status (Irwin & Narasimhan 2011). The present checklist substantially reduces the number of endemic species that was estimated in previous studies, but in no way downlists Meghalaya's globally importance in endemism.

Therefore, it may be concluded that the state is rich in endemic flora. But since the last few decades, the forests in the region have been disappearing at an alarming rate due to fragmentation, expansion of agriculture, logging, mining and other developmental activities (Upadhaya et al. 2013; Pao & Upadhaya 2017). Destruction of forests has resulted in the degradation of the environment and habitat of native species of the state. The rich genetic diversity has been depleted and many plant species are facing the threat of extinction in their natural habitats (Haridasan & Rao 1985−87). This is evident by the fact that some of the species, exclusively endemic to the state (*Carex repanda* C.B. Clarke and *Sterculia khasiana* Debb.) are considered possibly Extinct (Nayar & Sastry 1987; Upadhaya et al. 2013). There is an urgent need for conservation of the remaining endemic flora of the region. Ecological restoration, through re-vegetation of disturbed areas should be done, using indigenous tree species. Intensive taxonomic and phylogenetic studies, vegetation surveys and biogeographical research should be conducted on the endemic flora. Moreover, the in situ conservation efforts have to be supported by adequate ex situ conservation measures.

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Image 7. *Acanthus leucostachyus*

Image 8. *Aeschynanthus hookeri*

Image 9. *Agapetes obovata*

Image 10. *Agapetes rugosus*

Image 11. *Agrostophyllum callosum*

Image 12. *Aquilaria khasiana*

Image 13. *Aristolochia saccata*

Image 14. *Balanophora dioica*

Image 15. *Baliospermum calycinum*

Image 16. *Begonia hatacoa*

Image 17. *Belshmiedia assamica*

Image 18. *Berberis wallichiana*

Image 19. *Brachycorythis galeandra*

Image 20. *Bulbophyllum gymnopus*

Image 21. *Bulbophyllum leopardianum*

Image 22. *Bulbophyllum leopardianum*

Image 23. *Bulbophyllum manabendrae*

Image 24. *Caulokaempferia secunda*

Image 25. *Ceropegia angustifolia*

Image 26. *Citrus latipes*

Image 27. *Coelogyne barbata*

Image 28. *Dendrobium khasianum*

Image 29. *Elaeocarpus rugosus*

Image 30. *Eria carinata*

Image 31. *Erythroxylum kunthianum*

Image 32. *Euonymus lawsonii*

Image 33. *Garcinia anomala*

Image 34. *Glochidion acuminatum*

Image 35. *Glochidion thomsonii*

Image 36. *Goniothalamus simonsii*

Image 37. *Gynocardia odorata*

Image 38. *Ilex embelioides*

Image 39. *Ilex khasiana*

Image 40. *Ilex venulosa*


Image 41. *Illicium griffithii*


Image 42. *Impatiens acuminata*


Image 43. *Impatiens khasiana*


Image 44. *Impatiens laevigata*


Image 45. *Lasianthus hookeri*


Image 46. *Lindera latifolia* Hook. f.


Image 47. *Luculia pinceana*


Image 48. *Magnolia lanuginosa*


Image 49. *Magnolia punduana*


Image 50. *Memecylon cerasiforme*


Image 51. *Neolitsea umbrosa*


Image 52. *Nepenthes khasiana*

Image 53. *Ormosia robustra*

Image 54. *Papilionanthe teres*

Image 55. *Photinia cuspidata*

Image 56. *Psychotria symplicifolia*

Image 57. *Rhododendron formosum*

Image 58. *Salacia khasiana*

Image 59. *Schima khasiana*

Image 60. *Strobilanthes hamiltoniana*

Image 61. *Sympagis maculata*

Image 62. *Vanda coerulea*

Image 63. *Viburnum simonsii*

Image 64. *Zingiber bipinianum*

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Appendix 1. List of endemic plant species along with their habit and distribution.

					Distribution	
Name	**Family**	**Habit**	**Voucher number**	**Nativness**	**Meghalaya**	**Worldwide**
Acanthus leucostachyus Wall. ex Nees	Acanthaceae	Sh	ASSAM, A.H. Mir, 00911 (10.x.2016) Phlangwanbroi, East Khasi Hills	E	Nokrek, Balphakram, Jowai	Indo-Burma
Gymnostachyum venustum (Nees) T.Anderson	Acanthaceae	H	ASSAM, D.K. Roy 129633 (11.iii.2013) Balpakram, South Garo Hills	E	Dawki, Sohka, Nokrek, Balpakram	Northeastern India
Justicia khasiana C.B.Clarke	Acanthaceae	H	ASSAM, A.H. Mir, 04372 (28.vii.2016) Mawranglang, South West Khasi Hills	E	Rngisawlia, Nongstoin	Indo-Burma
Justicia assamica C.B.Clarke*	Acanthaceae	Sh	Specimen not seen	NE	Khasi hills (locality not specified)	Meghalaya
Phlogacanthus guttatus Nees	Acanthaceae	Sh	ASSAM, A.H. Mir, 00626 (09.iv.2014) Rangthaliang, East Khasi Hills	E	Balphakram, Nokrek	Northeastern India and Bhutan
Phlogacanthus pubinervis T.Anderson	Acanthaceae	Sh	ASSAM, D.K. Roy 129495 (08.iii.2013) Balpakram, Garo Hills	E	Pynursla, Sutnga	Eastern Himalaya and Indo-Burma
Phlogacanthus tubiflorus Nees	Acanthaceae	Sh	ASSAM, A.H. Mir, 90331 (22.ii.2014) Pongtung, East Khasi Hills	E	Balphakram, Dambu, Pongtung	Indo-Burma
Phlogacanthus wallichii C.B.Clarke*	Acanthaceae	Sh	ASSAM, U. Kanjilal 2765 (19.x.1913), Syndai, Khasi Hills	E	Syndai	Indo-Burma
Pseuderanthemum indicum A.M.Cowan & Cowan	Acanthaceae	Sh	ASSAM, G. Panigrahi 6059 (26.iii.1957), Shillong Peak, Khasi Hills	E	Shillong Peak	Eastern Himalaya and Indo-Burma
Strobilanthes brunoniana Nees	Acanthaceae	Sh	ASSAM, D.K. Roy 129495 (08.iii.2013) Balpakram, Garo Hills	E	Balphakram, Barapani, Tharia, Pongtung, Mawmluh, Mawsmai	Northeastern India
Strobilanthes denticulata T.Anderson*	Acanthaceae	Sh	ASSAM, G.K. Deka 19131 (06.i.1959), Mahadeo, Garo Hills	E	Balphakram, Nokrek	Northeastern India
Strobilanthes discolor (Nees) T.Anderson	Acanthaceae	Sh	ASSAM, A.H. Mir, 03068 (19.viii.2014) Pongtung, East Khasi Hills	E	Balphakram, Tura Peak	Eastern Himalaya and Indo-Burma
Strobilanthes hamiltoniana (Steud.) Bosser & Heine	Acanthaceae	Sh	ASSAM, D.K. Roy 130079 (05.ii.2014) Balpakram, Garo Hills	E	Tura, Jarain, Balphakram	Eastern Himalaya and Indo-Burma
Strobilanthes nobilis C.B.Clarke	Acanthaceae	Sh	ASSAM, B. Singh, 118458 (04.ii.2009) Wagechiringre	E	Jarain, Pynursla, Wagechiringre	Indo-Burma
Strobilanthes rubescens T.Anderson*	Acanthaceae	Sh	ASSAM, N.P. Balakrishnan 49957 (17.xi.1969), Jarain, Jaintia Hills	E	Jarain, Jowai	Eastern Himalaya and Indo-Burma
Sympagis maculata (Nees) Bremek.	Acanthaceae	Sh	ASSAM, AH Mir, 01024 (05.ii.2017) Umtong, East Khasi Hills	NE	Jowai, Jarain, Cherrapunjee, Umtong.	Meghalaya
Sympagis monadelpha (Nees) Bremek*	Acanthaceae	Sh	ASSAM, G.K. Deka 17521 (06.xi.1938), Jawai, Jaintia Hills	E	Ialong, Jowai.	Eastern Himalaya and Indo-Burma
Rhinacanthus calcaratus Nees*	Acanthaceae	Sh	Specimen not seen	E	Khasi hills (locality not specified)	Northeastern India
Staurogyne argentea Wall.*	Acanthaceae	H	K (image!), Griffith, W., #s.n., K000838873	E	Khasi Hills (locality not specified)	Northeastern India
Staurogyne simonsii Kuntze*	Acanthaceae	H	ASSAM, S.R.Sharma 12186 (28.viii.1935) East Khasi Hills	NE	Barapani, Pontung, Shella	Meghalaya
Strobilanthes adnatus C.B.Clarke*	Acanthaceae	H	ASSAM, S.R. Sharma 17580 (14.ix.1947), Cherra forest	E	Cherrapunjee	Northeastern India
Strobilanthes khasyana T.Anderson*	Acanthaceae	H	K (image!), K000882913, C.B. Clarke, 15226 (20.xi.1871), Khasia, Nongpuang	E	Nongpoh	Eastern Himalaya, Meghalaya
Tarphochlamys affinis (Griff.) Bremek.*	Acanthaceae	H	North-Eastern Hill University, K.Haridasan 9867, Khasi hills	NE	Shillong	Meghalaya
Gynocardia odorata R.Br.	Achariaceae	T	ASSAM, A.H. Mir, 90411 (19.xii.2015) Mawsynram, East Khasi Hills	E	Jarain, Mawsynram, Laitsohum, Balphakram, Nokrek	Eastern Himalaya and Indo-Burma
Hydnocarpus kurzii (King.) Warb.	Achariaceae	T	ASSAM, A.H. Mir, 90337 (19.viii.2016) Mawrapat, South West Khasi Hills	E	Jarain, Tura, Nokrek, Mawsynram, Laitsohum, Mawkasain, Balphakram	Indo-Burma
Crinum amoenum Ker Gawl. ex Roxb.*	Amaryllidaceae	H	ASSAM, G.Panigrahi 4233 (30.x.1956). Garampani	E	Saitbakon, Nonglynkien	Indo-Burma
Cotinus kanaka (R.N.De) D.Chandra*	Anacardiaceae	T	ASSAM, S.R. Sharma 20742 (01.viii.1940) Sonakurung, Khasi Hills	NE	Sona kurung.	Meghalaya
Drymycarpus racemosus (Roxb.) Hook.f.	Anacardiaceae	T	ASSAM, AH Mir, 00670 (11.ix.2015) Mawsmai, East Khasi Hills	E	Cherrapunjee, Mawmluh, Mawsmai, Mawsynram	Indo-Burma

					Distribution	
Name	Family	Habit	Voucher number	Nativness	Meghalaya	Worldwide
Rhus khasiana Hook.f.*	Anacardiaceae	T	K (image!), K000695086, JD Hooker and T. Thomson 1901 (?.vii.1850), Khasi Hill	NE	Barapani	Meghalaya
Toxicodendron hookeri (K.C. Sahni &Bahadur) C.Y. Wu & T.L. Ming*	Anacardiaceae	T	ASSAM, N.P. Balakrishnan (27. viii.1968) Nartiang, Jaintia Hills	E	Raliang, Nartiang	Indo-Burma
Toxicodendron bimannii Barbhuiya	Anacardiaceae	T	ASSAM, D.K. Roy 125634 (25. iv.2012) Balpakram, South Garo Hills	E	Balphakram National Park	Northeastern India
Artabotrys caudatus Wall. ex Hook.f. & Thomson*	Annonaceae	Cl	ASSAM, U.K. 4140 (09.iv.1914), Makum range, Garo Hills	NE	Balphakram, Nokrek and Rongrengiri Garo hills	Meghalaya
Cyathocalyx martabanicus Hook.f. & Thomson*	Annonaceae	T	ASSAM, P.C. Kanjilal 5230 (05. iii.1915), Tura Peak, Garo Hills	E	Sanitarium Garo Hills	Northeastern India
Fissistigma verrucosum (Hook.f. & Thomson) Merr.	Annonaceae	Cl	ASSAM, A.H. Mir, 90471 (10. viii.2016) Pynursla, East Khasi Hills	E	Ialong, Raliang, Jowai Raliang, Nokrek, Shangpung, Wakhen	Northeastern India
Goniothalamus simonsii Hook.f. & Thomson	Annonaceae	T	ASSAM, D.K. Roy 130164 (05. vi.2014), Balpakram, South Garo Hills	NE	Nokrek, Nongkhyllem, Borlang, Lailad, Balphakram	Meghalaya, Assam
Polyalthia jenkinsii (Hook.f. & Thomson) Hook.f. & Thomson	Annonaceae	T	ASSAM, A.H. Mir, 90327 (27. ix.2015) Mawkyrwat, East Khasi Hills	E	Laitkynsew, Cherrapunjee, Balphakram	Indo-Burma
Polyalthia meghalayensis V.Prakash & Mehrotra*	Annonaceae	Sh	K (image!), K000691478, V. Prakash, #17130 Garo Hills, Meghalaya	NE	Boldoringri forest, Tura Peak	Meghalaya
Trivalvaria kanjilalii D.Das*	Annonaceae	T	ASSAM, U. Kanjilal 6348 (10. xii.1915), Nongkla, Khasi Hill	NE	Syndai	Meghalaya
Uvaria hamiltonii Hook.f. & Thomson*	Annonaceae	Cl	ASSAM, J. Joseph 22298 (24. vi.1940), Nongpoh, Ri Bhoi	E	Balphakram, Rongrengiri, Maheshkola, Nongpoh	Indo-Burma
Uvaria lurida Hook. f. & Thomson*	Annonaceae	Cl	ASSAM, S.R. Sarma s.n. (16. xi.1938), Umsaw, Ri.Bhoi	NE	Balphakram, Maheshkola	Meghalaya
Trachyspermum khasianum (C.B.Clarke) H.Wolff.*	Apiaceae	H	K (image!), K000685640, J.D.Hooker and T. Thomson 1901 (19.viii.1850), Boge Panee, Khasi Hill	E	Jarain	Indo-Burma
Bupleurum khasianum (Clarke) P.K.Mukh.*	Apiaceae	H	K (image!), K000687107, C.B.Clarke, 16663, (31.x.1871), Mairang, Khasia	NE	Mairang	Meghalaya
Gongronema ventricosum Hook.f.*	Apocynaceae	Sh	K (image!), K000872892, s.coll. 6, India, Khasia	NE	Khasi hills (locality not specified)	Meghalaya
Ilex embelioides Hook.f.	Aquifoliaceae	T	ASSAM, A.H. Mir, 90384 (03. xii.2015) Saitbakon, East Khasi Hills	NE	Raliang, Jowai, Dawki, Jarain, Tyrsad, Cherrapunjee, Mawkyrwat, Pariong, Laitryngew, Mawmluh, Mawsmai, Rngisawlia, Saitbakon	Meghalaya
Ilex khasiana Purkay.	Aquifoliaceae	T	ASSAM, AH Mir, 88687 (15.xi.2015) Pyndengnongbri, East Khasi Hills	NE	Shillong peak, Upper Shillong, Elephant falls, Mylliem, Mawtangor, Jakrem, Pyndengnongbri	Meghalaya
Ilex venulosa Hook.f.	Aquifoliaceae	T	ASSAM, A.H. Mir, 88686 (12.v.2015) Cherrapunjee, East Khasi Hills	E	Jowai, Laitlyngkot, Sohrarim, Jarain, Pongtung, Shangpung, Cherrapunjee, Pynursla, Saitbakon, Wakhen, Mawkyrnot, Mawmluh, Laitryngew, Mawkyrwat, Umtong, Jakrem, Nokrek	Indo-Burma
Ilex godajam Colebr. ex Hook.f.	Aquifoliaceae	T	ASSAM, A.H. Mir, 90343 (20.x.2015) Lawbah Mawsynram, East Khasi Hills	E	Lawbah, Mawsynram, Balphakram	Eastern Himalaya and Indo-Burma
Arisaema album N.E.Br.	Araceae	H	ASSAM, D.K. Roy 130337 (26. viii.2014), Siju, South Garo Hills	E	Mawsmai, Nokrek, Balphakram	Eastern Himalaya and Northeastern India
Arisaema nepenthoides (Wallich) Martius ex Schott & Endlicher	Araceae	H	ASSAM, A.H. Mir, 00591 (15. ix.2014) Pongtung, East Khasi Hills	E	Pongung, Pynursla, Saitbakon	Indo-Burma
Rhaphidophora hookeri Schott	Araceae	Ep	ASSAM, B. Singh, 114714 (27. ii.2007) Nokrek Peak, Garo Hills	E	Nokrek	Eastern Himalaya and Indo-Burma

Name	Family	Habit	Voucher number	Nativness	Distribution	
					Meghalaya	Worldwide
Sauromatum meghalayense D.K. Roy, A.D. Talukdar, B.K.Sinha & M. Dutta Choud.	Araceae	H	ASSAM, D.K.R. 130216 (05.vi.2014), Hatisia, South Garo Hills	NE	Balphakram National Park	Meghalaya
Aralia thomsonii Seem. ex C.B.Clarke	Araliaceae	Sh	ASSAM, A.H. Mir, 90478 (23.x.2016) Mawranglang, East Khasi Hills	E	Ialong, Jowai, Wakhen, Pynndengnongbri	Eastern Himalaya and Indo-Burma
Brassaiopsis hispida Seem	Araliaceae	T	ASSAM, B. Singh, 118480 (09.iv.2009) Nokrek Peak, Garo HillsHills	E	Ialong, Nokrek Peak	Eastern Himalaya and Indo-Burma
Panax pseudoginseng Wall.	Araliaceae	H	ASSAM, A.H. Mir, 00757 (05.ii.2016) Rngisawlia, South West Khasi Hills	E	Laitkor, Nongkrem, Mawphlang, Upper Shillong, Tyrsad, Nongstoin	Eastern Himalaya and Indo-Burma
Tupidanthus calyptratus Hook. f. & Thomson	Araliaceae	Sh	ASSAM, A.H. Mir, 90335 (09.v.2014) Cherrapunjee, East Khasi Hills	E	Ialong, Raliang, Jowai, Balphakram, Swer, Mawmluh, Sohra, Rngisawlia, Nokrek	Indo-Burma
Brassaiopsis glomerulata var. *rufostellata* (Blume) Regel.*	Araliaceae	Sh	ASSAM, J. Joseph 43783(12.iii.1966), N.R.Soil conservation, IB, Umling	E	Umling	North east India
Macropanax meghalayensis Harid. & R.R.Rao*	Araliaceae	Sh	North-Eastern Hill University, K. Haridasan, 10233A, B, Lailad	NE	Lailad	Meghalaya
Calamus erectus Roxb.	Arecaceae	Sh	ASSAM, A.H. Mir, 90423 (10.ix.2015) Pongtung, East Khasi Hills	E	Baghmara, Nokrek, Jarain, Mawshun, Cherrapunjee, Pongtung, Balphakram	Eastern Himalaya and Indo-Burma
Calamus floribundus Griff.*	Arecaceae	Cl	ASSAM, R.S. 113302 (06.xii.2006) Dawegiri, Garo Hills	E	Cherrapunjee, Smit, Pongtung, Shangpung, Dawegiri	Eastern Himalaya and Indo-Burma
Calamus leptospadix Griff.	Arecaceae	Sh	ASSAM, A.H. Mir, 00584 (15.ii.2016) Nongstoin, West Khasi Hills	E	Nokrek, Balphakram	Eastern Himalaya and Indo-Burma
Calamus meghalayensis A.J.Hend.*	Arecaceae	Cl	Specimen not seen	NE	Locality not known	Meghalaya
Calamus tenuis Roxb.	Arecaceae	Cl	ASSAM, A.H. Mir, 00637 (11.xi.2014) Mawmluh, East Khasi Hills	E	Cherrapunjee, Mawmluh, Mawsmai, Mawsynram	Indo-Burma
Livistona jenkinsiana Griff.	Arecaceae	T	ASSAM, A.H. Mir, 90477 (04.iii.2015) Tynnai, South West Khasi Hills	E	Swer, Kharang, Nongstoin, Tynnai, Hilland, Mawsynram, Weiloi	Indo-Burma
Phoenix rupicola T.Anderson	Arecaceae	Sh	ASSAM, B. Singh, 114930 (27.ii.2007) Nokrek Peak, Garo Hills	E	Nokrek Peak	Northeastern India
*Aristolochia saccata*Wall.	Aristolochiaceae	Cl	ASSAM, A.H. Mir, 90403 (13.ix.2015) Mawmluh, East Khasi Hills	E	Nokrek, Cherrapunjee	Eastern Himalaya and Indo-Burma
Ceropegia angustifolia Wight	Asclepiadaceae	Cl	ASSAM, A.H. Mir, 90409 (16.x.2015) Pynursla	NE	Balphakram, Garampani, Jowai, Jarain, Nokrek	Meghalaya
Ceropegia arnottiana Wight*	Asclepiadaeae	Cl	Specimen not seen	E	Khasi hills (locality not specified)	Meghalaya, Myanmar, Thailand
Ceropegia lucida Wall.	Asclepiadaceae	Cl	ASSAM, B. Singh, 114719 (27.ii.2007) Nokrek Peak, Garo Hills	E	Tharia, Nokrek Peak	Eastern Himalaya and Indo-Burma
Cynanchum wallichii Wight.*	Asclepiadaceae	Cl	ASSAM, SR Sarma 12128 (28.viii.1935), Pungtong, Khasi Hills	E	Dawki, Pongtung, Nongstoin	Indo-Burma
Hoya lobbii Hook.f.	Asclepiadaceae	Ep	ASSAM, A.H. Mir, 90451 (22.v.2015) Cherrapunjee, East Khasi Hills	NE	Nokrek, Rongrengiri, Dawki, Nongthala, Nongpoh	Meghalaya
Hoya acuminata (Wight) Benth. ex Hook.f.	Asclepiadaceae	Ep	ASSAM, B. Singh, 118556 (11.iv.2009) Mandalgiri, Garo Hills	E	Mawsmai, Nokrek, Cherrapunjee, Balphakram, Mandalgiri	Eastern Himalaya and Indo-Burma
Ophiopogon reptans Hook.f.*	Asparagaceae	H	K (image !), K000846109, C.B.Clarke, 43087(14.ii.1886), Tura, Garo Hills	E	Tura, Garo hills, Garampani, Sonapahar	Indo-Burma
Peliosanthes griffithii Baker	Asparagaceae	H	ASSAM, A.H. Mir, 90470 (05.v.2015) Lynshing, East Khasi Hills	E	Cherapunjee, Mawmluh, Mawsmai, Mawrapat, Lynshing, Balphakram	Indo-Burma
Tupistra nutans Wall.	Asparagaceae	H	BSIS, B.K. Singh 3270 (14.x.2006) Nokrek, West Garo Hills	E	Pynursla, Sohra, Mawsmai, Nokrek	Indo-Burma
Tupistra tupistroides (Kunth) Dandy*	Asparagaceae	H	ASSAM, NP Balakrishna 49972 (17.xi.1969) Jarain, Jaintia Hills	E	Jarain, Nunklow, Cherrapunjee, Mawsmai	Meghalaya, Sikkim

					Distribution	
Name	**Family**	**Habit**	**Voucher number**	**Nativness**	**Meghalaya**	**Worldwide**
Asplenium finlaysonianum Wall. ex Hook.	Aspleniaceae	H	ASSAM, B. Singh, 118391 (03. ii.2009) Ringrey, Garo Hills	E	Baghmara, Balphakram, Siju, Nokrek, Ringrey	Eastern Himalaya and Indo-Burma
Asplenium khasianum Sledge*	Aspleniaceae	H	K (image !), K001092516, C.B. Clarke, Umwai	NE	Umwai	Meghalaya
Inula kalapani C.B.Clarke*	Asteraceae	Sh	ASSAM, G.Panigrahi 16337 (17. vi.1958), Kynshi-Markasa, West Khasi Hills	E	Kynshi, Markasa	Northeastern India
*Synotis jowaiensis (*Balak.) R.Mathur*	Asteraceae	H	ASSAM, 47400, (?), Jowai	NE	Jowai, Jarain	Meghalaya
Balanophora dioica R.Br. ex Royle	Balanophoraceae	P	ASSAM, A.H. Mir, 90398 (19. xi.2014) Nongstoin, West Khasi Hills	E	Ialong, Raliang, Jowai, Nokrek, Cherrapunjee, Mawmluh, Lynshing, Mawkyrwat, Phud Juad, Nonglang, Shillong, Nongstoin	Eastern Himalaya and Indo-Burma
Impatiens khasiana Hook.f.	Balsaminaceae	H	ASSAM, A.H. Mir, 90308 (10. viii.2015) Lyngiong, East Khasi Hills	NE	Ialong, Laitkyrhong, Raliang, Jowai, Swer, Tyrsad and Lyngiong	Meghalaya
Impatiens porrecta Wall.	Balsaminaceae	H	ASSAM, M.K.V. Rao 64126 (16. vi.1975) Balphakram,Garo Hills	NE	Jowai, Jarain, Nokrek, Cherrapunjee, Balphakram, Mawsmai and Parkseh	Meghalaya
Impatiens acuminata Benth.	Balsaminaceae	H	ASSAM, C. Deori & S.R.Talukdar 134320 (07.vii.2016), Mawchawma, South West Khasi Hills	E	Jowai, Sokha-Nongthala	Northeastern India
Impatiens laevigata Wall.	Balsaminaceae	H	ASSAM, A.H. Mir, 90428 (10.x.2015) Laitryngew, East Khasi Hills	E	Nokrek, Khleihrait, Mynso, Sokha-Nongthalang, Syndai, Raliang, Mawmluh, Laitryngew, Mawkyrwat, Umsaw	Northeastern India
Impatiens tripetala Roxb. ex DC.	Balsaminaceae	H	ASSAM, C.Deori & S.R.Talukdar 134384, (07.vii.2016) Nongstoin, Nongkhunum river island, West Khasi Hills	E	Nongstoin, Nokrek, Dawki	Indo-Burma
Impatiens jurpia Buch.-Ham.	Balsaminaceae	Sh	ASSAM, DB Deb 28935 Tura Peak, Garo Hills	E	Nokrek, Balphakram	Eastern Himalaya and Northeastern India
Impatiens depauperata Hook.f.*	Balsaminaceae	H	K (image!), K000694748, Griffit, s.n, Khasiya	NE	Khasi hills (locality not specified)	Meghalaya
Impatiens striolata Hook.f.*	Balsaminaceae	H	K (image!), K000694625, J.D. Hooker & T. Thomson 2026 (05. viii.1830), Kalapanee	NE	Khasi hills (locality not specified)	Meghalaya
Begonia brevicaulis A.DC.*	Begoniaceae	H	K (image!), Hooker & Thomson 26, Khasia (Terya to -Cherrapunjee)	E	Khasi Hills (locality not specified)	Indo-Burma
Begonia josephi A.DC.	Begoniaceae	H	ASSAM, A.H. Mir, 90462 (07. viii.2016) Wakhen, East Khasi Hills	E	Wakhen, Pynursla	Eastern Himalaya and Indo-Burma
Begonia hatacoa Buch.-Ham. ex D.Don	Begoniaceae	H	ASSAM, C.Deori & S.R.Talukdar 134282, (07.vi.2016), Nongumiam, West Khasi Hills	E	Dawki, Jarain, Syndai, Muktapur, Cherrapunjee, Laitkynsew, Mawkyrwat, Mawphlang, Mawmluh	Eastern Himalaya and Indo-Burma
Begonia thomsonii A.DC.	Begoniaceae	H	ASSAM, B. Singh 115968, (12.x.2007) Nokrek Peak, Garo Hills	E	Nokrek	Eastern Himalaya and Indo-Burma
Berberis wallichiana DC.	Berberidaceae	Sh	ASSAM, A.H. Mir, 00601 (01.i.2014) Thangsnieng, East Khasi Hills	E	Mawphlang, Mawkyrwat, Nonglang, Nonsynrieh, Nonglynkien, Thangsning	Eastern Himalaya and Indo-Burma
Tournefortia viridiflora Wall.	Boraginaceae	Sh	ASSAM, D.K. Roy 130389 (08. xi.2014) Balpakram, South Garo Hills	E	Tura, Balphakram	Indo-Burma
Cordia fragrantissima Kurz.	Boraginaceae	T	ASSAM, B. Singh 110587, (04. ii.2009), Tura range, Garo Hills	E	Tura	Indo-Burma
Cordia grandis Roxb.*	Boraginaceae	T	ASSAM, R.N. De 20584 (25.iii.1941), Tura range, Garo Hills	E	Lailad, Baghamara, Tura range	Indo-Burma
Canarium strictum Roxb.*	Burseraceae	T	(image!), K000651668, G. Mann s.n. (June 1878) Nongpoh, Ri Bhoi	E	Lailad, Raliang, Umdem, Nongpoh	Indo-Burma
Phanera khasiana (Baker) Thoth.	Caesalpinaceae	Cl	ASSAM, B. Singh 110586 (04. ii.2009), Tura range, Garo Hills	E	Balphakram, Tura range, Umtapoh.	Indo-Burma

					Distribution	
Name	Family	Habit	Voucher number	Nativness	Meghalaya	Worldwide
Adenophora khasiana (Hook.f. & Thomson) Oliv. ex Collett & Hemsl.*	Campanulaceae	H	ASSAM, GK Deka 18758 (06. viii.1938), Upper Shillong, Khasi Hills	E	Lakiang, Shillong Peak	Eastern Himalaya and Indo-Burma
Cyclocodon parviflorus (Wall. ex A.DC.) Hook.f. & Thomson*	Campanulaceae	Sh	ASSAM, NP Balakrishnana 49853 (15.xi.1969), Jarain, Jaintia Hills	E	Dawki, Cherrapunjee, Mairang	Eastern Himalaya, Indo-Burma
Capparis olacifolia Hook.f. & Thomson*	Capparidaceae	Sh	ASSAM, B. Singh, 118549 (11. iv.2009), Mandalgiri, Garo Hills	E	Crinioline falls	Eastern Himalaya and Indo-Burma
Viburnum colebrookeanum Wall. ex DC.	Caprifoliaceae	T	ASSAM, A.H. Mir, 04144 (25. viii.2015) Mawtongor, South West Khasi Hills	E	Lailad, Pynursla, Mawsynram	Eastern Himalaya and Indo-Burma
Viburnum simonsii Hook.f. & Thomson	Caprifoliaceae	T	ASSAM, A.H. Mir, 90420 (19. iv.2016) Nongthamai, East Khasi Hills	E	Cherrapunjee, Mawmluh, Mawsmai, Mawsynram	Meghalaya
Silene khasiana Rohrb.*	Caryophyllaceae	H	K(image !), K000728810, JD Hooker & T Thomson s.n., Mawphlong, Khasi Hills	E	Khasi Hills-Mawphlang	Eastern Himalaya and Indo-Burma
Celastrus hookeri Prain	Celastraceae	Cl	ASSAM, A.H. Mir, 04366 (27.ii.2017) Nongstoin, West Khasi Hills	E	Cherrapunjee, Mawsynram, Nongstoin	Indo-Burma
Euonymus attenuatus Wall.	Celastraceae	T	ASSAM, A.H. Mir, 90422 (10. xi.2015) Cherrapunjee, East Khasi Hills	E	Pongtung, Cherapunjee, Mawsynram, Jakrem, Mawsmai and Nongstoin, Balphakram	Bangladesh and Northeastern India
Euonymus lawsonii C.B.Clarke ex Prain	Celastraceae	T	ASSAM, A.H. Mir, 90377 (19. xi.2015) Mawmluh, East Khasi Hills	E	Shillong, Raliang, Nokrek, Jarain, Mawsynram, Cherrapunjee, Pomshomen, Mawmluh	Indo-Burma
Maytenus simonsii D.C.S.Raju	Celastraceae	Sh	ASSAM, B. Singh, 110589 (08. viii.2007), Chokpot, Garo Hills	NE	Chokpot	Meghalaya
Salacia khasiana Purkayastha	Celastraceae	Cl	ASSAM, D.K .Roy 130138 (05. vi.2014) Balpakram, South Garo Hills	E	Balphakram, Umsaw	Northeastern India
Salacia roxburghii Wall.	Celastraceae	Cl	ASSAM, A.H. Mir, 03108 (22. viii.2016) Swer, East Khasi Hills.	E	Cherrapunjee, Mawkyrwat, Mawsynram, Swer	Indo-Burma
Garcinia elliptica Wall. ex Wight	Clusiaceae	T	ASSAM, D.K. Roy 130263 (09. vi.2014) Balpakram, South Garo Hills	E	Mawsmai, Cherrapunjee, Balpakram	Indo-Burma.
Garcinia anomala Planch. & Triana	Clusiaceae	T	ASSAM, A.H. Mir, 03048 (17.i.2014) Laitryngew, East Khasi Hills	E	Cherrapunjee, Sohrarim, Mawsmai, Balphakram	Indo-Burma.
Garcinia pedunculata Roxb. ex Buch.-Ham.	Clusiaceae	T	ASSAM, D.K. Roy 130387 (08. xi.2014) Balpakram, South Garo Hills	E	Sohkha, Balphakram	Indo-Burma.
Mesua floribunda (Wall.) Kosterm.*	Clusiaceae	T	ASSAM, R.N. De 8440 (08.viii.1930) Rongrengiri, Garo Hills	E	Nokrek, Baghmara	Indo-Burma.
Combretum wallichii var. *flagrocarpum* (C.B.Clarke) M.G.Gangop. & Chakrab.	Combretaceae	Sh	ASSAM, B. Singh 115881 (08.x.2007), Rongsinggiri, Garo Hills	E	Tura, Nokrek, Rongsinggiri	Indo-Burma.
Combretum pilosum Roxb. ex G.Don	Combretaceae	Sh	ASSAM, D.K. Roy 130122 (04. vi.2014) Balpakram, South Garo Hills	E	Narpuh, Balphakram	Indo-Burma.
Pollia pentasperma C.B.Clarke*	Commelinaceae	H	K (image!), K000854045, C.B.Clarke 17624, Shillong, East Khasi Hills	E	Shillong Peak	Northeastern India
Argyreia splendens (Hornem.) Sweet*	Convolvulaceae	Cl	ASSAM, J. Joseph 45156 (16. iii.1966), Nongpoh, Ri-Bhoi District	E	Garampani, Nongpoh	Indo-Burma
Erycibe peguensis Prain*	Convolvulaceae	T	ASSAM, S.R. Sarma 10610 (06. xi.1933), Mawsmai, Khasi Hills	E	Nokrek, Tura	Northeastern India
Carex repanda C.B.Clarke*	Cyperaceae	H	K (image!), K000998912, JD Hooker & T. Thomson s.n. (15.vi.1850) Cherrapunjee, Khasi Hills	NE	Cherrapunjee	Meghalaya
Dipteris wallichii (R.Br.) T.Moore	Dipteridaceae	H	ASSAM, D.K. Roy 129532 (09. iii.2013) Balpakram, South Garo Hills.	E	Raliang, Jarain, Amlarem, Balphakram	Eastern Himalaya and Indo-Burma
Diospyros lanceifolia Roxb.	Ebenaceae	T	ASSAM, B. Singh, 114986 (07.x.2007), Dopgre, Garo Hills	E	Lailad, Siju, Dopgre	Indo-Burma
Diospyros pilosiuscula G.Don	Ebenaceae	T	ASSAM, D.K. Roy 129735 (01. ii.2014) Balpakram, South Garo Hills	E	Dawki, Balphakram	Indo-Burma

					Distribution	
Name	Family	Habit	Voucher number	Nativness	Meghalaya	Worldwide
Diospyros stricta Roxb.*	Ebenaceae	T	ASSAM, S.R. Sarma 17974 (05.xi.1938), Pungtong, Khasi Hills	E	Devbandh (Balphakram)	Bangladesh and Northeastern India
Diospyros variegata Kurz*	Ebenaceae	T	ASSAM, M.K.V. Rao 52504 (10.iv.1974) Tura Peak, West Garo Hills	E	Tura, Balphakram	Indo-Burma
Elaeagnus pyriformis Hook.f.	Elaeagnaceae	Sh	ASSAM, B. Singh, 114933 (27.ii.2007), Dopgre, Garo Hills	E	Shillong Peak, Pynursla, Balphakram	Eastern Himalaya and Indo-Burma
Echinocarpus dasycarpus Benth.	Elaeocarpaceae	T	ASSAM, A.H. Mir, 03059 (18.xi.2015) Nongstoin, West Khasi Hills	E	Nokrek, Pynursla, Mawsmai, Swakpoh-Wanniang, Mawsynram, Nongstoin	Eastern Himalaya and Indo-Burma
Elaeocarpus acuminatus Wall. ex Mast.	Elaeocarpaceae	T	ASSAM, AH Mir, 90442 (20.vi.2015) Mawsmai, East Khasi Hills	E	Mawsmai, Nokrek, Cherrapunjee, Mawmluh	Bangladesh and Northeastern India
Elaeocarpus rugosus Roxb. ex G.Don	Elaeocarpaceae	T	ASSAM, AH Mir, 88693 (01.ii.2014) Saitbakon, East Khasi Hills	E	Jarain, Nongtalang, Pongtung, Lailad, Mawsynram	Indo-Burma
Elaeocarpus lanceifolius Roxb.	Elaeocarpaceae	T	ASSAM, AH Mir, 04131 (22.xii.2015) Cherrapunjee, East Khasi Hills	E	Cherrapunjee, Mawsynram, Mawmluh, Lyngiong, Lynshing, Tyrsad, Nongbri, Mawkyrwat, Nongstoin, Jowai, Jarain, Nongpoh, Dawki, Balat	Eastern Himalaya and Northeastern India
Elaeocarpus prunifolius Wall. ex Müll.Berol.	Elaeocarpaceae	T	ASSAM, A.H. Mir, 90304 (20.v.2015) Mawsmai, East Khasi Hills	E	Jarain, Sweet falls, Mawsmai, Cherrapunjee, Mahadeo, Mawmluh, Pongtung, Pynursla, Sutnga, Pyndengnongbri, Mawsynram	Northeastern India
Elaeocarpus sikkimensis Mast.	Elaeocarpaceae	T	ASSAM, G. Panigrahi 16563 (21.vi.1958) Nongstoin, Khasi Hills	E	Dawki, Nongstoin, Nongsteng	Eastern Himalaya and Northeastern India
Elaeocarpus simplex Kurz	Elaeocarpaceae	T	ASSAM, A.H. Mir, 90379 (15.vi.2015) Nongstoin, West Khasi Hills	E	Nongstoin	Indo-Burma
Echinocarpus tomentosus Benth.	Elaeocarpaceae	T	ASSAM, A.H.Mir, 88694 (08.viii.2018) Mawnai, West Khasi Hills	E	Mawnai, Mawkyrwat, Raliang	Indo-Burma
Agapetes acuminata (Wall.) D.Don ex G.Don	Ericaceae	Sh	ASSAM, B. Singh, 114708B (27.ii.2007) Nokrek Peak, Garo Hills.	E	Mawsmai, Nokrek	Indo-Burma
Agapetes incurvata (Griff.) Sleumer	Ericaceae	Sh	ASSAM, A.H. Mir, 90400 (10.iv.2015) Lynshing, East Khasi Hills	E	Mawphlang, Shillong peak, Lynshing, Umtong	Eastern Himalaya and Indo-Burma
Agapetes lobbii C.B.Clarke	Ericaceae	Ep	ASSAM, B. Singh, 114708 (27.ii.2007) Nokrek Peak, Garo Hills	E	Railang, Jarain, Nokrek	Indo-Burma
Agapetes obovata (Wight) Benth. & Hook.f.	Ericaceae	Ep	ASSAM, A.H. Mir, 00713 (12.xii.2015) Lynshing, East Khasi Hills	E	Mawsmai, Cherrapunjee, Mawsynram, Lynshing, Lyngiong, Nokrek, Pynursla, Saitbakon, Pongtung, Nongstoin	Indo-Burma
Agapetes rugosus (Hook.f.) Harid. & R.R.Rao	Ericaceae	Ep	ASSAM, A.H. Mir, 90455 (08.vi.2014) Pongtung, East Khasi Hills	NE	Shillong Peak, Mawmluh, Cherrapunjee, Lynshing, Mawsynram, Pynrsula	Meghalaya
Agapetes saligna (Hook.f.) Benth. & Hook.f.	Ericaceae	Ep	ASSAM, B. Singh, 114346 (27.ii.2007) Nokrek Peak, Garo Hills	E	Jarain, Nokrek	Indo-Burma
Agapetes setigera (Wall.) D.Don ex G.Don	Ericaceae	Sh	ASSAM, A.H. Mir 01021 (02.ii.2017) Dympep, East Khasi Hills	E	Upper Shillong, Cherrapunjee, Mawkynrew, Mawsynram	Indo-Burma
Craibiodendron henryi W.W. Sm.*	Ericaceae	T	E, Royal Botanic Garden Edinburgh, W.W. Smith 158 (?.?.1884), Jowai	E	Jowai.	Indo-Burma
Rhododendron formosum Wall.	Ericaceae	Sh	ASSAM, A.H. Mir, 90397 (23.xi.2015) Umlangmar, East Khasi Hills	NE	Jakrem, Elephant falls, Mairang, Umsaw, Jowai, Jarain, Shillong Peak, Swer, Tyrsad, Mawranglang	Meghalaya
Rhododendron inequale Hutch.	Ericaceae	Ep	ASSAM, D.K. Roy 129735 (01.ii.2014) Balpakram, South Garo Hills	E	Myrung, Kyllang, Pynursla, Umsong, Mawpglong, Dympep, Wah-Soh-Pho, Mawsmai, Riat Laban, Laitlyngkot	Northeastern India

Name	Family	Habit	Voucher number	Nativness	Distribution	
					Meghalaya	Worldwide
Rhododendron iteophyllum Hutch.*	Ericaceae	Sh	ASSAM, A.A. Mao & D.K. Roy 110464 (21.iv.2015) Woodland Campus, Khasi Hills	NE	Myntang valley, Sohrarim, Mahadew, Jakrem, Umphang	Meghalaya
Vaccinium dunalianum Wight*	Ericaceae	Sh	K (image!),K000618561, J.D. Hooker s.n. Cherapunjee, Khais Hills	E	Jowai, Mawsynram, Cherrapunjee	Eastern Himalaya and Indo-Burma
Vaccinium griffithianum Wight*	Ericaceae	Sh	K (image!), K000780703, J.D. Hooker & T. Thomson 1405 Khasi Hills	NE	Nongstoin	Meghalaya
Vaccinium vacciniaceum (Roxb.) Sleumer	Ericaceae	Sh	ASSAM, A.H. Mir, 90439 (02.xi.2015) Mawsmai, East Khasi Hills	E	Mawsmai, Cherrapunjee.	Eastern Himalaya and Indo-Burma
Eriocaulon gregatum Körn.*	Eriocaulaceae	H	K (image!), K000457742, J.D. Hooker & T Thomson s.n. Khais Hills	E	Sohra, Rongrenggiri	Northeastern India
Eriocaulon barba-caprae Fyson*	Eriocaulaceae	H	Specimen not seen	NE	Locality not known	Meghalaya
Eriocaulon cherrapunjianum R.Ansari & N.P.Balakr.*	Eriocaulaceae	H	Specimen not seen	NE	Locality not known	Meghalaya
Erythroxylum kunthianum Kurz	Erythroxylaceae	T	ASSAM, A.H. Mir, 90410 (07.ix.2015) Pynursla, East Khasi Hills	E	Pynursla, Nongstoin, Rangthalliang, Tyrsad, Ureksew, Cherrapunjee, Mawmluh, Mawsmai, Lynshing, Lyngiong, Laitkynsew, Nonglang, Mawthynrew, Mairang, Nongbri	Indo-Burma
Baliospermum calycinum Muell.Arg	Euphorbiaceae	Sh	ASSAM, A.H. Mir, 00614 (08.i.2014) Cherrapunjee, East Khasi Hills	E	Tura, Cherrapunjee, Balphakram	Eastern Himalaya and Indo-Burma
Baliospermum calycinum var.*micranthum* (Müll.Arg.) Chakrab. & N.P.Balakr.	Euphorbiaceae	Sh	ASSAM, B. Singh, 115949 (11.x.2007) Daribogre, Garo Hills	NE	Nokrek, Mawsmai, Cherrapunjee, Mawphlang, Mawkyrwat, Jowai, Jarain, Dawki, Umsaw, Umiam, Daribogre	Meghalaya
Bridelia assamica Hook.f.	Euphorbiaceae	T	ASSAM, D.K. Roy 130871 (11.xi.2014) Deobandh-Teptepa, Garo Hills	E	Balpakram, Nokrek.	Northeastern India and Bangladesh.
Cleistanthus nokrensis B.Singh	Euphorbiaceae	Sh	ASSAM, B. Singh, 115856 (08.x.2010), Rongsigiri, Garo Hills	NE	Nokrek Biosphere Reserve.	Meghalaya.
Croton joufra Roxb.	Euphorbiaceae	T	ASSAM, A.H. Mir, 00661 (10.v.2015) Lawbah, East Khasi Hills	E	Maheshkola, Cherrapunjee	Indo-Burma
Glochidion acuminatum Müll. Arg.	Euphorbiaceae	T	ASSAM, A.H. Mir, 90354 (23.iii.2015) Sohra, East Khasi Hills	E	Nokrek, Pyndengnongbri, Mawmluh, Mawsynram, Lynshing	Eastern Himalaya and Indo-Burma
Glochidion ellipticum Wight	Euphorbiaceae	T	ASSAM, B.Singh 116647 (16.x.2007) Dilching river, Garo Hills	E	Nokrek, Darugiri, Balphakram	Eastern Himalaya and Indo-Burma
Glochidion multiloculare (Rottler ex Willd.) Voigt*	Euphorbiaceae	T	ASSAM, M.K.V. Rao 64103 (14.ix.1975) Nokrek, Garo Hills	E	Nokrek, Mawsynram, Balpakram	Eastern Himalaya and Indo-Burma
Glochidion thomsonii (Muell. Arg.) Hook.f.	Euphorbiaceae	T	ASSAM, A.H. Mir, 90429 (10.x.2015) Khrang, East Khasi Hills	E	Jowai, Syndai, Nokrek, Cherapunjee, Mawsmai, Mawmluh, Nonglang, Mawkyrwat, Raliang, Jarain, Balphakram	Eastern Himalaya and Indo-Burma
Mallotus roxburghianus Müll. Arg.	Euphorbiaceae	T	ASSAM, A.H. Mir, 03071 (19.viii.2015) Wakhen, East Khasi Hills	E	Tura, Balphakram	Eastern Himalaya and Indo-Burma
Trigonostemon semperflorens (Roxb.) Muell.Arg.	Euphorbiaceae	Sh	ASSAM, D.K. Roy 125566 (26.iv.2012) Balpakram, Garo Hills	E	Nokrek, Balphakram	Bangladesh and Northeastern India
Trigonostemon viridissimus var. chatterjii (Deb & G.K. Deka) N.P. Balakr. & Chakrab.	Euphorbiaceae	T	ASSAM, D.K. Roy 129632 (11.iii.2013) Balpakram, Garo Hills	NE	Dawki, Balphakram National Park	Meghalaya
Crotalaria khasiana Thoth. & A.A.Ansari	Fabaceae	H	ASSAM, A.H. Mir, 03095 (22.v.2014 Mawmluh, East Khasi Hills	E	Mawmluh, Cherrapunjee, Mawsmai, Mawsynram	Indo-Burma
Dalbergia rimosa Roxb.	Fabaceae	T	ASSAM, B. Singh, 118575 (13.iv.2009), Mandalgiri Garo Hills	E	Balphakram, Dambu, Baghmara, Dawki, Umsaw, Pungtung, Tharia, Nongpoh, Sohra, Mandalgiri	Eastern Himalaya and Indo-Burma

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Name	**Family**	**Habit**	**Voucher number**	**Nativness**	**Meghalaya**	**Worldwide**
Gymnocladus assamicus U.N.Kanjilal ex P.C.Kanjilal*	Fabaceae	T	North Eastern Regional Institute of Science and Technology, A. Arunachalam 11839 (02.iv.2014), Shella, Khasi Hill	E	Laitkseh	Northeastern India
Ormosia robusta Baker	Fabaceae	T	ASSAM, A.H. Mir, 00590 (15. ix.2014) Lyngiong, East Khasi Hills.	E	Balphakram, Baghmara	Eastern Himalaya and Indo-Burma
Campylotropis thomsonii (Baker) Schindl.*	Fabaceae	Sh	K (image!), K000894916, J.D.Hooker & T.Thomson, s.n., Khasiya	E	Khasi hills (locality not specified)	Indo-Malaya
Dalbergia clarkei Thoth.*	Fabaceae	Sh	LE (image!), LE00014482, C.B. Clarke, (29.i.1886), Maoksandoam	E	Khasi hills	Eastern Himalaya, Northeastern India
Dalbergia volubilis Roxb var. *assamica**	Fabaceae	Sh	ASSAM, U.N.Kanjilal (30.iii.1915), Garo hills	E	Garo hills (locality not specified)	Northeastern India
Derris pseudorobusta Thoth.*	Fabaceae	Sh	ASSAM, N.P. Balakrishnan 47038 (24.viii.1968), Garam Pani-Rytiang Road	E	Garampani	Eastern Himalaya, North east India
Indigofera sesquipedalis Sanjappa*	Fabaceae	Sh	ASSAM, D. Verma 134145 (28. vi.14), Mukhaialong, Meghalaya	E	Mukhaialong near jowai	Eastern Himalaya, Northeastern India
Lespedeza elliptica Benth.*	Fabaceae	Sh	ASSAM, G. Panigrahi 3756 (26. ix.56), Elephant falls, 7th miles from Shillong	E	Elephant falls	Eastern Himalaya, North east India
Corydalis khasiana Liden*	Fumariaceae	H	K (image!), K000653652, Magnus Liden, Khasi Hills	NE	Khasi Hills (locality not specified)	Meghalaya
Crawfurdia campanulacea Wall. & Griff. ex C.B.Clarke*	Gentianaceae	H	K (image!), K000195242, J.D.Hooker, s.n. India, Khasia (Mawflong)	E	Mawphlang	Himalaya, North east India
Aeschynanthus mannii Kurz ex C.B.Clarke	Gesneriaceae	Ep	ASSAM, B. Singh, 114710 (27. ii.2007), Nokrek peak, Garo Hills	NE	Jowai, Balphakram, Nokrek	Meghalaya.
Aeschynanthus parasiticus (Roxb.) Wall.	Gesneriaceae	Ep	ASSAM, B. Singh, 116864 (29. iii.2008), Nabokgre, Garo Hills	E	Jarain, Jowai, Raliang, Ialong, Cherrapunjee, Mawsmai, Mawsynram, Nokrek, Nabokgre	Eastern Himalaya and Indo-Burma
Aeschynanthus superbus C.B.Clarke	Gesneriaceae	Ep	ASSAM, A.H. Mir, 90393 (13. ix.2016) Rangtheliang, East Khasi Hills	E	Raliang, Jarain, Jowai, Nartiang, Nokrek, Mawsynram, Rangthaliang, Cherrapunjee,	Eastern Himalaya and Indo-Burma
Aeschynanthus parviflorus (D.Don) Spreng.	Gesneriaceae	Ep	ASSAM, B. Singh, 115860 (07.x.2007), Rongsingiri, Garo Hills	E	Ialong, Raliang, Mawsmai, Mawmluh, Cherapunjee, Lynshing, Jowai, Nokrek, Shillong peak, Rongsingiri	Eastern Himalaya and Indo-Burma
Aeschynanthus hookeri C.B.Clarke	Gesneriaceae	Ep	ASSAM, A.H. Mir, 90464 (10. viii.2016) Wakhen, East Khasi Hills	E	South Garo hills, Wakhen, Balphakram	Eastern Himalaya and Indo-Burma.
Boeica filiformis C.B.Clarke*	Gesneriaceae	Sh	ASSAM, M.K.V. Rao 64551 (17. vii.1976), Baghmara, Garo Hills	E	Nokrek	Northeastern India.
Sycopsis griffithiana Oliv.*	Hamamelidaceae	T	ASSAM, S.R. Sarma 103299 (23. xi.1935) Mawsmai, Khasi Hills	NE	Tharia forest, Cherrapunjee, Mawsmai, Lan-Nong-Kah, Mahadeo forest	Meghalaya.
Molineria garoense D.K. Roy & D.Vijayan	Hypoxidaceae	H	ASSAM, D.K.Roy 129632 (06. vi.2014) Balpakram, Garo Hills	NE	Balpakram	Meghalaya.
Ixonanthes khasiana Hook.f.	Ixonanthaceae	T	ASSAM, A.H. Mir, 05653 (11.x.2016) Pongtung, East Khasi Hills	NE	Syreyngam, Nongtalang, Dawki, Nongsteng, Cherrapunjee, Mawsynram	Meghalaya and Arunachal Pradesh.
Callicarpa vestita Wall. ex C.B.Clarke	Lamiaceae	T	ASSAM, A.H. Mir, 90457 (17. vii.2015) Pongtung, East Khasi Hills	E	Raliang, Pongtung	Northeastern India and Eastern Himalaya.
Gomphostemma lucidum wall ex Benth.	Lamiaceae	Sh	ASSAM, A.H. Mir, 90460 (21. ix.2015) Mawmluh, East Khasi Hills	E	Jowai, Jarain, Cherrapunjee, Mawmluh, Nongthmai	Indo-Burma.
Pogostemon strigosus (Benth.) Benth.	Lamiaceae	Sh	ASSAM, A.H. Mir, 90328 (08. vii.2015) Lyngshing, East Khasi Hills	NE	Ialong, Jowai, Jarain, Ummulong, Lawbah, Mawsmai, Pomshomen, Mawmluh, Mawsynram	Meghalya.
Premna bracteata Wall. ex C.B.Clarke	Lamiaceae	T	ASSAM, B. Singh 114965 (20. vi.2007), Bandari fall, Garo Hills	E	Tura Peak	Eastern Himalaya and Indo-Burma.

					Distribution	
Name	Family	Habit	Voucher number	Nativness	Meghalaya	Worldwide
Premna milleflora C.B.Clarke*	Lamiaceae	T	ASSAM, U. Kanjilal 5249 (06. iii.1915) Tura Forests, Garo Hills	E	Songsak, Tura Peak	Indo-Burma.
Premna racemosa Wall. ex Schauer	Lamiaceae	T	ASSAM, A.H. Mir, 00615 (09.i.2014) Laitryngew, East Khasi Hills	E	Pynrsula, Tura	Indo-Burma.
Alseodaphne khasyana (Meisn.) Kosterm.	Lauraceae	T	ASSAM, A.H. Mir, 90378 (21.x.2015) Nongstoin, West Khasi Hills	NE	Pynursla, Mawkyrwat, Cherrapunjee, Mawmluh, Laitkynsew, Lawba, Nongstoin	Meghalaya.
Actinodaphne reticulata Meisn.*	Lauraceae	T	K (image!), K000778977, J.D. Hooker & T. Thomson, s.n (?.x.1820) Khasia, Nongkhlaw	E	Nongkhlaw	Eastern Himalaya, Meghalaya
Alseodaphne petiolaris Hook.f.	Lauraceae	T	ASSAM, U.N. Kanjilal 4051 (06. vi.1914), 37 half mile post, G.S.Road, Shillong	E	Khasi hills (locality not specified)	Indo-Burma
Beilschmiedia fagifolia Nees*	Lauraceae	T	ASSAM, U. Kanjilal 5251 (07. iii.1915) Tura Peak, Garo Hills	E	Tura Peak	Eastern Himalaya and Indo-Burma.
Beilschmiedia assamica Meisn.	Lauraceae	T	ASSAM, A.H. Mir, 90408 (21.ii.2016) Mawsmai, East Khasi Hills	E	Nokrek, Pynursla, Cherrapunjee, Mawkyrwat, Nongstoin, Mawsmai, Mawmluh	Indo-Burma.
Beilschmiedia brandisii Hook.f.	Lauraceae	T	ASSAM, A.H. Mir, 01013 (09. xi.2016) Nongstoin, West Khasi Hills	E	Tura peak, Nongkrem, Nokrek	Northeastern India.
Beilschmiedia gammieana King ex Hook.f.	Lauraceae	T	ASSAM, U.N. Kanjilal 7105 (29. xi.1916), Upper Shillong.	E	Upper Shillong	Eastern Himalaya
Cinnamomum bishnupadae M.Gangop.*	Lauraceae	T	Specimen not seen	E	Locality not known	Northeastern India (Meghalaya)
Cinnamomum curvifolium (Lam.) Nees	Lauraceae	T	ASSAM, D.K. Roy 130065 (05. ii.2014) Balpakram, Garo Hills	E	Raliang, Jowai, Sohrarim, Mawmluh, Cherrpunjee, Lyngiong, Lynshing, Mawkyrwat, Mawsynram, Umsaw, Balphakram, Jarain, Nartiang, Dawki, Bhoirymbong, Nongpoh, Nongstoin	Indo-Burma
Cinnamomum suvrae M.Gangop.*	Lauraceae	T	Specimen not seen	E	Locality not known	North east India (Meghalaya)
Cryptocarya amygdalina Nees	Lauraceae	T	ASSAM, A.H. Mir, 00677 (09.x.2015) Laitsohum, East Khasi Hills	E	Nokrek, Balphakram	Indo-Burma and Nepal
Lindera latifolia Hook.f.	Lauraceae	T	ASSAM, AH Mir, 90365 (22.ix.2015) Mawkyrwat, South West Khasi Hills	E	Nokrek, Ialong, Raliang, Jowai, Amlarem, Nonglang, Cherrapunjee, Mawmluh, Phudjuad, Nongstoing, Lyngiong	Indo-Burma
Litsea laeta (Wall. ex Nees) Hook.f.	Lauraceae	T	ASSAM, A.H. Mir, 90447 (21. viii.2015) Cherrapunjee, East Khasi Hills	E	Cherrapunjee, Mawsmai, Mawmluh, Laitryngew, Mawsynram, Nongstoin, Jakrem, Shangpung, Wakhen, Lawbah, Nongstoin, Nongpoh, Nokrek, Balphakram, Mawkasain, Laitsohum	Indo-Burma and Bhutan
Machilus gamblei King ex Hook.f.	Lauraceae	T	ASSAM, B. Singh118504 (12. iv.2009), Nokrek Peak, Garo Hills	E	Darugiri, Cherapunjee, Lyngiong, Nongkrem, Smit, Mawkyrwat. Lailad, Mawmluh, Mawsmai, Mawsynram, Balphakram, Nokrek	Eastern Himalaya and Indo-Burma
Neolitsea umbrosa(Nees) Gamble	Lauraceae	T	ASSAM, A.H. Mir, 00583 (15.i.2016) Cherrapunjee, East Khasi Hills.	E	Lailad, Dympep, Pynursla, Cherrapunjee, Satifalls, Balpakram	Himalaya, Indo-Burma
Persea kingii (Hook.f.) Kosterm.	Lauraceae	T	ASSAM, A.H. Mir, 00652 (07.v.2015) Swer, East Khasi Hills.	NE	Shillong peak, Cherrapunjee, Mawmluh, Mawsmai, Mawkyrwat, Nokrek, Nongstoin	Meghalaya
Persea minutiflora Kosterm.	Lauraceae	T	ASSAM, A.H. Mir, 00638 (12. xi.2014) Pongtung, East Khasi Hills	E	Nokrek	Indo-Burma

					Distribution	
Name	Family	Habit	Voucher number	Nativness	Meghalaya	Worldwide
Persea parviflora (Meisn.) Harid. & R.R.Rao	Lauraceae	T	ASSAM, A.H. Mir, 05646 (22.i.2016) Laitsohum, East Khasi Hills	NE	Tura, Ialong, Raliang, Jowai, Nongstoin	Meghalaya
Phoebe attenuata (Nees) Nees	Lauraceae	T	ASSAM, A.H. Mir, 00662 (10.v.2015) Lawbah, East Khasi Hills	E	Tura	Eastern Himalaya and Meghalaya
Phoebe cooperiana P.C.Kanjilal & Das	Lauraceae	T	ASSAM, B.S. 118408 (02.ii.2009), Doparakgre, Garo Hills	E	Nongpoh, Nokrek	Northeastern India
Lindera assamica (Meisn.) Kurz	Lauraceae	T	ASSAM, R.N. De 17565 (11.xi.1938), Mawsmai forest	E	Cherrapunjee, Mawsmai	Eastern Himalaya, Indo-Burma
Loranthus gracilifolius Roxb. ex Schult. & Schult.f.	Loranthaceae	Ep	ASSAM, R.N. De 19967 (10. xii.1940), Damra forests, Garo Hills	E	Balphakram, Damra	Eastern Himalaya and Indo-Burma
Taxillus assamicus Danser	Loranthaceae	P	ASSAM, AH Mir, 90323 (13.ix.2015) Cherrapunjee, East Khasi Hills	E	Cherrapunjee, Mawmluh, Damalgiri	Indo-Burma
Macrosolen psilanthus (Hook.f.) Danser*	Loranthaceae	Sh	ASSAM, RN De 19967 (28.iii.1941), Damra forests, Garo Hills	E	Jarain, Damra	Northeastern India and Bhutan
Magnolia baillonii Pierre	Magnoliaceae	T	ASSAM, A.H. Mir, 00756 (02.ii.2016) Nongsteng, East Khasi Hills	E	Umsaw, Nongsteng. Nokrek, Nartiang	Eastern Himalaya and Indo-Burma
Magnolia griffithii Hook.f. & Thomson*	Magnoliaceae	T	ASSAM, D.B. Deb 28900 (29. viii.1962), Tura Forests, Garo Hills	E	Nongpoh, Nokrek	Indo-Burma.
Magnolia insignis Wall.	Magnoliaceae	T	ASSAM, A.H. Mir, 90415 (12.v.2015) Cherrapunjee, East Khasi Hills	E	Ialong, Raliang, Shillong peak, Mawmluh, Jarain, Shangpung, Khlerihat, Nongpoh, Nonsynreih, Nonglang, Cherrapunjee, Lyngiong, Mawynram	Eastern Himalaya and Indo-Burma
Magnolia oblonga (Wall. ex Hook.f. & Thomson) Figlar	Magnoliaceae	T	ASSAM, AH Mir, 90313 (24.iii.2016) Swer, East Khasi Hills	E	Swer, Tura	Bangladesh and Northeastern India
Magnolia punduana (Hook.f. & Thomson) Figlar	Magnoliaceae	T	ASSAM, A.H. Mir, 90404 (19. ix.2015) Mawmluh, East Khasi Hills	E	Jowai, Jarain, Cherrapunjee, Mawkyrwat, Nongstoin, Pynursla, Lynshing, Nonglang	Northeastern India
Magnolia rabaniana (Hook.f. & Thomson) D.C.S.Raju & M.P.Nayar	Magnoliaceae	T	ASSAM, A.H. Mir, 88685 (19. iii.2015) Cherrapunjee	E	Mawsmai, Cherrapunjee, Sangriang, Nongthmmai	Northeastern India
Magnolia lanuginosa (Wall.) Figlar & Noot.	Magnoliaceae	T	ASSAM, A.H. Mir, 88695 (02. viii.2015) Mawnai, West Khasi Hills	E	Mawnai, Khrang, Rngisawlia, Pariong, Kynshi, Pyndengnongbri, Mawkyrwat	Indo-Burma
Aspidopterys elliptica (Blume) A.Juss.*	Malpighiaceae	Cl	ASSAM, R.N. De 20551 (25.iv.1941), Damra forests, Garo Hills	E	Tura, Maheskhola, Damra	Eastern Himalaya and Indo-Burma
Hiptage acuminata Wall. ex A.Juss.	Malpighiaceae	Cl	ASSAM, A.H. Mir, 01015 (11. xi.2016) Nonglynkien, South West Khasi Hills	E	Nokrek, Nonglynkien	Indo-Burma
Aspidopterys jainii R.C.Srivast.*	Malpighiaceae	Cl	Specimen not seen	E	Locality not specified	Northeastern India (Meghalaya)
Heritiera dubia Wall. ex Kurz*	Malvaceae	T	Specimen not seen	E	Locality not specified	Northeastern India (Assam, Meghalaya)
Memecylon cerasiforme Kurz	Melastomataceae	T	ASSAM, A.H.Mir, 00595 (15.x.2016) Mawmluh, East Khasi Hills	E	Lailad, Balphakram	Indo-Burma
Osbeckia capitata Benth. ex Naudin	Melastomataceae	H	ASSAM, A.H. Mir, 90359 (15. vi.2015) Lyngiong, East Khasi Hills	E	Jowai, Mawlai, Pongtung, Raliang, Cherrapunjee, Nongstoin, Mairang, Nongbri, Lyngiong, Mawkyrwat, Pynursla, Wakhen, Jarrain, Lawbah, Mawphlang, Laitryngew, Phlanwangbroi	Indo-Burma
Osbeckia nutans Wall. ex C.B.Clarke	Melastomataceae	Sh	ASSAM, D.K .Roy 129644 (11. iii.2013) Balpakram, Garo Hills	E	Nokrek, Jowai, Balphakram.	Eastern Himalaya and Northeastern India
Osbeckia nayarii G.S.Giri*	Melastomataceae	H	Specimen not seen	NE	Locality not specified	Meghalaya
Oxyspora senguptae Subram. & Nayar*	Melastomataceae	Sh	Specimen not seen	NE	Locality not specified	Meghalaya
Sonerila khasiana C.B.Clarke	Melastomataceae	H	ASSAM, A.H. Mir, 03094 (22.v.2014) Cherrapunjee, East Khasi Hills	E	Ialong, Jowai, Balphakram, Cherrapunjee, Nongsynrieh, Mawthnrew, Nongstoin	Himalaya, Indo-Burma

					Distribution	
Name	**Family**	**Habit**	**Voucher number**	**Nativness**	**Meghalaya**	**Worldwide**
Sonerila arguta R.Br.*	Melastomataceae	H	K (image!), K000867662, s.coll., Amane	NE	Locality not specified	Meghalaya
Chisocheton cumingianus subsp. *balansae* (C.DC.) Mabb.	Meliaceae	T	ASSAM, B. Singh, 118416 (03.ii.2009) Tamadugre, Garo Hills	E	Mahadeo, Pynursla, Pongtung, Balpakram, Nokrek, Tamadugre	Eastern Himalaya and Indo-Burma
Cyclea bicristata (Griff.) Diels	Menispermaceae	Cl	ASSAM, A.H. Mir, 04356 (26.iv.2015) Cherapunjee, East Khasi Hills	E	Cherrapunjee, Mawsynram	Indo-Burma
Cyclea debiliflora Miers	Menispermaceae	Cl	ASSAM, B. Singh118347 (30.i.2008) Sangkinigre, Garo Hills	NE	Nokrek, Balphakram, Sangkinigre	Meghalaya
Haematocarpus thompsonii Miers	Menispermaceae	Cl	ASSAM, A.H. Mir, 00619 (05.ii.2014) Mawkyrwat, South West Khasi Hills	E	Sonapahar	Northeastern India
Stephania glandulifera Miers*	Menispermaceae	Cl	ASSAM, s.coll., 29036 (30.viii.1962), Tura forest, Meghalaya	E	Tura peak, Nokrek	Eastern Himalaya, North east India
Calliandra umbrosa subsp. *griffithii* (Benth.) S.R.Paul	Mimosaceae	Sh	ASSAM, A.H. Mir, 03082 (21.xii.2016) Ureksew, East Khasi Hills	NE	Umtapoh, Mawsmai, Balphakram	Meghalaya
Artocarpus chama Buch.-Ham.	Moraceae	T	ASSAM, B .Singh115741 (23.vi.2007) Oragitok, Garo Hills	E	Umlimg, Balphakram, Nokrek, Oragitok	Bangladesh and Indo-Burma
Ficus squamosa Roxb.	Moraceae	Sh	ASSAM, B Singh118245 (01.ii.2008) Rongrengiri, Garo Hills	E	Umling-Lailad, Rongrengiri	Eastern Himalaya and Indo-Burma
Musa velutina H.Wendl. & Drude	Musaceae	T	ASSAM, B Singhs.n. (26.ii.2007) Chandigre, Garo Hills	E	Nokrek, Chandigre	Eastern Himalaya and Indo-Burma
Horsfieldia amygdalina (Wall.) Warb.	Myristicaceae	T	ASSAM, U. Kanjilal 23959 (28.iii.1915) Dambu, Garo Hills	E	Laitkynsew, Dambu , Nongpoh	Eastern Himalaya and Indo-Burma
Antistrophe oxyantha (Wall. ex A.DC.) A.DC.	Myrsinaceae	T	ASSAM, B. Singh114670 (27.ii.2007) Nokrek Peak, Garo Hills	E	Nokrek Peak, Balphakram	Northeastern India and Bangladesh
Ardisia depressa C.B.Clarke	Myrsinaceae	Sh	ASSAM, B. Singh115852(07.x.2008) Rongsingiri, Garo Hills	E	Umsaw, Nongpoh, Nokrek, Rongsingiri	Eastern Himalaya and Indo-Burma
Ardisia griffithii C.B.Clarke	Myrsinaceae	Sh	ASSAM, A.H. Mir, 90394 (28.x.2016) Laitryngew, East Khasi Hills.	NE	Ialong, Raliang, Jowai, Mawlai, Nokrek, Cherrapunjee, Mawkyrwat	Meghalaya
Ardisia neriifolia Wall. ex A.DC.	Myrsinaceae	Sh	ASSAM, A.H. Mir, 00676 (08.x.2015) Khrang, East Khasi Hills.	E	Mawlai, Jarain, Balpakram	Eastern Himalaya and Indo-Burma
Ardisia odontophylla Wall. ex A.DC.	Myrsinaceae	Sh	ASSAM, B. Singh118477 (09.iv.2009) Nokrek Peak, Garo Hills	E	Pynursla, Jowai, Mawsynram, Nokrek	Indo-Burma
Ardisia pedunculosa Wall.*	Myrsinaceae	Sh	ASSAM, G. Panigrahi 22605 (15.xii.1960) Rongrengiri, Garo Hills	NE	Raliang, Garo Hills	Meghalaya
Embelia subcoriacea (C.B.Clarke) Mez	Myrsinaceae	Sh	ASSAM, A.H. Mir, 90459 (24.x.2016) Mawmluh, East Khasi Hills	E	Mawmluh, Cherrapunjee, Jowai, Weiloi, Mawsynram, Jarain	Indo-Burma
Embelia tsjeriam-cottam (Roem. & Schult.) A.DC.	Myrsinaceae	Sh	ASSAM, A.H. Mir, 00578 (15.vii.2015) Cherrapunjee, East Khasi Hills	E	Nongpoh	Indo-Burma
Embelia vestita Roxb.	Myrsinaceae	Sh	ASSAM, A.H. Mir, 00579 (15.vii.2015) Cherrapunjee, East Khasi Hills	E	Sadew, Ialong, Jowai	Northeastern India
Syzygium diospyrifolium (Wall. ex Duthie) S.N.Mitra	Myrtaceae	T	ASSAM, A.H. Mir, 00653 (08.v.2015) Cherrapunjee, East Khasi Hills	E	Lailad, Balphakram	Bangladesh and Northeastern India
Syzygium kurzii (Duthie) N.P.Balakr.	Myrtaceae	T	ASSAM, B. Singh 114985 (21.vi.2007) Dopgre, Garo Hills	E	Dambu, Balphakram, Nokrek, Dopgre	Indo-Burma
Syzygium praecox (Roxb.) Rathakr. & N.C.Nair	Myrtaceae	T	ASSAM, B. Singh 115938 (11.x.2007), Williamnagar, Garo Hills	E	Baghmara, Williamnagar	Indo-Burma
Syzygium ramosissimum (Blume) N.P.Balakr.*	Myrtaceae	T	ASSAM, U. Kanjilal 5237 (05.iii.1915) Sanitorium Hills, Garo Hills	E	Baghmara, Nokrek, Sanitorium Hills.	Eastern Himalaya and Indo-Burma
Syzygium khasianum (Duthie) N.P.Balakr	Myrtaceae	T	ASSAM, A.H. Mir, 03046 (16.vi.2016) Mawsmai, East Khasi Hills	E	Cherrapunjee, Mawmluh, Mawsmai, Mawsynram	Notheast India
Nepenthes khasiana Hook.f.	Nepanthaceae	Sh	ASSAM, A.H. Mir, 90306 (19.ix.2014) Jarain, South West Hills	NE	Balphakram, Nokrek, Sutunga, Jarain, Bapung, Maheshkhola, Bagmara, Siju, Lawbah	Meghalaya

					Distribution	
Name	**Family**	**Habit**	**Voucher number**	**Nativness**	**Meghalaya**	**Worldwide**
Anacolosa ilicoides Mast.	Olacaceae	T	ASSAM, DK Roy 125983 (22.iv.2012) Balpakram, Garo Hills	E	Nokrek, Siju	Indo-Burma
Jasminum cardiomorphum P.S. Green*	Oleaceae	Sh	K (image!), K000545655, Tessier-Yandell, (?.ii.1973), Meghalaya	NE	Khasi & Jaintia hills (locality not specified)	Meghalaya
Jasminum listeri King ex Gage	Oleaceae	Sh	ASSAM, B. Singh 114602 (23. ii.2007) Daribokgre, Garo Hills	E	Sella forest, Dawki, Nokrek, Balpakram, Daribokgre	Indo-Burma
Jasminum subglandulosum Kurz	Oleaceae	Sh	ASSAM, A.H. Mir, 00914 (09. xi.2016) Nongstoin, West Khasi Hills	E	Umsaw.	Indo-Burma
Ligustrum myrsinites Decne.	Oleaceae	T	ASSAM, AH Mir, 03075 (20.i.2016) Lyngiong, East Khasi Hills	NE	Elephent falls, Upper Shillong, Sadew, Dympep, Mawphlang	Meghalaya
Olea salicifolia Wall. ex G.Don	Oleaceae	T	ASSAM, A.H. Mir, 04128 (22. ix.2016) Laitkynsew, East Khasi Hills	E	Cherrapunjee, Sohrarim, Mawsmai, Mawkyrwat, Nongstoin, Nongsynrieh	Indo-Burma.
Acampe ochracea (Lindley) Hochr	Orchidaceae	Ep	ASSAM, B. Singh 116699 (?), Nokrek Peak, Garo Hill	E	Dawki, Nongpoh, Garampani, Raliang, Nokrek Peak	Indo-Burma
Acampe papillosa (Lindley) Lindley	Orchidaceae	Ep	ASSAM, B. Singh 116700 (?), Daribokgre, Garo Hill	E	Burnihat, Nongpoh, Raliang, Gokha, Rongrenggre	Eastern Himalaya and Indo-Burma
Agrostophyllum brevipes King & Pantl.*	Orchidaceae	Ep	ASSAM, R.N. De 17137 (?), Nokrek Hills, Garo Hills	E	Jowai, Laitryngew, Leska, Ialong, Raliang, Nokrek.	Indo-Burma
Agrostophyllum callosum Rchb.f.	Orchidaceae	Ep	ASSAM, A.H. Mir, 05649 (06.ii.2017) Cherrapunjee, East Khasi Hills	E	Cherapunjee, Laitryngew, Kynshi, Mawphlang, Pynursla, Shillong Peak, Mawmluh, Nokrek	Eastern Himalaya and Indo-Burma
Agrostophyllum flavidum Phukan*	Orchidaceae	Ep	ASSAM, S. Phukan 68257B (?.v.1985), Khasi Hills	NE	Shillong Peak	Meghalaya
Agrostophyllum planicaule (Wall. ex Lindl.) Rchb.f.	Orchidaceae	Ep	ASSAM, B. Singh 35839 (?), Nokrek Peak, Garo Hills	E	Dawki, Lundai, Mawsmai, Cherrapunjee, Syndai, Jarain, Nongpoh, Balpakram, Nokrek	Indo-Burma
Arachnis labrosa (Lindl. & Paxton) Rchb.f.*	Orchidaceae	Ep	ASSAM G.K. Deka 36069 (04.x.1950) Khasi & Jaintia Hills	E	Markasa, Umsaw, Dawki	Eastern Himalaya and Indo-Burma
Brachycorythis galeandra (Rchb.f.) Summerh.	Orchidaceae	H	ASSAM C.Deori & S.R.Talukdar 134226 (5.vii.16), Nongstoin, West Khasi Hills	E	Cherrapunjee, Mawmluh, Laitlyngkot, Mawryngkneng, Nongkrem, Nongstoin, Sadew, Umkhlaw, Shillong Peak	Eastern Himalaya and Indo-Burma
Bulbophyllum blepharistes Rchb.f.*	Orchidaceae	H	ASSAM, G.K. Deka 35652, Nongpoh, Ribhoi district	E	Cherapunjee	Indo-Burma
Bulbophyllum careyanum (Hook.) Spreng.	Orchidaceae	Ep	ASSAM, D.K. Roy 129659 (12. iii.2013) Balpakram, Garo Hills	E	Bholaganj, Pynursla, Nongpoh, Balphakram	Eastern Himalaya and Indo-Burma
Bulbophyllum cauliflorum Hook.f.	Orchidaceae	Ep	ASSAM, D. Verma 134121 (28. vi.2014) Mukhaialong, Jaintia Hills	E	Cherrapunjee, Dawki, Jowai	Indo-Burma
Bulbophyllum cherrapunjeensis Barbhuiya & D.Verma*	Orchidaceae	Ep	ASSAM, Barbhuiya &Verma 112212 (07.vii.2013), Cherrpunjee, West Khasi Hills	NE	Cherrapunjee	Meghalaya
Bulbophyllum chyrmangensis D.Verma, S.Lavania & Sushil K. Singh*	Orchidaceae	Ep	ASSAM, D. Verma 53 (08.x.2013) Chyrmang, West Jaintia Hills District	NE	Chyrmang	Meghalaya
Bulbophyllum griffithii (Lindl.) Reiclb*	Orchidaceae	Ep	ASSAM, J.Joseph 37309 (17.x.66) Elephant falls, East Khasi Hills	E	Ialong, Jowai Nokrek Balpakram, Shillong, Upper shillong	Indo-Burma
Bulbophyllum gymnopus Hook.f.	Orchidaceae	Ep	ASSAM, C.Deori & S.R.Talukdar 134502 (30.xi.16) Mawthawpdah, South West Khasi Hills	E	Cherapumjee, Mawsmai, Shillong, Saifalls, Balpakram, Nokrek	Eastern Himalaya and Indo-Burma
Bulbophyllum hirtum (Smith) Lindl.	Orchidaceae	Ep	ASSAM, C.Deori 1011285 (12.xi.13), Cherrapunjee, East Khasi Hills	E	Barapani, Cherrapunjee, Shillong Peak, Nongpoh	Indo-Burma
Bulbophyllum leopardinum (Wall.) Lindl.	Orchidaceae	Ep	ASSAM, C.Deori & S.R.Talukdar 137747 (30.vi.17), Kyllang forest West khasi Hills District	E	Pynurslla, Sadew forest, Sohrarim, Shillong	Eastern Himalaya and Indo-Burma
Bulbophyllum leptanthum Hook.f.*	Orchidaceae	Ep	K (image!), K000894303, Hooker J.D. and Thompson T. Cherrapunjee.	E	Pynursla, Sadew, Sohrarim, Shillong	Northeastern India

Name	Family	Habit	Voucher number	Nativness	Distribution	
					Meghalaya	Worldwide
Bulbophyllum manabendrae D.K. Roy Barbhuiya & A.D. Talukdar	Orchidaceae	Ep	ASSAM, D.K. Roy 129694 (12. iii.2013) Balpakram, Garo Hills	NE	South Garo hills	Meghalaya
Bulbophyllum moniliforme Part. ex. Reichb. f.	Orchidaceae	Ep	ASSAM,N.C.Deori, 51737 (21.ii.73) Jarain, Jaintia Hills District	E	Jarain	Nepal and Indo-Burma
Bulbophyllum piluliferum King & Pantl.*	Orchidaceae	Ep	ASSAM, N.P. Balakrishnan 42283 (31.v.1965) Jowai, Jaintia Hills	E	Jowai	Northeastern India
Bulbophyllum scabratum Reichb.f.	Orchidaceae	Ep	ASSAM, C. Deori & S.R.T. 137724 (10.v.17), West Khasi Hills	E	Cherapunjee, Shillong Peak, Mawsmai	Eastern Himalaya and Indo-Burma
Bulbophyllum striatum (Griff.) Reichb.f	Orchidaceae	Ep	ASSAM, A.H. Mir, 05644 (06.ii.2017) Dympep, East Khasi Hills.	E	Jowai, Kynshi- Markasa, Shillong-peak, Nokrek	Eastern Himalaya and Indo-Burma
Calanthe densiflora Lindl.*	Orchidaceae	H	ASSAM, G.Panigrahi 4620 (21. xi.56) Dawki from Pynursla I.B.	E	Jowai, Pynursla, Shillong, Mahadeo, Nokrek	Indo-Burma
Cheirostylis griffithii Lindl.	Orchidaceae	H	ASSAM, AH Mir, 04140 (25.vi.2015) Nonglang, South West Khasi Hills	E	Mawphlang, Mawkyrwat, Nongstoin, Mawmluh, Mawsmai	Eastern Himalaya and Indo-Burma
Cheirostylis pusilla Lindl.*	Orchidaceae	H	ASSAM, D.K. Roy & D. Vijayan 128919 (11.ix.2018) Pongtung, Khasi Hills	NE	Khasi Hills – Pontung	Meghalaya
Cleisostoma appendiculatum (Lindl.) Benth. & Hook. f. ex Jackson	Orchidaceae	Ep	ASSAM, D.B. Deb 29295 (?), Nokrek Peak, Garo Hill	E	Jarain, Nongstoin, Balpakram, Nokrek	Indo-Burma
Cleisostoma aspersum (Rchb.f.) Garay*	Orchidaceae	Ep	ASSAM, C.Deori 131605 (16.xii.15) Botanical garden, collected from Pynursla, East Khasi Hills	E	Pynursla, Shillong Peak	Eastern Himalaya and Indo-Burma
Cleisostoma filiforme (Lindley) Garay	Orchidaceae	Ep	ASSAM, B. Singh 116760 (?), Rongrengiri, Garo Hill	E	Umsaw, Rongrengiri, Nongpoh, Nokrek, Rongrengiri	Eastern Himalaya and Indo-Burma
Cleisostoma racemiferum (Lindley) Garay*	Orchidaceae	Ep	ASSAM, M.K.V. Rao 64609 (?) Nokrek Peak, Garo Hills	E	Jowai, Ramtai, Syndai, Umsaw, Umrangshu	Eastern Himalaya and Indo-Burma
Cleisostoma subulatum Blume*	Orchidaceae	Ep	ASSAM, M.K.V. Rao 64609 (?) Nokrek Peak, Garo Hills	E	Nongpoh, Pyndeng-slu-Kop, Balpakram, Nokrek	Indo-Burma
Coelogyne barbata Griff.	Orchidaceae	Ep	ASSAM, AH Mir, 03061 (19.ii.2015) Saitbakon, East Khasi Hills.	E	Cherrapunjee, Mawsmai, Sohrarim, Nongstoin, Balpakram, Nokrek	Eastern Himalaya and Northeastern India
Coelogyne corymbosa Lindl.*	Orchidaceae	Ep	ASSAM, G.V.S.R. 28188 (?) Nokrek, Garo Hills	E	Dympep, Mawphlang, Sohrarim, Pyunrsla, Saitbakon, Lynshing, Nokrek	Eastern Himalaya and Indo-Burma
Coelogyne flaccida L.	Orchidaceae	Ep	ASSAM, B Singh 116786 (?) Simsanggre, Garo Hills	E	Jarain, Jowai, Shillong Peak, Nokrek	Eastern Himalaya and Northeastern India
Coelogyne fuscescens Lindl.	Orchidaceae	Ep	ASSAM, B Singh 116759 (?) Rongrengre, Garo Hills	E	Cherrapunjee, Sohrarim, Nokrek, Rongrengre.	Eastern Himalaya and Indo-Burma
Coelogyne longipes Lindl.	Orchidaceae	Ep	ASSAM, B. Singh 116695 (?) Sisubibra, Garo Hills	E	Cherrapunjee, Nokrek	Eastern Himalaya and Indo-Burma
Coelogyne micrantha Lindl.*	Orchidaceae	Ep	ASSAM, S. Das 55474 (11.ii.1975) Jarain, Jaintia Hills	E	Cherrapunjee, Jowai, Nongkhlaw, Nongstoin	Eastern Himalaya and Indo-Burma
Coelogyne occultata Hook.f.*	Orchidaceae	Ep	ASSAM, S.D. Sangma 60130 (?) Sellengiri, Garo Hills	E	Cherrapunjee, Jarain, Lynshing, Pynursla, Pongtung, Nokrek	Eastern Himalaya and Indo-Burma
Coelogyne ovalis Lindl.*	Orchidaceae	Ep	ASSAM, SR Sarma 20266 (22. xi.1938) Sohrarim, Jaintia Hills	E	Pongtung, Sohra-rim, Shella, Nokrek	Indo-Burma and Nepal
Coelogyne prolifera Lindl.	Orchidaceae	Ep	ASSAM, M.K.V. Rao 61442 (?) Darogiri, Garo Hills	E	Cherrapunjee, Mawsmai, Jarain, Nongkhyllem, Nokrek	Eastern Himalaya and Indo-Burma
Coelogyne punctulata Lindl.	Orchidaceae	Ep	ASSAM, A.H. Mir, 03085 (22. vi.2014) Pynursla, East Khasi Hills	E	Amwee, Cherrapunjee, Mawmluh, Mawsmai, Jarain, Kyllang rock, Shillong, Balpakram, Nokrek	Eastern Himalaya and Indo-Burma
Coelogyne schultesii S.K.Jain & S.Das	Orchidaceae	Ep	ASSAM, B. Singh 116695 (?) Sisubibra, Garo Hills	E	Cherrapunjee, Nongstoin, Jarain, Markasa, Nokrek	Indo-Burma
Coelogyne stricta (Don) Schltr.*	Orchidaceae	Ep	ASSAM, SD Sangma 55496 (04. iv.1974) Salbengiri, Garo Hills	E	Jarain, Cherrapunjee, Nokrek	Eastern Himalaya and Indo-Burma

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Coelogyne suaveolens (Lindl.) Hook.f.	Orchidaceae	Ep	ASSAM, B. Singh 116716 (?) Khalakgre, Garo Hills	E	Cherrapunjee, Jowai, Nongkhlaw, Nongpoh, Umsning- Noonmati, Nokrek	Indo-Burma
Coelogyne viscosa Rchb.f.*	Orchidaceae	Ep	ASSAM, G.K.Deka 25053 (07.iii.1961), Jowai, Jaintia Hills	E	Jarain, Barapani, Jowai	Eastern Himalaya and Northeastern India
Corybas himalaicus (King& Pantl.) Schltr*	Orchidaceae	Ep	ASSAM, J. Joseph 84079 (?) Nokrek Peak, Garo Hills	E	Upper Shillong, Elephant falls, Nokrek	Indo-Burma.
Crepidium khasianum (Hook.f.) Szlach.	Orchidaceae	H	ASSAM, A.H. Mir, 02235 (14. vi.2017) Mawkyrwat, South West Khasi Hills	E	Jarain, Shillong Peak	Indo-Burma and Nepal
Cryptochilus sanguinea Wall.*	Orchidaceae	Ep	ASSAM, R.N. De 22167 (?) Tura Peak, Garo Hills	E	Cherrapunjee, Mawsmai, Dawki, Jarain, Pynursla, Jowai, Nokrek, Tura Peak	Northeastern India, Bhutan and Nepal
Cymbidium cochleare Lindl.*	Orchidaceae	Ep	ASSAM, G.K.Deka 25053 (07.iii.61), Jowai, Jaintia Hill district	E	Jarain, Jowai, Nongstoin	Eastern Himalaya and Northeastern India.
Cymbidium devonianum Paxt. Mag*	Orchidaceae	Ep	ASSAM, T.M.Hynniewta 50835 (07. iv.72), Cherrapunjee, East Khasi Hills	E	Cherrapunjee, Nongstoin, Nokrek	Northeastern India, Bhutan, Nepal and Thailand
Cymbidium eburneum Lindl.*	Orchidaceae	Ep	ASSAM, T.M.Hynniewta 51864 (15. xi.72) Jarain, Jaintia Hills district	E	Markasa, Sonapur, Nongstoin, Mairang, Shillong peak, Nokrek	Nepal and Indo-Burma
Cymbidium elegans Lindl.	Orchidaceae	Ep	ASSAM, DK Roy 129741 (01.ii.2014) Balpakram, Garo Hills	E	Mawphlang, Nongkhlaw, Peak Forest, Shillong, Smit, Nongkrem, Balpakram	Eastern Himalaya and Indo-Burma
Cymbidium mastersii Griff.*	Orchidaceae	Ep	ASSAM, G. K. Deka Accn. no. 36054 (31.x.52), Pontung, Khasi & Jaintia Hills,	E	Pongtung, Shillong	Eastern Himalaya and Indo-Burma
Dendrobium anceps Swartz	Orchidaceae	Ep	ASSAM, C.Deori & SRT, 137765 (09.vi.17) BSI, Botanical garden, originally collected from Nongkhlaw, West Khasi Hill District	E	Mawphlang, Nongpoh, Nokrek	Himalaya, Indo-Burma
Dendrobium gibsonii Lindl.	Orchidaceae	Ep	ASSAM, C. Deori 101155 (29. vii.04),Jowai, Jaintia Hill District	E	Cherrapunjee, Shillong peak, Nongkhlaw	Eastern Himalaya and Indo-Burma
Dendrobium hookerianum Lindl.	Orchidaceae	Ep	ASSAM), C.Deori 101157 (29. vii.2004) Shillong Peak, East Khasi Hills	E	Cherrapunjee, Mawphlang, Pynursla, Shillong peak	Indo-Burma
Dendrobium infundibulum Lindl*	Orchidaceae	Ep	ASSAM, G. K. Deka 35539, Nongpoh	E	Nongpoh, Nokrek	Indo-Burma
Dendrobium khasianum Deori	Orchidaceae	Ep	ASSAM, C. Deori 101136 (01.v.04), Experimental Garden, Barapani, originally collected from Pongtong forest	E	Pontang forest, Mawphlang	Meghalaya, Nagaland
Dendrobium longicornu Lindl.	Orchidaceae	Ep	ASSAM, A.H. Mir, 03077 (21. vii.2015) Pongtung, East Khasi Hills	E	Cherapunjee, Nongstoin, Mawmluh, Pongtung, Saitbakon, Jarain, Nongthalang	Eastern Himalaya and Indo-Burma
Dendrobium ruckeri Lindl.	Orchidaceae	Ep	ASSAM, A.H. Mir, 02135 (13. iii.2015) Nongstoin, West Khasi Hills	E	Cherrapunjee, Pongtung, Nongpoh	Eastern Himalaya and Indo-Burma
Dendrobium terminale Par. & Reichb. f.*	Orchidaceae	Ep	ASSAM, J. Joseph 45653, Nongpoh	E	Jowai, Nongpoh, Nokrek	Nepal and Indo-Burma
Eria acervata Lindl.*	Orchidaceae	Ep	ASSAM Nongpoh forest, N.P.Balakrishnan 47389 (14.xi.69), Jowai	E	Shillong, Sonapahar, Nongpoh	Eastern Himalaya and Indo-Burma
Eria arunachalensis A.N.Rao	Orchidaceae	Ep	ASSAM, C.Deori 116279 (15. iii.2007), Sohryngkham, Jaintia Hills district	NE	Jowai	Indo-Burma
Eria bambusifolia Lindl.	Orchidaceae	Ep	ASSAM, C.Deori & S.R.Talukdar 145438 (5.iv.18), Nongstoin, West Khasi Hill	E	Sutnga, Balpakram	Indo-Burma
Eria carinata Gibs.*	Orchidaceae	Ep	ASSAM, N.P.Balakrishnan 47337 (10.xi.70), Jarain	E	Cherrapunjee, Dawki-Pynursla, Pongkung	Eastern Himalaya and Indo-Burma
Eria clavicaulis Lindl.	Orchidaceae	Ep	ASSAM, B Singh 118275 (?) Sabokgre, Garo Hills	E	Jarain, Pynursla, Nokrek	Eastern Himalaya and Northeastern India
Eria coronaria (Lindl.) Reichb.f	Orchidaceae	Ep	ASSAM, A.H. Mir, 03087 (22. vii.2014) Lynshing, East Khasi Hills.	E	Cherrapunjee, Laitkor, Mawphlang, Mairang, Nokrek	Eastern Himalaya and Indo-Burma

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Name	**Family**	**Habit**	**Voucher number**	**Nativness**	**Meghalaya**	**Worldwide**
Eria excavata (Wall.) Lindl.*	Orchidaceae	Ep	ASSAM, R.S. Rao 11191 (05.vi.1958) Shillong Peak, Khasi Hills	E	Barapani, Cherrapunjee, Mawphlang, Mawrynkneng, Nongstoin, Pongtung	Eastern Himalaya, North east India.
Eria ferruginea Lindl.	Orchidaceae	Ep	ASSAM, A.H. Mir, 02143 (13.v.2015) Mawmluh, East Khasi Hills.	E	Cherrapunjee, Mawsynram, Jarain, Nokrek	Eastern Himalaya and Meghalaya
Eria glandulifera Deori & Phukan	Orchidaceae	Ep	ASSAM, N.C.Deori 71816B (18. iv.78), Mawsmai forest, East Khasi Hill District	E	Mawsmai	Northeastern India
Eria paniculata Lindl.	Orchidaceae	Ep	ASSAM,C.Deori & S.R.Talukdar 137613 (06.iv.17), Mawthawdong, West Khasi Hills	E	Jarain, Jowai, Pynursla-Dawki, Nokrek	Eastern Himalaya and Indo-Burma
Eria pannea Lindl.*	Orchidaceae	Ep	ASSAM, C.Deori & S.R.Talukdar 137613 (06.iv.17), Trysung, West Khasi Hills	E	Cherrapunjee, Jarain	Eastern Himalaya and Indo-Burma
Eria pusilla (Griff.) Lindl.	Orchidaceae	Ep	ASSAM, C.Deori 51609 (16.iv.72), Jarain, Jaintia Hill district	E	Cherrapunjee, Mawmloo, Pongtung, Nokrek	Indo-Burma
Eria stricta Lindl.	Orchidaceae	Ep	ASSAM, B. Singh 114676 (?) Nokrek Peak, Garo Hills	E	Umlowu, Jarain-Dawki, Nongstoin, Balpakram, Nokrek	Nepal and Indo-Burma
Eriodes barbata (Lindl.) Rolfe*	Orchidaceae	Ep	ASSAM, C.Deori & S.R.Talukdar, 134847(01.xii.16)Nongstoin community forest, West Khasi Hill District	E	Kyllang rock, Shillong peak	Eastern Himalaya and Northeastern India
Esmeralda cathcartii (Lindl.) Rchb.f.*	Orchidaceae	Ep	ASSAM, S.Phukan 102814 Khasi Hills	E	Shillong Peak	Eastern Himalaya and Northeastern India
Esmeralda clarkei Rchb.f.*	Orchidaceae	Ep	ASSAM, S. Phukan 102900 (30.x.2006) Balpakram, Garo Hills	E	Kyllang rock.	Eastern Himalaya and Indo-Burma
Galeola falconeri Hook.f.*	Orchidaceae	H	ASSAM, U. Kanjilal 7189 (08. vi.1917) Barapani, Ribhoi District	E	Barapani, Mawphlang, Mairang, Pariong	Eastern Himalaya and Indo-Burma
Gastrochilus acutifolius (Lindl.) O.Ktze.*	Orchidaceae	Ep	ASSAM, N.P. Balakrishnan 42757 (20.vii.65) Jarain	E	Nokrek, Sutunga, Cherrapunjee, Mawsmai, Jowai, Jarain	Eastern Himalaya and Indo-Burma
Gastrochilus distichus (Lindley) Kuntze*	Orchidaceae	Ep	ASSAM, G.K. Deka 36167 (15. iii.1950) Lawlyngdoh forest	E	Mawphlang, Nokrek	Eastern Himalaya, North east India
Gastrochilus inconspicuus (Hook. f.) Kuntze*	Orchidaceae	Ep	ASSAM, G.Panigrahi, 4123 (28.x.57.) Jowai, Jaintia Hills	E	Nokrek, Jowai, Nongpoh, Sohrarim, Nartiang, Umsaw, Rongrengree, Balphakram	Eastern Himalaya and Northeastern India
Gastrodia exilis Hook.f.*	Orchidaceae	Ep	ASSAM, N.C.Deori 51777 (21.x.73), Pynursla, East Khasi hills	E	Amwee, Nongkhyllem, Railang	Northeastern India and Thailand
Goodyera hispida Lindl.*	Orchidaceae	H	GH (image!), GH00090573, J.D. Hooker & T.Thomson 2110 (18. viii.1850) Khasia, Cherrapunjee, East Khasi Hills District	E	Cherrapunjee, Jowai	Indo-Burma
Goodyera recurva L.*	Orchidaceae	Ep	ASSAM G.K. Deka 10115, Nokrek National Park, Garo Hill	NE	Mawphlang, Nokrek	Meghalaya
Habenaria khasiana Hook.f.	Orchidaceae	H	ASSAM, A.H. Mir, 00903 (05. viii.2016) Lynshing, East Khasi Hills	E	Cherrapunjee, Jarain, Jowai, Lailyngkot, Pongtung, Khelierat, Rytiang, Mawsmai	Indo-Burma
Habenaria malleifera Hook.f.*	Orchidaceae	H	K (image!), K000873762, J.D.Hooker & T.Thomson, 257 (28.vii.1850), Myrang, West Khasia Hills	E	Tura, Mairang, Nongkhlaw	Northeastern India
Herpysma longicaulis Lindl.*	Orchidaceae	H	ASSAM, D.B. Deb 29138 (?) Baghmara, Garo Hills	E	Cherrapunjee, Nokrek	Indo-Burma
Liparis bistriata E.C.Parish. & Reichb.f.*	Orchidaceae	Ep	ASSAM, G.V.S. Rao 28198 (23.iii.65), Nongstoin	E	Nongstoin, Cherrapunjee	Indo-Burma
Liparis luteola Lindl.	Orchidaceae	Ep	ASSAM, C. Deori & S.R.Talukdar 134509 (30.xi.16) Mawthawpdap, South west Khasi Hills	E	Mawthawpdap, Jowai, Jarain, Nokrek, Cherrapunjee, Pynursla, Mawsmai, Balphakram,	Indo-Burma
Liparis nervosa (Thunb.) Lindl.*	Orchidaceae	Ep	ASSAM, M.K.V. Rao 53324 (?) Baghmara, Garo Hills	E	Garampani, Jowai, Jorain, Balphakram, Nokrek	Eastern Himalaya and Northeastern India

					Distribution	
Name	**Family**	**Habit**	**Voucher number**	**Nativness**	**Meghalaya**	**Worldwide**
Liparis petiolata (D.Don) P.F.Hunt & Summerh.*	Orchidaceae	H	ASSAM, T.M.Hynniewta 50897 (17. vi.72), Mawphlang,	E	Cherrapunjee, Mawphlang, Shillong Peak, Mawsmai	Eastern Himalaya and Northeastern India
Liparis resupinata Ridl.	Orchidaceae	Ep	ASSAm, C. Deori & S.R.Talukdar 134836 (5.xii.16), Umeit forest, west khasi Hill District	E	Lailyngkot, Laitkor, Shillong peak	Eastern Himalaya and Meghalaya
Luisia psyche Reichb.f.*	Orchidaceae	Ep	ASSAM, N.P. Balakrishnan 50244 (23.iii.1970) Jowai, Jaintia Hills	E	Shillong, Smit, Jowai	Indo-Burma
Micropera mannii (Hook.f.) Tang & F.T.Wang	Orchidaceae	Ep	ASSAM, B. Singh 116887 (?) Neingmandalgiri, Garo Hills	E	Garampani, Cherrapunjee, Jowai, Pynursla, Dawki, Shillong Peak, Nokrek	Northeastern India
Micropera rostrata (Roxb.) N.P.Balakr.	Orchidaceae	Ep	ASSAM, A.H. Mir, 04360 (26. iv.2015) Cherrapunjee, East Khasi Hills.	E	Cherrapunjee, Jowai, Dawki, Pynursla, Umkhlaw, Mawmluh	Indo-Burma
Neogyna gardneriana (Lindl.) Rchb.f.	Orchidaceae	Ep	ASSAM C. Deori 131667(12.xi.15) East Khasi Hills	E	Cherrapunjee, Pynursla, Dawki, Mawmluh, Nongkhlaw, Nokrek	Eastern Himalaya and Indo-Burma
Nephelaphyllum cordifolium Lindl.	Orchidaceae	Ep	ASSAM, A.H. Mir, 04361 (26. iv.2015) Cherrapunjee, East Khasi Hills	E	Jarrain, Cherapunjee.	Northeastern India
Oberonia acaulis Griff.*	Orchidaceae	Ep	ASSAM, M.K.V. Rao 22530 (?) Tura Peak, Garo Hills	E	Cherrapunjee, Jowai, Nongstoin, Shillong peak, Balpakram, Nokrek	Eastern Himalaya and Northeastern India
Oberonia ensiformis (Smith) Lindl.	Orchidaceae	Ep	ASSAM, AH Mir, 02240 (15.v.2017) Mawmluh, East Khasi Hills	E	Cherapunjee, Mawmluh, Bholaganj, Nongpoh, Umling	Nepal and Indo-Burma
Oberonia jenkinsiana Griffith	Orchidaceae	Ep	ASSAM, A.H. Mir, 02241 (15.v.2017) Mawmluh, East Khasi Hills	E	Dympep, Lailyngkot, Laitkor, Shillong peak	Indo-Burma
Oberonia obcordata Lindl.*	Orchidaceae	Ep	ASSAM, S.Phukan 102809 (02. vi.2004), Khasi Hills	E	Cherrapunjee, Sohrarim, Mawmluh	Eastern Himalaya and Indo-Burma
Oberonia pyrulifera Lindl.*	Orchidaceae	Ep	ASSAM, G.Panigrahi 21238 (23. ii.60) Mawphlang	E	Cherrapunjee, Jowai.	Indo-Burma
Odontochilus lanceolatus (Lindl.) Blume	Orchidaceae	H	ASSAM, B. Singh 35835 (?), Nokrek Peak, Garo Hill	E	Pongtung, Nokrek	Eastern Himalaya and Indo-Burma
Otochilus albus Lindl.*	Orchidaceae	Ep	ASSAM, N.P.Balakrishnan 42297 (31.viii.65) Jowai-Jarain road	E	Dympep, Jowai, Jowai-Jarain, Shillong Peak	Indo-Burma.
Otochilus fusca Lindl.*	Orchidaceae	Ep	ASSAM, G.Panigrahi 464425.xi.56). on the way to Dawki from Pynursla	E	Amwee, Jowai, Kyllang Rock, Pynursla-Dawki, Shillong Peak, Nokrek	Northeastern India and Nepal.
Panisea uniflora (Lindl.) Lindl	Orchidaceae	Ep	ASSAM, D.K. Roy 129671 (12. iii.2013) Balpakram, Garo Hills	E	Khasi hills, Balphakram	Eastern Himalaya and Indo-Burma
Paphiopedilum insigne (Wall.) Pfitz.	Orchidaceae	H	ASSAM, B. Singh sn (?) Nokrek, Garo Hills	E	Cherrapunjee, Lawba, Balphakram, Nokrek	Indo-Burma
Paphiopedilum venustum (Wall ex Sims.) Pfitz.	Orchidaceae	H	ASSAM, D.K. Roy 129663 (12. iii.2013) Balpakram, Garo Hills	E	Jarain, Pynursla, Syndai, Lumshnong, Balphakram	Indo-Burma and Nepal
Papilionanthe teres (Roxb.) Schltr.	Orchidaceae	Ep	ASSAM, Singh sn (?) Nokrek Hills, Garo Hills	E	Bholaganj, Dawki, Burnihat, Mairang, Nongpoh, Shillong Peak, Balphakram, Nokrek	Indo-Burma
Papilionanthe uniflora (Lindl.) Garay*	Orchidaceae	Ep	ASSAM, G.K.Deka 36111 (18.iii.52) Upper Shillong.	E	Markasa, Shillong Peak, Burnihat, Mawphlang	Meghalaya and Eastern Himalaya
Pelatantheria insectifera (Rchb.f.) Ridl.*	Orchidaceae	Ep	ASSAM, G. Panigrahi 4123 (28.x.57), Jowai	E	Jowai, Pynursla	Eastern Himalaya and Indo-Burma
Pennilabium labanyaeanum C.Deori, N.Odyuo & A. A.Mao	Orchidaceae	Ep	ASSAM, C.Deori N.Odyuo 134226 (23.vii.14), Laitkyrhong, East Khasi Hills	NE	Laitkyrhong, East Khasi Hills	Meghalaya
Pennilabium proboscideum AS Rao & Joseph*	Orchidaceae	Ep	ASSAM, A.S.Rao 45622B (23. vii.1966), between Umran & Umsaw, Ribhoi district	NE	Umran, Umsaw	Meghalaya
Peristylus cubitalis (L.) Kraenzl.*	Orchidaceae	H	CAL, C.B.Clarke, 38575, (07. viii.1885), Meghalaya, Shillong	E	Pynursla	Indo-Burma
Peristylus mannii (Rchb.f.) Muke.*	Orchidaceae	H	ASSAM, G.H.Bhowmik 60317, West Khasi Hills	E	Cherrapunjee, Mairang, Mawphlang, Shillong peak, Laitlyngkot	Indo-Burma

					Distribution	
Name	Family	Habit	Voucher number	Nativness	Meghalaya	Worldwide
Pholidota convallariae (Reichb.f.) Hook.	Orchidaceae	Ep	ASSAM, A.H. Mir, 01022 (03.ii.2017) Dympep, East Khasi Hills	E	Dympep, Jowai, Nongpoh, Shangpung, Shillong, Mahadeo, Tanglo woods	Eastern Himalaya and Indo-Burma
Pholidota griffithii Hook.f.	Orchidaceae	Ep	ASSAM, B. Singh 116698 (?) Daribokgre, Garo Hills	E	Cherrapunjee, Kyllang rock, Umtasor, Nokrek, Daribokgre	Eastern Himalaya and Indo-Burma
Pholidota pallida Lindl.	Orchidaceae	Ep	ASSAM, B. Singh 116891 (?) Mandalgiri, Garo Hills	E	Cherrapunjee, Mawmluh, Laitkynsew, Nongstoin, Dympep, Jowai, Shillong peak, Jarain, Amlarem, Nongpoh, Nokrek.	Indo-Burma, Nepal, Bhutan
Pholidota recurva Lindl.*	Orchidaceae	Ep	ASSAM, M.K.V. Rao 59475 (?) Rongrengiri, Garo Hills	E	Cherapunjee, Podeng Slui, Nokrek.	Northeastern India and Nepal
Pholidota rubra Lindl.*	Orchidaceae	Ep	ASSAM, S.K.Srivastava 84047 (16. xi.83), Cherrapunjee	E	Cherapunjee, Mawmluh, Jarrain, Jowai.	Indo-Burma and Bhutan
Platanthera dyeriana (King & Pantl) Kraenzl.*	Orchidaceae	H	K (image!), K000247397, R.C. Thakur 1768, East Khasi Hills District, Laitlynkot, Meghalaya	E	Laitlyngkot, Mawsynram.	Indo-Burma
Pleione humilis (Smith) D.Don*	Orchidaceae	Ep	ASSAM, S.K. Kataki 37117 (?) Nokrek Peak, Garo Hills	E	Dympep, Mawphlang, Shillong Peak, Jowai, Nokrek.	Eastern Himalaya and Indo-Burma
Podochilus cultratus Lindl.	Orchidaceae	EP	ASSAM, D.K. Roy 130346 (27. viii.2014) Balpakram, Garo Hills	E	Balphakram	Eastern Himalaya, Indo-Burma
Podochilus khasianus Hook.f.*	Orchidaceae	Ep	ASSAM, G. Panigrahi 4624 (25. xi.1956) Dawki, Jaintia Hills	E	Pongtung, Pynursla, Dawki, Balphakram	Northeastern India and Eastern Himalaya
Porpax gigantea Deori	Orchidaceae	Ep	ASSAM, N.C. Deori Isotype 51757B(1.vii.73), Jarain, Jaintia Hill District	NE	Jarain, Dawki	Meghalaya
Rhomboda pulchra (King & Pantl.) Ormerod & Av.Bhatt.	Orchidaceae	Ep	ASSAM, A.H. Mir, 02150 (14. vi.2016) Mawkyrwat, South West Khasi Hills	E	Jarain, Cherrapunjee, Mawsynram.	Eastern Himalaya and Northeas India
Stereochilus hirtus Lindl.*	Orchidaceae	Ep	ASSAM, J.Jopseph 45165 (19.vii.66), Umsaw forest, Ribhoi District	E	Umsaw	Northeastern India, Burma and Nepal
Stigmatodactylus serratus (Deori) A.N.Rao*	Orchidaceae	Ep	ASSAM, C. Deori 51262C (15.ix.18), Shillong Peak forest, East Khasi Hills	NE	Shillong Peak forest	Meghalaya
Sunipia bicolor Lindl.*	Orchidaceae	Ep	ASSAM, T.M.Hynniewta, 51855 (25.x.72) Shillong Peak, East Khasi Hills	E	Mawphlang, Shillong, Elephant Falls, Balphakram	Indo-Burma and Eastern Himalaya; China
Sunipia candida (Lindl) P.F.Hunt*	Orchidaceae	Ep	ASSAM, R. Seihgal 53049, Cherrapunjee	E	Mawphlang, Sohrarim, Shillong Peak, Malki	Eastern Himalaya and Indo-Burma
Sunipia racemosa (J.E.Sm.) Tang & Wang*	Orchidaceae	Ep	ASSAM C.Deori & S.R.T. 137731 (12.v.17), Mawkynjoi, West Khasi Hills	E	Jarain, Kyllang Rock, Markasa-Patharkhang, Nongkhlaw	Indo-Burma and Eastern Himalaya; China, Vietnam
Tainia latifolia (Lindl) Benth*	Orchidaceae	H	ASSAM, SK Kataki 37166 (?.ii.1965) Jarain, Jaintia Hills	E	Jarain, Pynursla	Eastern Himalaya and Indo-Burma
Tainia minor Hook.f.*	Orchidaceae	H	ASSAM, SR Sharma 20260 (29.v.32), Dampep, Garo Hills	E	Dympep, Bampothang, Mawsmai	Eastern Himalaya and Indo-Burma
Tainia viridifusca (Hook.) Benth	Orchidaceae	H	ASSAM, C.Deori & S.R.Talukdar 137611 (06.iv.17), Photkynraw, West khasi hills District	E	Jarain, Cherrapunjee	Eastern Himalaya, Indo-Burma
Thelasis khasiana Hook.f.*	Orchidaceae	Ep	ASSAM, G.H. Bhowmik 60427, Nongkhlaw, West Khasi Hills	NE	Jowai, Nongkhlaw, Barapani, Amwee, Pomrang, Cherrapunjee, Pynursla	Meghalaya, Thailand, Vietnam
Thelasis longifolia Hook.f. *	Orchidaceae	Ep	ASSAM, D.B.D. 29220 (?) Rongrengiri	E	Jarain, Nokrek	Eastern Himalaya and Northeastern India.
Thrixspermum muscaeflorum Rao and Joseph*	Orchidaceae	Ep	ASSAM, A.S. Rao 45638B (08.xi.67), Umran and Umsaw forest, Ribhoi District	NE	Pongtung, Pynursla, Umran, Umsaw, Nongpoh	Meghalaya
Thrixspermum pygmaeum (K. & P.) Holtt.	Orchidaceae	Ep	ASSAM, A.H. Mir, 02234 (14. vi.2017) Mawkyrwat, South West Khasi Hills	E	Cherrapunjee	Eastern Himalaya, Nepal and Vietnam.
Uncifera acuminata Lindl.	Orchidaceae	Ep	ASSAM, C.Deori & S.R.Talukdar 137763 (05.xii.17), Nongkhlaw, West Khasi Hill District	E	Cherrapunjee, Sohrarim, Dympep, Pynursla	Eastern Himalaya and Indo-Burma

					Distribution	
Name	Family	Habit	Voucher number	Nativness	Meghalaya	Worldwide
Uncifera obtusifolia Lindl.	Orchidaceae	Ep	ASSAM, C.Deori 131624 (25.ix.14), East Khasi Hill District	E	Pongtung, Pynursla, Jarain, Nongkhlaw, Umran, Shella, Balphakram	Eastern Himalaya and Indo-Burma
Vanda coerulea Griff ex Lindl.	Orchidaceae	Ep	ASSAM, Singh sn (?) Nokrek, Garo Hills	E	Barapani, Jowai, Nartiang, Nokrek	Eastern Himalaya and Indo-Burma
Vanda cristata Lindl.*	Orchidaceae	Ep	ASSAM, G.K. Deka 5114 (24.i.57) Raliang	E	Jowai, Pongtung, Raliang	Eastern Himalaya and Indo-Burma
Vandopsis undulata (Lindl) J.J.Sm.*	Orchidaceae	Ep	ASSAM, G. Panigrahi 3979 (22.xii.57), Peak forest, Shillong	E	Jarain, Mawphlang, Shillong Peak, Elephant Falls, Laitkor.	Eastern Himalaya and Indo-Burma
Dendrobium jaintianum Sabap.*	Orchidaceae	Ep	Specimen not seen	NE	Jaintia hills (locality not specified)	Meghalaya
Vanda jainii A.S.Chauhan*	Orchidaceae	Ep	Specimen not seen	NE	Locality not specified	Meghalaya
Zeuxine pulchra King & Pantl.*	Orchidaceae	Ep	Specimen not seen	E	Mawphlang	North east India
Dactylicapnos torulosa (Hook.f. & Thomson) Hutch.*	Papaveraceae	H	K (image!) K000653381, T. Thomson, s.n. (29.vii.1850), Khasia	E	Khasi hills (locality not specified)	Indo-Burma
Passiflora napalensis Wall.	Passifloraceae	Cl	ASSAM, A.H. Mir, 90358 (13. viii.2016) Cherrapunjee, East Khasi Hills	E	Mawmluh, Mawsmai, Swer, Cherrapunjee.	Eastern Himalaya and Indo-Burma
Adinandra griffithii Dyer	Pentaphyllaceae	T	ASSAM, A.H. Mir, 88690, East Khasi Hills	E	Cherrapunjee, Mawsynram, Lynshing, Umlangmar, Shangpung, Balphakram.	Meghalaya, Nagaland
Cleyera japonica var. *grandiflora* (Wall. ex Choisy) Kobuski	Pentaphyllaceae	T	ASSAM, AH Mir, 90445 (15.vi.2016) Cherrapunjee, East Khasi Hills	NE	Laitryngew, Mawmluh, Cherrapunjee, Nongstoin, Hilland, Pudjuad, Jarain	Meghalaya
Aporosa octandra (Buch.-Ham. ex D.Don) Vickery	Phyllanthaceae	T	ASSAM, D.K. Roy 129481 (08. iii.2013) Balpakram, Garo Hills	E	Lailad, Mawsynram, Balpakram	Indo-Burma
Antidesma khasianum Hook.f.	Phyllanthaceae	Sh	North-Eastern Hill University, K.Haridasan 2858, Meghalaya	NE	Raliang, Mawsmai	Meghalaya
Piper cornilimbum C.DC.*	Piperaceae	Cl	G (image!), G00329633, Gallatly, G., (1878), Khasi and Jaintia Hills	NE	Khasi and Jaintia hills (locality not specified)	North east India (Meghalaya)
Piper griffithii C.DC.	Piperaceae	H	ASSAM, AH Mir, 90449 (13.x.2015) Cherrapunjee, East Khasi Hills	E	Borlong, Jowai, Nartiang, Mawsmai, Mawsynram, Nokrek	Indo-Burma
Piper khasianum C.DC.*	Piperaceae	Cl	ASSAM, G.K.Deka 10489 (08.i.1933), Umnran	E	Umran	North east India
Piper peepuloides Roxb.	Piperaceae	H	ASSAM, A.H. Mir, 90305 (16.v.2015) Mawkyrwat, South West Khasi Hills	E	Pongtung, Mawkyrnot, Cherrapunjee, Nongstoin, Mawkyrwat	Eastern Himalaya and Indo-Burma
Pittosporum humile Hook.f. & Thomson	Pittosporaceae	Sh	ASSAM, A.H. Mir, 02146 (13. iv.2016) Cherapunjee, East Khasi Hills	NE	Barapani, Mawsynram	Meghalaya
Agrostis filipes Hook.f.*	Poaceae	H	K (image!), K000032333, C.B.Clarke 43426, Shillong	NE	Shillong, Cherrapunjee, Laitlynkot, Mawkadok, Shillong peak	Meghalaya
Anthoxanthum horsfieldii (Benn.) Reeder*	Poaceae	H	K (image!), K000290605, C.B. Clarke 4553a Lailam Kote, Khasia	E	Nongkrem, Lumdarin	Northeastern India
Arundinella khasiana Nees ex Steud.	Poaceae	H	ASSAM, A.H. Mir, 00625 (18. viii.2014) Jongksha, East Khasi Hills	E	Cherapunjee, Laitryngew, Nongsteng, Mawsynram, Mawrapat, Mawkasain	Notheast India
Calamagrostis elatior (Griseb.) A.Camus*	Poaceae	H	W (image!), W18890241773, J.D.Hooker & T.Thomson, 2244, Nokrek	NE	Nokrek, Upper Shillong, Shillong peak	Meghalaya
Cephalostachyum mannii (Gamble)Stapleton*	Poaceae	H	K (image!), K000912086, G Mann 21845 (?.viii.1889) Jarain, Jaintia Hills	E	Amkasur, Jarain, Umtru	Indo-Burma
Cephalostachyum pallidum Munro	Poaceae	Sh	ASSAM, A.H. Mir, 00678 (09.x.2015) Swer, East Khasi Hills	E	Jarain, Dawki, Pynursla, Cherrapunjee	Indo-Burma
Chimonocalamus griffithianus (Munro) Hsueh & T.P.Yi*	Poaceae	Sh	K (image!), K000246139, W. Griffith 39, Khasia Hills	E	Nokrek, Dawki	Indo-Burma
Cymbopogon khasianus (Hack.) Stapf. ex Bor.*	Poaceae	H	ASSAM, M.Bhowmik 116548 (26. ix.2007); Leska Dam site	E	Jowai, Nokrek, Williamnagar	Indo-Burma

					Distribution	
Name	**Family**	**Habit**	**Voucher number**	**Nativness**	**Meghalaya**	**Worldwide**
Digitaria jubata (Griseb.) Henrard*	Poaceae	H	K (image!), K000885974, J.D.Hooker & T.Thomson 2010 (02.viii.1850), Khasia Hills	NE	Shillong, Jowai, Songsak	Meghalaya
Drepanostachyum khasianum (Munro) Keng f.*	Poaceae	Sh	K (image!), K000246122, W.Griffith 6741, Khasia	E	Jowai, Mairang, Nongstoin, Mantendu, Mawphlang, Pynursla, Shillong, Upper Shillong	Northeastern India and Eastern Himalaya
Eragrostiella leioptera (Stapf) Bor*	Poaceae	H	K (image!),K000907161, C.B.Clarke, 38871 (18.viii.1885), Shillong, East Khasi Hills	NE	Shillong, Mawmluh, Balphakram.	Meghalaya
Eulalia speciosa var. *velutina* (Deb.) Ktze.*	Poaceae	H	ASSAM, N. L. Bor 15406 (21.i.37) Cherrapunjee, East Khasi Hills	NE	Cherrapunjee/Dawki.	Meghalaya
Hierochloe khasiana C.B.Clarke ex Hook.f.*	Poaceae	H	K (image!), K000032289, C.B. Clarke 43956 (23.v.1886), Mairang, West Khasi Hills	NE	Shillong, Mairang	Meghalaya
Ischaemum hubbardii Bor*	Poaceae	H	K (image!), K000245695, N.L. Bor 2264, Khasia & Jaintia hills	NE	Cherrapunjee, Dympep, Sohrarim	Meghalaya
Yushania hirsuta (Munro) R.B.Majumdar*	Poaceae	H	K (image!), K000246099, W.Griffith 6726 (9.xi.1835) Mairang, West Khasi Hills	NE	Mairang, Mawphlang, Soiong	Meghalaya
Bambusa khasiana Munro*	Poaceae	Sh	K (image!), K000854816, J.D.Hooker & T.Thomson (11. vi.1850), Meghalaya, Khasia	NE	Khasi hills (Mahadeb)	Meghalaya
Bambusa majumdarii P.Kumari & P.Singh*	Poaceae	Sh	P. Kumari & P. Singh, 2009, Kew Bulletin 64: 565.571 (2009)	NE	Tura	Meghalaya
Bambusa mohanramii P.Kumari & P.Singh*	Poaceae	Sh	P. Kumari & P. Singh, 2009, Kew Bulletin 64: 565.571 (2009)	NE	Khleiriaht, Mawryngkneng	Meghalaya
Bambusa pseudopallida R.B.Majumdar*	Poaceae	Sh	ASSAM, U. Kanjilal 6108A.D (24.x.1915) Barapani, Meghalaya	E	Barapani	Indo-Burma
Cephalostachyum mannii (Gamble) Stapleton*	Poaceae	Sh	K (image!), K000912085 G.Mann, 21845 (?.viii.1889), Jaintia	NE	Khasi and Jaintia hills-Jarain	Meghalaya
Panicum khasianum Munro ex Hook.f.*	Poaceae	H	K (image!), K000245236 C.B. Clarke (05.ix.1886), Khasia Hills	E	Khasi hills (locality not specified)	Indo-Burma
Pyrrosia flocculosa (D.Don) Ching	Polypodiaceae	H	ASSAM, A.H. Mir, 02252 (15. vii.2015) Cherrapunjee, East Khasi Hills	E	Cherrapunjee	Himalaya, Indo-Burma
Ardisia khasiana C.B.Clarke	Primulaceae	Sh	ASSAM, A.H. Mir, 90326 (18. xii.2015) Cherrapunjee, East Khasi Hills	E	Mawsynram, Mawrapat, Laitryngew, Tura, Lailad	Indo-Burma
Hymenandra wallichii A.DC.	Primulaceae	Sh	ASSAM, A.H. Mir, 90357 (19.v.2016) Laitsohum, East Khasi Hills	E	Laitsohum, Mawsynram, Lawba	Northeastern India
Amblyanthopsis membranacea (Wall.) Mez*	Primulaceae	Sh	Specimen not seen	E	Locality not known	Himalays, Northeastern India
Ardisia meghalayensis M.P.Nayar & G.S.Giri*	Primulaceae	Sh	Specimen not seen	NE	Locality not specified	Meghalaya
Maesa montana A.DC.*	Primulaceae	Sh	North-Eastern Hill University, K. Haridasan 4735, Lailad	E	Dambu, Lailad, Nongpoh	Himalaya, Northeastern India
Helicia excelsa (Roxb.) Blume	Proteaceae	T	ASSAM, B. Singh s.n. (?), Nokrek Peak, Garo Hills	E	Umtesor, Mawkyrwat, Mawmluh, Nokrek Peak, Nongstoin	Indo-Burma
Drypetes assamica (Hook.f.) Pax & K.Hoffm.*	Putranjivaceae	T	NEHU, Haridasan 4054 (?), Tura Peak, Garo Hills	E	Tura, Nokrek	Indo-Burma
Drypetes jaintensis (C.B.Clarke) Pax & K.Hoffm	Putranjivaceae	T	K (image!), K000246661, C.B.Clarke, 44760A, (30.viii.1886), Jowai, Khasia	NE	Jowai	Meghalaya
Clematis acutangula Hook.f. & Thomson*	Ranunculaceae	Cl	K (image!), K000075704, J.D. Hooker & Thomson, Mawlyn, Khasia	E	Jowai.	Bhutan, Meghalaya and Nagaland
Clematis apiculata Hook.f. & Thomson*	Ranunculaceae	Cl	K (image!), K000675161, J.D. Hooker & T.Thompson, s.n. (?.ix.1850), Khasia	E	Khasi hills (locality not specified)	North east India
Delphinium altissimum Wall.*	Ranunculaceae	H	ASSAM, U.N. Kanjilal 2480 (08. ix.13) Mawphlang	E	Upper Shillong, Smit, Um-Risa, Sohiong, Mawphlang	Eastern Himalaya and Indo-Burma
Rubus calycinus Wall. ex D.Don*	Rosaceae	H	ASSAM, G.K. Deka 2035 (25.v.2041) Sohraim, Khasi Hills	E	Cherrapunjee, Sohrarim	Eastern Himalaya and Indo-Burma

Name	Family	Habit	Voucher number	Nativness	Distribution	
					Meghalaya	Worldwide
Eriobotrya angustissima Hook.f.*	Rosaceae	Sh	ASSAM, U.N. Kanjilal l.c. (?), Rongenriri, Garo Hills	NE	Kapili rivir basin, Rongrengiri	Meghalaya
Photinia cuspidata (Bertol.) N.P.Balakr.	Rosaceae	T	ASSAM, A.H. Mir, 88688, East Khasi Hills	NE	Shangpung, Jarain, Mawsmai, Mawmluh, Mawkyrwat, Laityngew, Nongstoin	Meghalaya
Photinia polycarpa (Hook.f.) N.P.Balakr.	Rosaceae	T	ASSAM, B Singh 74641 (27.ii.2010), Nokrek Peak, Garo Hills	E	Jarain, Shangpung	Indo-Burma
Prunus jenkinsii Hook.f. & Thomson	Rosaceae	T	ASSAM, A.H. Mir, 90435 (12.v.2015) Sangriang, West Khasi Hills	E	Nongstoin, Jarain, Nongkrem, Pynursla, Railiang, Nongsynreih, Sangriang, Nonglynkien	Bhutan and Indo-Burma
Rubus assamensis Focke	Rosaceae	Sh	ASSAM, A.H. Mir, 04137 (24.iv.2015) Mawsmai, East Khasi Hills	E	Elephant falls	Indo-Burma
Rubus hexagynus Roxb.	Rosaceae	Sh	ASSAM, A.H. Mir, 03049 (17.iii.2016) Tynnai, South West Khasi Hills	E	Jowai, Nongpoh, Mawsmai, Mawmluh.	Indo-Burma
Rubus khasianus Cardot	Rosaceae	Sh	ASSAM, A.H. Mir, 01057 (03.v.2017) Lawbah, East Khasi Hills	NE	Nokrek, Ialong, Raliang, Jowai, Umtapoh, Laitryngew, Cherrapunjee, Nongstoin, Mawsmai, Mawmluh, Jakrem	Meghalaya
Rubus lucens Focke	Rosaceae	Sh	ASSAM, A.H. Mir, 01058 (03.v.2017) Lawbah, East Khasi Hills	E	Umtesor, Nokrek	Indo-Burma
Cotoneaster khasiensis G.Klotz*	Rosaceae	Sh	ASSAM, U.Kanjilal 2650, (25.ix.1913), Laitlynkot, Meghalaya	NE	Laitlyngkot	Meghalaya
Micromeles meghalayensis Panigrahi*	Rosaceae	T	Specimen not seen	NE	Locality not specified	Meghalaya
Micromeles polycarpa (Hook.f.) Panigrahi*	Rosaceae	T	Specimen not seen	NE	Locality not specified	Meghalaya
Potentilla khasiana C.B.Clarke ex Dikshit & Panigrahi*	Rosaceae	H	ASSAM, H. Deka, 18309 (05.iv.1959), Shillong	NE	Shillong, Shillong-peak	Meghalaya
Argostemma khasianum C.B.Clarke	Rubiaceae	H	ASSAM, A.H. Mir, 90437 (05.vi.2015) Mawsmai, East Khasi Hills	E	Saitbakon, Pongtung, Cherrapunjee, Balpakram, Syndai, Muktapur	Indo-Burma
Argostemma rostratum Wall.*	Rubiaceae	H	K (image!), De Silva, F, 8395, Khasia	NE	Balphakram, Nokrek.	Meghalaya
Benkara fasciculata (Roxb.) Ridsdale	Rubiaceae	T	ASSAM, D.K. Roy 125447 (21.iv.2012) Balpakram, Garo Hills	E	Mawsmai, Cherapunjee, Balphakram.	Eastern Himalaya and Indo-Burma
Benkara griffithii (Hook.f.) Ridsdale	Rubiaceae	T	ASSAM, D.K. Roy 125656 (25.iv.2012) Balpakram, Garo Hills	E	Nokrek, Cherapunjee, Mawsynram, Mawmluh, Jarain, Jowai, Amlarem, Shangpung, Madeo, Lyngiong, Balpakram.	Northeastern India and Eastern Himalaya
Coffea khasiana (Korth.) Hook.f.	Rubiaceae	Sh	ASSAM, A.H. Mir, 90389 (15.iv.2015) Swer, East Khasi Hills	E	Khnongshnong to Raliang, Lynshing, Lyngiong, Cherrapunjee, Mawsynram, Laitsohum, Mairang, Pynndengnongbri, Mawkyrwat, Nongstoin	Indo-Burma
Hyptianthera stricta (Roxb. ex Schult.) Wight & Arn.	Rubiaceae	Sh	ASSAM, A.H. Mir, 03066 (19.v.2016) Laitryngew, East Khasi Hills	E	Tura, Balphakram	Eastern Himalaya and Indo-Burma
Ixora subsessilis Wall. ex G.Don	Rubiaceae	T	ASSAM, A.H. Mir, 90387 (03.v.2015) Mawsmai, East Khasi Hills	E	Mawsmai, Cherapunjee, Jarain	Indo-Burma
Lasianthus hookeri C.B.Clarke ex Hook.f.	Rubiaceae	Sh	ASSAM, A.H. Mir, 90338 (03.v.2016) Mawsmai, East Khasi Hills	E	Nokrek, Dawki, Narpuh, Sokha, Lawbah, Balphakram	Indo-Burma
Leptodermis griffithii Hook.f.*	Rubiaceae	Sh	ASSAM, P.C. Kanjilal 8046 (17.v.1930) Mawphlang, Khasi Hills	E	Upper Shillong, Mawphlang, Elephant falls, Jowai	Northeastern India
Leptomischus wallichii (Hook.f.) H.S.Lo	Rubiaceae	Sh	ASSAM, D.K. Roy 125589 (26.iv.2014) Balpakram, Garo Hills	NE	Jowai, Balpakram	Meghalaya
Luculia pinceana Hook.	Rubiaceae	Sh	ASSAM, A.H. Mir, 90432 (08.ii.2016) Sawsymper, South West Khasi Hills	E	Balphakram, Mawsynram, Nokrek	Eastern Himalaya

					Distribution	
Name	Family	Habit	Voucher number	Nativness	Meghalaya	Worldwide
Mussaenda corymbosa Roxb.*	Rubiaceae	Sh	ASSAM, N.P. Balakrishnan 49836 (15.xi.1969) Jarain-Dawki, Jaintia Hills	E	Dawki and Cherrapunjee	Indo-Burma
Mussaenda roxburghii Hook.f.	Rubiaceae	Sh	ASSAM, A.H. Mir, 03063 (19.v.2014) Kynshuild, East Khasi Hills	E	Nokrek, Jarain, Pongtung, Shillong, Cherrapunjee	Eastern Himalaya and Indo-Burma
*Myrioneuron nutans*Wall. ex Hook.f.*	Rubiaceae	Sh	ASSAM, A. Carlon 21174 (15. xi.1967) Cherrapunjee, Khasi Hills	E	Sokha, Balphakram	Eastern Himalaya and Indo-Burma
Neanotis oxyphylla (Wall. ex G.Don) W.H.Lewis	Rubiaceae	Sh	ASSAM, D.K. Roy 130067 (05. ii.2014) Balpakram, Garo Hills	E	Mawsmai, Nokrek, Balphakram	Meghalaya and Eastern Himalaya
Neohymenopogon parasiticus (Wall.) Bennet*	Rubiaceae	Sh	ASSAM, P.K. Hajra 51949 (09. ix.1973) Mawphlang, Khasi Hills	E	Mairang, Law-Lyngdoh, Sohrarim, Mawsmai, Upper Shillong, Mawphlang, Laitlyngkot	Eastern Himalaya and Indo-Burma
Ophiorrhiza pauciflora Hook.f.*	Rubiaceae	H	ASSAM, N.P. Balakrishnan 42258 (30.v.65) Jowai	E	Jowai	Meghalaya. and Eastern Himalaya
Ophiorrhiza subcapitata Wall. ex Hook.f.	Rubiaceae	H	ASSAM, A.H. Mir, 04359 (26. iv.2015) Cherapunjee, East Khasi Hills	E	Jowai, Cherapunjee, Mawsynram	Meghalaya, Burma and Thailand
Ophiorrhiza tingens C.B.Clarke*	Rubiaceae	H	K (image!), K000031237, C.B. Clarke 38076 (09.v.1185), Khasia	E	Mawphlang	Indo-Burma
Ophiorrhiza treutleri Hook. f.*	Rubiaceae	Sh	ASSAM, R.S. Rao 14055 (24. viii.1958) Shillong Peak, Khasi Hills	E	Balphakram NP, Mawphlang, Shillong Peak, Lawlyndoh	Northeastern India and Eastern Himalaya
Ophirrhiza hispida Hook.f.*	Rubiaceae	H	ASSAM, G. K. Deka 10105, Narpuh Reserve, K & J Hills	E	Mawsynram	Indo-Burma
Pavetta subcapitata Hook.f.	Rubiaceae	Sh	ASSAM, D.K. Roy 125565 (26. iv.2012) Balpakram, Garo Hills	E	Nokrek, Balphakram	Indo-Burma and Bhutan
Psychotria monticola Kurz*	Rubiaceae	Sh	ASSAM, G.H. Bhaumik 62028 (06.v.1975) Mawsynram, Khasi Hills	E	Mawsynram, Umling	Indo-Burma
Psychotria symplocifolia Kurz	Rubiaceae	Sh	ASSAM, A.H. Mir, 90424 (08.x.2015) Pongtung, East Khasi Hills	E	Sohrarim, Jowai, Nokrek, Jarain, Pongtung, Cherapunjee, Nongpoh, Bhoirymbong, Mawkyrwat	Indo-Burma
Saprosma ternatum (Wall.) Hook.f.	Rubiaceae	T	ASSAM, A.H. Mir, 90434 (06. ix.2015) Mawrapat, South West Khasi Hills	E	Mawrapat, Mawkasain, Balpakram	Indo-Burma
Uncaria macrophylla Wall.	Rubiaceae	Cl	ASSAM, B. Singh 114791 (03. iii.2007) Chandigre, Garo Hills	E	Mahadeo, Balphakram, Nokrek	Eastern Himalaya and Indo-Burma
Citrus latipes (Swingle) Yu.Tanaka	Rutaceae	T	ASSAM, A.H. Mir, 90465 (06. ix.2015) Mawrapat, South West Khasi Hills	NE	Ialong, Raliang, Jowai Umjaisaw, Mairang, Lyngiong, Mawranglang, Mawkyrwat, Pyndengnongbri	Meghalaya
Paramignya micrantha Kurz	Rutaceae	Sh	ASSAM, A.H. Mir, 90303 (23.v.2015) Lyngiong, East Khasi Hills	E	Balphakram, Raliang, Jowai, Nokrek, Cherrapunjee, Mawkyrwat, Pynrsula, Khrang	Eastern Himalaya and Northeastern India
Zanthoxylum khasianum Hook.f.*	Rutaceae	Cl	ASSAM, U. Kanjilal 4408 (06. ix.1914) Shillong Peak, Khasi Hills	E	Shillong, Jarain	Indo-Burma
Zanthoxylum oxyphyllum Edgew.	Rutaceae	Sh	ASSAM, A.H. Mir, 03080 (21. iv.2017) Laitkynsew, East Khasi Hills	E	Lailad, Jowai, Jarain, Cherrapunjee, Balphakram	Eastern Himalaya and Northeastern India
Sabia lanceolata Colebr.	Sabiaceae	Cl	ASSAM, A.H. Mir, 00907 (01.x.2016) Jakrem, East Khasi Hills.	E	Lailad, Nokrek, Balphakram	Indo-Burma and Northeastern India
Sabia parviflora Wall.*	Sabiaceae	Cl	ASSAM, P.C .Kanjilal 8770 (01. xi.1930), Barapani, Ri-Bhoi	E	Barapani, Kynshi, Elephant falls	Indo-Burma
Sabia purpurea Hook.f. & Thomson*	Sabiaceae	Cl	ASSAM, M.K.V. Rao 63977 (?) Nokrek, Garo Hills	E	Cherrapunjee, Mawsynram, Mawmluh, Jakrem, Umtong, Balphakram, Lawbah, Nokrek	Indo-Burma
Homalium bhamoense Cubitt & W. W. Sm.*	Salicaceae	T	ASSAM, G.K. Deka 21203 (?), 35th Mile, Khasi Hills	E	Tura Peak, Khasi Hills	Indo-Burma

Name	Family	Habit	Voucher number	Nativness	Distribution	
					Meghalaya	Worldwide
Homalium schlichii Kurz*	Salicaceae	T	North-Eastern Hill University, Haridasan l.c. (?), Balphakram, Garo Hills	NE	Balphakram, Jarain	Meghalaya
Salix psilostigma Andersson	Salicaceae	Sh	ASSAM, AH Mir, 90315 (08.v.2016) Swer, East Khasi Hills.	E	Jowai, Swer, Nongkrem, Phudjuad, Mawsynram	Indo-Burma
Sarcosperma arboreum Hook.f.	Sapotaceae	T	ASSAM, A.H. Mir, 90356 (19.ix.2015) Cherrapunjee, East Khasi Hills	E	Mawsynram, Cherapunjee, Jarain, Tura, Balphakram	Indo-Burma
Sarcosperma griffithii Hook.f. ex C.B.Clarke	Sapotaceae	T	ASSAM, A.H. Mir, 90418 (28.viii.2015) Cherrapunjee, East Khasi Hills	E	Raliang, Jowai, Lumshnong, Cherrapunjee, Mawsynram, Laitryngew, Mawkyrwat, Hilland, Tynnai, Jarain, Amlarem, Nongthalang, Pynursla, Phlangmawsyrpat, Nongstoin, Balphakram	Eastern Himalaya and Indo-Burma
Xantolis assamica (C.B.Clarke) P.Royen*	Sapotaceae	T	ASSAM, J. Joseph 45115 (14.iii.1966), Umling, Ri-Bhoi	E	Umling	Northeastern India
Xantolis hookeri (C.B.Clarke) P.Royen*	Sapotaceae	T	North-Eastern Hill University, Haridasan l.c. (?), Balphakram, Garo Hills	E	Lailad, Balphakram	Eastern Himalaya and Burma
Saurauia punduana Wall.	Saurauiaceae	T	ASSAM, A.H. Mir, 90382 (05.iv.2014) Laitkynsew, East Khasi Hills	E	Laitkynsew, Mawiong, Wakhen, Cherrapunjee, Mawsynram, Nokrek	Indo-Burma
Illicium griffithii Hook.f. & Thomson	Schisandraceae	T	ASSAM, A.H. Mir, 88684, East Khasi Hills	E	Nonglynkien, Tynnai, Mawkyrwat, Lynshing, Laitryngew, Cherrapunjee, Mawsynram	Indo-Burma and Bhutan
Smilax myrtillus A.DC.	Smilacaceae	Sh	ASSAM, A.H. Mir, 0332 (20.x.2016) Laitrengew, East Khasi Hills	E	Nongstoin, Pongtung, Jowai, Amlarem, Cherrapunjee, Lynshing, Tyrsad, Nokrek, Jakrem, Pynursla	Bhutan and Indo-Burma
Reevesia wallichii R.Br.	Sterculiaceae	T	ASSAM, A.H. Mir, 88696 (15.ix.2015) Cherrapunjee, East Khasi Hills	E	Cherrapunjee, Laitryngew, Mawmluh, Mawkasain, Mawsynram, Nongstoin, Mawkyrwat	Indo-Burma
Sterculia hamiltonii (Kuntze) Adelb.	Sterculiaceae	T	ASSAM, A.H. Mir, 01059 (03.v.2017) Lawbah, East Khasi Hills	E	Nokrek, Cherrapunjee, Mawsynram, Lyngiong, Balphakram	Eastern Himalaya and Indo-Burma
Stixis suaveolens (Roxburgh) Pierre	Stixaceae	Cl	ASSAM, AH Mir, 90453 (25.ix.2015) Pongtung, East Khasi Hills	E	Tharia, Pongtung, Nongsteng, Balpakram, Nokrek	Indo-Burma
Bruinsmia polysperma (C.B.Clarke) Steenis*	Styracaceae	T	K (image!), K000728941, J.D. Hooker s.n. (?) Khasi Hills	E	Umsaw	Indo-Burma
Tectaria subconfluens Ching*	Tectariaceae	H	K (image!), K001080779, C.B. Clarke (?.xi.1872), Umwai, Khasia	NE	Umwai	Meghalaya
Camellia cauduca Cl. ex Brandis	Thaeceae	Sh	ASSAM, A.H. Mir, 90399 (22.xi.2015) Lyngiong, East Khasi Hills	NE	Jowai, Mawlai, Pongtung, Raliang, Cherrapunjee, Nongstoin, Mairang, Nongbri, Lyngiong, Mawkyrwat, Pynursla, Wakhen, Jarain, Mawphlang, Laitryngew, Lawbah, Phlanwangbroi	Meghalaya
Camellia kissii Wall.	Theaceae	Sh	ASSAM, AH Mir, 01018 (10.xii.2016) Parkseh, East Khasi Hills	E	Jarain to Umngat, Mawsynram, Jowai, Nokrek, Ialong, Mawsynram, Mawkyrwat, Phudjuad, Nongstoin, Lynshing, Lyngiong, Tyrsad, Weiloi, Pynursla, Nokrek, Balphakram, Raitong, Mawmluh, Nokrek	Meghalaya

					Distribution	
Name	Family	Habit	Voucher number	Nativness	Meghalaya	Worldwide
Schima khasiana Dyer	Theaceae	T	ASSAM, A.H. Mir, 90480 (03. vii.2015) Laitryngew, East Khasi Hills	E	Shillong peak, Sohrarim, Jowai, Mawlai, Pongtung, Raliang, Nongbri, Cherrapunjee, Nongstoin, Mairang, Lyngiong, Mawkyrwat, Pynursla, Wakhen, Jarain, Mawphlang, Lawbah, Phlanwangbroi	Indo-Burma and Northeastern India
Gordonia dipterosperma Kurz	Theaceae	T	ASSAM, A.H. Mir, 90355 (19. xi.2015) Mawsynram, East Khasi Hills	E	Cherapunjee, Laitryngew, Nongsteng, Mawsynram, Mawrapat, Mawkasain.	Bhutan and Northeastern India
Pyrenaria khasiana R.N.Paul*	Theaceae	T	CAL, S. Kurz 161A (?), Khasi Hills and Brahmaputra plains	E	Khasi Hills (Location not specified).	Indo-Burma
Pyrenaria cherrapunjeana Mir	Theaceae	T	ASSAM, A.H. Mir, 02245 (15.v.2017) Mawmluh, East Khasi Hills	NE	Cherrapunjee, Mawsynram, Sohrarim.	Meghalaya
Thelypteris didymochlaenoides (Ching) Ching*	Thelypteridaceae	H	Specimen not seen	NE	Locality not known	Meghalaya
Aquilaria khasiana Hallier f.	Thymelaeaceae	T	ASSAM, A.H. Mir, 90340 (21. ix.2016) Mawkasain, East Khasi Hills.	E	Mawsynram, Umsaw,	Indo-Burma
Daphne involucrata Wall.	Thymelaeaceae	Sh	ASSAM, A.H. Mir, 90376 (04.ii.2015) Mawmluh, East Khasi Hills	E	Mawsynram, Cherrapunjee, Mawkyrwat, Mawmluh, Lynshing.	Indo-Burma
Daphne sureil W.W. Smith & Cave*	Thymelaeaceae	Sh	ASSAM, U. Kanjilal 2373 (01. viii.1913), Upper Shillong, Khasi Hills	E	Jarain, Jowai, Garampani, Ummulong, Mynso, Mawsynram, Lawbah, Mawsmai	Eastern Himalaya and Indo-Burma
Ulmus lanceifolia Roxb. ex Wall.*	Ulmaceae	T	ASSAM, R.N. De 19979 (10.xii.1940) Rangengree, Garo Hills	E	Lailad, Umling	Eastern Himalaya and Indo-Burma
Elatostemma sikkimensis Clarke.	Urticaceae	H	ASSAM, G.K. Deka 3316 (04. vi.1963) Near Crinoline, Khasi Hills	E	Cherrapunjee, Jowai, Jarain, Mawkyrwat, Mawsynram	Indo-Burma
Clerodendrum hastatum (Roxb.) Lindl.	Verbenaceae	Sh	ASSAM, B. Singh, 118413 (03. ii.2009) 118233A, Garo Hills	E	Umling, Nokrek, Umsemlem, Nokrek	Indo-Burma
Leea compactiflora Kurz	Vitaceae	T	ASSAM, B. Singh, 114900 (07.x.2007) Rongsinggri, Garo Hills	E	Tura, Rongsinggri	Eastern Himalaya and Indo-Burma
Tetrastigma obovatum Gagnep.	Vitaceae	Cl	ASSAM, A.H. Mir, 90386 (23. viii.2016) Umtong, East Khasi Hills	E	Khnongshnong to Raliang, Lynshing, Lyngiong, Cherrapunjee, Mawsynram, Laitsohum, Mairang, Pynndengnongbri, Mawkyrwat, Nongstoin	Indo-Burma
Amomum jainii S. Tripathi & V. Prakash	Zingiberaceae	H	ASSAM, D.K. Roy 125556 (26. iv.2012) Balpakram, Garo Hills	E	Baghmara Reserve forest	Northeastern India
Amomum deorianum D.P.Dam & N.Dam*	Zingiberaceae	H	ASSAM, N.C. Deori & D. P. Dam 51766, East of Dwaki, Jaintia Hills	NE	Dawki	Meghalaya
Amomum garoense S.Tripathi & V.Prakash*	Zingiberaceae	Sh	CAL, S. Tripathi 20834 (14.v.1997), Baghmara, Garo Hills	NE	Baghmara Reserve forest	Meghalaya.
Amomum vermanum S. Tripathi & V.Prakash*	Zingiberaceae	H	CAL, S. Tripathi 20835 (10.v.1997), Baghmara, Garo Hills	NE	Cherrapunjee	Meghalaya.
Boesenbergia hamiltonii Mood, S.Dey & L.M.Prince*	Zingiberaceae	H	ASSAM, Dey NU53 (?.vii.2009), Nongpoh, RiBhoi District	NE	Nongpoh, Balphakram	Meghalaya
Boesenbergia meghalayensis Aishwarya & M. Sabu*	Zingiberaceae	H	CAL, Sanoj E. 95637 (18.viii.2004), Nortiang, Khasi Hills	NE	Nartiang	Meghalaya
Caulokaempferia linearis (Wall.) K.Larsen	Zingiberaceae	H	ASSAM, AH Mir, 90320 (28.vii.2016) Mawmluh, East Khasi Hills.	E	Mawmluh, Mawsmai, Pynrsula	Northeastern India
Caulokaempferia secunda (Wall.) K. Larsen	Zingiberaceae	H	ASSAM, AH Mir, 00765 (05.v.2016) Mawsynram, East Khasi Hills	E	Nokrek, Balphakram	Eastern Himalaya and Indo-Burma
Curcuma prakasha S.Tripathi	Zingiberaceae	H	S. Tripathi, 2001. Nord. J. Bot. 21: 549.550.	NE	GaroHills-Baghmara	Meghalaya
Globba multiflora Wall. ex Baker in J.D.Hooker*	Zingiberaceae	H	ASSAM, G.K.Deka 21981 (22. viii.1946), Umsaw, Ribhoi	E	Jowai, Tura Peak, Umsaw	Northeastern India, Indo-Burma
Hedychium forrestii Diels*	Zingiberaceae	H	ASSAM, N.P. Balakrishnan 46119 (16.viii.1996), Ummulong, Jowai	E	Mynso, Jarain, Jowai, Garampani, Raliang, Ummulong	Indo-Burma

					Distribution	
Name	**Family**	**Habit**	**Voucher number**	**Nativness**	**Meghalaya**	**Worldwide**
Hedychium hookeri C.B.Clarke ex Baker*	Zingiberaceae	H	K (image!), K000640479, s.coll. 1350 (27.vi.1850) Kalapani, Khasia Hills	E	Kala Panee, Ri-Bhoi	Northeastern India
Hedychium calcaratum A.S.Rao & D.M. Verma	Zingiberaceae	H	ASSAM, G.K.Deka 10134 B.C (27. vii.1957), Jowai (60 miles from Shillong), Meghalaya	NE	Jowai	Meghalaya
Hedychium elwesii Baker	Zingiberaceae	H	K (image!), K000640501 H.J.Elwes, 44675, (08.ix.1886), Shillong	NE	Bishop falls- Shillong	Meghalaya
Hemiorchis rhodorrhachis K. Schum.*	Zingiberaceae	H	K (image!), K000640564, s. coll. (?.iii.1888), Khasi Hills	E	Tharia, Nokrek.	Eastern Himalaya, Burma and Bangladesh
Zingiber bipinianum D.K. Roy, D.Verma, Talukdar & Dutta Choud.	Zingiberaceae	H	ASSAM, DK Roy 130318 (11. vi.2014) Balpakram, Garo Hills	NE	Balphakram	Meghalaya
Zingiber roseum (Roxb.) Roscoe	Zingiberaceae	H	ASSAM, AH Mir, 90381 (05.v.2016) Laitkynsew, East Khasi Hills	E	Umsaw	Indo-Burma.
Zingiber meghalayense Kumar, Mood, Singh & Sinha*	Zingiberaceae	H	ASSAM, R. Kumar, 104078 (26. iii.2011), Nokrek	NE	Tura Peak	Meghalaya

Legend: T—tree | Sh—shrub | Cl—climber | P—parasite | H—herb | E—Endemic | NE—Narrowly Endemic | species marked with asterisk (*) could not be collected during the survey and have been included based on secondary sources; Specimen not seen- voucher specimens that we could not locate in the herbaria at Botanical Survey of India, Eastern Regional Centre, Shillong and Department of Botany, North-Eastern Hill University and in digital form.

COMMUNICATION

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Shola tree regeneration is lower under *Lantana camara* L. thickets in the upper Nilgiris plateau, India

Muneer Ul Islam Najar [1], **Jean-Philippe Puyravaud** [2] & **Priya Davidar** [3]

[1,3] Pondicherry University, Bharat Ratna Dr. B.R. Ambedkar Administrative Building, R.V. Nagar, Kalapet,
Puducherry 605014, India.
[2] The Sigur Nature Trust, Chadapatti, Masinagudi PO, Nilgiris, Tamil Nadu 643223, India.
[1] mislam.esst@gmail.com (corresponding author), [2] jp.puyravaud@gmail.com, [3] pdavidar@gmail.com

Abstract: *Lantana camara* is a dominant invasive shrub in many protected areas of India including the Nilgiri Biosphere Reserve (NBR). We conducted a study to assess the regeneration potential of endemic native (shola) trees under different levels of *Lantana* infestation in the upper plateau of NBR. A total of 61 plots in a total area of 0.73ha were sampled, out of which 0.57ha was in *Lantana* dominated sites and 0.16ha in undisturbed shola forests. The plots were classified as per the level of *Lantana* infestation (intensive, moderate, and low infestation). We found that regeneration of shola trees, including endemics decreased with increasing intensity of *Lantana* invasion. No regeneration occurred in the intensively infested plots whereas regeneration was high in undisturbed shola forests.

Keywords: India, invasive alien species, *Lantana* infestation, Nilgiris, shola forest, regeneration.

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Author details: Mr. Muneer Ul Islam Najar is a PhD scholar in the Department of Ecology and Environmental Sciences, Pondicherry University, Puducherry, India. His study focuses on the ecology of invasive alien plants. Dr. Priya Davidar retired as a Professor in Ecology and Environmental Sciences, Pondicherry University, India. She received her PhD in Zoology (Ornithology) from Bombay University in 1979 under the guidance of Dr. Salim Ali. She was a post-doctoral fellow at the Smithsonian Institution and Harvard University, USA. She is active in the field of conservation advocacy and research. Dr. Jean-Philippe Puyravaud is the director of the Sigur Nature Trust. He received his PhD in ecology from University Pierre and Marie Curie, Paris, France. He works in landscape ecology and conservation.

Author contribution: MUIN carried out the field work and data analyses. JPP and PD helped with study design, statistical analyses and editing.

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INTRODUCTION

Invasion by alien species is one of the major threats to the local and global biological diversity (D'Antonio & Kark 2002), and is regarded as one among the five top ecosystem disrupters (Millennium Ecosystem Assessment 2005). Besides affecting the native flora and fauna, a single invasive plant can alter biodiversity (Powell et al. 2011), hydrology (Le Maitre 2004), soil properties (Ehrenfeld 2010), disturbance regimes (Mack & D'Antonio 1998), fire frequency (Brooks et al. 2004), as well as above and below ground trophic interactions (Levine et al. 2003). There is a close link between invasion by exotics and extinction of native species because deforestation, decline of native species, and spread of invasive species occur simultaneously (Gurevitch & Padilla 2004). Plant extinctions, however, are least noticeable as they happen over a larger time scale (Gilbert & Levine 2013).

Lantana camara L. (hereafter referred to as *Lantana*) is one of the most successful invasive alien plants with its origin in Neotropical region. This plant has successfully established itself in more than 60 countries (Day et al. 2003). It was first introduced into India at the National Botanical Garden of Calcutta in the early 19th Century by the British as an ornamental plant (Iyengar 1933; Anonymous 1942). Since then *Lantana* has spread extensively throughout the country up to altitudes of 2,000m (Sharma et al. 1988). It occurs in a wide variety of habitat types ranging from tropical evergreen forests, tropical moist- and dry deciduous forests, tropical scrub forests to subtropical moist and dry deciduous forests (Hiremath & Sundaram 2013). It is prevalent in the Himalaya and Western Ghats (WG) biodiversity hotspots (Shaanker et al. 2010) where it affects native plant diversity (Cruz et al. 1986). Presently, *Lantana* is a dominant shrub in many important protected areas of the Nilgiri Biosphere Reserve which includes Mudumalai National Park, Bandipur National Park, and Wayanad Wildlife Sanctuary (Hiremath & Sundaram 2013). In these ecosystems, *Lantana* negatively impacts biota (Sharma & Raghubanshi 2007; Prasad 2010) by reducing grass cover which is important for the survival of herbivores like elephants (Kumar et al. 2012; Prasad 2012). In Mudumalai, it is reported that the presence of excessive amounts of *Lantana* has led to a decrease in the feeding rates and changes in the behavior of elephants (Wilson et al. 2014). *Lantana* invasion increases the fuel load making an area prone to fire and the fire in turn, paves the way for more invasion (Hiremath & Sundaram 2005).

The upper plateau of the Nilgiri Mountains (≥ 1,800m), part of the Western Ghats biodiversity hotspot, supports the unique tropical montane evergreen forests locally called 'sholas', interspersed with grasslands. Sholas support many endemic plants including *Cinnamomum wightii*, *Daphniphyllum neilgherrense, Lasianthus venulosus*, *Litsea wightiana*, *Magnolia nilagirica*, *Mahonia leschenaultii*, *Neolitsea cassia*, *Psychotria nilgiriensis*, *Symplocos foliosa*, and *Syzygium tamilnadensis* (Mohandass & Davidar 2009). These forests are highly threatened due to extensive deforestation and other anthropogenic pressures (Rawat 2008; Rao 2012). There has been a considerable loss of shola forests since 1850 A.D. due to conversion to monoculture plantations (Rawat et al. 2003).

Lantana invasion could potentially alter the successional processes operating in shola forests (Mohandass & Davidar 2010), that could affect the recruitment of slow growing native trees and lianas, leading to decreased diversity and biomass. The invasion is so extreme in some parts of the Nilgiris that it has rendered some agricultural lands barren (Muneer Ul Islam Najar pers. obs. 15 February 2017) making it very difficult for poor farmers to afford the costs of removal and subsequent management of the fields.

In this study we selected 61 plots with differing densities of *Lantana* including four control plots in shola forests in different sites above 1,800m in the Nilgiris South Division of the Nilgiri Biosphere Reserve (NBR). We assessed *Lantana* densities, and densities of regenerating shola trees including endemic species under *Lantana* cover and in shola forests. Our objective was to assess regeneration of shola trees under different levels of *Lantana* infestation, and to see which shola species survive under *Lantana*, because these species could be more useful for shola restoration under *Lantana* cover. We tested the null hypothesis that shola tree densities would not be associated with differing *Lantana* densities.

MATERIAL AND METHODS

STUDY AREA

This study was conducted in the reserved forests of Nilgiris South Division (11.20–11.49^{0}N & 76.55–76.68^{0}E; Fig. 1) of the Nilgiri Biosphere Reserve (NBR), India. Located in the Nilgiris District of Tamil Nadu, the Nilgiris South Division includes mostly the upper plateau of the biosphere reserve at about 2,200m and some areas extend to lower elevations of about 900m.

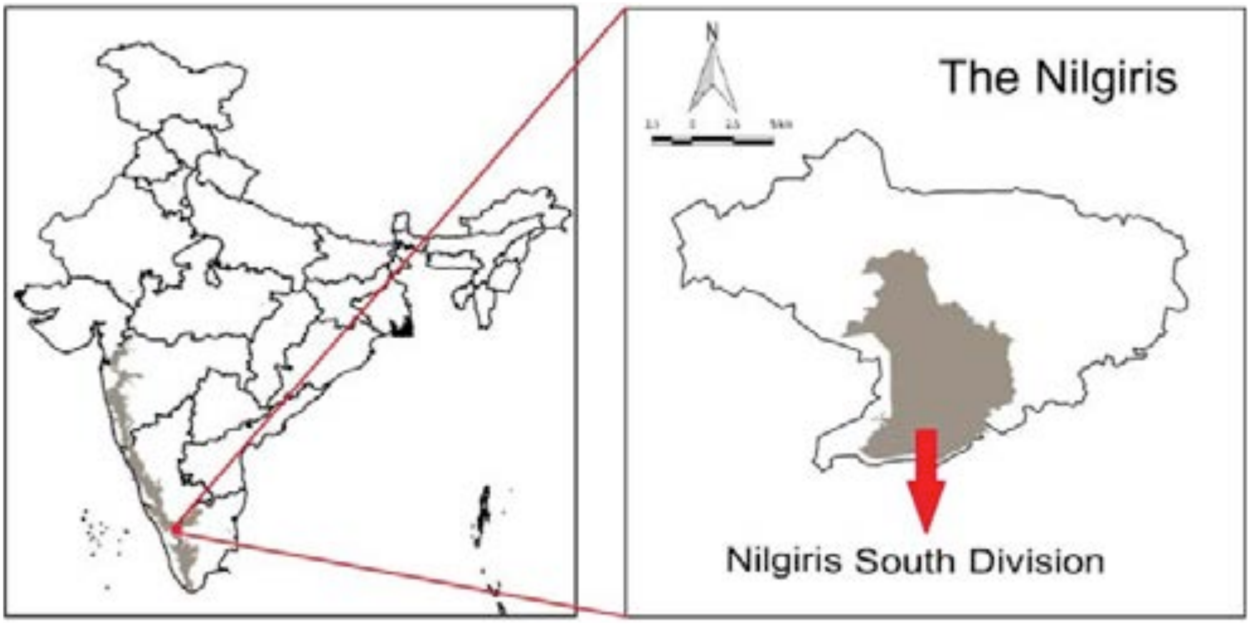

Figure. 1. Study area in the Western Ghats and in the Nilgiris District of Tamil Nadu.

The forest department of Tamil Nadu has divided it into seven forest ranges. Two ranges namely, Kundah and Naduvattam, have been extensively invaded by *Lantana.*

The Nilgiris upper plateau receives rainfall annually from both the southwest and northeast monsoons. Temperature ranges from a mean maximum of 24^0C in April to a mean minimum of 5^0C in December. Frost occurs between November and March and mainly in the valleys rather than on the higher hill slopes (Caner et al. 2007).

Nilgiris is home to many endemic plant and animal species. Some of these plant genera having maximum endemic taxa are *Actinodaphne*, *Cinnamomum*, *Glochidion*, *Litsea*, *Memecylon*, *Symplocos*, and *Syzygium* (Rao 2012). The Nilgiris has viable populations of the Endangered and endemic Nilgiri Tahr *Nilgiritragus hylocrius*, the Asian Elephant *Elephas maximus*, and the Lion-tailed Macaque *Macaca silenus*.

METHODS

This study was conducted between April 2016 and May 2017 in the study sites at altitudes ranging 913–2,033 m. All the ranges of Nilgiris South Division were covered except Naduvattam.

A total of 61 plots were studied: 57 plots each of size 10×10 m in the *Lantana* dominated sites, the total area sampled being 0.57ha, and four control plots each of size 20×20 m in undisturbed shola patches of total area 0.16ha (Table 1; Image 1). The number of trees (tree density, ≥10cm GBH) and the number of *Lantana* stems (*Lantana* density) inside the plots was recorded. The number of endemic trees was noted separately. The plots were assigned to different classes as per intensity of *Lantana* invasion: plots with >400 *Lantana* stems were assigned to the 'Intensive' infestation class, those with 200–400 stems to the 'moderately' infested class, and those with <200 stems to the 'low' infestation class.

The data were checked for normal distribution by Shapiro-Wilk test and the Spearman's rank correlation coefficient was used to test for association between *Lantana* and tree densities. The analysis was carried out using R (R Core Team 2019).

RESULTS

The distribution of *Lantana* densities differed significantly from normality (Shapiro-Wilk test=0.95, p=0.03). Similarly the distribution of tree densities (Shapiro-Wilk test=0.5, p<0.0001), and endemic tree densities (Shapiro-Wilk test=0.33, p<0.0001) also deviated from normality.

As the density values were not normally distributed, the median was used as a measure of density. The *Lantana* density in 57 plots ranged from a minimum of zero stems to a maximum of 908 stems per plot with a median of 330. Tree density ranged from zero to 117 with a median of six trees per plot. There were zero to 33 endemic trees with a median of zero trees per plot (Table 1). In contrast, the four control plots were

Table 1. Median values (Range: minimum to maximum) of *Lantana*, tree and endemic tree densities in the plots with different levels of *Lantana* infestation. Area sampled was 0.57ha in the experimental plots and 0.16ha in the control plots.

	Lantana infestation				Total
Category	Intensive (20 plots)	Moderate (26 plots)	Low (11 plots)	Control (shola, 4 plots)	61 plots
Lantana	473 (405–908)	322.5 (227–395)	119 (63–197)	0 (0)	330 (0–908)
All trees	1 (0–9)	5.5 (0–10)	15 (8–25)	99.5 (88–117)	6 (0–117)
Endemic species	0 (0)	0 (0–3)	1 (0–3)	25.5 (19–33)	0 (0–33)


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Image 1. A plot showing *Lantana* infestation in the upper Nilgiris plateau.

composed of shola trees belonging to the following genera: *Cinnamomum, Daphniphyllum, Ilex, Lasianthus, Litsea, Meliosma, Microtropis, Neolitsea, Nothapodytes, Psychotria, Rapanea, Rhododendron, Rhodomyrtus, Saprosma, Strobilanthes, Symplocos,* and *Syzygium*.

The 20 intensively infested plots had a median of 473 *Lantana* stems per plot and a median of one tree per plot but no endemic tree species (Table 1). The 26 moderately *Lantana*-infested plots had a median of 322.5 *Lantana* stems per plot, 5.5 trees but no endemic species per plot. Similarly, the 11 plots with low *Lantana* infestation had a median of 119 *Lantana* stems per plot, 15 trees, and one endemic tree per plot. Both the tree density and the density of endemic tree species was highest in the shola (control) plots with a median tree density of 99.5 trees per plot and a median of 25.5 endemic trees per plot (Table 1).

Endemic tree density decreased significantly and negatively with increase in *Lantana* density (Spearman rank correlation coefficient r_s=–0.72, p<0.0001).

DISCUSSION

Our study shows that the regeneration of shola trees including endemic species decreases with increase in *Lantana* density. Few shola trees survive under moderate *Lantana* cover and none under heavy infestation. These results support the findings of Prasad (2012) who found a negative relationship between *Lantana* abundance and tree density. We found species of *Lasianthus*, *Litsea*, *Neolitsea*, *Symplocos*, and *Syzygium* growing in plots with moderate and low infestation.

It has been found that a forest with a composition of about 75% of native species effectively prevents the establishment of *Lantana* (Stock 2004), however, as the *Lantana* cover increases and crosses 75% mark, the richness of native species decreases (Gooden et al. 2009). This is because of the effects of *Lantana* on soil fertility (Bhatt et al. 1994) and soil seed banks (Fensham et al. 1994). In the Himalayan foothills of India, Sharma & Raghubanshi (2007) found reduced native tree species richness and regeneration in *Lantana* dominated plots. In another study, Sharma & Raghubanshi (2010) found that *Lantana* alters the tree composition and structure, due possibly to suppression of native tree regeneration. Similarly, in the Nilgiri Biosphere Reserve, *Lantana* has been found to adversely affect the regeneration of native trees, and reduce plant diversity and alter species composition in the forest under-storey in Bandipur Tiger Reserve (Prasad 2010), and in Mudumalai Tiger Reserve (Ramaswami & Sukumar 2013). Other researchers (Lamb 1991; Fensham et al. 1994; Sharma & Raghubanshi 2007) too have found a negative relationship between the regeneration of trees and *Lantana* density.

The regeneration of 52 shola species was studied by Madhu et al. (2017) in the Nilgiris. They found the highest survival rates for the two species of *Syzygium* (*S. cumini* and *S. gardneri*) at all elevations and aspects, with an average of 77% regeneration. *Syzygium* spp. could be beneficial for the restoration of shola patches because of their highest chances of survival, but need protection at the initial stages as livestock and wild herbivores forage on their leaves due to their high nutritional value (Mohandass et al. 2016). Moreover, *Syzygium cumini* can grow well in open conditions, whereas most shola species including other *Syzygium* spp. cannot, as they need shade to regenerate. Therefore, planting *Syzygium cumini* will facilitate regeneration of shola trees. Thus, growing a mix of species including both shade tolerant and light tolerant pioneer species as advocated by Sekar (2008) and Mohandass et al. (2016) could be a better strategy. In addition to *Syzygium cumini*, *Rhododendron nilagiricum*, *Syzygium calophyllifolium*, and *Viburnum hebanthum* which are common can be planted (Murugan 2006; Mohandass et al. 2016). *Viburnum hebanthum* has an added advantage that it tolerates poorly drained or water soaked soils. Murugan (2006) found the seed viability of two species of *Syzygium* (*S. tamilnadensis* and *S. calophyllifolium*) to be 70–80% followed by *Rhododendron nilagiricum* (50–60%), and *Viburnum hebanthum* (50%). The species of *Rhododendron*, *Syzygium*, and *Viburnum* have long been used as enrichment plants to assist natural regeneration (Chandrasekhara & Muraleedharan 2001). We also advise growing *Rhodomyrtus tomentosa* for it acts as a nurse plant for other shola species (Yang et al. 2010). The nurse plants create favorable microhabitats for seed germination and seedling recruitment (Franco & Nobel 1989), however, the nursing effects depend on the shade tolerance of the species to be restored. The species with greater shade tolerance help to accelerate the restoration process.

Once the *Lantana* is removed, planting of early successional species like *Berberis tinctoria*, *Daphniphylum neilgherrense*, *Syzygium densiflorum* (Mohandass et al. 2016), *Rhododendron nilagiricum* (Mohandass & Davidar 2010), and *Rhodomyrtus tomentosa* (Yang et al. 2010) could be helpful. As pointed out by Mohandass & Davidar (2010) the frost resistant species of *Rhododendron* along with *Rhodomyrtus* sp. act as pioneers in the ecotones and grasslands and over time pave the way for more shade tolerant species. Hence we suggest the planting of *Rhododendron nilagiricum*, *Rhodomyrtus tomentosa*, *Syzygium calophyllifolium*, *Syzygium cumini*, *Syzygium tamilnadensis*, and *Viburnum hebanthum* for the successful restoration of sholas in the Nilgiris post *Lantana* removal.

The cut root stock method as described by Love et al. (2009) could be used to remove *Lantana* as it has been found to be highly efficient to control its reinvasion. Babu et al. (2009) in India (Corbett Tiger Reserve), Woodford (2000) and Somerville et al. (2011) in Australia have effectively managed *Lantana* and successfully regenerated native plants post *Lantana* removal. What is common in these studies is that the *Lantana* was removed manually, a herbicide was sprayed over the area, or the removed *Lantana* was set on fire. After this, seeds of native trees were planted and allowed to germinate with continuous monitoring and de-weeding until the trees were high enough to prevent the reinvasion by *Lantana*. As Nilgiris South Division is one of the wettest areas of the reserve, the chances of shola restoration are high, as recovery of native species was higher in wetter areas (Prasad et al. 2018) in NBR.

CHALLENGES TO RESTORATION

Climate change allows alien species to expand their ranges (Dukes & Mooney 1999; Simberloff 2000) particularly at higher altitudes due to the alleviation of cold limitation (Dukes et al. 2009) and makes the influence of invasions difficult to predict (Tylianakis et al. 2008). In case of *Lantana* which has greater genetic variability (Day et al. 2003) some genes can adapt to the new climatic conditions and can help it to colonize new landscapes (Ledig et al. 1997). Climate change may also lead to extirpation of those species which are not genetically diverse because a narrower genotype range makes them least adaptable to environmental conditions (Rice & Emery 2003). All this can severely impact the regeneration of shola trees and other native and endemic species in the upper Nilgiris. Another challenge is restoration of species with smaller population sizes like some endemic or rare species (Bell et al. 2003), where a minimum viable population number is necessary for the establishment of these species (Falk et al. 2006).

CONCLUSION

The invasion by *Lantana* in the upper Nilgiris is disastrous to the biological wealth of this plateau and necessary steps for its removal need to be taken. In the last few years, the forest department has taken measures to stop its spread by planting native plant species but with little success. The removal of *Lantana* and *Acacia* has been carried out in the reserve forests of the Nilgiris for many years, however, studies are necessary to assess its effectiveness. The measures have to be taken persistently, and fast growing native plants have to be planted in the cleared plots with continuous monitoring for the first few years to restore the habitats. Doing this would prevent the sites from functioning as a source for further invasion deep into the forests. An adaptive management system needs to be developed in which *Lantana* removal could be used to enhance the local population livelihoods (Shaanker et al. 2010). Although, there is no hard and fast solution to completely remove *Lantana* at this moment, we must continue working to develop innovative approaches. The efforts of Woodford (2000), Babu et al. (2009), and Somerville et al. (2011) have shown us the way forward for the effective management of *Lantana* and successful regeneration of native plants post *Lantana* removal. With some persistence and coordination between different stakeholders, similar plans could be worked out for *Lantana* in the Nilgiris.

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OVERCOMING THE POLLINATION BARRIER THROUGH ARTIFICIAL POLLINATION IN THE WILD NUTMEG *KNEMA ATTENUATA* (MYRISTICACEAE), AN ENDEMIC TREE OF THE WESTERN GHATS, INDIA

Murugan Govindakurup Govind [1], **Koranapallil Bahuleyan Rameshkumar** [2] & **Mathew Dan** [3]

[1,3] Plant Genetic Resource Division, [2] Phytochemistry and Phytopharmacology Division,
Jawaharlal Nehru Tropical Botanic Garden and Research Institute (Research Center, University of Kerala), Palode, Thiruvananthapuram, Kerala 695562, India.
[1] University of Kerala, Senate House Campus, Palayam, Thiruvananthapuram, Kerala 695034, India.
[1] govindkyl@gmail.com (corresponding author), [2] kbrtbgri@gmail.com, [3] danmathew2002@gmail.com

Abstract: The barrier to pollination and pollinator assemblage were investigated in *Knema attenuata*, a dioecious tree species endemic to the Western Ghats of India. It occupies an intermediate canopy stratum of the low and mid-elevation wet evergreen forests. In order to observe floral display, insect foraging and fruit development, four populations of *K. attenuata* were selected. The population diagram of each population was constructed by marking one female tree as the centre and male trees available at different radii from the female tree. Direct observations and swap net trapping were used to sample insects in the canopy during the flowering season of 2016 and 2017. *Knema attenuata* exhibited generalised pollination through diverse insects: thysanopterans (thrips), coleopterans (beetles), halictid bees, and dipterans (syrphid and phorid flies), where thrips played the major role. On analysing the floral display, it was found that the male flowers provided no rewards and thus attracted less pollinators than the female flowers. Among the four populations studied, three showed more than 70% fruit setting and the rate of abscission in flowers and young fruits were negligible. One population was without fruit setting and trials on artificial pollination resulted in fruit setting. A very low frequency of seed germination was observed in natural conditions which was enhanced by a seed germinator.

Keywords: Fruit setting, seed germinator, syrphid flies, thrips.

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Author details: M.G. Govind, Research scholar (University of Kerala), Plant Genetic Resource Division JNTBGRI perusing PhD entitled chemotaxonomic studies on the family Myristicaceae from the Western Ghats. Research involves complete taxonomic revision as well as phytochemical profiling of all Myristicaceae members of the Western Ghats. Dr. K.B. Rameshkumar, Senior Scientist, Phytopharmacology Division actively working on phytochemical profiling endemic plants of the Western Ghats especially with high medicinal potential. Currently Principal Investigator of SERB funded project 'Phytochemical studies on Indian Cyperaceae'. Dr. Mathew Dan, Head and Senior Scientist Of Plant Genetic Resource Division, JNTBGRI actively involved in conservation and charecterisation medicinal plants research and a leading plant taxonomist specialized in Zingeberaceae. Currently principal investigator of SERB funded project 'Revision of Indian Piperaceae' .

Author contribution: First author carried out Research work as part of PhD program under combined guidance and supervision of second and third authors.

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INTRODUCTION

Myristicaceae R.Br. has a pantropical distribution, represented by about 21 genera and 520 species (Christenhusz & Byng 2016). The members are well represented in the moist evergreen forests of the Western Ghats by three genera — *Knema* Lour., *Myristica* Gronov. and *Gymnacranthera* Warb. Genus *Knema* has 93 species in total (Mabberley 2018) and the distribution ranges from southern India through southeastern Asia to southern China and Indo-China, and throughout Malaysia (Wilde 1979). In India, eight species and two sub species of the genus *Knema* were reported. In the Western Ghats, *Knema attenuata* (Wall. ex Hook.f. & Thomson) Warb. is the only representative which is also endemic (Nayar et al. 2014). *Knema attenuata* is a Least Concern (World Conservation Monitoring Centre 1998) riparian, dioecious, medium-sized tree species. It mainly inhabits forest river basins and low–mid elevation of forest areas of the Western Ghats. It is one of the ingredients of 'Ashwagandadhi nei' a medicated ghee used in Ayurvedic treatment (Ravikumar et al. 2000). The plant has anti-bacterial, anti-fungal, anti-oxidation, anti-larval, and insecticidal properties (Vinayachandra et al. 2011; Vinayachandra & Chandrashekar 2014). *Knema attenuata* is known as 'Chora pine' in Malayalam due to its blood coloured exudates from its bark. Because of its regularly whorled axial branching pattern, people just cut them down and use it as a cloth stand.

There are many conflicting reports on the pollination of the family Myristicaceae. Many researchers have pointed out the presence of a specialized beetle pollination syndrome (Armstrong & Drummond 1986; Armstrong & Irvine 1989; Armstrong 1997; Momose 2005). In *Knema*, different beetles belonging to Curculinoids, Staphylinids, and Chrysomelids were reported as pollinators (Momose 2005). The floral morphology of this family might also host non-beetle pollinators. Thrips have always been found on Myristicaceae and have been established as pollinators in *Horsfieldia grandis* in Sarawak (Momose et al. 1998) and *M. dactyloides* in Western Ghats (Sharma & Armstrong 2013).

The present study was an attempt to determine the pollinators, to conduct artificial pollination trials, to confirm the pollination barrier, and to find out the germination efficiency of seeds in *Knema attenuata*.

MATERIALS AND METHODS

Population study

Four populations of *K. attenuata* were selected from different localities of Agasthyamala Biosphere Reserve of the southern Western Ghats and GPS (with Garmin etrex 30) coordinates were recorded. The sites were Ponmudi forest area (Population 1), Kallar eco-tourism area (Population 2), Shendurney Wildlife Sanctuary (Population 3), and Jawaharlal Nehru Tropical Botanic Garden and Research Institute (JNTBGRI) campus in Palode (Population 4), and the map of the study area was prepared using QGIS software (Fig. 1). The study was carried out during peak flowering and fruiting seasons, November–February, in the consecutive years 2016 and 2017. In each population, one healthy female tree with girth at breast height (GBH) of more than 30cm was spotted and marked. The male trees within a 100m radius of the central female plant were marked and a population diagram was drawn ("RADAR model"). The perimeter from female tree was divided into six classes and the number of male trees in each class was marked indicating the vicinity of male plants (Fig. 2).

Morphological characterisation

Quantitative morphological characters (length and diameter of fruits) as well as qualitative characters of (colour, taste, smell, and texture of aril and rind) were recorded (Table 1). The flower exhibition and enumeration were also recorded. The number of flowers in 30 inflorescences each on four female trees and four male trees representing different populations were evaluated using standard arithmetic mean and standard deviation. The female flowers were dissected and examined under a stereo microscope (Carl Zeiss Stemi DV4) to observe gynoecium characters. The nectar measurements were made using graduated microcapillaries. The pollen grains from 10 flowers of male trees in each population were taken and the viability was assessed on alternate days after anthesis using acetocarmine staining technique. The viability was calculated as per the standard procedures proposed by Shivanna & Rangaswamy (2012) using a Leica DM 2500 microscope.

$$\text{Pollen viability (\%)} = \frac{\text{Number of stained pollen}}{\text{Total number of pollen}} \text{x } 100$$

Observations on pollination

The insects near the inflorescence were caught using a sweep net, immobilized using chloroform vapour and

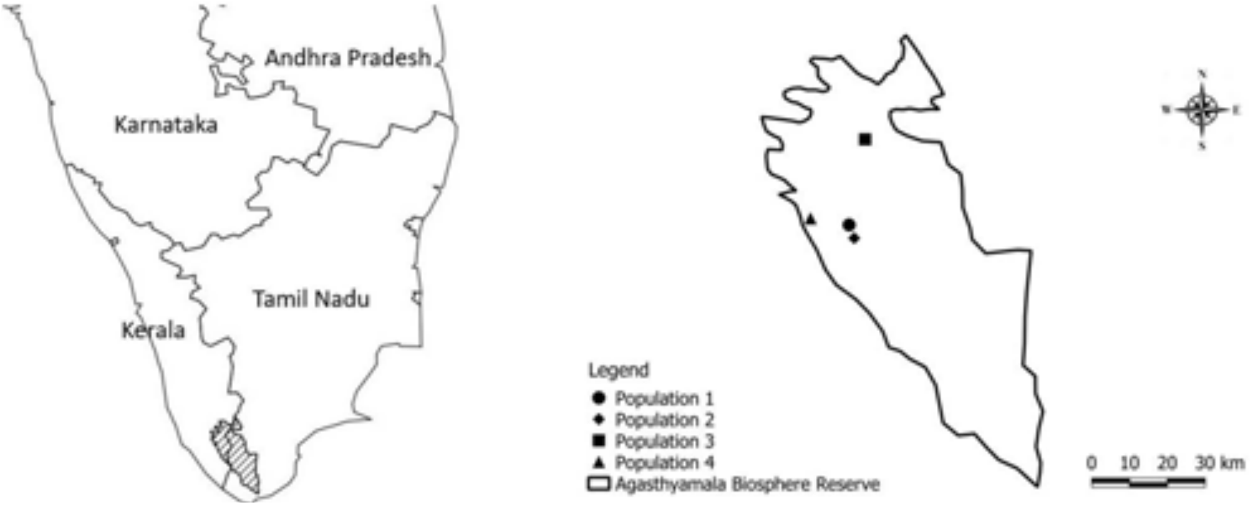

Figure 1. Population 1—Ponmudi Hills (8.443^{0}N, 77.071^{0}E) | Population 2—Kallar eco-tourism area (8.423^{0}N, 77.080^{0}E) | Population 3—Shendurney Wildlife Sanctuary area (8.565^{0}N, 77.093^{0}E) | Population 4—Jawaharlal Nehru Tropical Botanic Garden and Research Institute campus (8.452^{0}N, 77.014^{0}E).

scanned under a stereo microscope (Carl Zeiss Stemi DV4). Those that contained any trace of pollen grain on their bodies were considered as potential pollinators. Identification of insects up to generic level was carried out by matching with standard references on the pollinators of Myristicaceae. The stigma of five female flowers from each population was observed under the stereo microscope to assess pollen deposition.

Though profuse flowering, receptive stigma, and the presence of suspected pollinators were observed in the female plant of *K. attenuata* in JNTBGRI campus (Population 4) during 2016 and 2017, fruit setting was totally nil. Therefore, artificial pollination was carried out. Fifty flower buds from 20 inflorescence were tagged (minimum 2 in each inflorescence) and bagged. The flowers were completely opened, after 16 days and a sticky exudate was found in the stigma. Using the pollen of male flowers collected from population 4, 48 flowers were artificially pollinated by softly rubbing the anther disc directly on to the stigma of the flower and the remaining two were set as control to examine the number of days taken for abscission of non-pollinated flowers (Image 1e). The pollinated and control flowers were re-bagged.

Germination

For germination study, 38 seeds obtained through artificial pollination (population 4) and 70 seeds each from normal fruit setting (populations 1, 2, 3) were selected. Each batch of seeds was wrapped in wet acid free paper towels, labelled, and placed in a seed germinator (Kemi Seed Germinator) in darkness, maintained at 30 ± 2^{0}C, and 80% relative humidity (RH). The vigour calculation was done using standard protocol (Czabator 1962).

Germination vigour = Mean daily germination (MDG) x Peak value.

$$\text{MDG} = \frac{\text{Final germination percentage}}{\text{Days for complete germination}}$$

$$\text{Peak value} = \frac{\text{Highest see germination}}{\text{No. of days for germination}}$$

Ten seeds from artificially pollinated population (population 4) and 20 each from naturally pollinated populations (populations 1, 2, 3) were sown in the experimental plot providing same edaphic conditions to evaluate germination.

RESULTS

Floral Morphology

An Inflorescence of both male and female contain 3–5 flowers. Male flowers were comparatively smaller than female flowers (Image 1a,b), both with three-lobed perianths. The androecium was stalked with 13 stamens arranged on dark red staminal disc. The gynoecium was with two stigmas, thick and short style and ovoid ovary. Maximum viable pollen grains were recorded

Table 1. Quantitative and qualitative characters of *Knema attenuata* mature fruits.

Characters	Population 1	Population 2	Population 3	Population 4*
Length (cm)	3.9 ± 0.05	3.5 ± 0.02	3.6 ± 0.03	3.6 ± 0.02
Diameter (cm)	2.50 ± 0.40	2.5 ± 0.38	2.6 ± 0.32	2.5 ± 0.23
Odour of aril	Pleasant	Pleasant	Pleasant	Pleasant
Taste of aril	Slightly sweet	Slightly sweet	Slightly sweet	Slightly sweet
Texture of rind	Tomentose	Tomentose	Tomentose	Tomentose

*-Artificially pollinated fruits. Population 1—Ponmudi Hills | Population 2—Kallar eco-tourism area | Population 3—Shendurney Wildlife Sanctuary area | Population 4—Jawaharlal Nehru Tropical Botanic Garden and Research Institute campus.

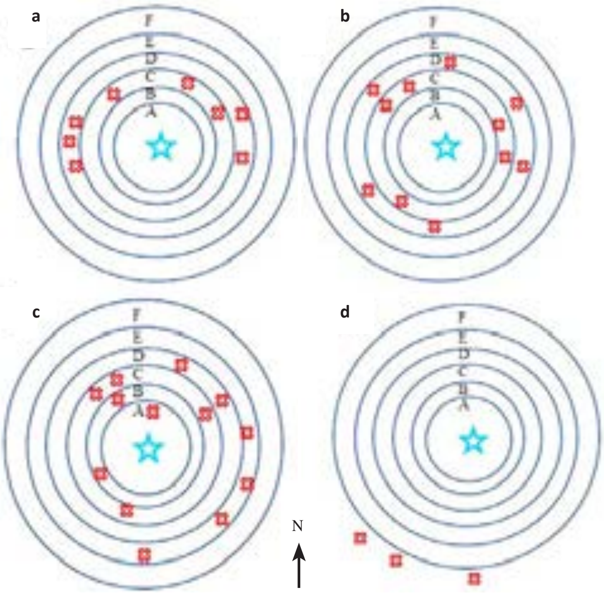

Figure 2. Population diagrams showing male distribution around female trees: a—population 1 | b—population 2 | c—population 3 | d—population 4. A—0–10 m | B—10–30 m | C—30–50 m | D—50–70 m | E—70–90 m | F—90–100 m.
☆—*Knema attenuata* female tree ⊞—*Knema attenuata* male tree

on the second and third day (66.4 ± 5.3% & 64 ± 5.8%, respectively) after anthesis. Morphologically the flowers in all the four populations were identical.

Proximity of male trees and pollination efficacy

Among the four populations studied, population 3 from Shendurney Wildlife Sanctuary showed the maximum success in pollination; that is about 70% of the female flowers produced fruits, which directly correlated to more number of male trees nearer to female tree, i.e., 13 male trees within 100m radius. Populations 1 and 2 showed comparatively lesser success rate of fruit setting, about 50% and 60%, respectively. It was in accordance with the lesser number of male trees, i.e., eight and 11 trees respectively within 100m radius, where the nearest one was 50–70 m from the female tree. There was no fruit setting in population 4 where the nearest male tree was beyond 100m from the female (Fig. 2d). Out of 60 female flowers examined from each population (populations 1, 2 & 3), 55–60 pollen grains were spotted on stigma in 3–4 day old flowers which showed 77.3 ± 4.6 % viability. Whereas, the female flowers of population 4 showed no traces of pollen grains, clearly indicating the remote occurrence of male trees (Fig.s 2a,b,c). The length of mature fruit was found to be 3.9 ± 0.05 cm and diameter (just before splitting) 2.5 ± 0.04 cm. The rind of fruits was golden brown in colour and tomentose in texture. The average fresh weight of the fruit was 15.05 ± 0.67 g. The bright red aril fully covered the shiny brown seed (Image 1f*)*.

The observations on insect visits revealed that thrips and syrphid flies were frequent visitors to both male and female flowers. Thrips were observed more and about 60% of them carried pollen. Some syrphid flies were also spotted with pollen grain. Non-pollinating visitors like ants and wasps were also observed. Though the presence of insects was observed in population 4, insects with pollen grains were not observed.

Artificial pollination

All artificially pollinated flowers in population 4 produced fruits and early stage abscission was not observed during fruit development and thus the success rate was 100%. The dimension of each fruit was recorded at an interval of five days of growth stage and compared to the data of naturally pollinated fruits, and no significant variation was found. The morphology of fruits in both types were also found identical (Table 1).

Seed germination

Seeds from both naturally as well as artificially pollinated flowers exhibited a similar period of dormancy, about 30 days in the seed germinator. Germination on both were observed from the 31st day onwards and

Image 1. *Knema attenuata*: a, b—male and female flowers | c—development stages of female flower | d—thrips bearing pollen | e—hand pollination | f—fully matured fruit | g, h—seed germination stages of natural and artificially pollinated fruits. © M.G. Govind.

the plumule appeared on the 46th day (Images 1g,h). The germination vigour of naturally pollinated seeds was slightly more than that of artificially pollinated seeds, 0.44 and 0.37, respectively. The percentage of germination in both naturally and artificially pollinated seeds was almost similar (82–84 %). The seeds of both groups were much delayed (> 80 days) to germinate when sowed in the experimental plot.

DISCUSSION

Though specialised beetle pollination syndrome was reported in Myristicaceae (Armstrong & Drummond 1986; Armstrong & Irivin 1989; Armstrong 1997), in *Knema* there were no previous reports on pollination. The present study throws some light on pollinators, the pollination barrier, and the possibility of artificial pollination in *K. attenuata*. During the study, pollen bearing thrips were detected in three populations. Earlier studies on Myristicaceae also established the presence of thrips with pollen (Armstrong & Drummond 1986; Armstrong & Irivin 1989; Williams et al. 2001). Another interesting observation was the occurrence of nymphs of thrips inside the urn-shaped flowers (Image 1d); this correlated with the observation by Moog et al. (2002) that the *Myristica* flowers appeared to be the hatching sites of thrips.

A high concentration of thrips was observed in the female tree, where male trees were at close proximity. Armstrong (1997) also specified that close vicinity of plants could result in effective movement of thrips from male flowers causing pollen export to female flowers. Syrphid flies (hover flies) were also clearly observed on both male and female plants showing scavenging activity and pollen shipment. Sharma & Shivanna (2011) reported the presence of hover flies in *Myristica dactyloides* and discovered them as the major pollinators. Due to wider male flowers and exposed stigma, the pollinators gain easy access to the flowers of *K. attenuata*.

Some beetles execute utilisation of female flowers as suitable sites for agonistic and mating activities (Gottsberger 1977, 1988; Goldblatt et al. 1998) and certain beetles prefer the temperature inside the flower (Bay 1995; Seymour & Schultze 1997; Bernhardt 2000), whereas others show forage activity on sticky exudation on stigma or petals (Momose 2005). Sharma & Shivanna (2011) observed the same phenomenon in *M. dactylodes* from Western Ghats, and stated that wet stigma and urn-shaped flower provide food and shelter for the beetles. The observations perfectly matched with that of the present study in *K. attenuata* where typical semi urn-shaped flower and sticky stigmatic exudate gave some reward for the pollinators. In *K. attenuata* floral exhibition was higher in male trees than female because of the attractive bright red-coloured staminal disc.

The investigations by Armstrong & Drummond (1986), Sharma & Shivanna (2011), and Sharma & Armstrong (2013) revealed that thrips as well as beetles are pollinators in certain species (*Myristica fragrans, M. dactyloides, M. fatua*, and *Gymnacranthera canarica*) of Myristicaceae. Sharma & Shivanna (2011) stated that majority of the loss in fruit set in *M. dactyloides* was due to flower abscission and the rest by the fruit abortion. But in *K. attenuata* it was observed that, floral abscission was comparatively very low and more than 70% flowers produced fruits and the rate of fruit abscission during maturation was also very low. Howe & Westley (1997) stated that high pollination efficiency and normal fruit set combined with observations on flower abscission and fruit abortion indicates no pollination limitation in the population. In spite of the receptive stigma in healthy female flowers and presence of pollinators and fertile pollen in the available male plant, pollination was absent in population 4 of *K. attenuata,* just because of the remoteness of the male plant. All the other populations studied (populations 1, 2, 3) showed >50% success in fruit setting. In all the four populations studied, abiotic and biotic components were almost similar except the proximity of male plants to female plants. All the data offers clear evidence that in *K. attenuata*, in spite of all favourable parameters, the distance of the male plant from the female plant affects successful pollination.

Trials on seed germination showed that seeds from both artificially pollinated and naturally pollinated flowers, expressed almost similar patterns in the germinator. No signs of germination were observed in field trials. This result correlates with the observation of locating only less than five seedlings within a radius of 100m around the female tree of *K. attenuata*. In order to confirm the shortage of seedlings, further explorations were conducted on different populations of *K. attenuata* (Coorg, Pathanamthitta, Wayanadu & Vazachal) in the southern Western Ghats, and the result was similar. The distance of the male plant from the female one could be a barrier for fruit setting and very low seed germination adversely affects the establishment of viable populations. Vigorous deforestation practices along with loss of habitat, utilisation for trade and natural calamities like flood and landslides are threats to the existence of species (Howe & Westley 1997). Ex situ production of seedlings and its reintroduction may aid establishment of the population of *K. attenuata,* one of the best approaches to safeguard this endemic species from extinction.

CONCLUSION

The observations on pollination in *K. attenuata* revealed that the pollinators are thrips and syrphid flies. The remoteness of male trees from female trees is a pollination barrier. For effective insect pollination, the optimum distance between male and female trees is 40–50 m. Artificial pollination was found to be effective in the successful production of viable seeds. Since the species is dioecious; the findings have great importance towards the conservation of this species.

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Short Communication

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The first photographic record of the Red Panda *Ailurus fulgens* (Cuvier, 1825) from Lamjung District outside Annapurna Conservation Area, Nepal

Ganesh Ghimire [1], **Malcolm Pearch** [2], **Badri Baral** [3], **Bishnu Thapa** [4] & **Rishi Baral** [5]

[1,4,5] Tribhuvan University, Central Department of Zoology, Kirtipur 44618, Kathmandu, Nepal.
[2] Harrison Institute, Centre for Systematics and Biodiversity Research, Bowerwood House, 15 St. Botolph's Road, Sevenoaks, Kent TN13 3AQ, United Kingdom.
[3] Nepal Environmental Research Institute, Tarakeshwor 9, Kathmandu, Nepal.
[5] National Trust for Nature Conservation, Annapurna Conservation Area Project, P.O. Box 183, Hariyo Kharka, Pokhara, Nepal.
[1] ganesh061nep@gmail.com, [2] harrisoninst@btinternet.com, [3] badribaral@neri.com.np,
[4] chhetry.bishnu366@gmail.com, [5] right.rishi1@gmail.com (corresponding author)

Abstract: In May and June, 2018, a series of field surveys was undertaken to determine the presence of the Red Panda *Ailurus fulgens* in Marsyangdi Rural Municipality in Lamjung District, western Nepal. A single, adult, Red Panda was photographed and recorded on video at Nafada Khola while scratch marks and distinctive scats provided evidence of Red Panda activity at eleven further localities at elevations between 3,150 and 3,650 m. Threats to the habitat of *A. fulgens* within the study area are discussed.

Keywords: *Ailurus fulgens*, Red Panda, distribution, Lamjung District, Nepal.

The Red Panda *Ailurus fulgens* is classified as Endangered by IUCN and is confined to the temperate forests in the foothills of the Himalaya. Its range extends from Kalikot District in western Nepal (Dangol 2014), eastwards through northeastern India, Bhutan, and northern Myanmar to Sichuan Province in south-central China (Glatston et al. 2015). Throughout its range, its preferred bamboo habitat is increasingly under threat from human activity, adding further pressure to its highly disjunct distribution.

Despite having extensive tracts of bamboo forest between 2,500 and 4,000 m, which is the species' preferred habitat, Nepal is considered currently to support only 1.9% of the total global population of Red Pandas (Bista & Paudel 2014).

In Nepal, *A. fulgens* has been reported from the following districts: Taplejung, Panchthar, Sankhuwasabha, Solukhumbu, Ramechhap, Dolakha, Sindhupalchowk, Rolpa, Rukum, and Mugu (Jnawali et al. 2012), Ilam (Williams 2004), Jajarkot (Baral 2014), Kalikot

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(Dangol 2014), Khotang (Mali 2014), Bhojpur, Dolpa, and Lamjung (MoFSC 2016), and Rasuwa, Nuwakot, Myagdi, Baglung, and Dhading (Bista et al. 2017). *Ailurus fulgens* was reported to occur in Manang District (Paudel 2009) but its presence there has not been confirmed (Bista et al. 2017).

The protected areas in Nepal in which the species is known to occur include Kangchenjunga Conservation Area (Mahato & Karki 2005; Yonzon 1996), Manaslu Conservation Area (Yonzon et al. 1997), Makalu Barun National Park (Jackson 1990), Sagarmatha National Park (Mahato 2004), Langtang National Park (Yonzon 1989; Yonzon & Hunter 1991; Yonzon et al. 1991; Fox et al. 1996), Annapurna Conservation Area (Shrestha & Ale 2001), Dhorpatan Hunting Reserve (Sharma & Kandel 2007), and Rara National Park (Sharma 2008).

Until the present study, *Ailurus fulgens* was known to occur in Lamjung District only within Annapurna Conservation Area (MoFSC 2016) although scats consistent with those of *A. fulgens* were identified also in the District at Ghermu (28.378^{0}N & 84.411^{0}E) (MoFSC 2016). The purpose of the current field surveys was to determine the presence and population status of *A. fulgens* in Lamjung District outside protected areas.

MATERIALS AND METHODS

Study area

Lamjung District is located in Gandaki Province in western Nepal. The total population of the district is 1,67,724 with 42,079 households (CBS 2011). The district is located between 28.055–28.510^{0}N and 84.189–84.189^{0}E (Fig. 1). It has an elevation range of

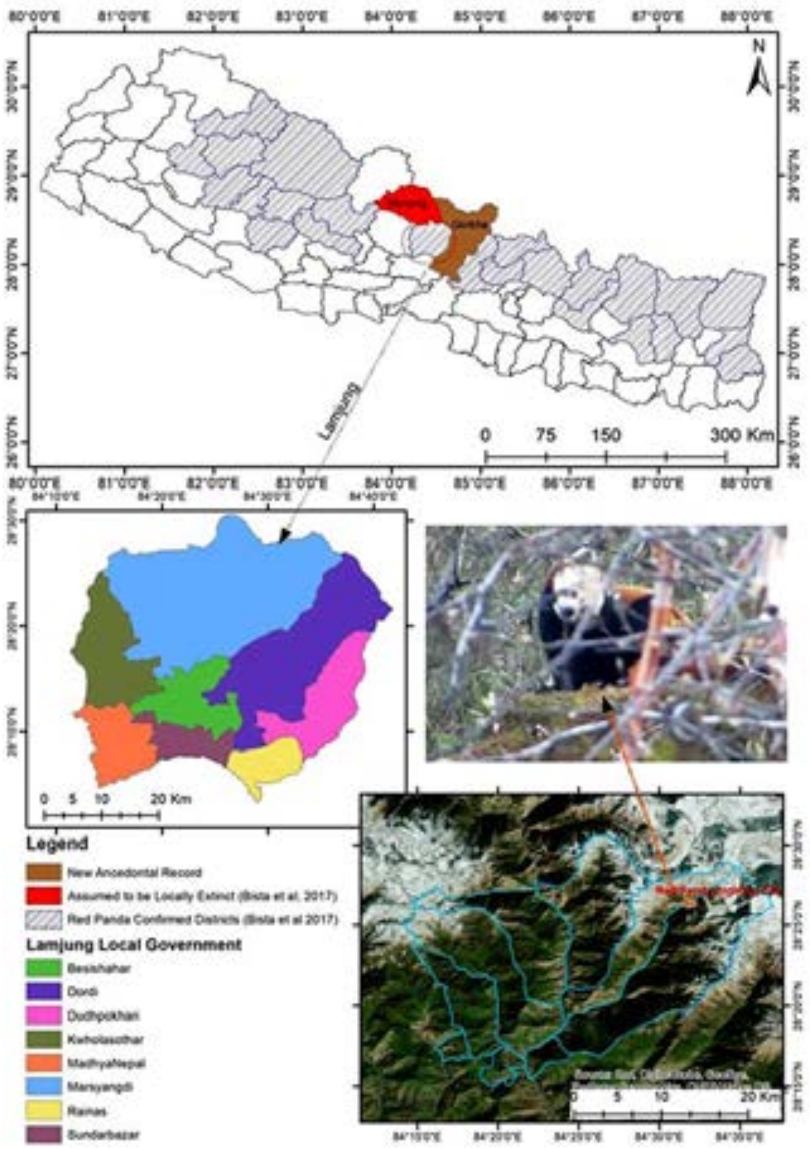

Figure 1. Study area in Marsyangdi Rural Municipality, Lamjung District, Nepal

385–8,162m and covers an area of 1,692km² (DDC 2011). The climate is dictated by elevation and topography, which results in a mosaic of different geographical zones, from subtropical conditions in southern areas to an alpine zone in the north. Average annual rainfall is 2,448mm. (www.meteomean.com), more than 80% of which occurs during the monsoon season (June to September) (DDC 2011). Average air temperature ranges from a minimum of 15.50°C to a maximum of 27.17°C (DDC 2011).

Marsyangdi Rural Municipality is the largest of the rural municipalities in Lamjung District and covers an area of 597.25km^2 with a total population of 18,759 (CBS 2011). The Municipality is located between 28.251–28.510^{0}N and 84.238–84.619^{0}E. Marsyangdi Rural Municipality is characterised by subtropical, temperate, subalpine, alpine, and nival vegetation. Common plant species include *Abies spectabilis*, *Betula utilis*, *Drepanostachyum falcatum*, *Juniperus* spp., *Quercus lanata*, *Q. semecarpifolia*, *Rhododendron anthopogon*, *R. arboreum*, *R. barbatum*, and *Tsuga dumosa.*

Marsyangdi Rural Municipality has nine wards, of which wards 5, 6, and 7 (Ghermu, Bahundanda, and Bhulbhule VDCs) lie outside Annapurna Conservation Area (ACA) with the remainder of the wards being managed as part of the ACA.

Seasonal transhumance (the movement of cattle and herders between lower valleys in winter and higher pastures in summer) is commonplace within the study area.

METHODS

As a part of a Rufford Small Grant project, a team comprising six members surveyed areas near Ghermu, Bahundanda, and Bhulbhule (Wards 5, 6, and 7 of Marsyangdi Rural Municipality) in May and June, 2018.

An area of 15.54km^2 of potential Red Panda habitat were searched and 12 line transect surveys were done. Length of transects varied between 780m and 1500m depending upon the terrain. Red Panda signs like scat, scratch marks were searched for 12 search-effort hours in the potential habitats. Relative abundance of signs per unit hour and unit kilometer was estimated.

A Canon Powershot SX 50 camera was used to photograph the single, adult *A. fulgens* together with arboreal scratch marks, and scats. A video of the Red Panda was recorded using the same camera. Co-ordinates of localities were ascertained using a hand-held Garmin eTrex10 GPS.

Figure 2. A—*Ailurus fulgens* photographed at Nafada Khola, Bhulbhule VDC, Lamjung District | B—Distinctive Red Panda scratch marks on a tree trunk at Nafada Khola | C—Fresh Red Panda scats on a tree limb at Nafada Khola | D—Red Panda habitat at Nafada Khola showing an understorey of Slender bamboo *Drepanostachyum falcatum*. © Ganesh Ghimire.

RESULTS

New locality record

One adult *Ailurus fulgens* was sighted in the forested area of Nafada Khola (28.438^{0}N & 84.530^{0}E), Marsyangdi Rural Municipality Ward Number 7 (Bhulbhule) on 28 May 2018 at 07.00h. (Fig. 1, Image 1A).

A total of 11 scat groups were observed in 12 line transects of length ranging between 780m and 1500m. Relative abundance of Red Panda scats was 1.44 scat groups per 1,000m walk and 0.92 scats groups per hour search effort in 15.54km^2.

Scratch marks consistent with those of *A. fulgens* were observed on a tree trunk approximately 50m east of the site (Fig. 1, Image 1B).

Scats consistent with those of *A. fulgens* were observed between 3,150m and 3,650m at 11 localities within 200m of the live observation site (Fig. 1, Image 2C). The principal threats to the preferred habitat of the Red Panda within the study area were identified as overgrazing by cattle, man-made forest fires, and the collection of tender shoots and mature stalks of bamboo by local people.

DISCUSSION

This paper provides the first photographic evidence of Red Panda in Lamjung, which was once reported as one of the potential areas for Red Panda (Jnawali et al. 2012). Different researchers have considered the panda sign encounter rate as the basis for abundance analysis. Williams (2004) found 5.1 Red Panda sign/km and 235 pellets per day in the altitudinal range of 2,800–3,000 m in eastern Nepal, Ilam. Pradhan et al. (2001) suggested rate of pellet groups and Red Panda to be 28.83±32.16 and 2.98 ± 2.1/100 hours walk respectively in Singhalila National Park, Darjeeling. In the study area, the scat group encounter rate was found to be 1.44 scat groups per 1,000m walk and 0.92 scats groups per hour search effort on an average which is lower than those encountered by Williams (2004). So, the study area may have lower relative density than Ilam and similar to Jumla. This relative abundance in small spatial scale over short period of study, however, may mislead the results hence an intensive study over a period of time is highly recommended for better understanding of numbers of Red Pandas in this isolated habitat and to meet Red Panda Conservation Action Plan (2019-2023)'s aim of protecting and managing the Red Panda population in Nepal through a holistic approach of conservation including research, monitoring, awareness building, habitat improvement, and threat management (DNPWC and DFSC 2018).

The adult Red Panda, which was observed from a distance of approximately 100m, was seen grooming itself and resting on a moss covered, horizontal limb of a mature Himalayan Birch *Betula utilis* (Image 1A). The tree was growing on a north-west facing slope with a gradient of 39˚ (cp. Wei et al. 1999). The immediate area was dominated by Himalayan Birch, Eastern Himalayan Fir *Abies spectabilis*, and *Rhododendron* spp. with an understorey of Slender Bamboo (*Drepanostachyum falcatum*). This floral matrix compares favourably with Red Panda habitat reported by Yonzon (1989). The nearest water source, the Nafada River, was at a distance of 100m.

Scratch marks considered to have been made by *A. fulgens* were observed on the trunk of a tree 50m east of the live observation site (Image 1B). Red Panda fur was found at the site.

Red Panda scats are spindle-shaped, soft, moist, and green in colour (Image 1C). They are highly diagnostic and are reliable indicators of Red Panda activity. Scats consistent with those of *A. fulgens* were observed at 11 localities within an area of 15.54km^2, each locality lying within 200m of the live observation site (Fig. 1). The localities were situated between 3,150 and 3,650 m. The fresh scats were found on the limbs of trees and on the ground over a two month period (May–June 2018). The size of Red Panda scats can be helpful in determining whether they are those of a mature or immature individual (Yonzon 1989). The size of scats ranged from 35.5mm to 40.3mm in length and 15.2mm to 20.7mm in width. Owing to the limited duration of the field survey, it was not possible to determine the abundance of Red Pandas in the study area but the variation in scat size would seem to indicate the presence of at least one mature and one immature individual and, accordingly, the possibility of a reproductive population.

Several threats to Red Panda habitat were identified within the survey area. Principal amongst these were grazing by livestock and man-made forest fires. Mahato (2004) mentioned overgrazing pressure between 3,200m and 3,400m in prime Red Panda habitats. We observed similar overgrazing pressure caused by the movement of cattle throughout the study area, particularly during seasonal transhumance. Grazing, trampling of vegetation and soil compaction were noted to damage the understorey and to impact negatively on floral regeneration. These movements during the main season when Red Pandas give birth and raise young (May–August) have been identified as a threat to Red Panda populations (Jnawali et al. 2012). Other threats to habitat integrity included the collection of bamboo and

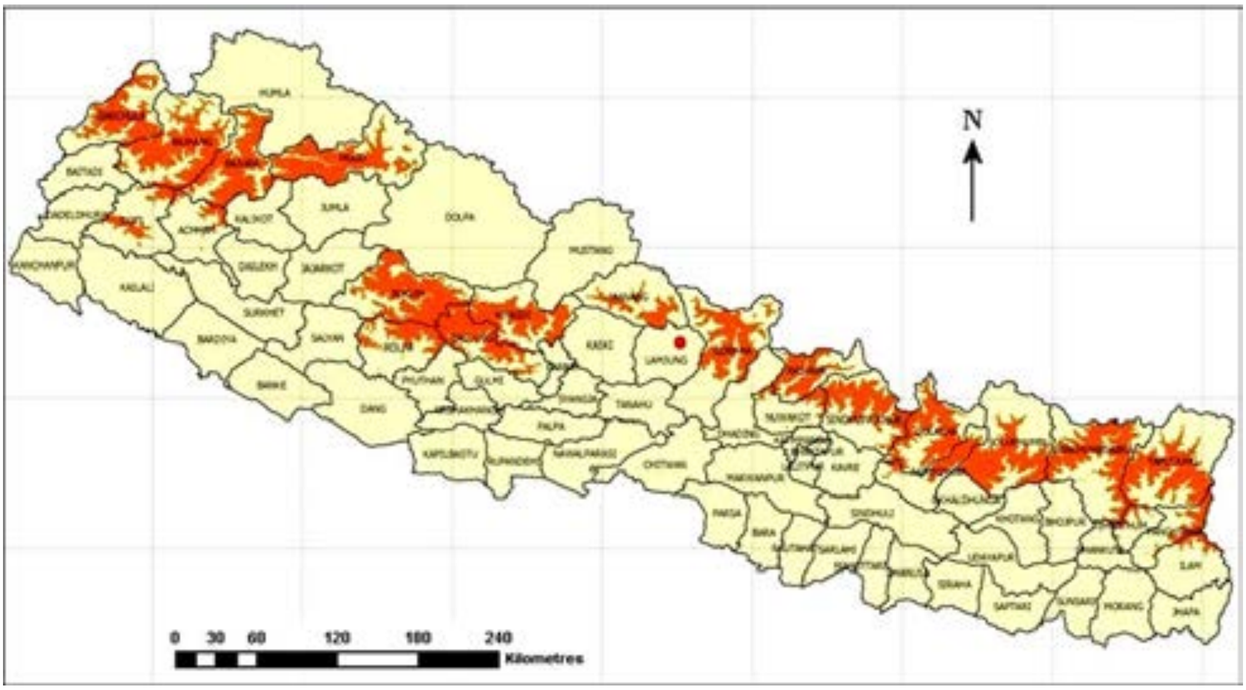

Figure 2. The distribution of *Ailurus fulgens* in Nepal (orange areas) (www.redpandanetwork.org). The new locality record from Nafada Khola in Lamjung District is indicated by the red dot.

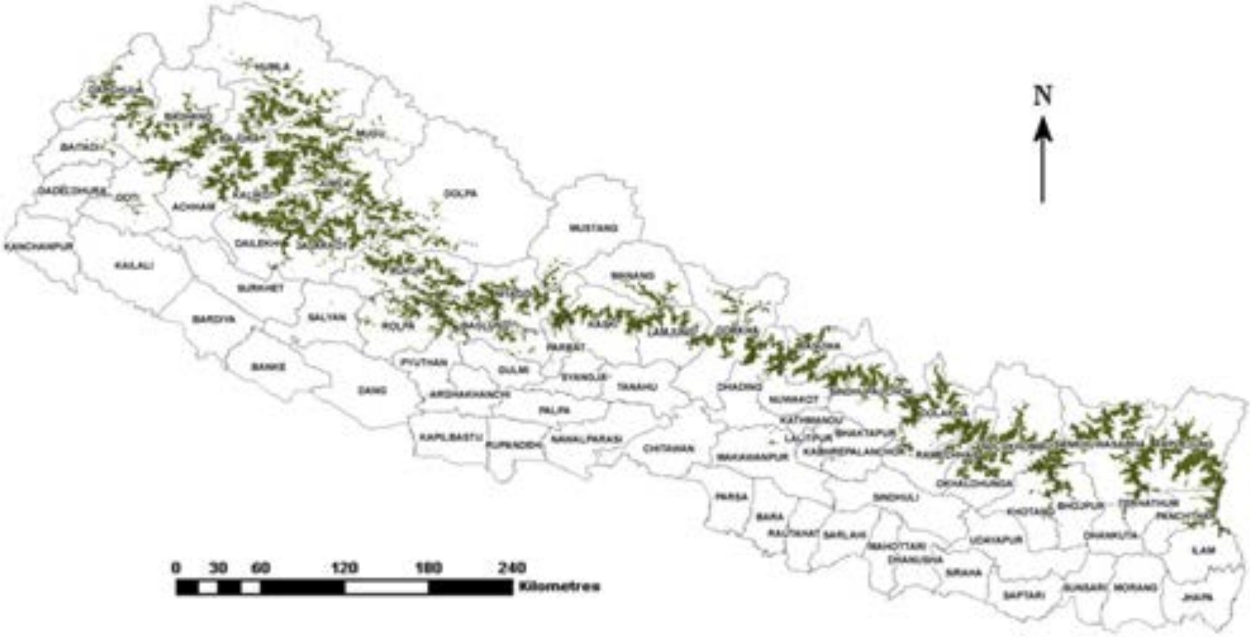

Figure 3. The extent of the preferred habitat of *Ailurus fulgens* in Nepal (dark green areas) (MoFSC 2016).

plants. Tender shoots of bamboo are utilised in cooking while the stalks are used as winter cattle fodder, in the construction of walls and roofs of buildings, to stabilise soil in the fields, for basket weaving, and for producing utilitarian bamboo products such as 'nanglo' (a flat, round, woven tray used for sifting grain) and 'mandro' (a mat for sun-drying cereals). Plants that are collected include *Paris polyphylla* (Himalayan Paris), *Berberis asiatica* (Asiatic Barberry), and *Daphne* spp. (Lokhta).

The current distribution of *A. fulgens* in Nepal is shown in Fig. 2 while Fig. 3 indicates the extent of the Red Panda's preferred habitat throughout the country. Although resident in a broad area of the Nepalese Himalaya, it is clear from a comparison of the two figures that the distribution of *A. fulgens* is markedly disjunct with a notable hiatus between eastern and western subpopulations. It is recommended that further field research be undertaken in Nepal, particularly in Kaski District, which adjoins Lamjung District to the west and from which there are no records of *A. fulgens* despite the presence of suitable Red Panda habitat. Efforts to create corridors between isolated groups to maintain genetically viable populations, as suggested by Bista et al. (2017), should be encouraged.

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PLATINUM
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DHOLE *CUON ALPINUS* (MAMMALIA: CARNIVORA: CANIDAE) REDISCOVERED IN BARDIA NATIONAL PARK, NEPAL

Shailendra Kumar Yadav [1], Babu Ram Lamichhane [2], Naresh Subedi [3], Ramesh Kumar Thapa [4], Laxman Prasad Poudyal [5] & Bhagawan Raj Dahal [6]

[1,2,3] National Trust for Nature Conservation, PO Box 3712, Kathmandu, Khumaltar, Lalitpur 44600, Nepal.
[4] Bardia National Parks, Thakurdwara - 9, Bardia 21800, Nepal.
[5] Departments of National Parks and Wildlife Conservation, PO Box: 860, Kathmandu 44600, Nepal.
[6] Zoological Society of London (ZSL) Nepal, P.O. Box 5867, Bishal Nagar Marg, Kathmandu 44600, Nepal.
[1] shailendrayadav69@gmail.com (corresponding author), [2] baburaml@gmail.com, [3] nareshsubedi@gmail.com,
[4] rameshkthapa@gmail.com, [5] laxpoudyal@gmail.com, [6] bhagawan.dahal2@gmail.com

Abstract: An increasing intensity of camera traps recorded the presence of poorly known and globally Endangered Asiatic Wild Dogs *Cuon alpinus* from different locations in recent years in Nepal. After 18 years since the previous report, we recorded 29 photos and a video of Dholes in four independent detections with an effort of 4,035 trap-nights during camera trap surveys targeted at tigers in the winter of 2016/2017. Solitary dholes were camera-trapped from four locations within 27.45km^2 area in Bardia National Park. The evidence of a dead Dhole probably killed in retaliation shows the threat to the species. Dholes co-exist in Bardia with sympatric carnivores like Tiger *Panthera tigris*, Leopard *Panthera pardus*, and Jackal *Canis aureus*.

Keywords: Asiatic Wild Dogs, camera trapping, jackal, leopard, retaliation, sympatric, tiger.

The Endangered Asiatic Wild Dog or Dhole *Cuon alpinus* (Pallas, 1981) is now confined to <25% of the historic range with an estimated 4,500–10,500 individuals globally (Kamler et al. 2017). They occur in Nepal historically (Pocock 1949) from the southern plains of the Terai to the Himalayan Alpine rangelands but their sighting is not common. Their status in Nepal is poorly understood (Thapa et al. 2013). The studies of Dholes such as status, space use, diet, and conflict with communities come mostly from India and Bhutan (Karanth & Sunquist 1995; Karanth & Sunquist 2000; Srivastava & Singh 2003; Wang & McDonald 2009).

In recent years, with increasing studies and with an extensive coverage of non-invasive camera trap surveys, the presence of Dhole has been recorded in different parts of Nepal. It has been reported from Kanchanjungha conservation area in the eastern Himalaya (Khatiwada et al. 2012), Chitwan and Parsa national parks in central Terai (Thapa et al. 2013), Barandabhar Corridor Forest, Chitwan (Lamichhane et al. 2018), and Api-Nampa conservation area in the western Himalaya (Raju Ghimire, Pers. Comm. 2015). Local people indicate or park records show their presence in Rara and Khaptad national parks, and Dhorpatan Hunting Reserve in the western Himalaya of Nepal.

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No photographic evidence has been presented from the western Terai in Nepal including the Bardia-Banke complex since the 1990s despite the continuous and extensive camera trap surveys and other ecological research on carnivores and their prey base. A pack of Dholes was reported but not confirmed by local people nearby Baghaura Phanta of Karnali Flood Plain in the park (Binti Ram Chaudhary, Pers. Comm. 2019). Thapa et al. (2013) reported the unconfirmed evidence of Dholes from the western Terai. We present here the first photographic evidence of Dhole in Bardia.

MATERIALS AND METHODS

As part of tiger monitoring in the western Terai complex, a camera trapping survey was conducted in the entire Bardia National Park (968km²) and the adjoining forest patches from December 2016 to February 2017. The park is located in the southwestern part of Nepal (28.249^0 – 28.666^0 N & 81.164^0 –81.794^0 E; Fig. 1). It is a part of the trans-boundary Terai Arc Landscape (Wikramanayake et al. 2004). A total of 269 grid cells of 2x2 km^2 were superimposed on a map of Bardia National Park (BNP), and 257 of these were surveyed in

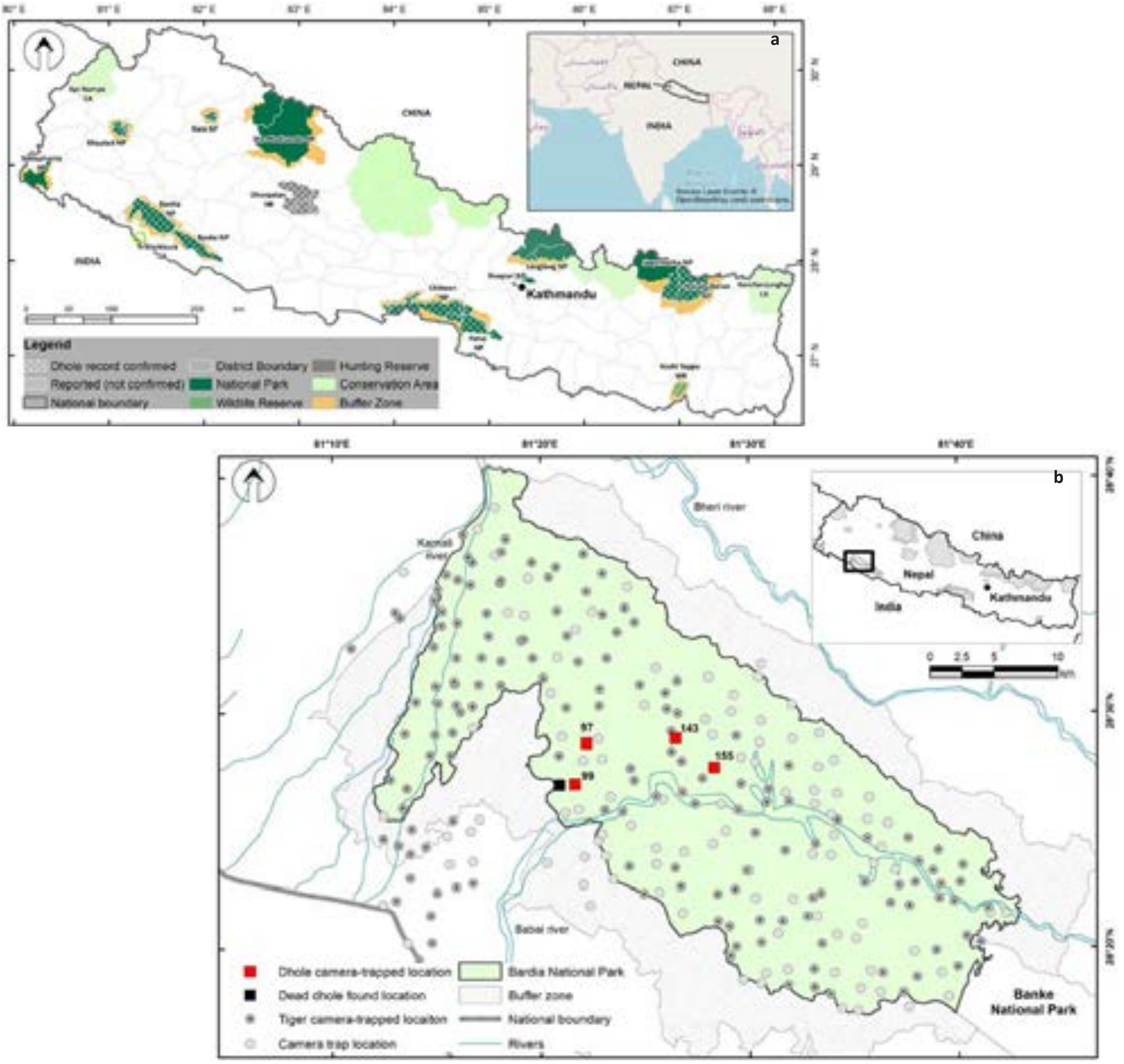

Figure 1. a—Protected areas where Dhole is reported and/or confirmed in Nepal | b—Dhole and Tiger recorded locations during camera trap survey (2016/2017) in Bardia National Park Nepal. Red squares are camera-trapped locations of Dhole, black square is the location where a dead Dhole was found. Tigers were captured in locations shown as a circle with dot inside. Political boundaries may not be accurate.

four shifts (blocks) successively. Twelve grid cells were not surveyed due to the inaccessibility of the terrain or difficulty to find suitable location for camera traps. The camera trap location within each grid cell was selected following an extensive survey of tiger signs. In each sampling point a pair of motion sensor camera traps (Cuddeback Color Model C1, Cuddeback Attack, Reconyx 500, and Reconyx 550) was installed at 45–60 cm above ground on either side of the game trail, forest road or stream bed, maximizing the possibility of tiger capture.

Camera traps were checked every alternate day to observe the photographs of tiger and other species captured on the previous nights. Cameras were active for a minimum of 15 days in each sampling location. Camera trap photos were given unique identification names and sorted species-wise in separate folders. We compared the photos obtained in camera traps with Dhole photos of IUCN Red List of Threatened Species (Kamler et al. 2015) and the National Red List of Mammals of Nepal (Jnawali et al. 2011) to confirm the identification. Photos obtained at one-hour intervals at the same camera location was considered as independent detections.

RESULTS

A total of 4,035 trap-nights of camera-trap effort from 257 sampling locations resulted in 47,871 photographs of 34 mammal species. We found 29 photographs and a video of Dholes from four locations in four independent detections between 10 December 2016 and 04 January 2017 (Table 1; Image 1; Video 1). All the photos were captured during the daytime between 10.22h and 17.39h. All the Dholes' captured locations were within 27.45km^2 area (12km periphery) in the central part of Bardia National Park.

Solitary dholes were captured in all locations but we could not confirm whether they were multiple individuals or repeated capture of a single individual due to the lack of any identification features. Other sympatric carnivores such as Tiger *Panthera tigris* and Striped Hyena *Hyaena hyaena* were also recorded in some of the locations. We found evidence (photograph) of one dead Dhole probably killed by villagers in retaliation in 2012, within 1.7km to the nearest camera trapped location (Image 2). Scat and footprint of possibly a single Dhole was also recorded in multiple locations in the periphery of camera-trapped location during the survey.

DISCUSSION

Our study confirmed the presence of Dhole in the western Terai of Nepal. Other sympatric carnivores in Bardia include Tiger, Leopard, Jackal, and Hyaena. Unlike the solitary Tigers and Leopards, Dholes are known as social hunters with usually 5–10 (up to 25 adults) in a pack (Karanth & Nicholas 1995). In tropical evergreen

Table 1. Details of the camera trap locations where dholes were photo captured in Bardia National Park.

Particulars	Camera trap grid ID			
	97	99	143	155
GPS	28.478^{0}N 87.369^{0}E	28.449^{0}N 87.360^{0}E	28.482^{0}N 87.441^{0}E	28.461^{0}N 87.472^{0}E
Elevation (in m)	228	193	270	293
No. of photo (Video)	5	9	5 (1)	10
No. of individuals	1	1	1	1
Duration of camera trap	09–24 Dec 2016	09–24 Dec 2016	09–24 Dec 2016	28 Dec 2016–12 Jan 2017
Photo captured date and time	22.xii.2016 14.54h	16.xii.2016 10.56h	10.xii.2016 10.22h	04.i.2017 17.39h
Terrain	Flat	Flat	Riverbed	Undulating
Habitat type	Mixed forest	Mixed forest	Mixed forest	Mixed forest
Nearest distance to village (in km)	2.3	0	0.66	0
Distance to nearest tiger captured locations (in km)	3.2	0	10.3	0
Other mammal species captured in the same station	Red Muntjac *Muntiacus muntjac*, Sambar *Rusa unicolor*, Rhesus Macaque *Macaca mulatta*, Large Indian Civet *Viverra zibetha*, Crab-eating Mongoose *Herpestes urva*	Tiger *Panthera tigris*, Striped Hyena *Hyaena hyaena*, Red Muntjac, Terai Grey Langur *Semnopithecus hector*, Indian Crested Porcupine *Hystrix indica*	Indian Crested Porcupine, Sambar, Chital *Axis axis*	Tiger, Indian Crested Porcupine, Sambar, Asian Elephant *Elephas maximus*, Malayan Porcupine *Hystrix brachyura*, Rhesus Macaque

Image 1. Camera trap photograph of a Dhole (2016) (© DNPWC/NTNC/ZSL Nepal).

Image 2. Dhole found dead in Bardia National Park (2012) (© NTNC/BNP).

forests of southeastern Asia, Dholes appear to persist in smaller packs, probably due to the low prey biomass and small size of ungulate prey in these habitats (Kawanishi & Sunquist 2008). In our study, however, we photographed only solitary Dholes. We assume that these Dholes are sub-adult individuals looking for locations to establish territory and form a pack.

Dhole populations are scattered across Nepal but connectivity between them is not understood well (Khatiwada et al. 2011). Dholes occur historically in Terai and Churia (Himalayan foothills) but their exact distribution at present is unknown. It is believed that their population is declining due to various threats (Kamler et al. 2015). Decline in prey species has been identified as a major threat for Dhole (Aantheria et al. 2007; Thapa et al. 2013). In Bardia, widespread prey hunting was reported during the early 2000s at the peak of insurgency between maoist rebels and government (Malla 2009; Bhattarai et al. 2016). This could have caused a decline of the Dhole population in Bardia. With restoration of security and control of hunting, in recent years, the prey density in Bardia has recovered (92 prey species/km^2, Dhakal et al. 2014), which could support a larger carnivore density. On the camera stations of Dhole capture, prey species like Chital *Axis axis*, Red Muntjac *Muntiacus muntjac*, Sambar *Rusa unicolor*, Rhesus Macaque *Macaca mulata*, Terai Grey Langur *Semnopithecus hector*, Indian Crested Porcupine *Hystrix indica*, and Malayan Porcupine *Hystrix brachyura* were also photographed. In addition, Hog Deer *Axis porcinus*, Swamp Deer *Rucervus duvaucelii*, and Four-horned Antelope *Tetracerus quadricornis* occur in Bardia that may serve as prey species of Dhole.

Unlike Chitwan where Thapa et al. (2013) reported no negative interactions with humans, we recorded attacks on livestock by a Dhole and retaliatory killing. Although dholes are pack hunters, our record included a solitary dhole which came into fringe area (close to village). Khatiwada et al. (2011) also reported retaliatory killing of dhole in Kanchanjungha Conservation Area. This emphasizes the threat to the species.

The habitat in Bardia (including grassland and Sal forest) is very similar to other Terai protected areas where Dholes are recorded in higher numbers (Thapa et al. 2013). Dhole camera trapped locations lie in Sal forest of Churia Hills or river floodplain. They were captured in a periphery of ~27km^2 which is about the home range size of a Dhole pack (Karanth & Sunquist 2000). Based on the location of the camera trapped Dhole, we assume that it came through the foothills all the way from Karnali River floodplain of Bardia. In the 1990s, a pack of Dhole was recorded from the Karnali floodplain (Binti Ram Chaudhary, NTNC pers. obs. during 1990s). This reappearance of Dhole in BNP opens up a new possibility to establish a Dhole population in Bardia. An intensive and close monitoring of the Dhole is required to understand their status. An awareness program targeted at local communities about the Dhole is necessary to prevent retaliatory killings. Supplementation of the Dhole in Bardia could be an option to re-establish a population and ensure their survival.

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SHORT COMMUNICATION

OBSERVATIONS OF BROWN MONGOOSE *HERPESTES FUSCUS* (MAMMALIA: CARNIVORA: HERPESTIDAE) IN THE WET EVERGREEN FORESTS OF THE WESTERN GHATS, INDIA

Vignesh Kamath [1] & Kadaba Shamanna Seshadri [2]

[1] Gubbi Labs, #2-182, 2nd Cross, Extension, Gubbi, Karnataka 572216, India.
[1] Current address: School of Geography and the Environment, University of Oxford, Oxford, UK.
[2] The Madras Crocodile Bank Trust and Centre for Herpetology, Post Bag No 4, Mahabalipuram, Tamil Nadu 603104, India
[1] vignesh@gubbilabs.in (corresponding author), [2] seshadri@u.nus.edu

Abstract: Brown Mongoose *Herpestes fuscus* is crepuscular in habit and rarely encountered. Information on its natural history and ecology is limited and consequently its conservation requirements are not well understood. We report observations of a Brown Mongoose feeding on a Nilgiri Langur *Semnopithecus johnii* carcass in the Kalakad Mundanthurai Tiger Reserve, southern India. A camera trap was deployed over the Nilgiri Langur carcass over 10 nights during which, the mongoose visited the carcass on eight nights. Based on the images captured, the mongoose behaviour was broadly categorized as vigilance, feeding, walking and grooming. The mongoose was most active between 03.30–06.00 h and 19.00–00.00 h. Additionally, we report observations of a pair of Brown Mongoose foraging, and an incident of road mortality. These observations will add to the limited current understanding of the species, necessary for assessing its conservation status and identifying interventions.

Keywords: Activity pattern, animal behaviour, camera-trapping, diet, scavenging, Western Ghats.

Brown Mongoose *Herpestes fuscus* is endemic to India and Sri Lanka (Phillips 1984). In India, it has been recorded in the wet evergreen forests of the Western Ghats at altitudes ranging 492–2,032 m (Kumara & Singh 2007; Mudappa et al. 2008; Sreehari et al. 2013). Detailed observations about the natural history and ecology of this species are lacking. Brown Mongoose is thought to be mostly crepuscular; it is often photographed by camera-traps between dusk (18.00h) and dawn (06.00h) from different parts of the Western Ghats (Sreehari et al. 2013; Jathanna 2014; Sreehari et al. 2016; Nikhil 2017).

Brown Mongoose was listed as Vulnerable in the IUCN Red List of Threatened Species in 2008 and subsequently re-assessed as a Least Concern species in 2015, primarily due to frequent sightings and camera trap records since the first evaluation suggesting that the species was much more common than previously assumed (Mudappa et al. 2008; Mudappa & Jathanna 2015). Information on the ecology and natural history of the Brown Mongoose is limited and the threats, if any, are not fully understood. Furthermore, there are no population estimates available across their geographic range (Mudappa & Jathanna 2015). The species has been commonly sighted in human-impacted habitats: it has been seen in coffee and tea plantations and at rubbish dumps close to human habitation (Mudappa & Jathanna 2015). Although the species' diet is yet to be fully understood, it is known to scavenge on the carrion of larger mammals

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like Gaur *Bos gaurus* (Mudappa & Jathanna 2015). We encountered Brown Mongooses whilst working in the Western Ghats of India. Specifically, we report the three sets of observations of Brown Mongoose. First, when a Brown Mongoose was observed to be scavenging on a Nilgiri Langur carcass; second, a pair was seen foraging alongside a road near human habitation; and third, an incident of road mortality.

MATERIALS AND METHODS

Study area

The Western Ghats are an undulating mountain chain running parallel to the western coast of peninsular India for over 1,500km and is a renowned global biodiversity hotspot (Das et al. 2006). Observations of Brown Mongoose reported here were made within the Kalakad Mundanthurai Tiger Reserve (KMTR, Figure 1), located in the southern Western Ghats (8.416^{0}N, 77.166^{0}E to 8.883^{0}N, 77.583^{0}E, c. 900km^2). The reserve encompasses a habitat matrix with dry scrub forests in the lower elevations and wet-evergreen forests in the higher elevations. The area receives a mean annual rainfall of ~3,000mm year^{-1}, from two distinct monsoon seasons in June–September and in October–January (Ganesh et al. 1996).

METHODS

During field work on frogs, a partially eaten carcass of a Nilgiri Langur was encountered along a stream, amidst dense clumps of native bamboo *Ochlandra travancorica* on 11 September 2016 (8.550^{0}N & 77.366^{0}E, 1200m). A Reconyx HC500 hyperfire trail camera was deployed to record animals scavenging on the Nilgiri Langur carcass. The camera-trap was deployed for 10 days, set up 0.5m above ground and 1m away from the carcass and was programmed to photograph three times when triggered. Each camera trap image of the animal was considered a record and was pooled over 30 and then 60-minute intervals for analysis. The camera trap sensed the temperature and we noted the weather conditions every day. Data were analyzed using Microsoft Excel®. Foraging behaviour of Brown Mongoose was observed

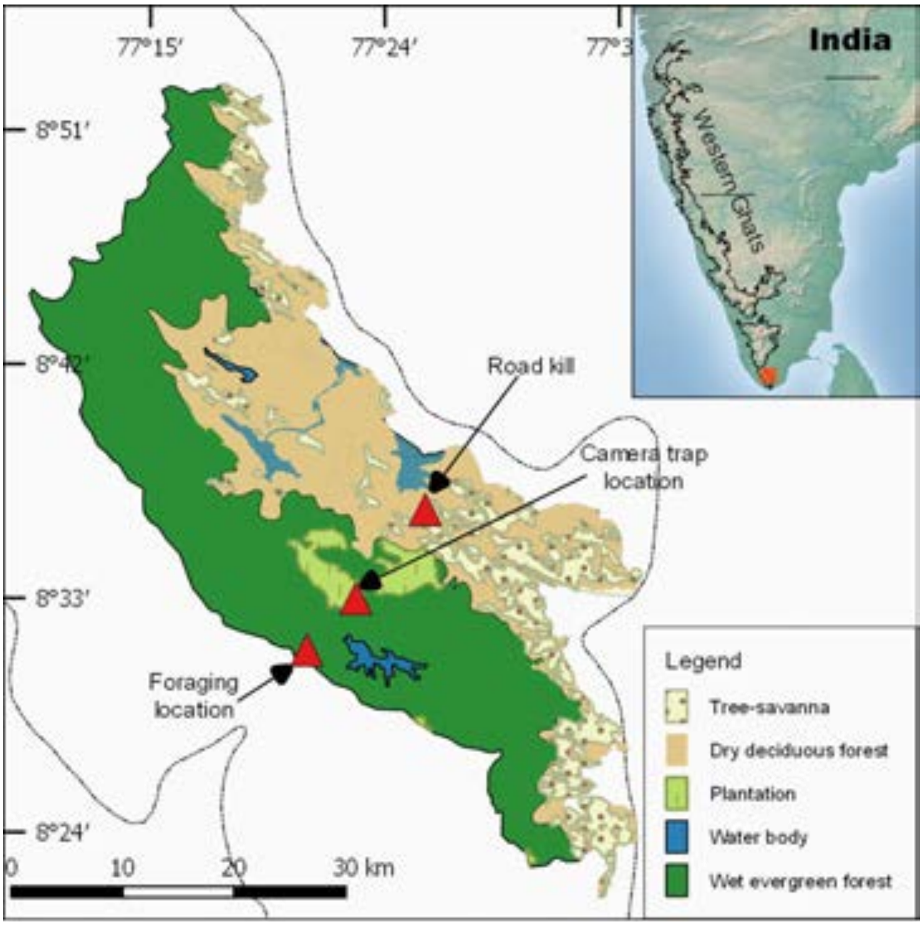

Figure 1. Kalakad Mundanthurai Tiger Reserve showing major habitat types and Brown Mongoose observation sites.

using a pair of binoculars (Zeiss Terra HD, 8X40) and recorded with a Sony® HDR-SR10 camera. Locations were marked using a hand-held Garmin ® etrex HC GPS device.

RESULTS

Brown Mongoose was observed to visit the Nilgiri Langur carcass on eight camera trap nights (501 images, Figure 3; Table 1). The mongoose was found to be most active near the carcass just before dawn (03.30–06.00 h, 312 images) and at night (19.00–00.00 h, 96 images). The mongoose was found to be active even later in the morning (08.30–09.00 h, 84 images). The temperature during this period ranged 15–20 °C. The sky was mostly clear during the day with occasional light drizzles in the evenings.

Scavenging behaviour

Using the camera trap images (n=501), we identified four behavioural aspects of the Brown Mongoose: feeding—where the animal is actively eating the carcass (Image 1a); vigilance—when the animal is alert, head raised and looking away from the carcass (Image 1b); walking—when the mongoose walked or ran into or out of the camera trap frame (Image 1c) and lastly, grooming—when the mongoose is licking or scratching itself (Image 1d). The mongoose fed on the carcass in 63% of images (Figure 4) and feeding emerged to be a predominant activity (Figure 5). Over the 10 trap nights, the mongoose was not alongside the carcass between 00.00–02.59 h, 06.00–06.59 h, 09.00–18.59 h, and 22.00–22.59 h (Figure 5). The other animals observed to be feeding on the carcass were a White-bellied Rat *Rattus* sp., and a Wild Boar *Sus scrofa* which took the carcass away. A Brown Palm Civet *Paradoxurus jerdoni* was also recorded near the carcass but was not feeding.

Foraging behaviour

On 26 September 2016, a pair of Brown Mongooses were observed on the Nalmukh–Kodayar road in Upper Kodayar (8.550^{0}N & 77.350^{0}E, 1,300m). Upper Kodayar is a small settlement with approximately 20 houses. The mongooses were observed walking on the road at 17.45h and observed until 18.00h. Initially one individual was seen and the second one emerged from the vegetation along the road verge. Both individuals were aware of our presence as they paused occasionally and stared in our direction. When amidst the grasses, they began to dig vigorously using their fore-limbs. They both appeared to be feeding before they crossed over to the other side, one after the other. They were seen to be vigilant before crossing the road and whenever they sensed our presence. They also were observed to be grooming their tails (https://youtu.be/m4QybRkLzhM). After the mongooses were gone, we walked up to the spot where they were digging and found that they had scraped into the mud, presumably looking for roots or invertebrates. It is unlikely that they were feeding on the root because we did not perceive any damage to the grass or its roots (Image 2). We had observed them to be walking past fine sand on the road and were able to locate foot prints on the sand as well (Image 3). On three nights between 12 September and 14 October 2016, we observed a solitary Brown Mongoose foraging in a small rubbish dump where three households in Upper Kodayar discard waste. This location is within a kilometre of the previous sighting where the mongoose pair was foraging.

Table 1. Hourly number of occurrences of different activities of the Brown Mongoose near the Nilgiri Langur carcass.

Time	Feeding	Vigilance	Walking	Grooming
00.00–00.59	-	-	-	-
01.00–01.59	-	-	-	-
02.00–02.59	-	-	-	-
03.00–03.59	45	27	22	3
04.00–04.59	152	36	12	-
05.00–05.59	11	2	2	-
06.00–06.59	-	-	-	-
07.00–07.59	3	-	6	-
08.00–08.59	74	8	2	-
09.00–09.59	-	-	-	-
10.00–10.59	-	-	-	-
11.00–11.59	-	-	-	-
12.00–12.59	-	-	-	-
13.00–13.59	-	-	-	-
14.00–14.59	-	-	-	-
15.00–15.59	-	-	-	-
16.00–16.59	-	-	-	-
17.00–17.59	-	-	-	-
18.00–18.59	-	-	-	-
19.00–19.59	2	6	10	-
20.00–20.59	26	15	13	-
21.00–21.59	3	6	6	-
22.00–22.59	-	-	-	-
23.00–23.59	-	-	9	-

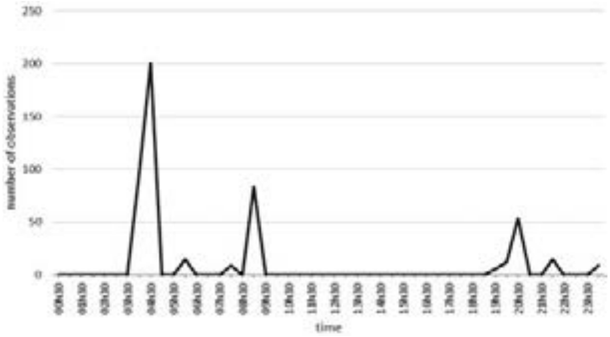

Figure 2. Half hourly observations on the activity of the Brown Mongoose visiting the Nilgiri Langur carcass over a span of 10 days based on camera-trap image captures.

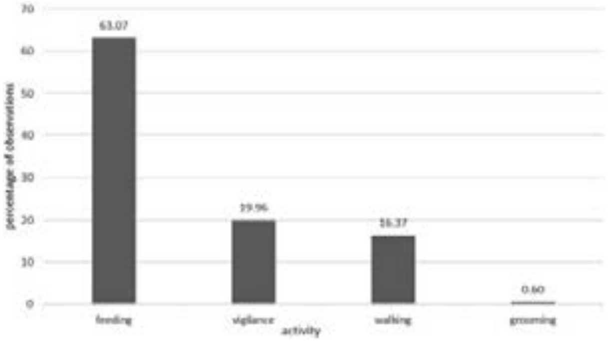

Figure 3. Behaviour of the Brown Mongoose while it was near the Nilgiri Langur carcass.

Image 1. Observations of different behaviours by the Brown Mongoose while it was near the Nilgiri Langur carcass. a—feeding on the carcass | b—vigilance - looking towards one direction with its head raised | c—walking out of the frame | d—grooming itself.

Incident of road morality

On 27 September 2011, one male Brown Mongoose was found dead on the road Manimuthar-Manjolai road at 16.46h (8.606^{0}N & 77.425^{0}E, , 400m, Image 4). It was determined as a male because of its penis; however, the scrotal sac was indistinct (Image 4c). Although most parts of the KMTR are restricted to tourists and vehicular movement, several vehicles are allowed up to Manjolai between 06.00h and 18.00h. The other vehicle movement is from vehicles of the Bombay Burmah Tea Estate, Tamil Nadu Electricity Board, local forest department, researchers and four public buses. One of us (KSS) was on a motorbike heading towards Upper Kodayar. Because the mongoose carcass was found in the evening, it would be unlikely that the individual was knocked down the previous night or early during the day as no other vehicle had run over it. The road passes through dry deciduous forests and Ruddy Mongoose *Herpestes smithii* are commonly encountered in the area.

Image 2. Scrape marks made by Brown Mongoose. A—position of scrape along road | b—close up at centre of scrape, no broken roots visible. Pen knife for scale is 90mm in length.

Image 3. Paw print of the Brown Mongoose (encircled). Arrow indicates front of paw. Pen knife for scale measures 90mm in length.

Discussion

The Brown Mongoose is endemic to the Western Ghats-Sri Lanka biodiversity hotspot (Mudappa & Jathanna 2015). The ecology of this species has not been studied systematically but has been improved by anecdotal observations leading to the down listing of the threat status from Vulnerable to Least Concern as per the IUCN Red List criteria (Mudappa & Jathanna 2015). The mongoose has been sighted with in 17 locations in the

Image 4. Adult male Brown Mongoose on road before Manjolai Estate. A—carcass on road | b—close up of face | c—ventral region.

southern Western Ghats of India up to elevations 450–2,000 m (Sreehari et al. 2016). The habitat where the Brown Mongoose has been observed range from human habitations near forests; coffee and tea plantations; wet evergreen forests and upper montane evergreen forests (Mudappa & Jathanna 2015; Sreehari et al. 2016).

The Brown Mongoose was considered to be rare and nocturnal but there appears to be increasing evidence of them being active even during the day. Our observation of the mongoose actively foraging during day light hours confirms that the animal is active during early parts of the day. Furthermore, our sighting of the mongoose scavenging on a Nilgiri Langur re-affirms previous observations of the mongoose scavenging on mammal carcasses.

This report on its behaviour adds to the growing body of knowledge about such understudied taxa and could potentially aid conservation efforts in future. The Brown Mongoose was recorded in human-impacted areas and close to human habitations, including rubbish dumps. Although the animal is found near human habitations, they might continue to be threatened by vehicular movement on roads and other linear intrusions such as railway lines bisecting their habitat. Road mortality is a well-documented threat to wildlife and several solutions such as blocking vehicle movement during the night hours have been proposed and successfully adopted in India (Seshadri & Ganesh 2015). Similar measures may be necessary to protect this species, especially where they are locally abundant. Indiscriminate use and disposal of plastics and other refuse may pose an additional threat to this species where it occurs in human dominated landscapes. Individuals of Brown Mongoose are known to forage near garbage dumps, and they may end up consuming plastic and other hazardous material which could have cascading effects on other taxa. The full extent of this species' adaptation to such altered habitats remain unknown. Support for research both locally (permits) and internationally (funds) to understanding the ecology, population structure and behaviour of this species and other elusive nocturnal mammals would contribute immensely to science and conservation.

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SHORT COMMUNICATION

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FURTHER STUDIES ON TWO SPECIES OF THE MOTH GENUS *PARALEBEDA* AURIVILLIUS (LEPIDOPTERA: BOMBYCOIDEA: LASIOCAMPIDAE) FROM NORTHWESTERN INDIA

Amritpal Singh Kaleka [1], **Devinder Singh** [2] & **Sujata Saini** [3]

[1,2] Department of Zoology & Environmental Sciences, Punjabi University, Patiala, Punjab 147002, India.
[3] Department of Biological Sciences, Indian Institute of Science Education & Research, SAS Nagar Mohali, Punjab 140306, India.
[1] apskaleka@gmail.com (corresponding author), [2] devinder.ss.61@gmail.com, [3] sujatasaini@iisermohali.ac.in

Abstract: The known Indian species of the moth genus *Paralebeda* Aurivillius namely *femorata* (Menetries) and the type species *plagifera* (Walker) have been taxonomically treated. The external morphological characters particularly species specific features such as wing venation and genitalic characters have been studied and illustrated. The genus diagnosis has been updated and a key has also been formulated.

Keywords: Genitalia, *femorata,* Lasiocampidae, *Paralebeda*, *plagifera,* taxonomy.

Abbreviations: 1A—First anal vein | 2A—Second anal vein | 3A—Third anal vein | AED—Aedeagus | ANT. APO—Anterior apophyses | AP.S—Apical spur | CRP. BU—Corpus Bursae | CRN—Cornuti | CU$_1$—First cubital vein | CU$_2$—Second cubital vein | CU.A—Cubile arms | DU.BU—Ductus Bursae | DU.EJ—Ductus Ejaculatorius | HM—Humeral Cell | HM.V—Humeral Vein | JX—Juxta | JX.P—Juxtal process | M$_1$—First median vein | M$_2$—Second median vein | M$_3$—Third median vein | PAP.A—Papilla Analis | PO.APO—Posterior apophyses | R$_1$—First radial vein | R$_2$—Second radial vein | R$_3$—Third radial vein | R$_4$—Fourth radial vein | R$_5$—Fifth radial vein | RS—Radial Sector | SA—Saccus | SC—Subcosta | SC+R$_1$—Subcosta+ First Radial vein | SIG—Signum | SOC—Socii | TG—Tegumen | UN—Uncus | VIN—Vinculum | VLV—Valva.

Aurivillius (1894) established the genus *Paralebeda* with *plagifera* (Walker) as its type species. This genus is represented by large sized moths with elongated wings having a pointed apex. The medial dark coloured loop in its forewing is its diagnostic feature. This genus is known from Palaearctic and Indo-Australian regions.

Lajonquière (1980) and Holloway (1982) reviewed this genus. Holloway (1987) included two species, i.e., *uniformis* Holloway and *lucifuga* (Swinhoe) of this genus in the *Moths of Borneo*. Chang (1989) and Kishida (1992) listed its species namely *femorata* (Menetries) from Taiwan and Nepal, respectively. While giving short taxonomic notes on four Asiatic species of this genus, Zolotuhin (1996) described three new subspecies, viz., *femorata*, *armata*, and *crinodes paos*. He considered *uniformis* Holloway as a subspecies of *crinodes* (Felder). Zolotuhin *et al*. (1997) reported three new species, namely, *lagua*, *achillesi*, and *pluto* along with one subspecies *achillesi mindoroensis* of this genus from the Philippines. Recently, Irungbam (2017) and Shah et al. (2018) reported *femorata* (Menetries) and *plagifera* (Walker) from Manipur and West Bengal whereas

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Irungbam & Irungbam (2018) listed *plagifera* (Walker) from Bhutan.

At present, this genus is represented by seven species namely *achillesi* Zolotuhin et al., *crinodes* (Felder), *femorata* (Menetries), *lagua* Zolotuhin et al., *lucifuga* (Swinhoe), *plagifera* (Walker), and *pluto* Zolotuhin et al. Out of these, only two species, *plagifera* (Walker) and *femorata* (Menetries), are known from India.

MATERIAL AND METHODS

While undertaking surveys, 14 adult representatives of the genus *Paralebeda* had been collected from Himachal Pradesh and Uttarakhand and identified with the help of relevant literature. The method proposed by Zimmerman (1978) was followed for the preparation of permanent slides of forewings and hindwings. The genitalia had been dissected out as per the method proposed by Robinson (1976). The terminology for naming genitalic parts is after Klots (1970).

RESULTS AND DISCUSSION

In the present study, the external morphological characters including the wing maculation, wing venation and particularly the external genitalic features of two species namely *plagifera* (Walker) and *femorata* (Menetries) of the genus *Paralebeda* Aurivillius have been studied on a uniform pattern. These characteristics have been included in the diagnosis and differentiation of these two species.

Genus *Paralebeda* Aurivillius

Aurivillius, 1894, Dt. Ent. Z. Iris. 7: 178; Holloway, 1987, *Moths Borneo*, 3: 13; Zolotuhin et al., 1997, Lasiocampidae Philippines, 17: 150; Zolotuhin & Witt, 2000, Lasiocampidae Vietnam, 3(11): 71; Zolotuhin & Pinratana, 2005, Lasiocampidae Thailand, 4: 83; Youqiao & Chunsheng, 2006, Fauna Sinica, 47: 303–304.

Type species: *Lebeda plagifera* Walker

Distribution: India, China, Korea, Nepal, Pakistan, Philippines, Russia, Taiwan, Thailand, Vietnam.

Diagnosis: Labial palpus long, upturned. Antennae bipectinate, well developed in males, shorter in females. Thorax dressed with scales. Forewing broad, elongated, apex pointed, medial dark colored loop prominent; discal cell closed; vein 1A+2A fused, without forming a basal fork; 3A present; M_3 from lower angle of cell; M_1 stalked with R_5 and R_4; R_3 and R_2 highly stalked; Sc from base of wing not reaching up to apex, conjoined with costa and R_1. Hindwing with discal cell closed; vein 1A and 2A present; 3A present; veins M_3 and M_2 stalked; $Sc+R_1$ anastomosing with Rs to form a short humeral cell, humeral veins obsolete. Legs clothed with scales; foreleg with epiphysis; mid-tibia and hind-tibia with a pair of minute tibial spurs; claws distinct. Abdomen clothed with scales. Male genitalia indistinct uncus; socii distinct; valva weak; cubile arms of vinculum flattened, without any tooth-like serrations; aedeagus tubular with diagnostic shape of apical spur. Female genitalia with corpus bursae globular, with or without signum; papilla analis prominent, armed with setae.

Key to the Indian species of genus *Paralebeda* Aurivillius

1. General colouration darker; forewing with medial loop broader, tornus with spot; vein R_4 from middle of common stalk of M_1 and R_5; hindwing with vein Rs beyond middle of cell; male genitalia with saccus rounded; cubile arms broader, petiolate; aedeagus of moderate size with two apical spurs ………………………… *femorata* (Menetries)

- General colouration paler; forewing with medial loop narrower, tornus without any spot; vein R_4 from before middle of common stalk of M_1 and R_5; hindwing with vein Rs before middle of cell; male genitalia with prominent, cone-shaped saccus; cubile arms narrow, not petiolate; aedeagus short with one apical spur ………………………………………. *plagifera* (Walker).

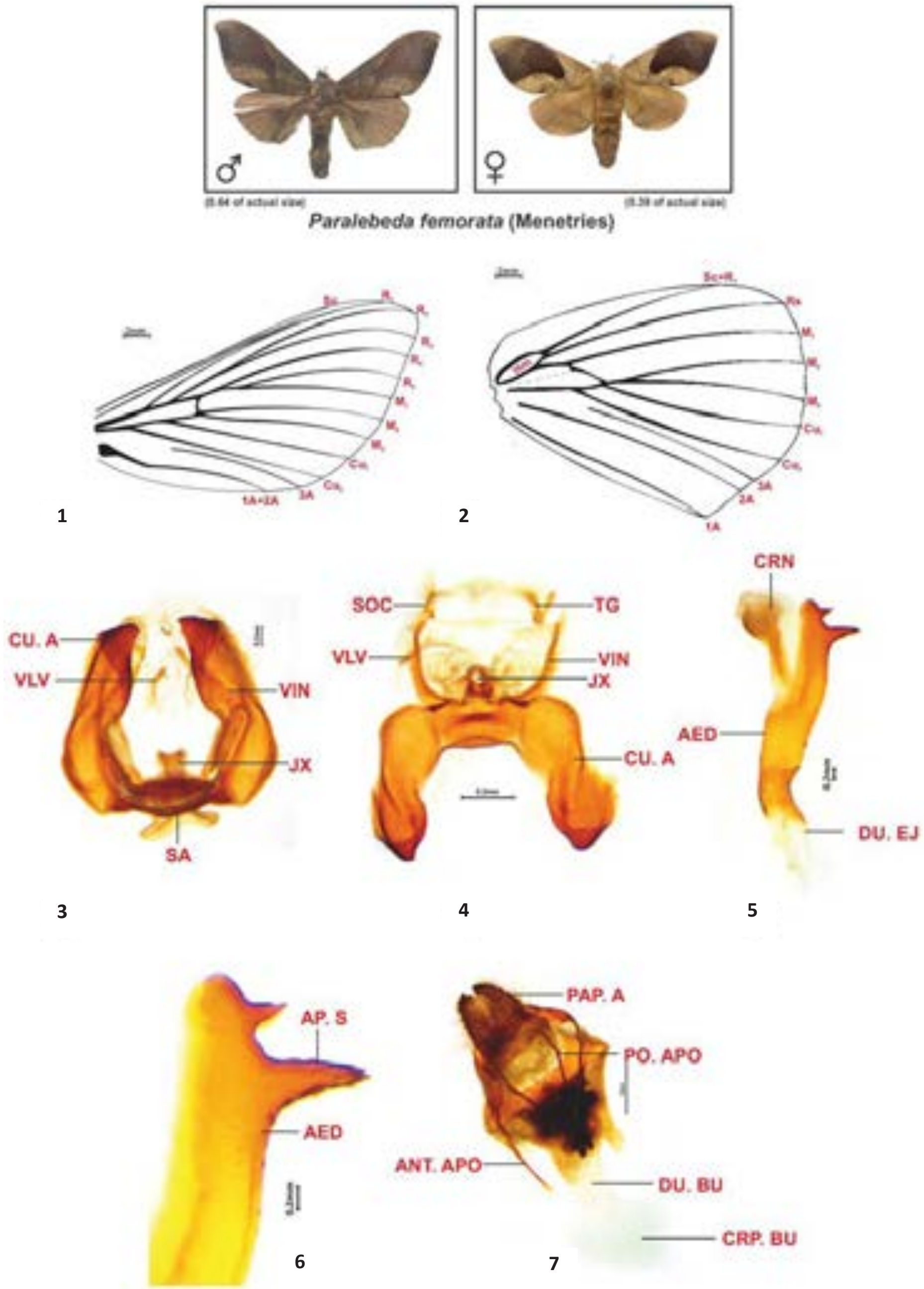
Paralebeda femorata (Menetries)
(Images 1–7)

Lasiocampa femorata Menetries, 1855, Bull. Acad. Imp. Sci. St. Petersburg, 17(24): 218.

Paralebeda femorata Menetries: Zolotuhin, 1996, Asiatic Lasiocampidae, 13(17): 247; Hauenstein et al., 2011; Lasiocampidae Bhutan, 67: 32.

Diagnosis: Head with vertex and frons clothed with fuscous scales. Labial palpus with fuscous scales. Antennae with scape and shaft fuscous. Thorax, collar and tegula clothed with fuscous scales; underside fuscous. Legs with fuscous scales. Abdomen covered with fuscous scales; underside fuscous.

Wing maculation: Forewing with ground colour fuscous, females brown; markings black; antemedial line distinct; medial loop broader, medial portion prominent with hump starting from inner margin, reaching below costa, upper zone of loop darker and reddish-brown; loop broader and less humped in females; a prominent dark black spot on tornus; postmedial line indistinct; submarginal dotted line present; underside fuscous, loop and tornal spot distinct. Hindwing with ground colour fuscous without any distinct pattern; antemedial and



Images 1–7. *Paralebeda femorata* (Menetries): 1—forewing | 2—hindwing | 3–4—male genitalia-ventral view | 5—aedeagus | 6—aedeagus-distal end | 7—female genitalia.

postmedial lines obsolete; medial line paler; underside fuscous.

Wing venation: Forewing with apex pointed; one-thirds length of wing; 3A present, basal half obsolete; 1A+2A from base of wing, basal area swollen; Cu_2 from one-thirds of cell; Cu_1 from just beyond two-thirds of cell; M_2 just above lower angle of cell; M_1, R_5 and R_4 stalked, R_4 from middle of common stalk of M_1 and R_5; R_3 and R_2 stalked from three-fourths of cell; R_1 from beyond middle of cell. Hindwing rounded; discal cell one-thirds length of wing; 3A present, basal area obsolete; Cu_2 from three-fourths of cell; Cu_1 from lower angle of cell; M_3 and M_2 well stalked from lower angle of cell; M_1 from upper angle of cell; Rs from beyond middle of discal cell; $Sc+R_1$ anastomosing with Rs to form a narrow humeral cell, shorter than discal cell, humeral veins absent.

Wing Expanse: male: 72–78 mm; female: 98mm

Body Length: male: 38–40 mm; female: 55mm

Male genitalia: Uncus absent; tegumen weakly developed, nearly membranous, lateral sides having setosed pads representing socii, slightly knobbed near vinculum; vinculum 'U' shaped, both arms narrow, medially dilated, oval, ending into rounded saccus; cubile arms larger, broader and petiolate, well sclerotized; juxta well developed, well sclerotized, dilated proximally, constricted in the middle, notched at distal end. Valva reduced, nearly membranous, basal one-third portion setosed; distally ending into finger-like projection with rounded apex. Aedeagus of moderate size, moderately sclerotized, constricted near proximal end; ductus ejaculatorius entering directly into proximal end; distal end having two apical spur, distal one shorter, both spur with dentate walls; vesica armed with minute denticles representing cornuti.

Female genitalia: Corpus bursae short, oblong, membranous without any signum; ductus bursae of moderate length, membranous, slightly dilated towards distal end; ductus seminalis originating from its middle; apophyses narrow with their apices dilated, posterior ones slightly longer than anterior ones; papilla analis well developed, long, setosed with micro and macro setae.

Material Examined: Himachal Pradesh: PUP-LA-78a-c, Basantpur, 9.vii.2013, 3 females (31.208° N, 77.174° E); PUP-LA-78d-e, Habban, 7.vii.2014, 2 males (30.915° N, 77.325° E); PUP-LA-78f-j, Jhumar, 10.vii.2015, 4 males, 1 female (32.560° N, 76.161° E).

Distribution: India (Himachal Pradesh, Jammu & Kashmir, Punjab, Uttarakhand); Bhutan; northeastern and eastern China; Nepal; northeastern Pakistan; northern Vietnam; Russia; Taiwan.

Remarks: The present species can be easily differentiated from *plagifera* (Walker) on the basis of general colouration, wing expanse and genitalic features.

Paralebeda plagifera (Walker)
(Images 8–13)

Lebeda palgifera Walker, 1855, List Spec. Lepid. Insects Colln. Br. Mus., 6: 1459.

Paralebeda plagifera Walker: Zolotuhin & Witt, 2000, Lasiocampidae Vietnam, 3(11): 72; Zolotuhin & Pinratana, 2005, Lasiocampidae Thailand, 4: 83-84; Youqiao & Chunsheng, 2006, Fauna Sinica, 47: 305; Zolotuhin & Ihle, 2008, Lasiocampidae Laos, 20(4): 14; Hauenstein et al., 2011; *Lasiocampidae* Bhutan, 67: 31.

Odonestis plagifera Walker: Grunberg, 1911, In Seitz, Pal. Schmett., 2: 175; Hampson, 1892, Moths India, 1: 427.

Odonestis urda Swinhoe, 1915, Ann. Mus. Nat. Hist. London, 16(8): 178.

Parlebeda urdabacki de Lajonquiere, 1980, Z. Arbeitsg, Osterr. Entomol., 32(1/2): 25.

Diagnosis: Head with vertex and frons clothed with brown scales. Labial palpus with brown scales. Antennae with scape and shaft brown. Thorax, collar and tegula furnished with brown scales; underside brown. Legs with brown scales. Abdomen covered with brown scales; underside brown.

Wing maculation: Forewing with ground colour brown suffused with reddish; antemedial line indistinct; medial loop narrow, short hump starting from inner margin, reaching just below costa, upper zone of loop darker and reddish-brown; postmedial line indistinct; dotted submarginal line distinct; cilia brown; underside brown, loop paler. Hindwing with ground colour brown; medial line distinct; postmedial and submarginal lines indistinct; cilia brown; underside brown.

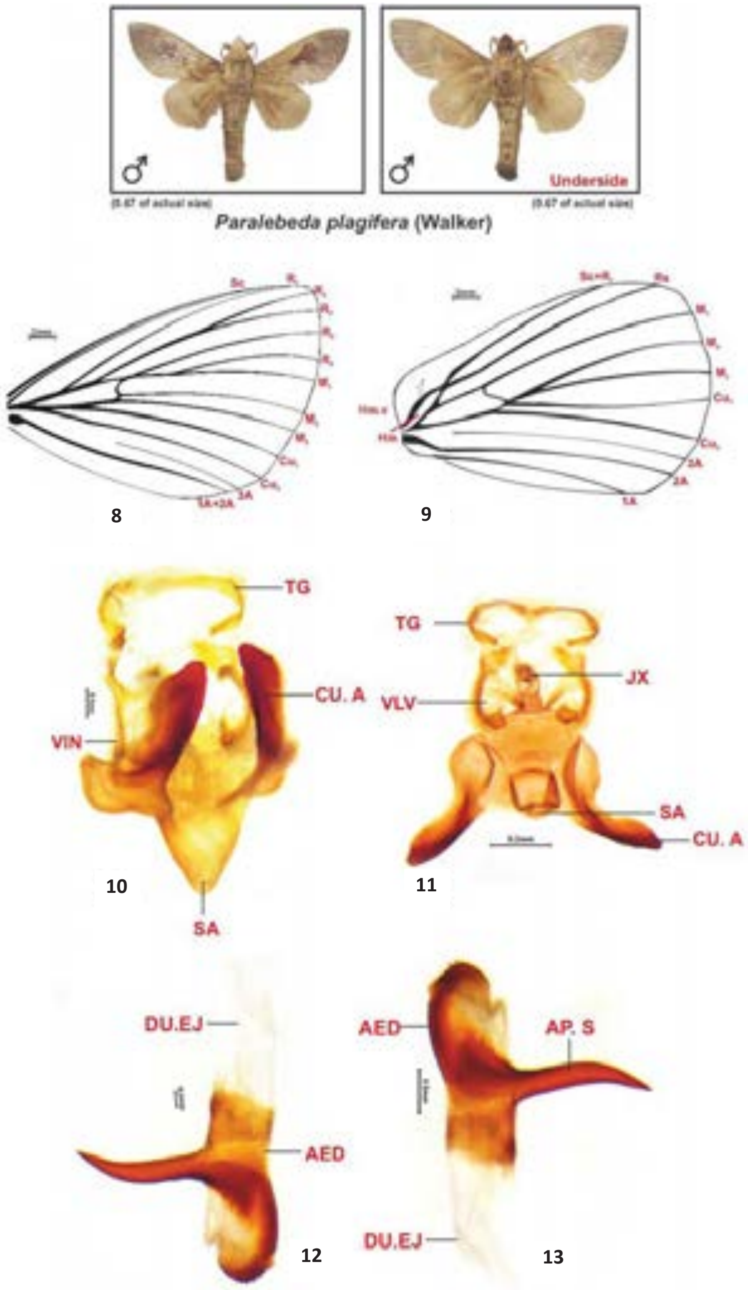
Wing venation: Forewing with apex pointed; discal cell one-thirds length of wing; 3A present, basal half obsolete; 1A+2A from base, basal area swollen; Cu_2 from one-thirds of cell; Cu_1 from two-thirds of cell; M_2 from above lower angle of cell; M_1, R_5 and R_4 well stalked, R_4 just before middle of common stalk of M_1 and R_5; R_3 and R_2 highly stalked from before upper angle of cell; R_1 from beyond middle of cell. Hindwing rounded; discal cell one-thirds length of wing; 1A present, 2A with basal area swollen; 3A present, basal area obsolete; Cu_2 from well before lower angle of cell; Cu_1 from lower angle of cell; M_3 and M_2 well stalked from lower angle of cell; M_1 from upper angle of cell; Rs before middle of cell; $Sc+R_1$ anastomosing with Rs to form narrow humeral cell, shorter than discal cell, humeral veins obsolete.

Wing Expanse: male: 62–64 mm; female: not examined

Body Length: male: 39–40 mm; female: not examined

Male genitalia: Uncus absent; tegumen weakly developed, 'C' shaped, lateral sides having minute setosed pads representing socii; vinculum well developed, triangular, ending into cone-shaped saccus with rounded end; cubile arms flattened, not petiolate, well sclerotized; juxta semi-sclerotized, oblong. Valva reduced, lower lobe triangular, setosed with rounded ending; upper lobe narrow with rounded apex, medial area membranous. Aedeagus short, moderately sclerotized; ductus ejaculatorius entering directly into proximal end; distal end rounded, armed with prominent dentations; medially having a prominent, long well sclerotized spur almost of same size of aedeagus; vesica without any distinct armature.

Material Examined: Himachal Pradesh: PUP-LL-



Images 8–13. *Paralebeda plagifera* (Walker): 8—forewing | 9—hindwing | 10–11—male genitalia-ventral view | 12–13—aedeagus.

77a-b, Sangla, 22.vi.2014, 2 males (31.425° N, 78.265° E); PUP-LA-77c, Serighat, 11.viii.2013, 1 male (31.050° N, 77.069° E); Uttarakhand: PUP-LA-77d, Kandikhal, 21.v.2014, 1 male (30.433° N, 78.405° E).

Distribution: Northern and central India; Bhutan; Laos; northern Myanmar; northern Thailand; northern Vietnam; southern and southeastern China.

Remarks: Its caterpillars are polyphagous in nature and feed on *Cupressus funebris* Endlicher, *Ginkgo biloba* Linnaeus, *Phoebe nanmu Gamble*, *Morus alba* Linnaeus, *Morus nigra* Linnaeus, *Quercus acutissima* Carruthers, *Quercus dentate* Thunberg, *Maesa chisia* Hamilton, *Citrus reticulata* Blanco, *Citrus maxima* Merrill, and *Theobroma cacao* Linnaeus (Robinson et al. 2001).

The external genitalic features in insects are highly species specific in general and of high relevance particularly in Lepidoptera. In the present study, these characters such as indistinct uncus; distinct socii; reduced valva; distinct cubile arms and tubular aedeagus with diagnostic shape of apical spur in male genitalia and globular corpus bursae, with or without signum and prominent papilla analis in female genitalia proved as important features of taxonomic significance for diagnosis and differentiation of these taxa.

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Short Communication

The genus *Grewia* (Malvaceae: Grewioideae) in Andaman & Nicobar Islands, India with a conservation note on the endemic *G. indandamanica*

K.C. Kishor[1] & **Mayur D. Nandikar**[2]

[1,2] Naoroji Godrej Centre for Plant Research (NGCPR), 431 Lawkim Campus, Shindewadi, Shirwal, Satara, Maharashtra 412801, India.
[1] kishorkeycee@gmail.com (corresponding author, 3999), [2] mnandikar@gmail.com

Abstract: The genus *Grewia* in Andaman & Nicobar Islands is reviewed with its identification key, descriptions, distribution and photographs. This article provides correct taxonomic identity of *G. laevigata* and *G. multiflora* with comprehensive morphology and conservation assessment for the endemic *G. indandamanica*.

Keywords: Angiosperm, Grewioideae, island biogeography, Red List, taxonomy, threatened.

Grewia L. (Malvaceae-Grewioideae) is a pantropical genus with about 300 recognised species (Bayer & Kubitzki 2003). In India the genus is accountable for c. 31 species (Daniel & Chandrabose 1993) out of which seven are endemic, viz.: *G. gamblei* J.R.Drumm. ex Dunn, *G. heterotricha* Mast., *G. indandamanica* J.L.Ellis & L.N.Ray, *G. kothayarensis* Murugan & Manickam, *G. palodensis* E.S.S.Kumar, A.E.S.Khan, Binu & S.M.Almeida, *G. pandaica* J.R.Drumm. ex Dunn, and *G. umbellifera* Bedd. (Singh et al. 2015). Among the 31 species of *Grewia*, 23 are known to occur in peninsular India (Kumar et al. 2001) and two of the species *G. laevigata* and *G. indandamanica* are reported only from the Andaman & Nicobar Islands. *Grewia indandamanica* is different from the rest of the *Grewia* species by having solitary flowers. It was described from the Saddle Peak National Park, North Andaman by J.L. Ellis & L.N. Ray (1991) and is not known from elsewhere so far. Since 1991, no further study adds to the distribution and status of *G. indandamanica*. The first ever collection of *G. indandamanica* was made by N.P. Balakrishnan & N.G. Nair in 1976 (PBL3807, PBL3808) from Saddle Peak National Park, but they failed to recognise it as a new species. Later in 1987 J.L. Ellis made further collection from the Saddle Peak and described it as a new species. Though Ellis & Ray (1991) provided an appropriate description, it lacks information on abundance, distribution range and threat assessment. The number of *Grewia* species occurring on the Islands are limited in comparison to the mainland. We recognized three species, viz., *G. laevigata*, *G. multiflora*, and *G. indandamanica* based on the field collections as well as herbarium and literature survey from the Andaman & Nicobar Islands. *Grewia laevigata* Vahl in India was misapplied as *G. multiflora* Juss. by various authors (Masters 1868, 1874; Brandis 1906; Dunn 1915;

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Ramamoorthy 1976; Matthew 1983). Chung (2006) reduced *G. pedicellata* Roxb., *G. umbellata* Roxb. ex DC., and *G. acuminata* Juss. as synonyms of *G. laevigata*. The former three are found conspecific to *G. laevigata* by sharing the similarities in habit, leaf shape, inflorescence pattern and fruit lobes. Similarly, the names *G. serrulata* DC., *G. glabra* Blume, *G. didyma* Roxb. ex G. Don, *G. disperma* Rottler ex Spreng., and *G. diplocarpa* Thwaites are vaguely used for most prior *G. multiflora*, which have been discussed with their detailed nomenclature.

All the three known species of the *Grewia* in Andaman & Nicobar Islands have been keyed out below for easy identification with detailed descriptions, distribution, phenology, and photographs. In addition, a conservation assessment has been conducted for *G. indandamanica* with a detailed geography, abundance, distribution range and population at Saddle Peak National Park.

STUDY AREA AND METHODS

Andaman & Nicobar Islands are an archipelago of islands situated in the Bay of Bengal. They fall under one among the seven union territories of India. For *Grewia indandamanica*, the forest patches from the Saddle Peak National Park (SPNP) were studied in detail. SPNP of North Andaman lies between 13.157°–13.166°N & 093.002°–093.010°E with a total area of 32.54km². It supports stunted, evergreen type of forests along the sea shores to moist deciduous forests and open scrub forests in some pockets on the hill top, the south-west as well as north-east monsoon provide heavy precipitation from June to mid-October. This heavy precipitation supports tropical vegetation and substantial diversity of plants. SPNP exhibits tropical evergreen as well as moist deciduous forests. Many endemics have been recorded from the Island and SPNP alone because of this peculiar habitat (Parkinson 1923; Ellis 1989; Reddy et al. 2004; Ramana et al. 2013). The occurrence and distribution of remaining two species (*G. multiflora* & *G. laevigata*) have been studied based on live plants as well as herbarium specimens placed at CAL, PBL and TCD (Thiers, http://sweetgum.nybg.org/science/ih/). *Grewia multiflora* is found throughout the Andaman & Nicobar group of Islands including the foothills of SPNP, whereas *G. laevigata* is found mainly in the Nicobar group of Islands. Protologues were gathered from BHL, the types from C, CAL, P and PBL (Thiers, http://sweetgum.nybg.org/science/ih/), JSTOR & Plants of the World Online (http://www.plantsoftheworldonline.org) to understand the global distribution range.

GeoCAT, an open source tool has been used for the threat assessment of *Grewia indandamanica*. (http://geocat.kew.org/). The Area of Occupancy (AOO) and Extent of Occurrence (EOO) have been determined by setting the value of cell width during the AOO analysis as standard IUCN value. Distribution and location details of *G. indandamanica* at Saddle Peak National Park are also provided.

Key to *Grewia* in Andaman and Nicobar Islands

1. Small or scandent shrub; leaves ovate, elliptic or oblong, secondary nerves less than 6, apex acute or abruptly acuminate, base rounded or subcordate, or obtuse or truncate; petals oblong or ovate; stigma 4-lobed 2
1. Large shrub or small tree; leaves lanceolate, elliptic-lanceolate or ovate-lanceolate, secondary nerves 7(–9), apex acuminate, base attenuate; petals broadly elliptic or obovate; stigma usually 5-lobed (rarely 4-lobed) .... *G. multiflora*
2. Inflorescence axillary or supra axillary, 3–5(–7) flowered; petals oblong; fruit depressed globose, 1–1.3(–2) cm across, frivolously 2–4 lobed .... *G. laevigata*
2. Inflorescence axillary, solitary; petals ovate; fruit globose, to 1cm across, deeply 2–4 lobed (rarely unlobed) .... *G. indandamanica*

TAXONOMIC TREATMENTS

Grewia multiflora Juss.

Ann. Mus. Natl. Hist. Nat. 4: 89. 1804

Image 1 (E–F)

G. serrulata DC., Prodr. 1: 510. 1824

G. glabra Blume, Bijdr. Fl. Ned. Ind. 3: 115. 1825

G. disperma Rottler ex Spreng., Syst. Veg., [ed. 16] 2. 579. 1825, syn. nov.

G. didyma Roxb. ex G. Don, Gen. Hist. 1: 549. 1831

G. diplocarpa Thwaites, Enum. Pl. Zeyl. 31. 1858, syn. nov.

G. laevigata auct. non Vahl 1790: Mast., Fl. Brit India 389. 1874; Cooke, Fl. Pres. Bombay 1: 143. 1901; Duthie, Fl. Gangetic Plain 116. 1903; Brandis, Indian Trees 96. 1906.

Type: PHILIPPINES: *Annon. s.n.* in *Herb. A. de Jussieu* 12554 (Holotype: P-JU).

A much-branched large shrub or small-tree, 3–6 m high. Stem terete, twigs pale green, glabrous, rarely sparsely puberulous, bark grey when mature. Stipules lanceolate, 1.5–2 mm long, base densely puberulous, apex narrow, caducous. Leaves alternate; petiole 0.8–1.2

cm long, puberulous; lamina lanceolate, elliptic, elliptic-lanceolate, rarely oblong-lanceolate, 7–20 × 3–7 cm, adaxial surface glabrous, or sparsely tufted hairy, abaxial surface glabrous; base attenuate, or rarely rounded, apex acuminate, acumen 1–2 cm long, margin serrate or serrulate; 3-nerved, prominent on both surfaces, secondary nerves 7–9 pairs, sparsely puberulous, prominent on both the surfaces. Inflorescences axillary, rarely supra-axillary, triflorous, 1–3 cm long, solitary or in clusters of 2 or 3, pedunculated cymes, peduncles 1–2.5 cm long, densely puberulous. Flowers: bracts narrowly lanceolate, unlobed, 1–2 × 0.5 mm, sparsely puberulous outside, glabrous-glabrescent inside; pedicel 1–1.5(–2) cm long, densely puberulous; sepals linear-lanceolate, ensiform, 8–13 × 2–2.5 mm, densely tufted puberulous outside, glabrous inside, pale green or stramineous, 1–2 grooved, white, margin incurved; petals broadly elliptic or ovate, 2–3.5 × 1.5–1.9 mm, apex sharply acute, margin entire, glabrous outside and inside (densely tufted puberulous around the gland); gland obovoid, c. 2 × 2 mm, densely puberulous; stamens numerous, filaments 2–6 mm long, filiform, glabrous, anthers lemon yellow, reniform, c. 0.5 mm across; androgynophores (torus) 2–4 mm long, cylindrical, lower portion glabrous, upper portion densely tufted puberulous, 5-grooved; ovary globose, 4-locular, c. 1 mm across, densely puberulous; styles 4–7 mm long, slender, glabrous, stigma irregularly 5-lobed (rarely 4-lobed), lobes spreading, recurved. Drupes dark green at young, deep black when dry, 0.7–1.2 cm across, deeply 2-partite, 4-lobed (rarely 2–3-lobed), sparsely puberulous, stone 3–4. Seeds brown, one in each locule, ovoid, obovoid, glabrous, brown.

Phenology: July–November

Traditional Uses: The stem fibres used for cordage and leaves as fodder. The tree is also recorded as one of the hosts of the Indian lac insect (Dagar & Singh 1999).

Distribution & habit: India: throughout mainland and Andaman & Nicobar Islands (North, Middle, South Andaman, Little Andaman, and Little Nicobar, Car Nicobar, Great Nicobar Islands); Thailand, Sumatra, Java, Borneo, and Philippine (fide Chung 2006). It grows along the secondary forest margins, roadsides and open scrub forests.

Specimens examined: INDIA: Andaman & Nicobar Islands. 13.i.1976, N. Bhargava 3428 (PBL); 28.i.1981, R.K. Premanath 8329 (PBL), 30.xi.2015, L. Rasingam 25861 (PBL); 13.xi.2007, R.P. Pandey 26186 (PBL); 25.xi.2009, C. Murugan 27924 (PBL); 5.x.2017, K.C. Kishor & Nandikar 1609 (NGCPR, PBL); 23.xi.1976, N.G. Nair 4886 (PBL); 20.i.1998, G.S. Lakra & M. Tigga 16984 (PBL); 8.x.2017, K.C. Kishor & Nandikar 1611 (NGCPR). Bihar. 14.xi.1963, Shetty 274 (CAL). Kerala. 31.xi.1965, J.L. Ellis 26393 (MH); 16.ii.1982, C.N. Mohanan 73307 (MH); 7.x.1983, A.G. Pandurangan 79277 (CAL); 2.vi.2017, K.C. Kishor 1096 (CAL, NGCPR). Maharashtra. 31.viii.2016, K.C. Kishor 1009 (CAL, NGCPR); 2.xii.2017, K.C. Kishor 1619 (CAL, NGCPR). Uttarakhand. 21.ix.2018, K.C. Kishor 1632 (CAL, NGCPR). West Bengal. 18.xi.1873, J.S. Gamble 1707 (MH); 1879, King s.n. (MH); 28.ix.2018, K.C. Kishor 1635 (CAL, NGCPR). PHILIPPINES: May 1907, A.D.E. Elmer 7923 (L); 12.x.1992, E.B. Barbon 8936 (L). THAILAND: 20.viii.2002, 25.viii.2002, D.J. Middleton, S. Suddee & C. Hemrat 1254, 1295 (L).

Note: *Grewia multiflora* is one taxon highly misinterpreted by different authors. Masters (1868) and Brandis (1906) synonymised *G. multiflora* under *G. laevigata* Vahl. Masters (1874) recognised *G. multiflora* as a distinct species and synonymised *G. serrulata*, he himself, Cooke (1901) and Duthie (1903) have misread the element *G. multiflora* as *G. laevigata*, while Dunn (1915), Ramamoorthy (1976) and Matthew (1983) misinterpreted as *G. disperma* Rottler ex Spreng. Chung (2006) provided clarity to this long-standing complex in his revision of genus *Grewia* for Malaysia and Borneo and raised as distinct species. In addition, based on field survey, literature review, and critical study based on the protologues and types of *G. disperma* and *G. diplocarpa* we have found both to be conspecific with *G. multiflora* in habit, inflorescence and lobed drupe character and are reduced to synonymy in *G. multiflora* here.

***Grewia laevigata* Vahl**

Symb. Bot. 1: 34. 1790.

Image 1 (C–D)

G. acuminata Juss., Ann. Mus. Hist. Nat. Paris 4: 91, t.48, f.2, 1804

G. umbellata Roxb. ex DC., Prodr. 1: 509. 1824

G. *pedicellata* Roxb. Fl. Ind. 2: 585. 1832

Type: India orientali: Koenig s.n. (Holotype: C [IDC microfiche: Vahl no. 35 II, 2-3], barcode C10019544).

A scandent shrub, to 6m tall. Twigs glabrous or sparsely stellate puberulous. Stipules caducous, narrowly lanceolate, 0.8–1.5 mm long, adaxial glabrous, abaxial sparsely stellate puberulous. Leaves alternate; petiole 0.5–1 cm long, glabrescent, or stellate puberulous; lamina elliptic, oblong, ovate or rarely lanceolate, 7–14 × 4–7cm, glabrous or sparsely stellate puberulous on both surfaces; base obtuse, truncate, margin serrulate, denticulate, or crenate, apex abruptly acuminate, acumen 0.5–1.5 cm long; 3-nerved, prominent on both the surfaces, secondary nerves 4–6 pairs, sparsely

Image 1. The genus *Grewia* from Andaman & Nicobar Island: A–B—*G. indandamanica* flowering & fruiting twig, C–D—*G. laevigata* flowering & fruiting twig, E–F—*G. multiflora* flowering & fruiting twig. © A & B— Mayur D. Nandikar | B & C—Lim and Leonardo | D & E—K.C. Kishor.

puberulous, midrib and secondary nerves prominent and raised on both surfaces. Inflorescences axillary, supra-axillary, leaf opposed, rarely terminal or subterminal, (3–)5–7(–13) flowered cymes, solitary or in 2–3 clusters. Flowers: bracts linear, lanceolate, 2–6 mm long, densely puberulous outside, glabrous inside; pedicels 7–15 mm long, densely stellate puberulous; sepals linear, lanceolate, 9–15 × 1–2 mm, densely puberulous outside, pale green, glabrous inside, white, deeply reclinate after opening; petals oblong, 5–6 × 1–1.5 mm, apex acute, lower portion on an orbicular clawed appendage, glabrous outside, sparsely puberulous at base, densely stellate puberulous around the glands; glands ovoid, c. 2 × 2 mm, glabrous; stamens numerous, filaments 5–10 mm long, filiform, glabrous, anther lemon yellow, reniform, c. 0.5mm across; androgynophores (torus) 1.5–3(–4) mm long, slightly grooved, lower portion glabrous, upper portion densely stellate puberulous; ovary globose or subglobose, 1–1.5(–2) mm across, 4-locular, densely stellate puberulous; style 6–8(–10) mm long, glabrous; stigma 4-lobed, narrow depression at the centre. Drupe depressed-globose, 1–1.3(–2) × 1–1.6 cm, sparsely stellate puberulous, glabrescent when mature, frivolously 2–4 lobed, rarely entire, each lobe with single stone (pyrene). Seeds not seen.

Phenology: Throughout the year.

Distribution & habit: So far, the species is recorded from Andaman & Nicobar Islands (Little Andaman, Little Nicobar and Great Nicobar Islands), India, and southeastern Asia (Myanmar, Sumatra, Thailand, Peninsular Malaysia, Java, Borneo, Philippines and Singapore) (fide Chung 2006). The species grows as a straggler or a scandent shrub in the secondary forests.

Traditional Uses: The stem fibres are used for ropes and strings and the leaves are applied to cuts and abrasions. In Nicobar a leaf decoction is given to women after delivery to reduce pain and to clean parturition wastes (Dagar & Singh 1999).

Specimens examined: INDIA: Andaman & Nicobar Islands. Great Nicobar, 20.viii.1975, N.P. Balakrishnan 2991 (PBL); 28.ix.1978, N.G. Nair 7118I (PBL); 27.x.1979, R.P. Dwivedi (PBL); 12.x.1980. D.K. Hore 8284 (PBL); 10.vi.2001, J. Jayanthi 18343 (PBL). Little Nicobar, 13.iv.2001, C. Murugan 28411 (PBL); 27.x.2009, C. Murugan 27771 (PBL). South Nicobar, 28.ix.1989, S.K. Srivastava 14911 (PBL). South Andaman, 26.ii.2004, K. Karthikeyan 21398 (PBL); s. dat, Wallich s.n. in Herb. DC (G-DC barcodes G00209183, G00209184). MALAYSIA: 1822, Wallich 1084 (NY, K, CAL); v.1889, Brutis s.n. (P barcode P05371354). MYANMAR: 1861, Herb. Griffith 626 (P). THAILAND: ix.1923, Kerr 7838 (TCD); v.1928, Kerr 15627 (TCD); vi.1928, Put 1763 (TCD).

Note: *Grewia laevigata* Vahl in India was deliberated as *G. didyma, G. disperma* or *G. glabra* (which are now synonyms of *G. multiflora*) by various authors viz., Don (1831), Wight & Arn. (1834), Masters (1874), Cooke (1901), Gamble (1902), Duthie (1903), and Brandis (1906) which is found erroneous after a critical evaluation of type, protologue and herbarium specimens.

In India, the correct use of the name *G. laevigata* was overlooked by many authors. Masters (1874) considered *G. umbellata* Roxb. ex DC. and synonymised *G. pedicellata* Roxb. but miscarried the distribution from India. Later, Daniel & Chandrabose (1993) accepted *G. acuminata* Juss. with the extended distribution to Andaman & Nicobar Islands. Subsequently, Debnath (1999) followed Daniel & Chandrabose (1993) and recognised *G. acuminata* from the Andaman & Nicobar Islands. Chung (2006) recognised the priority of *G. laevigata* over the others in his revision. After a thorough investigation of literature and field survey throughout India, we found *G. umbellata, G. acuminata* and *G. pedicellata* are agreeing with the type of *G. laevigata* Vahl at Copenhagen (C) and distributed only in Andaman & Nicobar Islands and hence propose the use of *G. laevigata* as the correct name.

Grewia indandamanica J.L. Ellis & L.N. Ray

in Candollea 46(2): 341. 1991.

Image 1 (A–B)

Type: INDIA: Andaman & Nicobar Islands: North Andaman, Saddle Peak National Park, 720m, 18.x.1987, J.L. Ellis 12775 (Holotype: CAL, barcode CAL 6356! isotypes: PBL, barcodes PBL0018, PBL0019! PBL0020!)

A branched shrub or small tree, 1–1.5 m high. Stem terete, bark ashy grey, wrinkled; branches grey, sparsely stellate puberulous. Stipules subulate, to 1mm long, base broad, margin sparsely stellate puberulous. Leaves alternate, faintly conduplicate; petioles 0.4–0.5 cm long, densely pubescent; lamina ovate-elliptic, 3–9 × 2.3–3 cm; base rounded to subcordate, apex acuminate, margin crenate-serrate; 3-nerved, prominent on both surfaces, sparsely stellate puberulous along the veins. Inflorescences axillary, one-flowered, 1–1.5 cm long, pedunculate cymes, peduncle 8–10 mm long, sparsely puberulous. Flowers: bracts linear-lanceolate, c. 2mm long, caducous; pedicel to 1cm long, puberulous with dense ring of stellate puberulous at the apex; sepals linear-lanceolate, 1–1.5 × 0.2–0.3 cm, base truncate, puberulous outside, green, 3–4 grooved, glabrous inside, white, margin incurved, stellate tomentose; petals white, ovate, 4–4.5 × 1–1.5 mm, apex obtuse, margin entire, glabrous outside, densely stellate pubescent along the margin from base to nearly half of the petal length, also around the glands, otherwise sparsely stellate pubescent at rest of the margin; glands obovoid, 2–2.5 × 0.8–1.4 mm, glabrous; stamens numerous, filaments nearly equal, 6–8 mm long, filiform, glabrous, anthers lemon yellow, reniform, c. 0.5mm across; androgynophore (torus) 2–2.5 mm long, lower portion glabrous, upper portion stellate pubescent, slightly 4-grooved; ovary globose, 1–1.5 mm across, 4-locular,1 ovule in each, densely puberulent; style to 1cm long, slender, densely stellate puberulous at base, sparsely puberulous in middle, glabrous towards apex; stigma 4-lobed, faintly spreading, recurved. Drupe 1cm across, shiny, black when dry, deeply bilobed–tetralobed (rarely entire to trilobed), testa wrinkled, stellate puberulous. Seeds brown, ovoid, one in each locule, glabrous, vestite with papery metallic silver cap, attached to 1mm long funicle.

Phenology: September to November.

Distribution & habit: Endemic to the Saddle Peak National Park, North Andaman. It is distributed in the open, stunted, hilltop forests at an elevation of 600–721 m.

Note: *Grewia indandamanica* is so far recorded only from type locality. It grows as a shrub or small tree to 1.5m high in the open, rocky habitats of Saddle Peak. It can be easily distinguished by faintly conduplicate leaves, acuminate apex and solitary flowers whereas the allied species constitutes flat leaves and three to multi-flowered cymes.

Specimens examined: INDIA: Andaman Islands. North Andaman, Saddle Peak National Park, 02.xii.1976, N.P. Balakrishnan & N.G. Nair 4797 (PBL); 18.x.1987, J.L. Ellis 12775A (CAL); 18.x.1987, J.L. Ellis 12775B-D (PBL); 23.vii.2001, R. Sumathi 17976 (PBL); 7.x.2017, K.C. Kishor & Nandikar 1610A–G (NGCPR), 1610H–I (CAL), 1610J–K (PBL).

CONSERVATION ASSESSMENT

Under the project 'Revision of genus *Grewia* L. (Malvaceae-Grewioideae) from India', the authors surveyed population of *Grewia indandamanica* at its type locality Saddle Peak National Park during October 2017; and it is claimed as endemic to the type locality. The expeditions to other parts of North Andaman also failed to locate any further populations of the species. Many of the localities, however, were inaccessible and also avoided due to local tribal settlements.

The species occurs at the hilltop peak at an elevation range of 600–721 m. It shares a scrub vegetation with other flowering plants like *Murdannia saddlepeakensis* M.V. Ramana & Nandikar, *Sonerila andamanensis* Stapf & King, *Dioscorea pentaphylla* L., *Atalantia monophylla* (Roxb.) DC., *Crotalaria uncinella* Lam. subsp. *elliptica* (Roxb.) Polhil, etc. The plant mostly grows in small open patches along the rocky cliffs. The total number of individuals were counted to be less than 80 from three known localities and their adjacent areas. At one place the species grows in proximity among the rocky boulders. It was also noted that the number of young individuals were less than five which depicts a very low recruitment rate which could be natural or anthropogenic. The previous collections made in 1976 and 1987 (N.P. Balakrishnan & N.G. Nair 4797 [barcodes PBL3807, PBL3808]; J.L. Ellis 12775 [barcodes PBL0018, PBL0019, PBL0020, CAL6356]) also reported the population as scarce.

Table 1. Distribution and location details of *Grewia indandamanica* at Saddle Peak National Park.

	Location	Lat., Long.	Elevation (in m)
1	Saddle Peak National Park Mount Top	13.166^{0}N, 093.002^{0}E	604
2		13.159^{0}N, 093.006^{0}E	721
3		13.157^{0}N, 093.010^{0}E	621

Based on GeoCAT (Moat 2007), the AOO and EOO were estimated as 8km² and 0.119 km² in the Saddle Peak National Park (Table 1). Although the localities fall within the protected area of National Park, but these habitats lies in close vicinity to the tourist and trekking areas, hence the quality of habitat is degrading. It is also assumed that the population has gone down since the previous collection of this species in 1976 and 1987. The species is highly restricted to its unique habitat of the open stunted forest patch at an elevation of 600–721 m and less than 100 mature individuals are known. Loss of population from any of the three locations will cause a drastic depletion in the population size. Based on these information and IUCN guidelines (IUCN 2019) *G. indandamanica* can be assessed as Endangered (EN) [B1+2ab(i, ii, ii, v)c(i,ii,iii,iv); C2a(i); D].

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THREE GRASSES (POACEAE), ADDITIONS TO THE FLORA OF ANDHRA PRADESH, INDIA

Anil Kumar Midigesi [1] & **Boyina Ravi Prasad Rao** [2]

[1,2] Department of Botany, Sri Krishnadevaraya University, Ananthapuramu, Andhra Pradesh 515003, India.
[1] anilbcdl@gmail.com, [2] biodiversityravi@gmail.com (corresponding author)

Abstract: *Bothriochloa insculpta* (A. Rich.) A. Camus, *Cyrtococcum patens* (L.) A. Camus var. *patens* and *Sacciolepis myosuroides* (R. Br.) A. Camus. (Panicoideae: Poaceae) are three grasses that were collected from Chittoor and Visakhapatnam districts of Andhra Pradesh. They are being reported here as new records for Andhra Pradesh State. Descriptions, illustrations, and important notes are provided for all the species.

Keywords: Angiosperm, Chittoor, new records, Visakhapatnam.

Abrrevations: SKU—Sri Krishnadevaraya University Herbarium

Floristic explorations in different parts of Andhra Pradesh from 2016 to 2017, yielded a few grass specimens from the Horsley Hills of Chittoor District, Paderu cultivated fields and the Lambasingi Ghat of Visakhapatnam District. After careful examination and identification with obtainable literature (Fischer 1928; Bor 1960; Kabeer & Nair 2009) these have been identified as *Bothriochloa insculpta*, *Cyrtococcum patens* var. *patens*, and *Sacciolepis myosuroides.*

Bothriochloa Kuntze comprising 35 species are distributed in Africa, Australasia, Europe, North & South America, Pacific, temperate & tropical Asia (Clayton et al. 2006), and represented by 17 species in India (Kabeer & Nair 2009), of which four are recorded in Andhra Pradesh (Pullaiah 2018). *Cyrtococcum* Stapf, comprising 15 species are distributed in Africa, Australasia, North & South America, Pacific, temperate & tropical Asia (Clayton et al. 2006) and represented by six species in India (Moulik 2007; Kabeer & Nair 2009) of which five are known to be distributed in Andhra Pradesh. *Sacciolepis* Nash comprising about 25 species are distributed in Africa, Australasia, North & South America, Pacific, temperate & tropical Asia (Clayton et al. 2006) and represented by four species in India (Karthikeyan et al.1989; Moulik 1997; Kabeer & Nair 2009), of which two are recorded from Andhra Pradesh.

A perusal of the literature pertaining to Andhra Pradesh State (Fischer 1928; Moulik 1997; Kabeer & Nair 2009; Pullaiah 2018) revealed that these three grass taxa have not been reported till date and the present collections form new distribution records for the state.

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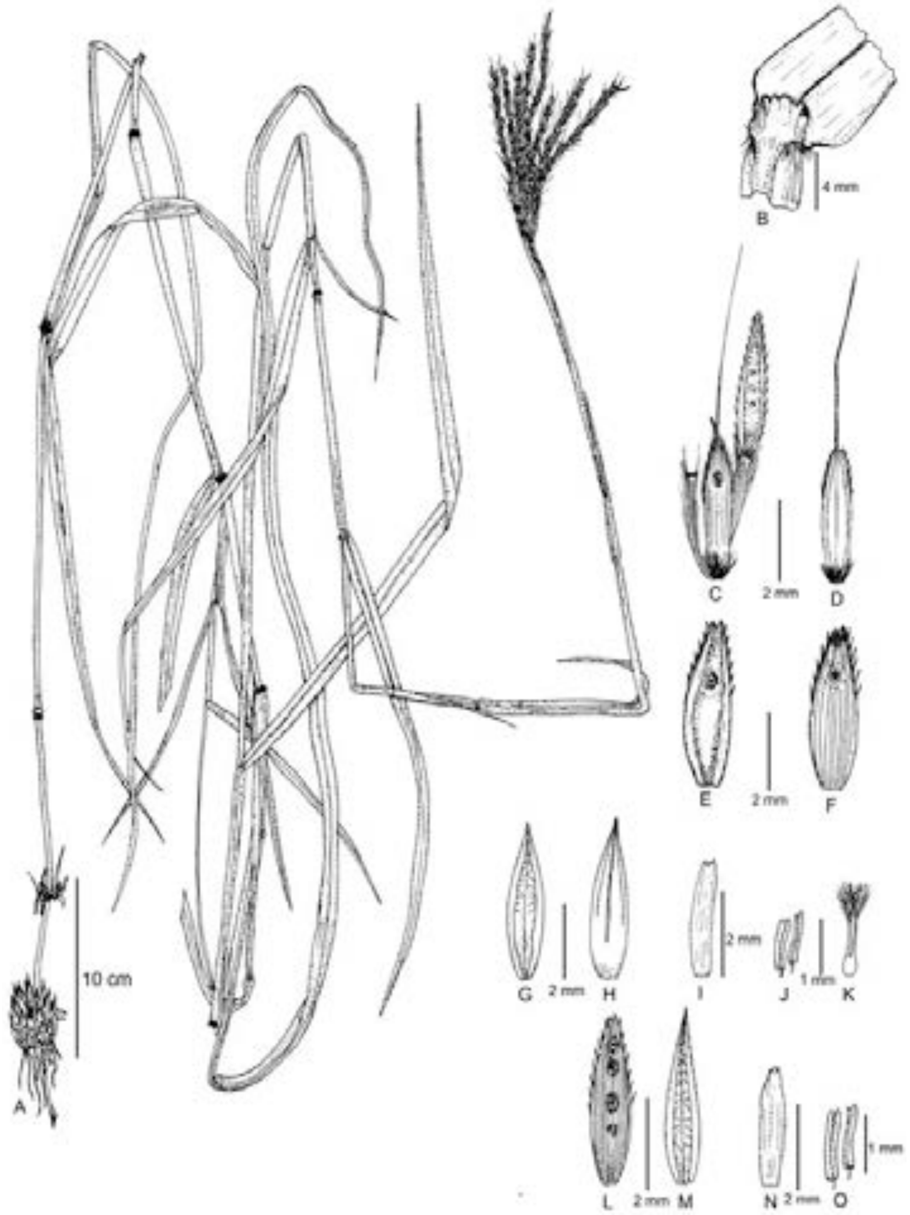

Figure 1. ***Bothriochloa insculpta*****: A—habit | B—ligule | C—spikelet pair | D—sessile spikelet | E—lower glume of sessile spikelet (ventral view) | F—lower glume of sessile spikelet (dorsal view) | G—upper glume of sessile spikelet (ventral view) | H—upper glume of sessile spikelet (dorsal view) | I—lower lemma of sessile spikelet | J—stamen | K—gynoecium | L—lower glume of pedicelled spikelet (dorsal view) | M—upper glume of pedicelled spikelet (ventral view) | N—lower lemma of pedicelled spikelet | O—stamen.**

Descriptions, illustrations, important notes and other details are provided for the three taxa.

Bothriochloa insculpta (A. Rich.) A. Camus in Ann. Soc. Linn. Lyon n. s., 76: 165. 1931; Bor, Grasses Burma, Ceylon, India & Pakistan: 107. 1960; Moulik, Grass. Bamb. India 1: 266. 1997. *Andropogon insculptus* Hochst. ex A. Rich., Tent. Fl. Abyss. 2: 458. 1851. *Andropogon pertusus* var. *insculptus* (A. Rich.) Hack., Monogr. Phan.6: 482. 1889; Hook. f., Fl. Brit. India 7: 174. 1896. *Amphilophis insculpta* (Hochst.) Stapf, Fl. Trop. Afr. 9: 176. 1917; C.E.C. Fisch. in Fl. Madras 3: 1732. 1934 (Fig. 1; Image 1).

Specimen examined: 51982 (SKU), 5.ix.2016, the Horsley Hills, Chittoor Distirct, Andhra Pradesh, India, coll. B. Ravi Prasad Rao & M. Anil Kumar

Perennials. Culms erect or rambling, up to 2.5m high; nodes hairy, basal nodes stilt rooted. Leaf sheaths glabrous, as long as or longer than nodes, 7–14 cm long, shortly ciliate at mouth; ligule membranous, shortly ciliate at apex; blades linear-lanceolate, glabrous, mid

Image 1. Herbarium of *Bothriochloa insculpta.*

nerve prominent, 20–28 × 0.6–0.8 cm long. Inflorescence of racemes, racemes digitate or sub digitate, racemes rachis internodes with translucent canal. Spikelets binate; sessile bisexual; pedicelled male. Sessile spikelet*:* 2–flowered, oblong–lanceolate, 4.25–4.5 mm long, awned. Lower glumes oblong–lanceolate, membranous – thinly chartaceous, flat, glabrous on dorsal surface, with a pit, margin narrowly winged in upper half, wings ciliate, apex shortly 2-lobed, 9–11-nerved, nerved inconspicuous; upper glumes lanceolate, membranous, boat shaped, glabrous, lower margins sparsely ciliate hairy, apex acuminate, 1-keeled, 3-nerved. Florets 2; lower barren; upper bisexual. Lower lemmas hyaline, nerveless, 2.8–3.2 mm long. Lower paleas minute or absent. Upper lemmas reduced to the base of awn, principal lemma awn from the apex, geniculate, 11–14 mm long over all; column twisted, scabrid on margins, 6–8 mm long; bristle 4–6 mm long. Paleas minute or absent. Stamen 3, anthers 1–1.5 mm long. Ovary ovate-oblong. Stigmas 2, plumose. Caryopsis not seen. Pedicelled spikelets: oblong-lanceolate, chartaceous, male, unawned; pedicel of pedicelled spikelets 2–3 mm long with a translucent canal, hairy on margins, 0.75 length of sessile spikelet. Lower glumes oblong-lanceolate, cartilaginous, glabrous on dorsal surface, pitted, pits 3 (2–4), glandular, margins narrowly winged in upper half, ciliate on margins, 11–13-nerved, nerved conspicuous; upper glumes more or less akin to upper glumes of sessile spikelets, 4–4.2 × c.1 mm long. Lemmas hyaline, nerveless, 2.5–2.8 mm long, unawned. Stamens 3, anthers 1–1.5 mm long.

Habitat & Ecology: Usually grows at high altitudes (above1100m).

Flowering & fruiting: November–March.

Distribution: India (Bihar, Maharashtra and peninsular India); Africa; western Indian ocean; Australasia; Europe; South America; temperate and tropical Asia.

Cyrtococcum patens (L.) A. Camus in Bull. Mus. Natl. Hist. Nat. 27: 118. 1921, var. ***patens***; C.E.C. Fisch. in Fl. Madras 3: 1786. 1934; Bor, Grasses Burma, Ceylon, India & Pakistan: 292. 1960; Moulik, Grass. Bamb. Ind. 1. 86. 1997. *Panicum patens* L., Sp. Pl.: 58. 1753. *Cyrtococcum radicans* (Retz.) Stapf., Hooker's Icon. Pl. 31: t. 3096. 1922; C.E.C. Fisch. in Fl. Madras 3: 1786. 1934. *Panicum radicans* Retz., Obsser. Bot. 4: 18. 1786. *Cyrtococcum muricatum* (Retz.) Bor, Grasses Burma, Ceylon, India & Pakistan: 291. 1960. *Panicum radicans* Retz., Observ. Bot. 4: 18. 1786. (Fig. 2; Image 2).

Specimen examined: 52962 (SKU), Lambasingi Ghat, 13.xii.2017, Visakhapatnam District, Andhra Pradesh, coll. B. Ravi Prasad Rao & M. Anil Kumar.

Annuals or perennials. Culms slender, erect, creeping, matt-forming, up to 40cm high. Leaf sheaths ciliate on one margin; ligules membranous 1–2 mm long; blades linear-lanceolate, dorsal surface ciliate with tubercle-based hairs, acuminate at apex, 2.5–12.5 × 0.5–1.2 cm long. Inflorescence of panicles, 5–10 cm long. Spikelets in pairs, one with short pedicel, another one with long pedicel, gibbose, 1.4–1.6 × c.1mm long. Lower glumes ovate, nearly as long as broad, margins much expanded or winged in the lower half, acute at apex, 3-nerved, c. 1× 0.9 mm long; upper glumes helmet shaped, elliptic-oblong, membranous, tuberculate ciliate on surface, 3-nerved, c.1.5 × c. 0.5 mm long. Florets 2, lower sterile; upper bisexual. Lower lemmas similar to upper glumes, longer than fertile lemmas, tuberculate ciliate on surface, obtuse at apex, 3-nerved. Lower palea absent. Upper lemmas gibbose, crustaceous, obtuse or subcute, with an appendage at apex, scarcely 3-nerved, c.1.2 × 0.8 mm long. Paleas obtuse at apex, as long as its lemmas, coriaceous, 2-keeled, 2-nerved, 1.2 × c. 0.4 mm long. Stamen 3. Stigmas 2, plumose. Caryopsis not seen.

Figure 2. *Cyrtococcum patens* var. *patens*: A—habit | B—spikelets along with pedicels | C—lower glume | D—upper glume (dorsal view) | E—upper glume (side view) | F—lower lemma (dorsal view) | F—lower lemma (ventral view) | G—upper lemma (side view) | H—upper palea.

Habitat & Ecology: Found under the shades of trees in moist deciduous forests.

Flowering & fruiting: July–May

Distribution: India (Andaman, Andhra Pradesh, Assam, Bihar, Karnataka, Kerala, Maharashtra, Manipur, Meghalaya, Odisha, Sikkim, Tamil Nadu, Tripura, Uttar Pradesh, and West Bengal); Sri Lanka, southeastern Asia.

Note*:* There are two forms in *Cyrtococcum patens* (L.) A. Camus var. *patens*: one has spikelets with glabrous nature and the other with verrucose. There is regular confusion while treating var. *latifolium* and var. *patens* as both have longer pedicels; var. *latifolium* pedicels, however, are very long and capillary; while in var. *patens* they are relatively shorter, but always longer than the length of spikelets. Bor (1960) treated spikelets with verrucose as a separate species, i.e., *C. muricatum* (Retz.) Bor, but now it has been made a synonym to the var. *patens*. In our present collections only one specimen has glabrous spikelets and remaining are with tuberculate or verrucose spikelets. Since *C. muricatum* has been reduced as a synonym to var. *patens*, the identification became much confused and also resolves the confusion in the occurrence of the taxon in Andhra Pradesh.

Image 2. Herbarium of *Cyrtococcum patens* var. *patens.*

Sacciolepis myosuroides (R.Br.) A. Camus in Fl. Indo–Chine 7: 460. 1922; C.E.C. Fisch. in Fl. Madras 3: 1786. 1934; Bor, Grasses Burma, Ceylon, India & Pakistan: 358. 1960; Moulik, Grass. Bamb. Ind. 1. 149. 1997. *Panicum myosuroides* R. Br., Prodr. Fl. Nov. Holl. 189. 1810; Hook. f., Fl. Brit. India. 7: 42. 1896. (Fig. 3; Image 3).

Specimen examined: 52840 (SKU), 13.xii.2017, Paderu fields, Visakhapatnam District, Andhra Pradesh, India, coll. B. Ravi Prasad Rao, M. Anil Kumar & P. Anjaneyulu.

Annuals. Culms erect, tufted or decumbent at

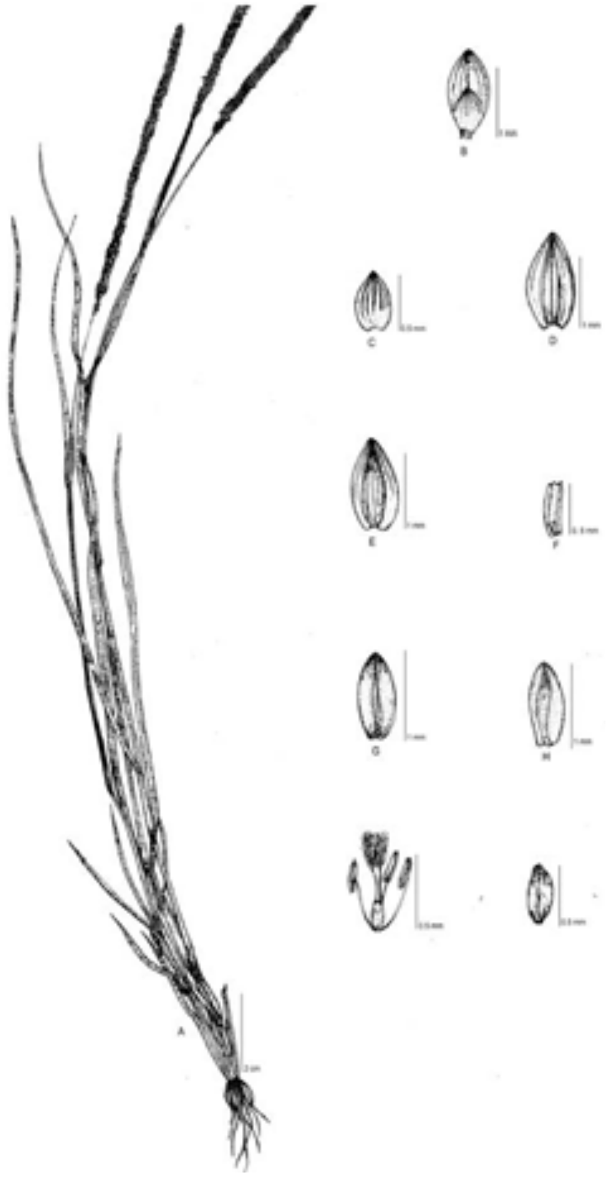

Figure 3. *Sacciolepis myosuroides*: A—habit | B—spikelet | C—lower glume | D—upper glume | E—lower lemma | F—lower palea | G—upper lemma | H—upper palea | I—stamens & gynoecium | J—caryopsis.

base, up to 1.1m high, nodes glabrous. Leaf sheaths glabrous or scabrid, 5–8 cm long; ligules membranous, truncate; blades linear-lanceolate, glabrous or scabrid, base rounded, acuminate at apex, 10–20 × 4 cm long. Inflorescence of panicles, spiciform, usually dark purple when young, 3–20 cm long. Spikelets ovate-obovate to oblong, elliptic, obtuse at apex, 1.2–1.6 × c. 1mm long. Lower glumes ovate, chartaceous, 5-nerved, 0.6–0.8 × c. 0.6–0.8 mm long; upper glumes as long as lemmas, glabrous, 7–9-nerved, c.1.5 mm long. Lower lemmas akin to upper glumes, 5–7-nerved, 1.2–1.4 mm long.

Image 3. Herbarium of *Sacciolepis myosuroides.*

Lower paleas more or less enveloped, elliptic, hyaline, 2-nerved, c. 0.5 mm long. Upper lemmas elliptic, coriaceous, 3-nerved, nerves obscure, 0.8–1.1 mm long. Upper paleas as long as upper lemmas, elliptic, 2-nerved. Stamen 3, anthers 0.4mm long. Ovary 0.3mm long, elliptic. Stigmas 2, plumose, 0.6mm long. Caryopsis ellipsoid, c. 0.5mm long.

Habitat & Ecology: Very common weed of cultivated fields, especially in paddy and similar swampy habitats.

Flowering & fruiting: July–January

Conservation status: Least concern (LC).

Distribution: India (Andaman, Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Odisha, Sikkim, Tamil Nadu, Telangana, Uttar Pradesh, and West Bengal); Africa, Australasia, North & South America, Pacific, and temperate & tropical Asia.

Notes

1. *Sacciolepis myosuroides* is often confused and also erroneously identified as *S. indica.* Many characters

are intermediate between *S. indica* and S. *myosuroides*, but can be easily identifiable by its smaller (c. 1.5mm), glabrous spikelets.

2. The species recorded was from Warangal and Medak districts in Telangana region of erstwhile Andhra Pradesh. All the publications prior to 2014 (Kabeer & Nair 2009; Mani 2011) mentioned its distribution as Andhra Pradesh. Since there are no records for the species from present day Andhra Pradesh state till date, the present collection forms a new distribution record for the same.

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Short Communication

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Ethnobotanical survey of indigenous leafy vegetables consumed in rural areas of Terai-Dooars region of West Bengal, India

Mallika Mazumder [1] & **Anup Kumar Sarkar** [2]

[1,2] Department of Botany, Dukhulal Nibaran Chandra College, Aurangabad, Murshidabad, West Bengal 742201, India.
[1] mallika.flk@gmail.com, [2] anupsarkar.jpg@gmail.com (corresponding author)

Abstract: There is always a need for novel, high quality, functional and inexpensive foods among consumers in the global markets. Leafy vegetables can fulfill such needs. Leafy vegetables are now used worldwide as food for their nutritional and medicinal values. In the present work an ethnobotanical survey was carried out on the utilization of edible plants by local communities of the Terai-Dooars Region of West Bengal. The information has been documented by interviewing traditional farmers, herbalists, various older men and women following different ethnobotanical methods. A total of 103 plant species under 44 families with their short botanical description, use, range of demands and cultivation status have been documented.

Keywords: Ethnobotany, indigenous, leafy vegetable, Terai-Dooars, tribe.

A large section of the population of the globe fulfil their nutritional requirements through the consumption of various leafy vegetables (Singh & Arora 1978). Technically, leafy vegetables refer to leaves of any plants used as vegetables, sometimes accompanied by petioles and shoots. In most cases, leafy vegetables are consumed for their nutritional values without much consideration for their medicinal importance. Leafy vegetables are primarily composed of polysaccharides, cellulose, hemicellulose, pectin, gum mucilage and some non-carbohydrate components (Islam et al. 2004). Epidemiological studies indicate that increased intake of leafy vegetables is associated with a decreased risk of nutrient depletion disorders as well as some serious diseases like cancers, cardiovascular disease, cataract, and other age-related diseases (Acho et al. 2014). Leafy vegetables deserve much attention in rural areas because of their possible usefulness during famine and similar scarcity situations. Rural tribal communities in many parts of the world depend on wild plants to fulfill their dietary requirements and these play a crucial role in their food security (Prasad et al. 2008). To earn additional income, they also sell them in their local markets. To fulfill the demands of the local markets several varieties of these leafy vegetables are either collected from the wild habitat or cultivated locally or even commercially. In the Terai-Dooars region of West Bengal, people have a long history of consuming leafy vegetables.

The Terai and Dooars region politically constitute the plains of Darjeeling District, the whole of Jalpaiguri and Alipurduar districts and the upper region of Cooch Behar District in West Bengal. The slope of the land is gentle, from north to south. The general height of the land is 80–100 m. The entire region is made up of sand, gravel and pebbles laid down by the Himalayan rivers namely, the Teesta, Torsa, Raidak, Jaldhaka, Sankosh and several other small rivulets. The Teesta has divided the area into two parts—the western part is known as the Terai whereas the eastern part is known as the Dooars

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or Duars. The area Dooars starts from the eastern bank of the river Teesta in the Jalpaiguri District stretching up to the western bank of the river Sankosh in Alipurduar District, spreading over a span of around 130km of which 40km area runs along the Himalayan foothills. This region is highly populated and characterized by the presence of different tribal communities. The local consumption of these leafy vegetables and their increased demand in the market, can create a threat to some species especially the wild species of this region. To overcome such problems the people of this region cultivate such threatened plants either in their home gardens for local consumption or in agricultural fields for marketing. Thus there is a real need of maintaining proper records of leafy vegetables and their status of conservation through agricultural practices. The present study was designed to evaluate the level of utilization, availability and cultivation practices of leafy vegetables of this region.

MATERIALS AND METHODS

Study Area

The present study was carried out in several rural and semi-urban areas of Terai-Dooars region of West Bengal, India. To record the indigenous and under-utilized leafy vegetables, extensive field surveys were conducted during three consecutive years between January 2016 to March 2019. For this study several tribal villages, rural markets and agricultural fields were visited. The plant specimens were collected, mounted on herbarium sheets and identified through the available taxonomic literature, books and some relevant articles. Data was collected through a combination of tools and questionnaires. The information thus gathered was compared with available literature sources.

RESULTS AND DISCUSSION

The present work is the outcome of ethno-botanical field survey of three consecutive years from different villages and markets of Terai-Dooars region of West Bengal. During the present investigation, it was found that 103 plant species are used as leafy vegetables in the study site. Most of the plants are used as health food and some are used only as medicines. The edible plants also have some medicinal values. The study records a total of 103 plant species belonging to 44 families (Table 1). The study provides important evidence about traditional knowledge and diversity of wild and cultivated leafy vegetables. Among the leafy vegetables, 54.81% are in high demand, 21.15% are in moderate demand, and 24.04% are rarely demanded. The study also reveals that among the plants 72.12% are collected or cultivated due to their edible leaves but 27.88% plants are notable for other parts like fruits, seeds, rhizomes, and leaves are of secondary importance.

CONCLUSION

These leafy vegetable plants and their utilization is well recognized by the local communities. It was observed that the majority of the local inhabitants were dependent on wild vegetation for under-utilized leafy vegetables but over-utilized leafy vegetable plants were

Table 1. List of leafy vegetable in Terai-Dooars region of West Bengal.

	Binomial name	Vernacular name	Family	Life form	Use	Range of use	Cultivation status	Major economical parts
1	*Hygrophila polysperma* (Roxb.) T. Anders.	Puinnya Shak	Acanthaceae	Herb	Cooked as vegetable	Limited	Wild	Leaf
2	*Andrographis paniculata* (Burm.f.) Nees	Kalmegh	Acanthaceae	Herb	Eaten raw as medicinal plant against stomach problem	Wide	Wild and locally cultivated	Leaf
3	*Justicia adhatoda* L.	Basak	Acanthaceae	Shrub	Leaf extract used as oral medicine for common cold and cough	Wide	Locally cultivated	Leaf
4	*Hygrophila auriculata* (Schumach.) Heine	Kulekhara	Acanthaceae	Herb	Eaten raw as medicinal plant	Wide	Wild and cultivated	Leaf
5	*Amaranthus tricolor* L.	Lalsak/Sadanote	Amaranthaceae	Herb	Cooked as vegetable	Wide	Commercially cultivated	Leaf
6	*Amaranthus blitum* subsp. *oleraceus* (L.) Costea	Sadanote	Amaranthaceae	Herb	Cooked as vegetable	Wide	Commercially cultivated	Leaf
7	*Digera muricata* (L.) Mart.	Latamouri/ Gungutiya	Amaranthaceae	Herb	Cooked as vegetable	Limited	Wild	Leaf
8	*Spinacia oleracea* L.	Palongsak	Amaranthaceae	Herb	Cooked as vegetable	Wide	Commercially cultivated	Leaf
9	*Beta vulgaris* L.	Beet sak	Amaranthaceae	Herb	Cooked as vegetable	Moderate	Commercially cultivated	Fruit

	Binomial name	Vernacular name	Family	Life form	Use	Range of use	Cultivation status	Major economical parts
10	*Alternanthera sessilis* (L.) R.Br. ex DC.	Notesak	Amaranthaceae	Herb	Cooked as vegetable	Limited	Wild	Leaf
11	*Amaranthus viridis* L.	Katanote	Amaranthaceae	Herb	Cooked as vegetable	Moderate	Wild and cultivated	Leaf
12	*Centella asiatica* (L.) Urb.	Thankunisak	Apiaceae	Herb	Eaten raw as medicinal plant	Wide	Wild	Leaf
13	*Carum roxburgianum* Benth.	Radhuni pata	Apiaceae	Herb	Cooked as vegetable	Moderate	Commercially cultivated	Fruit
14	*Coriandrum sativum* L.	Dhonepata	Apiaceae	Herb	Used to prepare sauce and salade	Wide	Commercially cultivated	Fruit
15	*Trachyspermum ammi* (L.) Sprague	Ajwan pata	Apiaceae	Herb	Used to prepare sauce and salade	Moderate	Commercially cultivated	Fruit
16	*Colocasia esculenta* (L.) Schott	Kochu	Araceae	Herb	Cooked as vegetable	Wide	Wild and commercially cultivated	Leaf and Rhizome
17	*Homalomena aromatica* (Spreng.) Schott.	Bankochu	Araceae	Herb	Cooked as vegetable	Wide	Wild and commercially cultivated	Leaf and Rhizome
18	*Alocasia macrorrhizos* (L.) G.Don	Mankochu	Araceae	Herb	Cooked as vegetable	Wide	Wild and commercially cultivated	Leaf and Rhizome
19	*Amorphophallus bulbifer* (Roxb.) Blume	Oal	Araceae	Herb	Cooked as vegetable	Moderate	Wild and commercially cultivated	Leaf and Rhizome
20	*Lasia spinosa* (L.) Thwait., Enum. Pl. Zeyl.	Kantakochu	Araceae	Herb	Cooked as vegetable	Moderate	Wild	Leaf and Rhizome
21	*Colocasia antiquorum* Schott.	Mukhikochu	Araceae	Herb	Cooked as vegetable	Moderate	Wild and commercially cultivated	Leaf and Rhizome
22	*Xanthosoma sagittifolium* (L.) Schott.	Mankochu	Araceae	Herb	Cooked as vegetable	Wide	Wild and commercially cultivated	Leaf and Rhizome
23	*Eclipta prostrata* (L.) L.	Vringraj	Asteraceae	Herb	Cooked as vegetable	Moderate	Wild	Leaf
24	*Enhydra fluctuans* Lour.	Helecha	Asteraceae	Herb	Cooked as vegetable	Moderate	Wild	Leaf
25	*Sonchus arvensis* L.	Bonpalong	Asteraceae	Herb	Cooked as vegetable	Moderate	Wild	Leaf
26	*Diplazium esculentum* (Retz.) Sw.	Dheki	Athyriaceae	Herb	Cooked as vegetable	Wide	Wild and commercially cultivated	Leaf
27	*Basella alba* L.	Puisak	Basellaceae	Herb	Cooked as vegetable	Wide	Commercially cultivated	Leaf
28	*Raphanus raphanistrum* subsp. *sativus* (L.) Domin	Mulo	Brassicaceae	Herb	Cooked as vegetable	Wide	Commercially cultivated	Tuber
29	*Brassica oleracea* L. var. *capitata*	Badhakopi/ Patakopi	Brassicaceae	Herb	Cooked as vegetable	Wide	Commercially cultivated	Leaf and Shoot
30	*Brassica oleracea* L. var. *botrytis*	Fulkopi	Brassicaceae	Herb	Cooked as vegetable	Wide	Commercially cultivated	Bud
31	*Brassica oleracea* L. var. gangyloides	Oolkopi	Brassicaceae	Herb	Cooked as vegetable	Wide	Commercially cultivated	Leaf and Shoot
32	*Brassica napus* L.	Sadasarisha/ Maghi sorisha shak	Brassicaceae	Herb	Cooked as vegetable	Moderate	Commercially cultivated	Seed
33	*Sinapis alba* L.	Sada sorisha shak	Brassicaceae	Herb	Cooked as vegetable	Wide	Commercially cultivated	Seed
34	*Brassica nigra* (L.) K.Koch	Kalo sarisa	Brassicaceae	Herb	Cooked as vegetable	Wide	Commercially cultivated	Seed
35	*Brassica rapa* L.	Shalgom	Brassicaceae	Herb	Cooked as vegetable	Wide	Commercially cultivated	Seed
36	*Lepidium sativum* L.	Halimshak	Brassicaceae	Herb	Cooked as vegetable	Moderate	Wild and locally cultivated	Seed
37	*Ananas comosus* (L.) Merr.	Anaras	Bromeliaceae	Herb	Leaf extract is used as medicine against stomach problem	Limited	Commercially cultivated	Fruit
38	*Cannabis sativa* L.	Bhang	Cannabaceae	Herb	Leaf dust used as stimulatory substances	Wide	Wild	Leaf
39	*Chenopodium album* L.	Bothuasak	Chenopodiaceae	Herb	Cooked or boiled as vegetable	Wide	Wild	Leaf

	Binomial name	Vernacular name	Family	Life form	Use	Range of use	Cultivation status	Major economical parts
40	*Operculina turpethum* (L.) Silva Manso	Dudh Kolmi	Convolvulaceae	Herb	Cooked as vegetable	Wide	Wild	Leaf
41	*Hewittia malabarica* (L.) Suresh	Dhudla Shak	Convolvulaceae	Herb	Cooked as vegetable	Limited	Wild	Leaf
42	*Ipomoea batatus* Lam.	Misti aloo	Convolvulacea	Herb	Cooked as vegetable	Moderate	Commercially cultivated	Tuber
43	*Ipomoea aquatica* Forssk.	Kolmi	Convolvulaceae	Herb	Cooked as vegetable	Wide	Wild	Leaf
44	*Stellaria media* (L.) Vill.	Marmurishak	Caryophyllaceae	Herb	Cooked as vegetable	Limited	Wild	Leaf
45	*Commelina benghalensis* L.	Kanshira	Commelinaceae	Herb	Cooked as vegetable	Limited	Wild	Leaf
46	*Bryophyllum pinnatum* (Lam.) Oken	Pathorkuchi	Crassulaceae	Herb	Eaten raw as healthy food	Wide	Wild and locally cultivated	Leaf
47	*Sechium edule* (Jacq.) Sw.	Squash/ Koash	Cucurbitaceae	Herb	Cooked as vegetable	Wide	Commercially cultivated	Fruit
48	*Momordica charantia* L.	Karola	Cucurbitaceae	Herb	Cooked as vegetable	Limited	Commercially cultivated	Leaf
49	*Lagenaria siceraria* (Molina) Standl.	Lao	Cucurbitaceae	Herb	Cooked as vegetable	Wide	Commercially cultivated	Leaf and Fruit
50	*Cucurbita maxima* Duchesne	Misti Kumra	Cucurbitaceae	Herb	Cooked as vegetable	Wide	Commercially cultivated	Leaf and Fruit
51	*Luffa cylindrica* (L.) M.Roem.	Dhundol	Cucurbitaceae	Herb	Cooked as vegetable	Moderate	Commercially cultivated	Leaf and Fruit
52	*Benincasa hispida* (Thunb.) Cogn.	Chalkumra	Cucurbitaceae	Herb	Cooked as vegetable	Wide	Commercially cultivated	Leaf and Fruit
53	*Luffa acutangula* (L.) Roxb.	Jhinge	Cucurbitaceae	Herb	Cooked as vegetable	Moderate	Commercially cultivated	Fruit
54	*Momordica cochinchinensis* (Lour.) Spreng.	Kakrol	Cucurbitaceae	Herb	Cooked as vegetable	Moderate	Commercially cultivated	Fruit
55	*Coccinea cordifolia* (L.) Cogn.	Telakucha	Cucurbitaceae	Herb	Cooked as vegetable	Moderate	Wild	Leaf and Fruit
56	*Microlepia strigosa* (Thunb.) C. Presl	Fita Dhekia	Dennstaedtiaceae	Herb	Cooked as vegetable	Limited	Wild	Leaf
57	*Dioscorea pentaphylla* L.	Kanta Aloo	Dioscoriaceae	Herb	Leaf extract is used as medicine against stomach problem	Moderate	Wild	Rhizome
58	*Cajanus cajan* (L.)Millsp.	Arahar sak	Fabaceae	Shrub	Leaf extract is used as medicine against jandice	Moderate	Commercially cultivated	Seed
59	*Pisum sativum* L.	Matorsak	Fabaceae	Herb	Cooked as vegetable	Wide	Commercially cultivated	Seed
60	*Cicer arietinum* L.	Chholasak But shak	Fabaceae	Herb	Cooked as vegetable	Limited	Commercially cultivated	Seed
61	*Lathyrus sativus* L.	Kashari shak	Fabaceae	Herb	Cooked as vegetable	Wide	Commercially cultivated	Seed
62	*Trigonella foenum-graecum* L.	Methisak	Fabaceae	Herb	Cooked as vegetable	Wide	Commercially cultivated	Fruit
63	*Leucas aspera* (Willd.) Link	Dandokalas/ Swetodron	Lamiaceae	Herb	Cooked as vegetable	Wide	Wild and locally cultivated	Leaf
64	*Mentha sicata* L.	Pudina	Lamiaceae	Herb	Cooked as vegetable	Wide	Locally cultivated	Leaf
65	*Ocimum gratissimum* L.	Ramtulsi	Lamiaceae	Shrub	Leaves are used as home remedy in the treatment of cough and cold.	Wide	Wild and locally cultivated	Leaf
66	*Ocimum tenuiflorum* L.	Krisna Tulsi	Lamiaceae	Herb	Leaves are used as home remedy in the treatment of cough and cold	Wide	Wild and locally cultivated	Leaf
67	*Ocimum basilicum* L.	Ban tulsi	Lamiaceae	Herb	Leaves are used as home remedy in the treatment of cough and cold	Wide	Wild and locally cultivated	Leaf
68	*Cinnamomum tamala* (Buch.-Ham.) T.Nees & Eberm.	Tej pata	Lauraceae	Tree	Leaves are used as spice	Wide	Commercially cultivated	Leaf
69	*Cinnamomum verum* J.Presl	Darcchini	Lauraceae	Tree	Leaves are used as spice	Limited	Commercially cultivated	Bark
70	*Allium cepa* L.	Peyaj	Liliaceae	Herb	Leaves are eaten raw and also cooked as vegetable	Wide	Commercially cultivated	Tuber

	Binomial name	Vernacular name	Family	Life form	Use	Range of use	Cultivation status	Major economical parts
71	*Allium sativum* L.	Rosun	Liliaceae	Herb	Cooked as vegetable	Limited	Commercially cultivated	Tuber
72	*Corchorus capsularis* L.	Titapat	Malvaceae	Shrub	Cooked as vegetable	Wide	Commercially cultivated	Fibre and Leaf
73	*Corchorus olitorius* L.	Mithapat	Malvaceae	Shrub	Cooked as vegetable	Wide	Commercially cultivated	Fibre and Leaf
74	*Malva verticillata* L.	Lafasak	Malvaceae	Herb	Cooked as vegetable	Wide	Commercially cultivated	Leaf
75	*Marsilea quadrifolia*	Sushni	Marsileaceae	Herb	Cooked as vegetable	Wide	Wild	Leaf
76	*Marsilea minuta (L.) Mant.*	Sushni	Marsileaceae	Herb	Cooked as vegetable	Wide	Wild	Leaf
77	*Azadirachta indica A.Juss.*	Neem	Meliaceae	Tree	Cooked as vegetable	Wide	Commercially cultivated	Leaf
78	*Tinospora sinensis* (Lour.) Merr.	Gulончa	Menispermaceae	Shrub	Cooked as vegetable	Limited	Wild	Leaf
79	*Moringa oleifera* Lam.	Sajina	Moringaceae	Tree	Cooked as vegetable	Wide	Commercially cultivated	Fruits
80	*Glinus oppositifolius* (L.) Aug.DC.	Gimasak	Molluginaceae	Herb	Cooked as vegetable	Wide	Wild	Leaf
81	*Mollugo pentaphylla L.*	Khetpapra	Molluginaceae	Herb	Cooked as vegetable	Limited	Wild	Leaf
82	*Nymphaea lotus* L.	Sapla	Nymphaeaceae	Herb	Cooked as vegetable	Wide	Wild	Leaf
83	*Boerhavia repens L.*	Purnima shak	Nyctaginaceae	Herb	Cooked as vegetable	Limited	Wild	Leaf
84	*Nyctanthes arbor-tristis* L.	Sephali	Oleaceae	Shrub	Leaf extract used as medicine against common cough	Limited	Locally cultivated	Leaf
85	*Ludwigia adscendens* (L.) H.Hara	Keshardam /Mulcha	Onagraceae	Herb	Cooked as vegetable	Limited	Wild	Leaf
86	*Oxalis corniculata* L.	Aamrul/Takpata	Oxalidaceae	Herb	Cooked as vegetable	Moderate	Wild	Leaf
87	*Oxalis debilis* Kunth	Aamrul	Oxalidaceae	Herb	Cooked as vegetable	Moderate	Wild	Leaf
88	*Bacopa monnieri* (L.) Wettst.	Bramhi	Plantaginaceae	Herb	Cooked as vegetable	Wide	Locally cultivated	Leaf
89	*Piper nigrum* L.	Kalomorich	Piperaceae	Herb	Eaten raw	Wide	Locally and commercially cultivated	Leaf
90	*Piper betle* L.	Panpata	Piperaceae	Herb	Eaten raw	Wide	Commercially cultivated	Leaf
91	*Piper longum* L.	Lata Pipul	Piperaceae	Shrub	Cooked as vegetable	Limited	Locally cultivated	Leaf
92	*Portulaca oleracea* L.	Baro Nunia shak	Portulacaceae	Herb	Leaves are used as flavouring substance	Limited	Wild	Leaf
93	*Portulaca quadrifida* L.	Choto Nunia shak	Portulacaceae	Herb	Leaves are used as flavouring substance	Limited	Wild	Leaf
94	*Pteris cretica* L.	Dhekia	Pteridaceae	Herb	Cooked as vegetable	Wide	Wild	Leaf
95	*Paederia foedtida* L.	Gando vadoli	Rubiaceae	Herb	Cooked as vegetable	Moderate	Locally Cultivated	Leaf
96	*Murraya koenigii* (L.) Spreng.	Kurrypata	Rutaceae	Tree	Leaves are used as flavouring substance	Wide	Locally cultivated	Leaf
97	*Citrus aurantiifolia* (Christm.) Swingle	Patilebu	Rutaceae	Shrub	Leaves are used as flavouring substance	Limited	Locally and commercially cultivated	Fruit
98	*Solanum tuberosum* L.	Aalu	Solanaceae	Herb	Cooked as vegetable	Wide	Commercially cultivated	Tuber
99	*Nicotiana tabacum* L.	Tamak	Solanaceae	Herb	Cooked as vegetable	Wide	Commercially cultivated	Leaf
100	*Camellia sinensis* (L.) Kuntze	Cha/Tea	Theaceae	Shrub	Leaves are used as flavouring substance	Wide	Commercially cultivated	Leaf
101	*Cyphostemma setosum* (Roxb.) Alston	Hashjor	Vitaceae	Herb	Cooked as vegetable	Limited	Wild	Leaf
102	*Aloe vera* (L.) Burm.f.	Grithakumari	Xanthorrhoeaceae	Herb	Leaf extract is eaten as healthy food	Wide	Locally and commercially cultivated	Leaf
103	*Zingiber officinale* Roscoe	Aada	Zingiberaceae	Herb	Leaves are used as flavouring substance	Limited	Locally and commercially cultivated	Rhizome

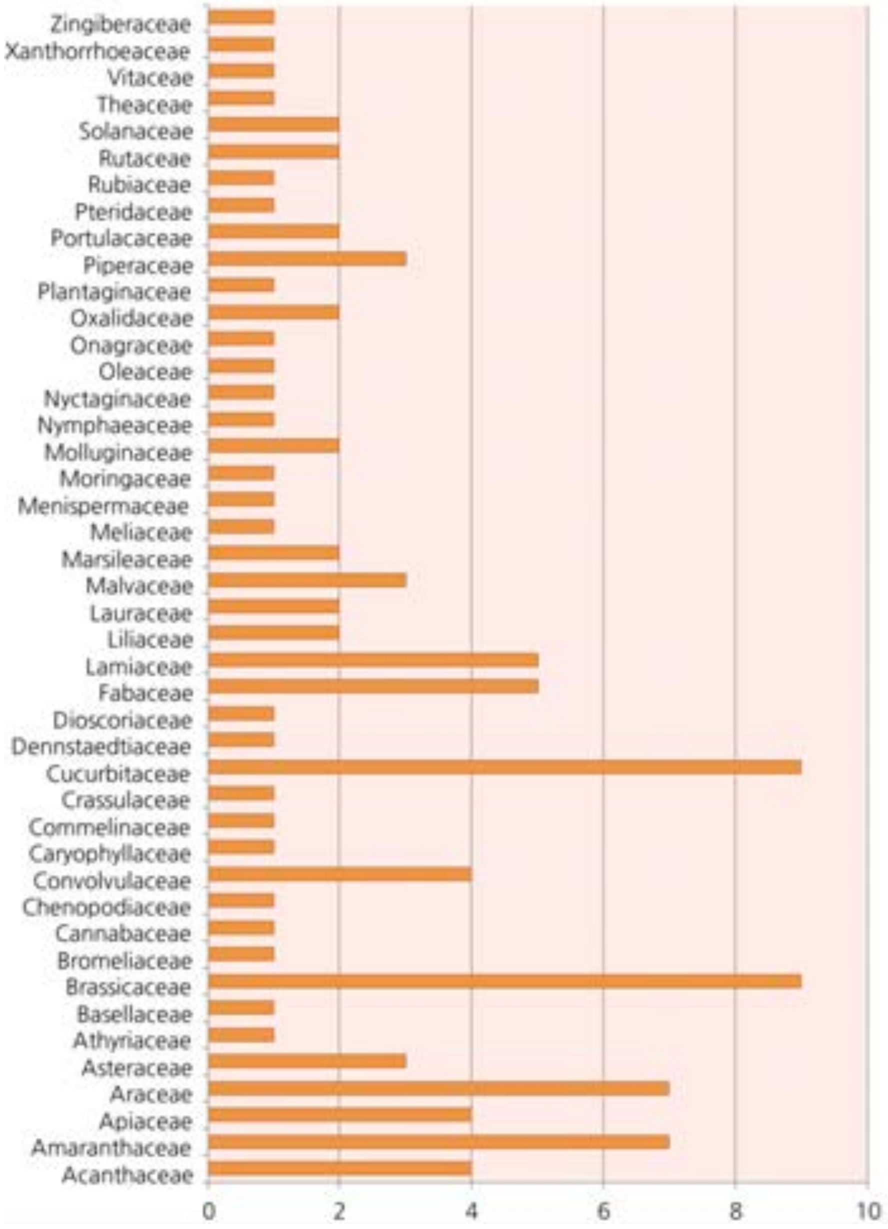

Figure 1. Number of leafy vegetables distributed in different families

Figure 2. Percentage of herb, shrub, tree used as leafy vegetable.

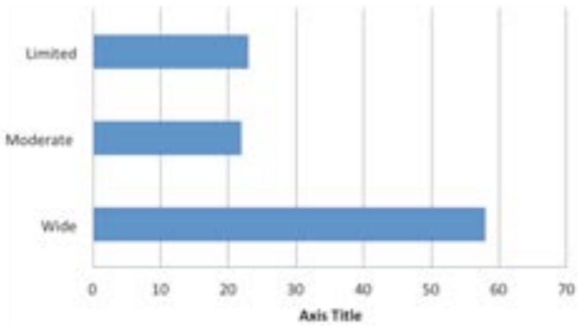

Figure 3. Percentage of range of use of leafy vegetables.

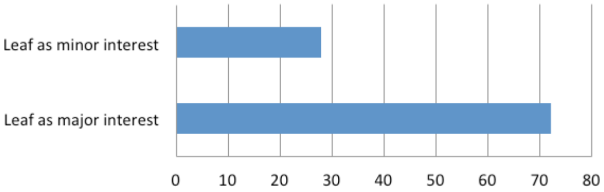

Figure 4. Number of leafy vegetables of major and minor interest.

commercially cultivated. In some cases over-utilization of such wild leafy vegetable may affect the diversity and create threats to the vegetation. Therefore, both wild and cultivated leafy vegetable plants need to be used in a sustainable manner. Using the present study as a baseline, if the nutrient compositions and other nutra-medicinal properties of the leafy vegetables, particularly under-utilized species could be determined, it would be possible to alleviate poverty and malnutrition in different corners of world.

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Short Communication

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Australasian sequestrate Fungi 20: *Russula scarlatina* (Agaricomycetes: Russulales: Russulaceae), a new species from dry grassy woodlands of southeastern Australia

Todd F. Elliott[1] & **James M. Trappe**[2]

[1] Ecosystem Management, University of New England, Armidale, New South Wales 2351, Australia.
[2] Department of Forest Ecosystems and Society, Oregon State University, Corvallis, Oregon 97331-5752, USA.
[2] USDA Forest Service, Pacific Northwest Research Station, Forestry Sciences Laboratory, 3200 Jefferson Way, Corvallis, Oregon 97331, USA.
[1] toddfelliott@gmail.com (corresponding author), [2] trappej@gmail.com

Abstract: *Russula scarlatina* sp. nov. is a common sequestrate fungus found in the dry sclerophyll *Eucalyptus* woodlands of southeastern Australia. Basidiomata are hypogeous or sometimes emergent; they are scarlet in youth and become dark sordid red or brown with advanced age. Historically, this species would have been placed in the genus *Gymnomyces,* but in light of recent revisions in the taxonomy of sequestrate Russulaceae, we place it in the genus *Russula*. It is morphologically distinct from other sequestrate species of *Russula* because of its scarlet peridium and unusual cystidial turf in youth. It has been collected only in dry grassy woodlands and open forest habitats of southeastern Australia.

Keywords: Basidiomycota, *Eucalyptus,* hypogeous fungus, grassy woodlands, open forests, Russulaceae, southeastern Australia.

Non-lactating sequestrate members of the Russulaceae were historically placed in one of six genera based on various aspects of their morphology (Lebel 1998). Recent genetic analysis supports the recombination of all of these genera with the common mushroom genus *Russula* (Lebel & Tonkin 2007; Lebel 2017; Elliott & Trappe 2018). It has been suggested that adaptations to abiotic environmental factors and symbiotic associations with vertebrates and invertebrates have led to evolution of sequestrate and hypogeous basidiomata (Thiers 1984; Trappe & Claridge 2005; Vernes & Dunn 2009; Galante et al. 2011). Nearly 60 of the approximately 145 described sequestrate *Russula* species are native to Australia and New Zealand,

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Competing interests: The authors declare no competing interests.

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and numerous undescribed taxa likely inhabit the region (Lebel 1998; Lebel & Tonkin 2007; Lebel 2017; Elliott & Trappe 2018). Australia also has a high diversity of native mammals and birds that feed on members of the Russulaceae (Nuske et al. 2017a,b; Elliott & Vernes 2019). These associations between vertebrates and the Russulaceae may have contributed to the evolution of the diverse sequestrate morphologies that are common in Australia.

During multiple collecting expeditions in the Australian Capital Territory, New South Wales, and Victoria, we have encountered *Russula scarlatina* sp. nov., a brightly colored, sequestrate fungus. It typically fruits with *Eucalyptus* spp. in dry sclerophyll woodlands, but we once found it emerging from bare, compacted soil between the base of a tree and the sidewalk in Mitchell, New South Wales.

MATERIALS AND METHODS

Basidiomata examined in this study were collected during the cold months of May through September between 2000 and 2010. We found them by raking away the leaf litter under *Eucalyptus* spp. and carefully examining the soil layer below. Occasionally, basidiomata were partially emergent from the soil or were found in the tailings piles of animal digs. We collected and photographed the basidiomata, recorded their fresh macroscopic characteristics, and then placed slices on a portable dehydrator. Dried material was freehand sectioned for slide mounts under a binocular compound microscope. Thin sections were mounted and examined in 3% KOH, H_2O, cotton blue, and Melzer's reagent. Heat was used to remove bubbles and for clearer viewing. Microscopic features were measured in 3% KOH mounts. Collections are curated in the herbaria listed in the Acknowledgements section.

Taxonomic description

Russula scarlatina sp. nov.

MycoBank Number: MB 829958

(Image 1)

Holotype: Australia, Australian Capital Territory, Mulligans Flat Nature Reserve, 55H 6106140, 696255, elev. 645m. In pure grove of *Eucalypus blakelyi*. Col. Ben Claridge, Georgia Claridge, Debbie Claridge, Andrew Claridge, & Jim Trappe #33233 (CANB; Isotypes OSC, MEL).

Etymology: *scarlatina* (Latin, "scarlet"), referring to the scarlet peridium covered with a turf of scarlet dermatocystia; a conspicuous feature distinguishing this species from other sequestrate *Russula* spp.

Description: *Basidiomata* hypogeous to partially emergent or sometimes exposed in animal digs, solitary or in scattered, gregarious groups. *Basidiomata* globose to subglobose, flattened, or irregular, (5–) –25 (–30) x (5–) –20 (–25) mm, in youth with a suprapellis turf of scarlet, tapered cystidia that fade when dried and a pellis mixture of pale yellow and scarlet areas that often separate into patches, with age the colors darkening to darker dull red and the turf fading and collapsing in patches, at senescence becoming dark reddish-brown with the suprapellis turf largely to entirely collapsed (Image 1a). Stipe absent or rarely present as a less than 2mm long, readily detaching stub at base of fruiting body, its surface concolorous with peridiopellis. Gleba loculate, in youth, the trama white to ivory or pale yellow, with age developing to brownish yellow with brown zones and brown tissue around worm holes, and at senescence brown overall (Image 1a & c); spores in mass in the locules white, often brownish where glebal tissue has stained brown. Odor in youth mild, later often faintly pleasant, at senescence somewhat unpleasant.

Peridium 115–180 µm thick, beset with a crowded to dispersed, scarlet pubescence. Peridiopellis 25–90 µm thick, scarlet in fresh mounts of young specimens and often with scattered red granular deposits near the surface, later darkening to brown or reddish-brown and paler towards gleba, the hyphae compact and tightly entangled, 4–8 µm broad, the suprapellis a pubescence of tapered, tangled, cystidia 20–40 µm tall, scarlet when fresh and sometimes with scattered scarlet deposits at the base but fading slowly after exposure, in microscope mounts of KOH quickly becoming hyaline (Image 1d). Subpellis averaging 90µm thick with loosely interwoven hyphae 3–8 µm thick. Gleba with a subhymenium up to 30µm thick, composed of irregularly shaped, inflated cells up to 11µm broad. Hymenophoral trama up to 18–31 µm thick, composed of tightly intertwined hyphae, 3–7 µm broad with occasional cells in trama inflated up to 18µm. Hymenophoral cystidia 39–42 x 8–11 µm, scattered, hyaline smooth, cylindrical to narrowly clavate with obtuse apices, walls less than 1µm thick (Image 1f). Basidia 41–48 x 9–11 µm, clavate, tapering near the base, smooth, less than 1µm thick, 2 and 4 spored, sterigmata 4–6 x 1–2 µm. Spores 7–8 x 7–9 µm, globose to subglobose with sterigmal attachment no more than 1µm long tapering towards the tip, spore wall less than 0.5µm thick, becoming slightly thicker near sterigmal attachment. Spore ornamentation less than 1µm tall, weakly amyloid, ranging from irregular granules to a well-developed reticulum (Image 1e).

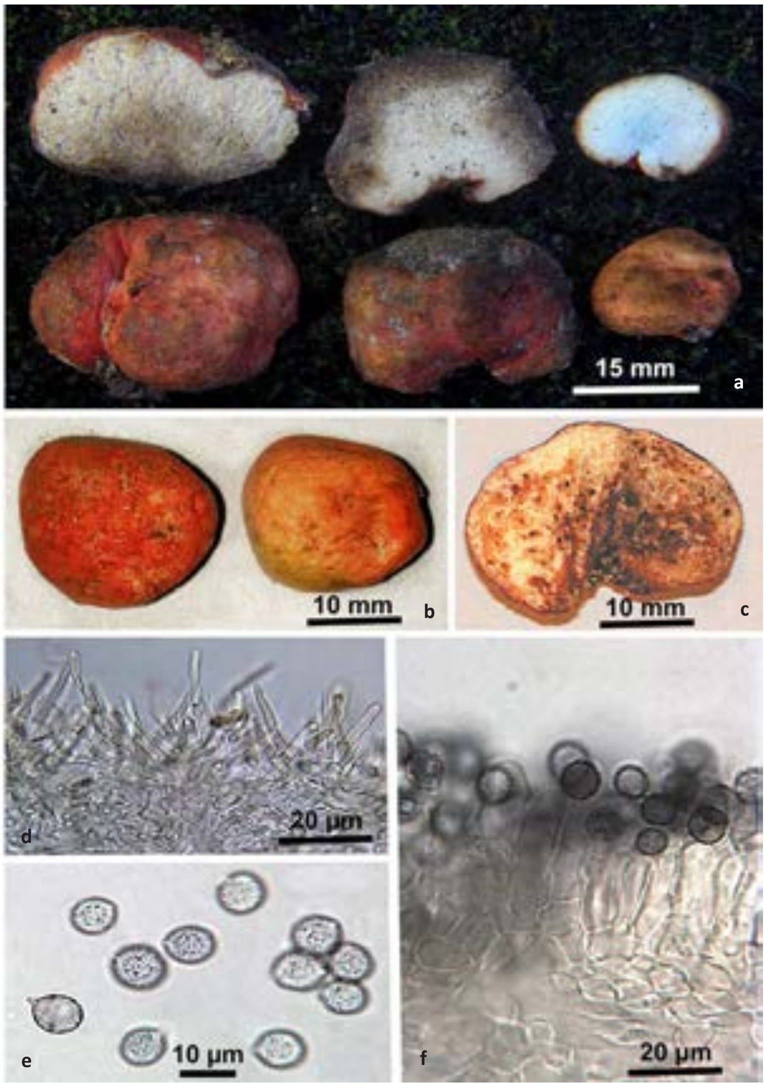

Image 1. Morphological features of *Russula scarlatina*. a—Different developmental stages in cross-section; note glebal darkening with age and maturation. b. Scarlet peridium of two young specimens | c—Gleba of a senescent specimen showing dark staining reaction around insect larval holes | d—Dermatocystidia and pigmented hyphae present in the peridiopellis turf. | e—Basisiospores, note the weak amyloid reaction and short ornamentation | f—Narrowly clavate hymenophoral cystidia. © a,d,e & f—Todd F. Elliott; b & c—James M. Trappe.

Habitat and Distribution

Primarily restricted to dry sclerophyll woodlands and open forest habitats from the Warrumbungle Mountains and New England Tablelands south through the South West Slopes, tablelands, and Riverina of New South Wales, and through the grassy woodlands of central and coastal Victoria at elevations of 10–678 m and fruiting between May and September. Associated trees are typically various mixtures of *Acacia* spp., *Allocasuarina luehmannii, Callitris endlicheri, Eucalyptus albens, E. blakeleyi, E. bridgesiana, E. camaldulensis, E. goniocalyx, E. leucoxylon, E. macrorhyncha, E. mannifera, E. melliodora, E. microcarpa, E. macrorhyncha, E. polyanthemos, E. populinea, E. sideroxylon,* and *E. tricarpa*. We have often encountered this species in nearly monodominant stands of *E. blakeley, E. camaldulensis* or *E. microcarpa*. The types of woodlands where *R. scarlatina* is commonly encountered vary considerably from North to South within its range: for example, the intensely studied box-gum grassy woodlands of the Australian Capital Territory (McIntire et al. 2010) and the Gippsland red gum grassy woodland in the Moormurng Flora and Fauna Reserve in the coastal sand plains near the Gippsland Lakes of Victoria (Australian Department of Environment 2010). The resilience and adaptability of *R. scarlatina* is graphically illustrated by collection 35049 (Mitchell, ACT) which was emergent on bare, compacted soil under an unidentified planted *Eucalyptus* sp. at the edge of the sidewalk. All other collections were from more intact albeit often degraded woodlands or open forests.

Paratypes: Australia, Australian Capital Territory: Goorooyaroo Nature Reserve, 55H 699328 N, 6103996 E, elev. 695 m, Trappe 32837, 9 Sep 2008 (OSC 158775, CANB); Mitchell, Hoskins St. T. Elliott, Trappe 35049, 2 Sep 2010 (CANB). NEW SOUTH WALES: Benambra Nature Reserve, from Holbrook on Mountain Creek Rd. 4.5km from Mullengandra Rd., J. Trappe 31627.1 & B. Skoro, 1 Aug 2006 OSC 158771, CANB); Burrinjuck Nature Reserve SE of Yass, P. Thrall, Trappe 31959, 28 Jun 2007 (OSC 158774, CANB) Murray River, Cottadidda State Forest, under *Eucalyptus camaldulensis,* R. Strömmer & J. Trappe 25209, 3 Jun 2000 (OSC 158744, CANB). Kosciuszko National Park, Barry Way 0.5km N of Pinch River crossing, Claridge Site 6, Jacobs Mapsheet Grid 625600 Easting 5927350 Northing, under *Acacia implexa* & *Eucalyptus albens,* A. Jumpponen, AWC 3305, 14 May 2001 (OSC 158814, CANB) Parkes Shire, Genaren Farm, Genaren Hill Sanctuary near N boundary fence, Tullamore map 8432-1 & 4, AMG 579900 E, 6396200 N, under *Eucalyptus dealbata, E. sideroxylon, Acacia doratoxyon, A. deanii,* and *Callitris glaucophylla*, J. Trappe 26478, 22 Jun 2001 (OSC 158757, CANB); Riverina, Kilpa Farm, 17.5km SE of Berrigan, under *Eucalyptus microcarpa. R. Strömmer,* J. Trappe 25144*,* 4 Jun 2000 (OSC 158741); Savernake Station, Horse Paddock, 26.5km N of Mulwala, under *Eucalyptus melliodora,* and *E. microcarpa*, J. Trappe 25197*,* 4 Jun 2000 (OSC 158743, CANB); Womboyne Farm N of Barooga, under *Acacia* sp.*,* J. Trappe 25368, 28 Jun 2000 (OSC 158754, CANB); Wandook Traveling Stock Route 10km W of Deniliquin, $35^0$27’47”S, $145^0$0’40”E, elev 90m, J. Trappe 28651, 16 Jul 2003 (OSC 158765, CANB); Warrumbungle National Park, E of Visitors Center, T. Elliott, Trappe 35062, 3 Sep 2010 (DAR). Weddin Mountains National Park, Weddin Gap, AMG 592950 E, 6241050 N, J. Trappe 26437, 19 Jun 2001 (OSC 158756, DAR). VICTORIA: Chiltern Box-Ironbark National Park, Donchi Hill Rd, R. Strömmer & J. Trappe 25219, 6 Jun 2000 (OSC 158745); East Gippsland, Moormurng Flora and Fauna Reserve, Leathams Dam Rd, T. Elliott, Trappe 35049, 26 Aug 2010 (OSC 158812, MEL); Maldon State Forest, Red White and Blue Track 1.7km S from Pullens Rd, AMG 242534 E, 5895655 N, elev 300m, J. Trappe 27595, 9 July 2002 (OSC 158759, MEL), Reef Hills Regional Park, Roes Rd., by pond, under *Eucalyptus albens,* J. Trappe 25263*,* 7 Jun 2000 (OSC 158749, MEL).

Discussion

Russula scarlatina is easy to recognize in the field because of its vibrant scarlet peridium, totally enclosed loculate gleba, and lack of a stipe; these characters set it apart from other members of the genus. Some *Arcangeliella* (sequestrate *Lactarius*) species appear somewhat similar but are readily distinguished from *R. scarlatina*. The most similar of these taxa have bright orange (not scarlet) peridia and lactate and/or have laticiferous hyphae, unlike *R. scarlatina*. Other distinctive characters of *R. scarlatina* include unusually short spore ornamentations that are weakly amyloid and a distinctive peridiopellis turf; furthermore, this species has been found only in dry sclerophyll woodlands and open forest habitats.

Russula theodoroui (T. Lebel) T. Lebel sometimes has reddish to scarlet peridia, but it differs from *R. scarlatina* in having a short but prominent stipe, a pileopellis epithelium of inflated cells (but lacking a turf of dermatocystidia), and larger spores (8–10 x 8–9.5 µm) with much larger and more strongly amyloid ornamentation. Because of its peridiopellis of inflated cells, *R. theodoroui* had earlier been placed in the genus *Cystangium* but now is in the genus *Russula* (Lebel 2017; Elliott & Trappe, 2018). *Russula theodoroui* has never been collected south of Queensland, whereas *R. scarlatina* has not been collected north of the Warrumbungle Mountains of New South Wales.

Russula westresii (T. Lebel) T. Lebel is one of the more common and widespread species in eastern Australia and resembles *R. scarlatina* in having a brown staining gleba, spores with short ornamentation, and sometimes orange to brick red streaks and patches on an otherwise yellowish-white to pale brownish-yellow peridium (but not the overall scarlet of *R. scarlatina*). *Russula westresii* also lacks a peridiopellis turf of dermatocystidia, and its spores are larger (8–10 x 7.5–9 µm) than those of *R. scarlatina*.

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Note

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THE HIMALAYAN CRESTLESS PORCUPINE *HYSTRIX BRACHYURA* LINNAEUS, 1758 (MAMMALIA: RODENTIA: HYSTRICIDAE): FIRST AUTHENTIC RECORD FROM BANGLADESH

Mohammad Ashraf Ul Hasan[1] & **Sufia Akter Neha**[2]

[1] B-8/C-5, Bandhan Complex, Agargaon Taltola Government Staff Quarter, Sher-e-Bangla Nagar, Dhaka 1207, Bangladesh.
[2] 39/1A, Road 10, Middle Badda, Gulshan, Dhaka 1212, Bangladesh.
[1] ashrafulhasan.jnu403@gmail.com (corresponding author),
[2] neha.jnu463@gmail.com

Hystrix is a genus of porcupines under the family Hystricidae, constituted by eight species: Thick-spined Porcupine *H. crassispinis*, Philippine Porcupine *H. pumila*, Sumatran Porcupine *H. sumatrae*, Himalayan Crestless Porcupine *H. brachyura*, Sunda Porcupine *H. javanica*, Cape Porcupine *H. africaeaustralis*, Crested Porcupine *H. cristata*, Indian Porcupine *H. indica* (Myers et at. 2019). The individuals of this genus are characterized by their coat of sharp quills, strictly nocturnal, primarily terrestrial, and herbivorous in nature. This fossorial rodent lives in family units and feeds on fruits, roots, tubers, barks and carcasses (Jnawali et al. 2011; Mallick 2012). They are widely distributed in Africa and southwestern, southern & southeastern Asia (McKenna & Bell 1997). *Hystrix brachyura* is found in India, Nepal, Bhutan, Indochina to the Malay Peninsula and China, as well as Hainan, Sumatra and Borneo Islands (Lekagul & McNeely 1988; Lunde et al. 2008; Mallick 2012). In the literature (Corbet & Hill 1992; Agrawal 2000; Wilson et al. 2016), this species already reported from Bangladesh; however, not found any authentic record. *Hystrix brachyura* is categorized as Least Concern globally (Lunde et al. 2016). The species is reported to be encountered in a wide variety of habitats such as temperate forests, tropical and subtropical montane forests to open areas, rocky mountains, riverine and ravines (Chung et al. 2016; Lunde et al. 2016). No records, however, have been confirmed this species from mangrove forest. Hence, the present study elucidates the first confirmation record of *Hystrix brachyura* from the Sundarbans Mangrove Forest, Bangladesh.

During our social survey in Sundarbans mangrove forest, Bangladesh, the *Hystrix brachyura* was sighted in the Supoti Forest Camp (22.047^{0}N & 89.827^{0}E), Sundarbans East Zone, Bangladesh (Figure 1). On 22 May 2018, opportunistically an individual of porcupine was directly spotted but it was soon fled away into the shrubs and unidentified at that moment. The observation area was dominated by *Acanthus ilicifolius* and *Phragmites karka*. To substantiate the confirmation, a subsequent attempt was taken on 24 May 2018. Though several studies have revealed that various kinds of bait lured to particular species in general, or attract more of a prescribed species has been of specific focus (Oswald & Flake 1994); considering the facts, pieces of apples and potatoes were used to attract porcupine in a suitable place where a clear observation could be made. One more time, an individual attracted to bait was seen under the shrub of *Phragmites karka* at 19.35h. Finally, a clear visual observation as well as several photographs were taken. We recorded the geographic coordination using Garmin GPSMAP 64S.

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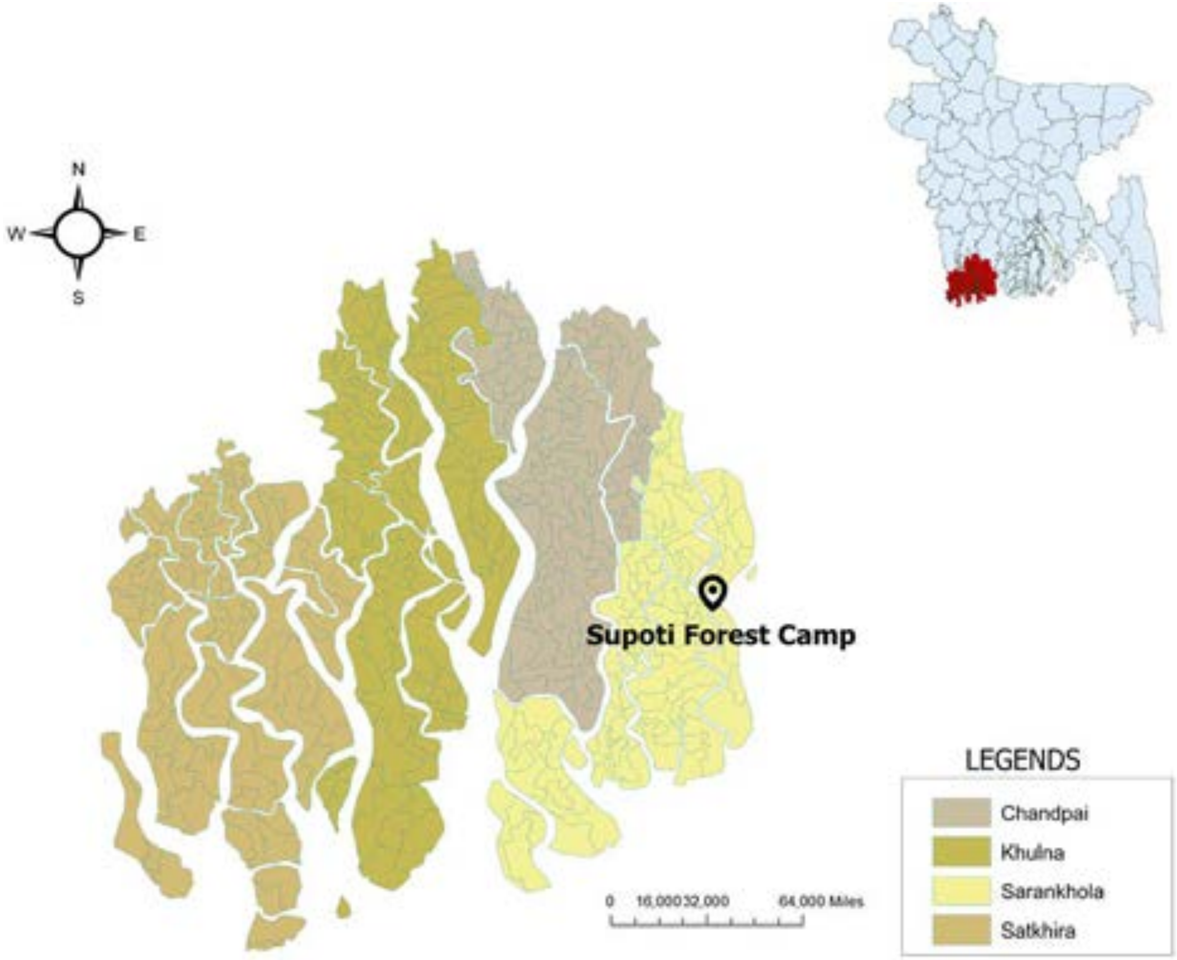

Figure 1. Location of the *Hystrix brachyura* recorded from Sundarbans, Bangladesh.


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Image 1. Lateral view of the Himalayan Crestless Porcupine *Hystrix brachyura* from the Supoti Forest Camp, Sundarbans, Bangladesh on 24 May 2018.

Image 2. Frontal view of the Himalayan Crestless Porcupine *Hystrix brachyura* showing its blunt muzzle, 24 May 2018.

The head-body length of *Hystrix brachyura* is 59–72 cm and the tail 6–11 cm long (Francis 2008). The weight is 8kg while short and sturdy limbs are covered with brown hairs which possess four claws on the forelimb and five on the hind limb (Menon 2014; Parr 2003; Jnawali et al. 2011; Lunde et al. 2016). Compared to *Hystrix indica*, it has relatively shorter dorsal crest; smaller tail instead of a visible tail (Menon 2014). Unlike *Hystrix indica* that has more than two dark bands on long dorsal quills, *Hystrix brachyura* has only one (Image 1). Another significant characteristic that can be distinguished from the *Hystrix indica* is its blunt muzzle (Image 2).

Hystrix brachyura is one of the three species found in southeastern Asia (Francis 2008; Chung et al. 2016). A total of 127 mammalian species including two species of Hystricidae family has been recorded so far by IUCN Bangladesh (2015), namely, *Atherurus macrourus* and *Hystrix indica*; therefore, *Hystrix brachyura* is new addition to the mammalian fauna of the country. Moreover, 42 species of mammals are found in Sundarbans, Bangladesh (IRMP 2010) and 49 mammalian species are recorded at Sundarban Tiger Reserve in India (Mallick 2011). Both sites of the Sundarbans mangrove region have not reported *Hystrix brachyura*, thus, this detection supports that the mangrove forest is another potential habitat.

Hystrix brachyura is a poorly studied rodent and therefore, little information available on its ecology across the southeastern Asian region. The species is threatened in its habitat due to habitat destruction and hunting for food and therapeutic purposes (Molur et al. 2005; Borschberg 2006). Consequently, rapid climate change and anthropogenic pressures affect the mangrove ecosystem which could eventually make the species vulnerable. An empirical study on this elusive species is needed which will fill the gap in porcupine studies and help in the promotion of conservation strategies.

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A NEW DISTRIBUTION RECORD OF *ASPLENIUM SCALARE* ROSENST. (ASPLENIACEAE) IN INDIA

Periyasamy Vijayakanth [1], Jaideep Mazumdar [2], S. Sahaya Sathish [3], Veluchamy Ravi [4] & Ramachandran Kavitha [5]

[1] Department of Botany, Arignar Anna College (Arts & Science), Krishnagiri, Tamil Nadu 635115, India.
[2] Department of Biological Sciences, Burdwan Town School, Burdwan, West Bengal 713101, India.
[3] Centre for Cryptogamic Studies (CCS), Department of Botany, St. Joseph's College (Autonomous), Tiruchirappalli, Tamil Nadu 620002, India.
[4] Department of Botany, Government Arts College (Men), Krishnagiri, Tamil Nadu 635001, India.
[5] Department of Botany, Holy Cross College, Tiruchirappalli, Tamil Nadu 620002, India.
[1] apvijayakanth@gmail.com (corresponding author), [2] jaideepmazumdar10@gmail.com, [3] sahayasathish@yahoo.in, [4] ravi.veluchamy@gmail.com, [5] kavibbt@gmail.com

The genus *Asplenium* L. (Aspleniaceae) in India is currently represented by 72 species (Fraser-Jenkins et al. 2016).

The fern species *Asplenium scalare* Rosenst. was first described as a new species by Rosenstock (1914) from Sumatra, Indonesia. It was also reported from Malaysia (Holttum 1966; Fraser-Jenkins 2012).

Based on an early collection by J. Joseph from Thiruvananthapuram, it was Fraser-Jenkins and Chandra et al. (2008) who first reported this species from Kerala in India. They found only one specimen at the Madras Herbarium (MH) and thus its nativity was not verified (see Fraser-Jenkins et al. 2016). This collection was mistaken for *A. phyllitidis* D. Don by earlier authors.

Here we report the occurrence of *A. scalare* in Tamil Nadu for the first time. As the previous report was not confirmed, our new report is the first verified one in India. It was found only in Kuzhivalavu, Kolli Hills (Image 1). Its natural occurrence suggests that *A. scalare* is native in India, not escaped from cultivation. This species has shortly caudate, simple fronds, with buds (Holttum 1966; Image 1). It is very rare in India and assessed as CR (Critically endangered) by Fraser-Jenkins (2012).

Another simple fronded, proliferous species *A. batuense* Alderw. was reported from the Nicobar Islands (Fraser-Jenkins 2012). In *A. scalare* midrib is not winged on lower surface, like *A. batuense* (Holttum 1966).

Asplenium scalare **Rosenst.,**

Repert. Spec. Nov. Regni Veg. Beih. 13: 214. 1914. (Image 1)

Lectotype (designated here): Indonesia. Sumatra. Batakerland, 1911, Dr. J. Winkler 73 a (S-P-1453; Isolectotypes UC391682, NY00128018).

Synonym: *Asplenium subscalare* Alderw., Bull. Jard. Bot. Buitenzorg, 2, 20: 6. 1915.

Distribution: India (Kerala, Tamil Nadu—present report), Indonesia, Malaysia.

Note: In the protologue Rosenstock (1914) did not mention any holotype. He only mentioned the collector: Dr. J. Winkler, collection no.: 73a. We traced the type specimens (syntypes) in UC (barcode UC391682), NY (barcode NY00128018) and S (Reg. no. S-P-1453) (herbarium acronyms from Thiers 2018). To fix the application of this name we selected specimen at S as Lectotype.

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Image 1. *Asplenium scalare* Rosenst. plant in Kolli Hills, India showing proliferous frond.

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Response to spiders of Odisha: a preliminary checklist additions to the spider checklist of Odisha

John T.D. Caleb

Zoological Survey of India, Prani Vigyan Bhawan, M-Block,
New Alipore, Kolkata, West Bengal 700053, India.
caleb87woodgate@gmail.com

Choudhury et al. (2019) presented a preliminary list of 248 spider species known to occur from Odisha State based on the compilation of all published literature and fresh collections carried out during 2016–2017. This is the most recent paper providing an overall view of the spider diversity known in the state, however, the presented checklist seems to be incomplete, since not all species have been identified up to the species level. Several species, as many as 77 morphospecies, were identified up to the genus level only. Furthermore, it has also missed out on recording several species described from Odisha State itself (Table 1).

The authors declare that they prepared the checklist based on 'published literature', but seem to have omitted a few important ones. Omission of a few species may happen inadvertently due to many reasons, one being the unavailability of the concerned literature. But that is no excuse in this case, since all published literature are available and accessible from the World Spider Catalog (2019). The magnanimous work of Prószyński (1992) was completely ignored by the authors while other faunistic works by non-specialists have been considered. Prószyński described numerous species from India and many of them were from Odisha State. Other works by Logunov (2001) and Tanasevitch (2018) have also not been referred.

The aim of a checklist must be to rather provide information on the species present in the given locality and not add unidentifiable entities just to increase the species number. Having 77 unidentified species in the list may be considered an unnecessary addition, unless important morphological characters had been illustrated. On the other hand, species which have to be on the list have been ignored.

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Table 1. Additions to the list of spider species known from Odisha State.

	Species	Locality	Reference
1	*Bianor angulosus* (Karsch, 1879)	Cuttack	Logunov 2001
2	*Carrhotus sannio* (Thorell, 1877)	Daitari	Prószyński 1992
3	*Epeus albus* Prószyński, 1992	Jajpur-Keonjahr District	Prószyński 1992
4	*Epeus indicus* Prószyński, 1992	Jajpur-Keonjahr District	Prószyński 1992
5	*Habrocestoides bengalensis* Prószyński, 1992	Daitari	Prószyński 1992
6	*Jajpurattus incertus* Prószyński, 1992	Daitari	Prószyński 1992
7	*Myrmaplata plataleoides* (O. P.-Cambridge, 1869)	Daitari	Prószyński 1992
8	*Okinawicius daitaricus* (Prószyński, 1992)	Daitari	Prószyński 1992
9	*Pancorius daitaricus* Prószyński, 1992	Daitari	Prószyński 1992
10	*Pandisus indicus* Prószyński, 1992	Jajpur-Keonjahr District	Prószyński 1992
11	*Phintella bifurcata* Prószyński, 1992	Daitari	Prószyński 1992
12	*Phintella debilis* (Thorell, 1891)	Daitari	Prószyński 1992
13	*Rhene daitarensis* Prószyński, 1992	Daitari	Prószyński 1992
14	*Toxeus jajpurensis* (Prószyński, 1992)	Daitari	Prószyński 1992
15	*Nasoona orissa* Tanasevitch, 2018	Padiakutibari	Tanasevitch 2018

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Reply to response: spiders of Odisha

Sudhir Ranjan Choudhury [1], Manju Siliwal [2] & Sanjay Keshari Das [3]

[1,3] University School of Environment Management, Guru Gobind Singh Indraprastha University, Sector 16-C, Dwarka, New Delhi 110078, India.
[2] Wildlife Institute of India, Post Box #18, Chandrabani, Dehradun, Uttarakhand 248001, India.
[1] sudhirranjanchoudhury@gmail.com, [2] manjusiliwal@gmail.com,
[3] skdasipu@gmail.com (corresponding author)

Comment: The authors declare that they prepared the checklist based on ‘published literature’, but seem to have omitted a few important ones. Omission of a few species may happen inadvertently due to many reasons, one being the unavailability of the concerned literature. But that is no excuse in this case, since all published literature is available and accessible from the World Spider Catalog (2019).

Reply: It was a huge and scattered data that is compiled in this checklist, many of them are local reporting which are till date not available in the World Spider Catalog.

Its welcome always to add to the list if it can’t be added during the compilation.

Comment: Having 77 unidentified species in the list may be considered an unnecessary addition, unless important morphological characters had been illustrated. On the other hand, species which have to be on the list have been ignored.

Reply: It is not at all unnecessary additions. In the present study we have 65 spiders identified up to the genus level only, of which many are either new report from India or new species that will be communicated separately with taxonomic details. Rest are reported by previous workers that cannot be ignored when we compile the checklist.

Comment Table 1:

***Myrmaplata plataleoides* (O.P.-Cambridge, 1869)**

***Nasoona orissa* Tanasevitch, 2018**

Reply: The first species already exists in the checklist.

The second species information was with us, but the paper was finalized and communicated before this species was discovered and we had in mind to include this in final checklist in future.

Moreover, our checklist was based on only one-year field survey data and is preliminary. The main aim was to compile the scattered data on spider fauna of this region. In future we will go for a detailed checklist.

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ravi@threatenedtaxa.org

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