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continued on the back inside cover

Cover: Fish species recorded in the Gowthami-Godavari Estuary, Andhra Pradesh: *Lutjanus johnii* (top left), *Triacanthus biaculeatus* (top right), *Acentrogobius cyanomos*, *Elops machnata*, *Trypauchen vagina*, *Oxyurichthys microlepis*. © Paromita Ray.

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ARTICLE

Dietary preference of Assamese Macaque *Macaca assamensis* McClelland, 1840 (Mammalia: Primates: Cercopithecidae) in Dampa Tiger Reserve, India

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Abstract: Dietary composition and selection of food items are important approaches for the flexibility and adaptability of macaques in different natural habitats. With a wide distribution range, Assamese Macaques feed on various food types. This study reports the consumption of 57 plant species from 30 families. A total of 2,233 scans resulted in 16,381 feeding behavioral records during the study period from 2018 to 2020. Macaques appear to be primarily folivorous in Dampa as leaves (young & mature) constitute 44.74% of their daily dietary intake while the fruit consumption was found to be 25.31% of the total dietary intake. Plant species like *Artocarpus lakoocha* (15.65%), *Albizia procera* (12.03%), *Glochidion hyneanum* (10.53%), *Diospyros glandulosa* (9.49%), and *Albizia lebbeck* (7.28%) contributed significantly to macaque's diet compare to other plants. No significant variation was observed on time spent for feeding on leaves, fruits, flowers, and seeds in both different months and seasons of the year. The highest percentage of the diurnal time invested on feeding activity was (59.04%) in the month of January (winter season), which may be due to the cold climate and scarcity of proper feeding items and the least was (35.19%) in June where food resources are more readily available. The richness of fruiting plants in Dampa Tiger Reserve appears to fulfill the dietary requirement of Assamese Macaque and therefore intactness of forest resources is necessary for their development and conservation.

Keywords: Conservation, diet, feeding behaviour, food selection, primate, richness.

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Competing interests: The authors declare no competing interests.

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INTRODUCTION

Diet or food selection is an important trade in an animal's life. Adaptation and alteration in dietary patterns account for the major ecological and behavioral differences among primate species especially in wild (Koirala et al. 2017; Ghimire et al. 2021). Dietary preference provides useful information on individual food species necessary for survival, insight into its level of dietary specialization, resource partitioning and also on monitoring strategies for threatened and elusive primates (Koirala & Chalise 2014; Koirala et al. 2017; Khatiwada et al. 2020). Assamese Macaque *Macaca assamensis* is one of the most widely distributed non-human primate species in southeastern Asia. They have a wide distribution range across the region inhabiting different forms of forest habitat such as evergreen broadleaf forests, deciduous broadleaf forests, mixed broadleaf, and conifer forests (Boonratana et al. 2008; Timmins & Duckworth 2013; Boonratana et al. 2020). It is categorized as a 'Near Threatened' species by the IUCN Red List of Threatened Species and listed as an Appendix II species of the Convention on International Trade in Endangered Species (CITES) (Boonratana et al. 2020; Ghimire et al. 2021) and also as Scheduled II species by the Indian Wildlife Protection Act, 1972.

Assamese Macaques (AM) are known to invest more than two-fifths (>40%) of the diurnal time on feeding (Ghimire et al. 2021) and are adaptable foragers able to modify their diet seasonally, being more folivorous in the dry season and more frugivorous in the wet season. Understanding the temporal availability of food to a particular species is crucial when examining the drivers of their feeding strategies (Bessa et al. 2015). Macaques in the tropics tend to consume more fruit and fewer leaves than temperate-living macaques (Hanya 2004; Tsuji et al. 2013; Hung et al. 2015; Li et al. 2019, 2020). Their natural feeding items in the wild include fruits, leaves, seeds, flowers, buds, young shoots, twigs, barks, roots, and resin of gymnosperms (Chalise 1999; Koirala & Chalise 2014; Koirala et al. 2017; Boonratana et al. 2020; Khatiwada et al. 2020; Ghimire et al. 2021). They may also feed on faunal resources such as grasshoppers, earthworms and other mammals, birds, reptiles, amphibians, mollusks, and spiders (Schulke et al. 2011; Hambali et al. 2014; Nila et al. 2014). Dietary selection among AM tend to be affected by factors like habitat quality, available foraging options, food resources, digestive capabilities, and the food nutrients it require (Chalise 1999; Poulsen et al. 2001; Jaman & Huffman 2012; Ghimire et al. 2021).

In recent years, the landscapes of northeastern India have witnessed swift alteration in the form of reduction of primary forest, shifting cultivation, mono-plantations, forests fire, habitat fragmentation due to constructions, threatening the primate diversity of the region (Choudhury 2001; Srivastava 2006; Choudhury 2011; Mazumder et al. 2014). Dampa Tiger Reserve (DTR), harbors several species of primates that inhabit the forest very close to the buffer areas and thereby have high chances of encroaching on the agricultural crop fields that are adjacent to the core. Such encroachment may lead to human-primate negative interactions due to crop loss suffered by local farmers. Hence understanding the feeding ecology of this species and developing suitable measures to mitigate them is necessary in the area. Till date, the macaque's response to such variations in the accessibility of food resources during seasonal changes is not yet reported in this region. As there is a scarcity of information on the feeding ecology and pattern of food selection, we intend to provide new insight to the food habits and dietary preferences of AM in the tropical forest of DTR in Mizoram, India, and possibly contribute for better management and conservation of the species and its habitat in the region.

Image 1. Assamese Macaque *Macaca assamensis* feeding on a grasshopper at Damparengpui in Teirei range, Dampa Tiger Reserve.

MATERIALS AND METHODS

Study area

The study was conducted from September 2018 to August 2020 at DTR (23.38–23.70 N & 92.27–92.43 E) located in the western part of Mizoram in Mamit district along the international border to Bangladesh. The reserve comprises a core area of 500 km^2 and a buffer 488 km^2, covering mountainous terrains, and elevation ranging 250–1,100 (Figure 1) (Johnson et al. 2021). The natural vegetation is distinct by the tropical evergreen to semi-evergreen of undulating, rugged in nature consisting of alternating ridges, medium hills, and slopes of mostly bamboo forest classified under the Cachar tropical evergreen and semi-evergreen: 1B/C3 and 2B/C2 forest, tropical moist deciduous forests: 3C/C3b and 3C2S1, sub-montane type: 2B1b (Champion & Seth 1968). The moist valley is lofty and evergreen, runs parallel along the rivers, steeper slopes have more deciduous elements, often with sympodial bamboos in the understory (Vanlalsiammawii et al. 2020). Weather pattern is characterized by a tropical humid climate with distinct cold (November–February), summer (March–June), and rainy (May–October) seasons. The temperature ranges from 4°C in winter (January) to 36°C in summer (May–June). The average annual rainfall is 2,200 mm. Forest canopy at lower elevation is 30–35 m, with evergreen and some deciduous trees

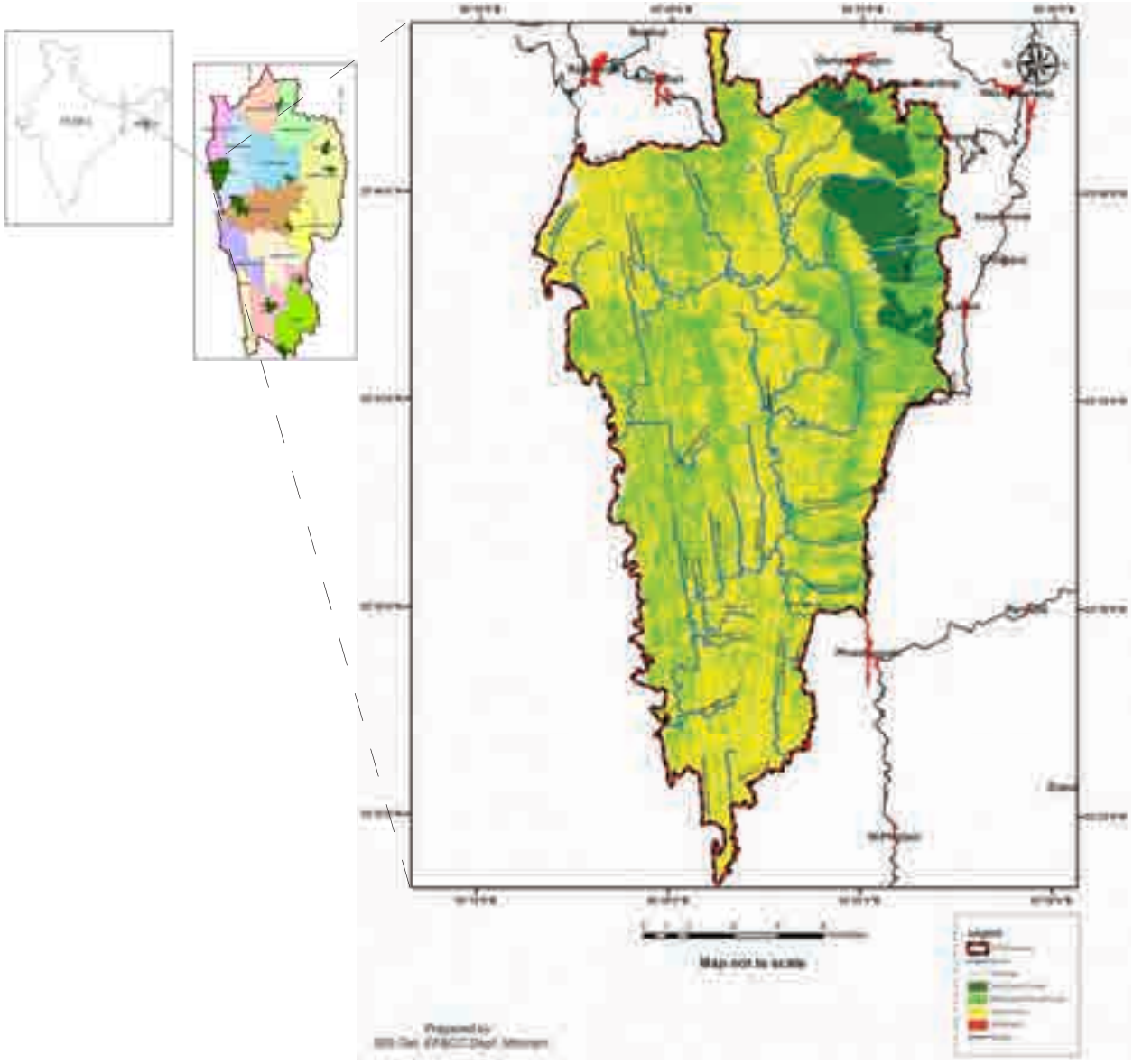

Figure 1. Dampa Tiger Reserve, the study area.

interspersed with tall (~40 m) emergent trees such as *Dipterocarpus turbinatus*, *Tetrameles nudiflora*, *Michelia champaca*, and *Arctocarpus chaplasha*, while from the elevation above 700 m, the forest forms a canopy at 25–35 m characterized by trees such as *Schima wallichii*, *Castanopsis indica*, and *Mesua ferrea* (Mandal & Raman 2016).

Other primate species in the DTR are Rhesus Macaque *M. mulatta*, Northern Pig-tailed Macaque *M. leonina*, Stump-tailed Macaque *M. arctoides*, Capped Langur *Trachypithecus pileatus*, Phayre's Leaf Monkey *T. phayrei*, Western Hoolock Gibbon *Hoolock hoolock*, and Bengal Slow Loris *Nycticebus bengalensis* (Pachuau et al. 2013).

Study subjects

The feeding ecology and dietary pattern of AM in DTR was determined by marking and following a particular troop. We observed for their daily activities and feeding plants from September 2018 to August 2020. The observation of AM in the field was conducted continuously during the study period along the adjacent buffer fringe. The time spent for monitoring AM was maximum, i.e., 10–12 h during dry seasons (winter and spring) and Minimal in monsoon (i.e., 6–7 h). Constraints faced during the survey period include inaccessible terrains, leeches, and bad weather conditions. Days lost to bad weather condition was compensated by the addition of observation hours and days during the dry and spring season. The individuals of the focal troop were identified with the help of different external characters and appearances such as body structure, facial features, fur color, cut marks, skin colour, and tail carriage. The troop consisted of two adult males, three adult females, five sub-adult females, three sub-adult males, two juveniles, and four infants that were classified by sex and age based on coloration, body size, and development of sexual characteristics following earlier established physical descriptions (Ulibarri & Gartland 2021).

Habitat and Vegetation sampling

Habitat and vegetation types in the study sites were determined by a stratified sampling method. We employed nine plots randomly in square subplots measured (20 x 20) m^2 in the Teirei range (23.68° N, 92.4° E and 23.66 N, 92.41° E) within an elevation range of 687–836 m. All sampling was made on foot on a transect line that were previously marked. The observation was made using a binocular, GPS, and digital camera. All the trees within the quadrats were identified to the species level (Sawmliana 2013; Hegde & Manpoong 2017), counted and their diameter at breast height was measured at approximately 1.37 m above the ground. The dominance of each species within a plot was calculated as the relative density (RD) and relative frequency (RF), following Irmayanti et al. (2022) and ultimately determined the Important Value Index IVI value for each plant species in a plot by summing the relative density (RD), relative basal area (RBA), and relative frequency (RF) following Deori et al. (2016).

Dietary composition and feeding activity

Data on the dietary composition and feeding behavior of AM were collected by direct observations in the field following the methods of Chalise et al. (2013). The feeding data was collected for 24 months from September 2018 to August 2020. Observations were noted down every 10 minutes per hour using direct observation of both adult male and female individuals from the time they were encountered to until out of sight via focal individual sampling, starting from 0600 h to 1700 h. Sampling was carried out for 5–10 consecutive days of every month (Solanki et al. 2008) until the focal individual under observation disappeared from view sight or retired to sleeping site (Altmann 1974; Bartlett 1999). The focal individual was randomly determined among adults prior to the observation and we focused mainly on adult male and female individuals and made 6 to 12 entries per day on information such as consumed food plants, food items, and feeding time based on the season. The feeding items or plant parts consumed were categorized as leaves (both young and mature leaves), flowers, fruits, seeds, and shoots. The time spent feeding on different food items was calculated as per Gupta & Kumar (1994):

$$T_a = \frac{N_a \text{ X } 100}{N}$$

where,

T_a = Percent time spent on feeding activity

N_a = Number of records with feeding activity, and

N = Total number of records for the day

Data Analysis

Kruskal-Wallis test was performed to determine the monthly and seasonal variation in time devoted to each plant part and the number of plant species consumed. A 'P' Value of <0.05 was considered statistically significant. SPSS version 16.0 software (SPSS Inc Chicago, Illinois, USA) and GraphPad Prism ver. 8.2 were used for statistical and graphical analysis.

RESULTS

Habitat types and vegetation

Vegetation in the study sites was determined through vegetative sampling and collection of ecological based data in various quadrats. The surveyed sites mainly consist of tropical deciduous forests and bamboo forests with ≥70% canopy cover. Tree species such as *Acer laevigatum*, *Canarium bengalense*, *Trema orientalis*, *Schima wallichi*, *Albizia chinensis*, *Derris robusta*, *Albizia rumphii*, *Ficus racemosa*, and *F. hirta* of basal width 40–80 cm were dominant in the surveyed sites. Bamboo species like *Dendrocalamus asper*, *D. longispatus*, *Cephalotachyum latifolium*, *Bambusa mizorameana*, *B. tulda*, and *Melocalamus compactiflorus* were also prevalent in the region. AM was observed to forage on 57 plant species belonging to 30 families (Table 1). Of the 57 feeding plants known to be consumed by AM, the highest relative density was recorded for *Melocana baccifera* (3.78%), followed by *Dendrocalamus longispathus* (3.36%), and *Artocarpus lakoocha* (2.94%) (Table 2). The highest relative frequency of the feeding plants was calculated for *Melocana baccifera* (4.87%), *Dendrocalamus longispathus* (4.38%), and *Musa ornata* (2.99%); while the least encountered plant species were the *Ficus* spp., i.e., *F. auriculata*, *F. elastica*, and *F. racemosa* with values of 0.49%, 0.73%, and 0.73%, respectively. The important value index (IVI) was contributed most by *Ficus auriculata* (15.2), *Bombax ceiba* (13.3), & *Albizia procera* (8.66) and the least was recorded for *Dysoxylum gotadhora* (2.80), *Gnetum gnemon* (2.81), & *Protium serratum* (2.96) (Table 2).

Dietary composition and feeding activity

In the study, 203 days of the survey resulted in 2,233 scans and 16,381 behavioural records. AM was observed to forage on 57 plant species from 30 families (Table 1). The number of food plant species consumed in each observation month ranges from 20 to 43 (32.42 ± 6.56) (Table 3). While plant species namely *A. lakoocha*, *C. graffithii* and all species of *Albizia* were fed throughout the year; species like *V. quinata, P. timoriana*, and *H. kurzii* were consumed in the least number (Table 3). Members of the family Moraceae (9), Meliaceae (5), Mimosaceae (4), and Euphorbiaceae (4) contributed to the most number of feeding plants in AM's diet, while the other listed plant families represent two or one plant species at most (Figure 2). Among the feeding plant species, trees accounted for 91%, herbs for 7%, and climbers/ vines for 2%. AM was found to munch on different plant parts such as fruits, leaves (young & matured), flowers, shoots, and seeds. Leaves formed the highest proportion of AM diet with 44.74% followed by fruits (25.31%), flowers (15.66%) seeds (12.14%), and shoots (2.14%) (Figure 3). Among the feeding plant species 13 species contributed for >1% feeding times. The major feeding plants of AM were identified to be *Artocarpus lakoocha* (15.65%), *Albizia procera* (12.03%), *G. hyneanum* (10.53%), *D. glandulosa* (9.49%), *Albizia lebbeck* (7.28%), *Cephalotaxus graffithii* (4.53%), and *F. auriculata* (4.20%) as it was observed to spend more time on this plants species. While plants such as *Walsura robusta* (0.31%), *Phyllanthus emblica* (0.30%), *Terminalia myriocarpa* (0.21%), *Vitex quinata* (0.12%) were found to be consumed in the least quantity (Table 1). Plants such as *A. lakoocha*, *Albizia procera*, *Diospyros glandulosa*, *P. serratum*, *Dendrocalamus longispathus*, and *Duabanga grandiflora* were identified to contribute with most number of consumable parts. Soft or tender shoots of *D. longispathus* and *M. baccifera* were the plants whose shoots were fed by AM. Distribution of feeding plant species indicates that *Melocana baccifera* (20), *Dendrocalamus longispathus* (18), *Caesalpinia cucullata* (16), *Musa ornata* (14), and *Walsura robusta* (13) were present in the highest number in the sampled quadrats although it does not represent the feeding utility by AM in its diet.

Monthly and seasonal effect on feeding phenology

In the present observation, leaves (young and mature) and fruits constituted the major food items of AM and they invested more time for feeding on these food items. Leaves, both young and mature leaves formed the highest bulk of AM's diet, as they were available throughout the years and no significant variation was observed on time spent on feeding leaves in different months of the year (X^2 = 19.46, df =11, p >0.05) (Figure 4). Similarly, there was no significant variation in the time spent on feeding of leaves in different seasons (X^2 = 3.429, df = 2, p >0.05). Fruits were most abundant during monsoon/summer and constituted the major food item during the month of June to August. They were observed to feed maximum fruits in the month of August (44.62% of the total food items), and the least consumption of fruits was recorded in the month of February (3.48% of the total food items). Time spent on feeding of fruits did not show significant variation in different months (X^2 = 15.87, df = 11, p >0.05) and seasons (X^2 = 4.571, df = 2, p >0.05). The highest consumption of flowers was observed in the month of February (28.05%), however, no significant variation in the time spent on feeding of flowers was observed monthly and seasonally

Table 1. Plants recorded that are consumed by Assamese Macaque *Macaca assamensis* in the study site.

	Species name	Family	Vernacular (Mizo)	Habit	Parts eaten by *M. assamensis*	Time spent for feeding (%)
1	*Artocarpus lakoocha*	Moraceae	Theitat	T	L, Fl, Fr, Sd	15.65
2	*Albizia procera*	Mimosaceae	Kangteknu	T	L, Fr, Fl, Sd	12.03
3	*Glochidion hyneanum*	Euphorbiaceae	Thingpawnchhia	T	Fl, L, Fr	10.53
4	*Diospyros glandulosa*	Ebenaceaea	Theivawkmit	T	L, Fr, Fl, Sd	9.49
5	*Albizia lebbeck*	Mimosaceae	Kangtek	T	L, Fl, Fr, Sd	7.28
6	*Cephalotaxus graffithii*	Cephalotaxaceae	Thinglenbuang	T	Fr, L	4.53
7	*Ficus auriculata*	Moraceae	Theibal	T	L, Fr	4.20
8	*Protium serratum*	Burseraceae	Bil	T	L, Fr, Sd	3.04
9	*Albizia chinensis*	Mimosaceae	Vang	T	L, Fr, Sd	1.57
10	*Bombax insigne*	Bombacaceae	Pang	T	L, Sd	1.44
11	*Dendrocalamus longispathus*	Poaceae	Rawnal	H	Sh	1.37
12	*Prunus ceylanica*	Rosaceae	Ruphir	T	Fr, Sd	1.21
13	*Garcinia succifolia*	Clusiaceae	Tuaithleng	T	L, Fr, Sd	1.15
14	*Cassia javanica*	Caesalpiniaceae	Makpazangkang	T	L, Fl, Sd	0.99
15	*Ficus semicordata*	Moraceae	Theipui	T	L, Fl, Fr	0.98
16	*Melocana baccifera*	Poaceae	Mautak	H	Sh	0.97
17	*Gmelia arborea*	Magnoliaceae	Ngiau	T	L	0.94
18	*Antidesma bunius*	Fabaceae	Thingkha	T	L, Fr	0.94
19	*Aporosa octandra*	Euphorbiaceae	Chhawntual	T	L, Sd	0.93
20	*Albizia odoratissima*	Moraceae	Kangtekpa	T	L, Sd	0.91
21	*Ficus elastica*	Moraceae	Thialret	T	Fl, L	0.87
22	*Parkia timoriana*	Mimosaceae	Zawngtah	T	Sd, L	0.87
23	*Dioscorea pentaphylla*	Verbenaceae	Thlanvawng	C	L, Sd	0.81
24	*Musa ornata*	Musaceae	Changvandawt	T	Fl, Fr	0.76
25	*Aglaia edulis*	Meliaceae	Raithei	T	L, Fl, Fr	0.76
26	*Bischofia javanica*	Euphorbiaceae	Khuangthli	T	L, Fr	0.75
27	*Magnolia oblonga*	Magnoliaceae	Ngiau	T	L, Fr	0.74
28	*Derris robusta*	Fabaceae	Thingkha	T	L, Fl, Sd	0.72
29	*Gnetum gnemon*	Gnetaceae	Pelh	T	L, Fl, Fr	0.70
30	*Bombax ceiba*	Bombacaceae	Phunchawng	T	Fl, L	0.66
31	*Artocarpus nitidus*	Moraceae	Tatte	T	L, Fl, Fr	0.65
32	*Mallotus macrostachyus*	Euphorbiaceae	Kharpa	T	L, Fl, Fr	0.64
33	*Chukrasia tabularis*	Meliaceae	Zawngtei	T	L, Fl, Fr	0.61
34	*Toona ciliata*	Meliaceae	Teipui	T	L, Fl, Fr	0.57
35	*Mangifera indica*	Anacardiaceae	Ramtheihai	T	Fl, Fr	0.56
36	*Syzygium cumini*	Myrtaceae	Lenhmui	T	L, Fl, Sd	0.55
37	*Ficus rumphii*	Moraceae	Hmawng	T	L, Fl, Fr	0.55
38	*Ficus racemosa*	Moraceae	Theichek	T	L, Fl, Fr	0.54
39	*Ficus retusa*	Moraceae	Rihnim	T	L, Fr	0.54
40	*Dillenia indica*	Dilleniaceae	Kawrthindeng	T	L, Fr, Fl	0.51
41	*Spondius pinnata*	Anacardiaceae	Tawitaw	T	L, Fr	0.49
42	*Dysoxylum gotadhora*	Meliaceae	Sahatah	T	L, Fl, Fr	0.48
43	*Hibiscus macrophyllus*	Malvaceae	Vaiza	T	L, Fl	0.48
44	*Caesalpinia cucullata*	Caesalpiniaceae	Hlingkhang	C	L, Fl, Sd	0.47

	Species name	Family	Vernacular (Mizo)	Habit	Parts eaten by *M. assamensis*	Time spent for feeding (%)
45.	*Anogeisus acuminata*	Combretaceae	Zairum	T	L, Fl, Fr	0.46
46	*Litsea monopetala*	Lauraceae	Nauthak	T	Fr	0.45
47	*Hydnocarpus kurzii*	Flacourtiaceae	Khawitur	T	L, Fl	0.44
48	*Heliconia rostrata*	Heliconiaceae	Changelpar	H	Fl	0.43
49	*Duabanga grandiflora*	Sonneratiaceae	Zuang	T	L, Fl, Fr, Sd	0.41
50	*Schima wallichii*	Theaceae	Khiang	T	L, Fr, Fl	0.37
51	*Xantolis tomentosa*	Sapotaceae	Maudo	T	L, Fr	0.37
52	*Terminalia crenulata*	Combrataceae	Tualram	T	L, Fl, Fr	0.36
53	*Castanopsis tribuloides*	Fagaceae	Thingsia	T	L, Sd	0.36
54	*Walsura robusta*	Meliaceae	Perte	T	L, Fl, Fr	0.31
55	*Phyllanthus emblica*	Phyllanthaceae	Sunhlu	T	Fr	0.30
56	*Terminalia myriocarpa*	Combretaceae	Char	T	L, Fl, Fr	0.21
57	*Vitex quinata*	Verbenaceae	Thlengreng	T	L, Fl, Sd	0.12

L—Leaves | FL—Flower | Fr—Fruits | Sh—Shoots | S—Seeds | T—Tree | H—Herb | C—Climber.

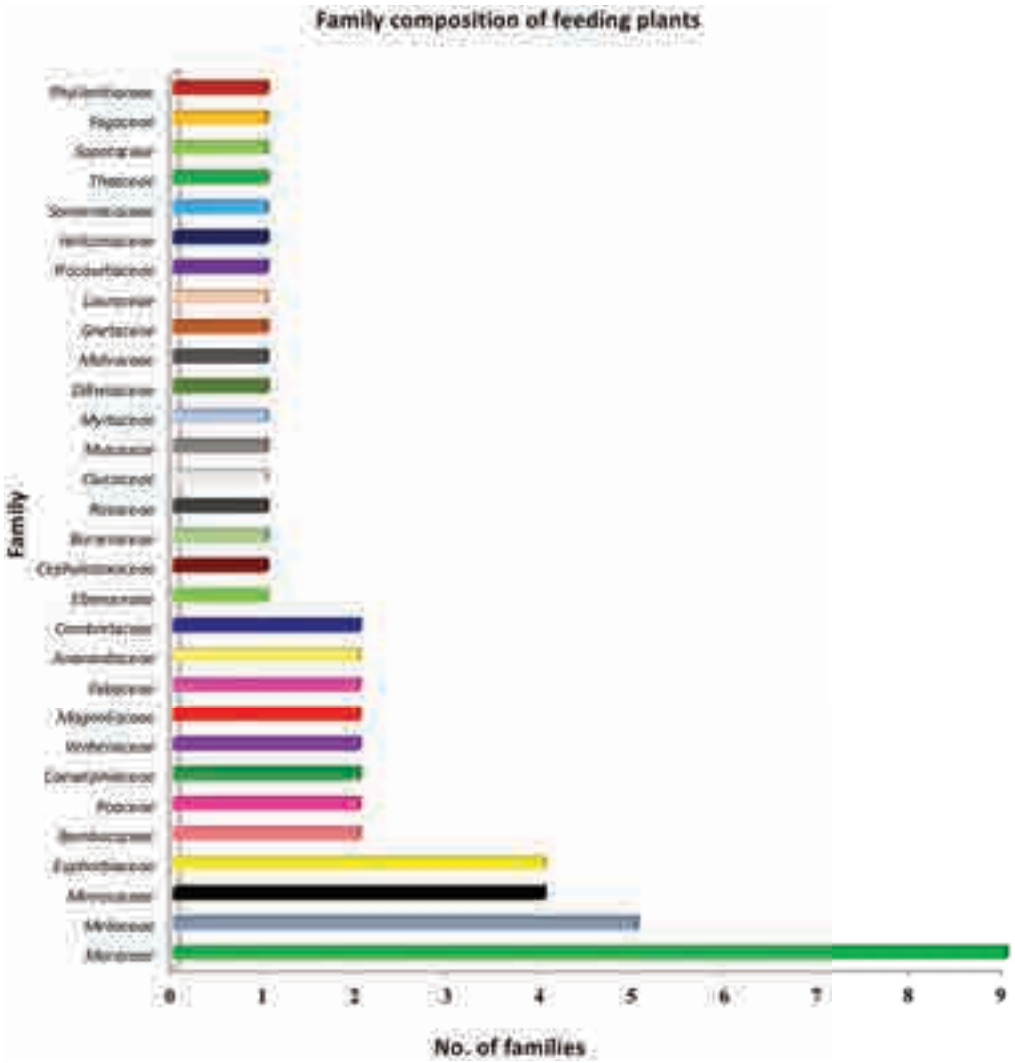

Figure 2. Diversity of feeding plant species.

Table 2. Distribution of feeding plant species in the study site in order of food preference.

Species name	Frequency of Occurrence	RF	R Den	R Dom	IVI
Artocarpus lakoocha	12.00	2.92	2.94	1.10	6.96
Albizia procera	7.00	1.70	2.52	4.44	8.00
Glochidion hyneanum	4.00	0.97	1.26	1.61	3.85
Diospyros glandulosa	5.00	1.22	0.84	1.21	3.27
Albizia lebbeck	7.00	1.70	2.56	2.42	6.69
Cephalotaxus graffithii	7.00	1.70	1.68	0.61	3.99
Ficus auriculata	2.00	0.49	0.85	13.86	**15.20**
Protium serratum	6.00	1.46	1.28	0.22	2.96
Albizia chinensis	5.00	1.22	1.28	1.69	4.19
Bombax insigne	4.00	0.97	1.28	4.84	7.10
Dendrocalamus longispathus	18.00	4.38	3.36	0.10	7.84
Prunus ceylanica	8.00	1.95	1.71	1.03	4.68
Garcinia succifolia	5.00	1.22	1.71	0.68	3.60
Cassia javanica	8.00	1.95	2.10	0.91	4.96
Ficus semicordata	5.00	1.22	1.28	0.62	3.12
Melocana baccifera	20.00	4.87	3.78	0.05	8.70
Gmelia arborea	4.00	0.97	1.28	4.05	6.31
Antides mabunius	5.00	1.22	1.71	0.81	3.73
Aporosa octandra	11.00	2.68	1.71	0.46	4.85
Albizia richardiana	8.00	1.95	2.56	1.88	6.39
Ficus elastica	3.00	0.73	0.85	5.24	6.83
Parkia timoriana	8.00	1.95	2.14	0.72	4.81
Dioscorea pentaphylla	9.00	2.19	2.56	0.97	5.72
Musa ornata	14.00	3.41	2.99	0.27	6.67
Aglaia edulis	11.00	2.68	2.56	0.81	6.05
Bischofia javanica	7.00	1.70	2.14	0.71	4.55
Magnolia oblonga	3.00	0.97	1.28	3.23	5.48
Derris robusta	12.00	2.92	2.56	0.54	6.03
Gnetum gnemon	6.00	1.46	1.28	0.07	2.81
Bombax ceiba	5.00	1.22	1.28	10.89	**13.39**
Artocarpus nitidus	9.00	2.19	1.71	1.21	5.11
Mallotus macrostachyus	6.00	1.46	2.14	1.29	4.88
Chukrasia tabularis	8.00	1.95	2.14	0.56	4.65
Toona ciliata	4.00	0.97	1.71	4.84	7.52
Mangifera indica	8.00	1.95	2.56	0.50	5.01
Syzygium cumini	5.00	1.22	1.28	2.42	4.92
Ficus rumphii	3.00	0.73	1.28	3.32	5.33
Ficus racemosa	3.00	0.73	1.28	3.23	5.24
Ficus retusa	3.00	0.73	1.28	2.39	4.40
Dillenia indica	4.00	0.97	0.85	1.21	3.04
Spondius pinnata	6.00	1.46	1.71	1.41	4.58
Dysoxylum gotadhora	4.00	0.97	1.28	0.54	2.80
Hibiscus macrophyllus	5.00	1.22	1.28	1.05	3.55
Caesalpinia cucullata	16.00	3.89	1.71	0.12	5.73

Species name	Frequency of Occurrence	RF	R Den	R Dom	IVI
Anogeissus acuminata	10.00	2.43	1.71	0.69	4.83
Litsea monopetala	5.00	1.22	1.71	1.41	4.34
Hydnocarpus kurzii	5.00	1.22	1.28	0.44	2.94
Heliconia rostrata	8.00	1.95	1.71	0.24	3.90
Duabanga grandiflora	9.00	2.19	1.71	0.20	4.10
Schima wallichii	11.00	2.68	1.71	0.38	4.77
Xantolis tomentosa	7.00	1.70	2.14	0.14	3.98
Terminalia crenulata	4.00	0.97	1.28	1.47	3.73
Castanopsis tribuloides	7.00	1.70	1.28	0.36	3.34
Walsurarobusta	13.00	3.16	2.14	0.36	5.66
Phyllanthus emblica	8.00	1.95	1.71	0.64	4.30
Terminalia myriocarpa	7.00	1.70	1.71	0.85	4.26
Vitex quinata	4.00	0.97	1.71	1.67	4.36

RF—Relative frequency | RDen—Relative density | R Dom—Relative dominance | IVI—Important value index.

(Table 4). Seeds were found to be consumed mainly in winters when there was a scarcity of fleshy fruits, and the highest seed consumption was recorded in January (12.4%). Shoots of bamboo sp. were fed only in monsoon (June–October) and the total time spent on feeding of shoots during the observation period was only 2.14%. Plant species such as *Cephalotaxus graffithii*, *Diospyros glandulosa, A. lakoocha*, *Albizia chinensis*, and *Bombax insigne* were observed to be eaten throughout the year and thus represent the primary sources of nutrients for AM. The highest percentage (59.03%) of the diurnal time invested on feeding was in the month of January and the least (35.19%) was in the month of June (Table 4).

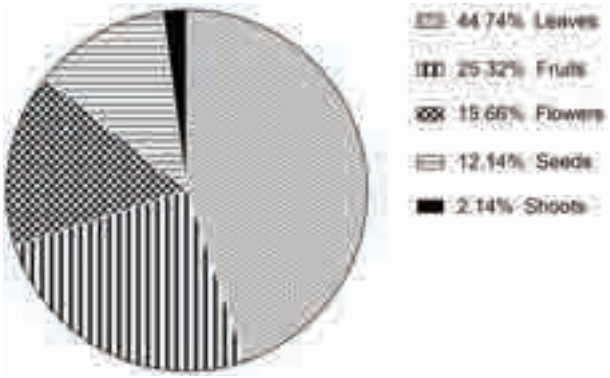

Figure 3. Dietary composition of Assamese Macaque *Macaca assamensis*.

DISCUSSION

Primates have a diverse feeding ecology and are highly adaptable in their dietary requirement. Dietary flexibility has permitted primates to live in a variety of habitats including tropical forests, semi-evergreen forests, montane forests, limestone bamboo forests, and secondary degraded forests (Timmins & Duckworth 2013; Mazumder et al. 2014; Huang et al. 2015; Koirala et al. 2017; Boonaratana et al. 2020). Similar to other findings across southeastern Asia, AM in DTR are also primary folivorous as leaves (young & mature) constitute 44.74% of their daily dietary intake compared to 25.32% of fruit (Srivastava 1999; Chalise et al. 2013; Zhou et al. 2011; Huang et al. 2015; Ghimire et al. 2021). Young leaves, when available were the major food items (spring and pre-monsoon). Contrastingly, mature leaves were the preferred food items during winter. Although the availability of young leaves decreased markedly from November to February, a high level of leaves was maintained in the diet of AM almost year-round as reported by Srivastava (1999) and Zhou et al. (2011). The scarcity of most young leaves during the dry winter season was compensated by some of the major food plants that thrived throughout the dry season in the study sites like *Albizia chinensis*, *A. lebbeck*, *A. procera*, *A. lakoocha*, *Bombax insigne*, and *Protium serratum* (Table 3). Apart from leaves, the amount of time invested among other food items such as, fruits, flowers, and seeds were high. We suggest that they like to avoid leaves (especially mature) and try to intake other more nutritive food whenever possible. Similar to this observation, AM in central Nepal switched between the young and mature leaves according to their availability, but the higher preference been the young leaves (Ghimire et al.

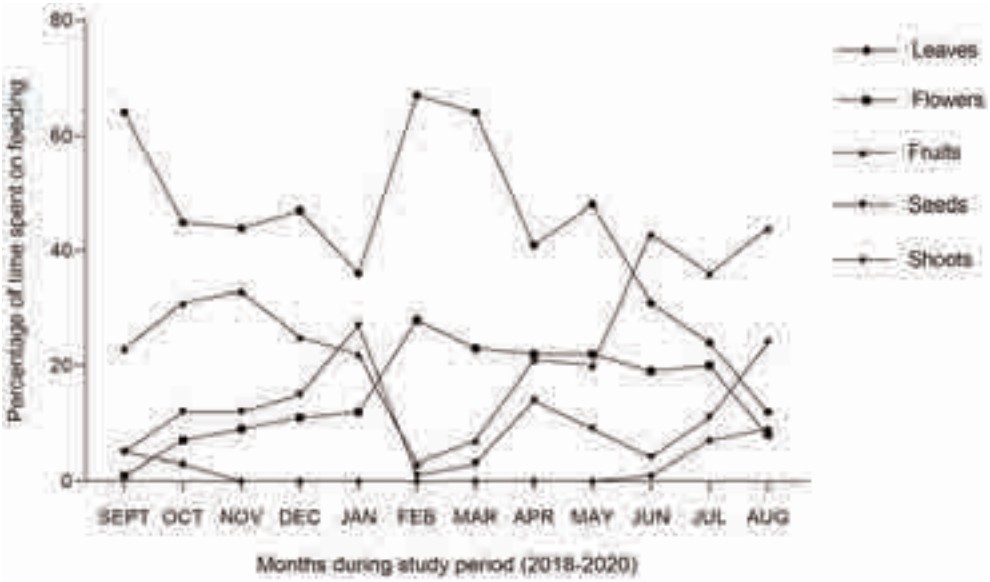

Figure 4. Monthly variation in feeding budget of Assamese Macaque *Macaca assamensis.*

2021). In the study, it was observed that the abundance of plant species has no correlation with the selection of feeding items. Plant species like *Ficus auriculata*, *Bombax ceiba*, and *Melocana baccifera* although were dominant and widely distributed, more preference was given to species like *Albizia* sp., *Ficus* sp., and *Artocarpus lakoocha,* which are in accordance with reports of Zhou et al. (2011) and Ghimire et al. (2021). AM are adaptable foragers able to modify their diet seasonally, being more folivorous in the dry season and more frugivorous in the wet season or post-monsoon (Li et al. 2019; Ghimire et al. 2021). Many studies have shown a strong correlation between rainfall and fruit availability in the dry season from November to March (Zhou et al. 2006, 2011).

AM in DTR spent majority (>44 % on average) of their diurnal time on feeding. They devoted more time in search of food items during the winter months (November–February) when resources were limited in cold and dry periods. Seasonal variation in the diet of AM was clearly linked to seasonal fluctuation in food availability which is a common observation across their home ranges. AM greatly altered their diet with a mixture of plant items including fruits, flowers, leaves, shoots and even seeds. While primate species such as Hoolock Gibbon *Hoolock hoolock*, Stump-tailed Macaque *Macaca arctoides*, and Rhesus Macaque *Macaca mulatta* are frequently encountered in crop fields (Mazumder et al. 2014), no such observation was made in DTR region, although they are reports available of crop raiding by AM in their home ranges (Regmi et al. 2013; Adhikari et al. 2018). The richness of fruiting plants in DTR appears to fulfill the dietary requirement of AM as no incidences of human-primate negative interactions are reported from the region and co-habitation was also observed between AM and other primate species. However, with the increase in settlement areas along the periphery of DTR, more dependency on forest resources, construction of road networks, and clearing of forests for cultivation, such conflict are inevitable in near future. Although in some cases, AM was found to survive in disturbed habitats, but the long-term consequences on reproduction and survival are unknown (Srivastava 2006). Hence understanding the feeding ecology of AM and adapting timely measures will be important for preventing human-AM negative interactions as well as conservation of primates in the region.

CONCLUSION

The macaques, changed their diets in accordance with the season and availability of food items as they appear to be folivorous in the dry and pre-monsoon season and more frugivorous in the monsoon and post-monsoon seasons. They consumed a wide range of trees, herbs, shrubs, and climbers. It is happening that the primates in northeastern India have been forced into crop raiding because of the loss of their natural habitat from various anthropogenic activities. However, it is evident that some species have clearly learned to co-exist with humans by raiding crops. Conflicts of this kind are likely to increase in the future as the human

Table 3. Monthly variation in feeding time (%) on each plant species during 2018–2020.

	Plant species	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	No. of food plants eaten in 12 months
1	*Aglaia edulis*	0.9	-	0.9	1.9	1.3	9.2	6.2	1.8	-	-	-	-	7
2	*Albizia procera*	11.8	7.3	11	11.3	11.4	9	10	-	4.3	19.3	3.5	12	11
3	*Albizia chinensis*	2.6	9.0	4	-	2.2	8.3	11	6.2	2.5	3.4	1.3	4.1	11
4	*Albizia lebbeck*	8.8	12.6	11.6	13.5	8.8	11.7	8.1	3.3	5.6	2.4	5.9	-	11
5	*Albizia richardiana*	0.3	0.6	-	1.1	1.2	5.2	5.4	2.3	-	-	-	3.1	8
6	*Anogeissus acuminata*	-	-	-	-	1.5	2.7	2.3	-	-	-	0.5	-	4
7	*Antidesma bunius*	-	0.8	-	0.5	1.2	1.4	1.7	0.8	0.9	0.9	0.8	-	9
8	*Aporosa octandra*	0.2	-	2.5	-	0.7	1.5	2.6	-	-	-	0.6	-	6
9	*Artocarpus chaplasha*	1.0	1.0	0.3	2.0	-	2.9	2.6	1.5	2.0	-	0.8	-	9
10	*Artocarpus lakoocha*	13.5	13.9	14.5	11.1	12.6	17.2	13.2	9.5	14.3	17.1	10.8	13.2	12
11	*Bischofia javanica*	-	-	1.2	1.9	2.6	2.3	2.3	0.9	0.4	-	2.3	-	8
12	*Bombax ceiba*	-	-	1.3	1.7	1.0	3.2	2.1	0.8	1.8	-	1.5	-	8
13	*Bombax insigne*	8.6	1.5	6.4	8.6	5.0	4.0	3.7	6.1	-	8.2	2.8	1.4	11
14	*Caesalpinia cucullata*	0.7	0.6	-	-	0.0	2.1	2	0.9	1.8	1.4	-	0.5	9
15	*Cassia javanica*	1.5	0.6	-	-	1.4	2.1	1.9	1.1	-	-	0.7	2.8	8
16	*Castanopsis tribuloides*	0.8	1.8	-	0.5	0.0	2.1	1.9	2.5	2.2	-	-	1.8	9
17	*Cephalotaxus graffithii*	3.2	2.3	3.8	4.5	3.9	3.1	3.9	5.6	6.4	1.8	3.2	5.5	12
18	*Chukrasia tabularis*	-	-	-	2.2	0.9	1.6	2.9	2.3	3.4	-	2.7	0.9	8
19	*Dendrocalamus longispathus*	4.5	2.4	-	-	-	-	-	-	-	1.6	3.8	2.5	5
20	*Derris robusta*	-	-	0.6	-	1.6	1.9	1.4	-	-	-	3.6	1.1	6
21	*Dillenia indica*	0.8	-	-	1.1	0.8	1.4	1.3	3	-	-	-	2.7	5
22	*Dioscorea pentaphylla*	-	1.7	1.2	1.6	0.9	1.3	1.9	0.4	2.3	-	-	-	8
23	*Diospyros glandulosa*	9.5	12.4	9.3	12.9	10.8	0.3	2.6	10	13	9.4	2.8	-	11
24	*Duabanga grandiflora*	-	-	0.9	-	2.3	1.2	1.1	-	-	-	1.4	-	5
25	*Dysoxylum gotadhora*	-	-	-	1.0	1.3	0.9	1.0	0.8	-	-	2.0	-	6
26	*Ficus auriculata*	2.7	2.5	-	-	0.0	-	0.4	6.7	7.9	7.9	7.3	11.2	9
27	*Ficus elastica*	-	0.9	0.6	-	1.2	0.6	0.6	-	2	-	0.6	-	7
28	*Ficus racemosa*	-	0.6	2.4	-	1.8	0.6	0.6	-	0.9	-	0.8	-	7

	Plant species	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	No. of food plants eaten in 12 months
29	*Ficus religiosa*	0.5	0.7	-	-	1.4	0.4	0.4	0.6	-	-	-	0.9	7
30	*Ficus retusa*	0.6	-	0.8	-	-	0.4	1.3	0.5	0.8	-	1.4	-	7
31	*Ficus variegata*	0.6	1.6	-	-	1.0	-	-	0.6	1.8	0.4	1.3	1.9	8
32	*Garcinia succifolia*	1.3	2.2	1.7	0.3	-	-	-	1.5	0.5	1.2	0.9	0.9	9
33	*Glochidion heyneanum*	5.9	10.7	9.5	10.3	7.4	-	3.0	8.3	14.2	15.7	7.0	12.4	11
34	*Gmelia arborea*	-	0.8	0.6	0.8	2.1	-	-	0.6	1.6	-	0.8	1.9	8
35	*Gnetum gnemon*	-	1.2	0.8	0.5	0.9	-	-	0.7	0.5	-	2.2	-	7
36	*Heliconia rostrata*	1.0	-	1.7	-	1.9	-	-	1.3	-	0.7	1.7	-	6
37	*Hibiscus macrophyllus*	-	-	1.0	-	1.4	-	-	-	-	-	1.9	-	3
38	*Hydnocarpus kurzii*	-	-	-	0.8	0.5	-	-	-	-	-	-	-	2
39	*Litsea monopetala*	1.0	0.4	-	-	0.0	-	-	0.9	-	1.7	-	1.9	8
40	*Magnolia oblonga*	1.5	2.9	1.6	-	1.3	-	-	1.6	1.9	-	2.8	0.8	8
41	*Mallotus macrostachyus*	-	0.8	0.4	0.5	1.1	-	-	0.8	-	0.8	-	0.6	7
42	*Mangifera indica*	1.3	0.4	1.3	-	-	-	-	1.8	-	-	1.3	2.0	6
43	*Melocana baccifera*	1.5	1.3	-	-	-	-	-	-	-	0.8	1.9	6.0	5
44	*Musa ornata*	-	-	1.3	-	0.5	-	-	0.5	-	-	3.2	-	4
45	*Parkia timoriana*	-	-	-	-	-	0.8	0.7	-	-	-	-	-	2
46	*Phyllanthus emblica*	4.2	0.9	-	1.1	-	-	-	1.7	-	-	0.9	-	5
47	*Protium serratum*	7.2	2.8	2.4	1.9	-	-	-	1.7	4.1	4.5	3.8	4.2	9
48	*Prunus ceylanica*	1.8	1.6	-	0.6	1.0	-	-	3.5	0.7	1.2	-	0.9	8
49	*Schima wallichii*	-	-	0.5	1.0	1.2	-	-	-	-	-	0.9	-	4
50	*Spondius pinnata*	-	-	-	0.4	-	-	-	1.1	-	-	-	2.8	3
51	*Syzygium cumini*	-	-	1.6	0.5	0.6	-	-	0.4	-	-	1.3	-	5
52	*Terminalia crenulata*	-	-	-	0.7	-	-	-	1.3	-	-	1.5	-	3
53	*Terminalia myriocarpa*	-	-	-	0.5	-	-	-	0.3	-	-	2.8	-	3
54	*Toona ciliata*	-	-	1.5	2.3	0.9	-	-	1.7	-	-	-	-	4
55	*Vitex quinata*	-	-	-	1	-	-	-	-	-	-	-	-	1
56	*Walsura robusta*	-	-	0.5	0.3	0.5	-	-	1.1	-	-	1.3	-	5
57	*Xantolis tomentosa*	0.9	-	1.3	-	-	0.8	-	0.7	2.3	-	1.1	-	6

population continues to grow exponentially in this region and encroachment on primate habitats continues. With increasing trends of habitat destruction in all the home ranges and reports of crop raiding, understanding keys factors and feeding ecology of the species in the wild will be crucial for addressing proper management and conservation of the species and their remaining habitat.

Table 4. Diurnal time invested on feeding activity.

	Month	Leaves			Flowers			Fruits			Seeds			Shoots			Diurnal time spent (%)
		2018–2019	2019–2020	Total	2018–2019	2019–2020	Total	2018–2019	2019–2020	Total	2018–2019	2019–2020	Total	2018–2019	2019–2020	Total	
1	Sep	142.8	221.2	364	0	5.8	5.8	34.2	100.6	134.8	22.4	8.0	30.4	8.4	21.4	29.8	39.22
2	Oct	165.2	149.6	314.8	20.0	29.4	49.4	112.2	110.0	222.2	30.0	56.8	86.8	8.8	16.8	25.6	48.52
3	Nov	161.8	136.4	298.2	33.4	33.4	66.8	109.6	117.6	227.2	22.0	61.8	83.8	0	0	0	46.94
4	Dec	143.3	149.6	292.9	51.4	20.8	72.2	107.4	48.0	155.4	44.9	49.0	93.9	0	0	0	42.66
5	Jan	162.6	150.4	313.0	78.1	32.0	110.1	79.2	116.2	195.4	106.8	124.8	231.6	0	0	0	59.03
6	Feb	204.2	246.1	450.3	94.4	94.0	188.4	15.0	8.4	23.4	5.6	4.0	9.6	0	0	0	42.89
7	Mar	311.4	206.6	518.0	97.4	91.6	189.0	49.2	12.0	61.2	5.6	24.2	29.8	0	0	0	55.41
8	Apr	144.6	104.6	249.2	79.8	55.1	134.9	30.8	97.0	127.8	23.6	65.6	89.2	0	0	0	41.74
9	May	144.0	139.0	283.0	76.0	56.0	132.0	30.3	90.0	120.3	0	53.9	53.9	0	0	0	40.91
10	Jun	64.5	97.0	161.5	49.6	47.0	96.6	107.9	111.2	219.1	9.0	13.0	22.0	7.6	0	7.6	35.19
11	Jul	55.0	89.0	144.0	65.8	52.6	118.4	95.2	117.8	213.0	32.8	35.0	67.8	21.6	24.4	46	40.91
12	Aug	39.4	36.2	75.6	43.8	5.6	49.4	109.4	151.0	260.4	47.4	93.6	141	28.0	29.2	57.2	40.52

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REVIEW

Natural history notes on three bat species

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Abstract: Three bat species have long been considered to occur within the state of Rajasthan—the Lesser Mouse-Eared bat *Myotis blythii* Tomes, 1857, the Large Barbastelle *Barbastella darjelingensis* Hodgson, in Horsfield, 1855 and the Serotine Bat *Eptesicus serotinus pachyomus* Tomes, 1857. Rajasthan is considered the type locality for two of these species—*Myotis blythii* and *Eptesicus serotinus pachyomus*. Despite targeted surveys, these bats have not been observed in Rajasthan for more than a century and a half. A chronological review of published literature reveals that the bats were never originally claimed to occur in Rajasthan and their inclusion among bats occurring in Rajasthan was a consequence of assumptions perpetuated as facts.

Keywords: Chiroptera, Large Barbastelle, Serotine Bat, Lesser Mouse-eared Bat, Rajasthan, India, British Museum, Captain Boys, Himalaya.

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INTRODUCTION

Bats (Chiroptera) are among the most widely distributed and diverse mammals in the world, second only to rodents in both regards (Sinha 1996). India is home to 127 species of bats (Talmale & Saikia 2018) and the state of Rajasthan has a long history of chiropteran study. There have been contributions by Blanford (1888–91), Ryley (1914), Wroughton (1918), Ellerman & Morrison-Scott (1951), Prakash (1963a,b, 1973), Agrawal (1967), Biswas & Ghosh (1968), and Sinha (1973, 1975, 1976, 1977) to chiropteran study in Rajasthan. Prakash's (1963a) study in Rajasthan was limited to nine bat species in the Thar Desert. Sinha (1980) carried out the first systematic study of bats covering all of Rajasthan, discussing in great detail, both the taxonomy and zoogeography of 21 species based on a field survey and published literature. Some of these 21 species were recorded for the first time in the state of Rajasthan (Sinha 1980). Sinha (1981), Sharma (1986), Bhupathy (1987) and Senacha & Dookia (2013) recorded a new species each for the state of Rajasthan. Srinivasulu et al. (2013) provided an 'intensive account' of 25 bat species recorded in Rajasthan.

However, despite targeted surveys and the consistent addition of new species to the list of bats occurring in Rajasthan, it is believed that three bat species have not been observed in the state for more than a century and a half: the Lesser Mouse-eared Bat *Myotis blythii* (Tomes, 1857), the Large Barbastelle *Barbastella darjelingensis* (Hodgson, in Horsfield, 1855) and the Serotine Bat *Eptesicus serotinus pachyomus* (Tomes, 1857). Rajasthan is in fact considered the type locality for two of these species—*Myotis blythii* and *Eptesicus serotinus pachyomus* (Thomas 1915; Wroughton 1918; Sinha 1980; Bates & Harrison 1997; Srinivasulu & Srinivasulu 2012; Srinivasulu et al. 2013). Information on these bats is fragmented, and the presence of these bats has only been questioned sporadically before in Rajasthan (Blanford 1888–91; Topal 1971). In addition to not being observed for more than a century, targeted field surveys such as by Sinha (1980) did not yield any results. The authors thus propose a thorough chronological review of published literature on these species to ascertain just why there has been absolutely no evidence of occurrence for such a long period of time.

OBSERVATIONS

Lesser Mouse-eared Bat *Myotis blythii* (Tomes, 1857)

The description for this species of bat (then *Vespertilio blythii)* was provided by R.F. Tomes (1857). Robert Fisher Tomes (1823–1904) was an English farmer and zoologist with an avid interest in Chiroptera. His description was based on a specimen preserved in the British Museum and thus he did not collect the specimen himself. Tomes (1857) wrote that the type specimen in the British Museum was labelled, "Hab. India, Nassenabad, from Mr. Warwick, 1848" and he added, "I believe collected by Captain Boys".

Tomes (1857) provides two pieces of information, a location in India, the fact that the specimen was sent to the British Museum by a Mr. Warwick in 1848. Now considering there already was a name attached to the specimen, why did Tomes (1857) speculate that the collector was Captain Boys? Where precisely "Nassenabad" is in India is also unknown, but Tomes (1857) created confusion by speculating that the collector might be Captain Boys. There is absolutely no mention of Rajasthan or as it was then known, Rajputana.

So what could be the reason behind this speculation? The "Mr. Warwick" referred to here was John Edington Warwick, a 'naturalist' employed by the Royal Surrey Zoological Gardens in Walworth, London at the time (not to be confused with the Zoological Gardens managed by the Zoological Society of London in Regent's Park) (Grigson 2016). The gardens sourced animals for their displays from at least three continents during Warwick's time (Editor 1835; Jardine 1858; Sclater 1870; Grigson 2016). Warwick appears to have occasionally sourced and procured animals back from overseas personally, such as giraffes from Egypt in 1836 (also brought back were five ostriches, 18 Numidian cranes, one camel and five jerboas) which became the subject of a book authored by him (Warwick 1836; Grigson 2016). The animals displayed at the gardens often became specimens for museums upon expiry. The gardens were clearly the final destination of many kinds of fauna from overseas, and it appears that Warwick's specimens were even sold to museums, such as the Cuban nightjar to the Derby Museum in 1849 (Sclater 1866), a year after the British Museum received the type specimen for *Myotis blythii*. It is therefore clear that although Warwick was certainly the source of the specimen, he was not necessarily the collector, prompting Tomes (1857) to speculate that perhaps it was Captain Boys who collected it from the field in India.

Which brings us to why Tomes (1857) speculated that

the collector might be Captain Boys. It is possible that Tomes (1857) connected Captain Boys to the locality "Nasirabad", and assumed that was what was meant by "Nassenabad" on the specimen label. However, there were multiple towns named "Nasirabad" in British India. A background on Capt. Boys might shed some light on such an assumption. Captain W.J.E Boys was an officer in the 6th Regt. Light Cavalry of the British East India Company and a known collector of specimens. Nasirabad in the district of Ajmer in Rajasthan has a very long history as a cantonment town. It is also quite possible that the label "Nassenabad" was a typological error since error by curators was not unheard of in the British Museum during that period (Benda & Mlíkovský 2008).

It should also be noted that Boys died three years before Tomes (1857) authored his description and thus could not be consulted to confirm nor refute the contents of the description or any work by subsequent authors. Nevertheless, the purported association of Captain Boys with Nasirabad, Rajasthan led to the perpetuation of certain assumptions regarding the type locality of this species, even though Tomes (1857) clearly never made any such claims.

It was Jerdon (1867) who first made the claim that the type specimen was procured from Rajasthan, and wrote that "The bat was found by Captain Boys in Nusserabad, Rajputana". Jerdon (1867) made three assumptions in this claim. The first is that the "Nassenabad" mentioned by Tomes (1857) is "Nusserabad". The second is that "Nusserabad" is in Rajputana (Rajasthan), thereby becoming the first author to connect an otherwise ambiguous locality to the state of Rajasthan. This is despite the fact there were multiple towns with the same name, which still exist to this day in independent India and Pakistan, including in the Indian states of Uttar Pradesh and Uttarakhand, where Boys was also known to be active. The third is that the collector of the specimen was Captain Boys. Therefore, Jerdon (1876) stated what was clearly a speculation by Tomes (1857) as fact.

Dobson (1878) in his 'Catalogue of the Chiroptera in the Collection of the British Museum', wrote that the type specimen was from "India" and from the "Warwick Coll." (Coll. =Collection). Dobson (1878) was thus most appropriate in his treatment of the specimen, for he did not include any speculative information in his account and mentioned the undisputed facts alone, which were that the type specimen was from India and that the origin was the collection of J.E. Warwick. Blanford (1888–91) was the first to question whether the locality of this report was correct, and wrote "This type of *V. blythii* was said to be from Nusserabad, in Rajputana, but this locality I think requires confirmation". However, Blanford (1888–91) did not stress this point any further and did not elaborate why he thought so.

Following Jerdon (1867), the aforementioned assumptions regarding the locality and collector are further perpetuated as facts by Thomas (1915) in the Bombay Natural History Society's Indian Mammal Survey, "Of this group of large grey species, the Indian representative in *M. blythii*, Tomes of which the Museum contains the type (skin and skull) from Nusserabad (Boys)". Which was in turn, further perpetuated by Ellerman & Morrison-Scott (1951), who claimed that the type locality of "1857, *Vespertilio blythii* Tomes" was "Nasirabad, Rajputana" and on distribution, commented, "Ranges to Simla, northern India". It should be noted that the text by Ellerman & Morrison-Scott (1951) did not exclusively focus on *Chiroptera*, but their text was a checklist on 'Palearctic and Indian Mammals- 1758 to 1946', and brought 'Rajputana' back into the discourse concerning this bat.

Nearly a century after Blanford (1888–91) questioned the locality of the report, Topal (1971) commented on the improbability of Nasirabad, Rajasthan being the origin of the type specimen discussed by Tomes (1857) on ecological grounds, and also suggested that the locality "Nassenabad" was in all likelihood, somewhere in the Himalayas. Topal (1971) wrote, "this site lies, on the one hand, at least 600 km. to the SW of the nearest locality of occurrence of *M. blythi,* and, on the other, in a climatically and zoogeographically utterly different region, separated by an extensive plain of hot and mostly dry climate from the Himalayas. It is therefore improbable that Nasirabad, Rajputana, could be the type-locality of *M. blythi.* Since Mussoorie, Chamba, Simla (Dodsworth 1914), Kashmir, and probably the locality Nassenabad all belong to the climatically and zoogeographically essentially uniform area of the western Himalaya, it is in all likelihood inhabited by a single form, the nominate one, of *Myotis blythi."*

Nevertheless, Sinha (1980) also gave "Nasirabad, Rajasthan" as the type locality for "*Vespertilio blythii* Tomes, 1857, *Proc. zool. Soc. Lond.*, 1857. p. 53" and citing Ellerman & Morrison-Scott (1951), described the distribution of the species in India to range from "Nasirabad (Rajasthan) to Simla, northern India". Sinha (1980) thus ignored Dobson (1878), Blanford (1888-91) and Topal (1971). Sinha (1980) only examined a female specimen sourced from Chamba (Himachal Pradesh) during this survey and not the type specimen in the British Museum.

Bates & Harrison (1997) in their book on *Bats of the Indian Subcontinent*, acknowledged Blanford (1888–91) and Topal (1971), by marking the locality in Rajasthan with a "?", on their distributional map for *Myotis blythii*. In the section on distribution, Bates & Harrison (1997), state the following, "Rajasthan: Nasirabad (type loc. of *blythii*, but Topal, 1971 suggests the correct locality is Nassenabad, possibly in the Himalayas)".

Srinivasulu & Srinivasulu (2012) in their book on: "Checklist of South Asian mammals" mentioned the type locality Nasirabad, Rajasthan without any further comment. Even more recently, Srinivasulu et al. (2013) (includes Y.P. Sinha as co-author) wrote that, "*Myotis blythi blythi* (Tomes, 1857) has been reported from Nasirabad (Ajmer District) which is also its type locality, but Topal suggests that the correct locality is Naseerabad, possibly in the Himalayas". While acknowledging the arguments made by Topal (1971), Srinivasulu et al. (2013) nevertheless perpetuated assumptions first made by Jerdon (1867) by including this species in their account of bats recorded in Rajasthan.

The Serotine Bat *Eptesicus serotinus pachyomus* (Tomes, 1857)

In the same publication, Tomes (1857) also provided a description for the Serotine Bat (then *Scotophilus pachyomus*), which was based on a specimen preserved in the British Museum. According to Tomes (1857), the collector was "Capt. Boys" and the specimen was from "Hab. India". There is no mention of Rajasthan (then known as Rajputana), but a non-specific type locality in the form of "India".

Dobson (1878) wrote in his catalogue that the type specimen for "*Scotophilus pachyomus*, Tomes" was from "India" and collected by "Capt. Boys [C]". This is completely consistent with Tomes (1857). As far as distribution in India is concerned, Dobson (1878) did not name *Rajputana* nor any contiguous region in the distribution of the species, but "India, where it inhabits the valleys of the Himalayas".

The first account of this species purportedly occurring in *Rajputana* or Rajasthan is by Wroughton (1918) in a manner similar to the last species by Jerdon (1867). In the Bombay Natural History Society's Indian Mammal Survey, in which Wroughton (1918) wrote, "Type Locality: Rajputana: Boys". It appears that this is an assumption presented as fact, quite possibly made on account of the collector of the type specimen being Captain Boys. Ellerman & Morrison-Scott (1951) further perpetuated this assumption, when they included "Rajputana" in the distribution area of this species. Therefore, once again, the purported association between Captain Boys and Rajputana or Nasirabad, caused the perpetuation of assumptions as facts regarding the type locality of the specimen.

Sinha (1980) also wrote that *E. serotinus pachyomus* "is found in Rajasthan" and that the type locality for "*Scotophilus pachyomus* Tomes, 1857, *Proc. zool. Soc. Lond.*, 1857. p. 50" as "*Rajputana*". Sinha (1980) then further added, "As informed by J.E. Hill (Brit. Mus.): It seems that Boy's collected the specimen in Rajputana, probably near Nasirabad, but labelled "India"; I failed to collect it in Nasirabad". J.E. Hill (now deceased) is consistent with Tomes (1857) and Dobson (1878) on the facts that Captain Boys collected the type specimen and that it was indeed labelled "India", however it is evident that the origin of the specimen being Nasirabad or anywhere else in *Rajputana* is guess work at best. Boys being the collector of the type specimen might well have informed Hill's speculation regarding the locality. Despite a clear lack of confirmation, Sinha (1980) included this species in his survey for Rajasthan. The three Indian specimens Sinha (1980) examined for this survey originated in "Kashmir".

Bates & Harrison (1997) included Rajasthan in the distributional area of the species but with the following caveat, "Rajasthan: no fixed locality (type loc. of *pachyomus*)". Rather pertinently, Bates & Harrison (1997) also did not mark any locality in Rajasthan on their distributional map for the subspecies. Srinivasulu & Srinivasulu (2012) in their book on: "Checklist of South Asian mammals" included Rajasthan in the distribution area for the subspecies *pachyomus* without providing any further details.

Srinivasulu et al. (2013) wrote that "The type locality of *Eptesicus serotinus pachyomus* (Tomes 1857) is "Rajputana" (present-day Rajasthan), India". Then, citing Sinha (1980), Srinivasulu et al. (2013) added "The type probably has been collected from Nasirabad (Ajmer District)". Despite a lack of confirmation regarding the origin of the type specimen and the absence of any other evidence of this bat's occurrence in Rajasthan, Srinivasulu et al. (2013) included this species in their account of bats recorded in Rajasthan.

In addition, Srinivasulu et al. (2013) also categorically stated, "The first account of bats from *Rajputana* (British name for Rajasthan and its surrounding states) dates back to 1857 in the work of R.F. Tomes who provided descriptions of *Scotophilus pachyomus* (presently *Eptesicus serotinus pachyomus*) and *Vespertilio blythi* (presently *Myotis blythi blythi*) collected from Nasirabad, 130 km south of Jaipur in the present-day Ajmer district".

However, it should be abundantly clear that Tomes (1857) never mentioned "Nasirabad" nor *Rajputana* in his accounts of the two species.

Large Barbastelle *Barbastella darjelingensis* (Hodgson, in Horsfield, 1855)

The first account of this species of bat purportedly occurring in Rajasthan is provided by Wroughton (1918). Wroughton (1918) includes "Rajputana" in the distribution of this species on account of a specimen in the British Museum, but does not mention a collector nor a specific locality within *Rajputana* for this specimen in the survey.

A close examination of the catalogue by Dobson (1878), reveals that in addition to the type specimen collected by B.H. Hodgson from the district of Darjeeling ("Darjiling" in the text) in northern West Bengal, there was one more specimen labelled from "India" with "Capt. Boys" named as the collector. There is no mention of *Rajputana* nor any specific locality in India for this specimen. Dobson (1878) also did not mention *Rajputana* in the distribution of this species in the accompanying account, "India (Darjiling, Khasia hills, Sikhim, Masuri, Simla); Yarkand".

This raises the obvious question, how then did Wroughton (1918) include *Rajputana* in the distribution of this species? Here too, it appears that the purported association between Captain Boys and Nasirabad or *Rajputana* (Rajasthan) led to the perpetuation of certain assumptions, similar to what transpired with the two species described by Tomes (1857).

Ellerman & Morrison-Scott (1951) also included *Rajputana* in the distribution area of this species. Sinha (1980) however, while pointing out that Wroughton (1918) and Ellerman & Morrison-Scott (1951) included "Rajputana" to the range of distribution of this species, mentions that he was unable to find any specimens in Rajasthan for his survey. However, here too, Sinha (1980) consulted J.E. Hill from the British Museum and wrote the following: "as informed by J.E. Hill (B.M.) the specimen from the British Museum is probably from Nasirabad but labelled as "India". J.E. Hill is consistent with Dobson (1878) on the fact that the specimen is labelled from just "India". However, it is quite clear that the origin of the specimen being "Nasirabad" is guess work. This is also the first instance of the specimen being alleged to have originated in Nasirabad, and not just *Rajputana*. It is quite possible that in addition to following Wroughton (1918) and Ellerman & Morrison-Scott (1951) as far as *Rajputana* is concerned, Hill speculated that the type locality is Nasirabad on account of the collector being Captain Boys (as Wroughton (1918) might have done for this species earlier for *Rajputana*), although Sinha (1980) does not mention Boys in this particular account.

In addition, the specimens that Sinha (1980) examined for this survey originated from locations in the Himalayas. Despite a clear lack of confirmation of the origin of the relevant specimen, Sinha (1980) included this species in his survey for Rajasthan. Bates & Harrison (1997) did not mention Rajasthan in the distributional area of this species in their text, nor did they mark any locality in Rajasthan on their distributional map for this species.

Srinivasulu & Srinivasulu (2012) in their book on: "Checklist of South Asian mammals" did not include Rajasthan in the distributional area for this species. Citing Wroughton (1918), Ellerman & Morrison-Scott (1951) and Sinha (1980), Srinivasulu et al. (2013) asserted, "*Barbastella darjelingensis* (Hodgson, 1855 in Horsfield 1855) has been reported from Nasirabad (Ajmer District)". Thus Srinivasulu et al. (2013) further perpetuated their assumptions by including this species to their account of bats recorded in Rajasthan.

DISCUSSION AND CONCLUSION

Our chronological review of literature reveals that many authors believed Captain Boys to be the collector of the relevant specimens for all three species. However, the original descriptions and account reveal that Boys was the collector of just two specimens (Tomes, 1857; Dobson, 1878). Tomes (1857) only traced the type specimen for *Myotis blythii* with certainty to J.E. Warwick of the Surrey Zoological Gardens in Walworth, London and merely speculated that Boys was the collector in India. Among the three species, only one specific locality was ever provided and this was the ambiguous "India, Nassenabad" for *Myotis blythii* (Tomes 1857). The relevant specimens for *Eptesicus serotinus pachyomus* and *Barbastella darjelingensis* were only described to have originated in "India" (Tomes 1857; Dobson 1878).

The erroneous belief regarding Boys evidently gained currency because authors either associated Captain Boys with *Rajputana* first and then Nasirabad (for *Eptesicus serotinus pachyomus* & *Barbastella darjilengensis),* or in the reverse order (for *Myotis blythii*) (Jerdon 1867; Thomas 1915; Wroughton 1918; Sinha 1980). The connection between Captain Boys and *Rajputana* or Nasirabad is unclear. It could possibly be on account of Boys having been a cavalry officer and that Nasirabad was a cantonment town.

On examination of Boys's life, it is evident that he was rather mobile through northern India. In 1843, he served as assistant to the Commissioner of Kumaon (Uttarakhand) (Piddington 1843) and was also a combatant in the second Anglo-Sikh war (Grant 1849). Boys eventually expired in Almora (Uttarakhand) on 21 March 1854 (Editor 1854).

Authors such as Wroughton (1918) categorically associated Captain Boys with the collection of mammal specimens in "Rajputana" during the early period of Indian Mammalogy (second quarter of the 19th century), however an examination of his work reveals that Boys was by no means limited to just *Rajputana* nor mammals.

Such was Boys's prowess in collecting specimens, that he was unanimously elected a member of the Asiatic Society of Bengal in 1842 (Prinsep 1842). Specimen contributions by Boys range from a snail from Agra (Uttar Pradesh) (Benson 1864), a wasp from Almora (Uttarakhand) (Turner 1912), a bird from a location in between Sindh (now Pakistan) and Ferozepur (Indian Punjab) (Blyth 1846), to even a caracal from Jaipur in Rajasthan (Blyth, 1845). Strickland & Strickland, in Jardine (1852), wrote of the auction of Boys's ornithological collection in London which included, "the result of many years residence in the upper Gangetic provinces of India, ….an extensive series of birds, amounting to between 500 and 600 species. Some of them very rare". Piddington (1843) even wrote of the Asiatic Society of Bengal providing Boys with financial assistance for geological expeditions to the "Thibet passes" (India-Tibet border areas).

Thus it is evident that Boys was not limited to just *Rajputana* in his endeavours and spent a considerable amount of time in the Himalayas (Piddington 1843; Strickland & Strickland, in Jardine 1852; Turner 1912). Incidentally, the Himalayas are where Topal (1971) believed the type specimen of *Myotis blythii* to originate from based on its ecology, and where there are at least two localities by the name Nasirabad (one in Haridwar district in the state of Uttarakhand, and the other in the Hunza district of Pakistan Occupied Ladakh).

It should also be noted that errors in the provenance of specimens were not only common, but often translated to taxonomic errors of great magnitudes. In a notable example, the eminent curator and zoologist John Edward Gray made just such an error with a small cat specimen in the British Museum. Gray (1867) declared a new species based on the aforementioned specimen, *Pardalina warwickii* or Warwick's Cat, which was apparently from the Himalayas. The specimen, when alive was exhibited as a "Himalayan Cat" in the Surrey Zoological Gardens (hence named after J.E. Warwick). It was not until 1870, that zoologist Philip Sclater proved that the cat was a Geoffroy's Cat (*L. geoffroyi*) from South America, a species which had been described much earlier in 1844 (Sclater 1870). Thus not only was the specimen not from the Himalayas, it was not even Asian. Gray (1874), in his recantation, commented that, "there was an inclination of the dealers to give Himalaya as the habitat of animals of which they did not know whence they came, as animals of that country were interesting and fetched a good price".

Thus the authors propose that until there is tangible evidence of occurrence of these three species in Rajasthan—*Myotis blythii* Tomes, 1857, *Eptesicus serotinus pachyomus* Tomes, 1857, and *Barbastella darjeligensis*, Hodgson, in Horsfield, 1855—they should be omitted from lists and accounts of *Chiroptera* occurring in Rajasthan. The bats were never originally claimed to occur in Rajasthan (Tomes 1857; Dobson 1878) and their inclusion among bats occurring in Rajasthan was a consequence of assumptions perpetuated as facts.

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REVIEW

The checklist of birds of Rajkot district, Gujarat, India with a note on probable local extinction

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Abstract: Rajkot District in Gujarat, India harbours abundant avifauna, yet systematic checklists of this region are lacking. Here we present a checklist of bird in key habitats both natural and man-made, including grasslands, open lands with scattered scrub forests, wetlands (urban lakes) and reservoirs in Rajkot District. We report 348 species of birds belonging to 74 families and 22 orders, of which 281 species were observed by us during the survey and 67 species were compiled from published literature. Species recorded were from the orders Passeriformes (140), Charadriiformes (50), Accipitriformes (28), Anseriformes (19), and Pelecaniformes (19); 316 species were classed as Least Concern (LC), 18 Near Threatened (NT), eight Vulnerable (VU), two Endangered (EN), and four Critically Endangered (CR) as per IUCN. One-hundred-and-forty-six species are resident, 138 winter visitors, 13 monsoon migrants, 12 vagrants, 12 local migrant, and the rest have multiple migratory status. With regards to habitat suitability, 116 species are aquatic (wetland dependant), 67 open land, 66 forest, 19 grassland, and the remainder show overlaps in habitat preference. A total of 124 species are found to breed in Rajkot District. It is important to note that 17 species have not been sighted in and around Rajkot District since 1990, hence they are listed as locally extinct, along with four Data Deficient species.

Keywords: Accipitriformes, Anseriformes, Avifauna, Charadriiformes, habitats, migratory status, Passeriformes, Pelecaniformes.

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INTRODUCTION

Avifaunal diversity is considered an essential ecological tool to evaluate the health of ecosystems (Bilgrami 1995). Baseline information like a checklist of fauna is a prerequisite for planning and monitoring management actions as well as for policy-making by wildlife authorities for the conservation of fauna and its habitat (Kumar et al.2005). Monitoring of birds of a particular locality is crucial in predicting the ecological health and productivity of the habitat of that locality (Newton 1995; Rotenberry & Wiens 2009). In their book, Ali & Ripley (1987) recorded 1,340 bird species from the Indian Subcontinent. Grimmett et al. (2016) listed 1,313 bird species in and around India that have been reliably recorded until 2010. Recently Praveen et al. (2020) listed 1,332 birds from India.

Gujarat is the only state in the country with five biogeographic zones: semi-arid region, desert, Western Ghats, coasts, and Deccan Peninsula (Solanki et al. 2021). Diverse wildlife habitats include the Great and Little Rann of Kachchh, the Banni grasslands, 42 off-shore islands in Marine National Park of the Gulf of Kachchh near Jamnagar, the dry deciduous forests of Gir and Barda Hills, the tropical thorn forest of Kachchh, Vijaynagar Polo, Ambaji-Balaram and Jessore Sloth Bear Sanctuary, and the moist deciduous forest of southern Gujarat, all of which provide excellent habitats for resident and migratory birds (Tiwari 2010). The bibliography of Gujarat Ornithological accounts dates back to 1758 (Pittie 2010), and in the early 19th Century, many observations on birds were published by Indian royalties and the British. Edward Butler published a catalog of 1,008 species of Birds of Sind, Cutch (Kutch), Ka'thia'war (Saurashtra), northern Gujarat, and Mount Aboo in 1879 (Butler 1879). Birds of Kutch and Birds of Saurashtra were published in the middle of the 19th Century comprising 255 and 444 bird species, respectively (Ali 1945; Dharmakumarsinhji 1955). The checklist of birds of Gujarat was published by Bird Conservation Society, Gujarat, which lists a total of 526 species (Parasharya et al. 2004). Later, this checklist was updated in 2016 with a total of 574 species (Ganpule 2016). The checklist of birds of Gujarat was further revised and updated in December 2017 with eight new species making a total of 582 (Ganpule 2017). In 2018 and 2019, 16 new bird species were added to the checklist of Gujarat, which makes the total 598.

Rajkot is the fourth largest city in Gujarat, located at the center of peninsular Saurashtra (Anon 2019). The city is surrounded by many reservoirs, urban lakes, grasslands, and scrub forests, which are home to variety of birds. Rajkot has a considerable number of birdwatchers, amateur birders, wildlife photographers, and conservationists, and scattered records of avian fauna are published on various platforms like: eBird, local newspapers, magazines, periodicals, newsletters, and journals (Butler 1879; Santharam 1990; Soni & Pandya 1995; Soni 2014a,b; Karia 2018; Radadia 2018; Raval et al. 2018). However, to date, no systematic checklist of the avifauna of Rajkot District is available. This study was planned to prepare a checklist of avifauna by carrying out a survey of various potential habitats, as well as compiling earlier and present observations from all possible available sources for Rajkot district, with a discussion on probable local extinction in the past three decades (1990–2020).

MATERIALS AND METHODS

Study Area

The avifaunal survey was conducted in and around Rajkot District, Gujarat, India. Rajkot lies at 128 m and the climate is classified as hot, arid steppes (Zone BSh) by the Köppen-Geiger system (Anon 2020). The area experiences an average annual temperature of 26.7 °C | 80.1 °F and precipitation of 674 mm | 26.5 inches per year. Different types of habitats including wetland, scrubland, agriculture, grassland, and forests were surveyed.

Methods

Primary observations of birds were made by conducting regular field visits in winter, summer and monsoon seasons. Birds were observed in the morning (0600–1000 h) and afternoon (1500–1800 h) with 10X binoculars and a 20–60X spotting scope, and photographs were captured with a DSLR camera with >300 mm focal length lens, and point & shoot bridge cameras with >40X optical zoom. The identification of birds was done with the help of Grimmett et al. (2016). For taxonomy, we followed English as well as scientific names as per Praveen et al. (2020). For evaluation and acceptance of species not observed by us, we followed modified Baidya & Bhagat (2018) for inclusion for species in the Rajkot checklist. Acceptance criterion 1: a sight record of a bird species with a photograph, either available online and/or eBird, or provided to us for scrutiny. Acceptance criterion 2: a sight record with/without photographs but published in reputed journals. A species is considered locally extinct, if not sighted or photographed after

1990 till 2020 (three decades). To retrieve relevant literature, we searched the online 'Bibliography of South Asian Ornithology' (http://www.southasiaornith.in/) to prepare a complete checklist of avifaunal diversity of the entire district (Pittie 2020). Birds recorded were categorized according to their migratory and IUCN Red List status.

RESULTS AND DISCUSSION

As per annexure 1, we reported 348 species of birds belonging to 74 families and 22 orders from Rajkot District, of which 281 species were observed by us during the survey, and records of 67 species were compiled based on evaluation and acceptance criteria, and past observations through published literature. A total of 124 species are found to breed in Rajkot district. As per Figure 1, the maximum number of species were from the order Passeriformes (140), followed by Charadriiformes (50) and Accipitriformes (28). Anseriformes and Pelecaniformes were represented with 19 species each. As per Figure 2, 146 species are resident, 138 winter visitor, 13 monsoon migrant, 12 vagrant as well as local migrant, and the rest have multiple migratory statuses. Regarding habitat suitability, 116 species are aquatic (wetland dependant), 67 open land, 64 forest, 19 grassland and rest show overlap in habitat preference. Along with the checklist of birds, their migratory/ resident status, IUCN status, and habitat preferences are also listed in Annexure 1 and summarised in Figure 3. Currently, on eBird, there are 296 bird species reported from the entire Rajkot district (eBird 2021). As per Figure 4, 316 species belong to Least Concern (LC), 18 species Near Threatened (NT), eight species Vulnerable (VU), two species Endangered (EN), and four species Critically Endangered (CR) as per IUCN.

Khirashara 'Vidi' (Vidi in Gujarati: Grassland) houses many bird species like francolins and quails (Galliformes) in monsoon, and also raptors in winter, providing important habitats for avifauna (Soni & Jadav 2007). A small lake situated beside the 'vidi' also attracts many migratory waterfowl. Chibhda Vidi and Khambhada Vidi open scrub forest houses Indian Courser *Cursorius coromandelicus*, Common Cuckoo *Cuculus canorus*, Montagu's Harrier *Circus pygargus,* Greater Short-toed Lark *Calandrella brachydactyla*, Painted Francolin *Francolinus pictus,* Savannah Nightjar *Caprimulgus affinis*, and Indian Nightjar *Caprimulgus asiaticus*. In Chibhada Vidi a small pond situated in the center,

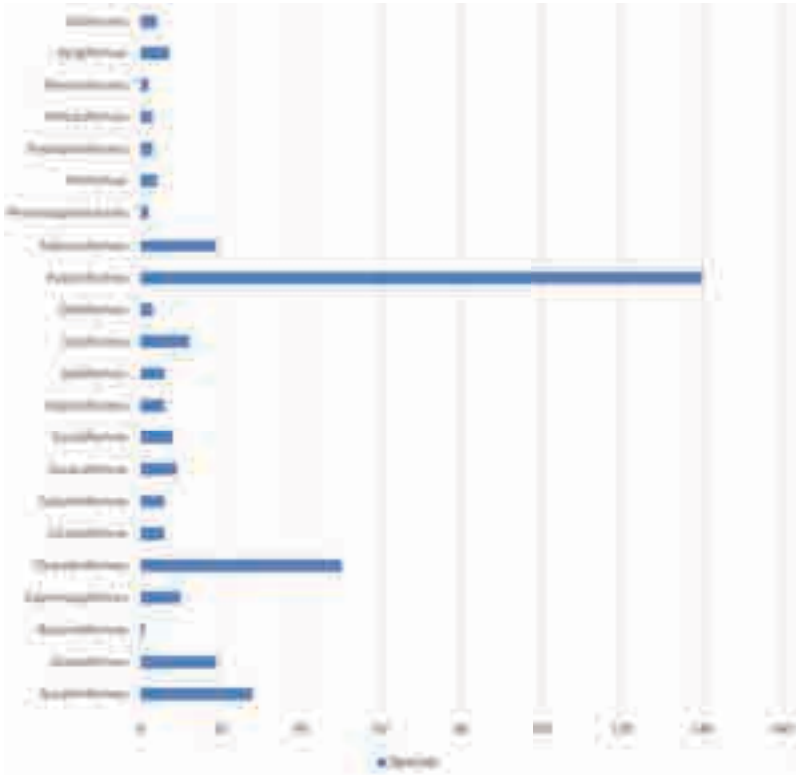

Figure 1. Species diversity of birds in different orders.

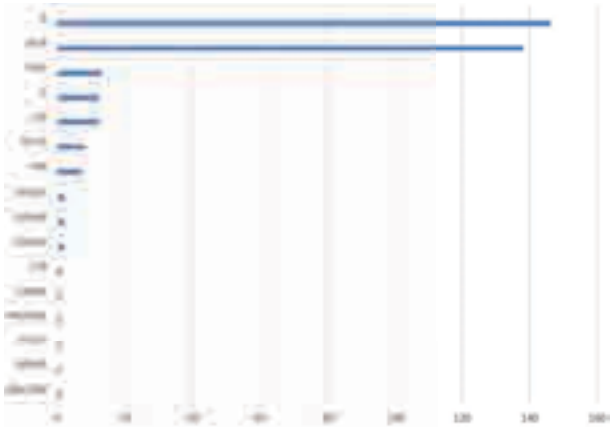

Figure 2. Species diversity in various migratory statuses of birds. LM—Local Migrant | MM—Monsoon Migrant | PM—Passage Migrant | R—Resident | V—Vagrant | WM—Winter Migrant.

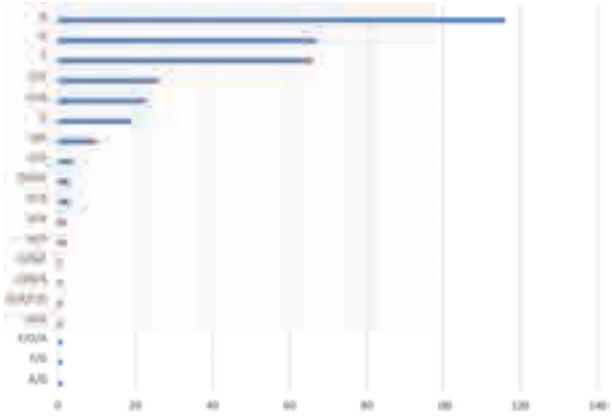

Figure 3. Species diversity across various habitats. A—Aquatic | F—Forest | G—Grassland | O—Open scrubland.

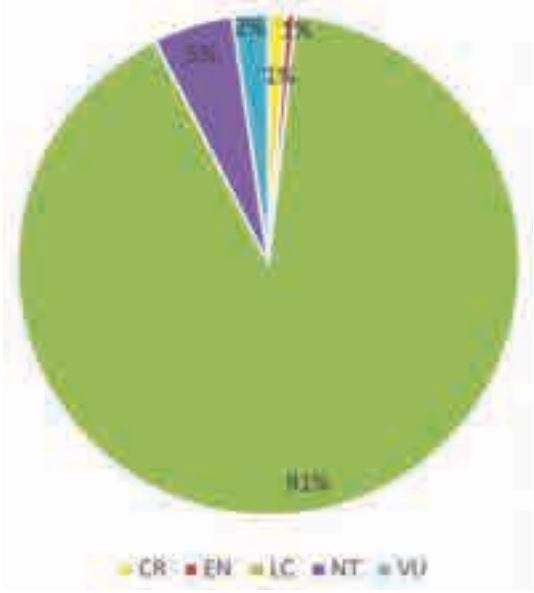

Figure 4. Species diversity in various IUCN Red List categories.

which fills with rainwater in monsoon and lasts till winter, provides drinking water. Aji River 1, Aji River 2, Nyari Dam 1, and Nyari Dam 2 are large-scale irrigation reservoirs that support diving birds such as cormorants, grebes, and pelicans, and also raptors such as Osprey *Pandion haliaetus* and Brahminy Kite *Haliastur indus*. River Terns *Sterna aurantia* have been nesting here for decades. One individual was ringed as a pullet in 1989 was photographed alive after 24 years at the same place (Mashru 2004a; Karia 2016). Banks of these dams act as a roosting place for ducks and waders. A colour aberrant Wood Sandpiper has been reported from here in the past (Khachar 1969). When it starts to dry up in late winter it provides a foraging area for pipits and wagtails. Such irrigation reserves, together with vast agricultural lands, attract migratory cranes in the winter season (Gole 1985). Irrigation reserves have been supporting large heronries in Rajkot for decades (Mashru 2004b, 2006). The Government of Gujarat has implemented the 'Saurashtra Narmada Avtaran Irrigation' scheme under which all the dams are filled up to their capacity till summer. Due to this dams are constantly filled at high water levels creating adverse situations for ducks and sandpipers. These dams also support good numbers of flamingos on its peripheries.

In Nyari-1 Dam, two reedbeds are created due to the seepage of water from the dam. These reedbeds houses reed beds specialist birds such as bitterns (three species), crakes (three species), Red Munia *Amandava amandava,* and Black-breasted Weaver *Ploceus benghalensis*. Randarda and Lalpari lakes harbor many important migratory waterbirds during winter such as Mallard *Anas platyrhynchos* and Raptors such as Long-legged Buzzard *Buteo rufinus*. Infact, the first breeding record of Small Pratincole *Glareola lactea* is from Lalpari Lake in the year 1968 (Jadav 1968). Many surprising records have been recorded from Rajkot Zoological Park such as White-browed Bulbul *Pycnonotus luteolus* and Black-naped Oriole *Oriolus chinensis* (Dhami 2018; Sitapara et al. 2019). A government nursery positioned near the lake provides shelter to many flycatchers and warblers. A Eurasian Scops Owl *Otus scops* was also sighted here which was the first record of Rajkot district (Radadia 2019).

CONCLUSION

Rajkot city and the adjacent area contain a variety of excellent habitats for different groups of birds. The district supports over half of the total bird species

of Gujarat, and almost 25% of bird species in India. It includes important resident as well as migratory species, including several Red Listed species. Being an important area for avifaunal diversity, sites in and around Rajkot should receive immediate attention for conservation. It is important to note that 17 species have not been sighted since 1990, hence we have listed them as locally extinct, while four other species are listed as data deficient.

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Annexure 1. Checklist of Rajkot birds with migratory status, Redlist status, preferred habitats, and breeding.

	Species	Status in Gujarat	IUCN Red List Category	Habitat	Breeding	eBird/ Media	Publication	Pers. Comm.	Data Deficient / Local Extinctiction	References
	I. Anseriformes									
	1. Anatidae (ducks, geese, swans)									
1	Lesser Whistling Duck *Dendrocygna javanica*	R	LC	A						
2	Bar-headed Goose *Anser indicus*	WM	LC	A						
3	Greylag Goose *Anser anser*	WM	LC	A			Y			Mashru & Jhala 2005
4	Knob-billed Duck *Sarkidiornis melanotos*	R	LC	A	Y					
5	Ruddy Shelduck *Tadorna ferruginea*	WM	LC	A						
6	Common Shelduck *Tadorna tadorna*	WM	LC	A			Y			Gherwada et al. 2018b
7	Cotton Teal *Nettapus coromandelianus*	R	LC	A						Photographed on 2.iii.2009 at Randarda lake by Bhavesh Trivedi
8	Garganey *Spatula querquedula*	WM	LC	A						
9	Northern Shoveler *Spatula clypeata*	WM	LC	A						
10	Gadwall *Mareca strepera*	WM	LC	A						
11	Eurasian Wigeon *Mareca penelope*	WM	LC	A						
12	Indian Spot-billed Duck *Anas poecilorhyncha*	R	LC	A	Y					
13	Mallard *Anas platyrhynchos*	WM	LC	A			Y			Trivedi & Trivedi 2018
14	Northern Pintail *Anas acuta*	WM	LC	A						
15	Common Teal *Anas crecca*	WM	LC	A						
16	Red-crested Pochard *Netta rufina*	WM	LC	A		Y				Santharam 1989
17	Common Pochard *Aythya ferina*	WM	VU	A						
18	Ferruginous Duck *Aythya nyroca*	WM	NT	A						
19	Tufted Duck *Aythya fuligula*	WM	LC	A						
	II. Galliformes									
	2. Phasianidae (partridges, pheasants, grouse)									
20	Indian Peafowl *Pavo cristatus*	R	LC	O	Y					
21	Common Quail *Coturnix coturnix*	WM	LC	G			Y			Mashru 2010
22	Rain Quail *Coturnix coromandelica*	MM	LC	G	Y					
23	Rock Bush Quail *Perdicula argoondah*	R	LC	G	Y					
24	Painted Francolin *Francolinus pictus*	R	LC	G	Y					
25	Grey Francolin *Francolinus pondicerianus*	R	LC	O/G	Y					

	Species	Status in Gujarat	IUCN Red List Category	Habitat	Breeding	eBird/ Media	Publication	Pers. Comm.	Data Deficient / Local Extinctiction	References
	III. Phoenicopteriformes									
	3. Phoenicopteridae (flamingos)									
26	Greater Flamingo *Phoenicopterus roseus*	R	LC	A						
27	Lesser Flamingo *Phoeniconaias minor*	R	NT	A						
	IV. Podicipediformes									
	4. Podicipedidae (grebes)									
28	Little Grebe *Tachybaptus ruficollis*	R	LC	A	Y					
29	Red-necked Grebe *Podiceps grisegena*	V	LC	A			Y			Mundkur 1990
30	Great Crested Grebe *Podiceps cristatus*	R/LM	LC	A	Y			Y		Makawana 2005
	V. Columbiformes									
	5. Columbidae (pigeons)									
31	Rock Pigeon *Columba livia*	R	LC	O	Y					
32	Eurasian Collared Dove *Streptopelia decaocto*	R	LC	O	Y					
33	Red Collared Dove *Streptopelia tranquebarica*	R	LC	F	Y					
34	Spotted Dove *Streptopelia chinensis*	R	LC	F	Y					
35	Laughing Dove *Streptopelia senegalensis*	R	LC	O	Y					
36	Yellow-footed Green Pigeon *Treron phoenicopterus*	R/LM	LC	F						
	VI. Pterocliformes									
	6. Pteroclidae (sandgrouse)									
37	Chestnut-bellied Sandgrouse *Pterocles exustus*	R	LC	O	Y					
38	Painted Sandgrouse *Pterocles indicus*	R	LC	F		Y				Ghervada 2017
	VII. Otidiformes									
	7. Otididae (bustards)									
39	Great Indian Bustard *Ardeotis nigriceps*	R	CR	O/G			Y		X	Rahmani & Manakadan 1990
40	Macqueen's Bustard *Chlamydotis macqueenii*	WM	VU	O		Y				Sojitra 2019
41	Lesser Florican *Sypheotides indicus*	MM	EN	G			Y		X	Mori et al. 2017
	VIII. Cuculiformes									
	8. Cuculidae (cuckoos)									
42	Greater Coucal *Centropus sinensis*	R	LC	F	Y					
43	Sirkeer Malkoha *Taccocua leschenaultii*	R	LC	O	Y					Photographed on 01.iv.2017 at Gadhka village by Dhaval Vargiya
44	Pied Cuckoo *Clamator jacobinus*	MM	LC	F	Y					
45	Asian Koel *Eudynamys scolopaceus*	R	LC	F	Y					

	Species	Status in Gujarat	IUCN Red List Category	Habitat	Breeding	eBird/ Media	Publication	Pers. Comm.	Data Deficient / Local Extinctiction	References
46	Grey-bellied Cuckoo *Cacomantis passerinus*	R/MM	LC	O/F						
47	Square-tailed Drongo Cuckoo *Surniculus lugubris*	MM	LC	O/F			Y			Andhariya & Ghedia 2017
48	Common Hawk Cuckoo *Hierococcyx varius*	R/MM	LC	O/F	Y					
49	Common Cuckoo *Cuculus canorus*	MM/PM	LC	F						
	IX. Caprimulgiformes									
	9. Caprimulgdae (nightjars)									
50	Jungle Nightjar Caprimulgus indicus	R	LC	F/O			Y			Naik et al. 1990
51	European Nightjar *Caprimulgus europaeus*	PM	LC	O			Y		X	Naik et al. 1990
52	Sykes's Nightjar *Caprimulgus mahrattensis*	WM	LC	O						
53	Indian Nightjar *Caprimulgus asiaticus*	R	LC	F	Y					
54	Savanna Nightjar *Caprimulgus affinis*	R	LC	O						
	10. Apodidae (swifts)									
55	Alpine Swift *Tachymarptis melba*	WM	LC	O/F			Y			Trivedi 2003
56	Common Swift *Apus apus*	V	LC	O/F			Y		X	Khachar 1958
57	Pacific Swift *Apus pacificus*	V	LC	O/F			Y		X	Khachar 1990
58	Indian House Swift *Apus affinis*	R	LC	O	Y					
59	Asian Palm Swift *Cypsiurus balasiensis*	R	LC	O						
	X. Gruiformes									
	11. Rallidae (rails and coots)									
60	Western Water Rail *Rallus aquaticus*	WM	LC	A						
61	Spotted Crake *Porzana porzana*	WM	LC	A			Y			Vala 2018
62	Common Moorhen *Gallinula chloropus*	R	LC	A	Y					
63	Common Coot *Fulica atra*	R	LC	A	Y					
64	Grey-headed Swamphen *Porphyrio poliocephalus*	R	LC	A	Y					
65	Watercock *Gallicrex cinerea*	MM	LC	A						Seen on 15.vi.2016 at Randarda lake by Bhavesh Trivedi; Mashru 2017b
66	White-breasted Waterhen *Amaurornis phoenicurus*	R	LC	A	Y					
67	Ruddy-breasted Crake *Zapornia fusca*	R	LC	A						
68	Brown Crake *Zapornia akool*	R	LC	A	Y					
69	Baillon's Crake *Zapornia pusilla*	WM	LC	A						
	12. Gruidae (cranes)									
70	Demoiselle Crane *Grus virgo*	WM	LC	A						
71	Common Crane *Grus grus*	WM	LC	A						

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	XI. Charadriiformes									
	13. Burhinidae (thick-knees)									
72	Indian Thick-knee *Burhinus indicus*	R	LC	O	Y					
73	Great Thick-knee *Esacus recurvirostris*	R	NT	O	Y					
	14. Recurvirostridae (stilts and avocets)									
74	Black-winged Stilt *Himantopus himantopus*	R	LC	A	Y					
75	Pied Avocet *Recurvirostra avosetta*	WM	LC	A						
	15. Haematopodidae (oystercatchers)									
76	Eurasian Oystercatcher *Haematopus ostralegus*	WM	LC	A				Y		Seen by Ashok Mashru on 29.iii.1998
	16. Charadriidae (plovers & lapwings)									
77	Pacific Golden Plover *Pluvialis fulva*	WM	LC	A						
78	Yellow-wattled Lapwing *Vanellus malabaricus*	R	LC	O/A	Y					
79	Red-wattled Lapwing *Vanellus indicus*	R	LC	O/A	Y					
80	White-tailed Lapwing *Vanellus leucurus*	WM	LC	A						
81	Lesser Sand Plover *Charadrius mongolus*	WM	LC	A						
82	Kentish Plover *Charadrius alexandrinus*	R	LC	A	Y		Y			Mashru 2009
83	Little Ringed Plover *Charadrius dubius*	R	LC	A	Y					
	17. Rostratulidae (painted-snipe)									
84	Greater Painted-snipe *Rostratula benghalensis*	WM	LC	A						
	19. Jacanidae (jacanas)									
85	Pheasant-tailed Jacana *Hydrophasianus chirurgus*	MM	LC	A						
86	Bronze-winged Jacana *Metopidius indicus*	R	LC	A						
	20. Scolopacidae (sandpipers)									
87	Eurasian Curlew *Numenius arquata*	WM	NT	A				Y		Raju Karia pers. comm.
88	Bar-tailed Godwit *Limosa lapponica*	WM	NT	A			Y		X	Raol 1963
89	Black-tailed Godwit *Limosa limosa*	WM	NT	A						
90	Ruddy Turnstone Arenaria interpres	WM	LC	A				Y		Seen by Raju Karia on 19.v.2020
91	Ruff *Calidris pugnax*	WM	LC	A						
92	Curlew Sandpiper *Calidris ferruginea*	WM	NT	A						
93	Temminck's Stint *Calidris temminckii*	WM	LC	A						
94	Little Stint *Calidris minuta*	WM	LC	A						
95	Common Snipe *Gallinago gallinago*	WM	LC	A						
96	Pintail Snipe *Gallinago stenura*	WM	LC	A			Y			Karia 2018

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97	Common Sandpiper *Actitis hypoleucos*	WM	LC	A						
98	Green Sandpiper *Tringa ochropus*	WM	LC	A						
99	Spotted Redshank *Tringa erythropus*	WM	LC	A						
100	Common Greenshank *Tringa nebularia*	WM	LC	A						
101	Marsh Sandpiper *Tringa stagnatilis*	WM	LC	A						
102	Wood Sandpiper *Tringa glareola*	WM	LC	A						Khachar 1969
103	Common Redshank *Tringa totanus*	WM	LC	A						
	21. Turnicidae (buttonquails)									
104	Small Buttonquail *Turnix sylvaticus*	MM	LC	F	Y					
105	Yellow-legged Buttonquail *Turnix tanki*	MM	LC	G	Y					
106	Barred Buttonquail *Turnix suscitator*	R	LC	F	Y					
	22. Glareolidae (coursers and pratincoles)									
107	Indian Courser *Cursorius coromandelicus*	LM	LC	O	Y					
108	Collared Pratincole *Glareola pratincola*	R/LM	LC	A						
109	Oriental Pratincole *Glareola maldivarum*	R/LM	LC	A						Seen on 14.xii.2011 at Lalpari Lake by Dhaval Vargiya
110	Small Pratincole *Glareola lactea*	MM/R	LC	A	Y					
	23. Laridae (gulls and terns)									
111	Black-headed Gull *Chroicocephalus ridibundus*	WM	LC	A						
112	Brown-headed Gull *Chroicocephalus brunnicephalus*	WM	LC	A						
113	Pallas's Gull *Ichthyaetus ichthyaetus*	WM	LC	A						
114	Lesser Black-backed Gull *Larus fuscus*	WM	LC	A						
115	Little Tern *Sternula albifrons*	R	LC	A						
116	Gull-billed Tern *Gelochelidon nilotica*	WM	LC	A						
117	Caspian Tern *Hydroprogne caspia*	WM	LC	A						
118	White-winged Tern *Chlidonias leucopterus*	PM/WM	LC	A			Y			Jani et al. 2019
119	Whiskered Tern *Chlidonias hybrida*	R	LC	A						
120	Common Tern *Sterna hirundo*	WM	LC	A				Y		Singhal 2013
121	River Tern *Sterna aurantia*	R	NT	A	Y					
	XII. Ciconiiformes									
	24. Ciconiidae (storks)									
122	Asian Openbill *Anastomus oscitans*	R	LC	A	Y					
123	Black Stork *Ciconia nigra*	WM	LC	A			Y			Khachar 1977

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124	Woolly-necked Stork *Ciconia episcopus*	R	VU	A						Photographed on 1.ix.2013 at Randarda Lake by Bhavesh Trivedi
125	European White Stork *Ciconia ciconia*	WM	LC	A/G			Y		X	Mathew et al. 1986; Shah et al. 2005
126	Black-necked Stork *Ephippiorhynchus asiaticus*	R	NT	A			Y			Mashru 2006b
127	Painted Stork *Mycteria leucocephala*	R	NT	A	Y					
	XIII. Suliformes									
	25. Anhingidae (darters)									
128	Oriental Darter *Anhinga melanogaster*	R	NT	A						
	26. Phalacrocoracidae (cormorants)									
129	Little Cormorant *Microcarbo niger*	R	LC	A	Y					
130	Great Cormorant *Phalacrocorax carbo*	R	LC	A	Y					
131	Indian Cormorant *Phalacrocorax fuscicollis*	R	LC	A						
	XIV. Pelecaniformes									
	27. Pelecanidae (pelicans)									
132	Great White Pelican *Pelecanus onocrotalus*	WM	LC	A						
133	Dalmatian Pelican *Pelecanus crispus*	WM	NT	A						
	28. Ardeidae (herons)									
134	Yellow Bittern *Ixobrychus sinensis*	MM	LC	A	Y					
135	Cinnamon Bittern *Ixobrychus cinnamomeus*	MM	LC	A	Y					
136	Black Bittern *Ixobrychus flavicollis*	MM	LC	A						
137	Grey Heron *Ardea cinerea*	R	LC	A	Y					
138	Purple Heron *Ardea purpurea*	R	LC	A	Y					
139	Great Egret *Ardea alba*	R	LC	A	Y					
140	Intermediate Egret *Ardea intermedia*	R	LC	A	Y					
141	Little Egret *Egretta garzetta*	R	LC	A	Y					
142	Western Reef Egret *Egretta gularis*	R/WM	LC	A						Photographed on 22.viii.2019 at Nyari-1 Dam by Trivedi & Mashru 2012a
143	Cattle Egret *Bubulcus ibis*	R	LC	A	Y					
144	Indian Pond Heron *Ardeola grayii*	R	LC	A	Y					
145	Striated Heron *Butorides striata*	R	LC	A						
146	Black-crowned Night Heron *Nycticorax nycticorax*	R	LC	A	Y					

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	29. Theskiornithidae (ibises)									
147	Glossy Ibis *Plegadis falcinellus*	R/LM	LC	A						
148	Black-headed Ibis *Threskiornis melanocephalus*	R	NT	A	Y					
149	Red-naped Ibis *Pseudibis papillosa*	R/LM	LC	A	Y					
150	Eurasian Spoonbill *Platalea leucorodia*	R	LC	A	Y					
	XV. Accipitriformes									
	30. Pandionidae (Osprey)									
151	Osprey *Pandion haliaetus*	R	LC	F/O/A						
	31. Accipitridae (kites, hawks and eagles)									
152	Black-winged Kite *Elanus caeruleus*	R	LC	F	Y					
153	Black Eagle *Ictinaetus malaiensis*	WM	LC	F						Photographed on 23.xii.2020 by Bhavesh Trivedi
154	Egyptian Vulture *Neophron percnopterus*	R/WM	EN	O						Seen on xii.1998 at Sat Hanuman near Rajkot City by Bhavesh Trivedi
155	Oriental Honey Buzzard *Pernis ptilorhynchus*	WM	LC	G						
156	Red-headed Vulture *Sarcogyps calvus*	R	CR	O/F			Y		X	Naik et al. 1990
157	White-rumped Vulture *Gyps bengalensis*	R	CR	O			Y			Santharam 1990; Anon 2005
158	Indian Vulture *Gyps indicus*	R	CR	O			Y		X	Naik et al. 1990
159	Griffon Vulture *Gyps fulvus*	WM	LC	O			Y			Naik et al. 1990
160	Crested Serpent Eagle *Spilornis cheela*	WM	LC	G			Y			Mashru 2007
161	Short-toed Snake Eagle *Circaetus gallicus*	WM	LC	G						
162	Indian Spotted Eagle *Clanga hastata*	WM/R	VU	O/G				Y		Raju Karia pers. comm.
163	Greater Spotted Eagle *Clanga clanga*	WM	VU	G						
164	Booted Eagle *Hieraaetus pennatus*	WM	LC	O/G						Seen on 5.xii.2016 at Gadhaka by Dhaval Vargiya & Photographed on 14.x.2017 at Khirarsara Vidi by Bhavesh Trivedi.
165	Tawny Eagle *Aquila rapax*	LM	VU	O/G						Naik et al. 1990
166	Bonelli's Eagle *Aquila fasciata*	R	LC	O/G						Seen on 2.xii.2016 at Gadhaka by Dhaval Vargiya & Photographed on 19.ii.2020 at Khirarsara Vidi by Bhavesh Trivedi.

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167	White-eyed Buzzard *Butastur teesa*	R	LC	O						
168	Western Marsh Harrier *Circus aeruginosus*	WM	LC	G						
169	Pallid Harrier *Circus macrourus*	WM	NT	G						
170	Montagu's Harrier *Circus pygargus*	WM	LC	G						
171	Shikra *Accipiter badius*	R	LC	O/G/F	Y					
172	Eurasian Sparrowhawk *Accipiter nisus*	WM	LC	O						
173	Northern Goshawk *Accipiter gentilis*	V	LC	O/F			Y		X	Khachar & Mundkur 1990
174	Red Kite *Milvus milvus*	V	NT	O			Y		X	Shivrajkumar 1964
175	Black Kite *Milvus migrans*	R	LC	G	Y					
176	Brahminy Kite *Haliastur indus*	R	LC	G						
177	Common Buzzard *Buteo buteo*	WM	LC	O						
178	Long-legged Buzzard *Buteo rufinus*	WM	LC	O/G/A				Y		Raju Karia pers. comm. 2020
	XVI. Strigiformes									
	32. Tytonidae (barn owls)									
179	Common Barn Owl *Tyto alba*	R	LC	F	Y					
	33. Strigidae (owls)									
180	Eurasian Scops Owl *Otus scops*	V	LC	G			Y			Radadia et al. 2019
181	Pallid Scops Owl *Otus brucei*	WM	LC	F						
182	Indian Eagle Owl *Bubo bengalensis*	R	LC	O/G	Y					
183	Spotted Owlet *Athene brama*	R	LC	F	Y					
184	Mottled Wood Owl *Strix ocellata*	R	LC	F			Y			Naik et al. 1990
185	Short-eared Owl *Asio flammeus*	LM	LC	G						
	XVII. Bucerotiformes									
	34. Upupidae (hoopoes)									
186	Common Hoopoe *Upupa epops*	LM	LC	G						
	XIX. Coraciiformes									
	35. Alcedinidae (kingfishers)									
187	Common Kingfisher *Alcedo atthis*	R	LC	A						
188	White-throated Kingfisher *Halcyon smyrnensis*	R	LC	A	Y					
189	Black Capped Kingfisher Halcyon pileata	R/LM	LC	A			Y			Vyas 1978; Sanghani 2000
190	Pied Kingfisher *Ceryle rudis*	R	LC	A	Y					
	37. Meropidae (bee-eaters)									
191	Green Bee-eater *Merops orientalis*	R	LC	O/A/F/G	Y					
192	Blue-cheeked Bee-eater *Merops persicus*	WM	LC	A/O			Y			Jhala 2006

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193	Blue-tailed Bee-eater *Merops philippinus*	LM	LC	A/O						Photographed on 5.xii.2019 at Randarda Lake by Bhavesh Trivedi.
	38. Coraciidae (rollers)									
194	European Roller *Coracias garrulus*	WM	LC	O						
195	Indian Roller *Coracias benghalensis*	R	LC	O						
	XX. Piciformes									
	39. Megalaimidae (barbets)									
196	Coppersmith Barbet *Psilopogon haemacephalus*	R	LC	F	Y					
	40. Picidae (woodpeckers)									
197	Eurasian Wryneck *Jynx torquilla*	WM	LC	F						
198	Yellow-fronted Pied Woodpecker *Leiopicus mahrattensis*	R	LC	F	Y					
199	Black-rumped Flameback *Dinopium benghalense*	R	LC	F	Y		Y			Khachar 1961a
	XXI.Falconiformes									
	41. Falconidae (falcons and caracaras)									
200	Common Kestrel *Falco tinnunculus*	WM	LC	O/G						
201	Red-necked Falcon *Falco chicquera*	R	NT	F	Y					Mashru 2020
202	Amur Falcon *Falco amurensis*	PM	LC	O/G		Y				Rindani 2017
203	Eurasian Hobby *Falco subbuteo*	PM	LC	O/G			Y			Jhala & Hathi 2006
204	Laggar Falcon *Falco jugger*	R	NT	O/G			Y			Trivedi 2003
205	Peregrine Falcon *Falco peregrinus*	WM	LC	O/A						
	XXII. Psittaciformes									
	42. Psittacuildae (Old World parrots)									
206	Alexandrine Parakeet *Psittacula eupatria*	R	NT	O						
207	Rose-ringed Parakeet *Psittacula krameri*	R	LC	O	Y					
208	Plum-headed Parakeet *Psittacula cyanocephala*	R	LC	F						
	XXIII. Passeriformes									
	43. Pittidae (pittas)									
209	Indian Pitta *Pitta brachyura*	MM	LC	F	Y		Y			Theba et al. 2019
	44. Campephagidae (minivets and cuckooshrikes)									
210	White-bellied Minivet *Pericrocotus erythropygius*	R	LC	O/F		Y				Vagadia 2016
211	Small Minivet *Pericrocotus cinnamomeus*	R	LC	O/F	Y					
212	Large Cuckooshrike *Coracina javensis*	WM	LC	F						

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213	Black-headed Cuckooshrike *Lalage melanoptera*	R	LC	F	Y		Y			Mashru 2006b
	45. Oriolidae (orioles, figbirds and allies)									
214	Indian Golden Oriole *Oriolus kundoo*	R	LC	F	Y					
215	Black-naped Oriole *Oriolus chinensis*	V	LC	F			Y			Dhami, 2018
	46. Vangidae (vangas and helmet-shrikes)									
216	Common Woodshrike *Tephrodornis pondicerianus*	WM	LC	F	Y					
	47. Aegithinidae (ioras)									
217	Common Iora *Aegithina tiphia*	R	LC	F	Y					
218	Marshall's Iora *Aegithina nigrolutea*	R	LC	O/F	Y		Y			Ganpule 2015
	48. Rhipiduridae (fantails)									
219	White-browed Fantail *Rhipidura aureola*	R	LC	F	Y					
	49. Dicruridae (drongos)									
220	Black Drongo *Dicrurus macrocercus*	R	LC	O/F	Y					
221	Ashy Drongo *Dicrurus leucophaeus*	R	LC	F						
222	White-bellied Drongo *Dicrurus caerulescens*	WM	LC	F						
	50. Monarchidae (monarchs & paradise-flycatchers)									
223	Black-naped Monarch *Hypothymis azurea*	R	LC	F	Y					
224	Indian Paradise-flycatcher *Terpsiphone paradisi*	R/LM	LC	F	Y					
	51. Laniidae (shrikes)									
225	Red-backed Shrike *Lanius collurio*	PM	LC	O/G						
226	Red-tailed Shrike *Lanius phoenicuroides*	PM	LC	O/G						
227	Isabelline Shrike *Lanius isabellinus*	WM	LC	O/G						
228	Brown Shrike *Lanius cristatus*	WM	LC	F			Y			Mashru 2012b
229	Bay-backed Shrike *Lanius vittatus*	R	LC	O/G	Y					
230	Long-tailed Shrike *Lanius schach*	R	LC	F	Y					
231	Great Grey Shrike *Lanius excubitor*	WM	LC	F						
	52. Corvidae (crows and jays)									
232	Rufous Treepie *Dendrocitta vagabunda*	LM	LC	O/F	Y					
233	House Crow *Corvus splendens*	R	LC	O	Y					
234	Large-billed Crow *Corvus macrorhynchos*	R	LC	F/O			Y			Naik et al. 1990

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	53. Stenostiridae (fairy-flycatcher and crested-flycatchers)									
235	Grey-headed Canary-flycather *Culicicapa ceylonesis*	WM	LC	F						
	54. Alaudidae (larks)									
236	Rufous-tailed Lark *Ammomanes phoenicura*	R	LC	O/G				Y		Mashru, 2017a
237	Ashy-crowned Sparrow Lark *Eremopterix griseus*	R	LC	O	Y					
238	Singing Bushlark *Mirafra cantillans*	R	LC	O						
239	Indian Bushlark *Mirafra erythroptera*	R	LC	O	Y					
240	Greater Short-toed Lark *Calandrella brachydactyla*	WM	LC	O						
241	Sykes's Short-toed Lark *Calandrella dukhunensis*	WM	LC	O/F			Y		DD	Naik et al. 1990
242	Crested Lark *Galerida cristata*	R	LC	O	Y			Y		Seen by Ashok Mashru on 11.iii.2012
243	Sykes's Lark *Galerida deva*	R	LC	O/G	Y					
	55. Cisticolidae (prinias and cisticolas)									
244	Common Tailorbird *Orthotomus sutorius*	R	LC	G/F	Y					
245	Rufous-fronted Prinia *Prinia buchanani*	R	LC	O/F	Y					
246	Grey-breasted Prinia *Prinia hodgsonii*	R	LC	G/F	Y					
247	Graceful Prinia *Prinia gracilis*	R	LC	O			Y		DD	Naik et al. 1990
248	Jungle Prinia *Prinia sylvatica*	R	LC	O/G	Y					
249	Ashy Prinia *Prinia socialis*	R	LC	G/F	Y					
250	Plain Prinia *Prinia inornata*	R	LC	G/F	Y					
251	Zitting Cisticola *Cisticola juncidis*	R	LC	G/F	Y					
	56. Acrocephalidae (brush, reed and swamp warblers)									
252	Booted Warbler *Iduna caligata*	WM	LC	O						
253	Sykes's Warbler *Iduna rama*	WM	LC	G/F						
254	Paddyfield Warbler *Acrocephalus agricola*	R	LC	O						
255	Blyth's Reed Warbler *Acrocephalus dumetorum*	WM	LC	G/F						
256	Clamorous Reed Warbler *Acrocephalus stentoreus*	WM	LC	F/G						
	57. Locustellidae (bush warblers)									
257	Grasshopper Warbler *Locustella naevia*	WM	LC	G/O			Y			Vagadiya 2018
	58. Hirundinidae (swallows)									
258	Grey-throated Martin Riparia chinensis	R	LC	O				Y		Raju Karia pers. comm.
259	Sand Martin *Riparia riparia*	WM	LC	O			Y		DD	Khachar 1961b
260	Pale Martin *Riparia diluta*	WM	LC	O			Y		DD	Naik et al. 1990

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261	Eurasian Crag Martin *Ptyonoprogne rupestris*	WM	LC	O			Y			Naik et al. 1990
262	Dusky Crag Martin *Ptyonoprogne concolor*	R	LC	O	Y					
263	Barn Swallow *Hirundo rustica*	WM	LC	O						
264	Wire-tailed Swallow *Hirundo smithii*	R	LC	O	Y					
265	Red-rumped Swallow *Cecropis daurica*	R	LC	O	Y					
266	Streak-throated Swallow *Petrochelidon fluvicola*	R	LC	O	Y					
267	Northern House Martin *Delichon urbicum*	V	LC	O			Y			Dharma-kumarsinhji 1968
	59. Pycnonotidae (bulbuls)									
268	Red-vented Bulbul *Pycnonotus cafer*	R	LC	O	Y					
269	White-browed Bulbul *Pycnonotus luteolus*	R	LC	F			Y			Sitapara et al. 2019
	60. Phylloscopidae (Old world leaf warblers)									
270	Hume's Warbler Phylloscopus humei	WM	LC	O						
271	Sulphur-bellied Warbler *Phylloscopus griseolus*	WM	LC	G/F						
272	Tickell's Leaf Warbler *Phylloscopus affinis*	WM	LC	F			Y			Akhtar& Tiwari 1994
273	Common Chiffchaff *Phylloscopus collybita*	WM	LC	G/F						
274	Green Warbler Phylloscopus nitidus	WM	LC	F				Y		
275	Greenish Warbler Phylloscopus trochiloides	WM	LC	G/F						
276	Western Crowned Warbler Phylloscopus occipitalis	WM	LC	F			Y		X	Shivrajkumar 1964
	61. Sylviidae (Sylviid warblers)									
277	Lesser Whitethroat *Sylvia curruca*	WM	LC	O						
278	Eastern Orphean Warbler *Sylvia crassirostris*	WM	LC	F						
279	Common Whitethroat *Sylvia communis*	PM	LC	O						Moteria 2018
	62 . Paradoxornithidae (Parrotbills, Fulvettas, & Myzornis)									
280	Yellow-eyed Babbler *Chrysomma sinense*	MM	LC	F	Y					
	63. Zosteropidae (white-eyes and yuhinas)									
281	Indian White-eye Zosterops palpebrosus	R	LC	F	Y					
	64. Leiothrichidae (babbler, laughingthrushes and allies)									
282	Quaker Tit Babbler *Alcippe poioicephala*	V/R	LC	F			Y		X	Harington 1915
283	Jungle Babbler *Argya striata*	R	LC	F/O	Y					
284	Common Babbler *Argya caudata*	R	LC	O	Y					

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285	Large Grey Babbler *Argya malcolmi*	R	LC	O/F	Y					
	65. Sturnidae (starlings)									
286	Rosy Starling *Pastor roseus*	LM	LC	O/F						
287	Brahminy Starling *Sturnia pagodarum*	WM	LC	O/F	Y					
288	Chestnut-tailed Starling *Sturnia malabarica*	WM	LC	F			Y			Sucheria 2018
289	Common Myna *Acridotheres tristis*	R	LC	O/F	Y					
290	Bank Myna *Acridotheres ginginianus*	WM	LC	O/F	Y					
	66. Turdidae (thrushes)									
291	Orange-headed Thrush *Geokichla citrina*	V/MM	LC	F			Y			Ghervada et al. 2017
292	Tickell's Thrush *Turdus unicolor*	WM	LC	F		Y				Panchasara 2021
	67. Muscicapidae (chats and flycatchers)									
293	Asian Brown Flycatcher *Muscicapa dauurica*	WM	LC	F						
294	Brown-breasted Flycatcher *Muscicapa muttui*	WM	LC	F						
295	Spotted Flycatcher *Muscicapa striata*	PM	LC	O/G						
296	Indian Robin *Saxicoloides fulicatus*	R	LC	O/F/G	Y					
297	Oriental Magpie Robin *Copsychus saularis*	R	LC	O/F	Y					
298	Tickell's Blue Flycatcher *Cyornis tickelliae*	WM/R	LC	F						
299	Verditer Flycatcher *Eumyias thalassinus*	WM	LC	F						
300	Indian Blue Robin *Larvivora brunnea*	V	LC	F			Y			Mashru 2014
301	Bluethroat *Luscinia svecica*	WM	LC	F						
302	Ultramarine flycatcher *Ficedula superciliaris*	WM	LC	F						
303	Rusty-tailed Flycatcher *Ficedula ruficauda*	PM/V	LC	F			Y		X	Naik et al. 1990
304	Taiga flycatcher *Ficedula albicilla*	WM	LC	F						
305	Kashmir Flycatcher *Ficedula subrubra*	WM	VU	F		Y				Bagda 2014
306	Red-breasted Flycatcher *Ficedula parva*	WM	LC	F						
307	Black Redstart *Phoenicurus ochruros*	WM	LC	O/F						
308	Blue-capped Rock Thrush *Monticola cinclorhyncha*	WM	LC	F			Y		X	Naik et al. 1990
309	Blue Rock Thrush *Monticola solitarius*	R	LC	O/G						
310	Stoliczka's Bushchat *Saxicola macrorhynchus*	WM	VU	O/G				Y		Raju Karia pers. comm.
311	Siberian Stonechat *Saxicola maurus*	WM	LC	O						
312	Pied Bushchat *Saxicola caprata*	WM	LC	O						
313	Isabelline Wheatear *Oenanthe isabellina*	WM	LC	O						
314	Desert Wheatear *Oenanthe deserti*	WM	LC	O						

	Species	Status in Gujarat	IUCN Red List Category	Habitat	Breeding	eBird/ Media	Publication	Pers. Comm.	Data Deficient / Local Extinctiction	References
315	Brown Rock Chat *Oenanthe fusca*	R	LC	O			Y			Parasharya & Vyas 2003
316	Variable Wheatear *Oenanthe picata*	WM	LC	O						
317	Red-tailed Wheatear *Oenanthe chrysopygia*	V	LC	O						
	68. Hypocoliidae (hypocolius and allies)									
318	Grey Hypocolius *Hypocolius ampelinus*	WM	LC	O			Y			Bhalodia & Mashru 2016; Sitapara et al. 2019
	69. Dicaeidae (flowerpeckers)									
319	Thick-billed Flowerpecker *Dicaeum agile*	R	LC	F			Y			Thakkar 2017
	70. Nectariniidae (sunbirds)									
320	Purple Sunbird *Cinnyris asiaticus*	R	LC	O/F/G	Y					
	71. Ploceidae (weavers)									
321	Baya Weaver *Ploceus philippinus*	R	LC	F	Y					
322	Black-breasted Weaver *Ploceus benghalensis*	LM	LC	F	Y					
	72. Estrildidae (waxbills)									
323	Red Munia *Amandava amandava*	R	LC	G	Y					
324	Indian Silverbill *Euodice malabarica*	R	LC	O/F/G	Y					
325	Scaly-breasted Munia *Lonchura punctulata*	LM	LC	G/A	Y					
326	Tricoloured Munia *Lonchura malacca*	LM	LC	G/A	Y		Y			Ghervada et al. 2018a
	73. Passeridae (sparrows, snowfinches and allies)									
327	House Sparrow *Passer domesticus*	R	LC	O/F	Y					
328	Yellow-throated Sparrow *Gymnoris xanthocollis*	LM	LC	O/F	Y					
329	Pale Rock Sparrow *Carpospiza brachydactyla*	V	LC	O/G				Y		Ganpule & Karia 2020
	74. Motacillidae (wagtails and pipits)									
330	Forest Wagtail *Dendronanthus indicus*	WM	LC	F				Y		Priyank Dhami pers. comm.
331	Grey Wagtail *Motacilla cinerea*	WM	LC	A						
332	Western Yellow Wagtail *Motacilla flava*	WM	LC	A						
333	Eastern Yellow Wagtail *Motacilla tschutschensis*	WM	LC	A			Y			Radadia 2018
334	Citrine Wagtail *Motacilla citreola*	WM	LC	A						
335	White-browed Wagtail *Motacilla maderaspatensis*	WM	LC	A	Y					
336	White Wagtail *Motacilla alba*	WM	LC	A						
337	Paddyfield Pipit *Anthus rufulus*	R	LC	O	Y					
338	Long-billed Pipit Anthus similis	WM	LC	O						Naik et al. 1990

	Species	Status in Gujarat	IUCN Red List Category	Habitat	Breeding	eBird/ Media	Publication	Pers. Comm.	Data Deficient / Local Extinctiction	References
339	Blyth's Pipit *Anthus godlewskii*	LM	LC	O		Y				
340	Tawny Pipit *Anthus campestris*	R	LC	O/G						
341	Tree Pipit *Anthus trivialis*	R	LC	O						
	75. Fringillidae (finches, euphonias and Hawaiian honeycreepers)									
342	Common Rosefinch *Carpodacus erythrinus*	WM	LC	O/F						
	76. Emberizidae (Old World Buntings)									
343	Crested Bunting *Emberiza lathami*	R	LC	F/O	Y		Y			Jebalia 2004
344	Black-headed Bunting *Emberiza melanocephala*	WM	LC	O						
345	White-capped Bunting *Emberiza stewarti*	WM	LC	O			Y		X	Khacher & Mundkur 1988
346	Grey-necked Bunting *Emberiza buchanani*	WM	LC	O						
347	Ortolan Bunting *Emberiza hortulana*	V	LC	O			Y		X	Naik et al. 1990
348	Striolated Bunting *Emberiza striolata*	WM	LC	O/F			Y			Rindani & Joshi 2018

LM—Local Migrant | MM—Monsoon Migrant | PM—Passage Migrant | R—Resident | V—Vagrant | WM—Winter Migrant | CR—Critically Endangered | EN—Endangered | VU—Vulnerable | NT—Near Threatened | LC—Least Concern | A—Aquatic | F—Forest | G—Grassland | O—Open Schrubland | Y—Breeding | DD—Data Deficiant | X—Extinct.

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REVIEW

Alien flora of Uttarakhand, western Himalaya: a comprehensive review

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Abstract: Alien plant species have captured attention of the scientific community, ecologists, and environmentalists throughout the world. Like other regions, the Himalayan region is also grappling with the disrupting impacts of plant invasions. Based on an extensive review of studies conducted on alien plant species in the Indian Himalayan region, we report 728 alien plant species belonging to 450 genera under 108 families in the state of Uttarakhand, which represents 15% of the state's flora. Fabaceae (89 species under 49 genera) followed by Asteraceae (63 species under 43 genera) and Poaceae (50 species under 35 genera) were the most diverse families amid alien species. *Eucalyptus* (15 species) followed by *Ipomoea* and *Euphorbia* (12 species each) and *Pinus* (11 species) were the most diverse genera. The maximum numbers of aliens (mostly herbs) in the state were introduced from America, followed by Europe. Owing to relatively high number of alien plant species in Uttarakhand, it is submitted that serious ecological and socio-economic consequences are likely to escalate in the future.

Keywords: Alien plants, biological invasion, Himalayan region, invasive species, plant invasion.

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Author contributions: SA conceived the idea, collected and analysed the data, wrote the manuscript; AK provided constructive suggestions in analysis and reviewed the manuscript; KNB and KA reviewed the manuscript.

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INTRODUCTION

Non-native species or alien species have captured attention of the scientific community, ecologists, and environmentalists. It was once considered that alien plants will not spread in high mountains, but ongoing processes of economic development such as trans-boundary trade and migration have altered the situation (Khuroo et al. 2007). Recent studies have reported that increasing global trade and climate change will drastically affect the spread of non-native species (Khuroo et al. 2007; Bellard et al. 2018; Panda & Behera 2019; Tripathi et al. 2019) outside their native habitats. Several studies have attempted to investigate the impact of climate change on the spread of invasive alien species (IAs) using predictive modelling (Wasowicz et al. 2013; Chakraborty et al. 2018; Wan & Wang 2018; Mungi et al. 2020). According to Ahmad et al. (2019), approximately 65% of the total geographical area of India is prone to invasion by *Parthenium hysterophorus*, one of the world's worst weeds, with the western Himalaya being highly vulnerable under changing climate scenarios. Adhikari et al. (2015) identified invasion hotspots of alien species in India, and reported that most of the biodiversity hotspots, coastal regions and forest reserves are prone to plant invasion. Half of the total geographical area of India is vulnerable to invasion by alien plant species owing to favorable climatic conditions. Mungi et al. (2018) and Thapa et al. (2018) predicted that global climate change in the future will lead to expansion of invasive species in the western Himalaya. Weber & Li (2008) suggested that economic development is directly proportional to the rate of biological invasion. Also, it is observed that higher levels of imports and human development were responsible for the increase in the number of invasive species (Nunez & Pauchard 2009). Invasive species have high capacity to tolerate wide environmental conditions, high growth and dispersal rates along with short generation time, which resulted in their successful establishment (Lamsal 2018). Besides having aesthetic costs, such as change in land-use patterns, reduced crop production (Born et al. 2004), loss of native species, degradation of resources (Everard 2018), these invasive alien species incur huge economic costs. Further, the annual costs due to invasive alien species have been estimated to about US$137 billion in USA, US$14.5 billion in China (Weber & Li 2008), €12 billion in Europe, and £1.7 billion in Great Britain (Reshi & Khuroo 2012). Considering this in view, the documentation, identification, and economic evaluation of invasive alien species at the national level in general and at regional levels, specifically would be required.

The spread of IAs has raised significant concerns around the world; studies aimed at tracking and understanding the impact of alien flora have been undertaken in China (Liu et al. 2005; Weber & Li 2008; Qin et al. 2018; Yang et al. 2018b; Zhu et al. 2018), Japan (Enomoto 1999), Korea (Koh et al. 2000), Taiwan (Wu et al. 2004), and Singapore (Corlett 1988). India is also facing problems of alien plant invasion that are expected to exacerbate further. Once known for their harsh climate, diverse habitats, varied environmental conditions and limited accessibility, the Indian Himalayan region (IHR) is now at high risk due to human interventions, climate change and economic development (Yang et al. 2018a). Despite of rich floral diversity and vulnerability to changing scenario, minuscule efforts have been attempted to inventorize, predict and map the alien flora of IHR. Thus, documentation of the alien flora of the region is called for to develop management strategies. Although a handful of workers such as Pathak et al. (2019) have highlighted the need and importance of studies relating to alien plant invasion in IHR. Further, comprehensive studies on the alien floras exists for some parts of the IHR such as the Kashmir Himalaya (Khuroo et al. 2007; Dar et al. 2018; Haq et al. 2018; Mehraj et al. 2018a,b; Muzafar et al. 2019; Shaheen et al. 2019), Himachal Pradesh (Jaryan et al. 2013; Ahmad et al. 2018), Arunachal Pradesh (Kosaka et al. 2010), and its adjoining hilly regions of Assam (Barua et al. 2013), West Bengal (Maiti & Bakshi 1981), Manipur (Khomdram et al. 2011) and Tripura (Debnath et al. 2017; Debnath & Debnath 2017). Unfortunately, a detailed inventory of alien plants is still lacking for the state of Uttarakhand. As a Himalayan biodiversity hotspot, the mountainous state has been invaded by several alien plant species. Noteably, a few studies at regional level have been conducted such as Negi & Hajra (2007) listed 436 alien plant species of Doon valley, and Sekar et al. (2012) documented a total of 163 invasive alien plant species in Uttarakhand. In spite of the fact that only a small percentage of alien plants have the potential to become invasive, the damage they incur is irreparable. Thus, a detailed inventory documenting alien plants, including naturalized as well as invasives, for the entire Indian Himalayan region in general and the state of Uttarakhand specifically is not yet available. The objective of this communication is to present a checklist of alien plants for Uttarakhand, and highlight the significance of studies carried out on alien plant species in the Indian Himalayan region.

MATERIAL AND METHODS

Study area

The state of Uttarakhand is largely mountainous and shares international boundaries with China in the north and Nepal in the east. With an area of 53,483 km^2, the state lies between 30.0668^{0}N & 79.0193^{0}E. Nested in the western Himalaya, Uttarakhand varies greatly in terms of altitude, climate and topography. This variation has resulted in the successful establishment of diverse flora that comprises approximately 5,000 vascular plant species in the state (Rana & Rawat 2017) including alien plant species. According to Champion & Seth (1968) and India State of Forest Report (2019), the state comprises of eight forest types, viz., tropical moist deciduous, tropical dry deciduous, sub-tropical Himalayan pine forests, Himalayan moist temperate, Himalayan dry temperate, sub-alpine forests, moist alpine scrub, and dry alpine scrub. The elevation ranges between 210–7,817m with glaciers at the highest elevation to tropical forests at the lower elevations. The average annual precipitation ranges 1,000–2,500 mm (Kala 2014) and temperature ranges from sub-zero to 43 °C (India State of Forest Report 2009).

Data collection

An extensive review of existing information in the form of scientific research articles, online database, books, reports, and thesis dealing with alien plant research and inventories were examined. Indian herbaria such as the Botanical Survey of India (BSD), Dehradun, Forest Research Institute (DD), Dehradun and Wildlife Institute of India (WII), Dehradun were consulted to validate the species. The listing of alien plant species was enriched by collating information from existing flora and relevant scientific literature on the state, such as Hajra & Balodi (1995), Gaur (1999), Singh & Prakash (2002), Uniyal et al. (2007), Negi & Hajra (2007), Reddy (2008), Sekar et al. (2012), Jaryan et al. (2013), Sankaran & Suresh (2013), Rana & Rawat (2017), Inderjit et al. (2018), and Pusalkar & Srivastava (2018) to name a few. Thus, the extensive review of these studies resulted in a master list comprising of the plant species which are alien to the state of Uttarakhand along with information on their nativity and life form. The authenticity of the plants occurring in the state and their growth form was also determined using regional floras or checklists such as Kanjilal (1928), Babu (1977), Osmaston (1994), Hajra & Balodi (1995), Gaur (1999), Singh & Prakash (2002), Uniyal et al. (2007), and Pusalkar & Srivastava (2018). Further, the plant names and family were rechecked using 'Plants of the World online (POWO)' (www.theplantsoftheworldonline.org.), the Plant List (www.theplantlist.org), and Tropicos (www.tropicos.org). Elimination of the synonyms was done to avoid the taxonomic inflation. The nativity of the plant species was established following POWO; International Plant Names Index (www.ipni.org), Khuroo et al. (2007), Negi & Hajra (2007), and Jaryan et al. (2012). The nativity of the species was further categorized at the continent level or geographical regions such as Africa, America (includes plant species occurring in Central or Tropical North and South America), North America (NAM), South America (SAM), Asia (excluding the Indian sub-continent, i.e., countries such as Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka), Australia, Europe, and Oceania. This resulted in the generation of a complete and updated list of the alien plant species that are reported in the state of Uttarakhand, located in the western Himalaya (Table 1).

RESULTS

A total of 728 alien plant species belonging to 450 genera under 108 families were noted in Uttarakhand (Table 1), representing 15% of total floral species. The most diverse families contributing to alien flora are Fabaceae (89 species), Asteraceae (63 species), Poaceae (50 species), Solanaceae (31 species), Malvaceae (29 species), Amaranthaceae (28 species), Myrtaceae (25 species), Euphorbiaceae (24 species), Brassicaceae (22 species), Cupressaceae (21 species), Rosaceae (19 Species), Convolvulaceae (16 species), Lamiaceae (15 species) Apocynaceae (14 species), Bignoniaceae (13 species), Pinaceae, & Rubiaceae (11 species each), Arecaceae & Cyperaceae (10 species each), which accounts 68% of the total alien flora of the Uttarakhand (Table 2). Seventeen genera account for majority of alien plant species, viz., *Eucalyptus* (15 species), *Ipomoea* and *Euphorbia* (12 species each), *Pinus* (11 species), *Acacia, Hibiscus, Solanum*, & *Juniperus* (08 species each), *Amaranthus* & *Senna* (07 species each), *Brassica* & *Indigofera* (06 species each), *Alternanthera*, *Cupressus*, *Bauhinia*, *Rosa*, *Trifolium*, & *Prunus* (05 species each). Herbs (338 species) account for 46% of alien taxa of Uttarakhand, followed by trees (197 species; 27%), shrubs (91 species; 12%), grasses (50 species; 7%), climbers (42 species; 6%), and sedge (10 species; 1%) (Figure 1). The highest number of species (62) among herbs belonged to Asteraceae, trees in Fabaceae (41), shrubs in Solanaceae (11 species), grasses in Poaceae

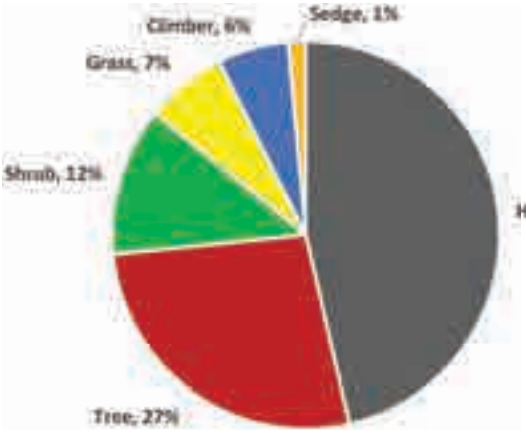

Figure 1. Life form categorization of alien plant species.

(50), climbers in Convolvulaceae (9), and sedges in Cyperaceae (10 species) (Table 2).

With respect to nativity, America (plant species occurring in central or tropical, North, and South America) contributed the maximum (146 species), i.e., 20% of alien introductions in Uttarakhand, followed by Europe 104 species (14%), South America 91 species (13%), Asia (excluding the Indian sub-continent) 80 species (11%), North America 79 species (11%), and Africa 76 species (10%) (Table 3). The remaining 20% of the alien plant species were contributed by other continents or geographical regions. Noteably, majority of the herbs were introduced from America (Table 3). Interestingly, a few workers have provided an account on the status of naturalized and invasive alien plants in different regions of IHR, the details are provided in Table 4.

DISCUSSION

Uttarakhand harbours a rich diversity of natural resources. Several workers (Kala & Rawat 2004; Uniyal et al. 2007; Mathur & Joshi 2013; Rai et al. 2017) have explored the rich floral diversity of this Himalayan state. Several studies have estimated aliens in different regions of India, for instance, Nayar (1977) reported that 18% of the Indian flora comprise of alien plant species. Khuroo et al. (2007) reported a total of 571 alien plant species (29%) from the Kashmir Himalaya. Jaryan et al. (2013) estimated that almost 14% of the flora of Himachal Pradesh comprises of alien plant species. Inderjit et al. (2018) documented naturalized alien plant species in the Indian states and found 181 alien species that have naturalized in Uttarakhand. According to Dutta (2018), climate change accelerates alien species invasion whereby a number of non-invasive species may become invasive. Negi et al. (2019) reported that increased level of demographic transitions and climate change will further exaggerate the situation in IHR, thus enabling suitable conditions for the spread of invasive alien species.

Of 108 plant families reported, 20 families comprise more than 68% of the alien flora of the state. Sekar et al. (2012) also reported Fabaceae as the largest family in terms of IAs in Uttarakhand. Reddy (2008) reported that Asteraceae also contributed a major portion of exotics in India. Khuroo et al. (2007) and Jaryan et al. (2013) also reported the dominance of Asteraceae and Poaceae from the Himachal Pradesh and Kashmir Himalaya, respectively. Subsequently, Baard & Kraaij (2014) in South Africa and Shen et al. (2017) in Yunnan province of China reported dominance of Asteraceae followed by Fabaceae and Poaceae that accounts for majority of the alien flora. Categorization of the growth form showed the preponderance of herbs (46%) which may be associated with its short generation time, greater viability and the ability to tolerate wide environmental fluctuations. Interestingly, this is in agreement with the other studies (Khuroo et al. 2007; Reddy 2008; Sekar et al. 2012; Adhikhari et al. 2015; Rastogi et al. 2015; Inderjit et al. 2018) carried out in India as well as in the world (Baard & Kraaij 2014; Shen et al. 2017; Lee et al. 2018; Vinogradova et al. 2018).

A large number of aliens in Uttarakhand are reported from America, accounting for the majority of herbs. A majority of alien introductions in China (Weber et al. 2008) and India (35%) (Khuroo et al. 2012), specifically in Himachal Pradesh (23%) (Jaryan et al. 2013) are from South America, while Europe contributes the highest percentage (38%) of alien species in Kashmir (Khuroo et al. 2007). The prevalence of genera such as *Eucalyptus*, *Ipomoea, Euphorbia*, *Pinus*, *Acacia, Juniperus*, *Amaranthus, Hibiscus*, and *Solanum* is observed in Uttarakhand, which is in accordance with the studies carried out in India (Khuroo et al. 2012), Himachal Pradesh (Jaryan et al. 2013). A report of comparatively higher number of alien plant species (728) in Uttarakhand could be attributed due to higher species richness (ca. 5,000) and lack of persuaded literature exclusively on alien plant species in other Himalayan states.

Table 1. List of alien plant species reported in Uttarakhand, western Himalaya.

	Name of the species	Family	Nativity	Life form	Reference
1	*Abelmoschus esculentus* (L.) Moench	Malvaceae	AS/AF	Herb	Khuroo et al. (2007); Negi & Hajra (2007)
2	*Acacia auriculiformis* A. Cunn. ex Benth.	Fabaceae	AU	Tree	Negi & Hajra (2007)
3	*Acacia confusa* Merr.	Fabaceae	AS (Philippines)	Tree	Negi & Hajra (2007)
4	*Acacia dealbata* Link	Fabaceae	AU	Tree	Sekar et al. (2012)
5	*Acacia decurrens* Willd.	Fabaceae	AU	Tree	Jaryan et al. (2013)
6	*Acacia farnesiana* (L.) Willd.	Fabaceae	SAM	Tree	Sekar et al. (2012)
7	*Acacia karroo* Hayne	Fabaceae	AF (South Africa)	Tree	Negi & Hajra (2007)
8	*Acacia robusta* Burch.	Fabaceae	AF (South Africa)	Tree	Negi & Hajra (2007)
9	*Acacia willdenowiana* Wendl.	Fabaceae	AF (South Africa)	Tree	Negi & Hajra (2007)
10	*Acalypha australis* L.	Euphorbiaceae	AS (China, Japan)	Herb	Negi & Hajra (2007)
11	*Acanthospermum hispidum* DC.	Asteraceae	SAM (Brazil)	Herb	Negi & Hajra (2007); Sekar et al. (2012)
12	*Acer negundo* L.	Sapindaceae	NAM	Tree	Jaryan et al. (2013)
13	*Achillea millefolium* L.	Asteraceae	EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
14	*Acmella radicans* (Jacq.) R.K. Jansen	Asteraceae	SAM	Herb	Rana & Rastogi (2017)
15	*Aconitum laeve* Royle	Ranunculaceae	EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
16	*Adonis aestivalis* L.	Ranunculaceae	EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
17	*Aerva sanguinolenta* (L.) Blume	Amaranthaceae	AF	Herb	Singh & Prakash (2002)
18	*Aeschynomene brasiliana* (Poir.) DC.	Fabaceae	NAM (Mexico)	Shrub	Negi & Hajra (2007)
19	*Afrocarpus gracilior* (Pilg.) C.N. Page	Podocarpaceae	AF (Kenya)	Tree	Tiwari et al. (2010)
20	*Afzelia martabanica* (Prain) J. Leonard	Fabaceae	AS (Burma)	Tree	Negi & Hajra (2007)
21	*Agathis robusta* (C. Moore ex F. Muell.) F.M. Bailey	Araucariaceae	AU/SAM (Brazil)	Tree	Negi & Hajra (2007); Tiwari et al. (2010)
22	*Agave americana* L.	Asparagaceae	America	Shrub	Negi & Hajra (2007)
23	*Ageratina adenophora* (Spreng.) R.M. King &H. Rob.	Asteraceae	SAM/NAM (Mexico)	Herb	Negi & Hajra (2007); Sekar et al. (2012); Jaryan et al. (2013)
24	*Ageratina riparia* (Regel) R.M. King & H. Rob.	Asteraceae	NAM (Mexico, West Indies)	Herb	Negi & Hajra (2007)
25	*Ageratum conyzoides* (L.) L.	Asteraceae	Trop. America/SAM	Herb	Khuroo et al. (2007); Negi & Hajra (2007); Sekar et al. (2012)
26	*Ageratum houstonianum* Mill.	Asteraceae	Trop. America	Herb	Sekar et al. (2012)
27	*Agrostis canina* L.	Poaceae	EU	Grass	Khuroo et al. (2007); Jaryan et al. (2013)
28	*Agrostis stolonifera* L.	Poaceae	NAM	Grass	Khuroo et al. (2007); Jaryan et al. (2013)
29	*Ailanthus altissima* (Mill.) Swingle	Simaroubaceae	AS (China)	Tree	Khuroo et al. (2007) Negi & Hajra (2007); Jaryan et al. (2013)
30	*Alcea rosea* L.	Malvaceae	AS	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
31	*Alisma lanceolatum* With.	Alismataceae	AF/NAM	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
32	*Allamanda cathartica* L.	Apocynaceae	Trop. America/SAM (Brazil)	Climber	Negi & Hajra (2007)
33	*Alliaria petiolata* (M. Bieb.) Cavara & Grande	Brassicaceae	EU	Herb	Sankaran & Suresh (2013)
34	*Allium ampeloprasum* L.	Amaryllidaceae	AS/EU	Herb	Khuroo et al. (2007)
35	*Allium cepa* L.	Amaryllidaceae	AS	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
36	*Allium sativum* L.	Amaryllidaceae	EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
37	*Allocasuarina littoralis* (Salisb.) L.A.S. Johnson	Casuarinaceae	AU	Tree	Negi & Hajra (2007)
38	*Aloe vera* (L.) Burm.f.	Xanthorrhoeaceae	Mediteranean/AF/EU	Herb	Khuroo et al. (2007)
39	*Alopecurus aequalis* Sobol.	Poaceae	NAM	Grass	Khuroo et al. (2007); Jaryan et al. (2013)
40	*Alopecurus arundinaceus* Poir.	Poaceae	EU	Grass	Khuroo et al. (2007); Jaryan et al. (2013)
41	*Alternanthera ficoidea* (L.) Sm.	Amaranthaceae	SAM (Brazil)	Herb	Negi & Hajra (2007)
42	*Alternanthera paronychioides* A. St.-Hil.	Amaranthaceae	Trop. America	Herb	Sekar et al. (2012)
43	*Alternanthera philoxeroides* (Mart.) Griseb.	Amaranthaceae	Trop. America	Herb	Negi & Hajra (2007); Sekar et al. (2012)
44	*Alternanthera pungens* Kunth	Amaranthaceae	Trop. America	Herb	Negi & Hajra (2007); Sekar et al. (2012)

	Name of the species	Family	Nativity	Life form	Reference
45	*Alternanthera sessilis* (L.) R.Br. ex DC.	Amaranthaceae	SAM	Herb	Negi & Hajra (2007); Sekar et al. (2012)
46	*Amaranthus blitum* subsp. *oleraceus* (L.) Costea	Amaranthaceae	AS/AF/SAM	Herb	Jaryan et al. (2013)
47	*Amaranthus caudatus* L.	Amaranthaceae	SAM	Herb	Khuroo et al. (2007); Negi & Hajra (2007); Jaryan et al. (2013)
48	*Amaranthus cruentus* L.	Amaranthaceae	NAM/SAM	Herb	Khuroo et al. (2007); Negi & Hajra (2007); Jaryan et al. (2013)
49	*Amaranthus graecizans* L.	Amaranthaceae	EU	Herb	Khuroo et al. (2007)
50	*Amaranthus hybridus* L.	Amaranthaceae	NAM/SAM	Herb	Khuroo et al. (2007)
51	*Amaranthus spinosus* L.	Amaranthaceae	Trop. America/SAM	Herb	Khuroo et al. (2007); Sekar et al. (2012)
52	*Amaranthus viridis* L.	Amaranthaceae	SAM	Herb	Singh & Prakash (2002)
53	*Anagallis arvensis* L.	Primulaceae	EU	Herb	Khuroo et al. (2007); Sekar et al. (2012)
54	*Anethum graveolens* L.	Apiaceae	AS/EU	Herb	Khuroo et al. (2007); Negi & Hajra (2007); Jaryan et al. (2013)
55	*Annona reticulata* L.	Annonaceae	Trop. America	Tree	Negi & Hajra (2007)
56	*Annona squamosa* L.	Annonaceae	EU/SAM	Tree	Jaryan et al. (2013)
57	*Anthemis cotula* L.	Asteraceae	EU/AS	Herb	Khuroo et al. (2007); Negi & Hajra (2007); Jaryan et al. (2013)
58	*Antigonon leptopus* Hook. & Arn.	Polygonaceae	Trop. America	Climber	Negi & Hajra (2007); Sekar et al. (2012)
59	*Antirrhinum majus* L.	Plantaginaceae	EU/AS (Syria)/America	Herb	Khuroo et al. (2007) ;Negi & Hajra (2007)
60	*Apium graveolens* L.	Apiaceae	EU	Herb	Negi & Hajra (2007); Jaryan et al. (2013)
61	*Arabidopsis thaliana* (L.) Heynh.	Brassicaceae	AF/EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
62	*Arachis hypogaea* L.	Fabaceae	SAM	Herb	Khuroo et al. (2007)
63	*Araucaria angustifolia* (Bertol.) Kuntze	Araucariaceae	SAM (Brazil)	Tree	Negi & Hajra (2007); Tiwari et al. (2010)
64	*Araucaria bidwillii* Hook.	Araucariaceae	AU	Tree	Negi & Hajra (2007); Tiwari et al. (2010)
65	*Araucaria columnaris* (G. Forst.) Hook.	Araucariaceae	Oceania (New Caledonia)	Tree	Negi & Hajra (2007); Tiwari et al. (2010)
66	*Araucaria cunninghamii* Mudie	Araucariaceae	AU	Tree	Negi & Hajra (2007); Tiwari et al. (2010)
67	*Arctium lappa* L.	Asteraceae	EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
68	*Argemone mexicana* L.	Papaveraceae	SAM/NAM (West Indies)	Herb	Negi & Hajra (2007); Sekar et al. (2012)
69	*Argemone ochroleuca* Sweet	Papaveraceae	SAM/NAM (Mexico)	Herb	Negi & Hajra (2007); Sekar et al. (2012)
70	*Aristolochia littoralis* Parodi	Aristolochiaceae	SAM	Herb	Negi & Hajra (2007)
71	*Artemisia absinthium* L.	Asteraceae	EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
72	*Artemisia dracunculus* L.	Asteraceae	EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
73	*Artemisia gmelinii* Weber ex Stechm.	Asteraceae	EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
74	*Arthraxon lancifolius* (Trin.) Hochst.	Poaceae	AF	Grass	Khuroo et al. (2007); Jaryan et al. (2013)
75	*Arundo donax* L.	Poaceae	Eurasia/AF/EU	Grass	Khuroo et al. (2007); Jaryan et al. (2013); Sankaran & Suresh (2013)
76	*Asclepias curassavica* L.	Apocynaceae	Trop. America/SAM	Herb	Negi & Hajra (2007); Sekar et al. (2012); Jaryan et al. (2013)
77	*Asphodelus tenuifolius* Cav.	Xanthorrhoeaceae	SAM	Herb	Sekar et al. (2012); Jaryan et al. (2013)
78	*Atriplex hortensis* L.	Amaranthaceae	EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
79	*Avena barbata* Pott ex Link	Poaceae	EU	Grass	Khuroo et al. (2007)
80	*Avena fatua* L.	Poaceae	EU	Grass	Khuroo et al. (2007); Jaryan et al. (2013)
81	*Avena sativa* L.	Poaceae	AS/EU	Grass	Jaryan et al. (2013)
82	*Bambusa vulgaris* Schrad.	Poaceae	NA	Grass	Negi & Hajra (2007)
83	*Bassia scoparia* (L.) A.J. Scoot	Amaranthaceae	EU/AS	Herb	Khuroo et al. (2007)
84	*Bauhinia carronii* F.Muell.	Fabaceae	AU	Tree	Negi & Hajra (2007)
85	*Bauhinia corymbosa* Roxb.	Fabaceae	AS (China)	Climber	Negi & Hajra (2007)
86	*Bauhinia galpinii* N.E.Br.	Fabaceae	AF (South Africa)	Shrub	Negi & Hajra (2007)
87	*Bauhinia hookeri* F. Muell.	Fabaceae	AU	Tree	Negi & Hajra (2007)
88	*Bauhinia picta* (Kunth) DC.	Fabaceae	SAM (Colombia)	Tree	Negi & Hajra (2007)
89	*Beaucarnea stricta* Lem.	Asparagaceae	NAM (Mexico)	Tree	Negi & Hajra (2007)

	Name of the species	Family	Nativity	Life form	Reference
90	*Bellis perennis* L.	Asteraceae	EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
91	*Beta vulgaris* L.	Amaranthaceae	EU/SAM	Herb	Jaryan et al. (2013)
92	*Bidens biternata* (Lour.) Merr. & Sherff	Asteraceae	NAM	Herb	Khuroo et al. (2007)
93	*Bidens cernua* L.	Asteraceae	EU/NAM	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
94	*Bidens pilosa* L.	Asteraceae	Trop. America/SAM	Herb	Sekar et al. (2012); Jaryan et al. (2013)
95	*Bidens tripartita* L.	Asteraceae	AF/EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
96	*Bixa orellana* L.	Bixaceae	SAM (Brazil)	Tree	Negi & Hajra (2007)
97	*Blainvillea acmella* (L.) Philipson	Asteraceae	Trop. America/SAM	Herb	Sekar et al. (2012); Jaryan et al. (2013)
98	*Blumea eriantha* DC.	Asteraceae	Trop. America	Herb	Sekar et al. (2012)
99	*Blumea lacera* (Burm. f.) DC.	Asteraceae	Trop. America/SAM	Herb	Sekar et al. (2012); Jaryan et al. (2013)
100	*Blumea obliqua* (L.) Druce	Asteraceae	Trop. America/SAM	Herb	Sekar et al. (2012); Jaryan et al. (2013)
101	*Boerhavia erecta* L.	Nyctaginaceae	Trop. America	Herb	Negi & Hajra (2007)
102	*Bolusanthus speciosus* (Bolus) Harms	Fabaceae	AF (South Africa)	Tree	Negi & Hajra (2007)
103	*Borassus flabellifer* L.	Arecaceae	AF	Tree	Sekar et al. (2012)
104	*Bothriochloa ischaemum* (L.) Keng	Poaceae	AF	Grass	Khuroo et al. (2007); Jaryan et al. (2013)
105	*Bougainvillea glabra* Choisy	Nyctaginaceae	SAM (Brazil)	Climber	Khuroo et al. (2007); Negi & Hajra (2007)
106	*Bougainvillea spectabilis* Willd.	Nyctaginaceae	SAM (Brazil)	Climber	Khuroo et al. (2007); Negi & Hajra (2007)
107	*Brachychiton acerifolius* (A. Cunn. ex G. Don) F. Muell.	Malvaceae	Oceania	Tree	Negi & Hajra (2007)
108	*Brachychiton rupestris* (T. Mitch. ex Lindl.) K. Schum.	Malvaceae	AU	Tree	Negi & Hajra (2007)
109	*Brassica cretica* Lam.	Brassicaceae	EU	Herb	Khuroo et al. (2007)
110	*Brassica juncea* (L.) Czern.	Brassicaceae	AS	Herb	Negi & Hajra (2007)
111	*Brassica napus* L.	Brassicaceae	EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
112	*Brassica nigra* (L.) K. Koch	Brassicaceae	EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
113	*Brassica oleracea* L.	Brassicaceae	EU	Herb	Khuroo et al. (2007); Negi & Hajra (2007); Jaryan et al. (2013)
114	*Brassica rapa* L.	Brassicaceae	EU/Mediterranean region	Herb	Khuroo et al. (2007); Negi & Hajra (2007)
115	*Breynia vitis- idaea* (Burm.f.) C.E.C. Fisch.	Phyllanthaceae	NAM (West Indies)	Shrub	Negi & Hajra (2007)
116	*Briza media* L.	Poaceae	EU	Grass	Khuroo et al. (2007); Jaryan et al. (2013)
117	*Bromus catharticus* Vahl	Poaceae	SAM	Grass	Khuroo et al. (2007); Sekar et al. (2012); Jaryan et al. (2013)
118	*Bromus inermis* Leyss.	Poaceae	EU	Grass	Khuroo et al. (2007); Jaryan et al. (2013); Sankaran & Suresh (2013)
119	*Bromus japonicus* Thunb.	Poaceae	EU	Grass	Khuroo et al. (2007); Jaryan et al. (2013)
120	*Bromus tectorum* L.	Poaceae	Mediterranean region	Grass	Sankaran & Suresh (2013)
121	*Brugmansia suaveolens* (Humb. &Bonpl. ex Willd.) Bercht. & J. Presl	Solanaceae	SAM (Brazil)	Shrub	Negi & Hajra (2007); Jaryan et al. (2013);
122	*Brunfelsia americana* L.	Solanaceae	NAM (West Indies)	Shrub	Negi & Hajra (2007)
123	*Brunfelsia densifolia* Krug & Urb.	Solanaceae	Trop. America	Tree	Negi & Hajra (2007)
124	*Brunfelsia latifolia* (Pohl) Benth.	Solanaceae	SAM (Brazil)	Shrub	Negi & Hajra (2007)
125	*Brunfelsia pauciflora* (Cham. & Schltdl.) Benth.	Solanaceae	Trop. America	Shrub	Negi & Hajra (2007)
126	*Buddleja davidii* Franch.	Scrophulariaceae	AS (China)	Shrub	Khuroo et al. (2007); Jaryan et al. (2013); Sankaran & Suresh (2013)
127	*Buddleja madagascariensis* Lam.	Scrophulariaceae	AS	Shrub	Jaryan et al. (2013)
128	*Buxus sempervirens* L.	Buxaceae	AS/AF/EU	Shrub	Khuroo et al. (2007)
129	*Byrsonima crassifolia* (L.) Kunth	Malpighiaceae	NAM (Mexico)	Tree	Negi & Hajra (2007)
130	*Caesalpinia ferrea* C.Mart.	Fabaceae	SAM (Brazil)	Tree	Negi & Hajra (2007)
131	*Caesalpinia pulcherrima* (L.) Sw.	Fabaceae	SAM (Brazil)	Shrub	Negi & Hajra (2007); Jaryan et al. (2013)
132	*Calendula officinalis* L.	Asteraceae	EU	Herb	Khuroo et al. (2007)
133	*Calliandra brevipes* Benth.	Fabaceae	SAM (Brazil)	Shrub	Negi & Hajra (2007)
134	*Calliandra haematocephala* Hassk.	Mimosaceae	NAM (Mexico)	Shrub	Negi & Hajra (2007)
135	*Calliandra houstoniana* (Mill.) Standl.	Fabaceae	NAM (Mexico)	Tree	Negi & Hajra (2007)

	Name of the species	Family	Nativity	Life form	Reference
136	*Callistemon citrinus* (Curtis) Skeels	Myrtaceae	AU	Tree	Negi & Hajra (2007)
137	*Callistemon viminalis* (Sol. ex Gaertn.) G. Don ex Loudon	Myrtaceae	AU	Tree	Negi & Hajra (2007); Jaryan et al. (2013);
138	*Callitris columellaris* F. Muell.	Cupressaceae	AU	Tree	Negi & Hajra (2007); Tiwari et al. (2010)
139	*Calotropis gigantea* (L.) Dryand.	Apocynaceae	AF	Shrub	Sekar et al. (2012); Jaryan et al. (2013)
140	*Calotropis procera* (Aiton) Dryand.	Apocynaceae	AF	Shrub	Sekar et al. (2012); Jaryan et al. (2013)
141	*Camellia japonica* L.	Theaceae	AS (Japan)	Shrub	Negi & Hajra (2007)
142	*Campsis grandiflora* (Thunb.) K. Schum.	Bignoniaceae	AS	Climber	Khuroo et al. (2007)
143	*Campsis radicans* (L.) Seem.	Bignoniaceae	NAM	Climber	Khuroo et al. (2007); Negi & Hajra (2007)
144	*Canna indica* L.	Cannaceae	Trop. America	Herb	Sankaran & Suresh (2013)
145	*Capsella bursa-pastoris* (L.) Medik.	Brassicaceae	EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
146	*Capsicum annuum* L.	Solanaceae	EU/NAM/SAM	Herb	Jaryan et al. (2013)
147	*Cardamine flexuosa* With.	Brassicaceae	EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
148	*Cardamine hirsuta* L.	Brassicaceae	Trop. America/EU	Herb	Khuroo et al. (2007); Sekar et al. (2012); Jaryan et al. (2013)
149	*Carduus edelbergii* Rech.f.	Asteraceae	EU	Herb	Khuroo et al. (2007)
150	*Carduus nutans* L.	Asteraceae	EU	Herb	Sankaran & Suresh (2013)
151	*Carica papaya* L.	Caricaceae	SAM/Trop. America	Tree	Negi & Hajra (2007); Jaryan et al. (2013)
152	*Cascabela thevetia* (L.) Lippold	Apocynaceae	SAM	Tree	Negi & Hajra (2007); Jaryan et al. (2013)
153	*Casimiroa edulis* La Llave	Rutaceae	NAM (Mexico)	Tree	Negi & Hajra (2007)
154	*Castanea sativa* Mill.	Fagaceae	AF/EU	Tree	Khuroo et al. (2007); Jaryan et al. (2013)
155	*Castanospermum australe* A.Cunn. & C.Fraser	Fabaceae	AU	Tree	Negi & Hajra (2007)
156	*Casuarina cunninghamiana* Miq.	Casuarinaceae	AU	Tree	Negi & Hajra (2007)
157	*Catharanthus pusillus* (Murray) G. Don	Apocynaceae	SAM	Herb	Sekar et al. (2012); Jaryan et al. (2013)
158	*Catharanthus roseus* (L.) G. Don	Apocynaceae	AF (Madagascar)/ NAM (West Indies)	Herb	Singh & Prakash (2002); Negi & Hajra (2007)
159	*Ceiba speciosa* (A.St.-Hil.) Ravenna	Malvaceae	NAM/SAM (Brazil)	Tree	Negi & Hajra (2007)
160	*Celosia argentea* L.	Amaranthaceae	SAM	Herb	Khuroo et al. (2007); Sekar et al. (2012); Jaryan et al. (2013)
161	*Celtis sinensis* Pers.	Cannabaceae	AS (China)	Tree	Negi & Hajra (2007)
162	*Cephalotaxus harringtonii* (Knight ex J. Forbes) K. Koch	Taxaceae	AS (Japan)	Tree	Negi & Hajra (2007); Tiwari et al. (2010)
163	*Cerastium glomeratum* Thuill.	Caryophyllaceae	EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013);
164	*Ceratophyllum demersum* L.	Ceratophyllaceae	NAM	Herb	Khuroo et al. (2007); Sekar et al. (2012); Jaryan et al. (2013)
165	*Cestrum nocturnum* L.	Solanaceae	NAM (West Indies)	Shrub	Negi & Hajra (2007); Jaryan et al. (2013)
166	*Cestrum parqui* (Lam.) L'Hér.	Solanaceae	Central and SAM	Shrub	Sankaran & Suresh (2013)
167	*Chamaecrista absus* (L.) H.S. Irwin & Barneby	Fabaceae	SAM	Herb	Sekar et al. (2012); Jaryan et al. (2013)
168	*Chamaecrista pumila* (Lam.) K. Larsen	Fabaceae	SAM	Herb	Sekar et al. (2012); Jaryan et al. (2013)
169	*Chamaerops humilis* L.	Arecaceae	EU	Shrub	Negi & Hajra (2007)
170	*Chenopodium album* L.	Amaranthaceae	EU	Herb	Khuroo et al. (2007); Sekar et al. (2012); Jaryan et al. (2013)
171	*Chenopodium hybridum* L.	Amaranthaceae	AS/EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
172	*Chenopodium murale* L.	Amaranthaceae	Trop. America/AF/EU	Herb	Khuroo et al. (2007); Sekar et al. (2012); Jaryan et al. (2013)
173	*Chenopodium opulifolium* Schrad. ex W.D.J. Koch & Ziz	Amaranthaceae	EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
174	*Chloris barbata* Sw.	Poaceae	Trop. America	Grass	Sekar et al. (2012)
175	*Chloris gayana* Kunth.	Poaceae	AF	Grass	Khuroo et al. (2007)
176	*Chromolaena odorata* (L.) R.M. King & H. Rob.	Asteraceae	Trop. America/SAM	Herb	Negi & Hajra (2007); Srivastava et al. (2014)
177	*Chrysophyllum oliviforme* L.	Sapotaceae	Trop. America	Tree	Negi & Hajra (2007)
178	*Cicer arietinum* L.	Fabaceae	AS/EU	Herb	Jaryan et al. (2013)
179	*Cinnamomum camphora* (L.) J. Presl	Lauraceae	AS (China)	Tree	Negi & Hajra (2007); Jaryan et al. (2013)

	Name of the species	Family	Nativity	Life form	Reference
180	*Cissampelos pareira* L.	Menispermaceae	SAM	Climber	Jaryan et al. (2013)
181	*Citrullus lanatus* (Thunb.) Matsum. & Nakai	Cucurbitaceae	SAM	Climber	Jaryan et al. (2013)
182	*Citrus reticulata* Blanco	Rutaceae	AS	Tree	Khuroo et al. (2007)
183	*Cleome gynandra* L.	Cleomaceae	Trop. America	Herb	Sekar et al. (2012)
184	*Cleome viscosa* L.	Cleomaceae	Trop. America	Herb	Sekar et al. (2012)
185	*Clerodendrum splendens* G.Don	Lamiaceae	AF (Angola)	Climber	Negi & Hajra (2007); Srivastava et al. (2014)
186	*Clitoria ternatea* L.	Fabaceae	EU/SAM	Herb	Jaryan et al. (2013)
187	*Consolida ajacis* (L.) Schur	Ranunculaceae	EU	Herb	Negi & Hajra (2007); Jaryan et al. (2013)
188	*Convolvulus arvensis* L.	Convolvulaceae	EU	Herb	Khuroo et al. (2007); Sekar et al. (2012); Jaryan et al. (2013)
189	*Corchorus aestuans* L.	Malvaceae	Trop. America/SAM	Herb	Sekar et al. (2012); Jaryan et al. (2013)
190	*Corchorus olitorius* L.	Malvaceae	AF	Herb	Sekar et al. (2012)
191	*Corchorus tridens* L.	Malvaceae	AF	Herb	Sekar et al. (2012); Jaryan et al. (2013)
192	*Corchorus trilocularis* L.	Malvaceae	AF	Herb	Sekar et al. (2012); Jaryan et al. (2013)
193	*Cordia africana* Lam.	Boraginaceae	AF (Sudan)	Tree	Negi & Hajra (2007)
194	*Cordia alba* (Jacq.) Roem. & Schult.	Boraginaceae	NAM (Mexico)	Tree	Negi & Hajra (2007)
195	*Coreopsis tinctoria* Nutt.	Asteraceae	NAM	Herb	Negi & Hajra (2007)
196	*Corymbia citriodora* (Hook.) K.D. Hill & L.A.S. Johnson	Myrtaceae	AU	Tree	Negi & Hajra (2007)
197	*Corymbia maculata* (Hook.) K.D. Hill & L.A.S. Johnson	Myrtaceae	AU	Tree	Negi & Hajra (2007)
198	*Corymbia torelliana* (F.Muell.) K.D. Hill & L.A.S. Johnson	Myrtaceae	AU	Tree	Negi & Hajra (2007)
199	*Cosmos bipinnatus* Cav.	Asteraceae	SAM	Herb	Jaryan et al. (2013)
200	*Crassocephalum crepidioides* (Benth.) S. Moore	Asteraceae	Trop. America	Herb	Sekar et al. (2012)
201	*Crotalaria pallida* Aiton	Fabaceae	Trop. America	Herb	Sekar et al. (2012); Srivastava et al. (2014)
202	*Crotalaria retusa* L.	Fabaceae	Trop. America	Herb	Sekar et al. (2012)
203	*Croton bonplandianus* Baill.	Euphorbiaceae	SAM	Herb	Negi & Hajra (2007); Sekar et al. (2012); Jaryan et al. (2013)
204	*Cryptomeria japonica* (Thunb. ex L.f.) D.Don	Cupressaceae	AS (Japan, China)	Tree	Khuroo et al. (2007); Negi & Hajra (2007); Tiwari et al. (2010); Jaryan et al. (2013)
205	*Cucurbita maxima* Duchesne	Cucurbitaceae	SAM	Climber	Khuroo et al. (2007); Jaryan et al. (2013)
206	*Cucurbita pepo* L.	Cucurbitaceae	AF/SAM/NAM	Climber	Khuroo et al. (2007); Jaryan et al. (2013)
207	*Cunninghamia lanceolata* (Lamb.) Hook.	Cupressaceae	AS (China)	Tree	Negi & Hajra (2007); Tiwari et al. (2010); Jaryan et al. (2013)
208	*Cupressus arizonica* Greene	Cupressaceae	NAM (Mexico)	Tree	Negi & Hajra (2007); Tiwari et al. (2010)
209	*Cupressus funebris* Endl.	Cupressaceae	AS (China)	Tree	Negi & Hajra (2007); Tiwari et al. (2010)
210	*Cupressus goveniana* Gordon	Cupressaceae	NAM (California)	Tree	Negi & Hajra (2007); Tiwari et al. (2010)
211	*Cupressus lusitanica* Mill.	Cupressaceae	NAM (Mexico)	Tree	Negi & Hajra (2007); Tiwari et al. (2010); Jaryan et al. (2013)
212	*Cupressus sempervirens* L.	Cupressaceae	EU (Cyprus)	Tree	Khuroo et al. (2007); Negi & Hajra (2007); Tiwari et al. (2010)
213	*Cuscuta reflexa* Roxb.	Convolvulaceae	Mediterranean region	Herb	Sekar et al. (2012)
214	*Cyanus segetum* Hill	Asteraceae	Mediterranean region	Herb	Negi & Hajra (2007)
215	*Cycas revoluta* Thunb.	Cycadaceae	AS (South Japan)	Tree	Negi & Hajra (2007); Tiwari et al. (2010)
216	*Cyclanthera pedata* (L.) Schrad.	Cucurbitaceae	SAM	Herb	Negi & Hajra (2007)
217	*Cyclospermum leptophyllum* (Pers.) Sprague	Apiaceae	America/AU	Herb	Negi & Hajra (2007)
218	*Cynodon dactylon* (L.) Pers.	Poaceae	AF	Grass	Srivastava et al. (2014)
219	*Cyperus cyperoides* (L.) Kuntze	Cyperaceae	Trop. America	Sedge	Srivastava et al. (2014)
220	*Cyperus difformis* L.	Cyperaceae	Trop. America/AF/EU	Sedge	Khuroo et al. (2007); Sekar et al. (2012); Jaryan et al. (2013)
221	*Cyperus involucratus* Rottb.	Cyperaceae	AF	Sedge	Khuroo et al. (2007); Srivastava et al. (2014)
222	*Cyperus rotundus* L.	Cyperaceae	EU	Sedge	Khuroo et al. (2007); Jaryan et al. (2013)

	Name of the species	Family	Nativity	Life form	Reference
223	*Cytisus scoparius* (L.) Link	Fabaceae	EU	Herb	Sekar et al. (2012); Jaryan et al. (2013)
224	*Dalbergia melanoxylon* Guill. & Pers.	Fabaceae	AF (Sudan)	Tree	Negi & Hajra (2007)
225	*Datura innoxia* Mill.	Solanaceae	Trop. America/NAM/ SAM	Shrub	Khuroo et al. (2007); Sekar et al. (2012); Jaryan et al. (2013)
226	*Datura metel* L.	Solanaceae	Trop. America/SAM	Shrub	Negi & Hajra (2007); Sekar et al. (2012); Jaryan et al. (2013)
227	*Datura stramonium* L.	Solanaceae	Trop. America/NAM/ SAM	Shrub	Khuroo et al. (2007); Sekar et al. (2012); Jaryan et al. (2013)
228	*Daucus carota* L.	Apiaceae	AF/EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
229	*Deeringia amaranthoides* (Lam.) Merr.	Amaranthaceae	AU	Climber	Khuroo et al. (2007); Jaryan et al. (2013)
230	*Delonix regia* (Hook.) Raf.	Fabaceae	AF (Madagascar)	Tree	Negi & Hajra (2007)
231	*Descurainia sophia* (L.) Webb ex Prantl	Brassicaceae	AF	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
232	*Desmodium tortuosum* (Sw.) DC.	Fabaceae	America	Herb	Negi & Hajra (2007)
233	*Dichrostachys cinerea* (L.) Wight & Arn.	Fabaceae	AF (Congo)	Shrub	Negi & Hajra (2007)
234	*Dicliptera paniculata* (Forssk.) I.Darbysh.	Acanthaceae	AF/Trop. America	Herb	Sekar et al. (2012)
235	*Digitalis lanata* Ehrh.	Plantaginaceae	EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
236	*Digitalis purpurea* L.	Plantaginaceae	EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
237	*Digitaria longiflora* (Retz.) Pers.	Poaceae	AF	Grass	Khuroo et al. (2007); Jaryan et al. (2013)
238	*Digitaria sanguinalis* (L.) Scop.	Poaceae	EU	Grass	Khuroo et al. (2007); Jaryan et al. (2013)
239	*Dolichandra unguis-cati* (L.) L.G. Lohmann	Bignoniaceae	Trop. America	Climber	Sankaran & Suresh (2013)
240	*Dombeya burgessiae* Gerrard ex Harv.	Malvaceae	AF	Shrub	Negi & Hajra (2007)
241	*Duboisia myoporoides* R.Br.	Solanaceae	AU	Tree	Negi & Hajra (2007)
242	*Duranta erecta* L.	Verbenaceae	NAM (Mexico)	Shrub	Negi & Hajra (2007); Jaryan et al. (2013); Srivastava et al. (2014);
243	*Dysphania ambrosioides* (L.) Mosyakin & Clemants	Amaranthaceae	SAM	Herb	Khuroo et al. (2007); Negi & Hajra (2007); Sekar et al. (2012)
244	*Dysphania botrys* (L.) Mosyakin & Clemants	Amaranthaceae	AF/EU	Herb	Khuroo et al. (2007)
245	*Echinochloa colona* (L.) Link	Poaceae	SAM/EU	Grass	Khuroo et al. (2007); Sekar et al. (2012); Jaryan et al. (2013)
246	*Echitesum bellatus* Jacq.	Apocynaceae	NAM (Florida)	Climber	Negi & Hajra (2007)
247	*Eclipta prostrata* L.	Asteraceae	Trop. America/SAM	Herb	Jaryan et al. (2013); Rana & Rastogi (2017)
248	*Eichhornia crassipes* (Mart.) Solms	Pontederiaceae	Trop. America/SAM	Herb	Sekar et al. (2012); Jaryan et al. (2013)
249	*Eleocharis atropurpurea* (Retz.) J. Presl & C. Presl	Cyperaceae	SAM	Sedge	Khuroo et al. (2007); Jaryan et al. (2013)
250	*Emilia sonchifolia* (L.) DC. ex DC.	Asteraceae	Trop. America/SAM	Herb	Sekar et al. (2012); Jaryan et al. (2013)
251	*Enterolobium contortisiliquum* (Vell.) Morong	Fabaceae	SAM (Brazil)	Tree	Negi & Hajra (2007)
252	*Epilobium hirsutum* L.	Onagraceae	AF/EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
253	*Epilobium parviflorum* Schreb.	Onagraceae	AF/EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
254	*Epilobium tetragonum* L.	Onagraceae	AF/EU	Herb	Khuroo et al. (2007)
255	*Eragrostis pilosa* (L.) P.Beauv.	Poaceae	AF	Grass	Khuroo et al. (2007); Jaryan et al. (2013)
256	*Erigeron annuus* (L.) Pers.	Asteraceae	NAM	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
257	*Erigeron bonariensis* L.	Asteraceae	SAM	Herb	Khuroo et al. (2007)
258	*Erigeron canadensis* L.	Asteraceae	SAM/NAM	Herb	Khuroo et al. (2007); Sekar et al. (2012)
259	*Erigeron karvinskianus* DC.	Asteraceae	SAM/Central America	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
260	*Eriobotrya japonica* (Thunb.) Lindl.	Rosaceae	AS (Japan, China)	Tree	Khuroo et al. (2007); Jaryan et al. (2013)
261	*Erodium cicutarium* (L.) L'Hér.	Geraniaceae	AF/EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
262	*Eruca vesicaria* (L.) Cav.	Brassicaceae	EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
263	*Eryngium foetidum* L.	Apiaceae	SAM	Herb	Negi & Hajra (2007)
264	*Erysimum hieraciifolium* L.f.	Brassicaceae	EU	Herb	Kumar et al. (2013)
265	*Eschscholzia californica* Cham.	Papaveraceae	NAM	Herb	Khuroo et al. (2007)
266	*Eucalyptus alba* Reinw. ex Blume	Myrtaceae	AU	Tree	Negi & Hajra (2007)
267	*Eucalyptus camaldulensis* Dehnh.	Myrtaceae	AU	Tree	Khuroo et al. (2007); Jaryan et al. (2013)

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268	*Eucalyptus deglupta* Blume	Myrtaceae	AS (Indonesia)	Tree	Negi & Hajra (2007)
269	*Eucalyptus drepanophylla* F.Muell. ex Benth.	Myrtaceae	AU	Tree	Khuroo et al. (2007); Jaryan et al. (2013)
270	*Eucalyptus globulus* Labill.	Myrtaceae	AU	Tree	Jaryan et al. (2013)
271	*Eucalyptus grandis* W.Hill	Myrtaceae	AU	Tree	Negi & Hajra (2007)
272	*Eucalyptus microcorys* F.Muell.	Myrtaceae	AU	Tree	Negi & Hajra (2007)
273	*Eucalyptus paniculata* Sm.	Myrtaceae	AU	Tree	Negi & Hajra (2007)
274	*Eucalyptus propinqua* H.Deane & Maiden	Myrtaceae	AU	Tree	Negi & Hajra (2007)
275	*Eucalyptus punctata* A.Cunn. ex DC.	Myrtaceae	AU	Tree	Negi & Hajra (2007)
276	*Eucalyptus resinifera* Sm.	Myrtaceae	AU	Tree	Negi & Hajra (2007)
277	*Eucalyptus robusta* Sm.	Myrtaceae	AU	Tree	Negi & Hajra (2007)
278	*Eucalyptus saligna* Sm.	Myrtaceae	AU	Tree	Jaryan et al. (2013);
279	*Eucalyptus sideroxylon* A.Cunn. ex Woolls	Myrtaceae	AU	Tree	Negi & Hajra (2007)
280	*Eucalyptus tereticornis* Sm.	Myrtaceae	AU	Tree	Negi & Hajra (2007)
281	*Eugenia uniflora* L.	Myrtaceae	SAM (Brazil)	Tree	Negi & Hajra (2007)
282	*Euphorbia chamaesyce* L.	Euphorbiaceae	AF (Mauritius)	Herb	Sekar et al. (2012)
283	*Euphorbia cotinifolia* L.	Euphorbiaceae	NAM (Mexico)/SAM	Shrub	Negi & Hajra (2007)
284	*Euphorbia cyathophora* Murray	Euphorbiaceae	Trop.America	Herb	Rana & Rastogi (2017)
285	*Euphorbia heterophylla* L.	Euphorbiaceae	Trop. America/SAM/ NAM (Mexico)	Herb	Khuroo et al. (2007); Sekar et al. (2012); Jaryan et al. (2013)
286	*Euphorbia hirta* L.	Euphorbiaceae	Trop. America/SAM	Herb	Sekar et al. (2012); Jaryan et al. (2013)
287	*Euphorbia leucocephala* Lotsy	Euphorbiaceae	NAM (Mexico)	Shrub	Negi & Hajra (2007)
288	*Euphorbia milii* Des Moul.	Euphorbiaceae	AF (Madagascar)	Shrub	Negi & Hajra (2007)
289	*Euphorbia peplus* L.	Euphorbiaceae	EU	Herb	Sekar et al. (2012)
290	*Euphorbia prostrata* Aiton	Euphorbiaceae	Trop. America/SAM	Herb	Negi & Hajra (2007); Jaryan et al. (2013)
291	*Euphorbia pulcherrima* Willd. ex Klotzsch	Euphorbiaceae	NAM (Mexico)	Shrub	Khuroo et al. (2007); Jaryan et al. (2013)
292	*Euphorbia thymifolia* L.	Euphorbiaceae	SAM	Herb	Jaryan et al. (2013)
293	*Euphorbia tirucalli* L.	Euphorbiaceae	AF (Kenya)	Shrub	Negi & Hajra (2007)
294	*Evolvulus nummularius* (L.) L.	Convolvulaceae	Trop. America	Herb	Negi & Hajra (2007); Sekar et al. (2012)
295	*Fagopyrum esculentum* Moench	Polygonaceae	AS	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
296	*Ficus carica* L.	Moraceae	EU	Tree	Khuroo et al. (2007); Jaryan et al. (2013)
297	*Ficus pumila* L.	Moraceae	AS	Climber	Jaryan et al. (2013)
298	*Ficus religiosa* L.	Moraceae	EU	Tree	Khuroo et al. (2007); Jaryan et al. (2013)
299	*Flindersia australis* R.Br.	Rutaceae	AU	Tree	Negi & Hajra (2007)
300	*Foeniculum vulgare* Mill.	Apiaceae	EU	Herb	Khuroo et al. (2007); Negi & Hajra (2007)
301	*Fragaria nubicola* (Lindl. ex Hook.f.) Lacaita	Rosaceae	EU	Herb	Khuroo et al. (2007)
302	*Fragaria vesca* L.	Rosaceae	EU/NAM/SAM	Herb	Jaryan et al. (2013);
303	*Fraxinus uhdei* (Wenz.) Lingelsh.	Oleaceae	NAM (Mexico)	Tree	Negi & Hajra (2007)
304	*Freesia refracta* (Jacq.) Klatt	Iridaceae	AF	Herb	Khuroo et al. (2007)
305	*Fuirena ciliaris* (L.) Roxb.	Cyperaceae	Trop. America	Sedge	Sekar et al. (2012)
306	*Galinsoga parviflora* Cav.	Asteraceae	Trop. America/SAM	Herb	Khuroo et al. (2007); Sekar et al. (2012); Jaryan et al. (2013)
307	*Galinsoga quadriradiata* Ruiz & Pav.	Asteraceae	NAM (Mexico)	Herb	Sekar et al. (2012)
308	*Galium aparine* L.	Rubiaceae	AF/EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
309	*Galium asperifolium* Wall.	Rubiaceae	EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
310	*Galium elegans* Wall. ex Roxb.	Rubiaceae	AF/EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
311	*Galphimia gracilis* Bartl.	Malpighiaceae	NAM (Mexico)	Shrub	Negi & Hajra (2007)
312	*Gardenia volkensii* subsp. *spathulifolia* (Stapf & Hutch.) Verdc.	Rubiaceae	AF (Uganda)	Shrub	Negi & Hajra (2007)
313	*Geijera parviflora* Lindl.	Rutaceae	AU	Tree	Negi & Hajra (2007)
314	*Gigantochloa albociliata* (Munro) Kurz	Poaceae	central America	Grass	Negi & Hajra (2007)
315	*Gigantochloa atter* (Hassk.) Kurz	Poaceae	AS (Malaysia)	Grass	Negi & Hajra (2007)

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316	*Gigantochloa verticillata* (Willd.) Munro	Poaceae	AS (Malaysia)	Grass	Negi & Hajra (2007)
317	*Ginkgo biloba* L.	Ginkgoaceae	AS (China, Japan)	Tree	Khuroo et al. (2007); Tiwari et al. (2010); Jaryan et al. (2013)
318	*Glebionis coronaria* (L.) Cass. ex Spach	Asteraceae	AF/EU/Mediterranean region	Herb	Khuroo et al. (2007); Negi & Hajra (2007)
319	*Gleditsia macracantha* Desf.	Fabaceae	AS (China)	Tree	Negi & Hajra (2007)
320	*Gleditsia sinensis* Lam.	Fabaceae	AS (China)	Tree	Negi & Hajra (2007)
321	*Gleditsia triacanthos* L.	Fabaceae	USA	Tree	Negi & Hajra (2007)
322	*Glycine max* (L.) Merr.	Fabaceae	AS	Herb	Khuroo et al. (2007)
323	*Gnaphalium pensylvanicum* Willd.	Asteraceae	Trop. America	Herb	Negi & Hajra (2007); Sekar et al. (2012)
324	*Gnaphalium polycaulon* Pers.	Asteraceae	Trop. America/SAM	Herb	Sekar et al. (2012); Jaryan et al. (2013)
325	*Gomphocarpus physocarpus* E. Mey.	Apocynaceae	AF	Shrub	Negi & Hajra (2007)
326	*Gomphrena celosioides* Mart.	Amaranthaceae	SAM	Herb	Khuroo et al. (2007); Sekar et al. (2012); Jaryan et al. (2013);
327	*Gomphrena globosa* L.	Amaranthaceae	SAM/Trop. America	Herb	Khuroo et al. (2007); Negi & Hajra (2007)
328	*Gomphrena serrata* L.	Amaranthaceae	Trop. America	Herb	Sekar et al. (2012)
329	*Gossypium hirsutum* L.	Malvaceae	Central America	Herb	Negi & Hajra (2007)
330	*Grangea maderaspatana* (L.) Poir.	Asteraceae	SAM	Herb	Sekar et al. (2012); Jaryan et al. (2013)
331	*Grevillea robusta* A.Cunn. ex R.Br.	Proteaceae	AU	Tree	Negi & Hajra (2007)
332	*Guadua angustifolia* Kunth	Poaceae	USA	Grass	Negi & Hajra (2007)
333	*Haematoxylum campechianum* L.	Fabaceae	NAM (Mexico)	Tree	Negi & Hajra (2007)
334	*Hamelia patens* Jacq.	Rubiaceae	SAM (Brazil)	Shrub	Negi & Hajra (2007)
335	*Hedera helix* L.	Araliaceae	EU	Climber	Khuroo et al. (2007); Sankaran & Suresh (2013)
336	*Helianthus annuus* L.	Asteraceae	NAM	Herb	Khuroo et al. (2007); Negi & Hajra (2007)
337	*Helianthus debilis* subsp. *cucumerifolius* (Torr. & A.Gray) Heiser	Asteraceae	NAM	Herb	Negi & Hajra (2007)
338	*Helianthus tuberosus* L.	Asteraceae	NAM	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
339	*Helictotrichon pratense* (L.) Pilg.	Poaceae	EU	Grass	Khuroo et al. (2007)
340	*Hemerocallis fulva* (L.) L.	Xanthorrhoeaceae	EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
341	*Hibiscus arnottianus* A.Gray	Malvaceae	NAM (Hawaii)	Shrub	Negi & Hajra (2007)
342	*Hibiscus cannabinus* L.	Malvaceae	SAM/Trop. America	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
343	*Hibiscus mutabilis* L.	Malvaceae	AS (China)	Shrub	Negi & Hajra (2007)
344	*Hibiscus rosa-sinensis* L.	Malvaceae	AS (China)	Shrub	Khuroo et al. (2007); Negi & Hajra (2007)
345	*Hibiscus sabdariffa* L.	Malvaceae	SAM	Herb	Jaryan et al. (2013)
346	*Hibiscus schizopetalus* (Dyer) Hook.f.	Malvaceae	AF	Herb	Khuroo et al. (2007)
347	*Hibiscus syriacus* L.	Malvaceae	AS (Syria) (Uncertain)	Shrub	Khuroo et al. (2007); Jaryan et al. (2013)
348	*Hibiscus trionum* L.	Malvaceae	AF	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
349	*Holosteum umbellatum* L.	Caryophyllaceae	AF	Herb	Khuroo et al. (2007)
350	*Hordeum vulgare* L.	Poaceae	EU/NAM	Grass	Khuroo et al. (2007); Jaryan et al. (2013)
351	*Hydrangea macrophylla* (Thunb.) Ser.	Hydrangeaceae	AS (China, Japan)	Shrub	Negi & Hajra (2007)
352	*Hyoscyamus niger* L.	Solanaceae	AF/EU	Herb	Khuroo et al. (2007)
353	*Hypericum perforatum* L.	Hypericaceae	EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013); Sankaran & Suresh (2013);
354	*Hyptis suaveolens* (L.) Poit.	Lamiaceae	Trop. America	Herb	Negi & Hajra (2007); Sekar et al. (2012);
355	*Iberis amara* L.	Brassicaceae	EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
356	*Imperata cylindrica* (L.) Raeusch.	Poaceae	Trop. America/AS/EU	Grass	Khuroo et al. (2007); Sekar et al. (2012); Jaryan et al. (2013)
357	*Indigofera astragalina* DC.	Fabaceae	Trop. America/SAM	Herb	Sekar et al. (2012); Jaryan et al. (2013)
358	*Indigofera glandulosa* Wendl.	Fabaceae	Trop. America	Herb	Sekar et al. (2012)
359	*Indigofera hirsuta* L.	Fabaceae	AF	Herb	Srivastava et al. (2014)
360	*Indigofera linifolia* (L.f.) Retz.	Fabaceae	SAM	Herb	Sekar et al. (2012); Jaryan et al. (2013)
361	*Indigofera linnaei* Ali	Fabaceae	AF	Shrub	Sekar et al. (2012)
362	*Indigofera trita* L.f.	Fabaceae	AF	Shrub	Sekar et al. (2012)

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363	*Ipomoea arborescens* (Humb. & Bonpl. ex Willd.) G.Don	Convolvulaceae	USA	Tree	Negi & Hajra (2007)
364	*Ipomoea cairica* (L.) Sweet	Convolvulaceae	AF	Climber	Khuroo et al. (2007); Jaryan et al. (2013)
365	*Ipomoea carnea* Jacq.	Convolvulaceae	Trop. America/SAM	Shrub	Sekar et al. (2012); Jaryan et al. (2013)
366	*Ipomoea hederifolia* L.	Convolvulaceae	Trop. America/SAM	Climber	Khuroo et al. (2007); Sekar et al. (2012); Jaryan et al. (2013)
367	*Ipomoea indica* (Burm.) Merr.	Convolvulaceae	EU/SAM	Climber	Jaryan et al. (2013);
368	*Ipomoea muricata* (L.) Jacq.	Convolvulaceae	Trop. America	Herb	Sekar et al. (2012)
369	*Ipomoea nil* (L.) Roth	Convolvulaceae	NAM/SAM	Climber	Khuroo et al. (2007); Jaryan et al. (2013)
370	*Ipomoea obscura* (L.) Ker Gawl.	Convolvulaceae	AF	Climber	Sekar et al. (2012); Jaryan et al. (2013)
371	*Ipomoea pes-tigridis* L.	Convolvulaceae	AF	Climber	Sekar et al. (2012); Jaryan et al. (2013)
372	*Ipomoea purpurea* (L.) Roth	Convolvulaceae	SAM	Climber	Khuroo et al. (2007); Sekar et al. (2012); Jaryan et al. (2013)
373	*Ipomoea quamoclit* L.	Convolvulaceae	Trop. America/SAM	Climber	Khuroo et al. (2007); Sekar et al. (2012); Jaryan et al. (2013)
374	*Ipomoea triloba* L.	Convolvulaceae	Trop. America	Climber	Negi & Hajra (2007)
375	*Iris germanica* L.	Iridaceae	EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
376	*Iris spuria* L.	Iridaceae	AS/EU	Herb	Khuroo et al. (2007)
377	*Ixora macrothyrsa* (Teijsm. & Binn.) T. Moore	Rubiaceae	AS (Indonesia)	Shrub	Negi & Hajra (2007)
378	*Jacaranda mimosifolia* D.Don	Bignoniaceae	SAM (Brazil)	Tree	Negi &Hajra (2007); Jaryan et al. (2013)
379	*Jasminum mesnyi* Hance.	Oleaceae	AS (China)	Shrub	Negi & Hajra (2007)
380	*Jatropha curcas* L.	Euphorbiaceae	Trop. America/SAM	Shrub	Khuroo et al. (2007); Jaryan et al. (2013); Srivastava et al. (2014)
381	*Jatropha gossypifolia* L.	Euphorbiaceae	SAM (Brazil)/Trop. America	Shrub	Negi & Hajra (2007); Srivastava et al. (2014)
382	*Jatropha integerrima* Jacq.	Euphorbiaceae	AS (China)	Shrub	Negi & Hajra (2007)
383	*Joannesia princeps* Vell.	Euphorbiaceae	SAM (Brazil)	Tree	Negi & Hajra (2007)
384	*Juncus inflexus* L.	Juncaceae	AF	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
385	*Juniperus bermudiana* L.	Cupressaceae	NAM (Bermuda)	Tree	Negi & Hajra (2007); Tiwari et al. (2010)
386	*Juniperus chinensis* L.	Cupressaceae	AS (China)	Shrub	Negi & Hajra (2007); Tiwari et al. (2010)
387	*Juniperus communis* L.	Cupressaceae	EU (Yugoslavia)	Shrub	Negi & Hajra (2007); Tiwari et al. (2010); Jaryan et al. (2013)
388	*Juniperus deppeana* Steud.	Cupressaceae	NAM (Mexico)	Tree	Negi & Hajra (2007); Tiwari et al. (2010)
389	*Juniperus oxycedrus* L.	Cupressaceae	AS (Syria)	Tree	Negi & Hajra (2007); Tiwari et al. (2010)
390	*Juniperus phoenicea* L.	Cupressaceae	AF (Algeria)	Tree	Negi & Hajra (2007); Tiwari et al. (2010)
391	*Juniperus procera* Hochst. ex Endl.	Cupressaceae	AF (Kenya)	Tree	Khuroo et al. (2007); Jaryan et al. (2013)
392	*Juniperus scopulorum* Sarg.	Cupressaceae	USA	Tree	Khuroo et al. (2007); Jaryan et al. (2013)
393	*Justicia procumbents* L.	Acanthaceae	Trop. America	Herb	Hajra & Balodi (1995); Singh & Prakash, (2002)
394	*Khaya senegalensis* (Desv.) A.Juss.	Meliaceae	AF (Mozambique)	Tree	Negi & Hajra (2007)
395	*Kigelia africana* (Lam.) Benth.	Bignoniaceae	AF (Rhodesia)	Tree	Negi & Hajra (2007)
396	*Koelreuteria paniculata* Laxm.	Sapindaceae	AS (China)	Tree	Khuroo et al. (2007); Negi & Hajra (2007)
397	*Lactuca dissecta* D.Don	Asteraceae	EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
398	*Lactuca sativa* L.	Asteraceae	AS/EU	Herb	Jaryan et al. (2013)
399	*Lagascea mollis* Cav.	Asteraceae	Trop. Central America	Herb	Sekar et al. (2012)
400	*Lagerstroemia speciosa* (L.) Pers.	Lythraceae	NAM	Tree	Jaryan et al. (2013)
401	*Lagerstroemia turbinata* Koehne	Lythraceae	AS (Vietnam)	Tree	Negi & Hajra (2007)
402	*Lantana camara* L.	Verbenaceae	Trop. America/SAM/ NAM (West Indies)	Shrub	Khuroo et al. (2007); Sekar et al. (2012); Jaryan et al. (2013)
403	*Laphangium affine* (D.Don) Tzvelev	Asteraceae	AF/EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
404	*Lathyrus aphaca* L.	Fabaceae	AF/EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
405	*Lathyrus odoratus* L.	Fabaceae	EU	Climber	Khuroo et al. (2007)
406	*Lathyrus sativus* L.	Fabaceae	AS/AF	Herb	Jaryan et al. (2013)
407	*Lens culinaris* Medik.	Fabaceae	EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)

	Name of the species	Family	Nativity	Life form	Reference
408	*Leonotis nepetifolia* (L.) R.Br.	Lamiaceae	AF	Herb	Sekar et al. (2012)
409	*Lepidium didymium* L.	Brassicaceae	SAM	Herb	Khuroo et al. (2007); Negi & Hajra (2007); Jaryan et al. (2013); Srivastava et al. (2014)
410	*Lepidium virginicum* L.	Brassicaceae	NAM	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
411	*Leucaena leucocephala* (Lam.) de Wit	Fabaceae	Trop. America/SAM/ NAM (Mexico)	Tree	Khuroo et al. (2007); Sekar et al. (2012); Jaryan et al. (2013)
412	*Ligustrum lucidum* W.T. Aiton	Oleaceae	AS (China)	Shrub	Khuroo et al. (2007); Negi & Hajra (2007); Jaryan et al. (2013); Sankaran &Suresh (2013)
413	*Linum usitatissimum* L.	Linaceae	EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
414	*Liquidambar formosana* Hance	Altingiaceae	AS (China)	Tree	Negi & Hajra (2007)
415	*Liriodendron tulipifera* L.	Magnoliaceae	USA	Tree	Negi & Hajra (2007)
416	*Livistona australis* (R.Br.) Mart.	Arecaceae	AU	Tree	Negi & Hajra (2007)
417	*Livistona chinensis* (Jacq.) R.Br. ex Mart.	Arecaceae	AS (China)	Tree	Negi & Hajra (2007)
418	*Lobularia maritima* (L.) Desv.	Brassicaceae	AF/EU	Herb	Khuroo et al. (2007)
419	*Lolium temulentum* L.	Poaceae	EU	Grass	Khuroo et al. (2007); Jaryan et al. (2013)
420	*Lonchocarpus guillemineanus* (Tul.) Malme	Fabaceae	SAM (Brazil)	Tree	Negi & Hajra (2007)
421	*Lonicera japonica* Thunb.	Caprifoliaceae	AS (China)	Shrub	Negi & Hajra (2007)
422	*Lophostemon confertus* (R.Br.) Peter G. Wilson & J.T. Waterh.	Myrtaceae	AU	Tree	Negi & Hajra (2007)
423	*Ludwigia adscendens* (L.) H.Hara	Onagraceae	Trop. America/SAM	Herb	Sekar et al. (2012); Jaryan et al. (2013)
424	*Ludwigia octovalvis* (Jacq.) P.H. Raven	Onagraceae	AF	Herb	Sekar et al. (2012); Jaryan et al. (2013)
425	*Ludwigia perennis* L.	Onagraceae	AF	Herb	Sekar et al. (2012); Jaryan et al. (2013); Srivastava et al. (2014)
426	*Lycopersicon esculentum* Mill.	Solanaceae	SAM	Herb	Khuroo et al. (2007)
427	*Lysiloma latisiliquum* (L.) Benth.	Fabaceae	Trop. America	Tree	Sekar et al. (2012)
428	*Maclura pomifera* (Raf.) C.K. Schneid.	Moraceae	USA	Tree	Negi & Hajra (2007)
429	*Magnolia soulangeana* Soul. -Bod.	Magnoliaceae	AS (China)	Tree	Negi & Hajra (2007)
430	*Magnolia figo* (Lour.) DC.	Magnoliaceae	AS (China)	Tree	Negi & Hajra (2007)
431	*Magnolia grandiflora* L.	Magnoliaceae	NAM	Tree	Khuroo et al. (2007); Negi & Hajra (2007)
432	*Magnolia wilsonii* (Finet & Gagnep.) Rehder	Magnoliaceae	AS (Japan)	Shrub	Negi & Hajra (2007)
433	*Malachra capitata* (L.) L.	Malvaceae	Trop. America	Herb	Sekar et al. (2012)
434	*Malva parviflora* L.	Malvaceae	EU	Herb	Negi & Hajra (2007)
435	*Malvastrum coromandelianum* (L.) Garcke	Malvaceae	Trop. America/SAM	Herb	Khuroo et al. (2007); Sekar et al. (2012); Jaryan et al. (2013)
436	*Malvaviscus arboreus* Cav.	Malvaceae	Trop. America	Shrub	Negi & Hajra (2007)
437	*Manihot dichotoma* Ule	Euphorbiaceae	SAM (Brazil)	Shrub	Negi & Hajra (2007)
438	*Manihot esculenta* Crantz	Euphorbiaceae	Trop. America	Tree	Negi & Hajra (2007)
439	*Mansoa alliacea* (Lam.) A.H. Gentry	Bignoniaceae	SAM	Climber	Negi & Hajra (2007)
440	*Markhamia lutea* (Benth.) K. Schum.	Bignoniaceae	AF (Uganda)	Tree	Negi & Hajra (2007)
441	*Martynia annua* L.	Martyniaceae	Trop. America/NAM	Herb	Sekar et al. (2012); Jaryan et al. (2013)
442	*Mecardonia procumbens* (Mill.) Small	Plantaginaceae	Trop. NAM	Herb	Sekar et al. (2012)
443	*Medicago lupulina* L.	Fabaceae	AF/EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
444	*Medicago polymorpha* L.	Fabaceae	EU/AF	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
445	*Medicago sativa* L.	Fabaceae	AF/EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
446	*Melaleuca styphelioides* Sm.	Myrtaceae	AF (Uganda)	Tree	Negi & Hajra (2007)
447	*Melilotus albus* Medik.	Fabaceae	Europe	Herb	Sekar et al. (2012)
448	*Melinis repens* (Willd.) Zizka	Poaceae	Trop. America	Grass	Sekar et al. (2012)
449	*Melochia corchorifolia* L.	Malvaceae	Trop. America	Herb	Sekar et al. (2012)
450	*Mentha piperita* L.	Lamiaceae	EU	Herb	Khuroo et al. (2007); Negi & Hajra (2007)
451	*Mentha arvensis* L.	Lamiaceae	AF/EU	Herb	Khuroo et al. (2007)
452	*Mentha longifolia* (L.) L.	Lamiaceae	AF/EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)

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453	*Mentha spicata* L.	Lamiaceae	EU/NAM	Herb	Khuroo et al. (2007)
454	*Merremia dissecta* (Jacq.) Hallier f.	Convolvulaceae	Trop. America	Herb	Srivastava et al. (2014)
455	*Millingtonia hortensis* L.f.	Bignoniaceae	AS (Myanmar, Malaya)	Tree	Khuroo et al. (2007); Jaryan et al. (2013)
456	*Mimosa pudica* L.	Fabaceae	SAM (Brazil)	Herb	Negi & Hajra (2007); Sekar et al. (2012)
457	*Mirabilis jalapa* L.	Nyctaginaceae	SAM	Herb	Khuroo et al. (2007); Sekar et al. (2012); Jaryan et al. (2013)
458	*Monochoria vaginalis* (Burm. f.) C. Presl.	Pontederiaceae	Trop. America/SAM	Herb	Sekar et al. (2012); Jaryan et al. (2013)
459	*Montanoa grandiflora* (DC.) Sch. Bip. ex Hemsl.	Compositae	NAM (Mexico)	Herb	Negi & Hajra (2007)
460	*Morus alba* L.	Moraceae	AS	Tree	Khuroo et al. (2007); Jaryan et al. (2013)
461	*Muehlenbeckia platyclados* (F. Muell.) Meisn.	Polygonaceae	Solomon Isles	Shrub	Negi & Hajra (2007)
462	*Mussaenda erythrophylla* Schumach. & Thonn.	Rubiaceae	Trop.AF	Shrub	Negi & Hajra (2007)
463	*Mussaenda philippica* A. Rich.	Rubiaceae	AS (Philippines)	Shrub	Negi & Hajra (2007)
464	*Najas graminea* Delile	Hydrocharitaceae	NAM/SAM	Herb	Khuroo et al. (2007)
465	*Nandina domestica* Thunb.	Berberidaceae	AS (China, Japan)	Shrub	Negi & Hajra (2007); Jaryan et al. (2013)
466	*Narcissus tazetta* L.	Amaryllidaceae	EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
467	*Nicandra physalodes* (L.) Gaertn.	Solanaceae	SAM	Herb	Khuroo et al. (2007) Jaryan et al. (2013)
468	*Nicotiana plumbaginifolia* Viv.	Solanaceae	Trop. America/SAM	Herb	Khuroo et al. (2007); Sekar et al. (2012); Jaryan et al. (2013)
469	*Nicotiana rustica* L.	Solanaceae	Central and SAM	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
470	*Nicotiana tabacum* L.	Solanaceae	NAM/Central and SAM	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
471	*Nigella sativa* L.	Ranunculaceae	EU	Herb	Negi & Hajra (2007)
472	*Nymphaea alba* L.	Nympheaceae	AF/EU	Herb	Khuroo et al. (2007)
473	*Nymphaea lotus* L.	Nympheaceae	AF	Herb	Khuroo et al. (2007)
474	*Ochrosia elliptica* Labill.	Apocynaceae	AU	Tree	Negi & Hajra (2007)
475	*Ocimum americanum* L.	Lamiaceae	Trop. America/SAM	Herb	Sekar et al. (2012); Jaryan et al. (2013)
476	*Oenothera biennis* L.	Onagraceae	NAM	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
477	*Oenothera rosea* L'Hér. ex Aiton	Onagraceae	SAM/ NAM (Mexico)	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
478	*Olea europaea* L.	Oleaceae	Mediterranean region	Tree	Negi & Hajra (2007)
479	*Ononis spinosa* subsp. *hircina* (Jacq.) Gams	Fabaceae	EU	Shrub	Khuroo et al. (2007)
480	*Opuntia elatior* Mill.	Cactaceae	SAM	Shrub	Sekar et al. (2012); Jaryan et al. (2013)
481	*Opuntia ficus-indica* (L.) Mill.	Cactaceae	SAM	Shrub	Negi & Hajra (2007); Sekar et al. (2012)
482	*Opuntia stricta* (Haw.) Haw.	Cactaceae	Trop. America	Shrub	Sekar et al. (2012)
483	*Origanum vulgare* L.	Lamiaceae	EU	Herb	Khuroo et al. (2007)
484	*Oryza sativa* L.	Poaceae	AS	Grass	Khuroo et al. (2007); Jaryan et al. (2013)
485	*Oxalis corniculata* L.	Oxalidaceae	EU/AS	Herb	Khuroo et al. (2007); Sekar et al. (2012); Jaryan et al. (2013)
486	*Oxalis debilis* var. *corymbosa* (DC.) Lourteig	Oxalidaceae	SAM/Trop.America	Herb	Negi & Hajra (2007); Jaryan et al. (2013) Srivastava et al. (2014)
487	*Oxytenanthera abyssinica* (A. Rich.) Munro	Poaceae	AF (Zambia)	Grass	Negi & Hajra (2007)
488	*Papaver dubium* L.	Papaveraceae	AF/EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
489	*Papaver rhoeas* L.	Papaveraceae	AF/EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
490	*Papaver somniferum* L.	Papaveraceae	EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
491	*Parapiptadenia rigida* (Benth.) Brenan	Fabaceae	SAM (Brazil)	Tree	Negi & Hajra (2007)
492	*Parkinsonia aculeata* L.	Fabaceae	NAM (Mexico)/SAM	Tree	Khuroo et al. (2007); Jaryan et al. (2013)
493	*Parthenium hysterophorus* L.	Asteraceae	Trop. NAM/SAM	Herb	Khuroo et al. (2007); Sekar et al. (2012); Jaryan et al. (2013)
494	*Paspalum dilatatum* Poir.	Poaceae	SAM	Grass	Khuroo et al. (2007); Jaryan et al. (2013)
495	*Paspalum distichum* L.	Poaceae	NAM	Grass	Khuroo et al. (2007); Jaryan et al. (2013)
496	*Passiflora caerulea* L.	Passifloraceae	SAM	Climber	Jaryan et al. (2013)
497	*Passiflora edulis* Sims	Passifloraceae	SAM (Brazil)	Climber	Khuroo et al. (2007); Negi & Hajra (2007)

	Name of the species	Family	Nativity	Life form	Reference
498	*Passiflora foetida* L.	Passifloraceae	Trop. SAM	Herb	Sekar et al. (2012)
499	*Passiflora suberosa* L.	Passifloraceae	NAM (West Indies)	Climber	Negi & Hajra (2007)
500	*Peltophorum africanum* Sond.	Fabaceae	AF (Uganda)	Tree	Negi & Hajra (2007)
501	*Peltophorum pterocarpum* (DC.) K. Heyne	Fabaceae	AS (Sri Lanka)	Tree	Negi & Hajra (2007)
502	*Pennisetum purpureum* Schumach.	Poaceae	Trop. America	Grass	Sekar et al. (2012)
503	*Pentas lanceolata* (Forssk.) Deflers	Rubiaceae	AF (Kenya, Egypt)	Shrub	Negi & Hajra (2007)
504	*Peperomia pellucida* (L.) Kunth	Piperaceae	SAM	Herb	Khuroo et al. (2007); Sekar et al. (2012); Jaryan et al. (2013)
505	*Pereskia aculeata* Mill.	Cactaceae	Trop. America	Climber	Negi & Hajra (2007)
506	*Pereskia grandiflora* Pfeiff.	Cactaceae	SAM (Brazil)	Climber	Negi & Hajra (2007)
507	*Persia americana* Mill.	Lauraceae	NAM (Mexico)	Tree	Negi & Hajra (2007)
508	*Persicaria amphibia* (L.) Delarbre	Polygonaceae	NAM	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
509	*Persicaria hydropiper* (L.) Delarbre	Polygonaceae	EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
510	*Petrea volubilis* L.	Verbenaceae	NAM (Mexico)	Shrub	Negi & Hajra (2007)
511	*Petunia hybrida* Vilm.	Solanaceae	NA	Herb	Khuroo et al. (2007)
512	*Phaseolus vulgaris* L.	Fabaceae	SAM	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
513	*Phleum pratense* L.	Poaceae	EU	Grass	Khuroo et al. (2007); Jaryan et al. (2013)
514	*Phlox drummondii* Hook.	Polemoniaceae	NAM	Herb	Khuroo et al. (2007)
515	*Phoenix canariensis* Chabaud	Arecaceae	AF (Canary Isles)	Tree	Negi & Hajra (2007)
516	*Phoenix reclinata* Jacq.	Arecaceae	Trop. AF	Tree	Negi & Hajra (2007)
517	*Phragmites australis* (Cav.) Trin. ex Steud.	Poaceae	SAM	Grass	Khuroo et al. (2007)
518	*Phyla nodiflora* (L.) Greene	Verbenaceae	SAM	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
519	*Physalis angulata* L.	Solanaceae	Trop. America/NAM	Herb	Khuroo et al. (2007); Sekar et al. (2012); Jaryan et al. (2013)
520	*Physalis heterophylla* Nees	Solanaceae	SAM (Peru)/NAM	Herb	Negi & Hajra (2007); Sekar et al. (2012)
521	*Physalis minima* L.	Solanaceae	Trop. America/SAM	Herb	Sekar et al. (2012); Jaryan et al. (2013)
522	*Physalis peruviana* L.	Solanaceae	SAM (Peru)	Herb	Khuroo et al. (2007); Sekar et al. (2012); Jaryan et al. (2013);
523	*Pilea microphylla* (L.) Liebm.	Urticaceae	Trop. SAM	Herb	Sekar et al. (2012)
524	*Pilea serpyllifolia* (Poir.) Wedd.	Urticaceae	NAM (Mexico)	Herb	Negi & Hajra (2007)
525	*Pinus canariensis* C.Sm.	Pinaceae	AF (Canary Island)	Tree	Khuroo et al. (2007); Jaryan et al. (2013)
526	*Pinus caribaea* Morelet	Pinaceae	NAM (Cuba)	Tree	Khuroo et al. (2007); Jaryan et al. (2013)
527	*Pinus densiflora* Siebold & Zucc.	Pinaceae	AS (Japan)	Tree	Khuroo et al. (2007); Jaryan et al. (2013)
528	*Pinus echinata* Mill.	Pinaceae	NAM (Mexico)	Tree	Tiwari et al. (2010)
529	*Pinus elliottii* Engelm.	Pinaceae	USA	Tree	Khuroo et al. (2007); Jaryan et al. (2013)
530	*Pinus halepensis* Mill.	Pinaceae	EU (Cyprus)	Tree	Khuroo et al. (2007); Jaryan et al. (2013)
531	*Pinus hartwegii* Lindl.	Pinaceae	Mediterranean	Tree	Khuroo et al. (2007); Jaryan et al. (2013)
532	*Pinus merkusii* Jungh. & deVriese	Pinaceae	AS (Myanmar)	Tree	Khuroo et al. (2007); Jaryan et al. (2013)
533	*Pinus oocarpa* Schiede	Pinaceae	NAM (Mexico)	Tree	Khuroo et al. (2007); Jaryan et al. (2013)
534	*Pinus patula* Schiede ex Schltdl. & Cham.	Pinaceae	NAM (Mexico)	Tree	Khuroo et al. (2007); Jaryan et al. (2013)
535	*Pinus radiata* D.Don	Pinaceae	USA	Tree	Khuroo et al. (2007); Jaryan et al. (2013)
536	*Pistia stratiotes* L.	Araceae	Trop. America	Herb	Sekar et al. (2012)
537	*Pisum sativum* L.	Fabaceae	AS/EU	Herb	Jaryan et al. (2013)
538	*Pithecellobium dulce* (Roxb.) Benth.	Fabaceae	NAM (Mexico)	Tree	Negi & Hajra (2007)
539	*Plantago lanceolata* L.	Plantaginaceae	AF/EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
540	*Plantago major* L.	Plantaginaceae	EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
541	*Platanus occidentalis* L.	Platanaceae	America	Tree	Negi & Hajra (2007)
542	*Platanus orientalis* L.	Platanaceae	AS/EU	Tree	Khuroo et al. (2007); Negi & Hajra (2007)
543	*Platycladus orientalis* (L.) Franco	Cupressaceae	AS (China)	Tree	Khuroo et al. (2007); Negi & Hajra (2007); Tiwari et al. (2010)
544	*Plumbago auriculata* Lam.	Plumbaginaceae	S.AF	Shrub	Negi & Hajra (2007)
545	*Plumeria alba* L.	Apocynaceae	America	Tree	Negi & Hajra (2007)

	Name of the species	Family	Nativity	Life form	Reference
546	*Plumeria rubra* L.	Apocynaceae	NAM (Mexico)	Tree	Negi & Hajra (2007)
547	*Poa annua* L.	Poaceae	EU	Grass	Khuroo et al. (2007); Jaryan et al. (2013)
548	*Poa pratensis* L.	Poaceae	EU/NAM	Grass	Khuroo et al. (2007); Jaryan et al. (2013)
549	*Podocarpus latifolius* (Thunb.) R.Br. ex Mirb.	Podocarpaceae	AF (Kenya)	Tree	Khuroo et al. (2007); Jaryan et al. (2013)
550	*Podocarpus macrophyllus* (Thunb.) Sweet	Podocarpaceae	AS (China, Japan)	Tree	Khuroo et al. (2007); Jaryan et al. (2013)
551	*Polemonium caeruleum* L.	Polemoniaceae	EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
552	*Polygonum aviculare* L.	Polygonaceae	EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
553	*Polypogon monspeliensis* (L.) Desf.	Poaceae	EU	Grass	Khuroo et al. (2007); Jaryan et al. (2013)
554	*Populus deltoides* Marshall	Salicaceae	USA	Tree	Negi & Hajra (2007)
555	*Populus nigra* var. *italica* Münchh.	Salicaceae	EU	Tree	Khuroo et al. (2007); Jaryan et al. (2013)
556	*Portulaca grandiflora* Hook.	Portulacaceae	SAM (Brazil)	Herb	Negi & Hajra (2007)
557	*Portulaca oleracea* L.	Portulacaceae	AF/NAM/SAM	Herb	Khuroo et al. (2007); Sekar et al. (2012); Jaryan et al. (2013)
558	*Portulaca pilosa* L.	Portulacaceae	SAM	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
559	*Portulaca quadrifida* L.	Portulacaceae	Trop. America/SAM	Herb	Sekar et al. (2012); Jaryan et al. (2013)
560	*Potamogeton crispus* L.	Potamogetonaceae	EU/SAM	Herb	Khuroo et al. (2007)
561	*Potamogeton lucens* L.	Potamogetonaceae	AF/EU	Herb	Khuroo et al. (2007)
562	*Potamogeton nodosus* Poir.	Potamogetonaceae	NAM	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
563	*Potentilla supina* L.	Rosaceae	AF/EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
564	*Prosopis chilensis* (Molina) Stuntz	Fabaceae	NAM (Mexico)	Tree	Negi & Hajra (2007)
565	*Prosopis juliflora* (Sw.) DC.	Fabaceae	NAM (Mexico)/SAM	Tree	Khuroo et al. (2007); Sekar et al. (2012); Jaryan et al. (2013)
566	*Prunella vulgaris* L.	Lamiaceae	AF/EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
567	*Prunus yedoensis* Matsum.	Rosaceae	AS (Japan)	Tree	Negi & Hajra (2007)
568	*Prunus armeniaca* L.	Rosaceae	AS	Tree	Khuroo et al. (2007); Jaryan et al. (2013)
569	*Prunus cerasus* L.	Rosaceae	AS/EU	Tree	Khuroo et al. (2007); Jaryan et al. (2013)
570	*Prunus domestica* L.	Rosaceae	AS	Tree	Khuroo et al. (2007); Jaryan et al. (2013)
571	*Prunus persica* (L.) Batsch	Rosaceae	AS (China)	Tree	Khuroo et al. (2007); Jaryan et al. (2013)
572	*Psidium cattleianum* Afzel. ex Sabine	Myrtaceae	SAM (Brazil)	Shrub	Negi & Hajra (2007)
573	*Psidium guajava* L.	Myrtaceae	SAM	Tree	Negi & Hajra (2007); Jaryan et al. (2013); Sankaran & Suresh (2013)
574	*Pterocarya stenoptera* C. DC.	Juglandaceae	AS(China)	Tree	Negi & Hajra (2007)
575	*Pycreus flavidus* (Retz.) T. Koyama	Cyperaceae	AF/EU	Sedge	Khuroo et al. (2007)
576	*Pycreus sanguinolentus* (Vahl) Nees	Cyperaceae	NAM/SAM	Sedge	Khuroo et al. (2007); Jaryan et al. (2013)
577	*Pyrostegia venusta* (Ker Gawl.) Miers	Bignoniaceae	SAM (Brazil)	Climber	Negi & Hajra (2007)
578	*Pyrus communis* L.	Rosaceae	AS/EU	Tree	Khuroo et al. (2007); Jaryan et al. (2013)
579	*Pyrus pyrifolia* (Burm.f.) Nakai	Rosaceae	AS (China)	Tree	Negi & Hajra (2007)
580	*Ranunculus arvensis* L.	Ranunculaceae	AF/EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
581	*Ranunculus laetus* Wall. ex Hook. f. & J.W. Thomson	Ranunculaceae	EU	Herb	Khuroo et al. (2007)
582	*Ranunculus muricatus* L.	Ranunculaceae	AF/EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
583	*Ranunculus sceleratus* L.	Ranunculaceae	EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
584	*Raphanus raphanistrum* subsp. *sativus* (L.) Domin	Brassicaceae	AF/EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
585	*Rauvolfia tetraphylla* L.	Apocynaceae	NAM (West Indies)	Herb	Srivastava et al. (2014)
586	*Ribes alpestre* Wall. ex Decne.	Grossulariaceae	AF/EU	Shrub	Khuroo et al. (2007); Jaryan et al. (2013)
587	*Richardia scabra* L.	Rubiaceae	SAM	Herb	Negi & Hajra (2007)
588	*Ricinus communis* L.	Euphorbiaceae	AF	Shrub	Khuroo et al. (2007); Jaryan et al. (2013)
589	*Rivina humilis* L.	Phytolaccaceae	SAM	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
590	*Robinia pseudoacacia* L.	Fabaceae	NAM	Tree	Khuroo et al. (2007); Jaryan et al. (2013); Sankaran & Suresh (2013)
591	*Rorippa dubia* (Pers.) H.Hara	Brassicaceae	Trop. America/SAM	Herb	Sekar et al. (2012); Jaryan et al. (2013)
592	*Rosa banksiae* R.Br.	Rosaceae	AS	Climber	Khuroo et al. (2007)

	Name of the species	Family	Nativity	Life form	Reference
593	*Rosa cathayensis* (Rehder & E.H. Wilson) L.H. Bailey	Rosaceae	AS (China)	Climber	Negi & Hajra (2007)
594	*Rosa laevigata* Michx.	Rosaceae	AS (China, Japan)/ America	Climber	Negi & Hajra (2007)
595	*Rosa moschata* Herrm.	Rosaceae	AF/EU	Shrub	Khuroo et al. (2007); Jaryan et al. (2013)
596	*Rosa multiflora* Thunb.	Rosaceae	AS	Shrub	Khuroo et al. (2007); Jaryan et al. (2013)
597	*Rosmarinus officinalis* L.	Lamiaceae	EU	Shrub	Khuroo et al. (2007)
598	*Rotheca myricoides* (Hochst.) Steane & Mabb.	Lamiaceae	AF	Climber	Negi & Hajra (2007)
599	*Roystonea regia* (Kunth) O.F. Cook	Arecaceae	NAM (Cuba)	Tree	Negi & Hajra (2007)
600	*Rubus ellipticus* Sm.	Rosaceae	Trop. America	Shrub	Sekar (2012)
601	*Ruellia tuberosa* L.	Acanthaceae	Trop. America/NAM (West Indies)	Herb	Negi & Hajra (2007); Sekar et al. (2012)
602	*Rumex dentatus* L.	Polygonaceae	AF/EU	Herb	Khuroo et al. (2007)
603	*Rumex nepalensis* Spreng.	Polygonaceae	AF/EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
604	*Russelia equisetiformis* Schltdl. & Cham.	Plantaginaceae	NAM (Mexico)	Shrub	Negi & Hajra (2007)
605	*Sabal palmetto* (Walter) Lodd. ex Schult. & Schult.f.	Arecaceae	NAM (Bermuda Island)	Tree	Negi & Hajra (2007)
606	*Saccharum ravennae* (L.) L.	Poaceae	EU	Grass	Khuroo et al. (2007)
607	*Sagina procumbens* L.	Caryophyllaceae	EU/NAM	Herb	Khuroo et al. (2007)
608	*Sagina saginoides* (L.) H. Karst.	Caryophyllaceae	EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
609	*Sagittaria sagittifolia* L.	Alismataceae	NAM	Herb	Khuroo et al. (2007)
610	*Salix babylonica* L.	Salicaceae	AS (China, Babylon)	Tree	Khuroo et al. (2007); Jaryan et al. (2013)
611	*Salvia coccinea* Buc'hoz ex Etl.	Lamiaceae	NAM/SAM	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
612	*Salvia officinalis* L.	Lamiaceae	EU	Shrub	Khuroo et al. (2007)
613	*Sambucus nigra* L.	Adoxaceae	EU	Shrub	Khuroo et al. (2007); Jaryan et al. (2013)
614	*Sanicula elata* Buch. -Ham. ex D.Don	Apiaceae	AF/EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
615	*Sapium sebiferum* (L.) Roxb.	Euphorbiaceae	AS (China)	Tree	Negi & Hajra (2007)
616	*Schefflera actinophylla* (Endl.) Harms	Araliaceae	AU	Tree	Negi & Hajra (2007)
617	*Schefflera arboricola* (Hayata) Merr.	Araliaceae	AS (Taiwan)	Shrub	Negi & Hajra (2007)
618	*Schizolobium parahyba* (Vell.) S.F. Blake	Fabaceae	SAM	Tree	Negi & Hajra (2007)
619	*Schoenoplectiella juncoides* (Roxb.) Lye	Cyperaceae	NAM	Sedge	Jaryan et al. (2013)
620	*Schoenoplectus triqueter* (L.) Palla	Cyperaceae	AF	Sedge	Khuroo et al. (2007)
621	*Scoparia dulcis* L.	Plantaginaceae	Trop. America/SAM	Herb	Khuroo et al. (2007); Sekar et al. (2012); Jaryan et al. (2013)
622	*Searsia lancea* (L.f.) F.A. Barkley	Anacardiaceae	Trop. AF	Tree	Negi & Hajra (2007)
623	*Sechium edule* (Jacq.) Sw.	Cucurbitaceae	SAM	Climber	Khuroo et al. (2007); Jaryan et al. (2013)
624	*Selenicereus grandiflorus* (L.) Britton & Rose	Cactaceae	NAM (Jamaica, Cuba)	Shrub	Negi & Hajra (2007)
625	*Senna alata* (L.) Roxb.	Fabaceae	Trop. America	Shrub	Rana & Rastogi (2017)
626	*Senna multijuga* (Rich.) H.S. Irwin & Barneby	Fabaceae	America/ AS (Malaysia)	Tree	Negi & Hajra (2007)
627	*Senna obtusifolia* (L.) H.S. Irwin & Barneby	Fabaceae	SAM	Herb	Sekar et al. (2012); Jaryan et al. (2013)
628	*Senna occidentalis* (L.) Link	Fabaceae	SAM	Herb	Negi & Hajra (2007); Sekar et al. (2012); Jaryan et al. (2013)
629	*Senna spectabilis (*DC.) H.S. Irwin & Barneby	Fabaceae	Trop. America	Tree	Negi & Hajra (2007)
630	*Senna splendida* (Vogel) H.S. Irwin & Barneby	Fabaceae	SAM (Brazil)	Tree	Negi & Hajra (2007)
631	*Senna tora* (L.) Roxb.	Fabaceae	Trop. SAM/SAM	Herb	Sekar et al. (2012); Jaryan et al. (2013)
632	*Sesamum indicum* L.	Pedaliaceae	AF	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
633	*Sesbania bispinosa* (Jacq.) W. Wight	Fabaceae	Trop. America/SAM	Herb	Sekar et al. (2012); Jaryan et al. (2013)
634	*Sesbania sesban* (L.) Merr.	Fabaceae	S.AF	Tree	Negi & Hajra (2007)
635	*Setaria palmifolia* (J. Koenig) Stapf	Poaceae	Trop. America	Grass	Sekar et al. (2012)
636	*Setaria parviflora* (Poir.) M.Kerguelen	Poaceae	Trop. America	Grass	Sekar et al. (2012)
637	*Sida acuta* Burm.f.	Malvaceae	Trop. America	Herb	Sekar et al. (2012)

	Name of the species	Family	Nativity	Life form	Reference
638	*Sida cordata* (Burm.f.) Borss. Waalk.	Malvaceae	SAM	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
639	*Silene latifolia* subsp. *alba* (Mill.) Greuter & Burdet	Caryophyllaceae	EU/AF/AS	Herb	Negi & Hajra (2007)
640	*Silybum marianum* (L.) Gaertn.	Asteraceae	AF/EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
641	*Sinapis alba* L.	Brassicaceae	AF/EU	Herb	Khuroo et al. (2007)
642	*Solanum aculeatissimum* Jacq.	Solanaceae	Trop. America	Herb	Srivastava et al. (2014)
643	*Solanum americanum* Mill.	Solanaceae	Trop. America/SAM	Herb	Sekar et al. (2012); Jaryan et al. (2013)
644	*Solanum asperolanatum* Ruiz & Pav.	Solanaceae	SAM (Peru)/Trop. America	Shrub	Khuroo et al. (2007); Sekar et al. (2012); Jaryan et al. (2013)
645	*Solanum pseudocapsicum* L.	Solanaceae	Trop. America/AS/AF	Herb	Khuroo et al. (2007); Sekar et al. (2012); Jaryan et al. (2013)
646	*Solanum seaforthianum* Andrews	Solanaceae	SAM (Brazil)	Climber	Sekar et al. (2012)
647	*Solanum torvum* Sw.	Solanaceae	NAM (West Indies)/ SAM	Shrub	Negi & Hajra (2007); Sekar et al. (2012)
648	*Solanum tuberosum* L.	Solanaceae	SAM	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
649	*Solanum viarum* Dunal	Solanaceae	Trop. America/SAM	Herb	Sekar et al. (2012); Jaryan et al. (2013)
650	*Solidago canadensis* L.	Asteraceae	NAM	Herb	Negi & Hajra (2007)
651	*Soliva anthemifolia* (Juss.) Sweet	Asteraceae	America/AU	Herb	Jaryan et al. (2013); Srivastava et al. (2014);
652	*Sonchus arvensis* L.	Asteraceae	AS/EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
653	*Sonchus oleraceus* (L.) L.	Asteraceae	Mediterranean/AS	Herb	Sekar et al. (2012); Jaryan et al. (2013)
654	*Sorghum bicolor* (L.) Moench	Poaceae	AF	Grass	Khuroo et al. (2007)
655	*Sorghum halepense* (L.) Pers.	Poaceae	EU	Grass	Khuroo et al. (2007); Jaryan et al. (2013)
656	*Spartium junceum* L.	Fabaceae	EU	Shrub	Khuroo et al. (2007); Jaryan et al. (2013)
657	*Spathodea campanulata* P. Beauv.	Bignoniaceae	AF (Uganda)	Tree	Negi & Hajra (2007)
658	*Spermacoce hispida* L.	Rubiaceae	Trop. America	Herb	Sekar et al. (2012)
659	*Spinacia oleracea* L.	Amaranthaceae	AS	Herb	Khuroo et al. (2007)
660	*Spiraea cantoniensis* Lour.	Rosaceae	AS (China)	Shrub	Negi & Hajra (2007); Khuroo et al. (2007)
661	*Spiraea prunifolia* Siebold & Zucc.	Rosaceae	AS (China)	Shrub	Negi & Hajra (2007)
662	*Stachytarpheta urticifolia* (Salisb.) Sims	Verbenaceae	Trop. America	Herb	Sekar et al. (2012)
663	*Stellaria media* (L.) Vill.	Caryophyllaceae	EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
664	*Swietenia macrophylla* King	Meliaceae	NAM (Honduras-part of central america)	Tree	Negi & Hajra (2007)
665	*Swietenia mahagoni* (L.) Jacq.	Meliaceae	NAM (West Indies)	Tree	Negi & Hajra (2007)
666	*Tabebuia heterophylla* (DC.) Britton	Bignoniaceae	NAM (West Indies)	Tree	Negi & Hajra (2007)
667	*Tagetes erecta* L.	Asteraceae	SAM/NAM (Mexico)	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
668	*Tagetes minuta* L.	Asteraceae	SAM	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
669	*Talinum paniculatum* (Jacq.) Gaertn.	Talinaceae	America	Herb	Negi & Hajra (2007)
670	*Tamarindus indica* L.	Fabaceae	AF (Ethiopia)	Tree	Negi & Hajra (2007); Jaryan et al. (2013)
671	*Tanacetum cinerariifolium* (Trevir.) Sch. Bip.	Asteraceae	EU	Herb	Khuroo et al. (2007)
672	*Taraxacum campylodes* G.E. Haglund	Asteraceae	EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
673	*Taxodium distichum* (L.) Rich.	Cupressaceae	NAM (Florida)	Tree	Khuroo et al. (2007); Jaryan et al. (2013)
674	*Taxodium huegelii* C. Lawson	Cupressaceae	NAM (Mexico)	Tree	Negi & Hajra (2007); Tiwari et al. (2010)
675	*Taxus wallichiana* Zucc.	Taxaceae	EU/AS (Afghanistan)/ AF	Tree	Khuroo et al. (2007); Tiwari et al. (2010)
676	*Tecoma castanifolia* (D.Don) Melch.	Bignoniaceae	SAM (Colombia)	Tree	Negi & Hajra (2007)
677	*Tecoma stans* (L.) Juss. ex Kunth	Bignoniaceae	NAM (South Florida, West Indies)/SAM	Tree	Negi & Hajra (2007)
678	*Terminalia sericea* Burch. ex DC.	Combretaceae	S. AF	Tree	Negi & Hajra (2007)
679	*Tetraclinis articulata* (Vahl) Mast.	Cupressaceae	AF (Algeria)	Tree	Negi & Hajra (2007)
680	*Tetrapanax papyrifer* (Hook.) K. Koch	Araliaceae	AS (China)	Tree	Negi &Hajra (2007)
681	*Thalictrum minus* L.	Ranunculaceae	EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
682	*Thuja occidentalis* L.	Cupressaceae	NAM (Canada)	Tree	Khuroo et al. (2007); Jaryan et al. (2013)
683	*Thymus serpyllum* L.	Lamiaceae	EU	Shrub	Khuroo et al. (2007)

	Name of the species	Family	Nativity	Life form	Reference
684	*Tipuana tipu* (Benth.) Kuntze	Fabaceae	SAM (Argentina)	Tree	Negi & Hajra (2007)
685	*Tithonia diversifolia* (Hemsl.) A. Gray	Asteraceae	NAM (Mexico)	Shrub	Srivastava et al. (2014)
686	*Trachycarpus fortunei* (Hook.) H. Wendl.	Arecaceae	AS (China, Japan)	Tree	Negi & Hajra (2007)
687	*Trapa natans* L.	Lythraceae	EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
688	*Trema orientalis* (L.) Blume	Cannabaceae	AF	Tree	Srivastava et al. (2014)
689	*Triadica sebifera* (L.) Small	Euphorbiaceae	AS	Tree	Jaryan et al. (2013)
690	*Tridax procumbens* (L.) L.	Asteraceae	Trop. America/SAM	Herb	Sekar et al. (2012); Jaryan et al. (2013)
691	*Trifolium dubium* Sibth.	Fabaceae	EU	Herb	Khuroo et al. (2007)
692	*Trifolium fragiferum* L.	Fabaceae	EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
693	*Trifolium hybridum* L.	Fabaceae	EU/AS	Herb	Negi & Hajra (2007)
694	*Trifolium pratense* L.	Fabaceae	EU	Herb	Khuroo et al. (2007)
695	*Trifolium repens* L.	Fabaceae	EU	Herb	Khuroo et al. (2007)
696	*Triticum aestivum* L.	Poaceae	NA	Grass	Khuroo et al. (2007); Jaryan et al. (2013)
697	*Triumfetta rhomboidea* Jacq.	Malvaceae	Trop. America/SAM	Herb	Sekar et al. (2012); Jaryan et al. (2013)
698	*Tropaeolum majus* L.	Tropaeolaceae	EU/SAM	Herb	Jaryan et al. (2013)
699	*Turritis glabra* L.	Brassicaceae	EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013); Kumar et al. (2013)
700	*Typha angustifolia* L.	Typhaceae	Trop. America/EU/ NAM	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
701	*Urena lobata* L.	Malvaceae	AF	Shrub	Khuroo et al. (2007); Sekar et al. (2012); Jaryan et al. (2013)
702	*Urtica dioica* L.	Urticaceae	AF/EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
703	*Vallisneria spiralis* L.	Hydrocharitaceae	EU	Herb	Khuroo et al. (2007)
704	*Verbascum thapsus* L.	Scrophulariaceae	EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
705	*Verbena bonariensis* L.	Verbenaceae	SAM	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
706	*Vernicia fordii* (Hemsl.) Airy Shaw	Euphorbiaceae	AS (China)	Tree	Negi & Hajra (2007)
707	*Veronica persica* Poir.	Plantaginaceae	AS	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
708	*Vicia faba* L.	Fabaceae	AS/AF	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
709	*Vicia hirsuta* (L.) Gray	Fabaceae	EU/NAM/SAM	Herb	Jaryan et al. (2013)
710	*Vinca major* L.	Apocynaceae	EU	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
711	*Viola tricolor* L.	Violaceae	EU	Herb	Khuroo et al. (2007)
712	*Vitis vinifera* L.	Vitaceae	AS/EU	Climber	Khuroo et al. (2007); Jaryan et al. (2013)
713	*Vulpia myuros* (L.) C.C. Gmel.	Poaceae	EU	Grass	Khuroo et al. (2007); Jaryan et al. (2013)
714	*Waltheria indica* L.	Malvaceae	Trop. America	Herb	Sekar et al. (2012)
715	*Washingtonia filifera* (Linden ex André) H. Wendl. ex de Bary	Arecaceae	NAM (Arizona, California)	Tree	Negi & Hajra (2007)
716	*Wigandia urens* (Ruiz & Pav.) Kunth	Boraginaceae	Central America	Shrub	efloraofindia
717	*Wisteria sinensis* (Sims) Sweet	Fabaceae	AS (China)	Climber	Negi & Hajra (2007)
718	*Wolffia arrhiza* (L.) Horkel ex Wimm.	Araceae	AF/EU	Herb	Khuroo et al. (2007)
719	*Xanthium strumarium* L.	Asteraceae	Trop. America/SAM/ AF/EU	Herb	BSI; Khuroo et al. (2007); Negi & Hajra (2007); Sekar et al. (2012); Jaryan et al. (2013)
720	*Youngia japonica* (L.) DC.	Asteraceae	Trop. SAM/SAM	Herb	Sekar et al. (2012); Jaryan et al. (2013)
721	*Yucca aloifolia* L.	Asparagaceae	NAM	Shrub	Khuroo et al. (2007)
722	*Yucca gloriosa* L.	Asparagaceae	EU/NAM	Shrub	Jaryan et al. (2013)
723	*Zannichellia palustris* L.	Potamogetonaceae	NAM/SAM	Herb	Khuroo et al. (2007); Jaryan et al. (2013)
724	*Zantedeschia aethiopica* (L.) Spreng.	Araceae	AF	Herb	Khuroo et al. (2007)
725	*Zea mays* L.	Poaceae	SAM	Grass	Khuroo et al. (2007); Jaryan et al. (2013)
726	*Zephyranthes candida* (Lindl.) Herb.	Amaryllidaceae	SAM	Herb	Khuroo et al. (2007); Jaryan et al. (2013); Srivastava et al. (2014)
727	*Zephyranthes citrina* Baker	Amaryllidaceae	AU	Herb	Jaryan et al. (2013)
728	*Zinnia elegans* L.	Asteraceae	SAM	Herb	Khuroo et al. (2007)

NA—information not available; Nativity | NAM—North America | SAM—South America | AS—Asia | EU—Europe | AF—Africa | AU—Australia.

Table 2. Dominant families and life forms in the alien flora of Uttarakhand, western Himalaya.

	Family	Climber	Grass	Herb	Sedge	Shrub	Tree	Grand total
1	Fabaceae	3				10	41	89
2	Asteraceae			62		1		63
3	Poaceae		50					50
4	Solanaceae	1		17		11	2	31
5	Malvaceae			19		7	3	29
6	Amaranthaceae	1		27				28
7	Myrtaceae					1	24	25
8	Euphorbiaceae			9		10	5	24
9	Brassicaceae			22				22
10	Cupressaceae					2	19	21
11	Rosaceae	3		3		5	8	19
12	Convolvulaceae	9		5		1	1	16
13	Lamiaceae	2		10		3		15
14	Apocynaceae	2		5		3	4	14
15	Bignoniaceae	5					8	13
16	Pinaceae						11	11
17	Rubiaceae			5		6		11
18	Arecaceae					1	9	10
19	Cyperaceae				10			10
20	Plantaginaceae			8		1		9

Table 3. Life form categorization of alien plant species in different continents or geographical regions.

	Continents	Climber	Grass	Herb	Sedge	Shrub	Tree	Total Species
1	NAM/SAM (Trop. A)	8	7	89	3	17	21	145
2	EU	2	16	72	1	8	5	104
3	SAM	13	4	47	1	9	17	91
4	AS	7	3	8	-	20	42	80
5	NAM	3	5	22	1	15	33	79
6	AF	5	8	18	2	16	27	76
7	AU	1	-	1	-	-	39	41
8	AF/EU	-	-	35	1	2	1	39
9	AS/EU	1	1	8	-	-	3	13

Abbreviations used: Trop. A—Tropical America | NAM—North America | SAM—South America | AS—Asia | EU—Europe | AF—Africa | AU—Australia.

CONCLUSION

Biological invasions have been considered as the second largest threat to global biodiversity after habitat loss, and undoubtedly a huge number of species extinctions are associated with such invasions. Recognising the array of impacts that invasive alien species can have, one needs to reconsider the strategies that have been developed to deal with invasions. Although, several international and regional programmes such as Global Invasive Species Programme, European Network of Invasive Species, Invasive Species Information Network and regional Eurasian networks have been initiated, little has been achieved in understanding and controlling plant invasions. Regional inventorization of alien flora is now considered a pre-requisite for gaining a better understanding and undertaking appropriate management practices. Also, modelling studies can

Table 4. Details of the alien plant species reported in the India, Uttarakhand and its adjoining states/regions.

	Topic	Area	Family	Genera	Species	Reference
1	Naturalized alien flora	India	-	271	471	Inderjit et al. (2018)
2	Invasive alien plants	Pantnagar, Uttarakhand	30	70	91	Rana & Rastogi (2017)
3	Invasive alien plants	Uttar Pradesh	41	100	149	Srivastava et al. (2014)
4	Alien flora	Himachal Pradesh	85	-	497	Jaryan et al. (2013)
5	Invasive alien plants	Uttarakhand	46	105	163	Sekar et al. (2012)
6	Wild and exotic gymnosperms	Uttarakhand	10	-	63	Tewari et al. (2010)
7	Exotic tree species	Doon Valley	14	-	18	Jaryan et al. (2013)
8	Alien flora	Kashmir	104	352	571	Khuroo et al. (2007)
9	Alien flora	Doon Valley, Uttarakhand	-	-	436	Negi & Hajra (2007)
10	Alien flora	Uttarakhand	108	450	728	Present study

predict the concurrence of invasion hotspots with biodiversity hotspots. Despite a large number of studies undertaken to assess the alien flora of the country, it is submitted that correct identification and authentication of names of several unresolved or illegitimate species, for instance, names of alien plant species such as *Adenostemma houstonianum, Anethum scandicina, Bignonia anguis-cati, Caesulia officinalis, Dombeya cayuseii, Hibiscus hawaii, Lagerstroemia floribunda, Luchea endopogon, Manihot tweediana, Oxalis dehradunensis, Oxalis richardiana, Peltophorum vogetianu, Persia owdenii, Phoenix senegalensis, Pterospermum semisagittatum, Roylea coccinea, Siegesbeckia marianum, Terminalia calamansanai, Terminalia oliveri*, and *Vigna faba* reported by various workers need to be carried out. There is an urgent need to rectify such information gaps to pave the way forward for the correct compilation of regional databases that will in turn strengthen the scientific pool of knowledge and management practices. Uttarakhand is vulnerable to alien plants, and unfortunately the intensity of introductions is expected to escalate rapidly due to climate change and economic developments.

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COMMUNICATION

New records of *Nyctalus leisleri* (Kuhl, 1817) and *Myotis nattereri* (Kuhl, 1817) (Mammalia: Chiroptera: Vespertilionidae) from National Park "Smolny" and its surroundings, Republic of Mordovia

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Abstract. Protected areas in the Republic of Mordovia are still poorly studied in relation to bats. Our research of the bat fauna in the National Park "Smolny", Republic of Mordovia was conducted in 2018–2020. A total of 573 bats of nine species belonging to the family Vespertilionidae were captured and studied. *Nyctalus leisleri* and *Myotis nattereri* were caught here for the first time. Three new sites of two rare bat species were discovered. The list of bats in the National Park "Smolny" currently includes 10 species.

Keywords: Bats, first finding, Leisler's Bat, Natterer's Bat, protected areas, Russia.

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INTRODUCTION

In recent years, the threat to biological diversity has increased in many countries of the world. Due to increasing anthropogenic impacts, many mammals are on the verge of extinction in different parts of the world (Bodmer et al. 1997; Bazhenov 2019; Bowyer et al. 2019; Loiseau et al. 2020; Rutovskaya et al. 2020). Protected areas are important for the protection of mammals, since regular monitoring of fauna and population density of rare species are conducted (Akpatou et al. 2018; Bowyer et al. 2019; Lebedinsky et al. 2019; Levykh & Panin 2019; Ahissa et al. 2020; Vekhnik 2020). Bats are one of the least-studied groups of mammals in protected areas, which is why increased survey efforts are required (Luo et al. 2013; Malekani et al. 2018; Barros et al. 2020; Belkin et al. 2021).

The territory of European Russia is home to 27 species of bats. Sixteen species inhabit the Volga Upland (Mammals of Russia 2020). The National Park "Smolny" is located in the central part of European Russia in the Republic of Mordovia. The fauna of Mordovia includes 12 bat species according to preliminary estimates (Artaev & Smirnov 2016). Previous studies from 2005 to 2015 established habitation of eight bat species in the National Park "Smolny" (Artaev & Smirnov 2016) which did not include *Myotis nattereri* (Kuhl, 1817) and *Nyctalus leisleri* (Kuhl, 1817). Both species are widespread in western Palaearctic. Their species ranges cover most of western, central, and eastern Europe (Juste & Paunović 2016; Smirnov et al. 2020). In most of their ranges they do not reach high population density and in some habitats they are rare. Currently, there is no information about a significant decline in the populations of *M. nattereri* and *N. leisleri*, therefore they are included in the IUCN Red List with the status 'Least Concern' (LC) (Juste & Paunović 2016; Gazaryan et al. 2020). However, these species, like other bats, are extremely vulnerable; therefore, in Europe all bat species are protected in accordance with EU directives and international agreements: The Bonn Convention on the Conservation of Migratory Species of Wild Animals and The Convention on the Conservation of European Wildlife and Natural Habitats. In European Russia, the vulnerability of bats and, in particular, *M. nattereri* and *N. leisleri* is due to the reduction and fragmentation of forest landscapes caused by the deforestation of primary forests and other anthropogenic transformations. There is also a decrease in the number of shelters caused by the cutting of old hollow trees.

In Russia, *M. nattereri*, commonly known as Natterer's Bat, inhabits the northwestern and central parts, the middle Volga Region, and the middle & southern Urals. The southern border of distribution range runs along the southern edge of the forest-steppe (Smirnov et al. 2020). In the Volga Region, *M. nattereri* is one of the rare bat species. Rare findings are due to the low abundance and sporadic distribution of this species (Smirnov 2013). Natterer's Bat inhabits deciduous and mixed forests, has a sedentary lifestyle and hibernates in deep crevices or underground spaces (Smirnov et al. 2007, 2008; Smirnov & Vekhnik 2009, 2011, 2014). Summer habitats are closely related with trees and are confined to regions with expressed karstic landforms (Ilyin & Smirnov 2000). The bat hunts, as a rule, over bushes and near the crowns of low trees (Smirnov & Vekhnik 2012). In the territory of Mordovia, *M. nattereri* is known from the only finding made in 2013 in the Mordovia State Nature Reserve (Artaev 2014).

Nyctalus leisleri, or Leisler's Bat, is a typical inhabitant of European floodplain deciduous and mixed forests (Smirnov 2013). In Russia, the distribution of the bat covers mainly the Western and Central part, the Middle Volga Region, the South Urals, and the North Caucasus (Ilyin et al. 2002; Kozhurina 2009). *Nyctalus leisleri* has a relatively low abundance everywhere. This bat species is included in almost all regional Red Lists of the Volga Region, as well as in the Republic of Mordovia. It is a migratory species, annually making long-distance seasonal migrations.

According to observations in the Zhiguli State Nature Reserve (Samara Oblast), as well as in the Ulyanovsk and Penza oblasts, the summer season of *N. leisleri* in the middle Volga region lasts from three and a half to four months (Bezrukov & Smirnov 2012; Smirnov, 2013). Wintering places are not yet determined. Taking into account the southern direction of the migration routes of bats, most likely, the middle Volga population of Leisler's Bat spends the winter in the Northern Caucasus (Ilyin & Smirnov 2010). There is almost no information on the biology of *N. leisleri* in the Republic of Mordovia. The species is known here from only three findings (Vechkanov et al. 2006; Ruchin et al. 2014; Artaev & Smirnov 2016).

The purpose of this study was to survey *Myotis nattereri* and *Nyctalus leisleri* in the National Park "Smolny", as well as the position of these species in the structure of the bat community in this protected area.

MATERIALS AND METHODS

The materials for this work were our own field studies of bats in the National Park "Smolny", which were carried out in period 2018 to 2020 in July and August. The map of the trapping places of bats is presented in Figure 1.

Bats were caught at night with mist nets. We used the common method of stretching net between two poles (Jones et al. 1996). Telescopic fishing rods 7–9 m long were used as poles, tied to metal pegs placed into the ground. During three years of research, we carried out 43net/night: 2018 – 9, 2019 – 18, and in 2020 – 16.

In the daytime, we searched for potential bat shelters (tree hollows, underground places, and buildings). To determine the species of bats in flight, we used a D-240x detector (Pettersson Elektronik AB, Sweden) with the time expansion of 10 and memory size of 1.7 sec. The calls were recorded on a zoom H2 handy recorder (Zoom Corp., Japan) in the "wav" format with a sampling rate of 44.1 kHz and 16 bit. Processing and analysis was carried out using the BatSound 3.31 software (Pettersson Elektronik AB). For the analysis, we selected from the records series of frequency-modulated pulses with a quasi constant component at the end (FM/QCF). They belonged to a search flight and did not include signals from the active phase of the approach and feeding buzzes, characterized by shrinking intervals between pulses. The following parameters were used as the characteristics of the calls: pulse duration (DUR), maximum (Fmax), minimum (Fmin), and peak (Fpeak) frequencies, as well as the inter-pulse intervals (IPI).

Descriptions of the three places of catching new bat species are given below (Figure 1, sites 4, 6, 10). The site in the Udalets River floodplain (54.792 ºN & 45.266 ºE) is a small forest glade, which is not part of the National Park (Figure 1, site 4; Image 1). The forest glade, where the animals were caught, is surrounded on all sides by the territory of the national park and is located just a few meters from its border. The forest glade with sedge-cereal forbs is bounded from north and east by a pine forest, from south and west by the floodplain forest of alders *Alnus glutinosa* (L.) and aspens *Populus tremula* L.

The Tashkinsky pond (54.747 ºN & 46.263 ºE) is a small reservoir (0.2 ha) located on the Chernushka River in the depth of an old pine forest (Figure 1, site 6; Image 1). Alders *Alnus glutinosa* (L.) and willows *Salix* spp. grow along the pond banks. The northern part of the pond is open with a small sandy beach. Coastal herbaceous

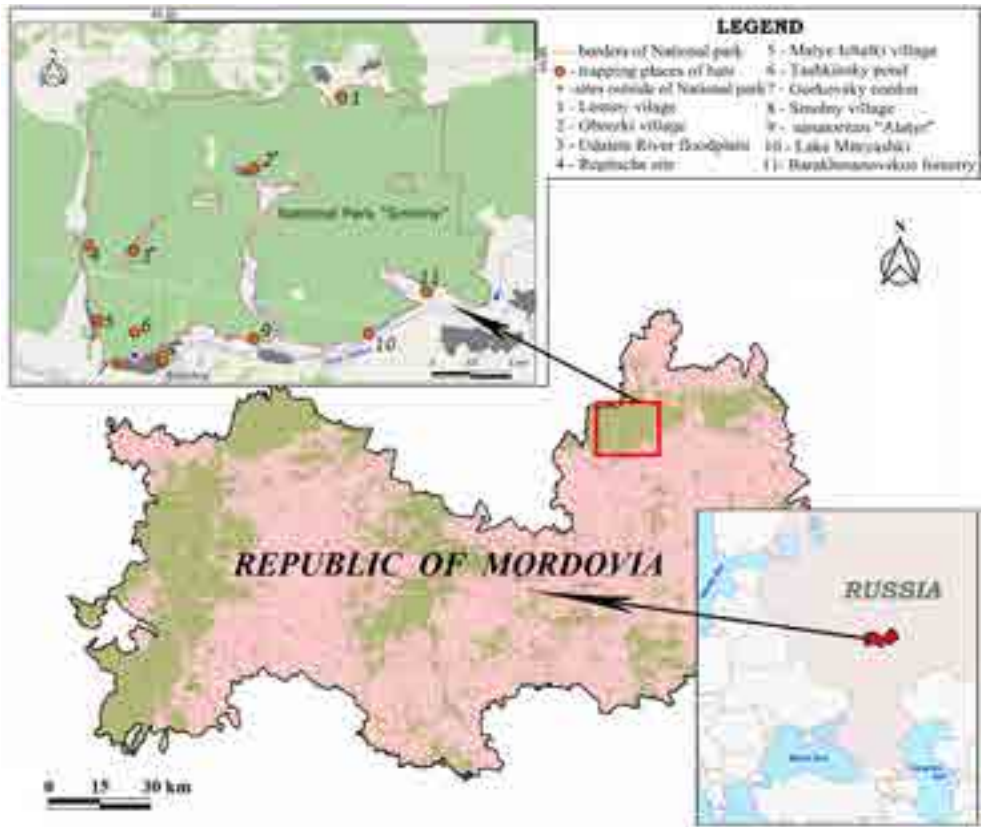

Figure 1. Trapping places of bats in the National Park "Smolny" and its surroundings in 2018–2020.

Image 1. Trapping places of *Nyctalus leisleri* and *Myotis nattereri*: A—glade in vicinity of Lake Mitryashki (inside of the National park) | B—Lake Mitryashki (boundary of the National park) | C—Tashkinsky pond (inside of the National park) | D—Udalets River floodplain (boundary of the National Park). © A—Dmitry Smirnov, B&D—Alexander Kirillov, c—Alexander Kirillov.

vegetation is represented by *Typha latifolia* L., *Carex* spp., *Bidens tripartita* L.

The site in the vicinity of Lake Mitryashki (54.745 ºN & 45.503 ºE) is situated in a forest glade (0.4 ha) with sedge-cereal forbs (Figure 1, site 10; Image 1). From the north and west, the glade is surrounded by a pine forest, from the east – a deciduous middle-aged forest (*Quercus robur* L., *Populus tremula* L., *Tilia cordata* Mill., *Ulmus laevis* (Pall.), and from the south there is a steep slope leading to the lake, overgrown with old alders along the shore.

The rates of occurrence and relative abundance were calculated using the previously proposed method (Strelkov & Ilyin 1990). The occurrence was estimated as the ratio of the number of findings of each species to the total number of findings of all species, given as a percentage. The relative abundance was the ratio of the number of caught and recorded individuals of each species to the total number of individuals caught from a given place of all bat species, expressed as a percentage.

RESULTS

A total of 573 bats of nine species were captured over three years of research (Table 1). We established two new species inhabiting the National Park "Smolny" – *Myotis nattereri* and *Nyctalus leisleri*.

On 9 July 2019, *N. leisleri* was observed visually and using ultrasound scanning of echolocation signals in the vicinity of Lake Mitryashki. A solitary individual was hunting along the edge of the forest for 20–30 min. Its search calls (n = 27) had the following characteristics: DUR = 8.27±0.23 (Lim 3.1–10.6), Fmax = 37.5±0.7 (Lim 28.4–53.7), Fmin = 26.1±0.1 (Lim 24.2–30.1), Fpeak = 28.7±0.2 (Lim 24.9–35.1), IPI = 195±53.5 (Lim 90.1–421.6). It was not caught in the installed mist net and did not appear on subsequent evenings. However, on 27 July 2020, a post-lactating female of this species was caught on the bank of lake Mitryashki.

On 16 July 2019, on a forest glade in the Udalets River floodplain (Figure 1, site 4) 10 individuals of *N. leisleri* were caught in the mist net, including two adult post-lactating females and eight young bats: five males

Table 1. Species composition, abundance and occurrence of bats in the National Park "Smolny" and its surroundings in 2018–2020.

Species	Abundance		Occurrence	
	N_1	%	N_2	%
Myotis brandtii Eversmann, 1845	34	5.9	6	13.0
Myotis daubentonii (Kuhl, 1817)	58	10.1	5	10.9
Myotis dasycneme (Boie, 1825)	5	0.9	2	4.4
Myotis nattereri (Kuhl, 1817)	1	0.2	1	2.2
Nyctalus noctula (Schreber, 1774)	116	20.2	8	17.4
Nyctalus leisleri (Kuhl, 1817)	12	2.1	3	6.5
Pipistrellus nathusii (Keyserling & Blasius, 1839)	291	50.8	10	21.7
Pipistrellus pygmaeus Leach, 1825	6	1.1	4	8.7
Vespertiliio murinus Linnaeus, 1758	50	8.7	7	15.2
Total	573	100	46	100

N_1—number of captured bats | N_2—number of occurrences.

and three females (Image 2). Several more animals, that hunted high above the tree crowns, were identified by their echolocation calls.

On 3 August 2020, one young female of *N. leisleri* was caught with a net on the bank of Tashkinsky pond (Figure 1, site 6).

On 29 July 2020 at the research base at Lake Mitryashki (Figure 1, site 10; Image 1a) one individual of *M. nattereri* was caught in a net. The captured animal was a post-lactating female (Image 3).

DISCUSSION

Before our research, the habitation of eight bat species was established for the territory of the National Park "Smolny" and its vicinity (Artaev & Smirnov 2016). In this study, we caught seven bat species from eight previously known. We were unable to find *Plecotus auritus* Linnaeus, 1758, which was recorded in the protected area earlier (Artaev & Smirnov 2016). Taking into account the newly-discovered *M. nattereri* and *N. leisleri*, the list of bats in the National Park "Smolny" currently includes 10 species. Despite the relatively high diversity of bats in this protected area, it still does not reach its maximum here, which is typical for the central part of European Russia. Thus, 15 species of bats have been established in the National Park "Samarskaya Luka" (Samara Oblast), located 300 km south-east (Smirnov & Vekhnik 2012). Five bat species: *Nyctalus lasiopterus* Schreber, 1780, *Pipistrellus kuhlii*, Kuhl, 1817, *Myotis mystacinus* (Kuhl, 1817), *Eptesicus nilssonii* (Keyserling & Blasius, 1839), and *Eptesicus serotinus* (Schreber, 1774) were not found in the National Park "Smolny". According to the results of long-term research, the most abundant and widespread species in the National park are *Pipistrellus nathusii*, Keyserling & Blasius, 1839 *Nyctalus noctula*, Schreber, 1774, *Myotis daubentonii*, Kuhl, 1817, *Vespertilio murinus*, Linnaeus, 1758, and *Myotis brandtii*, Eversmann, 1845 (Artaev & Smirnov 2016; this study). The high abundance of these species is common for the all territory of central Russia. For example, the results of bat studies in the National Park "Samarskaya Luka" confirm their dominance in the bat community (Smirnov & Vekhnik 2012). On the contrary, the lowest occurrence was noted for *M. nattereri, Myotis dasycneme* (Boie, 1825), and *N. leisleri* (Smirnov & Vekhnik 2012).

Myotis nattereri is also one of the rarest species, while *N. leisleri* only slightly exceeds *Pipistrellus pygmaeus* Leach, 1825 and *M. dasycneme* in the number of captured individuals (Table 1). At the same time, throughout the territory of Mordovia, *P. pygmaeus* and, especially, *M. dasycneme* dominate *N. leisleri* in occurrence and relative abundance (Artaev & Smirnov 2016). The widely distributed *N. leisleri* occurs sporadically, in colonies of 5 to 15 individuals (Smirnov & Ilyin 1997, Ivancheva & Ivanchev 2000, Ilyin et al. 2002, Kozhurina 2009). Therefore, findings of the species in local habitats can significantly affect the rates of relative abundance. All findings of *N. leisleri* are usually linked to reservoirs with old woody vegetation on the banks. We caught and detected *Nyctalus leisleri* during the first 60 minutes after sunset; therefore, the records of solitary animals at the Lake Mitryashki and the Tashkinskiy pond may indicate the absence of colonies in these sites. We assume that the animals used these territories as foraging places, having arrived here from more distant localities. On the contrary, the capture of post-lactating females and young bats in the Udalets River floodplain indicates the possible presence of a colony there.

The finding of *M. nattereri* in the National Park "Smolny" can be considered as unexpected and unique. The species summer habitats of this species are usually situated close to the wintering places (Smirnov & Vekhnik 2014). However, there are no karstic areas with possible underground cavities in the national park; hence the wintering places of this species are probably outside the protected area. The nearby places of the bat wintering grounds are situated in the Nizhny Novgorod region, about 150 km north-west and 100 km north (Bakka & Bakka 1999). It is possible that some individuals wintering there migrate to Mordovia for summertime. Flights over such distances for this species are possible

Image 2. Adult female of *Nyctalus leisleri*, trapped in Udalets River floodplain. © Dmitry Smirnov.

Image 3. Post-lactating female of *Myotis nattereri,* trapped in the vicinity of Lake Mitryashki. © Dmitry Smirnov.

and well known (Steffens et al. 2007).

Records of *M. dasycneme* in the National park "Smolny" need particular discussion. The species is included in the IUCN Red List as "Near Threatened" (NT). The vulnerability of *M. dasycneme* is due to its sporadic distribution, the specificity of the habitat selection (open calm water bodies with a large open water surface) and the vulnerability of its colonies, usually located in buildings (Piraccini 2016). This is a rare species for the National Park "Smolny". During three years of research, we caught only five individuals in two habitats: four bats in the vicinity of Lake Mitryashki and one bat in vicinity of the Obrezki village. Previously, *M. dasycneme* was recorded only in the vicinity of the Obrezki village (Artaev & Smirnov 2016).

CONCLUSION

As a result of our field studies for the fauna of Mordovia and the middle Volga region, three new habitats of two rare bat species, *Myotis nattereri* and *Nyctalus leisleri* were found for the first time in the National Park "Smolny" and should be recommended for inclusion in the Red List of the Republic of Mordovia. The capture of post-lactating females and juveniles indicates these species use this territory for breeding.

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COMMUNICATION

Avifaunal diversity in unprotected wetlands of Ayodhya District, Uttar Pradesh, India

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Abstract: Nine unprotected wetlands of Ayodhya district, Uttar Pradesh, India were studied to assess the bird species composition and richness from March 2019 to February 2020 using point count method. A total of 105 species of birds belonging to 79 genera, distributed among 35 families and 12 orders were recorded. Passeriformes had the highest diversity with 25 species and 12 families. Anatidae was the most dominant family with 15 species, constituting 14.29% of the wetland bird community in the study area. These wetlands provided habitat for 62 residential species, 42 winter migrants and one vagrant. The carnivore guild was the most dominant with 46 species. The wetland sites under study were continuously used by humans mainly for land encroachment, fishing activities and livestock grazing apart from other minor uses. Out of the nine selected wetlands, three wetlands (<2 ha) had very few bird species (≤3), therefore were excluded from further calculations. But the rest of the six selected wetlands (>5 ha) provided habitat for 12 bird species of conservation importance (one Endangered species, five Vulnerable species, and six Near Threatened species) according to the IUCN Red list. These wetlands also supported 39 species of birds having a declining population trend globally. These findings highlight the role of medium and large-sized unprotected wetlands in providing critical habitat to the birds throughout the year in Ayodhya district. Future research must concentrate on understanding the key factors influencing the presence and absence of birds in such unprotected wetlands so that these wetlands can be managed effectively to secure the potential habitat of birds.

Keywords: Birds, conservation importance, feeding guild, relative diversity index, species richness.

Hindi: बिंदु गणना पद्धति का उपयोग करके मार्च 2019 से फरवरी 2020 तक पक्षी प्रजातियों की संरचना और समृद्धि का आकलन करने के लिए अयोध्या जिले, उत्तर प्रदेश, भारत की नौ असरक्षित जलीय क्षेत्रो का अध्ययन किया गया।12 वर्गों तथा 35 कुलों से सम्बन्ध रखने वाली पक्षियों की 79 वंशो की उपस्थिति का पता चला जो कि 105 प्रजातियों को निरूपित करते है। पेसैरीफार्मिस सबसे अधिक कुल (12) और 25 पक्षी प्रजाति के साथ सबसे अधिक विविधता वाला गण था। एनाटिडे 15 प्रजातियों के साथ सबसे प्रमुख कुल था, जो अध्ययन क्षेत्र में मौजूद पक्षी समुदाय का 14.29% था। ये जलीय क्षेत्रो में 62 स्थानीय प्रजातियां, 42 शीतकालीन प्रवासी पक्षी और एक घुमन्तु पक्षी को आवास प्रदान करते है। 46 प्रजातियों के साथ मांसाहारी गिल्ड सबसे प्रमुख था। अध्ययन के तहत आने वाले जलीय क्षेत्रो का उपयोग मनुष्यों द्वारा मुख्य रूप से मछली पकड़ने, पशुओं को चराने तथा भूमि अतिक्रमण के लिए किया जाता था । नौ चयनित जलीय क्षेत्रो में से, तीन जलीय क्षेत्रो में (<2 हेक्टेयर) बहुत कम पक्षी प्रजातियां (≤3) थीं, इसलिए आगे की गणना में उन्हें नगण्य माना गया है। लेकिन शेष छह चयनित जलीय क्षेत्रो (>5 हेक्टेयर) ने आईयूसीएन रेड लिस्ट के अनुसार 12 संकटग्रस्त पक्षी प्रजातियों (एक संकटापन्न प्रजाति, पांच संवेदनशील प्रजातियों और छह संकट निकटवर्ती प्रजातियों) के लिए आवास प्रदान किया। इन जलीय क्षेत्रो ने विश्व स्तर पर घटती जनसंख्या प्रवृत्ति वाले पक्षियों की 39 प्रजातियों भी पायी गई। ये निष्कर्ष अयोध्या जिले में पूरे वर्ष पक्षियों को महत्वपूर्ण आवास प्रदान करने में मध्यम और बड़े आकार की असुरक्षित जलीय क्षेत्रो की भूमिका को उजागर करते हैं। भविष्य में किए जाने वाले अनुसंधान को ऐसी असुरक्षित जलीय क्षेत्रो में पक्षियों की उपस्थिति और अनुपस्थिति को प्रभावित करने वाले प्रमुख कारकों को समझने पर ध्यान केंद्रित करना चाहिए ताकि इन जलीय क्षेत्रो को पक्षियों के संभावित आवास को सुरक्षित करने के लिए प्रभावी ढंग से प्रबंधित किया जा सके।

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INTRODUCTION

Wetlands are transitional zones between terrestrial and aquatic ecosystems, which can be permanently or seasonally flooded but retain saturated soils throughout the unflooded period (TWI 2020). Wetlands occupy about 6% of the earth's surface, comprising bogs (30%), fens (26%), swamps (20%), and flood plains (15%) (Shine & Klemm 1999). Wetlands are highly diverse and biologically rich, providing habitats to many groups of species like waterbirds, fish, amphibians, reptiles, invertebrates, mammals, and plants. Wetlands play an important role in maintaining the hydrological cycle. The other services provided by wetlands include flood protection, water purification and recreational opportunities (Woodward & Wui 2001). Birds are an inseparable entity in wetland ecosystems as they play an important role in nutrient recycling and occupy different trophic levels in the food web (Custer & Osborn 1977; Rajashekara & Venkatesha 2010). Birds also act as useful bio-indicators reflecting the ecological health of the wetland ecosystems (Custer & Osborn 1977). Wetlands are important for resident as well as migratory birds as they provide them with foraging, breeding, & nesting habitats and sometimes also serve as stopover sites (Kumar et al. 2016). India has around 4.7% of the total geographical area of the country under wetlands (Bassi et al. 2014). Nearly 310 bird species are reported to be wetland dependent in India (Kumar et al. 2005). Uttar Pradesh has 12,42,530 ha of area under wetlands, i.e., 5.16% of the total geographical area, whereas Ayodhya district has 23,050 ha, i.e., 1.86% of land under wetlands (NWA 2010). Many wetlands in this region are under threat due to anthropogenic pressure like conversion of wetlands into agricultural lands or for commercial fishing purposes, fertilizers run-offs from surrounding agricultural lands, hunting, unsustainable harvest of wetland resources, invasion of alien species, eutrophication, extraction of edible nuts of *Trapa natans*, pumping out water for agricultural purposes (Yashmita-Ulman pers. Comm. February 2020) thus, threatening the very existence of the resident and migratory wetland birds. Unprotected wetlands defined as those wetlands which have no official protection or conservation status and are also open for public use (Blanckenberg et al. 2020), are usually ignored, but such wetlands too provide the required habitat to the birds. So, to understand the anthropogenic impacts on wetland birds and their habitat in the future, it is necessary to have a baseline information on the species occurrences and habitat choices. Such information will also help in long term monitoring of the habitat and preparing conservation and management strategies for the species as well as their habitat. This exercise will also highlight the ecological health of the wetlands. The bird species checklist thus generated will provide a base for further research.

The state of Uttar Pradesh has been reported to host 528 bird species (eBird 2021). It has eight wetlands listed under Ramsar Sites, which is the highest in India as compared to any other state. In addition to this, the state has many unprotected wetlands. But most of the studies on biodiversity in wetlands of Uttar Pradesh are concentrated on Ramsar and protected wetland sites. Studies have been conducted on plant diversity (Reddy et al. 2009), land-use changes (Behera et al. 2012) in Samaspur Bird Sanctuary, Rae Bareli, on plant diversity (Jha 2013) in Sandi Bird Sanctuary, Hardoi, and on butterfly diversity (Sharma 2007), medicinal plant diversity (Rani et al. 2009) & water quality monitoring (Gopal et al. 2015) in Sur Sarovar wetlands. There has been a study on bird diversity in agricultural landscapes of Ayodhya district (Yashmita-Ulman & Singh 2021), but there are no studies on wetlands of this district. As most of the wetlands present in Ayodhya district are either isolated, disturbed, unprotected or not designated as Ramsar sites, the inventories of these wetlands have not been done so far. So, this study is the first attempt to prepare a checklist of birds present in some selected unprotected wetlands of Ayodhya district.

MATERIALS AND METHODS

Study Area

Depending upon factors like easy accessibility and financial feasibility, three tehsils namely, Milkipur, Sohawal and Sadar of Ayodhya district (Figure 1) were chosen for the survey. Regular monitoring of the selected wetlands in these tehsils was possible as these tehsils fell in the daily commute route of the authors, i.e., from Rikabganj (Sadar tehsil) to Acharya Narendra Deva University of Agriculture and Technology (Milkipur tehsil) via NH 330A. The areas under these three tehsils were thoroughly searched for the presence of wetlands through google maps. Once the wetlands were identified, the areas were visited for ground truthing and preliminary bird survey. Depending on the presence of motorable roads, preliminary bird surveys and information from local people, a total of nine wetlands, three from each tehsil were selected for monthly bird surveys. Out of these nine wetlands, three wetlands

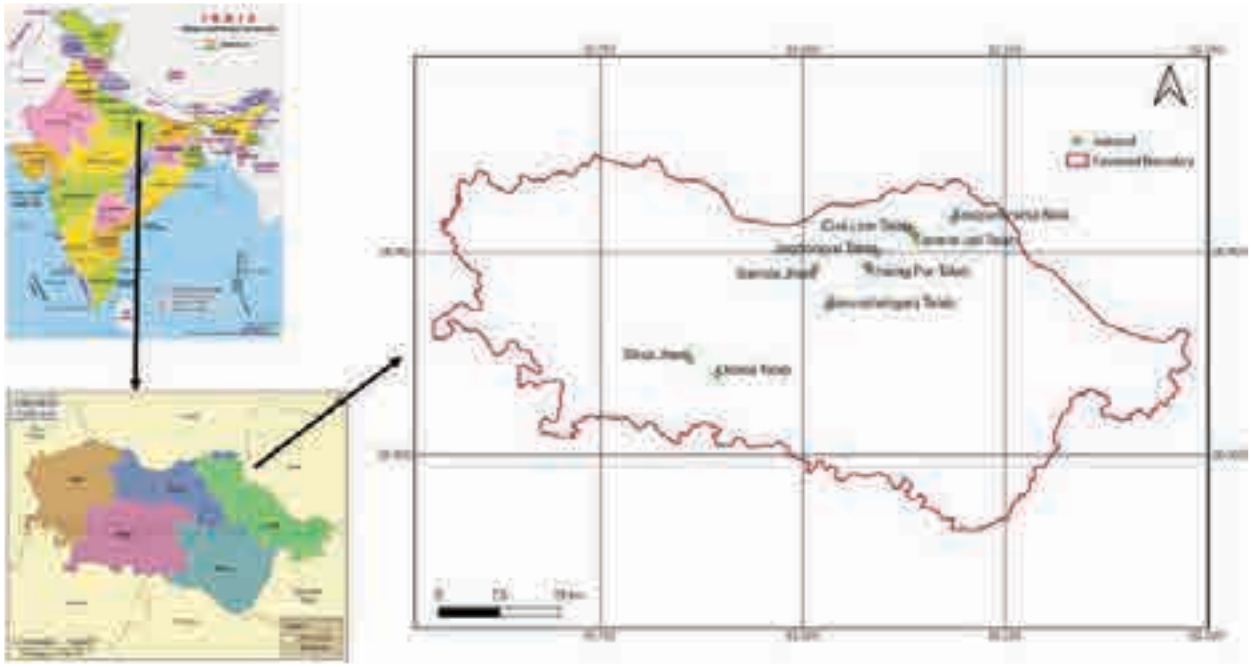

Figure 1. The study area and study locations.

(<2 ha) supported very few bird species (≤3) and that too on an irregular basis (Table 1). So, data from these wetlands was not included in further analysis to avoid discrepancies in results. Therefore, this study reports the analyzed results only from six unprotected wetlands, three from Milkipur tehsil (Udaila Talab (Figure 1 & Image 1a), Sirsa Jheel (Figure 1 & Image 1b), & Barunshahganj Talab (Figure 1 & Image 1c); two from Sohawal tehsil (Jagdishpur Talab (Figure 1 & Image 1d) & Samda Jheel (Figure 1 & Image 1e); and one from Sadar tehsil (Kosiparikrama Nallah (Figure 1,2f) of Ayodhya district, Uttar Pradesh.

Ayodhya district is situated between 26.7730 °N and 82.1458 °E, and has an elevation of 93 m (KVK 2021). This district has an area of around 2,764 km^2 (KVK 2021). Ayodhya city is situated on the banks of the river Ghagra locally known as 'Saryu'. The climate is humid (Kumar 2018) and experiences summer season from March to June, rainy season from July to October and winter season from November to February (Sundar & Kittur 2012). The annual rainfall of the district is around 1,067 mm. The average temperature is 32 ^{0}C during summer season and 16 ^{0}C during winter season (KVK 2021). *Oryza sativa – Triticum aestivum* is the main cropping system. *Saccharum officinarum* and *Brassica juncea* are also grown in the area along with horticultural crops (*Mangifera indica, Psidium guajava, Phyllanthus emblica*, and *Musa* sp.) (KVK 2021). The detailed description of the selected unprotected wetlands is given in Table 1.

Methods

Bird surveys were conducted monthly using point-count method (Bibby et al. 2000) in the selected study sites from March 2019 to February 2020. Two point counts were fixed on the perimeter of each wetland making a total of 18 point counts in the whole district. In the same wetland the distance between the two point counts was at least 250 m. Each point count was surveyed 24 times during the entire study duration. After arriving at each point count, the observations of the initial 5 mins were not recorded giving time for the birds to settle down. After the initial 5 mins, bird species were recorded for the next 15 mins at the same point. During winters, fog conditions affected visibility early in the morning, so the observations were made whenever visibility was good (usually between 1000 to 1230 h) and for the rest of the seasons survey was conducted between 0600 to 0830 h. Birds were recorded directly with the help of field binoculars (Nikon 7x35). On each sighting, the details such as, species name, number of individuals and habitat were recorded. Birds flying across were not counted. The opportunistic counts were also recorded during other times of the day by scanning the periphery or banks of the wetlands. Grimmett et al. (2011) was used for bird identification and for knowing the residential status of birds (residents, winter visitor,

Image 1. Some of the selected unprotected wetland sites for study: a—Udaila Talab | b—Sirsa Jheel | c—Barunshahganj Talab | d—Jagdishpur Jheel | e—Samda Jheel | f—Kosiparikrama Nallah. © Authors.

summer visitor). Praveen et al. (2020) was followed for the taxonomic position and names. The classification of birds into major feeding guilds was done using Ali & Ripley (1987) and field observations. The IWPA (1972) and CITES (2012) were followed for assigning the conservation status of species. The Red List of IUCN (2021) was followed to compile the conservation status and the global population trend (decreasing, increasing, stable, unknown) of the recorded species.

Species richness was calculated as total number of bird species recorded in the study area.

The following community parameters were calculated using the below given formulae:

[i] Relative diversity of bird families (RDi) (Torre-Cuadros et al. 2007)

$$RDi = \frac{\text{Number of bird species in a family}}{\text{Total number of species}} \times 100$$

[ii] Shannon Weiner index (Shannon & Weiner 1963)

$$H' = \sum_{i=1}^{s} p_i \ln p_i$$

where, p_i is often the proportion of individuals

belonging to the 'i'th species in the dataset and 's' is the species richness. The values usually lies between 1 and 4 where 1 shows less diversity and 4 shows high diversity.

[iii] Margalef Richness Index (Margalef 1958)

$$\text{Margalef Richness Index (D)} = \frac{S-1}{\text{Log (n)}}$$

where, 'S' is the total number of species and 'n' is the total number of individuals in the sample.

[iv] Simpson's index (Simpson 1949)

This was calculated according to Simpson (1949) to measure the concentration of dominance (CD) of bird species.

$$CD = \sum_{i=1}^{s} (pi)^2$$

where pi is the proportion of the Importance Value Index (IVI) of the 'i'th species and IVI of all the species (ni/N). The values of Simpson's index is limited to 1 where 1 shows dominance by a single species.

[v] Pielou's evenness index (Pielou 1966) = H'/ $\log_{10}$N(S)

where H' is the Shanon Weiner Index of diversity and S is the total number of species.

This index ranges from 0 (no evenness) to 1 (complete evenness).

[vi] Sorenson's similarity coefficient (Sorenson 1948)

$$\text{Sorenson similarity coefficient} = \frac{2C}{A+B}$$

where C is the number of species common to both sites, A is the total number of species in site A, and B is the total number of species in site B. Sorenson's coefficient gives a value between 0 and 1, the closer the value is to 1, the more the communities have in common.

RESULTS

Out of nine wetlands, three wetlands (<2 ha) had very few bird species (≤3) and that too on an irregular basis and were not considered in calculations to avoid discrepancies in results (Table 1). A total of 105 species of birds belonging to 79 genera, distributed among 35 families and 12 orders were recorded from the six unprotected wetlands of Ayodhya district, Uttar Pradesh during the study period (Table 2). Out of 105 species found, 73 species were wetland-associated and 32 species were terrestrial. Among the recorded bird species, 45 species (42.85%) were found commonly at all the six unprotected wetlands and 60 species (57.14%) were found at specific unprotected wetlands sites (Table 2). Passeriformes had the highest diversity with 25 species and 12 families, followed by Charadriiformes with 22 species from eight families (Figure 3). Anatidae was the most dominant family with 15 species and the highest RDi value (14.29) (Table 3). This was followed by Accipitridae with 10 species (Figure 2). Acrocephalidae, Alaudidae, Anhingidae, Columbidae, Dicruridae, Falconidae, Glareolidae, Gruidae, Laridae, Leiothrichidae, Pandionidae, Passeridae, Phylloscopidae, Recurvirostridae, Rostratulidae were represented by just a single genus and were the least represented (Figure 2).

Of all the bird species recorded, 62 species (59.05%) were resident, 42 species (40.00%) were winter visitors and one species (0.95%) was vagrant. As far as the foraging habit of the bird community in the selected wetland sites were concerned, five major feeding guilds were identified (Figure 3). The carnivore guild was the most dominant with 46 species (43.81%), followed by omnivore 42 species (40.00%), insectivore 15 species (14.29%) and frugivore and granivore with one species each (0.95%) (Figure 3). The maximum number of bird species were recorded in the months of January and February (89 each) and the least was recorded in the month of August (Figure 4). The unprotected wetland sites of Ayodhya district supported one Endangered species—*Aquila nipalensis*, five Vulnerable species—*Antigone antigone, Aquila rapax, Aythya ferina, Clanga hastata*, & *Sterna aurantia*, and six Near Threatened species—*Anhinga melanogaster, Ciconia episcopus, Mycteria leucocephala, Vanellus duvaucelii, Esacus recurvirostris*, & *Threskiornis melanocephalus* (Table 2). Moreover, these wetlands supported 39 species (37.14%) of birds having a declining population trend globally (Table 2).

The Shannon-Weiner index and Margalef richness index across the six unprotected wetland sites revealed that Udaila Talab was the most diverse and species rich wetland (3.86, 26.94) with 92 species (Table 4). This was followed by Samda Jheel (3.82, 25.41), Sirsa Jheel (3.80, 24.52), Jagdishpur Jheel (3.63, 23.66), Kosiparikrama Nallah (3.62, 23.82). Barunshahganj Talab (3.55, 22.59) was found to be the least diverse of all (Table 4). All the wetlands showed diverse species and no single species showed dominancy (Table 4). The similarity in species composition of birds was measured using Sorenson's similarity index (Table 5), the results of which highlighted that Udaila Talab and Samda Jheel showed the highest similarity (0.91) in bird communities, followed by Udaila Talab and Sirsa Jheel (0.89) and Samda Jheel and Sirsa Jheel (0.88) (Table 5). The least bird species similarity was shown between Jagdishpur Jheel and Kosiparikrama Nallah (0.76) (Table 5).

Table 1. Brief description about the surveyed unprotected wetlands of Ayodhya district, Uttar Pradesh, India.

	Name of wetland	Name of tehsil	Co-ordinates	Size (ha)	Features	Species (No. of individuals) observed	Remark
1	Udaila Talab	Milkipur	26.59822° N 81.8937° E	62	This wetland is surrounded by main road on one side and agricultural land on the other side. There are aquatic plants and trees surrounding the wetland. The undulating topography has created many natural bunds in this wetland which are used as resting sites by the birds. Fishing and cattle grazing activities are carried out in this wetland. This is a stagnant water body.	92 (2381)	Data included in analysis
2	Sirsa Jheel	Milkipur	26.6174° N 81.86063° E	90	This wetland is surrounded by agricultural land and human habitation. The wetland is also surrounded by trees and bushes in its vicinity and has abundant aquatic weeds supporting aquatic zooplankton. This is a stagnant water body.	81 (1828)	Data included in analysis
3	Barun-shahganj Talab	Milkipur	26.68102° N 82.03081° E	13.3	This wetland is surrounded by human habitations on one side and agricultural land on other side and lies adjacent to state highway NH 330A. The wetland is also surrounded by trees and bushes and has abundant aquatic weeds supporting aquatic zooplankton. This wetland is used for fishing and irrigation purposes. This is a stagnant water body.	72 (1387)	Data included in analysis
4	Samda Jheel	Sohawal	26.789° N 82.185° E	78	This wetland is surrounded by agricultural land and is bisected by a road. The bisecting road on both the sides is lined with trees and the wetland is also surrounded with trees and bushes and has plenty of aquatic weeds. The forest department has recently developed raised platforms or bunds to provide artificial resting and nesting sites for the wetland birds. This is a stagnant water body.	85 (2019)	Data included in analysis
5	Jagdishpur Talab	Sohawal	26.732° N 82.018° E	12.6	This wetland is surrounded by agricultural land on one side and human habitation on the other side. This wetland has trees planted on its periphery and has abundant aquatic weeds. The water from this wetland is used for irrigation purposes. This wetland is being encroached upon for paddy cultivation. It is used for extraction of edible nuts of *Trapa natans*. This is a stagnant water body.	78 (1796)	Data included in analysis
6	Kharagpur Talab	Sohawal	26.73324° N 82.07941° E	1.10	This wetland is surrounded by agricultural fields from three sides and a village road on one side. Fishing and cattle grazing activities are carried out in this wetland. This is a stagnant water body.	*Bubulcus ibis* (8) *Vanellus indicus* (4)	Data excluded from analysis
7	Kosipari-krama Nallah	Sadar	26.74853° N 82.09177° E	6.38	This wetland is surrounded by main road (Kosi-Parikrama road) on one side and *Psidium guajava* orchard on the other side. This wetland in some parts has high abundance of aquatic weeds and reeds, but in some areas is devoid of aquatic vegetation as it has been cleared for fishing purposes. This wetland is also used for cattle grazing and some area is being encroached upon for conversion into agricultural land. The Nallah primarily is used to dump the sewage of the city and finally meets with the Saryu river. This is a flowing water body.	76 (1404)	Data included in analysis
8	Central Jail Talab	Sadar	26.77113° N 82.13801° E	0.69	This wetland is surrounded by the District Jail on one side, plantation on two sides. A railway track is also present on one side of this wetland creating high noise levels. This wetland is used by the locals for fishing activities. This wetland has abundant aquatic weeds. This is a stagnant water body.	*Bubulcus ibis* (8) *Microcarbo niger* (5)	Data excluded from analysis
9	Civil Line Talab	Sadar	26.77586° N 82.13421° E	1.75	This wetland is surrounded by human settlements (residential and commercial) on all sides creating high noise levels. This is a stagnant water body.	*Bubulcus ibis* (6) *Microcarbo niger* (7)	Data excluded from analysis

Table 2. Checklist and status of avifauna recorded in unprotected wetlands of Ayodhya district, Uttar Pradesh, India

	Order/Family/ Common name	Scientific name	Residential status	Feeding guild	Conservation status			Global status	Wetland sites						Plate No.
					IUCN (2021)	CITES (2012)	IWPA (1972)		UDT	SDJ	SSJ	JDJ	KPN	BST	
Accipitriformes Accipitridae (10)															
1	Black Kite	*Milvus migrans* (Boddaert, 1783)	R	C	LC	II	I	→	√	√	√	√	√	√	
2	Black-winged Kite	*Elanus caeruleus* (Desfontaines, 1789)	R	C	LC	II	I	→	√	√	√	√	√	√	
3	Indian Spotted Eagle	*Clanga hastata* (Lesson, 1831)	R	C	VU	II	I	↓	√	√	×	√	×	×	
4	Long-legged Buzzard	*Buteo rufinus* (Cretzschmar, 1829)	WV	C	LC	II	I	→	√	√	√	×	×	×	
5	Oriental Honey Buzzard	*Pernis ptilorhynchus* (Temminck, 1821)	R	C	LC	II	I	↓	√	√	√	×	√	√	
6	Shikra	*Accipiter badius* (Gmelin, 1788)	R	C	LC	II	I	→	√	√	√	√	√	√	
7	Steppe Eagle	*Aquila nipalensis* (Hodgson, 1833)	WV	C	EN	II	I	↓	√	√	√	×	√	×	
8	Tawny Eagle	*Aquila rapax* (Temminck, 1828)	R	C	VU	II	I	↓	×	×	×	√	×	×	
9	Western Marsh Harrier	*Circus aeruginosus* (Linnaeus, 1758)	WV	C	LC	II	I	→	√	√	×	×	√	×	
10	White-eyed Buzzard	*Butastur teesa* (Franklin, 1831)	R	C	LC	II	I	→	√	√	√	×	√	√	
Pandionidae (1)															
11	Osprey	*Pandion haliaetus* (Linnaeus, 1758)	WV	C	LC	II	I	↑	√	×	√	√	×	√	
Anseriformes Anatidae (15)															
12	Bar-headed Goose	*Anser indicus* (Latham, 1790)	WV	O	LC	-	IV	↓	√	√	×	√	√	×	
13	Common Pochard	*Aythya ferina* (Linnaeus, 1758)	WV	O	VU	-	IV	↓	√	×	√	×	×	×	
14	Common Teal	*Anas crecca* (Linnaeus, 1758)	WV	O	LC	-	IV	?	√	√	×	×	×	×	
15	Cotton Pygmy-goose	*Nettapus coromandelianus* (Gmelin, 1789)	R	O	LC	-	IV	→	√	√	√	√	√	√	
16	Gadwall	*Mareca strepera* (Linnaeus, 1758)	WV	O	LC	-	IV	↑	×	√	√	×	√	×	
17	Garganey	*Spatula querquedula* (Linnaeus, 1758)	WV	O	LC	-	IV	↓	×	×	√	√	×	√	
18	Graylag Goose	*Anser anser* (Linnaeus, 1758)	WV	O	LC	-	IV	↑	√	√	×	×	×	×	
19	Indian Spot-billed Duck	*Anas poecilorhyncha* (Forster, 1781)	R	O	LC	-	IV	↓	√	√	√	√	√	√	
20	Knob-billed Duck	*Sarkidiornis melanotos* (Pennant, 1769)	R	O	LC	II	IV	↓	√	√	√	×	√	×	
21	Lesser Whistling Duck	*Dendrocygna javanica* (Horsfield, 1821)	R	O	LC	-	IV	↓	√	√	√	√	√	√	
22	Mallard	*Anas platyrhynchos* (Linnaeus, 1758)	WV	O	LC	-	IV	↑	×	×	×	×	√	×	
23	Northern Pintail	*Anas acuta* (Linnaeus, 1758)	WV	O	LC	-	IV	↓	√	√	√	√	√	×	
24	Northern Shoveler	*Spatula clypeata* (Linnaeus, 1758)	WV	O	LC	-	IV	↓	√	√	√	×	√	×	
25	Ruddy Shelduck	*Tadorna ferruginea* (Pallas, 1764)	WV	O	LC	-	IV	?	√	√	√	×	√	×	

	Order/Family/ Common name	Scientific name	Residential status	Feeding guild	Conservation status			Global status	Wetland sites						Plate No.
					IUCN (2021)	CITES (2012)	IWPA (1972)		UDT	SDJ	SSJ	JDJ	KPN	BST	
26	Tufted Duck	*Aythya fuligula* (Linnaeus, 1758)	WV	O	LC	-	IV	→	×	×	√	×	×	×	
Charadriiformes Burhinidae (2)															
27	Eurasian Thick-knee	*Burhinus oedicnemus* (Linnaeus, 1758)	R	O	LC	-	IV	↓	√	√	√	√	√	√	
28	Great Thick-knee	*Esacus recurvirostris* (Cuvier, 1829)	R	C	NT	-	IV	↓	√	√	√	√	×	×	
Charadriidae (6)															
29	Grey-headed Lapwing	*Vanellus cinereus* (Blyth, 1842)	WV	C	LC	-	IV	↓	√	√	×	×	×	×	
30	Kentish Plover	*Charadrius alexandrinus* (Linnaeus, 1758)	WV	C	LC	-	IV	↓	×	×	×	√	√	√	
31	Little Ringed Plover	*Charadrius dubius* (Scopoli, 1786)	R	O	LC	-	IV	→	√	√	√	√	√	√	
32	Red-wattled Lapwing	*Vanellus indicus* (Boddaert, 1783)	R	O	LC	-	IV	?	√	√	√	√	√	√	1a
33	River Lapwing	*Vanellus duvaucelii* (Lesson, 1826)	R	C	NT	-	IV	↓	√	√	√	√	√	√	
34	Yellow-wattled Lapwing	*Vanellus malabaricus* (Boddaert, 1783)	R	C	LC	-	IV	→	√	√	√	√	√	√	
Glareolidae (1)															
35	Small Pratincole	*Glareola lactea* (Temminck, 1820)	R	I	LC	-	IV	?	√	√	×	×	×	×	
Jacanidae (2)															
36	Bronze-winged Jacana	*Metopidius indicus* (Latham, 1790)	R	O	LC	-	IV	?	√	√	√	√	√	√	1b
37	Pheasant-tailed Jacana	*Hydrophasianus chirurgus* (Scopoli, 1786)	R	O	LC	-	IV	↓	√						
Laridae (1)															
38	River Tern	*Sterna aurantia* (Gray, 1831)	R	C	VU	-	IV	↓	√	√	√	√	×	×	
Recurvirostridae (1)															
39	Black-winged Stilt	*Himantopus himantopus* (Linnaeus, 1758)	WV	C	LC	-	IV	↑	√	√	√	√	√	√	1c
Rostratulidae (1)															
40	Greater Painted-snipe	*Rostratula benghalensis* (Linnaeus, 1758)	R	O	LC	-	IV	↓	√	√	√	√	√	√	
Scolopacidae (8)															
41	Common Greenshank	*Tringa nebularia* (Gunnerus, 1767)	WV	C	LC	-	IV	→	√	√	√	√	√	√	
42	Common Redshank	*Tringa totanus* (Linnaeus, 1758)	WV	C	LC	-	IV	?	√	√	√	√	√	√	
43	Common Sandpiper	*Actitis hypoleucos* (Linnaeus, 1758)	WV	C	LC	-	IV	↓	√	√	√	√	√	√	
44	Common Snipe	*Gallinago gallinago* (Linnaeus, 1758)	WV	O	LC	-	IV	↓	×	×	×	×	√	√	
45	Green Sandpiper	*Tringa ochropus* (Linnaeus, 1758)	WV	O	LC	-	IV	↑	√	√	√	√	×	√	
46	Little Stint	*Calidris minuta* (Leisler, 1812)	WV	O	LC	-	IV	↑	×	×	×	√	×	×	
47	Temminck's Stint	*Calidris temminckii* (Leisler, 1812)	WV	O	LC	-	IV	?	√	√	√	√	√	√	

	Order/Family/ Common name	Scientific name	Residential status	Feeding guild	Conservation status			Global status	Wetland sites						Plate No.
					IUCN (2021)	CITES (2012)	IWPA (1972)		UDT	SDJ	SSJ	JDJ	KPN	BST	
48	Wood Sandpiper	*Tringa glareola* (Linnaeus, 1758)	WV	O	LC	-	IV	→	√	√	√	√	×	√	
Columbiformes Columbidae (1)															
49	Yellow-footed Green-pigeon	*Treron phoenicopterus* (Latham, 1790)	R	F	LC	-	IV	↑	√	√	√	√	×	√	
Coraciiformes Alcedinidae (4)															
50	Common Kingfisher	*Alcedo atthis* (Linnaeus, 1758)	R	C	LC	-	IV	?	√	√	√	√	√	√	
51	Pied Kingfisher	*Ceryle rudis* (Linnaeus, 1758)	R	C	LC	-	IV	?	√	√	√	√	√	√	
52	Stork-billed Kingfisher	*Pelargopsis capensis* (Linnaeus, 1766)	R	C	LC	-	IV	↓	√						
53	White-throated Kingfisher	*Halcyon smyrnensis* (Linnaeus, 1758)	R	C	LC	-	IV	↑	√	√	√	√	√	√	
Falconiformes Falconidae (1)															
54	Common Kestrel	*Falco tinnunculus* (Linnaeus, 1758)	WV	C	LC	II	IV	↓	√	×	√	√	√	×	1g
Gruiformes Gruidae (1)															
55	Sarus Crane	*Antigone antigone* (Linnaeus, 1758)	R	O	VU	-	IV	↓	√	√	√	√	×	√	1h
Rallidae (5)															
56	Common Coot	*Fulica atra* (Linnaeus, 1758)	R	O	LC	-	IV	↑	√	√	√	√	√	√	
57	Common Moorhen	*Gallinula chloropus* (Linnaeus, 1758)	R	O	LC	-	IV	→	√	√	√	√	√	√	
58	Purple Swamphen	*Porphyrio porphyrio* (Linnaeus, 1758)	R	O	LC	-	IV	?	√	√	√	√	√	√	2a
59	Watercock	*Gallicrex cinerea* (Gmelin, 1789)	R	C	LC	-	IV	↓	√	√	×	√	√	√	
60	White-breasted Waterhen	*Amaurornis phoenicurus* (Pennant, 1769)	R	O	LC	-	IV	?	√	√	√	√	√	√	2b
Passeriformes Acrocephalidae (1)															
61	Blyth's Reed Warbler	*Acrocephalus dumetorum* (Blyth, 1849)	WV	O	LC	-	IV	↑	√	√	×	√	√	√	
Alaudidae (1)															
62	Sand Lark	*Alaudala raytal* (Blyth, 1845)	R	O	LC	-	IV	→	√	√	√	√	√	√	
Cisticolidae (2)															
63	Ashy Prinia	*Prinia socialis* (Sykes, 1832)	R	I	LC	-	IV	→	√	√	√	√	×	√	2c
64	Plain Prinia	*Prinia inornata* (Sykes, 1832)	R	I	LC	-	IV	→	√	√	√	√	×	×	2d
Dicruridae (1)															
65	Black Drongo	*Dicrurus macrocercus* (Vieillot, 1817)	R	C	LC	-	IV	?	√	√	√	√	√	√	
Estrildidae (2)															
66	Indian Silverbill	*Euodice malabarica* (Linnaeus, 1758)	R	G	LC	-	IV	→	√	√	√	×	√	√	

	Order/Family/ Common name	Scientific name	Residential status	Feeding guild	Conservation status			Global status	Wetland sites						Plate No.
					IUCN (2021)	CITES (2012)	IWPA (1972)		UDT	SDJ	SSJ	JDJ	KPN	BST	
67	Scaly-breasted Munia	*Lonchura punctulata* (Linaeus, 1758)	R	O	LC	-	IV	→	√	√	√	√	×	√	
Hirundinidae (4)															
68	Barn Swallow	*Hirundo rustica* (Linnaeus, 1758)	WV	I	LC	-	IV	↓	×	×	×	√	√	√	
69	Plain Martin	*Riparia paludicola* (Vieillot, 1817)	R	I	LC	-	IV	↓	√	√	√	×	√	√	
70	Streak-throated Swallow	*Petrochelidon fluvicola* (Blyth, 1855)	R	I	LC	-	IV	↑	√	√	√	√	√	√	
71	Wire-tailed Swallow	*Hirundo smithii* (Leach, 1818)	R	I	LC	-	IV	↑	√	√	√	√	√	√	
Leiothrichidae (1)															
72	Common Babbler	*Argya caudata* (Dumont, 1823)	R	O	LC	-	IV	→	√	√	√	√	√	×	
Motacillidae (5)															
73	Citrine Wagtail	*Motacilla citreola* (Pallas, 1776)	WV	I	LC	-	IV	↑	√	×	√	√	√	√	
74	Grey Wagtail	*Motacilla cinerea* (Tunstall, 1771)	WV	I	LC	-	IV	→	×	√	×	√	×	×	
75	Western Yellow Wagtail	*Motacilla flava* (Linnaeus, 1758)	WV	I	LC	-	IV	↓	√	×	√	√	√	√	
76	White Wagtail	*Motacilla alba* (Linnaeus, 1758)	WV	I	LC	-	IV	→	√	√	√	×	√	√	
77	White-browed Wagtail	*Motacilla maderaspatensis* (Gmelin, 1789)	R	I	LC	-	IV	→	√	√	√	√	√	√	
Muscicapidae (2)															
78	Black Redstart	*Phoenicurus ochruros* (Gmelin, 1774)	WV	I	LC	-	IV	↑	√	×	×	√	√	√	
79	Bluethroat	*Luscinia svecica* (Linnaeus, 1758)	WV	I	LC	-	IV	→	√	√	×	×	×	×	2f
Passeridae (1)															
80	House Sparrow	*Passer domesticus* (Linnaeus, 1758)	R	O	LC	-	IV	↓	√	√	√	√	√	×	
Phylloscopidae (1)															
81	Hume's Warbler	*Phylloscopus humei* (Brooks, 1878)	WV	I	LC	-	IV	→	×	×	×	×	√	×	
Sturnidae (4)															
82	Asian Pied Starling	*Gracupica contra* (Linnaeus, 1758)	R	O	LC	-	IV	↑	√	√	√	√	√	√	
83	Bank Myna	*Acridotheres ginginianus* (Latham, 1790)	R	O	LC	-	IV	↑	√	√	√	√	√	√	
84	Brahminy Starling	*Sturnia pagodarum* (Gmelin, 1789)	R	O	LC	-	IV	?	√	×	×	√	√	√	
85	Common Myna	*Acridotheres tristis* (Linnaeus, 1766)	R	O	LC	-	IV	↑	√	√	√	√	√	√	
Pelecaniformes Anhingidae (1)															
86	Oriental Darter	*Anhinga melanogaster* (Pennant, 1769)	WV	O	NT	-	IV	↓	√	√	√	√	×	√	
Ardeidae (8)															
87	Black-crowned Night Heron	*Nycticorax nycticorax* (Linnaeus, 1758)	R	O	LC	-	IV	↓	√	√	√	√	√	√	

	Order/Family/ Common name	Scientific name	Residential status	Feeding guild	Conservation status			Global status	Wetland sites						Plate No.
					IUCN (2021)	CITES (2012)	IWPA (1972)		UDT	SDJ	SSJ	JDJ	KPN	BST	
88	Cattle Egret	*Bubulcus ibis* (Linnaeus, 1758)	R	C	LC	-	IV	↑	√	√	√	√	√	√	
89	Great Egret	*Ardea alba* (Linnaeus, 1758)	R	C	LC	-	IV	?	√	√	√	√	√	√	
90	Grey Heron	*Ardea cinerea* (Linnaeus, 1758)	WV	C	LC	-	IV	?	√	×	×	√	√	×	2f
91	Indian Pond Heron	*Ardeola grayii* (Sykes, 1832)	R	C	LC	-	IV	?	√	√	√	√	√	√	
92	Intermediate Egret	*Ardea intermedia* (Wagler, 1829)	R	C	LC	-	IV	↓	√	√	√	√	×	√	
93	Little Egret	*Egretta garzetta* (Linnaeus, 1766)	R	C	LC	-	IV	↑	√	√	√	√	√	√	
94	Purple Heron	*Ardea purpurea* (Linnaeus, 1766)	R	C	LC	-	IV	↓	√	√	√	√	√	√	2g
Ciconiidae (3)															
95	Asian Openbill	*Anastomus oscitans* (Boddaert, 1783)	R	C	LC	-	IV	?	√	√	√	√	√	√	1d
96	Painted Stork	*Mycteria leucocephala* (Pennant, 1769)	WV	C	NT	-	IV	↓	√	×	√	√	×	×	1f
97	Woolly-necked Stork	*Ciconia episcopus* (Boddaert, 1783)	R	C	NT	-	IV	↓	√	√	√	×	√	√	1e
Phalacrocoracidae (2)															
98	Indian Cormorant	*Phalacrocorax fuscicollis* (Stephens, 1826)	WV	C	LC	-	IV	?	√	√	√	√	×	√	
99	Little Cormorant	*Microcarbo niger* (Vieillot, 1817)	R	C	LC	-	IV	?	√	√	√	√	√	√	
Threskiornithidae (2)															
100	Black-headed Ibis	*Threskiornis melanocephalus* (Latham, 1790)	V	C	NT	-	IV	↓	×	√	√	×	√	√	2h
101	Red-naped Ibis	*Pseudibis papillosa* (Temminck, 1824)	WV	C	LC	-	IV	↓	√	√	√	√	√	√	
Phoenicopteriformes Podicipedidae (2)															
102	Great Crested Grebe	*Podiceps cristatus* (Linnaeus, 1758)	WV	C	LC	-	IV	?	×	√	×	×	√	×	
103	Little Grebe	*Tachybaptus ruficollis* (Pallas, 1764)	R	C	LC	-	IV	↓	√	√	√	√	√	√	
Strigiformes Strigidae (2)															
104	Jungle Owlet	*Glaucidium radiatum* (Tickell, 1833)	R	C	LC	-	IV	→	√	√	√	√	√	√	
105	Spotted Owlet	*Athene brama* (Temminck, 1821)	R	C	LC	II	IV	→	√	√	√	√	√	√	

IUCN: International Union for Conservation of Nature and Natural Resources; CITES: Convention on International Trade in Endangered Species of Wild Fauna and Flora; IWPA: Indian Wildlife Protection Act; R: Resident, WV: Winter Visitor, V: Vagrant; C: Carnivorous; O: Omnivorous; I: Insectivorous; F: Frugivorous; G: Granivorous; LC: Least Concern; EN: Endangered; VU: Vulnerable; NT: Near Threatened; CITES II: Appendix-II species of CITES are the ones that are not necessarily threatened now with extinction but may become so unless trade is closely controlled; IWPA I: Schedule - I species of IWPA (high priority species); IV: Schedule - IV species of IWPA (relatively low priority species); ?: Unknown; →: Stable; ↑: Increasing; ↓: Decreasing; UDT: Udaila Talab; SDJ: Samda Jheel; SSJ: Sirsa Jheel; JDJ: Jagdishpur Jheel; KPN: Kosiparikrama Nallah; BST: Barunshahganj Talab; √: Species recorded in the site; ×: Species not recorded in the site.

Table 3. Relative diversity (Rdi) of various avian families in unprotected wetlands of Ayodhya district, Uttar Pradesh, India

Avian family	Number of species recorded	Rdi value
Anatidae	15	14.29
Accipitridae	10	9.52
Ardeidae	9	8.57
Scolopacidae	8	7.62
Charadriidae	6	5.71
Rallidae	5	4.76
Motacillidae	5	4.76
Alcedinidae	4	3.81
Hirundinidae	4	3.81
Sturnidae	4	3.81
Ciconiidae	3	2.86
Burhinidae	2	1.90
Jacanidae	2	1.90
Cisticolidae	2	1.90
Estrildidae	2	1.90
Muscicapidae	2	1.90
Phalacrocoracidae	2	1.90
Threskiornithidae	2	1.90
Podicipedidae	2	1.90
Strigidae	2	1.90
Pandionidae	1	0.95
Glareolidae	1	0.95
Laridae	1	0.95
Recurvirostridae	1	0.95
Rostratulidae	1	0.95
Columbidae	1	0.95
Falconidae	1	0.95
Gruidae	1	0.95
Acrocephalidae	1	0.95
Alaudidae	1	0.95
Dicruridae	1	0.95
Leiothrichidae	1	0.95
Passeridae	1	0.95
Phylloscopidae	1	0.95
Anhingidae	1	0.95

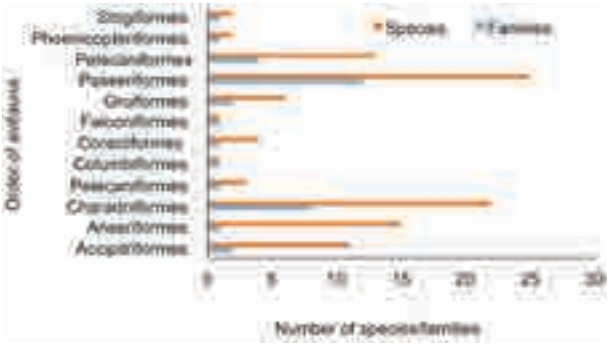

Figure 2. Composition of avian community in unprotected wetlands of Ayodhya district, Uttar Pradesh, India.

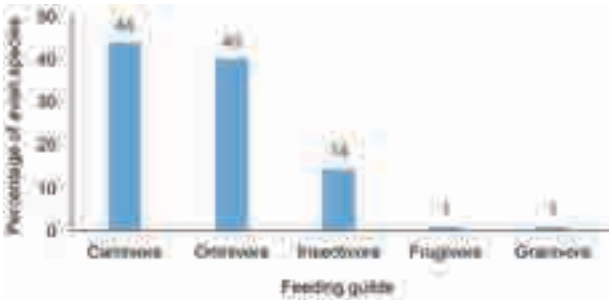

Figure 4. Guild-based classification of avian species recorded in unprotected wetland sites of Ayodhya district, Uttar Pradesh, India

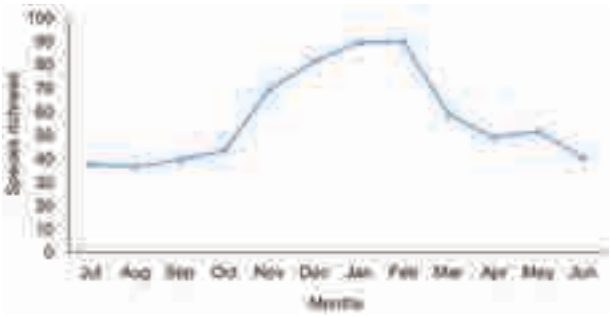

Figure 5. Monthly variation in species richness of avifauna recorded in unprotected wetland sites of Ayodhya district, Uttar Pradesh, India

DISCUSSION

In this survey, the Passeriformes was the dominant order which conforms to the studies of Kumar & Sharma (2018). Family Anatidae was the most dominant of all families of bird species found in the selected unprotected wetlands of Ayodhya district. Similar results were found by Kumar & Gupta (2009), Tak et al. (2010), Chopra & Sharma (2012), and Kumar et al. (2016). Nearly 60% of the bird species found were resident. This result conforms to the studies of Mazumdar (2019) who also recorded the majority of birds to be resident in nature. In the present study, it was found that the birds belonged to five feeding guilds, the dominant guild being carnivores, followed by omnivores. This finding implies that the wetlands catered to the needs of the birds providing them with diverse food items like fish, crustaceans, invertebrates, water plants and plankton

Table 4. Measurements of avian diversity and richness at unprotected wetland sites of Ayodhya district, Uttar Pradesh, India.

Wetland sites	Species richness	Shannon-Weiner Diversity Index (SDI)	Margalef's Richness Index (MRI)	Simpson's Dominance Index	Pielou's Evenness Index (PEI)
Udaila Talab	92	3.86	26.94	0.03	0.85
Samda Jheel	85	3.82	25.41	0.03	0.86
Sirsa Jheel	81	3.80	24.52	0.03	0.86
Jagdishpur Jheel	78	3.63	23.66	0.05	0.83
Kosiparikrama Nallah	76	3.62	23.82	0.03	0.83
Barunshahganj Talab	72	3.55	22.59	0.04	0.83

Table 5. Sorenson's Similarity Index of avian species between selected unprotected wetland sites of Ayodhya district, Uttar Pradesh, India.

Wetland sites	Udaila talab	Samda Jheel	Sirsa Jheel	Jagdishpur Jheel	Kosiparikrama Nallah	Barunshahganj Talab
Udaila talab	0.000					
Samda Jheel	0.915	0.000				
Sirsa Jheel	0.890	0.880	0.000			
Jagdishpur Jheel	0.847	0.798	0.830	0.000		
Kosiparikrama Nallah	0.810	0.795	0.803	0.766	0.000	
Barunshahganj Talab	0.817	0.803	0.850	0.853	0.824	0.000

(Basavarajappa 2006).

The highest species richness was recorded in the months of January and February (89 species each) which conforms to the observations of Mazumdar (2019) in Okhla Bird Sanctuary, Uttar Pradesh. It was found that the bird species starts to increase from October and reaches the maximum in the months of January and February (Figure 4). This is due to the migrating waterfowls which arrive in the wetlands during this season as Uttar Pradesh is a part of the Central Asian Flyway serving as a wintering ground for these species. This is also one of the reasons for recording a high number of winter visitors (42 species) in this study. The wetlands along with the agricultural landscapes in Ayodhya district prove to be a good habitat for these migratory birds and therefore support a high diversity, especially in winters (Yashmita-Ulman & Singh 2021). These migratory species gradually start flying back to their breeding grounds from March so, the species richness declines slowly from March and reaches the lowest in the monsoon months (Figure 4).

The wetland avian diversity and composition are influenced by factors like wetland size, location, vegetation (Sundar & Kittur 2013), type and level of anthropogenic activities, presence of additional and diverse foraging ground (Yashmita-Ulman & Singh 2021), water depth and quality (Saygili et al. 2011). Moreover, water birds usually prefer shallow water bodies with variations in depth (Helmers 1992; Colwell & Taft 2000). The Udaila Talab was surrounded by agricultural fields and had diverse vegetation like floating hydrophytes (*Azolla pinnata, Eichhornia cracipes, Jussiaea repens, Ipomoea aquatica*) and submerged hydrophytes (*Najas graminea, Potamogeton nodosus*). Trees like *Eucalyptus tereticornis, Phyllanthus emblica*, and *Mangifera indica* were found on the edge of the water body. It was a large sized water body with shallow water. Moreover, the undulating topography of the wetland gave rise to natural mounds and small isolated islands which served as resting places for the various bird species. As, Udaila Talab might have met all the requirements of bird species like alternative and diverse food supply, water depth variations, diverse microhabitats, it has registered as the wetland with the highest species richness and diversity. As far as both Sirsa and Samda Jheel were concerned, they both were surrounded with agricultural fields and trees, haboured rooted and emergent plants and had large areas under shallow water and marshy lands. Artificial mounds had been built in Samda Jheel by the Forest department to provide resting places to the water birds. All these factors might have attracted birds towards these jheels. So, both the wetlands supported a high avian diversity after Udaila Talab.

Deep waters are less preferred by waterbirds as they reduce the availability and accessibility of invertebrates (Murkin & Kadlec 1986). The Jagdishpur Jheel and Kosiparikrama Nallah therefore, had less to offer to the

Image 2. A—*Vanellus indicus* | b—Female of *Metopidius indicus* | c—*Himantopus himantopus* | d—*Anastomus oscitans* | e—*Ciconia episcopus* | f—*Mycteria leucocephala* | g—*Falco tinnunculus* | h—*Antigone antigone*. © Authors.

Image 3. a—*Porphyrio porphyrio* | b—*Amaurornis phoenicurus* | c—*Prinia socialis* | d—*Prinia inornata* | e—*Luscinia svecica* | f—*Ardea cinerea* | g—*Ardea purpurea* | h—*Threskiornis melanocephalus*. © Authors.

birds as they had higher water depths. Most of the birds found in these sites were restricted to the edge of the water bodies where the water was shallow. Only some ducks were found foraging in deep water. Moreover, the sewage water of the city of Ayodhya is drained into the Kosiparikrama Nallah and later this nallah merges with the Saryu river. So, mainly the birds like *Himantopus himantopus* which prefer feeding in polluted waters were found abundantly in this wetland. Both these wetlands were also smaller in size as compared to the other six wetlands in the study area. All these factors might be the reason for lower bird diversity in these wetlands as compared to Udaila Talab. On the other hand, though the Barunshahganj Talab has shallow water depth, it is a highly disturbed site as it lies next to the state highway NH 330A and has increasing land encroachment problems and is, therefore, shrinking in size and thus might have resulted in the lowest avian diversity as compared to the other wetlands in the study area.

It can be clearly understood from this study that all the wetlands in the study area have a great potential for conservation of avian communities. Though all the six wetlands under study were unprotected and had tremendous anthropogenic pressure, they were still capable of fulfilling the feeding, nesting and breeding requirements of the birds, and thus proved to be an optimum habitat. All the six wetlands in the study area had highly heterogeneous and mosaic of microhabitats as they were surrounded either by agricultural fields, orchards or plantations. The various tree species on the banks of wetlands provided the sites for perching, roosting and nesting of kingfishers, egrets, raptors, herons, cormorants and storks. The wading birds like storks, herons, ibises, snipe, redshank were found in shallow water and marshes. The wagtails, swamphens, waterhens and kingfishers were found in the adjoining agricultural fields as also reported by Urfi (2003). The plovers and sandpipers were found in the marshes. The waders like jacanas, egrets, herons, storks, ibises were found mostly feeding on *Nymphea* sp. The swimming and diving birds like coots, swamphens, ducks, cormorants, teal feasted on submerged vegetation (*Vallisneria* sp., *Ceratophylum* sp.) and emergent hydrophytes (*Oryza rufipogon, Polygonum barbatum*). So, all these might be the reasons for registering a high avian community composition even though these sites are unprotected and highly disturbed.

This survey shows 12 bird species (11.42%) of conservation importance in six unprotected and disturbed wetlands of Ayodhya district, Uttar Pradesh. In addition to this, species like *Sarkidiornis melanotos* and other raptor species listed in Appendix II of CITES are also found in these wetlands. All the species recorded in these wetlands are also listed under Schedule of Indian Wildlife (Protection) Act, 1972. Moreover, the global population trend of 39 bird species recorded from these wetlands is declining. So, from a global bird conservation point of view, the protection of these species and their habitat is of utmost importance.

On the other hand, three wetlands surveyed in this district yielded very few bird species (≤3) (Table 1) due to which they were removed from further analysis. The size of all three wetlands was less than 2 ha which was very less as compared to the other wetlands currently under study. So, the size of the wetlands might have influenced the bird diversity. This finding is well supported by Sarkar et al. (2013) who found similar results. This study also brings to the notice that though the medium and large sized wetlands in this area support sensitive species, the existence of the wetlands is itself in peril due to invasion of species like *Eichhornia crassipes* and anthropogenic activities such as fishing, land encroachment for fishing and agriculture, cattle grazing, fertilizer run-off, harvesting of *Trapa natans*, and urban development. Thus, endangering the habitat and survival of these bird species.

CONCLUSION

The sighting of 12 bird species of conservation importance and 39 species of birds having a declining population trend globally, highlights the significance of the medium and large sized unprotected and highly disturbed wetlands from the bird conservation point of view. The wetlands intermingled with the adjacent agricultural landscapes, orchards, plantations which created a congenial environment for resident as well as migratory birds as both of them have been reported in high numbers in the study area. But at the same time, small sized wetlands have reported very few bird species (≤3). This finding puts emphasis on the need for further research and replication of management activities like the ones taken up by the Forest Department in Samda Jheel in other potential medium and large sized unprotected wetlands of the district. So, this study acts as a reminder that medium and large sized wetlands, though isolated, disturbed and not designated as Ramsar sites, have the potential to be critical habitats for the most endangered species. Therefore, such wetlands should be given conservation and research priorities or else there is a

possibility of losing these valuable water bird habitats forever as is evident from the three wetlands which yielded just three bird species.

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COMMUNICATION

Can the Sri Lankan endemic-endangered fish *Labeo fisheri* (Teleostei: Cyprinidae) adapt to a new habitat?

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Abstract: *Labeo fisheri* is an endemic and endangered freshwater fish of Sri Lanka. Mainly restricted to the upper reaches of the Mahaweli River basin, it has been previously reported living in deep rapids and among large rocks and boulders. An accidental record of a *Labeo fisheri* specimen from Victoria Reservoir led us to further study this habitat during the period from January to August 2017. This study was carried out to confirm the presence of a population of *Labeo fisheri* within the Victoria Reservoir and report its new habitat type in deep stagnant waters. We further investigated the food habits by analyzing the gut contents of *L. fisheri* in the Victoria Reservoir. Seven individuals were recorded from fishermen's gill net catch in three fish landing sites along Victoria Reservoir, with an average total length of 24.80 ± 4.30 cm, average standard length of 19.70 ± 3.86 cm and average body weight of 197.69 ± 107.12 g. Based on gut content analysis, only phytoplankton, especially diatoms and cyanobacteria, were found in the gut of *L. fisheri*. This new population is facing the direct threat of fishing. Effective conservation measures are doubtful, since a fishery is well established in the Victoria Reservoir and the fishing gear used is not species-specific. More research is necessary to understand the population dynamics of *L. fisheri* in the Victoria Reservoir. In order to conserve it at this locality, community-based conservation measures are recommended.

Keywords: Adaptation, habitats, feeding habit, freshwater fish, gut analysis, *Labeo fisheri*, new locality, stagnant water, Victoria Reservoir.

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Author contributions: DT—specimen identification and measuring, data analysis and manuscript writing; GH—specimen collection, measuring and manuscript writing.

INTRODUCTION

Sri Lanka and the Western Ghats of India collectively are one of the 34 biodiversity hotspots in the world (Bossuyt et al. 2004; Gunawardene et al. 2007). Sri Lanka is situated at the southeastern tip of the Indian peninsula between 6° & 9° north of the equator and 79° & 82° east of the Greenwich mean line. It is a small island (65,610 km^2) with rich biological diversity. Its proximity to the equator, heterogeneity of topography and climatic conditions help to support vast diversity of both flora and fauna (Weerakoon 2012). Sri Lanka harbors a rich ichthyofaunal diversity comprising 127 species, including 61 endemics and 30 introduced species (De Silva et al. 2015; Goonatilake et al. 2020). Exotic species have been introduced to the island mainly to increase the inland fisheries, and the rest are from aquarium escapes (Goonatilake 2007). According to the distribution patterns of freshwater fish, four major zones have been identified: transition, southwestern, Mahaweli, and dry (Senanayake & Moyle 1982). Of these four zones, the Mahaweli zone and southwestern zone have the highest species diversity. This is due to the high heterogeneity of the habitats, rainfall patterns and the topography of these regions. Although the fish of the Mahaweli zone are relatively well known, it continues to produce significant discoveries despite widespread habitat destruction (Senanayake & Moyle 1982).

Taxonomic nomenclature is an important tool to identify fish species. Nomenclature of Sri Lankan freshwater fish has been extensively revised during the past two decades. For example, the genus *Rasbora* (Silva et al. 2011; Sudasinghe et al. 2020), genus *Rasboroides* (Batuwita et al. 2013; Sudasinghe et al. 2018), genus *Puntius* (Pethiyagoda et al. 2012; Sudasinghe et al. 2020, 2021), genus *Devario* (Batuwita et al. 2017; Sudasinghe et al. 2020), genus *Labeo* (Sudasinghe et al. 2018), and genus *Esomus* (Sudasinghe et al. 2019) were revised and new species have been described. Taxonomy has been always important as scientists struggle to identify species in order to understand the evolutionary relationships and complex interactions of ecosystems threatened due by anthropogenic activities. The genus *Labeo* is one such fish group that was recently revised by Sudasinghe et al. (2018).

Labeo fisheri (Jordan & Starks, 1917), commonly called Sri Lankan Mountain Labeo, is an endemic and endangered freshwater fish species (MOE 2012; Goonatilake et al. 2020). It is mainly confined to the upper reaches of the Mahaweli River, and is also recorded at a few locations of the lower reaches of the river. It has not been recorded from any other river basin in Sri Lanka (Sudasinghe et al. 2018). It is found in deep, rocky areas with rock crevices where the water current is strong with rich oxygen. It is reported that *L. fisheri* is highly sensitive to these microhabitat conditions (Pethiyagoda 1991). The alteration of river morphology as a result of different hydropower projects since the 1980s has caused habitat loss for *L. fisheri*. This has probably led to a population fragmentation. In the inland fishery sector, there is a high demand for this fish not only for its delicacy, but also for perceived aphrodisiac effect of its flesh (NARA 2017). Initially an accidental observation of a specimen of *L. fisheri* in a fisherman's catch was made in 2017 from the Victoria Reservoir. This catch was otherwise composed of *Oreochromis niloticus* (around 30 individuals) and a 9 cm stretched mesh size gill net was used by the fishermen. This accidental finding prompted us to investigate the presence of *L. fisheri* in Victoria Reservoir, with the aim of establishing a new distribution record and determining diet preference in the new habitat.

MATERIALS AND METHODS

Study Site and study period

Fieldwork was conducted from January to August 2017. The study sites were in the Victoria Reservoir between Thennekumbura (7.281 N, 80.666 E) and Anuragama (7.247 N, 80.731 E), Sri Lanka (Figure 1; Image 1). These sites are located in the intermediate zone with elevation ranging 641–764 m. The mean annual rainfall in this area is 50–200 mm.

Survey of *Labeo fisheri* in the Victoria reservoir

Fishermen were advised to collect any specimens of *L. fisheri* found in their daily catch and inform the members of our research team, who in turn collected the specimens during the study period. Specimens collected by fishermen were photographed using a Nikon (5300) digital camera and brought to the aquarium in the Department of Zoology, University of Peradeniya for further study. Caudal fin samples of each individual specimen were collected into 100% ethanol vials onsite, and stored at 4°C for molecular analysis. After taking the meristic and morphometric measurements, the collected specimens were dissected and the gut was separated into 90% ethanol containers for diet analysis.

Taxonomic identification

The fish were identified using available fish guides and literature (Pethiyagoda 1991; Goonatilake 2007;

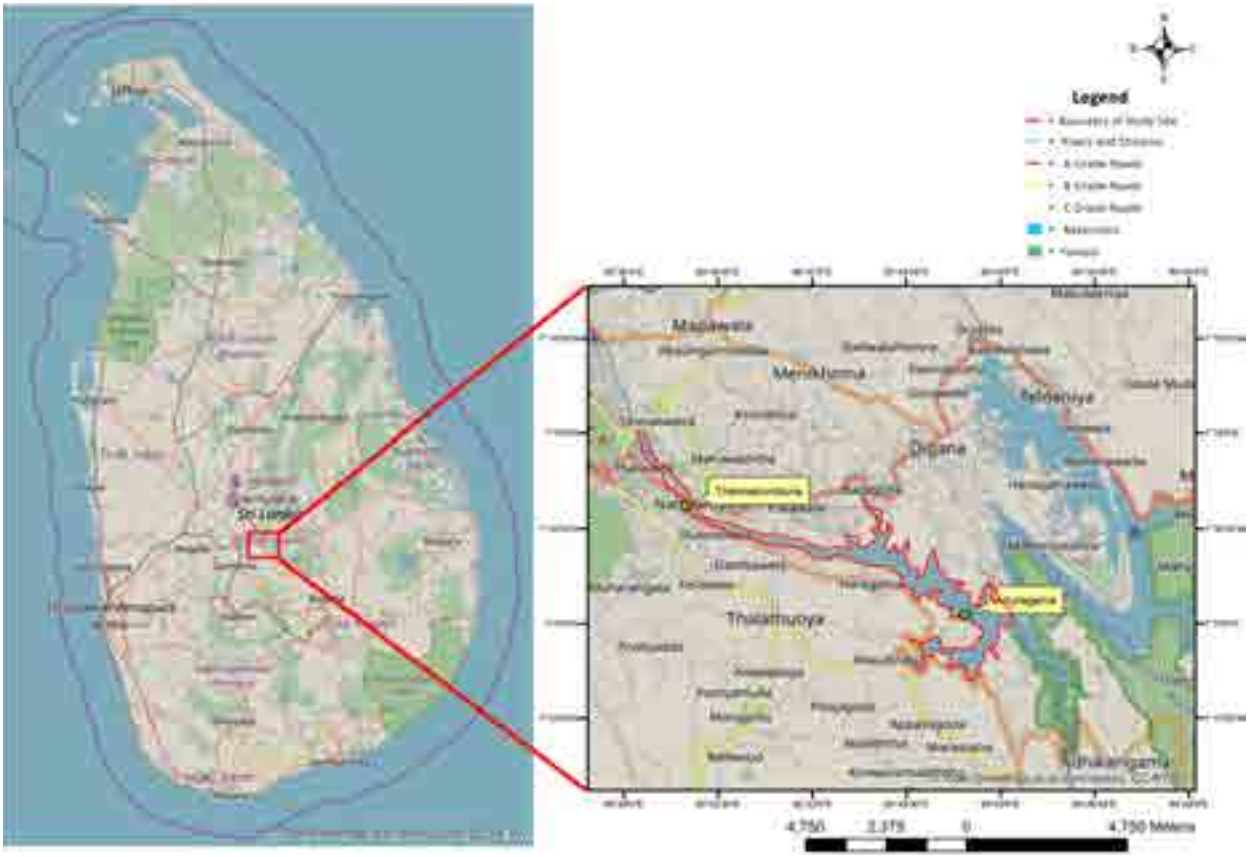

Figure 1. A Geographical map of the Victoria Reservoir where the new locality of *Labeo fisheri* was found starting from Thennekumbura to Anuragama, Sri Lanka.

Image 1. Habitat of *Labeo fisheri* in Victoria Reservoir between Thennekumbura and Anuragama, Sri Lanka. © Tithira Lakkana.

De Silva et al. 2015; Sudasinghe et al. 2018). Taxonomic analysis was done for further confirmation of the *L. fisheri* captured from Victoria Reservoir.

The morphometric measurements (total body length, standard body length, body depth, caudal peduncle depth, caudal peduncle length, pre-dorsal length, length of dorsal fin base, length of anal fin base, height of dorsal fin, height of anal fin, length of pectoral fin, length of pelvic fin, length of longest dorsal fin, spine, head length, head width, snout length, suborbital width, length of orbit to pre-opercular angle, eye diameter, upper jaw length, and gape width) of the collected fish were measured using a digital Vernier caliper. The following meristic characters (dorsal fin spines, dorsal fin rays, anal fin spines, anal fin rays, pectoral fin rays, scales along lateral line, scales above lateral line, scales below lateral line, scales before dorsal fin and scales around caudal peduncle) of the fish were also noted (Armbruster 2012). These morphometric

measures were used in principal component analysis (PCA) in Minitab® 17.1.0 (©2013 Minitab Inc.) to compare the morphometric characters of individuals collected from Victoria Reservoir.

Analysis of food habit of *Labeo fisheri*

The anterior part of the gut was crushed adding distilled water and the gut content was extracted. The crushed solution was used to analyze the food habit of the fish. The gut solution was mixed well and 0.05 ml was pipetted onto a clean glass slide, covered with a cover slip and observed under a Primo-star light microscope. Ten drops (0.05 ml each) of gut solution were analyzed for each individual captured from the Victoria Reservoir. Types of plankton species present in the samples were identified using plankton guides (Fernando & Weerewardhena 2002; Yatigammana & Perera 2009) and photographed using a Zeiss Primo star inverted microscope attached with camera. The relative abundance of each plankton species was calculated as follows:

$$\text{Relative abundance} = \frac{\text{Number of individuals of a particular plankton species}}{\text{Total number of individuals of all plankton species}} \times 100\%$$

Comparisons were determined using one-way ANOVA in R version 3.6.1 (R foundation for statistical computing) using 95% confidence intervals ($\alpha = 0.05$).

RESULTS

A total of seven *Labeo fisheri* specimens were collected during this period. The specimens showed two distinct coloration patterns. Adults with olive green body coloration dorso-laterally, the color becoming lighter in the ventral region. Sub adults (<~220 mm snout length) have yellowish-brown color dorso-laterally and white ventrally. Base of the fins show dark green color and it eventually turn into the reddish-orange color towards the top. All specimens have a black blotch at the base of the caudal peduncle which is 6–7 scales long and 4–5 scales high. There is a single pair of barbels which is maxillary in position. Its mouth is ventrally positioned and has a well-developed rostral fold with thick fleshy lips. The snout was covered with white color tubercles (Image 2).

The average total body length of the seven specimens collected was 24.80 ± 4.30 cm and the average standard length was 19.70 ± 3.86 cm (Table 1). The maximum recorded standard length and the body weight of *Labeo fisheri* from Victoria reservoir was 24.00 cm and 333.00 g, respectively. The average body weight of the seven specimens was 197.69 g. Morphometric characters expressed as a ratio to the standard length are given in the Table (2). Principal component analysis (PCA) carried out for the Victoria population revealed that this population share the same morphometric characters compared to the *L. fisheri* populations in some other Mahaweli tributaries such as Moragolla and Gatambe (Figure 2).

Table 1. Body length and body weight of captured *Labeo fisheri* in Victoria Reservoir, Sri Lanka (N = 7).

	Average total body length / cm	Average standard length / cm	Average body weight / g
Mean	24.80	19.70	197.69
SD	4.31	3.86	107.12
SE	0.62	0.55	15.30

SD—Standard Deviation | SE—Standard Error

The dorsal fin comprised of two simple rays and 10–12 branched rays. The anal fin had two simple rays and five branched rays. The pectoral fin comprised of one simple ray and 15–18 branched rays. Ventral fins composed of one simple and eight branched rays. The lateral line is complete with 38–39 lateral line scales. There are 16–18 scales along the pre dorsal region. The formula for meristic characters could be given as; D ii/10-12; A ii/5; P i/15-18; V i/8; LL 38-39; L. lat 7 ½ / 5½.

According to the food habit analysis, a total of 21 phytoplankton species belonging to five classes were identified in the gut contents of *Labeo fisheri* recorded from the Victoria Reservoir. Bacillariophyceae (diatoms) and Cyanophyceae (cyanobacteria) were the dominant classes, although the preference for species each differed ($F = 3.01$; $p < 0.05$). The most preferred were *Aulacoseira* sp., followed by *Chlorococcus* sp. and *Staurastrum cingulum*. It is also found that the diatoms *Closterium* sp., *Cyclotella* sp., *Lyngbya* sp., *Merismopedia* sp., *Nostoc* sp., *Oscillatoria* sp., *Staurastrum megacanthum*, and *Tabellaria* sp. were least preferred (Image 3; Figure 3).

DISCUSSION

Labeo fisheri has been exclusively recorded from Mahaweli river basin and mostly in the upper reaches of the river. Highest recorded elevation is Ulapane-Gampola at 562 m and lowest is Angammedilla-Polonnaruwa at 80 m (NARA 2017; Sudasinghe et al. 2018). It had been earlier recorded along the Mahaweli River (upstream of the Victoria Reservoir) at Ulapane-Gampola, Getambe, Lewella, Polgolla, and Digana. They were also earlier recorded downstream of the Victoria reservoir at Randenigala, Minipe anicut, and Badulu Oya (Sudasinghe

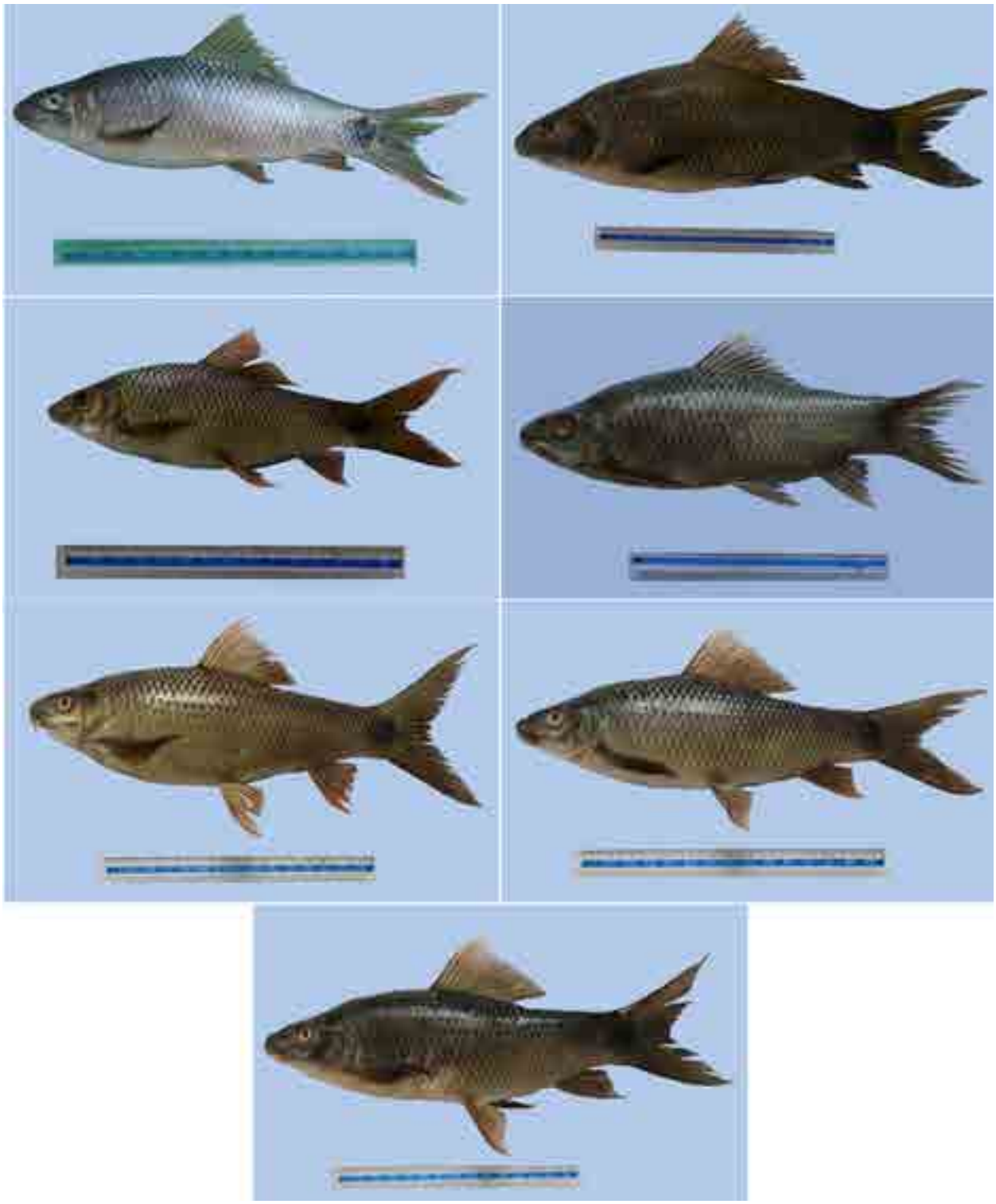

Image 2. Seven captured specimens of *Labeo fisheri* in the Victoria Reservoir, Sri Lanka show mainly two colorations. Adults have olive green dark color body on dorso-laterally and sub-adults have yellowish brown dorso-laterally. © Dinelka Thilakarathne & Gayan Hirimuthugoda.

et al. 2018). *Labeo fisheri* was also recorded in the Mahaweli tributaries at Heen Ganga, Thelgamu Oya, and Amban Ganga (NARA 2017; Sudasinghe et al. 2018). *Labeo fisheri* was last recorded in 1952 at Lewella (type locality) and in 1991 at locations around Victoria Reservoir such as Randenigala, Digana, and Polgolla. In this study, for the first time we confirm a presence of a well-established population of *L. fisheri* in the Victoria Reservoir.

In the past *L. fisheri* was found in lentic habitat conditions. This is a strong indication that *L. fisheri* can change habitat from lotic to lentic, and introduction of exotic species such as Tilapia and tank cleaners may have played a role. *L. fisheri* was earlier recorded in deep rapids among large rock crevices and boulders, whereas juveniles and sub-adults were common in shallow regions with a moderate, non-turbulent flow (Sudasinghe et al. 2018). Specimens in this study were collected from the middle of the reservoir in stagnant waters, and the depth they were entangled in the net is around 10 m. It is possible that there are more recordings of *L. fisheri* from the Victoria Reservoir, because we only collected specimens from three landing sites out of a total of ten around the Reservoir. Therefore, more research work has to be done to confirm the presence of a viable population in the reservoir. Since fisheries in the reservoir are being monitored by National Aquaculture Development Authority (NAQDA), Sri Lanka, they are able to collect such extensive fisheries data.

Gut content analysis is the best method to get a proper understanding of fish feeding habits. Previous studies have shown that *L. fisheri* scrapes submerged rocks using thick and horny lips in the ventral mouth. Earlier Pethiyagoda (1991) reported that they only feed on algae. It is believed that *L. fisheri* in Ulapane and Gatambe feed on an aquatic plant belonging to the family Podostemaceae (NARA 2017). However, according to our findings they mainly feed on diatoms and cyanobacteria. This may be due to inadequate submerged vegetation and algae in the Victoria Reservoir.

Water entering to the Victoria reservoir during the rainy season is highly turbid due to wash off from upstream areas. At the reservoir where water is stagnant, soil particles start to settle at the bottom. Sedimentation increases and reduces the production of algae and macrophytes due to lack of oxygen in the bottom of the reservoir. Sedimentation also increases eutrophication of the reservoir. Both these factors affect the transparency of the water and limit sunlight penetration to the bottom, which can damage the food source of *L. fisheri*.

Many people use Mahaweli River for washing, bathing and dumping garbage. All these pollutants are collected and concentrated at the reservoir. Thus water pollution is observable in the reservoir. The gut content analysis of *L. fisheri* also confirmed that this reservoir was highly polluted because *Aulacoseira* sp. and some cyanobacteria were the most prominent phytoplankton species in the gut of the *L. fisheri*. *Aulacoseira* sp., and *Navicula* sp. often attain high biomass in eutrophic rivers and reservoirs (Akinyemi et al. 2007). Thus, it is a useful indicator species

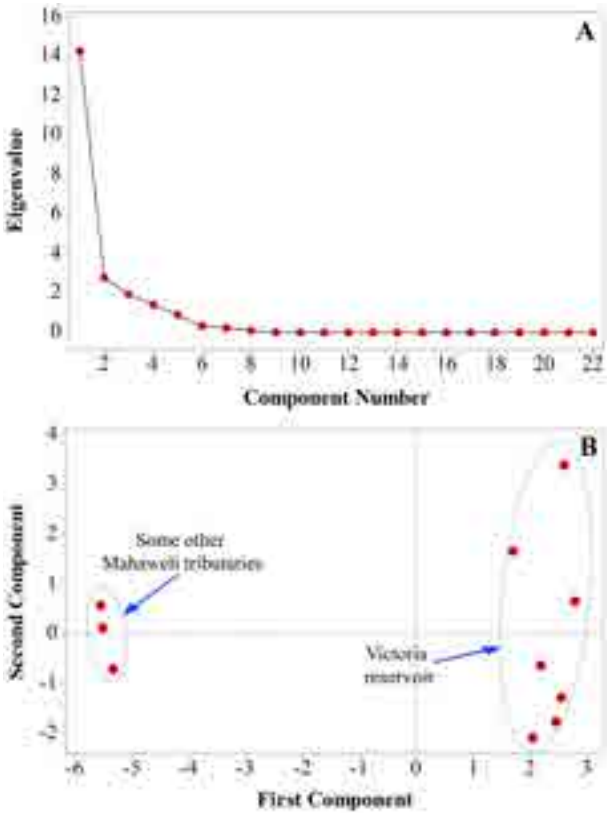

Figure 2. PCA analysis of morphometric characters of seven specimens of *Labeo fisheri* obtained from Victoria reservoir, Sri Lanka: A—Scree plot | B—Score plot.

for trophic conditions (Akinyemi et al. 2007). So, this is a clear indication that water in the Victoria Reservoir is polluted and it may have adverse effects on the native species living there. Some of the areas of Victoria Reservoir have been used as dumping sites for garbage which also contributes to the water pollution of the reservoir.

Sometimes illegal small-meshed gill nets were used to capture fish, especially at the shallow areas and at mouths of tributaries. These are potential habitats of juveniles and sub adults of *L. fisheri* though they migrate up streams for spawning and they are subjected to be caught. This new population is facing the direct threat of inland fisheries. Effective conservation measures are doubtful since fisheries are well established in the Victoria reservoir and the fishing gear is size specific but, not species specific. During the dry season from February to September, the reservoir water level goes down and they are highly vulnerable to be captured by the gill nets.

Victoria Reservoir has several invasive species of fish such as *Pterygoplichthys disjunctivus* (tank cleaner), potentially invasive *Oreochromis mossambicus* and *Oreochromis niloticus*. *Pterygoplichthys* sp. was initially an aquarium escapee, which later became well-established in

Table 2. Morphometric characteristics of *Labeo fisheri* in Victoria Reservoir, Sri Lanka (N = 7).

	Ratio to standard length																		
	Body depth	Caudal peduncle depth	Caudal peduncle length	Pre-dorsal length	Length of dorsal base	Length of anal base	Height of dorsal fin	Height of anal fin	Length of pectoral fin	Length of pelvic fin	Length of longest dorsal spine	Head length	Head width	Snout length	Suborbital width	Length of orbit to pre-opercula angle	Eye diameter	Upper jaw length	Gape width
Mean	0.30	0.14	0.16	0.44	0.20	0.08	0.19	0.16	0.23	0.19	0.11	0.23	0.16	0.09	0.05	0.09	0.09	0.06	0.14
SD	0.02	0.01	0.02	0.02	0.01	0.01	0.02	0.02	0.01	0.01	0.03	0.02	0.01	0.01	0.01	0.01	0.13	0.01	0.01
SE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00

SD—Standard deviation of sample | SE—Standard error of sample.

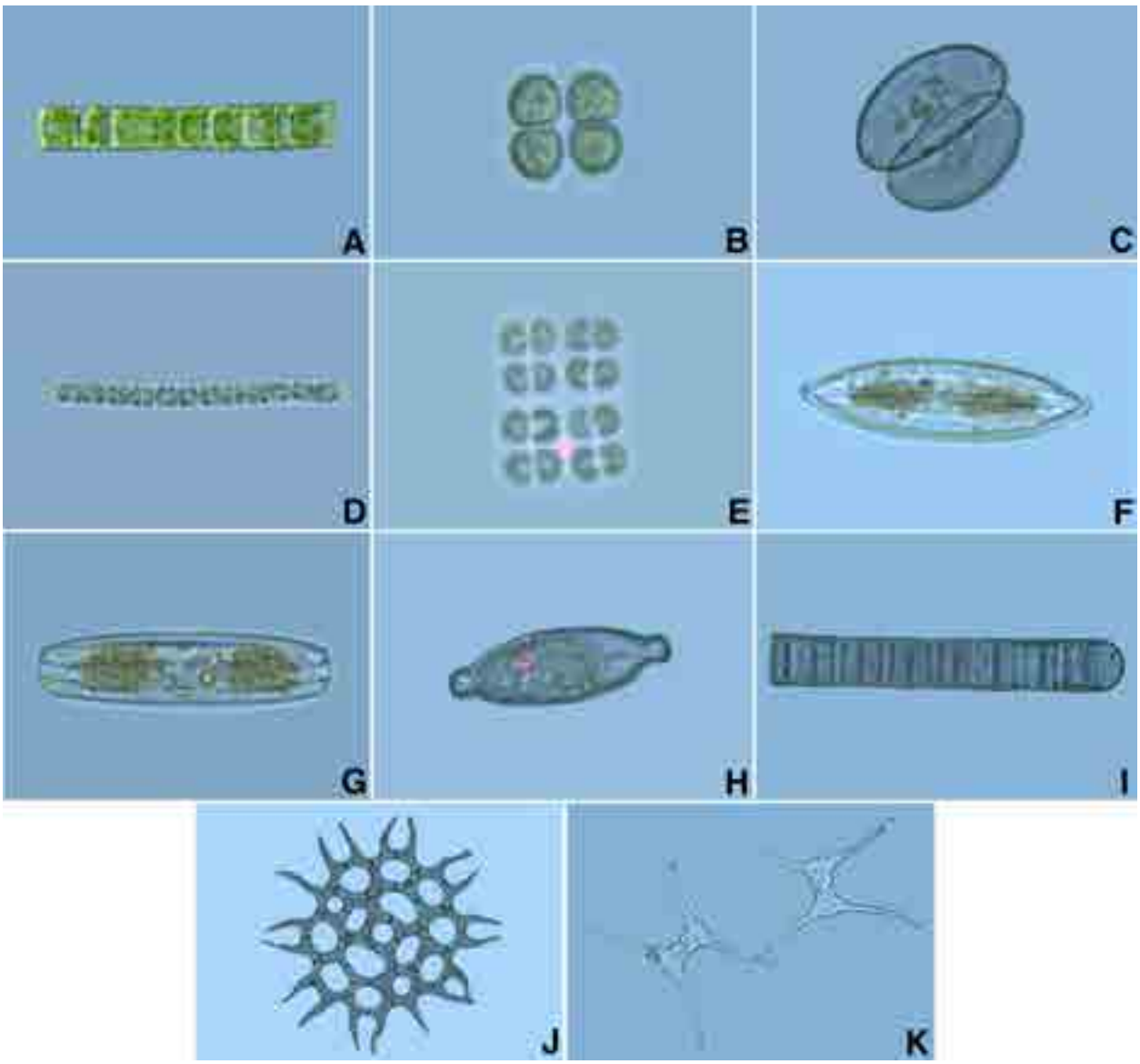

Image 3. Gut contents of *Labeo fisheri* in the Victoria Reservoir, Sri Lanka: A—*Aulacoseira* sp. | B—*Chlorococcus* sp. | C—*Cosmarium* sp. | D—*Lyngbya* sp. | E—*Merismopedia* sp. | F—*Navicula lanceolate* | G—*Navicula* sp. | H—*Navicula* sp. | I—*Oscillatoria* sp. | J—*Pediastrum duplex* | K—*Staurastrum cingulum*. © Dinelka Thilakarathne & Nayanaka Wickramasinghe.

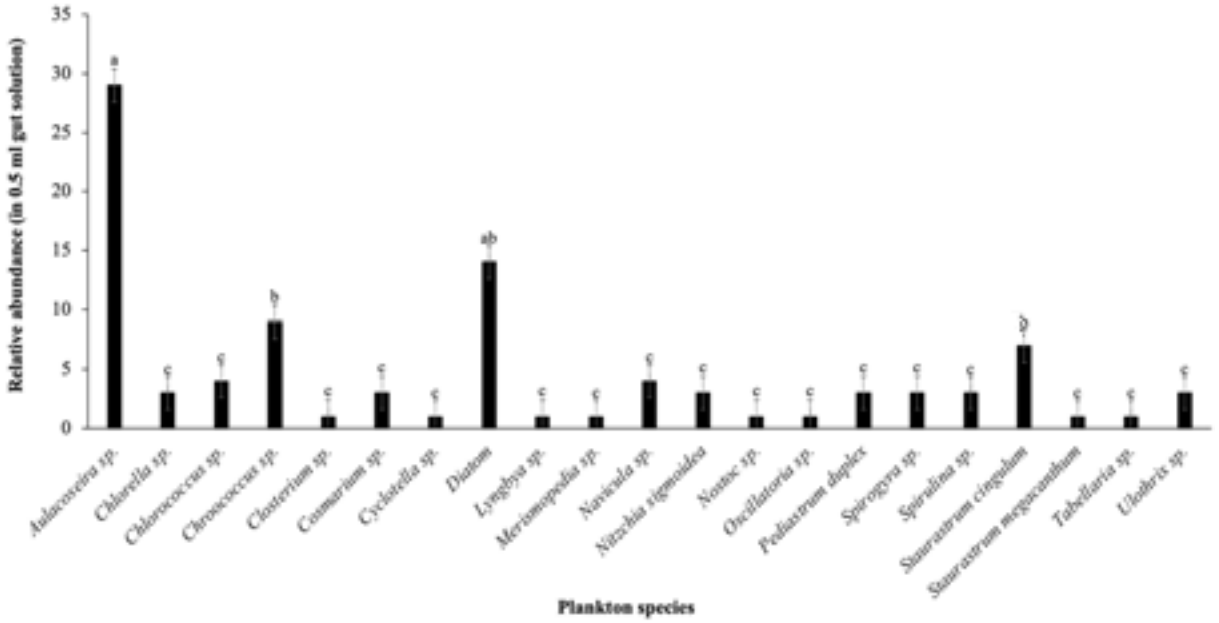

Figure 3. Relative abundance of phytoplankton in the gut contents of *Labeo fisheri* recorded from Victoria Reservoir, Sri Lanka. (a, b and c denote the significant different among relative abundance of the plankton species; F = 3.01; p <0.05).

the river and reservoir systems of the country. They have a high rate of reproduction and high rate of survival during harsh environmental conditions. *Pterygoplichthys* sp. is piscivorous and feeds on the native species, especially fry, fingerling and juvenile stages (Bambaradeniya et al. 1999). *Oreochromis mossambicus* and *Oreochromis niloticus* were introduced in to reservoirs as food fish and to encourage a commercial capture fishery (De Silva 1988). They are competitive species for the food and space in the reservoir. Due to their high natality rates, survival rate and voracious feeding habit, the native fish populations declined. In the dry zone, *Oreochromis mossambicus* is considered responsible for the extinction of *L. lankae*, due to overlapped habitats and niches in the dry zone reservoirs (Pethiyagoda 2006). In the same way *Oreochromis* sp. might pose risk for the extinction of *Labeo fisheri* as well due to the niche overlapping. Unlike the *Oreochromis* sp., *L. fisheri* cannot adapt well to the new habitats. They have to compete for their usual food and other resources in the reservoir. That may cause the population reduction of *Labeo fisheri* from the reservoir in the future. Other than the *L. fisheri*, *L. rohita* was recorded from the Victoria reservoir and *Labeo heladiva* was recorded from the Rantambe reservoir downstream of the Mahaweli River. This indicates that the some of the species in the genus *Labeo* can adapt to the lentic conditions.

Most of the endemic and threatened freshwater fish are found outside protected areas with high anthropogenic activities. Therefore, they need to be protected by protecting habitats (their catchment areas and the quality of water). Any type of development that cause harm to these habitats (such as mini hydro projects) needs to be clearly assessed. Species oriented and habitat-oriented conservation programs should be established at least for the endangered species. When the species are located outside of the protected areas, the local communities must be made aware and have to be involved in conservation programs. Such community awareness program has been successfully implemented for *Pethia bandula* (MOE 2012; Goonatilake et al. 2020). Ex situ breeding programs, translocation, reintroduction should be established with the aim of increasing the wild population. Some of these translocation programs have been highly successful while others have failed (Goonatilake 2012; Sudasinghe et al. 2018). Therefore, we need to find proper conservation measures and implement early to help safeguard the *Labeo fisheri* in the Victoria Reservoir.

CONCLUSIONS

Endemic and endangered *Labeo fisheri* is recorded in a new locality (Victoria Reservoir) where it has not been previously recorded and this appears to be a new habitat. It is interesting that this fish was able to adapt for stagnant water apart from its original habitat (fast flowing waters).

Not only that, their food habit is slightly changed from algae to diatoms and cyanobacteria due to the availability in this reservoir. However, more research work has to be done to ensure the existence of a viable population in the reservoir and since fisheries in the reservoir is being monitored by National Aquaculture Development Authority (NAQDA), they are in a better position to collect such extensive fisheries data. Water pollution and direct exposure to the fisheries poses greatest threat to its survival. Community based conservation efforts should be taken if this species needs to be conserved at this locality.

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COMMUNICATION

An overview of the fish diversity and their threats in the Gowthami-Godavari Estuary in Andhra Pradesh, India

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Abstract: The fish diversity of different estuarine habitats of the Gowthami-Godavari River was studied from 2014 to 2017. We recorded 231 species of finfishes belonging to 27 orders, 81 families, and 167 genera. Perciformes was the most speciose order, followed by Carangiformes and Clupeiformes. Of the 231 species, one is an Endangered species (*Silonia childreni*), three are Vulnerable (*Tenualosa toli*, *Cirrhinus cirrhosis*, and *Wallago attu*), three are Near Threatened, and 11 are Data Deficient species. We also recorded five exotic species from the study area, of which *Oreochromis mossambicus* was the most dominant. The major threats, including potential impacts of river regulation and climate change on the estuarine habitats of Gowthami-Godavari, are also discussed.

Keywords: Coringa, dam, eastern coast, ichthyofauna, mangroves.

సారాంశం: 2014 నుండి 2017 మధ్య కాలంలో, గౌతమి-గోదావరి నదికి చెందిన వివిధ నదీముఖ ఆవాసాలలో ఉండే చేపల వైవిధ్యం మీద అధ్యయనం చేయబడింది. మా అధ్యయనంలో 231 ఫిన్‌ఫిష్ జాతులను నమోదు చేసాము, ఇవి 27 ఆర్డర్‌లు, 81 ఫామిలీస్ మరియు 167 జెనెరేలకు చెందినవి. నమోదు చెయ్యబడిన ఈ 231 ఫిన్‌ఫిష్‌లలో, అత్యధికంగా పెర్సిఫార్మ్స్ జాతులు ఉన్నాయి, వాటి తర్వాత కారంగిఫార్మ్స్ మరియు క్లూపీఫార్మ్స్ జాతులు ఉన్నాయి. ఈ 231 జాతులలో, ఒకటి అంతరించిపోతున్న జాతి (సిలోనియా చిల్డ్రని), మూడు వాల్నరబుల్ (టెనువాలోసా టోలి, సిర్రినస్ సిర్రోసిస్, మరియు వల్లగో అట్టు), మూడు ముప్పు వొంచి ఉన్నవి మరియు 11 డేటా లోపం ఉన్న జాతులు. మా అధ్యయనంలో ఐదు అన్యదేశ జాతులను కూడా నమోదు చేసాము, వాటిలో ఒరియోక్రోమిస్ మొసాంబికస్ ఎక్కువుగా కనిపించాయి. అంతే కాకుండా గౌతమి-గోదావరి నదీముఖ ఆవాసాలపై నియంత్రణ మరియు వాతావరణ మార్పుల గురించి కూడా మా అధ్యయనంలో చర్చించబడ్డాయి.

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INTRODUCTION

Among the large monsoonal rivers of the Indian peninsula, the Godavari River is the largest, with a drainage basin of 312,812 km^2 (Rao et al. 2015). The river originates at Triambakeshwar in the Western Ghats and travels eastward for ~1,460 km flowing through eight states and various landscapes such as the Western Ghats, Deccan traps of central India, and the Eastern Ghats along the eastern coast. It finally drains into the Bay of Bengal through a number of distributaries before creating a large, fertile delta in Andhra Pradesh. The Godavari river basin accounts for nearly 10% of India's geographical area, thereby playing a major role in accruing socio-ecological, economic, and cultural benefits to the country.

At its confluence with Bay of Bengal, numerous distributaries of the Godavari River form an estuarine complex constituting a diverse array of coastal habitats that include the estuaries formed at the river mouths, mangrove forests, and a large bay partially enclosed by a natural sand spit known as Hope Island. The mangroves created at the confluence of Gowthami River, a major distributary of the Godavari River, are among the largest mangrove forests in India. These habitats support rich and unique biodiversity, including rare mangrove species such as *Ceriops decandra* and *Xylocarpus granatum*, and threatened mammals such as the Fishing Cat *Prionailurus viverrinus* and Smooth-coated Otter *Lutrogale perspicillata* (Malla 2014; Malla et al. 2019). The estuarine complex and the mangrove-lined creeks of the estuary located at the interface of freshwater and salt water also contributes immensely to the region's fisheries particularly supporting the sustenance of the local small-scale fisheries.

Many studies, including those by Krishnamurthy & Jeyaseelan (1981), Mukherjee et al. (2013), Ramachandra et al. (2013), and Ramanujam et al. (2014), have documented the diversity of fish fauna present in Indian estuaries. In the case of the lower basin of the Godavari River, earlier ichthyological studies provide substantial information on the distribution and taxonomy of fish species (Day 1888; Chacko & Ganapati 1949; Rao 1965, 1976; Rajyalakshmi 1973; Rao 1976; Talwar & Jhingran 1991). Species including *Awaous fluviatilis* Rao, 1971 and *Incara multisquamatus* Rao, 1961 were first described from the Godavari delta. Nearly two decades ago, Krishnan & Mishra (2001) provided a comprehensive summary of the fish diversity of the Godavari River estuary, accounting for 312 species belonging to 189 genera and 88 families.

In this paper, we provide an overview of the fish diversity and distribution in different habitats of the Godavari River estuarine complex, and specifically focusing on the fish diversity in the mangrove-lined creeks. We also discuss various threats to these mangrove forests, and their fish communities. This study is important in the context of the vulnerability of this estuary, and its biological communities to potential large-scale changes triggered by rising sea levels and freshwater regulation by an under-construction large dam.

METHODS

Study area

This study was conducted in the Godavari River Estuary located in the southeastern state of Andhra Pradesh in peninsular India. Before its confluence with the sea, the river branches out into two major distributaries, namely the Gowthami-Godavari and Vasistha-Godavari. The present study focuses on the Gowthami distributary of the river (16.98 °N, 82.30 °E and 16.58 °N, 82.31 °E).

With an area of 316 km^2, a substantial part of the mangroves formed at the northern confluence of Gowthami-Godavari with the sea are protected inside the Coringa Wildlife Sanctuary (CWS) (Bagaria et al. 2021). Here, the mangroves are drained by three major sub-tidal creeks, namely Thulyabhaga, Coringa, and Gaderu; these creeks flow south to north, dividing the sanctuary into different zones. Another smaller sub-tidal creek, namely Giriyampeta is located outside the southern border of the sanctuary. In addition to these major creeks, the sanctuary is drained by several smaller sub-tidal and intertidal creeks.

The subtidal creeks drain into the Kakinada Bay, a naturally formed semi-enclosed bay formed at the northern edge of the sanctuary. The main branch of the Gowthami-Godavari creates a riverine estuary at the southern edge of the sanctuary, where the tidal influence can extend up to 50 km upstream.

Sampling sites

Fish sampling was carried out across 52 sites between 2014 and 2017 (Figure 1). Of these, 28 sites were located within mangrove creeks of the CWS (Image 1), 16 sites were in the riverine part of the estuary, and eight sites were located in the Kakinada Bay. Additional surveys were carried out in the local fish markets and landing centers located adjacent to the mangroves, and the river

Figure 1. Map showing the location of Coringa Wildlife Sanctuary along with all the fish sampling sites, including landing centers in East Godavari district, Andhra Pradesh.

Image 1. One of the sampling sites during spring high tide. This site was located within the mangrove creeks surveyed inside the Coringa Wildlife Sanctuary, Andhra Pradesh. © Giridhar Malla.

Image 2. An aquaculture pond adjoining the mangrove forests of the Coringa Wildlife Sanctuary, Andhra Pradesh. © Paromita Ray.

Image 3. Intrusion of sand into the mangrove forests noticed on the seaward side of the Coringa Wildlife Sanctuary, Andhra Pradesh. © Giridhar Malla.

mouth.

In the main river within the sanctuary, fishes were collected using locally available trammel nets and gill nets, which were set perpendicular to the water flow for a period of one hour during low tides. In the case of intertidal creeks, block nets were placed at the creek entrance at the beginning of low tide. The fishes that remained within the blocked creek were collected before the onset of the next high tide. Since sampling was conducted inside a protected area, only unidentified specimens were collected for further identification in the laboratory. On a few occasions, specimens were collected opportunistically from fishers' catches from the subtidal creeks, bay, or the river mouth.

Identifications were made using the FAO Fish Catalogue (Fischer & Whitehead 1974; Fischer & Bianchi 1984) and other taxonomic keys available for the region (Day 1888; Jayaram 2010). The correct taxonomy of the species was updated in accordance with the California Academy of Sciences' online repository, the Catalog of Fishes (Fricke et al. 2021). The functional guilds and migratory behavior of the species were confirmed following FishBase (Froese & Pauly 2021) while the threatened status of each of the species followed the latest IUCN Red List of Threatened Species (IUCN 2021).

RESULTS AND DISCUSSION

Diversity and distribution of fishes in the estuary

In the present study, total of 231 species of finfish belonging to 27 orders, 81 families, and 167 genera were recorded (Table 1; Images 4–7). Order Perciformes was the most speciose with 41 species, 22 genera, and 10 families. It was followed by Carangiformes (30 species, 29 genera, and 12 families), and Clupeiformes (25 species, 16 genera, and five families). Among the families (Figure 2), Carangidae was represented by the highest number of species (16 species), followed by Gobiidae and Sciaenidae (both represented by 12 species each). Of all the recorded species, 179 were carnivorous, 45 were omnivorous and two were herbivorous.

In comparison to the earlier study carried out by Krishnan & Mishra (2001), fewer finfish species were recorded during this study. This difference may not necessarily suggest a decline in the overall number of species in the estuary, but is more reflective of the taxonomic and nomenclatural changes. As an example, Krishnan & Mishra (2001) reported seven species of *Stolephorus* from this estuary: *S. andhraensis, S. baganensis, S. commersonii, S. dubiosus, S. indicus, S. insularis*, and *S. waitei*. However, Hata et al. (2020, 2021) made several revisions to the genus *Stolephorus* including updating the species' distribution records. The authors suggested the non-occurrence of *S. baganensis*, *S. commersonii* and *S. waitei* in India, thus making the records of these three species in the Godavari estuary questionable.

On the other hand, species including *Plectorhinchus gibbosus*, *Diagramma pictum,* and non-native species such as *Oreochromis mossambicus* and *Piaractus brachypomus* were recorded for the first time from this estuary. Moreover, the study by Krishnan & Mishra (2001) had a broader scope, having included other distributaries of Godavari River, in comparison to the current study whose focus was the Gowthami-Godavari system. Likewise, the number of species recorded in this study is relatively lower than other large estuaries or mangrove forests located on the east coast of India, including the Sundarbans mangroves (Bhattacharya et al. 2018) and Chilika Lake (Mohanty et al. 2015), from where 312 and 299 species have been recorded, respectively.

Many of the species recorded during this study have also been recorded from other Indian estuaries (Bijukumar & Sushama 2000; Ghosh et al. 2011; Mohanty et al. 2015; Bhattacharya et al. 2018; Sreekanth et al. 2020; Roshni et al. 2021). A number of freshwater species belonging to orders Cypriniformes and Siluriformes were recorded from the mangrove creeks. While a few of them, such as *Mystus gulio* and *Etroplus suratensis* (Image 7a) are known to occur in brackish water habitats (Bijukumar & Sushama 2000), the occurrence of carp species including *Labeo rohita, L. calbasu*, and *L. fimbriatus* were recorded in a few creeks during the post-monsoon season. This is the time when the mangrove forest gets flushed annually with sediment-laden fresh water from the river. The occurrence of these freshwater fishes in the mangrove creeks, however, may also be explained by the stocking of these species in aquaculture ponds abutting the mangroves, creeks, and canals across the East Godavari district. The number of species recorded from the mangrove-lined creeks (150 species), river mouth (151 species), and the Kakinada Bay (149 species) was similar. Nearly 67% of the total species occurred in at least two habitat types showing a high degree of overlap between the estuarine habitats of the delta. Of these, 64 species were found in all three habitat types. The high degree of overlap in species between the habitats indicates the importance of connectivity within this estuarine complex. Fishes recorded exclusively from the bay and the river mouth respectively, constituted nearly 16% and 11% of the total number of species recorded during this study.

Connectivity between the three estuarine habitats and the seascape of East Godavari district is crucial for migratory species occurring in the estuary. The flagship migratory species is *Tenualosa ilisha*, which undertakes large-scale migration from the sea into the Godavari River during the monsoon, when they contribute to important fisheries. It is popularly known as 'Pulasa' in Andhra Pradesh (or 'Hilsa' throughout the Indian sub-continent) and has high commercial value. Other important migratory species occurring in the estuary include *Tenualosa toli*, *Anodontostoma chacunda*, *Lates calcarifer* (Image 4a), and many eel species. Other species, such as mullets (Mugilidae), undertake migrations in the creeks on shorter temporal scales, mainly driven by the tidal regimes and food availability.

Threatened and exotic species

Four species recorded from this estuarine complex are assessed as threatened on the IUCN Red List. These include the Endangered *Silonia childreni,* and the Vulnerable *Tenualosa toli, Cirrhinus cirrhosus* and *Wallago attu*. The Godavari River is an important habitat for *Silonia childreni*, a highly threatened catfish species occurring in the large river systems of peninsular India. On

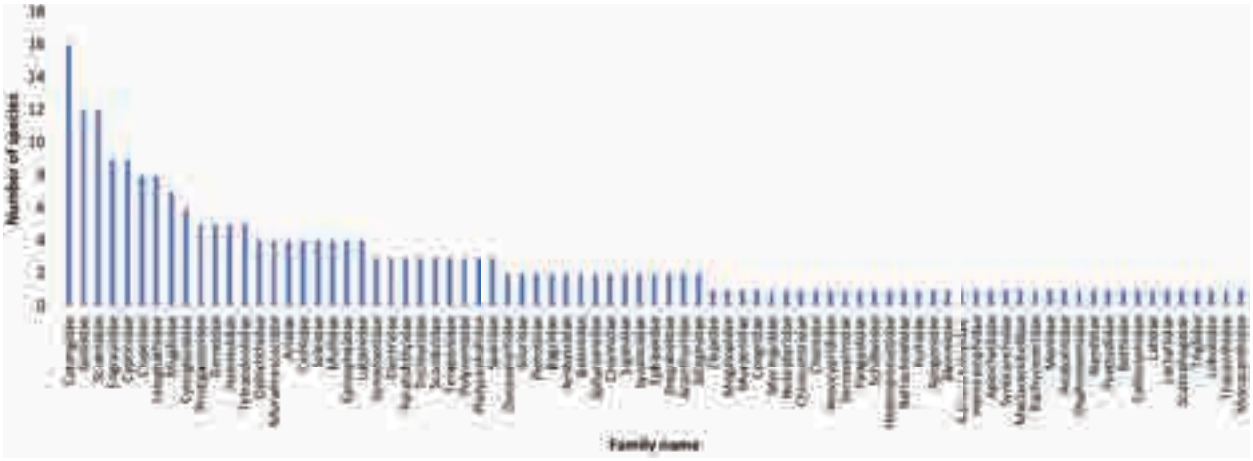

Figure 2. Family-wise number of species recorded in this study.

multiple occasions, the authors recorded its distribution from various parts of the river stretch in Andhra Pradesh, including the estuarine part of the river. Despite this, catches of this large catfish species has been declining, as observed by the local fishers. Additionally, three Near Threatened species: *Ompok bimaculatus, Harpadon nehereus*, & *Protonibea diacanthus* and 10 Data Deficient species: *Platycephalus indicus*, *Epinephelus tauvina*, *Acanthopagrus datnia*, *Rastrelliger kanagurta*, *Scomberomorus guttatus*, *Parapocryptes rictuosus*, *Taenioides cirratus*, *Psettodes erumei*, *Cynoglossus arel*, & *Megalops cyprinoides* were recorded during this study (Table 2). Of the 10 Data Deficient species, *P. indicus* was among the more commonly occurring species in the estuary, which was recorded from all the three habitat types during this study. The two eel species, *Parapocryptes rictuosus* and *Taenioides cirratus*, were recorded only on one occasion in a fisher's catch from the mangrove creek of Tulyabagha inside the CWS.

Five exotic species were also recorded during this study. These include *Oreochromis mossambicus, O. niloticus, Ctenopharyngodon idella, Cyprinus carpio*, and *Piaractus brachypomus*. The first four species are recognized as worst invasive species' of the world by the IUCN Global Invasive Species Database (2021) due to their negative impacts on native fauna. Alarmingly, *O. mossambicus* was found to be among the most dominant species in the CWS. This species appeared to have established a self-sustaining wild population within the Thulyabagha and Coringa creeks of the sanctuary, where the salinities annually ranged from 2 ppt to 20 ppt. The remaining exotic species were recorded only from the riverine zone of the estuary complex.

The main pathway of exotic fish introduction is likely to be through the aquaculture ponds that stock these exotic species. *Piaractus brachypomus* (Pirapitinga), a native of South America, was first recorded from the fish landing centre by the authors in 2013. Since then, this species has become a popular fish in the region (and across the country) and is being extensively stocked in aquaculture ponds along the river, mangrove creeks and canals. It is commonly sold in the local fish markets under the guise of 'white pomfret' or 'freshwater pomfret' and is even being recorded in the catches made by the local fishers in the river (Paromita Ray and Giridhar Malla pers. obs.). This could indicate its possible escape from the aquaculture farms into, and possible establishment within, the river. The authors also noted two occurrence records of *Pterygoplichthys* sp. (family Loricariidae) from the freshwater upstream zone of the river in the East Godavari district. Local fishers recorded this species during the flood season.

Major threats

The Godavari River delta and the estuarine complex have been greatly altered by human activities. The Godavari River delta, along with the Krishna River delta to its south, constitutes one of the largest offshore natural gas reserves in India. The Kakinada Bay also acts as a natural harbour as well as an important port for the state. Additionally, the industrial city of Kakinada (also the headquarters of the East Godavari district) is located adjacent to the mangroves and the estuary. Some of the main causes for degradation of the estuarine ecosystems and the mangrove forests include: diversion for aquaculture, agriculture, salt pans and industries; and rapid and unplanned urbanization (Jayanthi et al. 2018; Bagaria et al. 2021). Other threats include discharge of untreated effluents from anthropogenic sources such as aquaculture farms and industries into the river, canals

Table 1. Habitat-wise list of finfish species recorded during this study from the Godavari River estuary complex.

	Order	Family	Species	Main River	Mangroves	Kakinada Bay
1	Elopiformes	Elopidae	*Elops machnata* (Fabricius, 1775) (Image 5e)	0	1	0
2		Megalopidae	*Megalops cyprinoides* (Broussonet, 1782)	1	1	1
3	Anguilliformes	Muraenidae	*Strophidon sathete* (Hamilton, 1822)	1	1	0
4		Ophichthidae	*Bascanichthys deraniyagalai* Menon, 1961	1	1	1
5			*Cirrhimuraena playfairii* (Günther, 1870)	1	1	0
6			*Pisodonophis boro* (Hamilton, 1822)	1	1	0
7			*Pisodonophis cancrivorus* (Richardson, 1848)	1	1	0
8		Muraenescocidae	*Congresox talabonoides* (Bleeker, 1852)	1	1	0
9			*Congresox talabon* (Cuvier, 1829)	1	1	0
10			*Muraenesox cinereus* (Forsskål, 1775)	1	1	0
11			*Muraenesox bagio* (Hamilton, 1822)	1	1	0
12		Congridae	*Uroconger lepturus* (Richardson, 1845)	1	0	0
13		Moringuidae	*Moringua raitaborua* (Hamilton, 1822)	1	1	1
14	Osteoglossiformes	Notopteridae	*Notopterus notopterus* (Pallas, 1769)	1	0	0
15	Clupeiformes	Clupeidae	*Anodontostoma chacunda* (Hamilton, 1822)	1	1	0
16			*Escualosa thoracata* (Valenciennes, 1847)	1	1	1
17			*Hilsa kelee* (Cuvier, 1829)	1	1	1
18			*Nematalosa nasus* (Bloch, 1795)	1	0	0
19			*Sardinella longiceps* Valenciennes, 1847	1	1	1
20			*Sardinella fimbriata* (Valenciennes, 1847)	1	1	1
21			*Tenualosa ilisha* (Hamilton, 1822)	1	0	0
22			*Tenualosa toli* (Valenciennes, 1847)	1	1	0
23		Dussumieriidae	*Dussumieria acuta* Valenciennes, 1847	0	1	1
24			*Dussumieria elopsoides* Bleeker, 1849	0	1	1
25		Engraulidae	*Coilia dussumieri* Valenciennes, 1848	1	1	1
26			*Coilia reynaldi* Valenciennes, 1848	1	1	1
27			*Setipinna taty* (Valenciennes, 1848)	1	1	1
28			*Setipinna tenuifilis (*Valenciennes, 1848)	1	1	1
29			*Stolephorus commersonnii* Lacepède, 1803	1	1	1
30			*Stolephorus indicus* (van Hasselt, 1823)	0	0	1
31			*Thryssa mystax* (Bloch & Schneider, 1801)	1	1	1
32			*Thryssa malabarica* (Bloch, 1795)	1	1	1
33			*Thryssa baelama* (Fabricius, 1775)	1	1	1
34		Chirocentridae	*Chirocentrus dorab* (Fabricius, 1775)	1	0	1
35		Pristigasteridae	*Ilisha melastoma* (Bloch & Schneider, 1801)	1	1	1
36			*Ilisha megaloptera* (Swainson, 1838)	1	1	1
37			*Opisthopterus tardoore* (Cuvier, 1829) (Image 4c)	1	1	1
38			*Pellona ditchela* Valenciennes, 1847	1	1	1
39			*Raconda russeliana* Gray, 1831	1	0	1
40	Gonorynchiformes	Chanidae	*Chanos chanos* (Fabricius, 1775)	1	0	1
41	Cypriniformes	Cyprinidae	*Cirrhinus cirrhosus* (Bloch, 1795)	1	1	0
42			*Cirrhinus mrigala* (Hamilton, 1822)	1	0	0
43			*Cyprinus carpio* Linnaeus, 1758	1	0	0

	Order	Family	Species	Main River	Mangroves	Kakinada Bay
44			*Labeo catla* (Hamilton, 1822)	1	0	0
45			*Labeo calbasu* (Hamilton, 1822)	1	1	0
46			*Labeo fimbriatus* (Bloch, 1795)	1	1	0
47			*Labeo rohita* (Hamilton, 1822)	1	1	0
48			*Puntius sophore* (Hamilton, 1822)	1	1	0
49			*Pethia ticto* (Hamilton, 1822)	1	0	0
50		Xenocyprididae	*Ctenopharyngodon idella* (Valenciennes, 1844)	1	0	0
51	Characiformes	Serrasalmidae	*Piaractus brachypomus* (Cuvier, 1818)	1	0	0
52	Siluriformes	Plotosidae	*Plotosus canius* Hamilton, 1822	1	1	0
53			*Plotosus lineatus* (Thunberg, 1787)	0	0	1
54		Ailiidae	*Silonia childreni* (Sykes, 1839)	1	0	0
55		Bagridae	*Mystus gulio* (Hamilton, 1822)	1	1	0
56			*Mystus vittatus* (Bloch, 1794)	1	1	0
57		Pangasiidae	*Pangasius pangasius* (Hamilton, 1822)	1	1	0
58		Siluridae	*Wallago attu* (Bloch & Schneider, 1801)	1	0	0
59			*Ompok bimaculatus* (Bloch, 1794)	1	0	0
60		Heteropneustidae	*Heteropneustes fossilis* (Bloch, 1794)	1	1	0
61		Ariidae	*Arius arius* (Hamilton, 1822)	1	1	1
62			*Arius gagora* (Hamilton 1822)	1	1	1
63			*Arius maculatus* (Thunberg, 1792)	1	1	1
64			*Plicofollis dussumieri* (Valenciennes, 1840)	0	0	1
65	Aulopiformes	Synodontidae	*Saurida tumbil* (Bloch, 1795)	0	0	1
66			*Synodus indicus* (Day, 1873)	0	0	1
67			*Harpadon nehereus* (Hamilton, 1822)	1	1	1
68	Batrachoidiformes	Batrachoididae	*Allenbatrachus grunniens* (Linnaeus, 1758) (Image 7c)	1	1	0
69	Scombriformes	Scombridae	*Katsuwonus pelamis* (Linnaeus, 1758)	0	0	1
70			*Rastrelliger kanagurta* (Cuvier, 1816)	1	0	1
71			*Scomberomorus guttatus* (Bloch & Schneider, 1801)	0	0	1
72		Trichiuridae	*Eupleurogrammus muticus* (Gray, 1831)	1	1	0
73			*Lepturacanthus savala* (Cuvier, 1829)	1	0	1
74			*Trichiurus lepturus* Linnaeus, 1758	1	0	1
75	Syngnathiformes	Mullidae	*Upeneus sulphureus* Cuvier, 1829	1	1	1
76			*Upeneus vittatus* (Forsskål, 1775)	1	0	0
77			*Upeneus moluccensis* (Bleeker, 1855)	0	0	1
78			*Upeneus taeniopterus* Cuvier, 1829	1	1	1
79		Callionymidae	*Callionymus carebares* Alcock, 1890	0	1	0
80	Kurtiformes	Kurtidae	*Kurtus indicus* Bloch, 1786 (Image 7d)	0	1	1
81		Apogonidae	*Jaydia queketti* (Gilchrist 1903) (Image 6d)	0	0	1
82	Gobiiformes	Eleotridae	*Eleotris fusca* (Bloch & Schneider, 1801)	1	1	0
83			*Butis butis* (Hamilton, 1822) (Image 5d)	0	1	0
84			*Butis humeralis* (Valenciennes, 1837)	0	1	0
85		Gobiidae	*Aulopareia cyanomos* (Bleeker, 1849) (Image 5b)	0	1	1
86			*Apocryptes bato* (Hamilton, 1822)	0	1	0
87			*Boleophthalmus boddarti* (Pallas, 1770)	0	1	1

	Order	Family	Species	Main River	Mangroves	Kakinada Bay
88			*Glossogobius giuris* (Hamilton, 1822)	1	1	0
89			*Oxyurichthys microlepis* (Bleeker, 1849) (Image 7b)	0	1	0
90			*Parapocryptes rictuosus* (Valenciennes, 1837)	0	1	0
91			*Periophthalmus chrysospilos* Bleeker, 1853	0	1	0
92			*Taenioides anguillaris* (Linnaeus, 1758)	1	1	0
93			*Taenioides cirratus* (Blyth, 1860)	1	1	0
94			*Trypauchen vagina* (Bloch & Schneider, 1801) (Image 6e)	1	1	0
95			*Yongeichthys nebulosus* (Forsskål, 1775)	1	0	0
96			*Stigmatogobius sadanundio* (Hamilton, 1822)	1	0	0
97	Synbranchiformes	Mastacembelidae	*Macrognathus pancalus* Hamilton 1822	1	0	0
98		Synbranchidae	*Ophisternon bengalense* McClelland, 1844	1	0	0
99	Anabantiformes	Anabantidae	*Anabas testudineus* (Bloch, 1792)	1	1	0
100		Osphronemidae	*Trichogaster fasciata* Bloch & Schneider, 1801	1	0	0
101		Channidae	*Channa punctata* (Bloch, 1793)	1	0	0
102			*Channa striata* (Bloch, 1793)	1	0	0
103		Nandidae	*Nandus nandus* (Hamilton, 1822)	0	1	0
104	Carangiformes	Latidae	*Lates calcarifer* (Bloch, 1790) (Image 4a)	1	1	0
105		Lactariidae	*Lactarius lactarius* (Bloch & Schneider, 1801)	1	0	1
106		Sphyraenidae	*Sphyraena obtusata* Cuvier, 1829	0	0	1
107			*Sphyraena jello* Cuvier, 1829	0	0	1
108		Polynemidae	*Eleutheronema tetradactylum* (Shaw, 1804)	1	1	1
109			*Polydactylus sextarius* (Bloch & Schneider, 1801)	1	1	1
110			*Leptomelanosoma indicum* (Shaw, 1804)	1	1	1
111		Psettodidae	*Psettodes erumei* (Bloch & Schneider, 1801)	1	0	1
112		Bothidae	*Bothus myriaster* (Temminck & Schlegel, 1846)	0	1	1
113		Paralichthyidae	*Pseudorhombus arsius* (Hamilton, 1822)	0	1	1
114			*Pseudorhombus triocellatus* (Bloch & Schneider, 1801)	0	1	1
115			*Pseudorhombus elevatus* Ogilby, 1912	1	1	1
116		Soleidae	*Aesopia cornuta* Kaup, 1858	0	0	1
117			*Solea ovata* Richardson, 1846	0	1	1
118			*Dagetichthys albomaculatus* (Kaup, 1858)	1	1	1
119			*Zebrias synapturoides* (Jenkins, 1910)	1	1	1
120		Cynoglossidae	*Cynoglossus arel* (Bloch & Schneider, 1801)	1	1	1
121			*Cynoglossus bilineatus* (Lacepède, 1802)	1	1	1
122			*Cynoglossus puncticeps* (Richardson, 1846)	1	1	1
123			*Cynoglossus lingua* Hamilton, 1822	1	1	0
124			*Cynoglossus cynoglossus* (Hamilton, 1822)	1	1	1
125			*Paraplagusia bilineata* (Bloch, 1787)	1	1	1
126		Menidae	*Mene maculata* (Bloch & Schneider, 1801)	0	1	0
127		Carangidae	*Megalaspis cordyla* (Linnaeus, 1758)	0	0	1
128			*Scyris indica* (Rüppell, 1830)	1	0	1
129			*Alepes djedaba* (Fabricius, 1775)	1	0	1
130			*Alepes kleinii* (Bloch, 1793)	1	0	1
131			*Atropus atropos* (Bloch & Schneider, 1801)	0	0	1

	Order	Family	Species	Main River	Mangroves	Kakinada Bay
132			*Atule mate* (Cuvier, 1833)	1	0	1
133			*Platycaranx malabaricus* (Bloch & Schneider, 1801)	0	0	1
134			*Caranx ignobilis* (Forsskål, 1775)	0	1	1
135			*Caranx sexfasciatus* Quoy & Gaimard, 1825	0	1	1
136			*Caranx heberi* (Bennett, 1830)	0	0	1
137			*Decapterus russelli* (Rüppell, 1830)	0	0	1
138			*Parastromateus niger* (Bloch, 1795)	0	1	1
139			*Scomberoides commersonnianus* Lacepède, 1801	0	0	1
140			*Scomberoides tol* (Cuvier, 1832)	0	0	1
141			*Selar crumenophthalmus* (Bloch, 1793)	0	0	1
142			*Trachinotus mookalee* Cuvier, 1832. (Image 6a)	0	1	1
143		Rachycentridae	*Rachycentron canadum* (Linnaeus, 1766)	0	0	1
144	Cichliformes	Ambassidae	*Ambassis gymnocephalus* (Lacepède, 1802)	1	1	0
145			*Chanda nama* Hamilton, 1822	1	1	0
146		Cichlidae	*Etroplus suratensis* (Bloch, 1790) (Image 7a)	1	1	0
147			*Pseudetroplus maculatus* (Bloch, 1795)	1	0	0
148			*Oreochromis mossambicus* (Peters, 1852)	1	1	0
149			*Oreochromis niloticus* (Linnaeus, 1758)	1	0	0
150	Cyprinodontiformes	Aplocheilidae	*Aplocheilus blockii* Arnold, 1911	1	1	0
151	Beloniformes	Belonidae	*Strongylura strongylura* (van Hasselt, 1823)	1	0	1
152			*Xenentodon cancila* (Hamilton, 1822)	1	1	0
153		Hemiramphidae	*Hyporhamphus limbatus* (Valenciennes, 1847)	1	1	1
154		Adrianichthyidae	*Oryzias dancena* (Hamilton 1822)	0	1	0
155	Mugiliformes	Mugilidae	*Mugil cephalus* Linnaeus, 1758	1	1	1
156			*Chelon parsia* (Hamilton, 1822)	1	1	1
157			*Planiliza subviridis* (Valenciennes, 1836)	1	1	1
158			*Planiliza planiceps* (Valenciennes, 1836)	1	0	0
159			*Planiliza tade* (Fabricius, 1775)	1	1	0
160			*Rhinomugil corsula* (Hamilton, 1822)	1	1	0
161			*Crenimugil seheli* (Fabricius, 1775)	1	1	1
162	Blenniiformes	Blenniidae	*Omobranchus ferox* (Herre, 1927)	1	1	0
163	Perciformes *sedis mutabilis*	Sillaginidae	*Sillaginopsis domina* (Cuvier, 1816)	0	0	1
164			*Sillago sihama* (Fabricius, 1775)	1	1	1
165		Lutjanidae	*Lutjanus johnii* (Bloch, 1792) (Image 4b)	1	1	1
166			*Lutjanus russellii* (Bleeker, 1849)	0	1	1
167			*Lutjanus argentimaculatus* (Forsskål, 1775) (Image 5c)	0	1	1
168			*Lutjanus fulviflamma* (Forsskål, 1775)	0	1	1
169		Gerreidae	*Gerres filamentosus* Cuvier, 1829	1	1	1
170			*Gerres limbatus* Cuvier, 1830	1	1	1
171			*Gerres setifer* (Hamilton, 1822)	1	1	1
172			*Gerres oyena* (Fabricius, 1775)	1	1	1
173			*Gerres longirostris* (Lacepède, 1801)	0	0	1
174		Haemulidae	*Pomadasys kaakan* (Cuvier, 1830)	1	1	1

	Order	Family	Species	Main River	Mangroves	Kakinada Bay
175			*Pomadasys argenteus* (Forsskål, 1775)	1	1	1
176			*Pomadasys maculatus* (Bloch, 1793)	1	1	1
177			*Plectorhinchus gibbosus* (Lacepède, 1802)	0	0	1
178			*Diagramma pictum* (Thunberg, 1792)	0	0	1
179		Sparidae	*Acanthopagrus berda* (Fabricius, 1775)	0	0	1
180			*Acanthopagrus datnia* (Hamilton, 1822)	0	0	1
181			*Rhabdosargus sarba* (Gmelin, 1789)	0	0	1
182		Sciaenidae	*Chrysochir aurea* (Richardson, 1846)	0	1	1
183			*Daysciaena albida* (Cuvier, 1830)	0	1	1
184			*Dendrophysa russelii* (Cuvier, 1829)	1	1	1
185			*Johnius belangerii* (Cuvier, 1830)	0	1	1
186			*Johnius coitor* (Hamilton, 1822)	1	1	1
187			*Johnius dussumieri* (Cuvier, 1830)	0	1	1
188			*Kathala axillaris* (Cuvier, 1830)	0	1	1
189			*Nibea maculata* (Bloch & Schneider, 1801)	0	1	1
190			*Nibea soldado* (Lacepède, 1802)	0	1	1
191			*Otolithes ruber* (Bloch & Schneider, 1801)	1	1	0
192			*Panna microdon* (Bleeker, 1849)	0	1	1
193			*Protonibea diacanthus* (Lacepède, 1802)	0	1	1
194	Perciformes	Epinephelidae	*Epinephelus coioides* (Hamilton, 1822)	0	1	1
195			*Epinephelus malabaricus* (Bloch & Schneider, 1801)	0	1	1
196			*Epinephelus melanostigma* Schultz, 1953	0	0	1
197			*Epinephelus tauvina* (Fabricius, 1775)	0	0	1
198		Platycephalidae	*Grammoplites scaber* (Linnaeus, 1758)	1	1	0
199			*Cociella crocodilus* (Cuvier, 1829)	1	0	0
200			*Platycephalus indicus* (Linnaeus, 1758)	1	1	1
201		Triglidae	Lepidotrigla sp.	0	0	1
202		Synanceiidae	*Minous monodactylus* (Bloch & Schneider, 1801) (Image 4f)	0	1	1
203			*Minous inermis* Alcock 1889	0	0	1
204	Centrarchiformes	Terapontidae	*Terapon jarbua* (Fabricius, 1775) (Image 6c)	1	1	0
205			*Terapon puta* Cuvier, 1829	1	1	0
206			*Pelates quadrilineatus* (Bloch, 1790)	1	0	1
207	Acanthuriformes	Lobotidae	*Lobotes surinamensis* (Bloch, 1790)	1	0	1
208		Drepaneidae	*Drepane longimana* (Bloch & Schneider, 1801)	1	1	0
209			*Drepane punctata* (Linnaeus, 1758)	0	1	0
210		Ephippidae	*Ephippus orbis* (Bloch, 1787)	0	0	1
211			Platax sp.	0	0	1
212		Leiognathidae	*Leiognathus equula* (Forsskål, 1775)	1	1	1
213			*Eubleekeria splendens* (Cuvier, 1829)	1	1	1
214			*Leiognathus berbis* (Valenciennes, 1835)	0	1	1
215			*Photopectoralis bindus* (Valenciennes, 1835)	1	1	1
216			*Gazza minuta* (Bloch, 1795)	0	0	1
217			*Deveximentum insidiator* (Bloch, 1787)	1	1	1
218			*Nuchequula blochii* (Valenciennes, 1835)	0	1	1

	Order	Family	Species	Main River	Mangroves	Kakinada Bay
219			*Leiognathus ruconius* (Hamilton, 1822) (Image 4d)	1	1	1
220		Scatophagidae	*Scatophagus argus* (Linnaeus, 1766)	1	1	1
221		Siganidae	*Siganus canaliculatus* (Park, 1797)	1	1	1
222			*Siganus javus* (Linnaeus, 1766) (Image 4e)	1	1	1
223		Acanthuridae	*Acanthurus mata* (Cuvier, 1829) (Image 5a)	1	0	0
224			*Acanthurus xanthopterus* Valenciennes, 1835	1	1	1
225	Tetraodontiformes	Triacanthidae	*Triacanthus biaculeatus* (Bloch, 1786) (Image 6b)	0	0	1
226		Tetraodontidae	*Takifugu oblongus* (Bloch, 1786)	0	0	1
227			*Chelonodontops patoca* (Hamilton, 1822)	1	1	1
228			*Dichotomyctere fluviatilis* (Hamilton, 1822)	1	1	1
229			*Lagocephalus lunaris* (Bloch & Schneider, 1801)	1	0	1
230			*Lagocephalus inermis* (Temminck & Schlegel, 1850)	1	0	1
231		Monacanthidae	*Aluterus monoceros* (Linnaeus, 1758)	0	0	1
			Total	**151**	**150**	**149**

1—Presence recorded | 0—Presence not recorded.

Image 4. Images of fish species recorded in this study along with their standard lengths whenever available: a—*Lates calcarifer* | b—*Lutjanus johnii* (137 mm) | c—*Opisthopterus tardoore* (98 mm) | d—*Leiognathus ruconius* (48 mm) | e—*Siganus javus* (78 mm) | f—*Minous monodactylus* (72 mm). © Paromita Ray.

and the mangrove creeks (Rao et al. 2018); sand mining at the river bed, dredging of the creeks and river mouth (Malini & Rao 2004) alteration of the natural flow of Godavari River and obstructing freshwater discharge and sediment load into the estuary and mangroves (Malini & Rao 2004). Large-scale deforestation and loss of aquatic habitats in the upper catchments of Godavari River, such as that found in and around the Papikonda National Park (Aditya & Ganesh 2019) which is ~80 km upstream of the estuary, also exacerbates the negative impacts on the estuarine biodiversity.

During the present study, we noticed a number of aquaculture ponds located very close to the mangrove forests, and adjoining the feeder creeks and canals (Image 2). This not only increases the risk of release of exotic fishes and causes degradation of the fringe mangroves, but also increases the risk of introduction of disease in the wild fish community. During the study period, two instances of fish kills were also observed in the Coringa creek draining into the CWS. On further enquiry by the authors, the local fishers informed us that fish kills have become a regular occurrence in the creeks due to the release of untreated effluents by the aquaculture ponds and the industries located upstream. The coastal zones of the East Godavari district are considered among the most polluted in the state (Muktha et al. 2018).

The mangroves of CWS are well-protected and support a diverse aquatic community. However, the mangrove patches at the edge of the sanctuary or the unprotected patches in the district are highly vulnerable to loss and conversion to other land uses, including aquaculture and industries. Bagaria et al. (2021) estimated a loss of 5.81 sq. km of unprotected mangroves in the delta between 1977 and 2015, complemented with a simultaneous rise of 177 km^2 in the area under aquaculture. The study has also highlighted the rapid increase in human settlements and industries and a loss of other natural coastal features, including coastal scrub, mudflats, and riverine vegetation. A recent report by Rao (2021) inferred that an unprotected patch of mangrove drained by a creek near Kakinada harbour had been reported to be reclaimed for city development.

As the unprotected mangroves on the landward side are being lost to land-use changes, climate change is

Image 5. Images of fish species recorded in this study along with their standard lengths whenever available: a—*Acanthurus mata* (56 mm) | b—*Acentrogobius cyanomos* (110 mm) | c—*Lutjanus argentimaculatus* (153 mm) | d—*Butis butis* (120 mm) | e—*Elops machnata*. © Paromita Ray.

Table 2. List of threatened, Near Threatened, and Data Deficient species as per the IUCN Red List of Threatened Species.

	Species name	Main river	Mangroves	Bay	IUCN Red List status
1	*Silonia childreni* (Sykes, 1839)	+	-	-	EN
2	*Tenualosa toli* (Valenciennes, 1847)	+	+	-	VU
3	*Cirrhinus cirrhosus* (Bloch, 1795)	+	+	-	VU
4	*Wallago attu* (Bloch & Schneider, 1801)	+	-	-	VU
5	*Ompok bimaculatus* (Bloch, 1794)	+	-	-	NT
6	*Harpadon nehereus* (Hamilton, 1822)	+	+	+	NT
7	*Protonibea diacanthus* (Lacepède, 1802)	-	+	+	NT
8	*Platycephalus indicus* (Linnaeus, 1758)	+	+	+	DD
9	*Epinephelus tauvina* (Fabricius, 1775)	-	-	+	DD
10	*Acanthopagrus datnia* (Hamilton, 1822)	-	-	+	DD
11	*Rastrelliger kanagurta* (Cuvier, 1816)	+	-	+	DD
12	*Scomberomorus guttatus* (Bloch & Schneider, 1801)	-	-	+	DD
13	*Parapocryptes rictuosus* (Valenciennes, 1837)	-	+	-	DD
14	*Taenioides cirratus* (Blyth, 1860)	+	+	-	DD
15	*Psettodes erumei* (Bloch & Schneider, 1801)	+	-	+	DD
16	*Cynoglossus arel* (Bloch & Schneider, 1801)	+	+	+	DD
17	*Megalops cyprinoides* (Broussonet, 1782)	+	+	+	DD

+—Presence recorded | ——Presence not recorded | EN—Endangered | VU—Vulnerable | NT—Near Threatened | DD—Data Deficient.

driving mangrove loss on the seaward side of the delta. An estimated 15 km^2 of mangroves in the East Godavari district have been lost due to sea-level rise between 1977 and 2015 (Bagaria et al. 2021). Visible signs of seaward changes, including degradation and intrusion of sand into the mangrove forests, were also observed by the authors during the present study (Image 3). This region is also among the coastal stretches of India that are most vulnerable to natural disasters including cyclones and storm surges (Mohapatra et al. 2012). The effects of sea-level rise compounded with the increasing degradation and conversion of the mangroves on the landward side is possibly driving them towards a situation of 'mangrove squeeze'.

In addition to the above threats, regulation of the Godavari River driven by the Polavaram Dam, a large dam being constructed nearly 100 km upstream of the river mouth, will potentially lead to drastic reductions in freshwater and sediment flow into the mangroves and the estuary. Studies from Portugal (Chicharo et al. 2006), China (Jiao et al. 2007) and other parts of the world have shown the negative impacts of damming on estuaries and marine habitats, including changes in salinity regime, nutrient flow, primary productivity and the fish community. Ezcurra et al. (2019) found a rapid coastal recession in otherwise accreting tropical river basins after they were dammed, coupled with losses in fisheries and other ecosystem services. With the presence of nine large dams and a number of smaller dams and irrigation projects, the Godavari River is a highly regulated river system of India. The annual sediment flux in the river basin has already decreased by an estimated 74% (Gupta et al. 2012). The Polavaram Dam has a high likelihood of exacerbating the downstream impacts by restricting the sediment discharge and further altering the freshwater flow regime, both of which play important roles in the sustenance of the mangroves as well as in structuring the estuarine fish assemblages. It will, therefore, be crucial to regularly monitor the estuary and its fish community once the dam becomes functional in the near future.

CONCLUSION AND RECOMMENDATIONS

This study documented the rich finfish diversity of the dynamic Godavari River estuarine complex. This estuary complex, formed by India's largest peninsular river, is undergoing rapid changes driven by number of anthropogenic factors coupled with sea-level rise, coastal erosion and natural disasters including cyclones. While the protected mangroves of the CWS do provide a crucial refuge for estuarine and juvenile marine fishes, it

Image 6. Images of fish species recorded in this study along with their standard lengths whenever available: a—*Trachinotus mookalee* (86 mm) | b—*Triacanthus biaculeatus* (129 mm) | c—*Terapon jarbua* (37 mm) | d—*Jaydia queketti* (88 mm) | e—*Trypauchen vagina*. © Paromita Ray.

is important to adopt a holistic and prescient approach to protect the unprotected coastal habitats of the region. As this study suggests, various fish species are utilizing the different estuarine habitats of the Godavari delta. Few migratory and conservation-concern species such as the 'Hilsa' or 'Pulasa' have also been recorded in this estuary. Therefore, to better manage the threats, and to protect the aquatic ecosystems of the East Godavari district, it is crucial to understand and acknowledge the importance of maintaining the ecological connectivity, both between and within the riverscape and the various estuarine habitats, including the river mouth, the mangrove-lined creeks and the bay. The information collected in this study will serve as a baseline to monitor future changes in the fish community of this region, driven by various anthropogenic and natural stressors.

The Polavaram Dam is already under construction, but it is still important to focus on mitigating the negative impacts on the riverine habitats, both upstream and downstream. The minimum freshwater flows to the downstream habitats must be ensured by the dam authorities, taking in consideration the river's natural pattern of seasonal variation in freshwater discharge. Alongside this, it is also important to recognize the negative impacts of stocking and introduction of non-native fish species as a mitigation measure. Several non-native species have been recorded in this study that were introduced either through fisheries or accidentally through aquaculture and the aquarium industry. The district authorities and the fisheries department need to take immediate steps to address this issue, while strictly prohibiting the stocking of non-native fishes in the reservoir, canals or aquaculture ponds in the district. The fisheries department can encourage protection of the carp and catfish species that are native to the Godavari River basin such as the threatened *Silonia childreni*.

We recommend mapping of the unprotected and degraded patches of mangroves in the delta region of

Image 7. Images of fish species recorded in this study along with their standard lengths whenever available: a—*Etroplus suratensis* (71 mm) | b—*Oxyurichthys microlepis* (72 mm) | c—*Allenbatrachus grunniens* | d—*Kurtus indicus* (62 mm). © Paromita Ray.

the district that serve as important nursery habitats for the fish species. This would help in identifying and prioritizing the most vulnerable stretches for focused conservation efforts. Declaring the most degraded and vulnerable mangroves as 'eco-sensitive zones' or 'community reserves' would provide them with basic protection from future conversions and losses. The authorities may follow this with restoration of the degraded mangrove patches. A similar prioritization exercise should also be carried out for other coastal habitats of the estuary, including the unprotected creeks, intertidal zones, mudflats, river banks and the river mouth.

Additionally, a minimum buffer should be allowed around the mangrove forests and the creeks on the landward side to allow them to maintain their structural integrity and landward shift driven by sea-level rise. The aquaculture ponds should particularly be located at a minimum distance away from the mangrove forests and the creeks. Strict monitoring of the ponds, as per the guidelines prescribed by the Coastal Aquaculture Authority of India, should be carried out to prevent untreated effluent discharge and release of non-native species into the natural habitats. Since the area under aquaculture in the district continues to grow each year, a scientific study is recommended that would assess the ecological capacity of this estuarine region to support this industry along with assessing the extant negative ecological and socio-economic impacts of the same. The policies pertaining to captive fisheries should actively encourage sustainable aquaculture practices rather than focusing on maximization of short-term economic gains.

The district authorities should also enhance monitoring of destructive activities in the river basin such as sand-mining, deforestation of the riparian zones, and conversion of river banks to other land-uses. In addition, the government should especially take actions to stop illegal mining of the river bed in the district, proactively monitor the pollution levels in the river, mangroves, and the associated creeks and canals and initiate action against the industries and aquaculture ponds found releasing untreated effluents into the estuary, as prescribed by law.

Garnering the support of local communities and other stakeholders is crucial for the long-term conservation and management of the Godavari estuarine complex and its associated biodiversity. For generating local support, district and village-level organizations such as the panchayat, self-help groups, fishers' collectives, and aquaculture collectives can be leveraged. Regular and focused campaigns would be helpful to improve awareness as well as generating local stewardship for

sustainable fisheries and biodiversity conservation. Such awareness programs should also be developed for policy makers, planners, and stakeholders from the agricultural and industrial sectors since their actions may also have serious impacts on the aquatic ecosystems of the district. Along with this, further inter-disciplinary studies are important to understand the different features of this estuarine complex including biological, ecological, social, cultural, and economic complexities.

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COMMUNICATION

DNA barcoding of a lesser-known catfish, *Clupisoma bastari* (Actinopterygii: Ailiidae) from Deccan Peninsula, India

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Abstract: DNA barcoding substantiates species identification, and simultaneously indicates the misnomer taxa. Based on the morphological descriptions, we identified a lesser-known catfish, *Clupisoma bastari*, from Godavari River basin, and contributed novel DNA barcode data to the GenBank. The Kimura 2 parameter genetic divergence between species, and the neighbour-joining phylogeny clearly depicted a distinct clade of *C. bastari* in the studied dataset. *Clupisoma bastari* maintained sufficient K2P genetic divergence (8.3% to 11.2%) with other congeners, and branched as a sister-species of *C. garua*. The present study highlights possible existence of a few misnomer taxa in the GenBank. We encourage further extensive sampling of different congeners of *Clupisoma* from a wide range of habitats to explore the species diversity and phylogenetic relationship.

Keywords: Eastern Ghats, ichthyology, species identification, taxanomy.

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Author contributions: BAL & HA did field surveys and collected the specimens. BAL studied the morphology and meristics of the specimens for taxonomic identification. HA generated the DNA data. BAL & SK did the molecular analysis. BAL, SK & DJ wrote the article. BAL & KC reviewed the article.

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INTRODUCTION

The genus *Clupisoma* Swainson is classified under a newly set up family Ailiidae, and is currently comprised of nine valid species (Wang et al. 2016; Fricke 2020), distributed across Salween basin in Yunnan, China, to westward Indus basin in Pakistan (Jayaram 1977; Ferraris 2004; Chen et al. 2005). Among them, four species are distributed in Indus, Ganges, Brahmaputra, and Godavari basins, in India. *Clupisoma bastari* Datta & Karmakar (1980) was described from Indravathi River, a tributary of river Godavari in peninsular India. Due to its limited distribution, the species has been poorly studied, and it was once categorized as 'Endangered' (Molur & Walker 1998). The species is currently categorized as 'Data Deficient' in the International Union for Conservation of Nature Red List and referred to as extant resident of the State Chattisgarh in central India (Dahanukar 2011). Apart from a few studies on the length-weight relationship, and food and feeding habit, on a collection of specimens during 1997–98 from upper Godavari basin (Bhowate & Mulgir 2006, 2009), the species was sometime reported from Ravi Shankar Sagar reservoir and from Tapti river in the central Mahanadi basin (Desai & Srivastava 2004; Siddiqui & Pervin 2017). *C. bastari* was not enlisted in the updated checklist of ichthyofauna of Eastern Ghats as well as studies from other localities within the Deccan Peninsula (Barman 1993; Devi & Indra 2003; Johnson et al. 2012; Laxammappa & Bakshi 2016). *C. bastari* has been presumably overlooked in the earlier studies due to misidentification of *Clupisoma* congeners in India.

Besides traditional taxonomy, the molecular data is effectively evidenced to identify and distinguish freshwater fishes around the world (Hubert et al. 2008; Ward et al. 2009; Steinke et al. 2009; April et al. 2011; Collins et al. 2012). Several small to large-scale attempts have been endeavored to build-up the DNA barcode reference library of freshwater fishes from India and neighboring countries, aiming to quick and reliable species identification and to illuminate species diversity from different biogeographic zones (Khedkar et al. 2014; Chen et al. 2015; Barman et al. 2018; Laskar et al. 2018; Kundu et al. 2019; Rahman et al. 2019). Although, the GenBank database holds several publicly available DNA barcode sequences of *Clupisoma* species, the genetic information on *C. bastari* was lacking. We studied *C. bastari* from central Godavari basin surrounding its type locality and generated the DNA barcode data to fill the gap of knowledge.

MATERIALS AND METHODS

Specimens of *Clupisoma garua* were collected from Mahanadi river basin, Odisha; and *C. bastari* from two different localities in Godavari River basin in Deccan Peninsula, India (Figure 1). The specimens are registered in the National Zoological Collections of Zoological Survey of India, Hyderabad. *Clupisoma garua*, FBRC/ZSI/F2445, ex 1, 190 mm SL; Odisha, Ib river, near Jharsuguda-Raigarh road, about 30 Km from Hirakud reservoir, 21.866N 83.951E, 28 August 2017; *C. bastari*, FBRC/ZSI/F2410, ex 1, 185 mm SL; Telangana, Sriram Sagar Reservoir, 18.99N 78.31E, 13 June 2017; and *C. bastari*, FBRC/ZSI/F3461, ex 1, 122 mm SL, Telangana, Godavari-Sabri confluence, near Konavaram bridge, 17.56N 81.26E, 24 November 2019.

The genomic DNA was extracted through QIAamp DNA Mini Kit (Qiagen, Valencia, CA) following manufacturer's procedures. The published primer pair (Ward et al. 2005): FishF1-5'TCAACCAACCACAAAGACATTGGCAC3' and FishR1-5'TAGACTTCTGGGTGGCCAAAGAATCA3' was used to amplify the partial cytochrome oxidase subunit I gene (mtCOI) in a Veriti® Thermal Cycler (Applied Bio systems, Foster City, CA). The 30 µl PCR mixture contains 10 pmol of each primer, 100 ng of DNA template, 1 × PCR buffer, 1.0–1.5 mM of MgCl2, 0.25 mM of each dNTPs, and 1U of Taq polymerase (Takara BIO Inc., Japan). The thermal profile comprised of an initial step of 2 min at 95 °C followed by 35 cycles of 0.5 min at 94 °C, 0.5 min at 54 °C, and 1 min at 72 °C, followed in turn by 10 min at 72 °C and subsequent hold at 4°C. The PCR products were further purified using QIAquickR Gel extraction Kit (Qiagen, Valencia, CA). The cycle sequencing and Sanger sequencing was executed commercially. Both forward and reverse chromatograms were checked through SeqScanner V1.0 (Applied Biosystems Inc., CA, USA), nucleotide BLAST (https://blast.ncbi.nlm.nih.gov/), and ORF finder (https://www.ncbi.nlm.nih.gov/orffinder/) to trim the low quality reads and gaps. The COI barcode sequences of *C. bastari* and *C. garua* generated in this study are available in GenBank and the accession numbers are reflected in the phylogenetic tree. Further, the sequences of nominal *Clupisoma* congeners were downloaded from the GenBank database to form a combined dataset for estimating genetic distance and phylogenetic analysis. However, a few sequences of nominal *C. garua* (accession numbers: KX455904, FJ459470, FJ459471, and MN259175) were not included in the final dataset assuming that these are probably conspecifics of *Silonia silondia* as observed in test of phylogeny covering all the available sequences of the

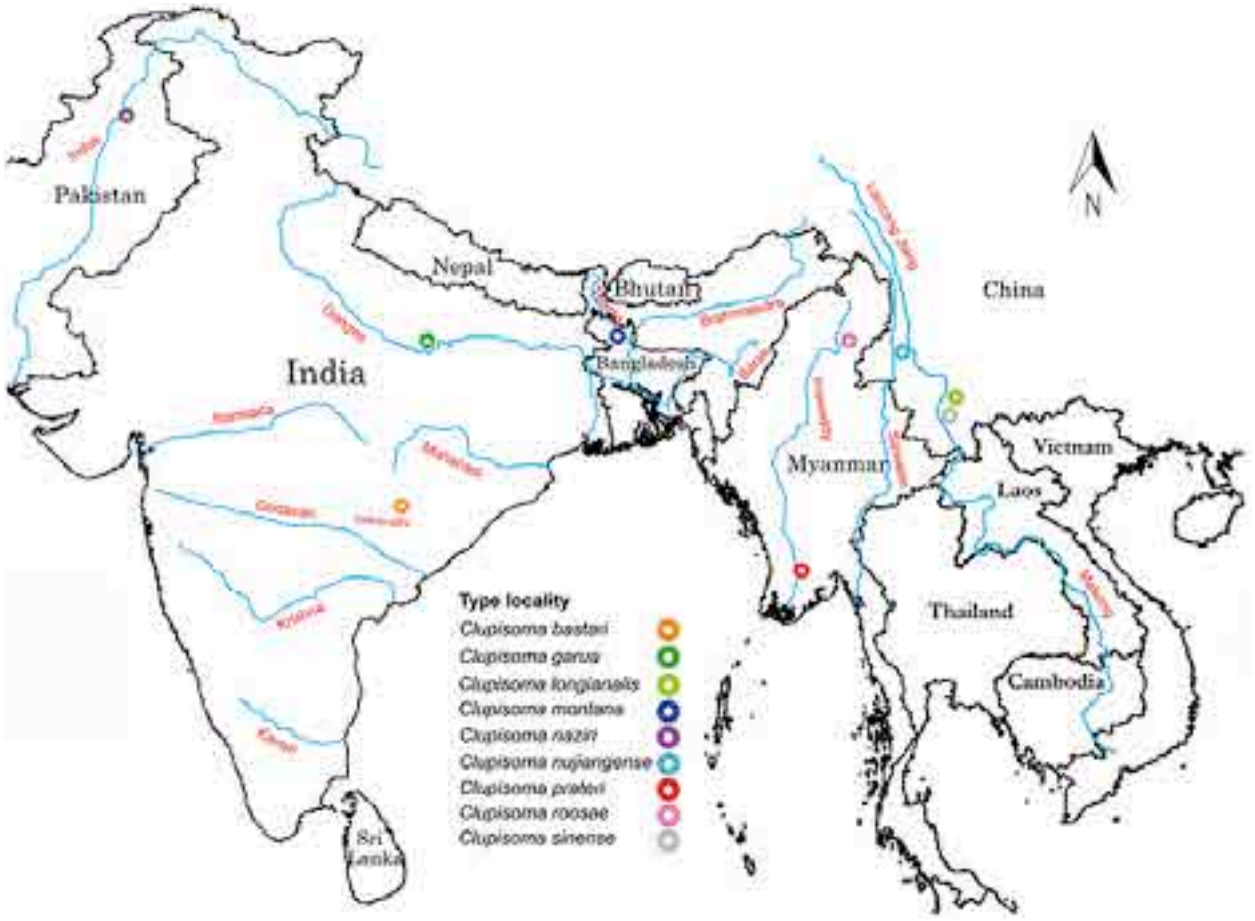

Figure 1. Map showing the type locality of *Clupisoma* congeners in different River systems in Pakistan, India, Bangladesh, Myanmar, and China.

family Ailiidae and Scilbeidae from NCBI database. The sequence of *Ailia coila* (MN083152) was used as an out-group in the phylogenetic analysis of the *Clupisoma* congeners. The dataset was aligned using ClustalX (Thompson et al. 1997) and Kimura 2 parameter (K2P) genetic distances and neighbor-joining phylogeny using K2P were generated by using MEGAX (Kumar et al. 2018).

RESULTS

The specimens were morphologically identified following the taxonomic descriptions (Hamilton 1822; Hora 1937; Datta & Karmakar 1980; Ferraris 2004). *Clupisoma bastari* (Image 1) is identified based on the combination of following morphological characters: body elongate and compressed, abdominal edge keeled from vent to thorax, snout bluntly pointed, eyes large, visible from ventral surface, mouth subterminal, cresentic, upper jaw slightly longer, teeth villiform in bands in both jaws, vomero-palatine band interrupted in middle. Median longitudinal groove on upper surface of head extends to hind border of eye. Barbels four pairs, maxillary barbels extending to anal fin base, inner mandibular barbels longer than outer mandibular barbels, both the mandibular barbels are longer than head, nasal barbels extend to posterior edge of eye. Rayed dorsal-fin inserted above middle of pectoral-fin, dorsal-fin with a strong spine serrated internally, adipose dorsal-fin above the last quarter of anal-fin base, pectoral-fin with a strong spine serrated internally, pelvic-fin ends before anal opening, caudal-fin deeply forked.

Although, the length of maxillary barbel and the extend of keel in abdominal edge place *C. bastari* in between *C. garua* (Hamilton, 1822) and *C. prateri* (Hora, 1937), but it is sufficiently distinct from them by the combination of other morphological characters, such as lengths of pectoral fins and maxillary barbels. Further, in *C. garua*, adipose fin is absent and anal fin is short while in the Burmese species *C. prateri*, the branched anal fin rays counts in the range from 37 to 42 (modally 39)

Table 1. The estimated inter- and intra-species genetic divergence in *Clupisoma* congeners.

Grouped Taxa/Clades	Between groups K2P (%)			Within group K2P (%)
	1	2	3	
1. *C. garua* (clade-1)				0.65
2. *C. bastari* (clade-2)	10.1			0.19
3. *C. sinense* (clade-3)	10.4	10.3		1.20
4. *C. montana* (clade-4)	10.9	11.2	10.0	0.16

and the abdominal edge keeled throughout. However, in *C. prateri*, maxillary barbel extends up to middle of pelvic, mandibular barbel reaches base of pectoral, and pectoral reaches pelvic origin. These morphological differences are sometime indiscernible leading to incorrect identification among the three species.

The generated DNA barcodes of *C. bastari* (accession numbers: MF601325 and MT821302) maintained 9.9% K2P genetic divergence with our generated sequence of *C. garua* (accession number: MG572775) as well as with the database sequences of topotypic *C. garua*, and similarly with the other congeners (Table 1). The NJ phylogeny revealed the occurrence of four species clades with a distinct lineage of *C. bastari* (Clade-2) in the studied dataset (Figure 2). The Clade-1 is unexpectedly included by sequences of three following nominal taxa maintaining very low genetic divergence of 0.6%: our own studied *C. garua* (Mahanadi River basin), *C. garua* (Barak River basin, Ganges River basin, and Narmada River basin in India; Surma River basin, Meghna River basin, and Sundarbans in Bangladesh), *C. prateri* (Narmada River basin in India, and Surma River basin and Sundarbans in Bangladesh), and *C. longianalis* (Huang, 1981) (Mekong River near its type locality).

The present genetic analysis evidenced the presence of misnomer taxa named as *C. prateri* and *C. longianalis* nested in *C. garua* clade-1 (Figure 2). The studied species, *C. bastari* (Clade-2) along with one database sequence (*Clupisoma* sp. JX260854 generated from Godavari River) showed 0.2% intra-species genetic divergence and maintained 9.9% K2P genetic divergence with *C. garua* (Clade-1) and 10.0–11.2% with other two clades (Clade-3 and Clade-4) (Table 1). The Clade-3 is comprising of three database sequences of *C. sinense* from Mekong basin. The Clade-4 is comprising of two database sequences (Accessions: MN178280 and KY909150) with the name *C. garua*, but the clade is distinct from the topotypic *C. garua* (clade-1) and also maintains sufficient species level genetic distance with the congeners. In NCBI database, no sequence is available with the name *C. Montana*. However, the two sequences (MN178280 from Ghaghara River, Nepal; KY909150 from Ranganadi River, Arunachal Pradesh, India) are presumed as possible lineage of *C. montana* and tentatively assigned as *C. Montana* having type locality in Teesta River, India.

The BIN list in public data portal in Boldsystem revealed four distinct BINs in the *Clupisoma*. The species, *C. bastari*, was assigned a distinct BIN: BOLD:ABY1142. There are two different BINs for the sequences named as *C. garua*. A few of the sequences named as *C. prateri* are included in one of the BINs of *C. garua*. Similarly, two sequences included in one of the BINs of *C. garua* appear as a misidentified case which we tentatively assigned as *C. Montana*.

DISCUSSION

Among all the congeners, *C. garua* is a widely distributed species and listed frequently in several freshwater fish inventories (Gupta & Banerjee 2016; Bhakta & Sonia 2020). However, the report of occurrence of *C. garua* from Godavari basin is doubtful. One of the sequences of *C. garua* from Barak River basin (JN628921) in this clade-1 was also morphologically identified as *C. garua* by the first author in previous

Image 1. *Clupisoma bastari* collected from Godavari River, Telangana.

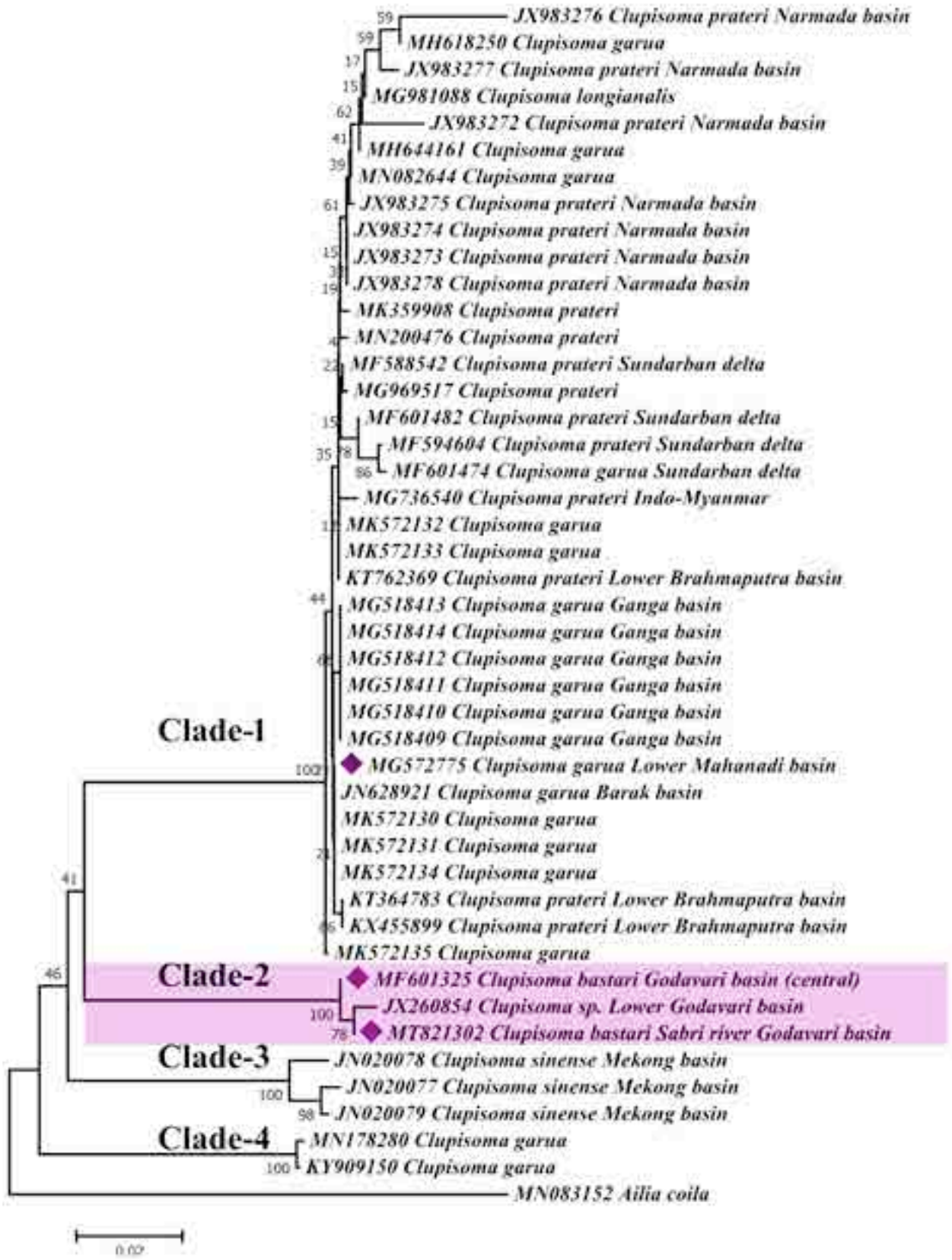

Figure 2. Neighbour-Joining phylogeny based on partial mtCOI gene inferred the distinctiveness of *Clupisoma bastari* from congeners.

studies (Bhattacharjee et al. 2012). Further, the sequences (JX983272 to JX983278) named as *C. prateri* sampled from Narmada basin have been corrected as *C. garua* (Khedkar et al. 2014). Nevertheless, *C. prateri* was originally described from Irrawady drainage in Myanmar. Later on, another species *C. roosae* Ferraris (2004) was described from the same river. But, no sequence information is available for *C. roosae*. Although, plethora of studies suggest the occurrence of *C. garua* in south Indian waters, but, no such specimen was observed in the Krishna River in Andhra Pradesh and the Godavari River in Telangana. We suggest further examination of *C. garua* using molecular data from southern Indian waters.

Based on the morphological characters, *C. montana* and *C. naziri* Mirza & Awan (1973) (type locality Indus River basin Pakistan) were placed into one group having abdominal edge rounded while that is keeled in *C. garua*, *C. bastari*, and *C. prateri* (Datta & Karmakar 1980). *Clupisoma montana* is also a poorly known species and has been occasionally reported from central India (Johnson et al. 2012), Bihar (Gunasekar & Isaac 2017) and part of lower Brahmaputra basin in Assam (Saha & Bordoloi 2009). Besides, a few haematological and biological studies on *C. Montana* are also available (Grover et al. 1999). Therefore, further DNA barcode data of *C. montana* from its type locality will ease to understand the phylogeny and distribution of this species in a precise manner.

DNA barcoding uses genetic information of an agreed upon segment of mtCOI gene for efficient discrimination of animal taxa at species level (Hebert et al. 2003). With the application of this advanced technique, taxonomic comparison becomes an easy task (Tautz et al. 2002). This tool also effectively utilized for below the species level identification, cryptic species or species-complex detection through intra- and inter-species barcode gap assessment (Blaxter 2003). With the improving trends in DNA barcoding, the ichthyofaunal diversity has been largely explored throughout the world including India. As of now a total of 11,613 DNA barcode sequences of class Actinopterygii have been generated from different biogeographic realms in India and deposited in the Barcode of Life data system (Accessed on 3 August 2020), and even GenBank consisted more than that. The present study contributes novel barcode sequences of morphologically identified lesser-known *C. bastari* to the GenBank database.

Data availability

The data that support the findings of this study are openly available at NCBI GenBank database at (https://www.ncbi.nlm.nih.gov) with the accession number (MF601325, MG572775, and MT821302), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

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COMMUNICATION

Description of the larva of *Vestalis melania* (Selys, 1873) (Odonata: Calopterygidae) identified through DNA barcoding

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Abstract: The larva of *Vestalis melania* is described and illustrated for the first time, based on specimens collected from Malaybalay, Bukidnon, Philippines. The identity of the larva was confirmed by matching its mitochondrial COI sequence with the adult. The larva can be distinguished by the shape of the prementum and its median cleft, lateral gills, and posterolateral abdominal spines. Comparison with other known larvae in the genus is also provided. The significance of using DNA barcoding for identifying larvae of Philippine Odonata is emphasized.

Keywords: COI sequencing, Odonata, Philippines, Mindanao, Zygoptera

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Author contributions: DMEG—conceptualization, data curation, methodology, investigation, formal analysis, writing; OMN: supervision, methodology, writing; SRRT—supervision, methodology, investigation, validation, writing; RJTV—supervision, validation, writing.

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INTRODUCTION

Vestalis Selys, 1853 is a genus of the Calopterygidae family with 16 species distributed in the Oriental region (Lieftinck 1965; Paulson & Schorr 2021). Like other members of Calopterygidae, the species thrive well in pristine habitats with good water quality (Orr 2003). In the past, the genus was subdivided into three groups, which were treated as full genera based on neural and penile characters (May 1935). These three are *Vestalis* Selys, 1853, *Vestinus* Kennedy, 1920, and *Vestalaria* May, 1953. Lieftinck (1965) dismissed this division, stating the instability of the characters defining *Vestinus.* However, molecular and morphological data supported the resurrection of the genus name *Vestalaria* (Hämäläinen 2006).

Vestalis melania, a member of the genus *Vestalis*, is geographically distinct for its insular distribution and restriction in the Philippines (Lieftinck 1965). The species is widely distributed in the country, except in Palawan, thrives mainly in the open or partly shaded streams and rivers (Villanueva 2009). Presently, only two of the 16 species within *Vestalis* have described larvae which are *V. amoena* and *V. luctuosa* (Ris 1912; Lieftinck 1965). Hence, in this study, the larva of *V. melania* was described for the first time. Larval identity was confirmed by matching the mitochondrial COI sequence of larvae and adults, a method increasingly utilized in Odonata (Orr & Dow 2015a,b, 2016; Steinhoff et al. 2016; Yu 2016; Wang et al. 2017; Saetung & Boonsoong 2019). Detailed morphology of the larva was also described and compared with other known larvae in the genus to gain more insights into its phylogenetic position.

MATERIALS AND METHODS

Collection of Specimens

Larval specimens were collected from the streams of Kibalabag, Malaybalay City, and Bukidnon. Specimens were collected through sieving substrates, leaf debris, and water vegetation in the margins of streams or water pockets near streams. Samples collected were preserved in 95% ethanol. All materials are deposited in the Natural Science Museum (NSM-4293 to NSM-4296) of Mindanao State University-Iligan Institute of Technology, Iligan City, Mindanao, Philippines. The collection was made under the DENR wildlife gratuitous permit no. R10-2021-27.

DNA Extraction and Polymerase Chain Reaction

Genomic DNA was extracted from the legs of specimens using the EZ-10 Spin Column Genomic DNA Minipreps Kit (BioBasic, Canada). The animal DNA barcode, COI (cytochrome c oxidase subunit I), was amplified by universal primers (5'GCTCAACAAATCATAAAGAYATYGG-3') and HCO2198 (5'-TAAACTTCAGGGTGACCAARAAYTCA-3') (Folmer et al. 1994). Each PCR reaction contains 30 µL of PCR master mix (Bio Basic, Inc.), 18 µL of ddH2O, 3 µL of each primer, and 6 µL of DNA template for a total volume of 60 µL. The PCR thermal regime consisted of pre-denaturation at 94 °C for four mins; 35 cycles of denaturation at 94°C for 30 sec., annealing at 48.5 °C for 30 sec., and extension at 72 °C for 90 sec.; final extension at 72 °C for seven mins; and hold for 4 °C at ∞. PCR products were then subsequently visualized on 1.5% agarose gel (Bio-rad) using blueGel electrophoresis system (Minipcrbio, Amyplus). PCR products were then sent to Macrogen Korea for sequencing.

DNA Barcode Analysis

The forward and reverse COI sequences were edited using Snapgene Viewer 5.2.5.1 (GSL Biotech; available at snapgene.com). Consensus sequences were then generated through queries of the forward and reverse sequence in NCBI Blast. Sequence analyses were carried out using MEGA 10 (Kumar et al. 2018). Pairwise distances were calculated using Kimura-2-parameter model using all sites and 1,000 bootstrap replications to determine the genetic distance between conspecific individuals.

Imaging and Description

Specimens were examined and photographed using a stereo microscope with an attached digital camera (AmScope) and a Canon EOS 60d. Illustrations were created through an Ipad using the procreate application (Savage Interactive, Australia), based on representative images. Measurements were obtained through ImageJ (Schneider et al. 2012). Terminologies for the larval morphology were based on Snodgrass (1954) and Kumar (1973). The mandibular formula follows Watson (1955). Abdominal segments 1–10 were indicated as S1–S10.

RESULTS

The COI sequences of all samples were amplified and sequenced successfully, producing barcodes 568–576 bp long. A maximum-likelihood tree including 11 reference sequences from *Vestalis* and *Vestalaria* (Table 1) is shown in Figure 1. *Euaphaea formosa* was used as

Table 1. Specimen data of COI sequence used in the analysis.

Species	Data Source	ID/AN	Locality	Date	Collector
Vestalis melania	BOLD	SKODO086-15	Tagbina, Surigao del Sur, Philippines	27.ii.2015	H. Cahilog
Vestalis melania	BOLD	SKODO047-15	Tboli, South Cotabato, Philippines	22.viii.2015	H. Cahilog
*Vestalis melania**	This study	KMBPH011/ NSM-4293	Kibalabag, Malaybalay City, Philippines	14.x.2020	D.M. Guadalquiver
*Vestalis melania**	This study	KMBPH015/ NSM-4294	Kibalabag, Malaybalay City, Philippines	14.x.2020	D.M. Guadalquiver
*Vestalis melania **	This study	KMBP016/ NSM-4295	Kibalabag, Malaybalay City, Philippines	14.x.2020	D.M. Guadalquiver
Vestalis amethystina	NCBI	MG885367.1	Singapore		
Vestalis amabilis	NCBI	KF369567.1	Sarawak, Malaysia	01.01.2010	J. Teo
Vestalis amoena	NCBI	MG885091	Singapore		
Vestalis amoena	NCBI	MG885368.1	Singapore		
Vestalis apicalis	NCBI	KU510326.1	India		
Vestalis apicalis	NCBI	MN255519.1	India		
Vestalis gracilis	NCBI	KX503058	India		
Vestalis gracilis	NCBI	MN387793.1	India		
Vestalis smaragdina	NCBI	KF369577.1			
Euphaea formosa	BOLD	GBMHO2948-19	Taiwan		

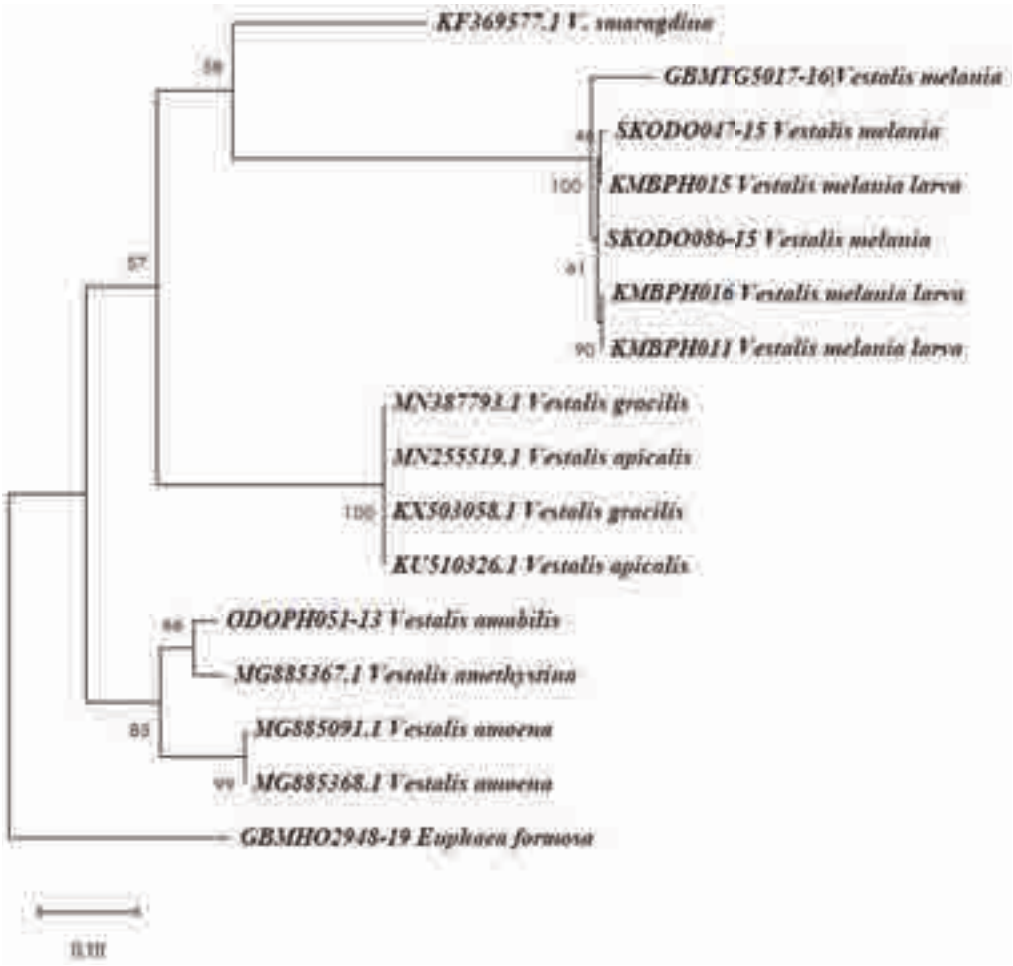

Figure 1. Phylogenetic reconstruction based on COI (587 bp), through maximum likelihood method and 1,000 bootstrap replication. Bootstrap values are indicated at nodes respectively. *Euphae formosa* was used as an outgroup.

Image 1. Larval habitus of *Vestalis melania*. Scale = 5 mm. © Don Mark E. Guadalquiver.

an outgroup. The adults of *Vestalis melania* distinctly formed a monophyletic group (MLB = 100) with prospect larvae. *Vestalis smaragdina*, a member of *Vestalaria*, also had the closest relationship with *V. melania*, forming a monophylum (MLB = 58). The results confirmed that the larvae concerned here are of the same species as adults, namely *V. melania*.

Taxonomic Account

***Vestalis melania* Selys, 1873**

Materials studied: Larvae: 14.x.2020, 1 male, 3 females: Kibalabag, Malaybalay City, Bukidnon, Philippines (8.258 N, 125.172 E), 1,200 m, coll. D.M. Guadalquiver, Natural Science Museum, MSU-IIT, Iligan, Philippines

Description: A slender zygopteran with a small head, moderately long antennae, laterally banded thorax with long and banded legs, elongated and cylindrical abdomen with lanceolate lamellae. Ground color of light brown but can be darker in some individuals (Image 1).

Head: Hexagon-shaped with a pointed snout, flattened above, with light banding, pointed & pigmented postocular lobe, and eyes longer than wide when dorsally viewed. Antennae (Figure 2a) seven-segmented excluding extra joint after segment 1, tapered from base to apex, with robust segment one almost twice as long as segments 2–7. Prementum (Figure 2b) elongated with the distal end expanding at angles 110 to 125^0 wide. Median lobes (Ligula) clefted roundly and with deepness 0.36 of the prementum, serrated on the outside, and containing a pair of setae. Labial palp robust, the inner lateral margin serrated with two sizes of teeth, and with three strong, long, and incurved distal teeth, of which the middle one is the longest; movable hook very long and robust with two setae on its base. Maxilla (Figure 2c) is twice as long as wide; galeo-laccinia with seven teeth: four long in the dorsal area and three short in the ventral area, and with numerous hair-like projections.

Palpus is two-segmented, with a small basal segment and distal segment that is banana-shaped but pointed, as long as galeo-laccinia, and covered in numerous hair-like projections. Mandibles (Figure 2d,e) with the formula L 1’1234 0 a($m^{1,2,3,4,5-7}$)b/ R 1’1234 y a. Left mandible with five incisors and molar crest with 5–7 fine cusps; right mandible with five incisors, an extra tooth, and a single mandible.

Thorax: Marked with strong bandings in the lateral area extending from the pronotum up to the dorsal region of synthorax. Prothorax smaller than head and synthorax. Pronotum hexagonal with a protuberance at the mediolateral proximities. Wing pads reaching the proximal margin of S4. Legs long and with two dark bands in femur and tibia and progressively longer from pro- to meta-thorax. Tibia longer than femur; tarsi three-segmented and covered with dense hair.

Abdomen: Long & slender and covered with dark pigmentation, amount varying between specimens, but less pigmented on the median region. Lateral spines on S9 and S10, with S10 spine more prominent (Figure 3a,b).

Table 2. Comparison of Characters from *Vestalis* and *Vestalaria* larvae.

	V. melania	*V. luctuosa*	*V. amoena*	*V. venusta*
Premental cleft	Round	Angled	Angled, narrow	Round
Anterior region of prementum	With angular expansion (110–125° angle)	Expanding obliquely	With angular expansion (110–125° angle)	Expanding obliquely
Premental setae	Two pairs	Two pairs	Two pairs	Three pairs
Lateral gills	Lamellate, longer than the middle, with light/ unpigmented spots in the edge	Lamellate, with dark spots in the edge, slim	Lamellate, truncated, almost similar length with middle gill, stout	Triquetral, significantly longer than the middle, slim
Vestigial joint between segments 1 and 2 of antenna	Present	Present	Present	Absent
Posterolateral spines in abdomen	S9–10, with S10 very prominent	S10, prominent	-	S10, inconspicuous

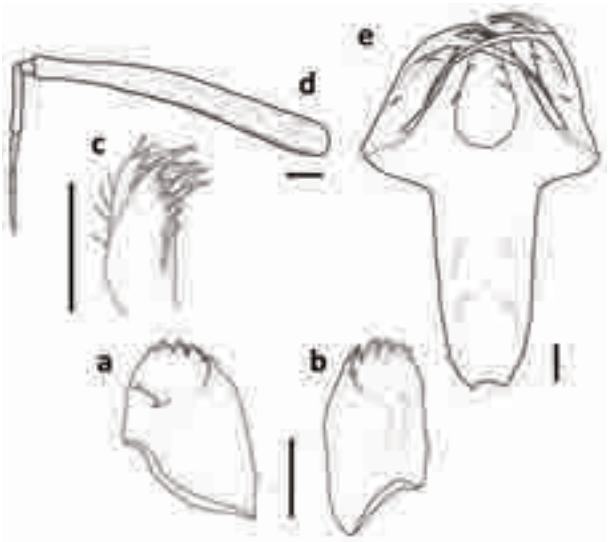

Figure 2. Anterior details of *Vestalis melania* larvae: a—right antenna, lateral | b—prementum, dorsal view | c—right maxilla, ventral view | d—left mandible, inner view |e—right mandible, inner view. Scale = 0.5 mm.

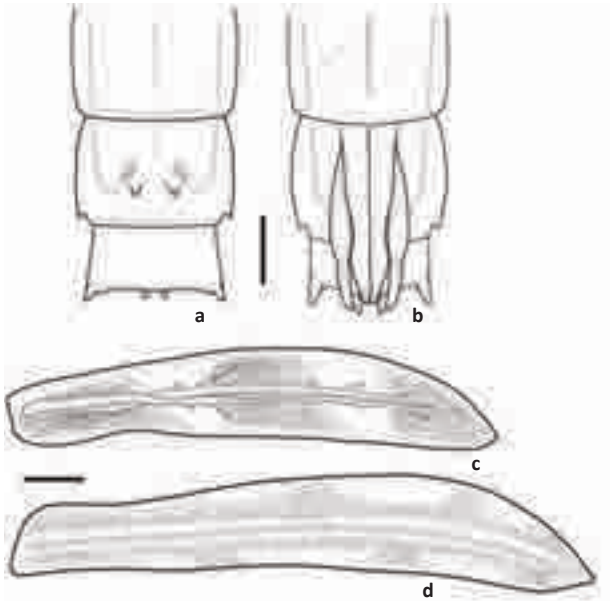

Figure 3. Posterior details of Vestalis melania larvae: a—S8–S10 of abdomen showing male gonopophyses, lateral spines, and cerci | b—S8–S10 of abdomen showing female gonopophyses, lateral spines, and cerci | c—median caudal gills, lateral view | d—lateral caudal gills, lateral view. Scale = 1 mm

Male gonapophyses protruding from the middle of S9, small and conical with black pigmentations in the upper lateral area (Figure 3a). Female inner gonapophyses large and extending from proximal margin of S9 to distal margin of S10; outer part protruding from middle of S9 to distal margin of S10, with distal region slight pointed upward (Figure 3b). Male cerci small and budlike; female cerci more pointed and slightly longer than male ones. Caudal gills are all lamellate, long, lanceolate shaped but blunt-tipped, and bearing some fine setae-like spines along margins. The lateral caudal gill (Figure 3d) is longer than the middle gill, with a prominent midrib and light to dark pigmentation covering the entire median region; banding manifests only in the lateral edges. Middle caudal gill (Figure 3c) with full banded pigmentation, translucent, and visible median venations.

Microhabitat and Behavior

Larvae were found in an unshaded, narrow, montane stream with a sandy substrate and dense marginal and submerged vegetation (Image 2). Larvae are abundant where they are found and were found clinging and scooped along with submerged vegetation. Adults of *V. melania* and *Euphaea amphicyana* were also abundant in the area.

DISCUSSION

The only described species within the genus *Vestalis* are *V. luctuosa* (Ris 1912; Lieftinck 1965) and *V. amoena* (Lieftinck 1965). Comparison of the larval morphology of *V. melania* from descriptions of these species shows that *V. melania* is different in several aspects. *Vestalis melania* shows stronger banding in the pronotum up to the thorax; round median cleft in the prementum compared to angular base, and sharp broadening in the anterior region of the prementum compared with gradual broadening in the other species.

The lateral gills also differ with *V. luctuosa* and *V. amoena*, in terms of pigmentation. In *V. melania,* pigmentation was concentrated and full in the central region, and the banding is observable only in the edges, giving it an appearance of having 'white' spots in the borders. In contrast, the lateral gills of *V. luctuosa* are less pigmented and show dark spots in the edges (Ris 1912), whereas *V. amoena* does not show much pigmentation and has a truncated shape (Lieftinck 1965) (Table 2).

The posterolateral spines in the abdomen of *V. melania* were also remarkable, being prominent in S9–10. In *V. amoena* and *V. luctuosa* (Lieftinck 1965), a small spine is also present in S10, but it is unclear if it is also present in S9.

Overall, the larval characteristics of *V. melania* are different in terms of stronger banding in the pronotum and thorax, characters in the prementum, lateral caudal gill, and posterolateral spines in the abdomen.

This study demonstrates once again the usefulness of DNA barcoding in matching the larvae with the adult. This method can be utilized to gain larval knowledge of endemic Philippine Odonata, especially endemic genus like *Risiocnemis*. As the marker COI has been proven helpful in differentiating many Philippine damselfly species (Casas et al. 2018), it can be effectively utilized to match most larvae and adults of the same species. Caution, however, should be observed in using COI genes for some species groups, as the gene may not be well-differentiated in some closely related species such as Philippine *Drepanosticta* species (Casas et al. 2018). Another example is the *Vestalis gracilis* and *V. apicalis* used in this study which showed no divergence (MLB

Image 2. Habitat of Vestalis melania larvae in Kibalabag, Malaybalay City, Bukidnon, Philippines. © Don Mark E. Guadalquiver.

= 100). Hence, other gene targets should be utilized as well, such as the nuclear ribosomal genes and the internal transcribed spacers.

CONCLUSION

This study describes for the first time the larvae of *Vestalis melania*. The mitochondrial COI sequence successfully matched the *V. melania* larvae with its adults and confirmed its identity, in congruence with their sympatric relationship. The larva of *V. melania* is highly similar to previously described congener species but different in terms of stronger banding in the pronotum and thorax, characters in the prementum, lateral caudal gill, and posterolateral spines in the abdomen. The larval morphology of the *V. melania* supports the unity within the genus *Vestalis* and the separate genus status of *Vestalaria*. It is recommended that larvae of other *Vestalis* species be further studied and DNA barcoding, should be incorporated to gain more larval knowledge of endemic Philippine Odonata. Because of the limitations of the COI marker in closely related species, it is also recommended that other gene targets and relevant data should be used for support.

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COMMUNICATION

Checklist of Carabidae (Coleoptera) in the Chinnar Wildlife Sanctuary, a dry forest in the rain shadow region of the southern Western Ghats, India

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Abstract: The first report on the composition of carabids from a natural forest in peninsular India as well as from a dry forest belt in the rain shadow region of the Western Ghats is provided, with data on the subfamilies, tribes, genera, species, geographic range, collection techniques, and the relevant literature details for all the listed species. Fifty-four species belonging to 11 subfamilies and 31 genera were recorded. Harpalinae, Lebiinae, and Scaritinae with 15, 14, and seven species, respectively, are the species-rich subfamilies. The species list also includes two first records from India, four first records from southern India, and six species endemic to the Western Ghats and Sri Lanka biodiversity hot spot.

Keywords: Carabids, Eastern slope, endemism, first Indian record, ground beetles, peninsular India.

സംഗ്രഹം: ഉപകുടുംബങ്ങൾ, ഗോത്രങ്ങൾ, ജനുസ്സുകൾ, സ്പീഷിസുകൾ, ഭൂമിശാസ്ത്രപരമായ ശ്രേണികൾ, ശേഖരണ സാങ്കേതികതകൾ, ലിസ്റ്റ് ചെയ്ത എല്ലാ ജീവജാലങ്ങളുടെയും പ്രസക്തമായ സാഹിത്യ വിശദാംശങ്ങൾ എന്നിവയെക്കുറിച്ചുള്ള അടിസ്ഥാനവിവരം സഹിതം, ഇന്ത്യൻ ഉപദ്വീപിലെ ചിന്നാർ വന്യജീവി സങ്കേതത്തിൽ നിന്നും പശ്ചിമഘട്ടത്തിലെ മഴനിഴൽ മേഖലയിലെ വരണ്ട വനമേഖലയിൽ നിന്നുമുള്ള കാരബിഡുക (Carabidae) ളുടെ ഘടനയെക്കുറിച്ചുള്ള ആദ്യ റിപ്പോർട്ട് നൽകിയിരിക്കുന്നു. 11 ഉപകുടുംബങ്ങളിലും 31 ജനുസ്സുകളിലുമായി 54 ഇനം രേഖപ്പെടുത്തിയിട്ടുണ്ട്. യഥാക്രമം 15, 14, 7, ഇനങ്ങളുള്ള ഹാർപാലിനേ (Harpalinae), ലെബിനേ (Lebiinae), സ്കാരിറ്റിനേ (Scaritinae) എന്നിവ ഇനങ്ങളാൽ സമ്പന്നമായ ഉപകുടുംബങ്ങളാണ്. സ്പീഷിസ് ലിസ്റ്റിൽ ഇന്ത്യയിൽ നിന്നുള്ള 2 ആദ്യ റെക്കോർഡുകളും ദക്ഷിണേന്ത്യയിൽ നിന്നുള്ള 4 ആദ്യ റെക്കോർഡുകളും പശ്ചിമഘട്ടത്തിലും ശ്രീലങ്കയിലെയും ജൈവവൈവിധ്യ ഹോട്ട് സ്പോട്ടിൽ മാത്രം കാണപ്പെടുന്ന 6 സ്പീഷിസുകളും ഉൾപ്പെടുന്നു.

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Author contributons: SKT and MCS reviewed the earlier works and discussed the distribution patterns. MCS conducted the field studies and prepared the images and the specimens.

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INTRODUCTION

The family Carabidae (ground beetles) is composed of over 34,000 species distributed among 1,927 genera worldwide. Carabids occupy most land habitats on nearly all continents (Lorenz 2005). These beetles are abundant in the field and attract attention with their peculiar shape and coloration. Adults and larvae of most ground beetle species are generalized predators of insects and other invertebrates; however, many species are herbivores, omnivores or scavengers (Allen 1979). Carabids are generally seen under stones, wood, moss, and bark (Andrewes 1929; Thiele 1977), are sensitive to their environment, and are commonly used as biological indicators (Rainio & Niemelä 2003; Koivula 2011). They are useful in controlling the population build-up of soil-dwelling insects like ants and termites (Kumar & Rajagopal 1990) as these beetles feed on the immature stage of soil and litter-dwelling insects.

The Western Ghats (WG), a chain of mountains of southwestern India, is one of the last remaining stretches of the biodiverse tropical wet evergreen rainforests in peninsular India and is a global biodiversity hotspot (Myers et al. 2000). The eastern slope of the WG relies heavily on the north-east monsoon (October–December) for precipitation, as opposed to the western scarps that receive almost 80% of their rainfall between May and August due to the south-west monsoon (Anu et al. 2009). This variance in monsoon dependence is hypothesized to have led to phenological differences amongst some congeneric populations from the eastern and western slopes (Janani et al. 2017; Chaitanya et al. 2018). Consequently, the faunal composition greatly varies between various segments of the WG as revealed by the vertebrate group studies (Vijayakumar et al. 2014; Deepak et al. 2016; Garg et al. 2017). Vertebrate groups have received a great deal of attention in ecological studies conducted in the WG but the same is not the case for most arthropod groups. Limited data exists on most coleopteran families in general from the WG including ground beetles (Carabidae). Most ground-beetles in the southern WG are found to live under upper layers of the soil below stones, lower layers of litter and woody debris, and dry dung of mega herbivores, and most are crepuscular and nocturnal. Available data on the taxonomy of ground beetles is based on the species reported in the classical work of Andrewes (1930), which is placed under two subfamilies: Harpalinae and Carabinae, following the earlier classification of the family and in the recent checklists of subfamilies, Lebiinae, Pterostichinae, Panagaeinae, and Dryptinae (Shiju & Sabu 2019; Divya & Sabu 2020; Jithmon & Sabu 2021) do not cover the entire family. There is no comprehensive data to understand the Carabidae groups present in a natural ecosystem in the WG. In this work, we list all the Carabidae species that have been recorded from a well-protected wildlife sanctuary in the dry eastern slope of the southern WG to provide baseline data about the composition of carabids in a natural habitat. This checklist should greatly facilitate taxonomic and ecological studies by complying with the current scientific knowledge. It will provide data on the subfamilies, tribes, genera, species, geographic range, collection techniques, and the relevant literature for all the listed species. Synonymies for each species are followed by Lorenz (2005, 2021). Furthermore, the checklist could be used in practical conservation programs for monitoring habitat changes in dry forests.

MATERIAL AND METHODS

Study area

Chinnar Wildlife Sanctuary is located in the rain shadow region of the WG (Figure 1). The Sanctuary falls under the Anamudi Elephant Reserve and is situated 18 km north of Marayur of Devikulam Taluk in Idukki district of Kerala, located between 10.25–10.35 N & 77.1–77.26 E, covering a total area of 90.44 km². The dominant vegetation is dry deciduous forests followed by scrub jungle and patches of riparian forests linearly spread out along the hill folds (Thomas et al. 2018). Annual rainfall ranges 300–500 mm, the bulk of the rainfall is received from north-east monsoon during October to December and the rainy season lasts for about one month leading to a prolonged dry season and a short rainy season (Management plan of Chinnar Wildlife Sanctuary 2012–13 to 2021–22; Sabu & Nithya 2016).

Methods

The collections of beetles were done using light traps, pitfall traps, and hand picking from the thorny scrub jungle (Chinnar), dry deciduous forest (Alampetty), and riparian forest (Kootar) during the dry season (January–September) and the rainy and post rainy wet season (October–December) in 2019–2020. We followed the classification pattern provided in Lorenz (2005) for subfamilies, tribes, genera, and species. Species-level identification was done with the aid of taxonomic keys in Andrewes (1929, 1935), Habu (1973), Balkenohl (2001), Kataev (2012, 2018), Shiju et al. (2012), Kataev & Wrase (2016), Roux et al. (2016), Sabu (2018), Shiju

Figure 1. Map of Indian subcontinent showing study area, Chinnar Wildlife Sanctuary.

(2018), Akhil (2019), Akhil & Sabu (2019), Akhil et al. (2019), Jithmon (2020), and by comparing with the holotypes and verified specimens available in the insect depository of Zoological Survey of India, Western Ghats Regional Centre (ZSI-WGRC) Kozhikode station. Images were taken using Leica M 205C stereo zoom microscope fitted with Leica MC 170 HD digital camera. Collected specimens are deposited at ZSI-WGRC. The checklist is grouped by order, family, subfamily, tribe, genera, and species, each of which is arranged alphabetically.

Abbreviations used

id. "Idem" (the same; as just mentioned) | @—First report from India | #—First report from southern India | *—Endemic to the Western Ghats | Ssp.—Subspecies.

World Zoogeographical Regions

AUR—Australian Region | IAR—Indo-Australian Region | ORR—Oriental Region | PAR—Palaearctic Region.

Geographical symbols

AF—Afghanistan; AST—Australia; BGD—Bangladesh; BT—Bhutan; CBD—Cambodia; CHN—China; EAI—East Indies; FUJ—Fujian; GUA—Guangdong; GUI—Guizhou; GUX—Guangxi; HAI—Hainan; HKG—Hong Kong; HUB—Hubei; HUN—Hunan; IDS—Indonesia; IN—Iran; JA—Japan; JIX—Jiangxi; LAO—Laos; MAC—Macao; MLS—Malaysia; MM—Myanmar; NC—North Korea; NEC—New Caledonia; NP—Nepal; PA—Pakistan; PP—Philippines; SC—South Korea; SCH—Sichuan; SEA—South East Asia; SHG—Shanghai; SM—Samoa; SRL—Sri Lanka; TAI—Thailand; TD—Tajikistan; TM—Turkmenistan; TWN—Taiwan; UZ—Uzbekistan; VTN—Vietnam; YUN—Yunnan.

RESULTS

A total of 54 species of ground beetles were examined. The checklist, distribution of the recorded species are given below.

Order Coleoptera
Family Carabidae Latreille 1802
Subfamily Anthiinae Bonelli 1813
Tribe Helluonini Hope 1838
i. Genus *Macrocheilus* Hope 1838

Macrocheilus Hope 1838: 166.
= *Acanthogenius* Reiche 1843
= *Macrochilus* Agassiz 1847
= *Macrocheilidius* Jeannel 1949

1. *Macrocheilus bensoni* Hope 1838

Macrocheilus bensoni Hope 1838: 166; Andrewes 1930: 208; Lorenz 2005: 512; Shiju et al. 2012: 100; Löbl & Löbl 2017: 577.

= *Carabus trimaculatus* Olivier 1790 (non Villers, 1789)
= *Helluo quadrimacultus* Guérin-Méneville 1840
= *Helluo tripustulatus* Guérin-Méneville 1843 (non Dejean, 1825)
= *Macrochilus quadripustulatus* Schmidt-Göbel 1846
= *Macrochilus infuscatus* Bates 1892a
= *Macrochilus benarensis* Jedlička 1963
= *Macrochilus bimaculatus* Jedlička 1965
= *Macrochilus quadrimaculatus* (Guérin-Méneville 1840)
= *Macrochilus trimaculatus* (G.A. Olivier 1790)

Specimens examined (n = 3): SJC-ZOO-CWSSMC001–003, Alampetty, 1 ex, Light trap, 25.ii.2020; 1 ex, hand picking, 26.ii.2020; Kootar, 1 ex, pitfall trap, 26.x.2019.

Distribution: ORR - India (Assam (Andrewes 1930: 208), Kerala: Kozhikode, Chinnar, Thamarassery (Shiju et al. 2012: 100)); SRL (Andrewes 1930: 208); MM (Andrewes 1930: 208); LAO (Andrewes 1930: 208); VTN (Andrewes 1930: 208); **PAR -** FUJ; GUA; GUI; GUX; HAI;

JIX; YUN (Löbl & Löbl 2017: 577); HKG (Andrewes 1930: 208); **IAR** - PP (Andrewes 1930: 208); MLS (Andrewes 1930: 208).

***2. *Macrocheilus chinnarensis* Akhil et al. 2019**

Macrocheilus chinnarensis Akhil et al. 2019: 28–33.

Distribution: ORR- India (Kerala: Chinnar (Akhil et al. 2019: 28–33)).

ii. Genus *Omphra* Dejean 1825

Omphra Dejean 1825: 168, 283; Reiche 1843: 330; Lacordaire 1854: 94; Chaudoir 1872a: 140; Sloane 1914: 570; Andrewes 1930: 236; Csiki 1932: 1577; Jedlička 1963: 511; Lorenz 2005: 511; Zhao et al. 2008: 372; Shiju & Sabu 2012: 2 ; Akhil & Sabu 2021: 11.

3. *Omphra pilosa* (Klug 1834)

Omphra pilosa (Klug) Reiche 1843: 330; Erichson 1847: 141; Redtenbacher 1867: 5; Chaudoir 1872a: 141; Putzeys 1875a: 45; Andrewes 1921a: 163; id. 1923b: 460; id. 1927: 101; id. 1930: 237; Csiki 1932: 1578; Jedlička 1963: 512; Lorenz 2005: 511; Zhao et al. 2008: 371; Shiju & Sabu 2012: 8; Löbl & Löbl 2017: 578.

Helluo pilosus Klug 1834: 71

= *Galerita attelaboides* Fabricius 1801

= *Helluo pilosus* Klug 1834

Specimens examined (n = 23): SJC-ZOO-CWSSMC004–026, Chinnar, 2 exs, pitfall, 25.ii.2020; Alampetty, 4 exs, pitfall trap, 26.x.2019; 3 exs, hand picking, 26.x.2019; 7 exs, pitfall trap, 25.ii.2020; 4 exs, hand picking, 25.ii.2020; Kootar, 3 exs, pitfall trap, 26.x.2019.

Distribution: ORR - India (Kerala: Arakulam, Chempery, Chinnar, Alampetty, Kuttiyadi, Kozhikode, Malappuram, Thodupuzha, Mahe (Shiju & Sabu 2012: 8)); SRL (Andrewes 1930: 237); **PAR** - India (Himachal Pradesh; Uttarakhand (Löbl & Löbl 2017: 578)); PA (Löbl & Löbl 2017: 578).

Subfamily Brachininae Bonelli 1810

Tribe Brachinini Bonelli 1810

iii. Genus *Styphlomerus* Chaudoir 1875

Styphlomerus Chaudoir 1875: 87, 88; Erwin 1970: 39.

4. *Styphlomerus striatus* Akhil & Sabu 2019

Styphlomerus striatus Akhil & Sabu 2019: 468.

Specimens examined (n = 2): SJC-ZOO-CWSSMC027–028, Alampetty, 2 exs, light trap, 26.x.2019.

Distribution: ORR - India (Tamil Nadu: Rajapalayam, Ettimadai; Kerala: Tholpetty (Akhil & Sabu 2019: 468))

Subfamily Dryptinae Bonelli 1810

Tribe Dryptini Bonelli 1810

iv. Genus *Drypta* Latreille 1796

Drypta Latreille 1796: 75; Fabricius 1801: 230; Latreille 1810: 117; Dejean 1825: 182; Schmidt- Göbel 1846: 22; Lacordaire 1854: 79; Andrewes 1924b: 51; id. 1930: 157; Lorenz 2005: 503; Jithmon & Sabu 2021: 18560.

5. *Drypta lineola* MacLeay 1825

Drypta lineola MacLeay 1825: 27; Dejean 1825: 184; Redtenbater 4; Chaudoir 1877: 262; Bates 1883: 279; id. 1891: 336; id. 1892a: 383; Heyne-Tasch 13.t.2.f.25; Bouchard 1903: 173; Andrewes 1919a: 167; id. 1924c: 469; id. 1923e (1924): 460; id. 1924b: 52; id. 1930: 158; Lorenz 2005: 503; Jithmon & Sabu 2021: 18562.

= *Desera lineola* (W.S. MacLeay 1825)

Specimens examined (n = 1): SJC-ZOO-CWSSMC029, Alampetty, 1 ex, light trap, 26.x.2019.

Distribution: ORR - Throughout southeastern Asia (Andrewes 1930: 158) India (Tamil Nadu: Rajapalayam, Kadayam (Jithmon & Sabu 2021: 18560); Kerala: Padinjarathara (Jithmon & Sabu 2021: 18560)); MM (Andrewes 1930: 158); **PAR -** TWN; YUN (Andrewes 1930: 158; **IAR** - IDS (Andrewes 1930: 158); PP (Andrewes 1930: 158); MLS (Andrewes 1930: 158).

Subfamily Harpalinae Bonelli 1810

Tribe Anisodactylini Lacordaire 1854

v. Genus *Pseudognathaphanus* Schauberger 1932

Pseudognathaphanus Schauberger 1932: 57; Habu 1973: 62; Noonan 1973: 344; id. 1976: 12; Löbl & Smetana 2003: 363; Lorenz 2005: 351; Park et al. 2006: 96; Kataev & Wrase 2016: 224; Löbl & Löbl 2017: 508.

= *Hiekea* Ito 1997

= *Protognathus* Basilewsky 1950

6. *Pseudognathaphanus rusticus* (Andrewes 1920)

Pseudognathaphanus rusticus (Andrewes) Löbl & Smetana 2003: 363; Lorenz 2005: 351; Kataev & Wrase 2016: 232; Löbl & Löbl 2017: 508.

Gnathaphanus rusticus Andrewes 1920a: 107; id. 1924b: 30; id. 1930: 172; Kushwaha & Hegde 2015: 403.

= *Gnathaphanus rusticus* Andrewes 1920

Specimens examined (n = 1): SJC-ZOO-CWSSMC030, Kootar, 1 ex, light trap, 26.ii.2020.

Distribution: ORR - India (New Delhi: Pusa; Uttar Pradesh: Lucknow; Bihar: Chapra, Muzaffarpur, Purnea, Patna, Samastipur; Madhya Pradesh; Odisha: Surada; Gujarat: Surat (Andrewes 1930: 172); Maharashtra: Mumbai, Pune (Kataev & Wrase 2016: 232), Chikalda,

Nagpur (Andrewes 1930: 172); Goa (Kataev & Wrase 2016: 232); Karnataka: Belgaum, Dharwar, North Karnataka (Andrewes 1930: 172); SRL (Andrewes 1930: 172); **PAR** - India (Uttarakhand: Dehradun, Haridwar and Roorkee (Andrewes 1930: 172)), NP; PA (Löbl & Löbl 2017: 508).

Tribe Stenolophini Kirby 1837

vi. Genus *Stenolophus* Dejean 1821

Stenolophus Dejean 1821: 15; id. 1829: 405; Lacordaire 1854: 303; Sloane 1898: 456; Tschitschérine 1900a: 364; id. 1901: 246; Andrewes 1924b: 40; id. 1930: 316; Habu 1973: 341; Noonan 1976: 17; Saha 1995: 67; Saha & Halder 2000: 15; Löbl & Smetana 2003: 404; Lorenz 2005: 353; Park et al. 2006: 96; Löbl & Löbl 2017: 573.

 # 7. *Stenolophus bajaurae* Andrewes 1924

Stenolophus bajaurae Andrewes 1924b: 95; id. 1926a: 69; id. 1930: 316; Kataev 2002: 724; Löbl & Smetana 2003: 405; Lorenz 2005: 354; Wrase 2005: 852; Kataev 2015: 93; id. 2015: 539; Kushwaha & Hegde 2015: 401; Jaeger & Ahmed 2017: 613; Kataev 2002: 724; Löbl & Löbl 2017: 574.

= *Egadroma bajaurae* (Andrewes 1924)

Specimens examined (n = 1): SJC-ZOO-CWSSMC031, Kootar, 1 ex, light trap, 25.ii.2020.

Distribution: ORR - India (Delhi (Kushwaha & Hegde 2015: 401); Uttar Pradesh: Fyzabad (Andrewes 1930: 316); Jharkhand: Sarju valley (Andrewes 1930: 316)); **PAR** - India (Jammu-Kashmir (Andrewes 1930: 316), Himachal Pradesh: Kangra, Bajaura, Spiti, Manikaran (Andrewes 1930: 316); Uttarakhand: Kumaon (Andrewes 1930: 316)); AF; NP; PA; TD; TM; UZ (Löbl & Löbl 2017: 574).

@8. *Stenolophus lucidus* Dejean 1829

Stenolophus lucidus Dejean 1829: 419; Andrewes 1930: 317; Löbl & Smetana 2003: 405; Lorenz 2005: 355; Löbl & Löbl 2017: 574.

= *Egadroma lucida* (Dejean 1829)

Specimens examined (n = 1): SJC-ZOO-CWSSMC032, Kootar, 1 ex, light trap, 26.ii.2020.

Distribution: ORR - EAI (Andrewes 1930: 317); **PAR -** BT; FUJ; GUA; GUX; HAI; TWN; YUN; JA; NP (Löbl & Löbl 2017: 574).

9. *Stenolophus quinquepustulatus* (Wiedemann 1823)

Stenolophus quinquepustulatus (Wiedemann) Dejean 1829: 414; Bates 1873: 270; Putzeys 1875a: 49; Bates 1889: 272; id. 1891: 333; Bouchard 1903: 172; Lesne 1904: 76; Sloane 1920a: 321; Andrewes 1921a: 171; id. 1924c: 469; id. 1930: 317; Habu 1973: 382; Saha 1995: 68; Löbl & Smetana 2003: 405; Lorenz 2005: 355; Park et al. 2006: 96; Jaeger & Ahmed 2017: 614; Löbl & Löbl 2017: 574.

= *Badister quinquepustulatus* Wiedemann 1823

= *Stenolophus rectifrons* Bouchard 1903 (non Bates 1892)

= *Stenolophus connexus* Schauberger 1928

= *Stenolophus apicalis* Jedlička 1952

= *Stenolophus tripustulatus* Jedlička 1952

= *Stenolophus conjunctus* Jedlička 1956

= *Stenolophus unipustulatus* Jedlička 1952

= *Acupalpus connexus* (Schauberger 1928)

= *Egadroma quinquepustulata* (Wiedemann 1823)

Specimens examined (n = 2): SJC-ZOO-CWSSMC033–34, Kootar, 2 exs, Light trap, 26.ii.2020.

Distribution: ORR - India (Uttar Pradesh; West Bengal: Singur, Hooghly (Saha 1995: 68)); MM (Habu 1973: 382); SRL (Habu 1973: 382); TAI (Habu 1973: 382); VTN (Park et al. 2006: 96); **PAR** - FUJ; GUI; GUX; HAI; HKG; HUB; HUN; JIX; MAC; TWN; YUN; NP; SC; SCH; SHG (Löbl & Löbl 2017: 574)); JA (Habu 1973: 382); PA (Habu 1973: 382); **IAR** - SM (Habu 1973: 382); IDS (Habu 1973: 382); MLS (Habu 1973: 382); PP (Habu 1973: 382); **AUR** - AST (Habu 1973: 382).

10. *Stenolophus smaragdulus* (Fabricius 1798)

Stenolophus smaragdulus (Fabricius) Bates 1886: 80; id. 1891: 333; id. 1892a: 349; Bouchard 1903: 172; Sloane 1920a: 321; Andrewes 1921a: 160; id. 1924b: 40; id. 1930: 318; Habu 1973: 377; Saha 1995: 69; Saha & Halder 2000: 16; Löbl & Smetana 2003: 405; Lorenz 2005: 355; Park et al. 2006: 96; Jaeger & Ahmed 2017: 614; Löbl & Löbl 2017: 575.

Carabus smaragdulus Fabricius 1798: 60; id. 1801: 209; Dejean 1829: 418; Hope 1838: 93; Schaum 1847: 49; Motschulsky 1855: 43.

= *Carabus smaragdulus* Fabricius 1798

= *Egadroma smaragdula* Motschulsky 1864

= *Harpalus trechoides* Hope 1845

= *Harpalus stolidus* Walker 1858

= *Egadroma apicalis* Motschulsky 1864

= *Stenolophus transmutans* Bates 1886

= *Stenolophus chalceus* Lesne 1904 (non Bates 1873)

= *Egadroma smaragdula* (Fabricius 1798)

= *Stenolophus apicalis* (Motschulsky 1864)

= *Stenolophus stolidus* (Walker 1858)

= *Stenolophus trechoides* (Hope 1845)

Specimens examined (n = 1): SJC-ZOO-CWSSMC035, Kootar, 1 ex, light trap, 25.ii.2020.

Distribution: Throughout the whole of Southeast Asia extending from JA in the North to Queensland in South (Andrewes 1930: 318); **ORR** - India (West Bengal: Kolkata, Kharagpur, Purulia, Medinipur (Saha 1995: 69); Meghalaya: Khasi, Jayantia Hill (Saha & Halder 2000: 16)); MM (Habu 1973: 377); SRL (Habu 1973: 377); TAI (Habu 1973: 377); VTN (Park et al. 2006: 96); **PAR** - India (Himachal Pradesh (Löbl & Löbl 2017: 575); West Bengal: Darjeeling District (Saha 1995: 69)); BT; FUJ; GUA; HAI; HKG; JIX; MAC; NP; PA; TWN; YUN (Löbl & Löbl 2017: 575); JA (Habu 1973: 377); **IAR -** IDS (Habu 1973: 377); MLS (Habu 1973: 377); PP (Habu 1973: 377); **AUR -** AST (Habu 1973: 377).

Tribe Harpalini Bonelli 1810

vii. Genus *Allosiopelus* Ito 1995

Allosiopelus Ito 1995: 153; Lorenz 2005: 376.

11. *Allosiopelus punctatipennis* Ito 1995

Allosiopelus punctatipennis Ito 1995: 154; Lorenz 2005: 376.

Specimens examined (n = 2): SJC-ZOO-CWSSMC036–037, Alampetty, 2 exs, light trap, 26.x.2019.

Distribution: ORR - India (Tamil Nadu: Tharangambadi; Pondicherry (Ito 1995: 154)).

viii. Genus *Amblystomus* Erichson 1837

Amblystomus Erichson 1837: 59; Lacordaire 1854: 301; Reitter 1883: 139; Tschitschérine 1900a: 348; Sloane 1920b: 131; Andrewes 1924b: 33; id. 1930: 17; Habu 1973: 15; Noonan 1976: 54; Saha 1995: 56; Löbl & Smetana 2003: 360; Lorenz 2005: 384; Park et al. 2006: 95; Löbl & Löbl 2017: 502.

= *Hispalis* Rambur 1838

= *Artizoum* Gistel 1857

= *Megaristerus* Nietner 1858

= *Notophilus* Blackburn 1888

= *Thenarotidius* Sloane 1898

= *Psilonothus* Sloane 1900

= *Entomorrhinus* Jeannel 1948

[@] 12. *Amblystomus aenescens* (Motschulsky 1858)

Amblystomus aenescens (Motschulsky) Andrewes 1928: 21; id. 1930: 17; id. 1933: 7; Lorenz 2005: 384.

= *Hispalis aenescence* Motschulsky 1858

Specimens examined (n = 4): SJC-ZOO-CWSSMC038–041, Alampetty, 3 exs, light trap, 26.ii.2020; 1 ex, pitfall trap, 26.ii.2020.

Distribution: ORR - EAI (Andrewes 1930: 17).

13. *Amblystomus fuscescens* (Motschulsky 1858)

Amblystomus fuscescens (Motschulsky) Bates 1892a: 334; Lesne 1904: 73; Andrewes 1919a: 198; id. 1928: 21; id. 1930: 18; Kapur 1945: 326; Lorenz 2005: 384.

= *Hispalis fuscescens* Motschulsky 1858

Specimens examined (n = 20): SJC-ZOO-CWSSMC042–061, Alampetty, 10 exs, light trap, 26.x.2019; 3 exs, pitfall trap, 26.x.2019; 2 exs, hand picking, 26.x.2019; 3 exs, light trap, 25.ii.2020; 1 ex, pitfall trap, 25.ii.2020; 1 ex, hand picking, 25.ii.2020.

Distribution: ORR - India (Assam; Manipur: Imphal Valley; Karnataka: Mysore (Kapur 1945: 326)); EAI (Andrewes 1930: 18); SRL (Andrewes 1930: 18); MM (Andrewes 1930: 18); TAI (Andrewes 1930: 18).

[#] 14. *Amblystomus indicus* (Nietner 1858)

Amblystomus indicus (Nietner) Bates 1886: 76; id. 1889: 271; id. 1891: 331; id. 1892a: 336; id. 1892b: 231; Sloane 1920a: 321; Andrewes 1927: 103; id. 1930: 19; Lorenz 2005: 384; Kushwaha & Hegde 2015: 402; Löbl & Löbl 2017: 502.

= *Megaristerus indicus* Nietner 1858

= *Entomorrhinus indicus* (Nietner 1858)

Specimens examined (n = 19): SJC-ZOO-CWSSMC062–80, Alampetty, 7 exs, light trap, 26.x.2019; 2 exs, pitfall trap, 26.x.2019; 3 exs, hand picking, 26.x.2019; 6 exs, light trap, 25.ii.2020; 1 ex, hand picking, 25.ii.2020.

Distribution: ORR - India (Uttar Pradesh: Jalaun, Orai, Jhansi; Madhya Pradesh: Pathrora (Kushwaha & Hegde 2015: 402); Jharkhand: Chota Nagpur, Tetara (Andrewes 1930: 19)); MM (Kushwaha & Hegde 2015: 402); VTN (Kushwaha & Hegde 2015: 402); SRL (Andrewes 1930: 19); **AUR -** AST (Andrewes 1930: 19).

ix. Genus *Dioryche* MacLeay 1825

Dioryche MacLeay 1825: 21; Lacordaire 1854: 300; Bates 1873: 271; Alluaud 1917: 321; Andrewes 1919a: 156; id. 1924b: 32; id. 1930: 146; Noonan 1976: 47; id. 1985: 34; Saha 1995: 62; Löbl & Smetana 2003: 369; Lorenz 2005: 376; Kataev 2012: 112; Kushwaha & Hegde 2015: 402; Löbl & Löbl 2017: 518.

= *Hypodioryche* Schauberger 1935

15. *Dioryche cuprina* (Dejean 1829)

Dioryche cuprina (Dejean) Kataev 2012: 114; Löbl & Löbl 2017: 518.

= *Selenophorus cuprinus* Dejean 1829

= *Harpalus colombensis* Nietner 1857a

= *Cardiaderus scitus* Walker 1858

= *Dioryche colombensis* (Nietner 1857)

= *Dioryche scita* (Walker 1858)

= *Selenophorus colombensis* (Nietner 1857)

Specimens examined (n = 2): SJC-ZOO-

CWSSMC081–082, Alampetty, 2 exs, light trap, 26.x.2019.

Distribution: ORR - India (Goa ; Karnataka : Kanara ; Tamil Nadu: Chennai, Kariakal, Coimbatore; Pondicherry; Kerala: Thiruvananthapuram, Mahe, Kozhikode, Kallar (Kataev 2012: 114)); SRL (Kataev 2012: 114); TAI (Kataev 2012: 114); **PAR -** NP (Kataev 2012: 114); PA (Löbl & Löbl 2017: 518).

16. *Dioryche dravidana* Kataev 2012

Dioryche dravidana Kataev 2012: 123.

Specimens examined (n = 1): SJC-ZOO-CWSSMC083, Alampetty, 1 ex, pitfall trap, 26.x.2019.

Distribution: ORR - India (Karnataka: Mysore, Shimoga; Tamil Nadu: Shambaganur, Madura (Kataev 2012: 123)).

17. *Dioryche torta* MacLeay 1825

Dioryche torta MacLeay 1825: 21; Hope 1838: T. 2; Bates 1873: 271; Andrewes 1919a: 154; id. 1926a: 68; id. 1930: 148; Noonan 1985: 35; Saha 1995: 63; Lorenz 2005: 376; Löbl & Smetana 2003: 369; Lorenz 2005: 376; Löbl & Löbl 2017: 518.

Specimens examined (n = 2): SJC-ZOO-CWSSMC084–085, Alampetty, 1 ex, pitfall trap, 26.x.2019; 1 ex, light trap, 25.ii.2020.

Distribution: ORR - All the Indian States (Saha 1995: 63) India (West Bengal: Murshidabad (Saha 1995: 63)); SRL (Andrewes 1930: 148); MM (Andrewes 1930: 148); **PAR -** GUA; HAI; NP; PA; YUN (Löbl & Löbl 2017: 518); **IAR** - IDS (Andrewes 1930: 148).

x. Genus *Ophoniscus* Bates 1892

Ophoniscus Bates 1892a: 337; Andrewes 1923b: 446; id. 1930: 242; id. 1939: 136; Noonan 1976: 46; id. 1985: 31; Saha 1995: 63; Löbl & Smetana 2003: 388; Kataev 2005: 269; Lorenz 2005: 376; Kataev & Wrase 2012: 215; Löbl & Löbl 2017: 546; Kataev 2018: 319.

***18. *Ophoniscus puneensis* Kataev 2018**

Ophoniscus puneensis Kataev 2018: 321.

Specimens examined (n = 1): SJC-ZOO-CWSSMC086, Alampetty, 1 ex, light trap, 25.ii.2020.

Distribution: ORR - India (Maharashtra: Mulshi environment (Kataev 2018: 321)).

xi. Genus *Parophonus* Ganglbauer 1891

Parophonus Ganglbauer 1891a: 340; Jeannel 1942: 625; Noonan 1976: 45; id. 1985: 19; Löbl & Smetana 2003: 392; Lorenz 2005: 373; Kataev 2010: 278; Löbl & Löbl 2017: 553.

19. *Parophonus acutangulus* (Bates 1891)

Parophonus acutangulus (Bates) Andrewes 1930: 184; Kataev 2010: 296; Löbl & Löbl 2017: 553.

= *Hypolithus acutangulus* Bates 1891

= *Hyperpalus gracilis* Andrewes 1947

= *Parophonus gracilis* (Andrewes 1947)

= *Trichotichnus javanus* (Gory 1833)

Specimens examined (n = 1): SJC-ZOO-CWSSMC087, Alampetty, 1 ex, light trap, 26.x.2019.

Distribution: ORR - India (Delhi; Uttar Pradesh: Allahabad, Sitapur; Jharkhand: Chota Nagpur- Tetara; Madhya Pradesh: Mhow; Gujarat: Surat; Maharashtra: Mumbai; Tamil Nadu: Coimbatore, Tharangambadi (Andrewes 1930: 184)); MM (Kataev 2010: 296); SRL (Andrewes 1930: 184); **PAR -** India (Jammu Kashmir (Kataev 2010: 296); Uttarakhand: Dehra Dun (Andrewes 1930: 184); West Bengal: Barodabri (Kataev 2010: 296)); NP (Kataev 2010: 296); PA (Kataev 2010: 296); **IAR** - IDS (Andrewes 1930: 184).

20. *Parophonus indicus* (Andrewes 1931)

Parophonus indicus (Andrewes) Noonan 1985: 22; Lorenz 2005: 374; Kataev 2010: 283 ; Löbl & Löbl 2017: 553.

= *Hyparpalus indicus* Andrewes 1931a

= *Hypolithus cyaneotinctus* Bates 1891 [non Bates 1889]

= *Trichotichnus indicus* (Andrewes 1931)

Specimens examined (n = 1): SJC-ZOO-CWSSMC088, Alampetty, 1 ex, light trap, 26.x.2019.

Distribution: ORR - India (Uttar Pradesh; Bihar: Monghyr; Jharkhand: Chota Nagpur-Tetara, Barwa, Konbir, Ranchi; Madhya Pradesh: Balaghat, South Mandla (Andrewes 1931a: 516), Motinala, Seoni, Khawasa (Kataev 2010: 283); Karnataka: Mysore, Bangalore, Nandidrug, Chikkaballapura (Andrewes 1931a: 516)); SRL (Kataev 2010: 283); **PAR -** India (Jammu Kashmir (Kataev 2010: 283); Uttarakhand: Dehra Dun (Andrewes 1931a: 516); Sikkim (Andrewes 1931a: 516)); PA (Kataev 2010: 283).

Subfamily Lebiinae Bonelli 1810

Tribe Cyclosomini Laporte De Castelnau 1834

xii. Genus *Cyclicus* Jeannel 1949

Cyclicus Jeannel 1949: 865, 870; Basilewsky 1953: 117; id. 1956: 464; Lorenz 2005: 452.

= *Metacyclicus* Jeannel 1949

21. *Cyclicus elegans* (Andrewes 1931)

Cyclicus elegans (Andrewes) Lorenz 2005: 452; Shiju & Sabu 2019: 11.

= *Tetragonoderus elegans* Andrewes 1931a

Specimens examined (n = 13): SJC-ZOO-CWSSMC089–101, Chinnar, 2 exs, light trap, 26.x.2019;

Kootar, 3 exs, light trap, 26.x.2019; 4 exs, pitfall trap, 26.x.2019; 2 exs, hand picking, 26.x.2019; 2 exs, pitfall trap, 25.ii.2020.

Distribution: ORR - India (Kerala: Charalmedu, Nedumkayam (Shiju & Sabu 2019: 11)); **PAR -** India (Uttarakhand: Bindal River, Chakata Range, Dehra Dun, Deoba Nadi River, Hathibarkala, Kali Valley, Nandhaur River, West Almora (Andrewes 1931a: 524)).

22. *Cyclicus fimbriatus* (Bates 1886)

Cyclicus fimbriatus (Bates) Lorenz 2005: 452; Shiju & Sabu 2019: 11.

Tetragonoderus fimbriatus Bates 1886: 202; Andrewes 1930: 344; Löbl & Löbl 2017: 498.

= *Tetragonoderus punctatus* Schmidt-Göbel 1846 (non Wiedemann 1823)

= *Cyclicus fimbriatus* (Bates 1886)

Specimens examined (n = 1): SJC-ZOO-CWSSMC102, Alampetty, 1 ex, light trap, 25.ii.2020.

Distribution: ORR - India (Karnataka: North Karnataka, Belgaum, Managanali, Mysore- Teppukadu (Andrewes 1930: 344); Tamil Nadu: Nilgiri Hills-Hill Grove (Andrewes 1930: 344), Srivilliputhur (Shiju & Sabu 2019: 11), Tiruchirappally (Andrewes 1930: 344); Kerala: Bhawani Valley (Andrewes 1930: 344), Kozhikode, Nedumkayam (Shiju & Sabu 2019: 11)); SRL (Andrewes 1930: 344); MM (Andrewes 1930: 344); **PAR -** CHN (Löbl & Löbl 2017: 498).

xiii. Genus *Tetragonoderus* Dejean 1829

Tetragonoderus Dejean 1829: 485; Schmidt-Göbel 1846: 92; Lacordaire 1854: 132; Chaudoir 1876a: 33; Horn 1882: 127; Andrewes 1924b: 60; id. 1930: 343; Blackwelder 1944: 52; Jeannel 1949: 865; Basilewsky 1956: 463; Jedlička 1963: 291; Saha et al. 1992: 49; Lorenz 2005: 453; Löbl & Löbl 2017: 498.

23. *Tetragonoderus notaphioides* Motschulsky 1861

Tetragonoderus notaphioides Motschulsky 1861: 99; Chaudoir 1876a: 54; Bates 1886: 201; Andrewes 1928: 24; id. 1930: 345; Lorenz 2005: 453; Shiju & Sabu 2019: 12.

Specimens examined (n = 2): SJC-ZOO-CWSSMC103–104, Kootar, 2 exs, pitfall trap, 26.x.2019.

Distribution: ORR - India (Odisha: Berhampur, Puri, Rambha- Ganjam, Barkuda Island- Chilka Lake; Maharashtra: Bhandara, Karnataka: North Karnataka; Tamil Nadu: Chennai, Tiruchirappally, Thrangambadi, Palni Hills (Andrewes 1930: 345); Kerala: Kozhikode, Ambalavayal (Shiju & Sabu 2019: 12)); SRL (Andrewes 1930: 345).

Tribe Lebiini Bonelli 1810

xiv. Genus *Anchista* Nietner 1857

Anchista Nietner 1857c: 523; id. 1857b: 374; Chaudoir 1877: 236; Andrewes 1926b: 346; id. 1930: 22; Csiki 1932: 1455; Jedlička 1963: 449; Habu 1967: 137; Darlington 1968: 139; id. 1970: 45; Habu 1982: 102; Kirschenhofer 1994: 1006; Lorenz 2005: 491; Löbl & Löbl 2017: 623.

= *Paraphaea* Bates 1873

24. *Anchista fenestrata* (Schimdt-Göbel 1846)

Anchista fenestrata (Schmidt-Göbel) Chaudoir 1872a: 168; Bates 1892a: 424; Andrewes 1923a: 20; id. 1930: 23; Csiki 1932: 1456; Jedlička 1963: 449; Lorenz 2005: 491; Shi et al. 2013: 27; Löbl & Löbl 2017: 623; Shiju & Sabu 2019: 40.

= *Plochionus fenestrata* Schmidt-Göbel 1846

Specimens examined (n = 15): SJC-ZOO-CWSSMC105–119, Chinnar, 1 ex, light trap, 26.x.2019; Alampetty, 6 exs, light trap, 26.x.2019; 4 exs, light trap, 25.ii.2020; Kootar, 3 exs, 26.x.2019; 1 ex, light trap, 25.ii.2020.

Distribution: ORR - India (Rajasthan; Bihar; Jharkhand: Singbhum (Andrewes 1930: 23); Karnataka: Gundelpet (Shiju & Sabu 2019: 40); Tamil Nadu: Alwarkurichi, Srivilliputhur, Thambaram (Shiju & Sabu 2019: 40); Pondicherry (Andrewes 1930: 23); Kerala: Charalmedu, Chinnar-Alampetty; Koorachundu, Nedumkayam, Thamarassery (Shiju & Sabu 2019: 40)); SRL (Andrewes 1930: 23); MM (Andrewes 1930: 23); **PAR -** India (Uttarakhand: Dehra Dun; West Bengal); NP (Löbl & Löbl 2017: 623).

xv. Genus *Anomotarus* Chaudoir 1875

Anomotarus Chaudoir 1875: 48; Sloane 1917: 435; id. 1920b: 170; Andrewes 1930: 27; Jedlička 1963: 450; Lorenz 2005: 497; Löbl & Löbl 2017: 580.

25. *Anomotarus stigmula* (Chaudoir 1852)

Anomotarus stigmula (Chaudoir) Andrewes 1930: 28; Jedlička 1963: 451; Lorenz 2005: 497; Löbl & Löbl 2017: 580; Shiju & Sabu 2019: 42.

= *Cymindis stigmula* Chaudoir 1852

Specimens examined (n = 1): SJC-ZOO-CWSSMC120, Alampetty, 1 ex, light trap, 26.x.2019.

Distribution: ORR - India (Assam: Gauhati (Andrewes 1930: 28); Maharashtra: Mumbai- Khandesh, Nagpur; Karnataka: Belgaum (Andrewes 1930: 28), Gundelpet (Shiju & Sabu 2019: 42), Mysore- Nandidurg; Tamil Nadu: Chennai (Andrewes 1930: 28), Srivilliputhur (Shiju & Sabu 2019: 42); Kerala: Charalmedu, Eravikulam National Park, Koorachundu, Nedumkayam, Thamarassery,

Vazhachal, Vettiozhinjathottam (Shiju & Sabu 2019: 42)); MM (Andrewes 1930: 28); SRL (Andrewes 1930: 28); **PAR -** India (Himachal Pradesh (Löbl & Löbl 2017: 580); Uttarakhand: Dehra Dun (Andrewes 1930: 28)); JA (Andrewes 1930: 28); NP; PA (Löbl & Löbl 2017: 580); TWN (Jedlička 1963: 451); **IAR -** IDS (Andrewes 1930: 28); NEC (Andrewes 1930: 28).

xvi. Genus *Apristus* Chaudoir 1846

Apristus Chaudoir 1846: 62; Lacordaire 1854: 123; Horn 1882: 133; Andrewes 1930: 33; Ganglbauer 1892: 397 & 401; Jedlička 1933a: 87; Blackwelder 1944: 59; Jedlička 1963: 427; Gueorguiev & Gueorguiev 1995: 32 & 229; Kryzhanovskij et al. 1995: 165; Lorenz 2005: 472; Park et al. 2006: 100; Löbl & Löbl 2017: 595.

= *Crepnos* Baudi Di Selve 1864

= *Crephnos* Jakobson 1908

26. *Apristus aeneipennis* (Schmidt-Göbel 1846)

Apristus aeneipennis (Schmidt-Göbel) Chaudoir 1850: 67; Motschulsky 1855: 50; Fairmaire 1888: 335; Andrewes 1923a: 15; id. 1930: 33; Jedlička 1963: 430; Lorenz 2005: 472; Park et al. 2006: 100; Shiju & Sabu 2019: 26.

= *Lionychus aeneipennis* Schmidt-Göbel 1846

Specimens examined (n = 1): SJC-ZOO-CWSSMC121, Alampetty, 1 ex, hand picking, 26.x.2019.

Distribution: ORR - India (Maharashtra: Lonavla; Karnataka: Mysore-Teppukadu (Andrewes 1930: 33)); MM (Andrewes 1930: 33); VTN (Andrewes 1930: 33).

27. *Apristus subtransparens* Motschulsky 1861

Apristus subtransparens Motschulsky 1861: 104; Bates 1886: 206; id. 1892b: 233; Andrewes 1928: 21; id. 1930: 34; Lorenz 2005: 472; Löbl & Löbl 2017: 596; Shiju & Sabu 2019; 27.

Specimens examined (n = 2): SJC-ZOO-CWSSMC122–123, Kootar, 2 exs, hand picking, 26.x.2019.

Distribution: ORR - India (Kerala: Chinnar, Koottar, Nedumkayam, Thamarassery (Shiju & Sabu 2019; 27)); SRL (Andrewes 1930: 34); NP; PA (Löbl & Löbl 2017: 596).

xvii. Genus *Catascopus* Kirby 1825

Catascopus Kirby 1825: 94; Latreille et Dejean 1824: 115; Macleay 1825: 14; Dejean 1825: 328; Schmidt-Göbel 1846: 80; Lacordaire 1854: 145; Chaudoir 1861: 116; id. 1872b: 244; Andrewes 1924b: 62; id. 1926b: 348; id. 1930: 74; id. 1931b: 62; id. 1937: 187; Jedlička 1935: 9; Jeannel 1942: 1017; Blackwelder 1944: 57; Basilewsky 1956: 485; Jedlička 1963: 379; Lorenz 2005: 454; Löbl & Löbl 2017: 620.

28. *Catascopus cingalensis* Bates 1886

Catascopus cingalensis Bates 1886: 203; Andrewes 1924b: 117; id. 1930: 75; Lorenz 2005: 454; Shiju & Sabu 2019: 15.

= *Catascopus reductus* Chaudoir 1861

= *Catascopus severini* Bates 1891

Specimens examined (n = 1): SJC-ZOO-CWSSMC124, Chinnar, 1 ex, hand picking, 26.x.2019.

Distribution: ORR - India (Jharkhand: Chota Nagpur-Tetara; Madhya Pradesh: Mhow; Odisha: Surada; Karnataka: Chikkaballapura; Tamil Nadu: Nilgiri Hills (Andrewes 1930: 75)); SRL (Andrewes 1930: 75).

29. *Catascopus cyanellus* Chaudoir 1848

Catascopus cyanellus Chaudoir 1848: 113; id. 1861: 118; Andrewes 1930: 75; Lorenz 2005: 454; Löbl & Löbl 2017: 620; Shiju & Sabu 2019 : 15.

= *Catascopus reductus* Walker 1858

Specimens examined (n = 7): SJC-ZOO-CWSSMC125–131, Chinnar, 2 exs, pitfall trap, 26.x.2019; 5 exs, hand picking, 26.x.2019.

Distribution: ORR - India (Maharashtra: Dapoli; Karnataka : North Karnataka; Tamil Nadu: Coimbatore (Andrewes 1930: 75)); **PAR** - India (Uttarakhand: Dehra Dun (Andrewes 1930: 75)); NP (Andrewes 1930: 75).

xviii. Genus *Lebia* Latreille 1802

Lebia Latreille 1802: 85; Dejean 1825: 253; Schmidt-Göbel 1846: 43; Lacordaire 1854: 127; Chaudoir 1871a: 111–255; id. 1871b: 1–87; Horn, 1882: 130; Fowler 1887: 136; Ganglbauer 1892: 397; Silvestri 1904: 68–84; Andrewes 1930: 191; Alluaud 1936: 8; Jedlička 1933b: 144; Jeannel 1942: 1028; id. 1949: 882, 902; Jedlička 1963: 314; Blackwelder 1944: 52; Mateu 1984: 398; Gueorguiev & Gueorguiev 1995: 31, 221; Kryzhanovskij et al. 1995: 161; Hůrka 1996: 468, 470; Lorenz 2005: 481; Park et al. 2006: 102; Löbl & Löbl 2017: 611.

30. *Lebia baconi* (Chaudoir 1871)

Lebia baconi (Chaudoir) Andrewes 1930: 191; Lorenz 2005: 487; Löbl & Löbl 2017: 616; Shiju & Sabu 2019 : 37.

= *Nematopeza baconi* Chaudoir 1871a

Specimens examined (n = 1): SJC-ZOO-CWSSMC132, Alampetty, 1 ex, light trap, 25.ii.2020.

Distribution: ORR - India (Bihar: Chapra; Madhya Pradesh: Hoshangabad (Andrewes 1930: 191); Tamil Nadu: Srivilliputhur (Shiju & Sabu 2019: 37)).

31. *Lebia calycophora* Schmidt-Göbel 1846

Lebia (Poecilothais) calycophora Schmidt-Göbel 1846: 44; Bates 1892a: 427; Andrewes 1923a: 21; id. 1930: 191; Jedlička 1963: 322–325; Lorenz 2005: 488;

Park et al. 2006: 102; Löbl & Löbl 2017: 616; Shiju & Sabu 2019: 37.

= *Lebia comitata* Bates 1873

= *Lebia farai* Jedlička 1951

Specimens examined (n = 3): SJC-ZOO-CWSSMC133–135, Alampetty, 2 exs, light trap, 26.x.2019; Kootar, 1 ex, light trap, 25.ii.2020.

Distribution: ORR - India (Nagaland: Naga Hills; Assam: Khasi Hills, Patkai Hills (Andrewes 1930: 191); Kerala: Aralam (Shiju & Sabu 2019: 37)); MM (Andrewes 1930: 191); TAI (Andrewes 1930: 191); VTN (Jedlička 1963: 322–325); **PAR -** CHN (Jedlička 1963: 322–325); FUJ; HUN; PA; TWN (Löbl & Löbl 2017: 616); **IAR -** IDS (Jedlička 1963: 322–325); MLS (Jedlička 1963: 322–325).

32. *Lebia indica* Liebke 1938

Lebia indica Liebke 1938: 109; Lorenz 2005: 487; Löbl & Löbl 2017: 616; Shiju & Sabu 2019: 37.

= *Nematopeza decora* Chaudoir 1871c

= *Lebia decora* (Chaudoir 1871)

= *Nematopeza indica* (Liebke 1938)

Specimens examined (n = 1): SJC-ZOO-CWSSMC136, Alampetty, 1 ex, light trap, 25.ii.2020.

Distribution: ORR - India (Tamil Nadu: Alwarkurichi, Sankarankovil (Shiju & Sabu 2019: 37))

Tribe Odacanthini Laporte De Castelnau 1834

xix. Genus *Pentagonica* Schmidt-Göbel 1846

Pentagonica Schmidt-Göbel 1846: 47; Lacordaire 1854: 133; Schaum 1863: 74; Bates 1873: 321; Chaudoir 1877: 212; Sloane 1898: 494 & 513; Dupuis 1913a: 2; Andrewes 1926b: 353; id. 1930: 259; Jeannel 1942: 1017; Blackwelder 1944: 63; Jeannel 1949: 768; Basilewsky 1956: 472; Jedlička 1963: 505; Darlington 1968: 192; id. 1970: 46; Lorenz 2005: 445; Park et al. 2006: 103; Löbl & Löbl 2017: 640.

= *Rhombodera* Reiche 1842

= *Didetus* LeConte 1853

= *Elliotia* Nietner 1856

= *Trichothorax* Montrouzier 1860

= *Xenothorax* Wollaston 1867

= *Wakefieldia* Broun 1880

33. *Pentagonica ruficollis* Schmidt-Göbel 1846

Pentagonica ruficollis Schmidt-Göbel 1846: 48; Bates 1892a: 426; Dupuis 1913a: t. 5, f. 9–11; Andrewes 1923a: 23; id. 1926b: 353; id. 1930: 261; Jedlička 1963: 509; Lorenz 2005: 446; Park et al. 2006: 104; Löbl & Löbl 2017: 641; Shiju & Sabu 2019: 8.

= *Pentagonica dichroa* Sloane 1903

Specimens examined (n = 2): SJC-ZOO-CWSSMC137–138, Alampetty, 1 ex, light trap, 26.x.2019; Chinnar, 1 ex, light trap, 25.ii.2020.

Distribution: ORR - India (Assam: Patkai Hills; Tamil Nadu: Aratapara, Nilgiri Hills (Andrewes 1930: 261)); SRL (Andrewes 1930: 261), MM (Andrewes 1930: 261); VTN (Andrewes 1930: 261); **PAR -** GUA; HKG; YUN; NP; TWN (Löbl & Löbl 2017: 641); **IAR -** IDS (Andrewes 1930: 261); **AUR -** AST (Andrewes 1930: 261).

34. *Pentagonica venusta* Andrewes 1933

Pentagonica venusta Andrewes 1933: 17; Lorenz 2005: 446; Shiju & Sabu 2019: 8.

Specimens examined (n = 1): SJC-ZOO-CWSSMC139, Alampetty, 1 ex, light trap, 26.x.2019.

Distribution: ORR - India (Karnataka: Belgaum, Coorg, Mysore- Nandidurg, South Mangalore; Tamil Nadu: Nilgiri Hills-Kallar (Andrewes 1933: 17)); SRL (Andrewes 1933: 17).

Subfamily Licininae Bonelli 1810

Tribe Chlaenini Brulle 1834

xx. Genus *Chlaenius* Bonelli 1810

Chlaenius MacLeay 1825: 13; Dejean 1826: 297, 368; Schmidt-Göbel 1846: Cover page; Chaudoir 1850: 407; LaFerté-Sénectère 1851: 212, 233, 238, 263, 293; Lacordaire 1854: 213, 217, 219, 220, 221, 223, 224, 235; Chaudoir 1856: 192; Motschulsky 1860: 515; id. 1864b: 334, 347; Chaudoir 1876a: 10, 11, 12, 16; Bates 1892a: 309; Sloane 1910: 437; Andrewes 1919c: 91; id. 1923a: 58; id. 1924b: 24; id. 1930: 82; Lorenz 2005: 328.

35. *Chlaenius hamifer* Chaudoir 1856

Chlaenius hamifer Chaudoir 1856: 209, 210; id. 1876: 62; Bates 1889b: 265; id. 1892b: 311; id. 1892c: 230; Bouchard 1903: 171; Lesne 1904: 69; Sloane 1910: 439; id. 1920a: 322; Andrewes 1919a: 140; id. 1924b: 24; id. 1930: 94; Lorenz 2005: 330; Löbl & Löbl 2017: 494.

= *Chlaenius bihamatus* Chaudoir 1856

= *Chlaenius colombensis* Jedlička 1964

= *Chlaenius queenslandicus* Sloane 1910

= *Dinodes bihamatus* (Chaudoir 1856)

= *Dinodes hamifer* (Chaudoir 1856)

= *Pachydinodes hamifer* (Chaudoir 1856)

Specimens examined (n = 2): SJC-ZOO-CWSSMC140–141, Chinnar, 2 exs, hand picking, 26.x.2019.

Distribution: ORR - India (Kerala: Tholpetty (Akhil 2019: 115)); SRL (Andrewes 1930: 94), MM (Andrewes 1930: 94); TAI (Andrewes 1930: 94); **PAR -** BT; IN; JA; NC; HKG; NP; PA; SC; SCH (Löbl & Löbl 2017: 494); TWN (Andrewes 1930: 94); **IAR -** IDS (Andrewes 1930: 94).

36. *Chlaenius nilgiricus* Andrewes 1919

Chlaenius nilgiricus Andrewes 1919c: 9; id. 1930: 99; Lorenz 2005: 335.

Specimens examined (n = 3): SJC-ZOO-CWSSMC142–144, Alampetty, 2 exs, hand picking, 26.x.2019; Chinnar, 1 ex, hand picking, 26.x.2020.

Distribution: ORR - India (Tamil Nadu: Coimbatore, Nilgiri Hills (Andrewes 1930: 99)).

Subfamily Orthogoniinae Schaum 1857

Tribe Orthogoniini Schaum 1857

xxi. Genus *Orthogonius* Macleay 1825

Orthogonius Macleay 1825: 26; Dejean 1825: 169, 269; Schmidt-Göbel 1846: 55, 61; Lacordire 1854: 269; Walker 1858: 203; Chaudoir 1850: 434; id. 1871b: 98; Andrewes 1924b: 58; id. 1930: 245; Csiki 1932: 1586; Jedlička 1963: 269; Tian & Deuve 2000: 2; Lorenz 2005: 391.

= *Aspectra* Schmidt-Göbel 1846

= *Haplopisthius* Chaudoir 1850

= *Maraga* Walker 1858

37. *Orthogonius baconi* Chaudoir 1871

Orthogonius baconi Chaudoir 1871d: 109; Bates 1892a: 401; Andrewes 1930: 246; Csiki 1932: 1587; Lorenz 2005: 391; Akhil 2019: 121.

Specimens examined (n = 4): SJC-ZOO-CWSSMC145–148, Alampetty, 2 exs, hand picking, 26.x.2019; Chinnar, 2 exs, light trap, 26.x.2020.

Distribution: ORR - India (Tamil Nadu: Nilgiri Hill; Kerala: Muthanga (Akhil 2019: 121)) MM (Andrewes 1930: 246); **PAR** - India (Uttarakhand: Almora, Bengal (Andrewes 1930: 246)).

38. *Orthogonius lucidus* Bates 1891

Orthogonius lucidus Bates 1891: 324–340; Andrewes 1924b: 59; id. 1930: 248; Lorenz 2005: 392; Abhitha et al. 2009: 372.

Specimens examined (n = 8): SJC-ZOO-CWSSMC149–156, Kootar, 1ex, light trap, 26.x.2020; Alampetty, 4 exs, hand picking, 26.x.2019; Chinnar, 2exs, light trap, 26.x.2020; 1 ex, hand picking, 26.x.2020.

Distribution: ORR - India (Jharkhand: Chota Nagpur: Konbir, Tetara, Ranchi; Odisha: Surada; Maharashtra: Mumbai, Igatpuri (Andrewes 1930: 248); Karnataka: Belgaum, northern Karnataka (Andrewes 1930: 248), Bengal: Raniganj (Andrewes 1930: 248); Kerala: Kannur, Kozhikode, Thamarassery, Wayanad: Muthanga, Idukki, Thodupuzha (Abhitha et al. 2009: 372)).

Subfamily Panagaeinae Bonelli 1810

Tribe Panagaeini Bonelli 1810

xxii. Genus *Craspedophorus* Hope 1838

Craspedophorus Hope 1838: 165; Lacordaire 1854: 210; Chaudoir 1878: 90; Andrewes 1919a: 126; id. 1924b: 22; id. 1930: 133; Kirschenhofer 2000: 328; Lorenz 2005: 320; Hackel & Kirschenhofer 2014: 276; Fedorenko 2016: 2; Löbl & Löbl 2017: 638.

= *Camptoderus* Hope 1838

= *Eudema* Laporte De Castelnau 1840

= *Isotarsus* LaFerté-Sénectère 1851

= *Epicosmus* Chaudoir 1846

= *Brachyonychus* Chaudoir 1879

= *Brachycosmus* Jeannel 1949

= *Acanthocosmus* Jeannel 1949

39. *Craspedophorus angulatus* (Fabricius 1781)

Craspedophorus angulatus (Fabricius) Andrewes 1919a: 125; id. 1921a: 154; id. 1924b: 115; id. 1924d: 462; id. 1930: 133; Jedlička 1965: 3; Kirschenhofer 2000: 323; Baehr 2003: 446; Lorenz 2005: 320; Pang & Tian 2012: 265; Hackel & Farkac 2012: 78; Hackel & Kirschenhofer 2014: 276 & 357; Fedorenko 2016: 4; Manthen & Hegde 2018: 206; Jithmon & Sabu 2021: 18566.

Carabus angulatus Fabricius 1781: 302; id. 1787: 197; id. 1792: 148

= *Carabus angulatus* Fabricius 1781

= *Pimelia fasciatus* Fabricius 1781

= *Cychrus reflexus* Fabricius 1801

= *Panagaeus tomentosus* Vigors 1825

= *Eudema bifasciatum* Chaudoir 1879

= *Panagaeus michardi* Fairmaire 1880

= *Craspedophorus bifasciatus* (Chaudoir 1879)

= *Craspedophorus fasciatus* (Fabricius 1781)

= *Craspedophorus michardi* (Fairmaire 1880)

= *Craspedophorus reflexus* (Fabricius 1801)

= *Craspedophorus tomentosus* (Vigors 1825)

= *Epicosmus bifasciatus* (Chaudoir 1879)

= *Eudema michardi* (Fairmaire 1880)

Specimens examined (n = 2): SJC-ZOO-CWSSMC157–158, Chinnar, 2 exs, hand picking, 25.ii.2020.

Distribution: ORR - India (Andhra Pradesh; Karnataka: Shivamoga, Mysore (Hackel & Kirschenhofer 2014: 357); Tamil Nadu: Coimbatore (Hackel & Kirschenhofer 2014: 276 & 357); Pondicherry (Hackel & Farkac 2012: 78); Kerala: Bonacaud (Jithmon & Sabu 2021: 18566)); SRL (Andrewes 1930: 133); BGD (Hackel & Farkac 2012: 78); MM (Hackel & Farkac 2012: 78).

40. *Craspedophorus bifasciatus* (Laporte De Castelnau 1835)

Craspedophorus bifasciatus (Laporte De Castelnau) Andrewes 1919a: 126; id. 1921c: 341; Andrewes 1930: 134; Kirschenhofer 2000: 323; Lorenz 2005: 320; Hackel & Farkac 2012: 78; Hackel & Kirschenhofer 2014: 276 & 346; Fedorenko 2016: 4; Jithmon & Sabu 2021: 18567.

= *Panagaeus bifasciatus* Laporte De Castelnau 1835

= *Epicosmus castelnaui* Chaudoir 1879

= *Craspedophorus castelnaui* (Chaudoir 1879)

= *Isotarsus bifasciatus* (Laporte 1835)

Distribution: ORR - India (Madhya Pradesh; Odisha: Barkuda Island-Lake Chilka (Andrewes 1930: 134); Andhra Pradesh: Udayagiri, Horsely Konda (Andrewes 1930: 134); Tamil Nadu: Kadayam, Coimbatore, Bharathiyar (Jithmon & Sabu 2021: 18567), Chennai, Mahabalipuram (Hackel & Kirschenhofer 2014: 346), Nilgiri Hills, Thiruchirapally (Andrewes 1930: 134); Pondicherry (Andrewes 1930: 134); Kerala: Chinnar (Jithmon & Sabu 2021: 18567)); SRL (Andrewes 1930: 134); BGD (Hackel & Farkac 2012: 78); MM (Hackel & Farkac 2012: 78).

Subfamily Pterostichinae Bonelli 1810

Tribe Abacetini Chaudoir 1872

xxiii. Genus *Abacetus* Dejean 1828

Abacetus Dejean 1828: 195; Lacordaire 1854: 315; Chaudoir 1859: 126; id. 1869: 355; Tschitschérine 1898: 519, 531 & 538; id. 1902: 506; Andrewes 1924b: 44; id. 1930: 1; id. 1939: 129; Jeannel 1948: 420; Löbl & Smetana 2003: 346; Lorenz 2005: 255; Löbl & Löbl 2017: 480.

41. *Abacetus haplosternus* Chaudoir 1878

Abacetus haplosternus Chaudoir 1878: 25; Andrewes 1930: 4; id. 1942b: 25; Lorenz 2005: 258; Divya & Sabu 2020; 9.

Specimens examined (n = 4): SJC-ZOO-CWSSMC159–162, Kootar, 3 exs, light trap, 25.x.2019; 1 ex, light trap, 25.ii.2020.

Distribution: ORR - India (Madhya Pradesh: Hoshangabad; Maharashtra: Nagpur (Andrewes 1930: 4)); TAI (Andrewes 1930: 4); **PAR -** India (Himachal Pradesh: Katrain; Uttarakhand: Almora, Ranikhet, Haldwani (Andrewes 1930: 4)); **IAR -** IDS (Andrewes 1930: 4).

xxiv. Genus *Cosmodiscus* Sloane 1907

Cosmodiscus Sloane 1907: 371; Andrewes 1920b: 445; id. 1930: 131; Löbl & Smetana 2003: 443; Lorenz 2005: 260; Kushwaha & Hegde 2015: 396, 401; Löbl & Löbl 2017: 481.

42. *Cosmodiscus picturatus* Andrewes 1920

Cosmodiscus picturatus Andrewes 1920b: 447; id. 1921c: 345; id. 1930: 131; Lorenz 2005: 260; Kushwaha & Hegde 2015: 396, 401; Divya & Sabu 2020: 11.

Specimens examined (n = 2): SJC-ZOO-CWSSMC163–164, Alampetty, 2 exs, light trap, 26.x.2019.

Distribution: ORR - India (Uttar Pradesh: Fyzabad, Odisha: Rambha: Ganjam, Barkuda and Gopkuda Island, lake Chilka; Maharashtra: Nagpur; Andhra Pradesh: Jammelamadugu (Andrewes 1930: 131); Kerala: Kozhikode (Divya & Sabu 2020: 11)).

Tribe Cratocerini Lacordaire 1854

xxv. Genus *Caelostomus* MacLeay 1825

Caelostomus MacLeay 1825: 23; Andrewes 1924b: 44; id. 1930: 55; Jeannel 1948: 383; Löbl I & Smetana 2003: 471; Lorenz 2005: 249; Faisal & Singh 2014: 342; Löbl & Löbl 2017: 678.

*** 43. *Caelostomus sculptipennis* (Motschulsky 1859)**

Caelostomus sculptipennis (Motschulsky) Chaudoir 1872c: 13; Tschitschérine 1900b: 263 (note); Andrewes 1928: 22; id. 1930: 57; Straneo 1938: 56; Lorenz 2005: 250; Divya & Sabu 2020: 12.

= *Stomonaxus sculptipennis* Motschulsky 1859

= *Stomonaxus sculpticollis* Motschulsky 1859

= *Caelostomus sculpticollis* (Motschulsky 1859)

Specimens examined (n = 1): SJC-ZOO-CWSSMC165, Chinnar, 1 ex, light trap, 25.ii.2020.

Distribution: ORR - India (Tamil Nadu: Nilgiri Hills (Straneo 1938: 56)); SRL (Andrewes 1930: 57).

Tribe Pterostichini Bonelli 1810

xxvi. Genus *Trigonotoma* Dejean 1828

Trigonotoma Dejean 1828: 182; Brulle 1834: 333; Chaudoir 1852: 71; Lacordaire 1854: 311; Chaudoir 1868: 158; Tschitschérine 1900b: 180; Kuntzen 1911: 182; id. 1914: 60; Andrewes 1930: 352; id. 1939: 138; Saha & Halder 2000: 20; Löbl & Smetana 2003: 520; Lorenz 2005: 300; Dubault et al. 2008: 240; Kushwaha & Hegde 2015: 396, 401; Löbl & Löbl 2017: 755.

#44. *Trigonotoma oberthueri* Tschitschérine 1894

Trigonotoma oberthueri Tschitschérine 1894b: 444; Kuntzen 1914: 63; Andrewes 1930: 355; Löbl & Smetana 2003: 520; Lorenz 2005: 300; Löbl & Löbl 2017: 755; Divya & Sabu 2020: 22.

Specimens examined (n = 1): SJC-ZOO-CWSSMC166, Chinnar, 1 ex, hand picking, 26.x.2019.

Distribution: PAR - India (West Bengal: Pedong, Gopaldhara, Mungphu, Kurseong, Lebong (Andrewes 1930: 355)).

Subfamily Scaritinae Bonelli 1810

Tribe Clivinini Rafinasque 1815

xxvii. Genus *Clivina* Latreille 1802

Clivina Latreille 1802: 96; Bonelli 1813: 480; Dejean 1825: 411; Schmidt-Göbel 1846 (cover); Motschulsky 1861: 101; Putzeys 1863: 29 & 68; id. 1867: 94; id. 1868: 10; id. 1873: 15; Fleisch 1899: 33; Tschitschérine 1904: 258; Andrewes 1919b: 470; id. 1924b: 11; id. 1926c: 372; id. 1929: 344, 351; id. 1930: 110; Balkenohl 2001: 13; Lorenz 2005: 141.

45. *Clivina brevior* Putzeys 1866

Clivina brevior Putzeys 1866: 126; Bates 1892a: 277; Andrewes 1926c: 375; id. 1929: 355, 378; id. 1930: 112; Balkenohl 2001: 14; Lorenz 2005: 142; Abhitha 2010: 105.

Specimens examined (n = 1): SJC-ZOO-CWSSMC167, Chinnar, 1 ex, light trap, 25.ii.2020.

Distribution: ORR - India (New Delhi: Pusa (Andrewes 1930: 112); Kerala: Kozhikode: Kuttikattoor, Medical College, Thamarassery (Abhitha 2010: 105)); MM (Andrewes 1930: 112); **IAR -** MLS (Andrewes 1930: 112).

46. *Clivina lobata* Bonelli 1813

Clivina lobata Bonelli 1813: 481; Dejean 1825: 414; Putzeys 1861: 50; id. 1867: 121, 122, 125; id. 1868: 1, 8; Bates 1892a: 276; Andrewes 1919a: 209; id. 1921c: 340; id. 1922: 392; id. 1924b: 11, 462; id. 1926c: 875; id. 1929: 355, 375; id. 1930: 114; Lorenz 2005: 143; Abhitha 2010: 107; Löbl & Löbl 2017: 255.

Specimens examined (n = 1): SJC-ZOO-CWSSMC168, Kootar, 1 ex, light trap, 25.ii.2020.

Distribution: ORR - India (Kerala: Kozhikode: Thamarassery, Wayanad: Thirunelli (Abhitha 2010: 107)); MM (Andrewes 1930: 114); TAI (Andrewes 1930: 114); **PAR -** JA (Löbl & Löbl 2017: 255).

xxviii. Genus *Pseudoclivina* Kult 1947

Pseudoclivina Kult 1947: 30; id. 1951: 18; Balkenohl 2001: 18; Lorenz 2005: 145; Löbl & Löbl 2017: 258.

***47. *Pseudoclivina costata* (Andrewes 1929)**

Pseudoclivina costata (Andrewes) 1929: 354, 364; id. 1930: 113; Kult 1951: 18; Bakenohl 2001: 18; Lorenz 2005: 145.

= *Clivina costata* Andrewes 1929: 354

Specimens examined (n = 1): SJC-ZOO-CWSSMC169, Alampetty, 1 ex, light trap, 25.ii.2020.

Distribution: ORR - India (Tamil Nadu: Nilgiri Hills (Andrewes 1930: 113)).

48. *Pseudoclivina memnonia* (Dejean 1831)

Pseudoclivina memnonia (Dejean) Kult 1947: 30; id. 1951: 18; Balkenohl 2001: 19; Lorenz 2005: 145; Abhitha 2010: 108; Löbl & Löbl 2017: 259.

Clivina memnonia Dejean 1831: 503; Putzeys 1846: 588; Bouchard 1903: 169; Andrewes 1919a: 187, 206; id. 1924b: 115; id. 1926c: 373; id. 1927: 105; id. 1929: 354, 362; id. 1930: 115; Saha & Biswas 1985: 120.

= *Clivina memnonia* Dejean 1831

= *Clivina indica* Putzeys 1846

= *Clivina rugosifrons* Nietner 1856

= *Clivina recta* Walker 1858

= *Pseudoclivina indica* (Putzeys 1846)

= *Pseudoclivina recta* (Walker 1858)

= *Pseudoclivina rugosifrons* (Nietner 1856)

Specimens examined (n = 2): SJC-ZOO-CWSSMC170–171, Alampetty, 1 ex, light trap, 26.x.2019; Chinnar, 1 ex, light trap, 26.x.2019.

Distribution: ORR - India (Kerala: Idukki: Chinnar; Kozhikode: Thamarassery, Engapuzha; Kasargod: Periya; Wayanad: Sulthan Bathery, Ambalavayal, Panamaram, Thirunelli, Muthanga, Tholpetty (Abhitha 2010: 108)); SRL (Andrewes 1930:115); MM (Andrewes 1930:115); **PAR -** GUA, HAI, YUN (Löbl & Löbl 2017: 259); **IAR -** IDS (Andrewes 1930:115).

Tribe Dyschiriini W. Kolbe 1880

xxix. Genus *Dyschirius* Bonelli 1810

Dyschirius Bonelli 1810: Panzer 1813: 67; Stephens 1827: 37, 40; Putzeys 1846: 524; Lacordaire 1854: 202; Putzeys 1867: 32; Fleischer 1899: 8; Andrewes 1919: 99; Müller 1922: 33; Andrewes 1926c: 377; id. 1929: 390; id. 1930: 159; Jeannel 1941: 250, 260, 275; id. 1946: 213, 215, 218; Moore & Brown 1979: 123; Clopton 1991: 53, 59; Saha et al. 1992: 9; Balkenohl 1994: 27; Fedorenko 1996: 5, 9, 11; Lorenz 2005: 151; Bulirsch 2009: 559; id. 2011: 1; Bousquet 2012: 431; Allegro & Bulirsch 2012: 235; Hogan 2012: 106, 111, 116, 231; Kushwaha & Hegde 2015: 399, 419; Fedorenko 2016: 439; Ghannem et al. 2016: 69; Bulirsch & Stachowiak 2017: 137; Löbl & Löbl 2017: 263; Bulirsch 2018: 229.

49. *Dyschirius paucipunctus* Andrewes 1929

Dyschiriodes paucipunctus (Andrewes) Lorenz 2005: 154.

Dyschirius mahratta Var. *paucipunctus* Andrewes 1929: 392, 397; id. 1930:160.

= *Dyschiriodes paucipunctus* (Andrewes 1929)

Specimens examined (n = 3): SJC-ZOO-CWSSMC172–174, Kootar, 3 exs, light trap, 26.x.2019.

Distribution: ORR - India (Maharashtra: Pune; Karnataka: Belgaum (Andrewes 1930: 160)); SRL

(Andrewes 1930: 160).

Tribe Scaritini Bonelli 1810

xxx. Genus *Oxylobus* Chaudoir 1855

Oxylobus Chaudoir 1855: 5; id. 1879: 129; Andrewes 1924b: 8; id. 1929: 292; id. 1930: 252; Lorenz 2005: 141.

50. *Oxylobus asperulus* Chaudoir 1857

Oxylobus asperulus Chaudoir 1857: 58; id. 1879: 133; Andrewes 1922: 215; id. 1924b: 129; id. 1929: 296, 311. id. 1930: 252; Lorenz 2005: 141.

Specimens examined (n = 1): SJC-ZOO-CWSSMC175, Alampetty, 1 ex, hand picking, 26.x.2019.

Distribution: ORR - India (Andhra Pradesh: Chittur district, Horseley Konda; Karnataka: Mysore; Tamil Nadu: Pillur, Kodaikanal, Yercaud, Madura, Nilgiri Hills, Shembaganur; Kerala: Dhoni forest, southern Malabar (Andrewes 1930: 252)); SRL (Andrewes 1930: 252).

ssp. ***Oxylobus asperulus amyntas* Andrewes 1924**

Oxylobus amyntas Andrewes 1924b: 70; id. 1929: 296, 313. id. 1930: 252; Lorenz 2005: 141.

Specimens examined (n = 2): SJC-ZOO-CWSSMC176–177, Alampetty, 2 exs, hand picking, 26.x.2019.

Distribution: ORR - India (Madhya Pradesh: Majgaon, Motinala, Mukhi (Andrewes 1930: 252)).

51. *Oxylobus porcatus* (Fabricius 1798)

Oxylobus porcatus (Fabricius) Heyne-Taschenberg 1894: 3: 32; id. 1895: 20; Andrewes 1921a: 157; id. 1924b: 8; id. 1929: 295, 305; Andrewes 1930: 254; Lorenz 2005: 141.

Scarites porcatus Fabricius 1798: 43; Hope 1838: 95; Motschulsky 1855: 40.

= *Scarites porcatus* Fabricius 1798

= *Oxylobus costatus* Chaudoir 1879

= *Oxylobus minor* Tschitschérine 1894a

= *Oxylobus obliterates* Andrewes 1929

Specimens examined (n = 3): SJC-ZOO-CWSSMC178–180, Alampetty, 3 exs, hand picking, 26.x.2019.

Distribution: ORR - India (Punjab: Baddia; West Bengal: Sahibganj, Rajmahal, Giridih; Jharkhand: Chakardharapore, Konbir, Chota Nagpur- Tetara, Tinpahar; Madhya Pradesh: Jubbulpore, Majgaon, Motinala; Chhattisgarh: Chitrakot; Odisha: Barkuda Island, Barkul, Chilka lake; Andra Pradesh: Visakhapatnam, Chittoor, Horseley Konda; Karnataka: Belgaum; Tamil Nadu: Coimbatore, Nilgiri Hills, Shevaroy Hills, Madura, Palni Hills, Kallar, Pillur, Ootacamund, Shembagannur; Kerala: Malabar Coast (Andrewes 1930: 254)); SRL (Andrewes 1930: 254).

Subfamily Trechinae Bonelli 1810

Tribe Bembidiini Stephens 1827

xxxi. Genus *Elaphropus* Motschulsky 1839

Elaphropus Motschulsky 1839: 73; Erwin 1975: 1; Kopecky 2002: 63; Lorenz 2005: 207; Löbl & Löbl 2017: 342.

*** 52. *Elaphropus nigellus* (Andrewes 1935)**

Elaphropus nigellus (Andrewes) Lorenz 2005: 210.

= *Tachys nigellus* Andrewes 1935

= *Tachyura nigella* (Andrewes 1935)

Specimens examined (n = 21): SJC-ZOO-CWSSMC181–201, Chinnar, 2 exs, light trap, 26.x.2019; Alampetty, 7 exs, light trap, 26.x.2019; 2 exs, pitfall trap, 26.x.2019; 2 exs, hand picking, 26.x.2019; 1 ex, light trap, 25.ii.2020; 2 exs, pitfall trap, 25.ii.2020; 2 exs, hand picking, 25.ii.2020; Kootar, 2 exs, light trap, 26.x.2019; 1 ex, hand picking, 26.x.2019.

Distribution: ORR - India (Tamil Nadu: Chennai, Nilgiri Hills; Kerala: Nilambur (Andrewes 1935: 277)).

*** 53. *Elaphropus nilgiricus* (Andrewes 1925)**

Elaphropus nilgiricus (Andrewes) Lorenz 2005: 210.

Tachys nilgiricus Andrewes 1925: 446; id. 1930: 334; id. 1935: 265.

= *Tachys nilgiricus* Andrewes 1925

= *Tachys unisculptus* Andrewes 1925

= *Elaphropus unisculptus* (Andrewes 1925)

= *Tachyura nilgirica* (Andrewes 1925)

Specimens examined (n = 2): SJC-ZOO-CWSSMC202–203, Alampetty, 1 ex, light trap, 26.x.2019; 1 ex, light trap, 25.ii.2020.

Distribution: ORR - India (Karnataka: Mysore (Andrewes 1930: 334); Tamil Nadu: Nilgiri Hills (Andrewes 1935: 446)); SRL (Andrewes 1930: 334).

 # 54. *Elaphropus politus* (Motschulsky 1851)

Elaphropus politus (Motschulsky) Lorenz 2005: 210; Kushwaha & Hegde 2015: 395.

Tachys politus Motschulsky 1851: 509; Putzeys 1875b: 743; Bouchard 1903: 170; Andrewes 1919a: 199; id. 1921a: 146; id. 1925: 448; id. 1930: 338; id. 1935: 269.

= *Tachys politus* Motschulsky 1851

= *Tachyura polita* (Motschulsky 1851)

Specimens examined (n = 20): SJC-ZOO-CWSSMC204–223, Chinnar, 2 exs, light trap, 26.x.2019; Alampetty, 5 exs, light trap, 26.x.2019; 2 exs, pitfall trap, 26.x.2019; 3 exs, hand picking, 26.x.2019; 2 exs, light trap, 25.ii.2020; 1 ex, pitfall trap, 25.ii.2020; Kootar, 4 exs, light trap, 25.x.2019; 1 ex, pitfall trap, 25.ii.2020.

Distribution: ORR - India (Uttar Pradesh: Auraiya, Fatehpur, Muradganj, Mathura, Kishori Kunj, Jhansi, Shahjahanpur (Kushwaha & Hegde 2015: 395)); SEA (Andrewes 1935: 448).

DISCUSSION

This is the first report about ground beetles from a natural habitat in the eastern slopes of Western Ghats and it represents the carabid composition in a dry deciduous forest in the southern WGs. Fifty-four species belonging to 11 subfamilies (Harpalinae: 15 species, Lebiinae: 14, Scaritinae: 7, Pterostichinae: 4, Anthiinae: 3, Trechinae: 3, Licininae: 2, Orthogoniinae: 2, Panagaeinae: 2, Brachininae: 1, Dryptinae: 1), and 31 genera were recorded. Harpalinae, Lebiinae, and Scaritinae are the species-rich subfamilies with 15, 14, and seven species respectively, in the study region which is a representative of the dry forest habitat in the rain shadow slopes of the southern WG. Two species—*Stenolophus lucidus* (Harpalinae) and *Amblystomus aenescens* (Harpalinae)—are first records from India (Image 1A,B). Four species, *Stenolophus bajaurae* (Harpalinae), *Amblystomus indicus* (Harpalinae), *Trigonotoma oberthueri* (Pterostichinae), and *Elaphropus politus* (Trechinae) (Image 2I,A,J,E) are first reports from southern India and *Oxylobus asperulus amyntas* (Scaritinae) is the first record of the subspecies from southern India (Image 2G). *Amblystomus indicus* was reported earlier from Sri Lanka and eastern & western India (Bates 1886, 1892; Andrewes 1930) and the record in southern India is significant indicating its continuous distribution in Sri Lanka and southern India. *Trigonotoma oberthueri*, a species with earlier reports only from the PAR in the central and eastern Himalayan region (Andrewes 1930; Löbl & Löbl 2017) is recorded from the Oriental region. Six species (*Macrocheilus chinnarensis* (Anthiinae), *Ophoniscus puneensis* (Harpalinae), *Caelostomus sculptipennis* (Pterostichinae), *Pseudoclivina costata* (Scaritinae), *Elaphropus nigellus* (Trechinae), *E. nilgiricus* (Trechinae) (Image 2F,B,H,C,D) are endemic to the WG and Sri Lanka biodiversity hot spot. *Macrocheilus chinnarensis* is a recently discovered new local endemic species (Akhil et al. 2019). *Ophoniscus puneensis* is recorded for the first time from south WG after its discovery in the northern WG (Kataev 2018). *Pseudoclivina costata* and *Elaphropus nigellus* are endemic to the southern WG (Andrewes 1925, 1929, 1930, 1935) and it is the first record of the species from the eastern slopes of the WG. *Caelostomus sculptipennis* and *Elaphropus nilgiricus* are known only from southern WG and Sri Lanka (Andrewes 1925, 1928, 1930, 1935; Straneo 1938; Divya & Sabu 2020).

Image 1. Habitus of: A—*Amblystomus aenescens* | B—*Stenolophus lucidus*.

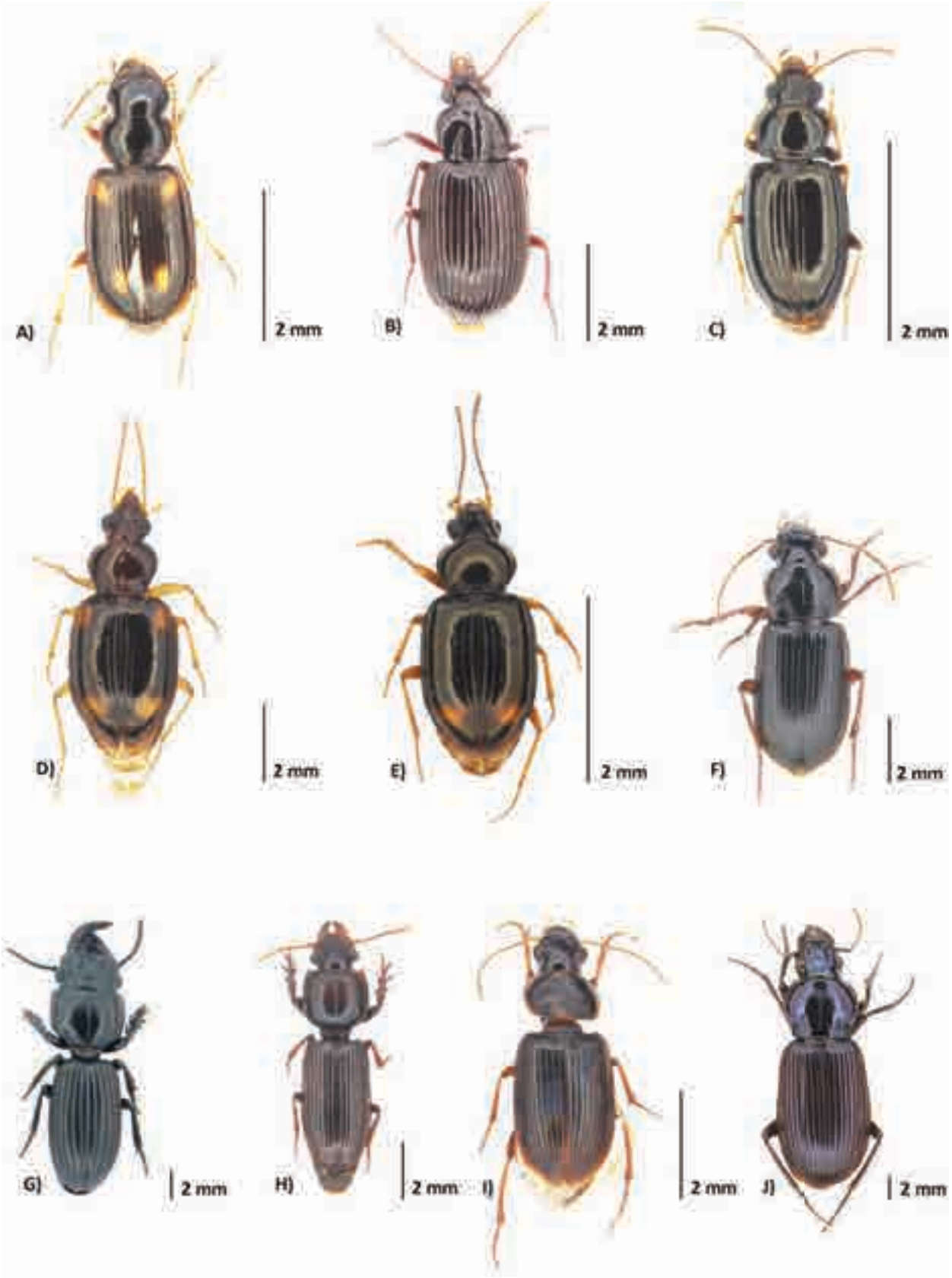

Image 2. Habitus of: A—*Amblystomus indicus* | B—*Caelostomus sculptipennis* | C—*Elaphropus nigellus* | D—*Elaphropus nilgiricus* | E—*Elaphropus politus* | F—*Ophoniscus puneensis* | G—*Oxylobus asperulus amyntas* | H—*Pseudoclivina costata* | I—*Stenolophus bajaurae* | J—*Trigonotoma oberthueri*.

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COMMUNICATION

Zoophily and nectar-robbing by sunbirds in *Gardenia latifolia* Ait. (Rubiaceae)

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Abstract: *Gardenia latifolia* is a semi-deciduous tree species which blooms during the dry season. Its flowers are hermaphroditic, strongly fragrant, nectariferous, and specialized with a narrow corolla tube and concealed deep seated nectar. Thrips act as resident pollinators while bats and carpenter bees act as non-resident pollinators. Sunbirds act as nectar robbers and have no role in pollination. The flowers are milky white and fragrant on days 1 and 2; they cease fragrance and change color to golden yellow on day 3. Bats visit newly open, day 1 fragrant flowers for pollen collection while thrips use day 1 and day 2 flowers. Carpenter bees and sunbirds visit only day 2 flowers. The flower visiting activity of all these foragers indicates that they do not visit non-fragrant, golden yellow colored flowers although they possess nectar. Fruit is an indehiscent berry with seeds placed in pulp inside; the birds are the most likely seed dispersal agents when they break the pericarp and feed on the fruit pulp.

Keywords: Bats, carpenter bees, *Cochlospermum religiosum*, *Croton scabiosus*, evening anthesis, hermaphroditism, *Maerua apetala*, *Mylabris phalerata,* pollination, thrips.

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INTRODUCTION

In Rubiaceae, *Gardenia* is one of the largest genera (Davis et al. 2009) with 142 species of evergreen shrubs and small trees distributed in tropical and subtropical regions of Africa, Asia, Madagascar, Australasia, and Oceania (Puttock 1988). It includes a number of well known widely cultivated horticultural species for their fragrant flowers (Smith 1974). This genus is characterized by hermaphroditic flowers, often large and showy with corolla lobes overlapping to the left, pollen in tetrads, 1-locular ovaries with two to many parietal placentas, and fruits with numerous lenticulate seeds (Rakotonirina et al. 2012). Despite the wide distribution of this genus in tropical belts and the value of its species in horticulture due to their floral fragrance, there are no systematic studies on the reproductive ecology of any species. However, there are sporadic reports on the pollinators of three *Gardenia* species, *G. tubifera, G. jasminoides* and *G. thunbergia*. Freeman et al. (1991) reported that *G. tubifera* is possibly pollinated by moths. Okomoto et al. (2008) reported that *G. jasminoides* is typically a hawk-moth pollinated species in Japan. Johnson et al. (2017) reported that the African shrub, *Gardenia thunbergia* is pollinated exclusively by the convolvulus hawk moth, *Agrius convolvuli*. Reddy et al. (2021) reported that *G. latifolia* commonly known as Indian Boxwood is a small deciduous tree with dense foliage. It occurs in all deciduous forests of India. Its stem, bark and fruit are used in the treatment of skin diseases, stomach pain & snake bite in humans, and ephemeral fever in live stock; its fruit is used for making perfume. Despite its common occurrence and traditional economical values, it has not been investigated for its pollination ecology which is very important to understand its sexual reproduction and its association with local pollinator fauna. With this backdrop, the present study was aimed at carrying out field studies on the pollination ecology of *G. latifolia* Ait. to know whether this species is also pollinated by hawk moths or other flower visiting insects or animals. Further, whether its long tubular hypocrateriform flowers with deeply seated nectar facilitates foraging visits by flower visitors to collect forage illegitimately and if so, what would be the role of illegitimate nectar robbing on plant fitness in dry deciduous ecosystem of Idupulapaya Reserve Forest, Kadapa District, Andhra Pradesh, India.

MATERIALS AND METHODS

Gardenia latifolia Ait. trees at Idupulapaya Reserve Forest representing rocky, rugged terrain with deciduous forest ecosystem (14.33 °N 78.51 °E, 273 m) in Kadapa District, Andhra Pradesh, India, were selected for study during February–May 2021. During this period, the tree species, *Croton scabiosus* Bedd. (Euphorbiaceae), *Cochlospermum religiosum* (L.) Alston (Cochlospermaceae), *Maerua apetala* (Roth) M. Jacobs (Capparaceae) and *Gardenia latifolia* Ait. (Rubiaceae) were found blooming simultaneously. Of these, the first two species bear new foliage during the flowering phase while the third species is completely leafless during the flower phase. In the Indian Boxwood, *G. latifolia*, the flowering phase is initiated at the fag end of leaf fall but peak flowering occurs when complete leaf flushing occurs (Image 1a,b). Further, *C. scabiosus* and *G. latifolia* trees with scattered distribution are present in considerable numbers while the other tree species consisting of a few individuals are present here and there. The floral aspects were carefully observed and recorded for the characteristic traits of *G. latifolia*. Twenty maturing buds were tagged and followed for recording the time of anthesis and anther dehiscence. The same buds were followed at random for the growth and protrusion of style and stigma in relation to the level of dehisced anthers through corolla tube to record whether secondary pollen presentation mechanism is functional or not because this mechanism is the rule in the Rubiaceae family. Further, the important floral traits of the other simultaneously blooming tree species were also noted. Nectar volume of *G. latifolia* was measured using a graduated pipette while its sugar concentration was recorded using a hand sugar refractometer (Erma, Japan); twenty flowers were used for recording these two aspects. For the analysis of sugar types, paper chromatography method described by Harborne (1973) was followed. Nectar was placed on Whatman No. 1 of filter paper along with standard samples of glucose, fructose and sucrose. The paper was run ascendingly for 24 hours with a solvent system of n-butanol-acetone-water (4:5:1), sprayed with aniline oxalate spray reagent and dried at 120 °C in an electric oven for 20 minutes for the development of spots from the nectar and the standard sugars. Then, the sugar types present were recorded.

The flower visitors were observed on five sunny days of the flowering season for their flower approaching, probing and forage collection behaviour. The foraging activity was observed from sunrise to sunset to record the flower-visiting schedules of diurnal foragers and of

bats from 1700 h to 0500 h. The field methods described in Dafni et al. (2005) were followed for the collection of data on foraging visits, foraging schedule, foraging mode and flower handling time. The number of foraging visits made by each diurnal foraging species was recorded for 10 minutes at each hour throughout the day between 0600 h and 1800 h on five different days. Based on these visits, the mean number of total foraging visits made per day was calculated. The foraging mode employed for forage collection was also recorded while the foragers were probing the flowers. The time spent for probing and collecting the floral reward by each forager species was counted in seconds by using a stop watch; the number of observations made were according to the foraging visits made to the flowers during observation period. Based on the data, the mean time for handling flowers to collect the forage by each forager species was calculated to understand the flower to flower mobility rate. Among the flower visitors, sunbirds were found to exhibit nectar robbing behaviour; this behaviour was carefully observed with reference to its role in effecting pollination rate negatively or positively. The flower morphological characters were also noted to evaluate their specialized traits that contribute to the exploitation by nectar robbing sunbirds. Further, the observations on the foraging activity of the forager species visiting *G. latifolia* on other tree species simultaneously blooming in the same area were also made to note whether they were resorting to display illegitimate or legitimate foraging behaviour to collect nectar. Fruit and seed characters were also described.

OBSERVATIONS

Gardenia latifolia is a medium-sized semi-deciduous tree with grey to light brown colored exfoliating bark displaying smooth, concave and rounded depressions. The leaves are oval to obovate, smooth and arranged opposite to each other or in whorls with very short stalks. Flowers are solitary, sessile, 5 cm long, extremely fragrant, hermaphroditic and appear at the end of branches. The calyx is bell-shaped with five valvate lobes apically. The corolla is hypocrateriform with a narrow tube and flaring suddenly into a flat arrangement of five obliquely obovate petals which are abot half as long as the corolla tube. The stamens are five, epipetalous, placed at the throat of the corolla tube; the anthers are dithecous and dehisce by longitudinal slits. The style springs up from the center of the flower, runs parallel to corolla tube and gradually protrudes out of the corolla tube. The stigma is 5-lobed, green, club-shaped, thick and fleshy (Image 1h). Fruit is a 3–5 cm long globose indehiscent berry with crowned calyx lobes and consists

Image 1. *Gardenia latifolia*: a—Trunk | b—Leaf flushing and flowering | c–f—Anthesis stages | g—Anther dehiscence by longitudinal slits in bud stage (stigma below the height of anthers) | h—Pistil | i—Brown marks on the corolla indicating bat visit to the flower | j—3rd day flower. © Prof. A.J. Solomon Raju

Table 1. List of foragers visiting the flowers of *Gardenia latifolia*.

Order	Family	Insect species	Foraging period (h)	No. of foraging visits/day# (N = 5 days)	Mode of foraging	Forage sought	Flower handling time (in seconds)
Hymenoptera	Apidae	*Xylocopa pubescens**	0700–1200 Peak activity: 0900–1200	42 ± 5.3	Legitimate	Pollen	3.2 ± 0.08 (n = 42)
		*Xylocopa latipes**	0700–1200 Peak activity: 0900–1200	39 ± 3.5	Legitimate	Pollen	2.8 ± 0.05 (n = 37)
Thysanoptera	Thripidae	Unidentified	0800–1700	Forages continuously	Legitimate	Pollen + Nectar	--
Passeriformes	Nectariniidae	*Nectarinia asiatica***	0700–1600	53 ± 3.2	Illegitimate	Nectar	2.3 ± 0.8 (n = 31)
		*Nectarinia zeylonica***	0700–1600	41 ± 2.2	Illegitimate	Nectar	2.6 ± 1.4 (n = 36)
Chiroptera	Pteropodidae	*Pteropus medius*	1830–0300	32 ± 3.7 (approx.)	Legitimate	Pollen	1.4 ± 0.8 (n = 27)

#No. of flowers under observation: Approximately 125 each day on a different tree.
*Collecting pollen from *Cochlosperm religiosum* and nectar from *Maerua apetala* legitimately.
**Collecting nectar from *Maerua apetala* legitimately and larvae of an unidentified local butterfly from the leaves of *Croton scabiosus*.

of many rugose seeds enclosed by pulp inside (Image 2h).

G. latifolia mature buds begin to open by 1600 h and are fully open by 1830 h (Image 1c–f). The flowers either stand erect or oriented slightly horizontally. The anthers dehisce about an hour prior to anthesis and each anther produces copious amount of fertile pollen (Image 1g). At anther dehiscence time, the stigma is placed below the height of the anthers but it gradually protrudes out of the corolla tube through the dehisced anthers at anthesis and in this process, the stigma is partially coated with self-pollen facilitating the occurrence of autonomous self-pollination. The stigma attains receptivity about an hour after flower-opening and extends its receptivity until the evening of the next day with peak receptivity from 1930 h to 1100 h on the next day. The corolla is milky white emitting strong sweet fragrance immediately after anthesis but it gradually fades losing fragrance simultaneously by the evening of the next day of anthesis. Then, the corolla appears golden yellow and turns light brown then withers and wilts on the 3rd day. The corolla together with stamens, style and stigma fall off gradually on 4th day while the calyx is persistent and provides protection to the apical part of the ovary with fertilized ovules throughout fruit growth, development, and maturation.

G. latifolia flowers initiate nectar secretion by nectaries at the base of the ovary during bud stage and its secretion ceases by the time of anthesis. Individual flowers produce 3.7 ± 0.76 µl of sucrose-rich nectar with 28.7 ± 2.5% total sugar concentration. The nectar remained in place throughout the flower life if not utilized by flower visitors. Field observations showed that the flower-visitors made visits to day-1 and day-2 flowers only despite the availability of nectar in day-3 and 4 flowers.

Mature buds showed different stages of thrips and moved out during and after anthesis. After anthesis, the thrips that moved out of the corolla visited the flowers of the same branch/tree. These thrips were present only in day-1 and day-2 flowers despite the availability of full load or residual pollen and nectar in day-3 (Image 1j) and day-4 flowers. They collected pollen and nectar and carried pollen on their body as they were found coated all over with pollen; this foraging activity could affect pollination within and between flowers of the same tree but their role as resident foragers in the pollination is yet to be established. The fruit set rate was 21% in manipulated autogamy and 37% in geitonogamy.

G. latifolia flowers were not foraged by hawk moths during night time but were foraged by the Indian Flying Fox, *Pteropus medius* (Image 2a,b) as soon as the flowers were fully open by 1830 h and continued its foraging activity until 0300 h especially during peak flowering season (Table 1). This bat foraged for pollen only as there was no possibility for it to access the nectar which is deeply concealed and protected by a long narrow corolla tube. Since the stigma and dehisced anthers are placed at or slightly above the corolla throat, they easily facilitate the occurrence of pollination while the bat was collecting pollen. The bat always collected pollen from day-1 flowers only. The flowers visited by this bat can be easily identified by the marks of claws left on the corolla; the place of marks oxidize gradually and become prominent as brownish scars by the next morning (Image 1i). On the following day, the carpenter

bees, *Xylocopa pubescens* Spinola and *X. latipes* Drury (Image 2c) foraged for pollen collection from 0700 h to 1200 h with intense activity at 0900-1100 h (Table 1). These bees approached the flowers in upright position and probed from the flower-opening side to collect pollen which is situated at the corolla throat; the pollen collection activity results in the occurrence of pollination due to the placement of both stamens and stigma at the same place at or above the corolla throat. There is no possibility for these bees to collect deeply seated and concealed nectar with their short proboscis/tongue. They never made any attempts to rob nectar illegitimately bypassing the pollination apparatus and also never visited day-3 and day-4 flowers. Further, they never made any attempts to rob nectar illegitimately by making a slit into the corolla tube. The Purple Sunbird, *Nectarinia asiatica* Latham (Image 2d,e) and the Purple-rumped Sunbird *N. zeylonica* L. (Image 2f) foraged for nectar illegitimately from day-2 flowers from 0700 h to 1600 h due to a wide mismatch between the length of their beak and the length of the corolla tube to access nectar location (Table 1). They slit the mid-portion of the corolla tube from outside with their curved beak to access and collect nectar without effecting pollination. This illegitimate foraging behavior employed by sunbirds characterizes primary nectar robbing. These birds never made attempts to rob nectar from day-3 and day-4 flowers. Therefore, the pollination occurs in day-1 flowers by pollen collection activity of bats and in day-2 flowers by pollen collection activity of carpenter bees. Further, the sunbirds rob nectar only from day-2 flowers despite the availability of nectar in day-3 and day-4 flowers indicating that pollination occurs only in white-colored fragrance emitting from day-1 and day-2 flowers. Flower-handling time to collect pollen or nectar by each foraging species is given in Table 1.

G. latifolia flowers attracted a blister beetle, *Mylabris phalerata* Pallas (Coleoptera, Meloidae) (Image 2g). This beetle consumed the corolla, stamens and partially the stigma during the entire flowering season. Several individuals of this beetle were found on each flowering tree; 45% of the sampled flowers on each tree were found either damaged or completely consumed by it. This flower feeding activity by this beetle was found to be negatively affecting the reproductive success of the plant.

In the biotope of the same forest, the tree species, *Croton scabiosus* (Image 3a), *Cochlospermum religiosum* (Image 3c,d), and *Maerua apetala* bloom (Image 3e,f) simultaneously with *G. latifolia*. But, these tree species are not closely spaced and occur scattered at random. Of these, *C. scabiosus* has considerable population while all other trees are represented by a few individuals. Of these, the first species is monoecious while the other tree species are hermaphroditic. Further, *C. religiosum* is nectarless while the other tree species are nectariferous. The carpenter bees used *C. religiosum* flowers as pollen source effecting pollination as in the case of *G. latifolia* while *M. apetala* (Image 3g) was used as nectar source effecting pollination. Since *C. religiosum* is represented by about ten individuals, there was no scope for competition between this tree species and *G. latifolia* for carpenter bees which collected only pollen from these species. Further, these bees used *G. latifolia* as pollen source only and *M. apetala* as nectar source, hence the question of competition between these species for pollination by carpenter bees was ruled out. Sunbirds, *N. asiatica* (Image 3b) and *N. zeylonica* used *C. scabiosus* as a source of insect food in the form of instars of larvae of an unidentified local butterfly; these birds picked up the larval instars from the leaves throughout the day. Further, these sunbirds also used *M. apetala* as nectar source by probing the flowers legitimately and effecting pollination (Image 3h,i).

DISCUSSION

Robbrecht (1988) reported that Rubiaceae members are entomophilous and the pollination mechanism in this family is conspicuously specialized via stylar modifications for passive pollen presentation. Anderson (1973) reported that in hermaphroditic isostylous flowers, protandry is predominant; the pollen matures early and is shed at or soon after anthesis. Before anthesis and in some cases for a period after anthesis, the elongation of the style is arrested, the immature stigmas are temporarily retained within the tube of the corolla, below the level of the anthers. During and/or after the release of the pollen the style elongates, eventually equalling or surpassing the anthers, and the stigmas belatedly mature. In this study, *G. latifolia* is a hermaphroditic isostylous species with weak protandry which occurs shortly before anthesis. The style elongation is not arrested but it continues to grow to surpass the dehisced anthers and matures as soon as anthesis occurs.

Puff et al. (2005) stated that protandry in isostylous flowers of Rubiaceae is associated with secondary pollen presentation. In this family, four types of secondary pollen presentation have been recognized according to the presenting area and receptive surfaces: i. pollen

deposition on the style only. Here, pollen deposition is strictly on non-receptive surfaces. The stigma and its receptive surfaces is higher up; 2. Pollen deposition on the style and outside of the stigma lobes. Pollen is solely deposited on non-receptive surfaces, but the abaxial surfaces of the stigma are also involved; 3. Pollen deposition on the outer side of the stigma; 4. Pollen deposition exclusively, largely or partly on the receptive surface of the stigma. In *G. latifolia*, the fourth type of pollen presentation mechanism is functional with partial pollen deposition on the receptive portion of the stigma. In this species, weak protandry facilitates overlap between the functional male and female stages within and between flowers of the same tree and hence, autonomous autogamy and geitonogamy are unavoidable (Bremer & Eriksson 2009) but the function of these pollination modes are not absolute. The secondary pollen presentation increases the efficiency and accuracy of pollen transfer because of the close proximity of pollen to the stigma (Ladd 1994). However, the proximity of pollen and stigma could also result in self-interference (Webb & Lloyd 1986), which is detrimental to plant fitness (Waites & Agren 2006). In *G. latifolia*, autonomous autogamy and geitonogamy mediated by insects are advantageous since its flowering period falls in summer season when pollinating insects are mostly either unavailable or not reliable due to harsh ambient environmental conditions in the biotope of this species.

Consolaro et al. (2005) reported that species of Rubiaceae generally present a wide range of floral visitors. Puff et al. (2005) reported that Rubiaceae family members present a wide range of flower forms, sizes and colours indicating the involvement of many different pollinators and most of them are almost exclusively zoophilous. Most of these pollinators include insects while birds and bats play a minor role in pollination. Among insects also, bees are important pollinators especially for small-flowered species; the showy large-flowered species are adapted for pollination by butterflies and hawk moths. The butterflies are pollinators for scentless flowers while hawk moths for long-tubed fragrant flowers. Different authors documented that in dry lands of Africa, the Long-proboscid Hawk Moth *Agrius convolvuli* is an extremely abundant species comprising up to 50% of all hawk moths in local assemblages. Several hundred plant species have become adapted for pollination by this moth which is most likely a result of the abundance of its individuals (Martins & Johnson 2013; Johnson & Raguso 2016; Johnson et al. 2017). The biotope of *G. latifolia* is typically deciduous in nature with rocky terrain and a few trees in bloom during the dry season. Despite the availability of fragrant flowers of this species and *Maerua apetala*, diurnal or nocturnal hawk moths never visited the flowers of these two species or any other species in the forest. Surprisingly, the bat, *Pteropus medius* consistently visits *G. latifolia* flowers for pollen collection although they are not appropriate for its visitation; its pollen feeding activity results in the occurrence of both self- and cross-pollination. The bat-visited flowers present brownish scars which can be taken as an indicator of bat foraging activity on this tree species. The *G. latifolia* flowers may produce tannins and the marks left by the visiting bats on corolla and stamens oxidize and appear conspicuous as brownish scars by the next morning. Jaeger (1961) reported that bats collect nectar and pollen from *Adansonia* flowers. He found considerable amount of pollen in the digestive tract of bats. Similarly, the bat visiting the flowers of *G. latifolia* collect pollen as a source of protein which would make an excellent balance in its diet with the sugar and water provided by nectar collected from other floral sources.

In *G. latifolia*, thrips by using the floral buds as breeding site and flowers as pollen and nectar sources as food could effect autogamy and/or geitonogamy but their role in pollination is yet to be studied. The carpenter bees, *Xylocopa pubescens* and *X. latipes* visit the flowers for pollen collection and in this act, they effect both self and cross-pollination but the flower is not appropriate for nectar collection by these bees as the flower is highly specialized with deeply seated nectar and a narrow corolla tube that prevents access to nectar by short-tongued bees such as carpenter bees. These bees also collect pollen from the simultaneously blooming *Cochlospermum religiosum* in the same forest. But, it is not known whether the same individuals of bees collect pollen from different floral sources alternately or exhibit fidelity to a particular floral source. Inouye (1983) reported that among insects, bees, wasps and ants are the most common primary nectar robbers of which bees make up the vast majority, and include carpenter bees, bumble bees, and stingless bees, and some solitary bees. They have some specific morphological structures to make holes on the corolla tube. Gerling et al. (1989) reported that carpenter bees use their maxillae to make slits in the sides of the flowers. Despite the copious amount of nectar produced by the flowers of *G. latifolia*, the carpenter bees never attempted to make a hole or slit in corolla tube tissue to steal nectar bypassing the floral opening used by legitimate pollinators although there is a dire need for nectar during the dry season. But, these bees collect nectar which is easily accessible by

Image 2. *Gardenia latifolia*: a,b—Bat, *Pteropus medius* collecting pollen | c—*Xylocopa latipes* collecting pollen | d–f—Sunbirds robbing nectar by making a slit on the corolla tube from outside | d—*Nectarinia asiatica* (male) | e—*Nectarinia asiatica* (female) | f—*Nectarinia zeylonica* (female) | g—*Mylabris phalerata* feeding on flowers | h—Fruits. © Prof. A.J. Solomon Raju.

Image 3. Co-blooming tree species in the biotope of *Gardenia latifolia*: a—*Croton scabiosus* habit | b—*Croton scabiosus* –Purple Sunbird *Nectariania asiatica* (male) collecting larval instars from the leaves | c,d—*Cochlospermum religiosum* | e–i—*Maerua apetala* | e—Tree habit | f—Flowers | g—Carpenter bee *Xylocopa latipes* collecting pollen | h—*Nectarinia asiatica* collecting nectar | i—*Nectarinia zeylonica* (male) perching. © Prof. A.J. Solomon Raju

legitimate probing from the flowers of *Maerua apetala* which blooms simultaneously in the same forest.

Castellanos et al. (2003, 2004) documented that floral adaptations that promote pollen transport by pollinators are treated as evidence of specialization to a particular pollinator type. Naravvo (2001) reported that specialization in floral architecture is vulnerable to exploitation by flower visitors which remove or steal nectar without effecting pollination. Rojas-Nossa et al. (2016) stated that nectar robbers display a particular behaviour to steal nectar. A common form is primary nectar robbing in which the flower visitor makes a hole,

slit, or tear in corolla tissue to steal nectar bypassing the floral opening used by legitimate pollinators; this form of robbing is most common on flowers with hidden nectar. The flowers with tubular corolla are vulnerable to nectar robbing. Irwin & Maloof (2002) reported that another form of secondary nectar robbing in which the flower visitor acquires nectar through holes made by primary nectar robbers bypassing the floral opening used by legitimate pollinators. Irwin et al. (2010) reported that all flower visitors are not pollinators. Some visitors rob nectar bypassing the contact with the anters and/or stigma and the effects of this nectar robbing behaviour by robbers range from negative to positive on female and male components of plant reproduction. Maloof & Inouye (2000) and Irwin et al. (2010) reported that nectar robbing is very frequent in plant species producing flowers with long corollas and abundant nectar production. In the present study, the sunbirds are just robbers of nectar of *G. latifolia* and this nectar robbing activity reduces nectar reward and increases variability in nectar standing crop. Such a situation is expected to promote pollination rate in general and cross-pollination in particular when legitimate pollinators visit *M. pubescens* flowers for nectar. Since there are no legitimate foragers to collect nectar from *G. latifolia* except the resident foragers, thrips, the nectar in this species remains in place if not utilized by sunbirds by robbing and hence the role of nectar in effecting pollination rate negatively or positively is totally ruled out. The absence of appropriate legitimate nectar seekers, diurnal hawk moths or nocturnal moths during the flowering season of *G. latifolia* could be attributed to unfavorable ambient temperature and unreliability of nectariferous floral resources with suitable nectar chemistry. Nevertheless, the availability of many flowering trees of *G. latifolia* during the dry season in this forest provides the needed levels of nectar for sunbirds that probe the flowers of this species illegitimately by robbing. It is interesting to note that bats use new and fresh flowers as soon as they are available upon anthesis and do not use the same flowers again on the next day or later while thrips use day-2 flowers also for forage collection. Bees and sunbirds use day-2 flowers only. All these foragers simply ignore day-3 and day-4 flowers which are faded by changing corolla color and lacking fragrance despite the availability of nectar in these flowers. This discriminatory behavior displayed by these foragers indicate that they use corolla color and strong fragrance as cues to visit the flowers of *G. latifolia*.

Puff et al. (2005) reported that fruits of Rubiaceae are of capsule type and classified into three types: those that split open at maturity, those that break into one-seeded mericarps and those that remain indehiscent. The species possessing indehiscent fruits are either drupes or berry-like. Ornithochory is the most prevailing mode of seed dispersal. In *G. latifolia,* the fruit is an indehiscent berry with seeds enclosed by pulp inside. But, the pericarp is not very hard to break by birds with their bill, hence, it is most likely that birds are involved in seed dispersal when they feed on the pulp along with small seeds.

CONCLUSIONS

Gardenia latifolia is a semi-deciduous hermaphroditic dry season blooming tree species. The flowers are milky white and strongly fragrant on day 1 and day 2 while they are golden yellow and non-fragrant on days 3 and 4. They produce copious amounts of nectar which is concealed deep inside at the base of the narrow corolla tube. Thrips use the floral buds as breeding sites and flowers as pollen and nectar source. As resident foragers, they use day 1 and day 2 flowers only for forage collection. Bats visit only day 1 flowers for pollen collection while carpenter bees use only day 2 flowers for pollen collection. Like carpenter bees, sunbirds use only day 2 flowers for robbing nectar by proving the flowers illegitimately. The flower visiting activity of all these foragers indicates that they do not visit non-fragrant, golden yellow colored flowers although they possess nectar. Fruit is an indehiscent berry with seeds placed in pulp inside; the birds are the most likely seed dispersal agents when they break the pericarp and feed on the fruit pulp.

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COMMUNICATION

A new population record of the Critically Endangered *Dipterocarpus bourdillonii* Brandis from the Anamalai Tiger Reserve, India

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Abstract: *Dipterocarpus bourdillonii*, a Critically Endangered tree species endemic to the Western Ghats, India, has hitherto been reported mainly from the states of Kerala and Karnataka on the western slopes of the mountain range. In Tamil Nadu, this species has been reported to occur in two locations, but no population details have been documented and the species has neither been listed in state floras nor in a recent compendium of plant species. The present study documents the occurrence of a population of the species, with at least 40 individuals, in the Anamalai Tiger Reserve, Tamil Nadu, extends the known upper limit of its altitudinal range to 733 m, and suggests further surveys and in situ conservation efforts.

Keywords: Anamalai Hills, new distribution records, threatened plants, tropical rainforest, Western Ghats.

சுருக்கக் குறிப்பு: *டிப்டெரோகார்பஸ் போர்டில்லோனி* (கரஞ்சிலி), இந்தியாவின் மேற்குத் தொடர்ச்சி மலைகளில் மட்டுமே காணப்படும் (ஓரிடவாழ்வி), அழிவின் விளிம்பிலுள்ள ஒரு மரமாகும். இது கேரளா, கர்நாடகா மாநிலங்களின் மலைச்சரிவுகளில் (மேற்குத் தொடர்ச்சி மலையின் மேற்குச் சரிவுகளில்) இருப்பதாகத் பதிவுசெய்யப்பட்டுள்ளது. இந்த இனம், தமிழ்நாட்டில் இரண்டு இடங்களில் இருப்பதாகப் பதிவுசெய்யப்பட்டுள்ளது. ஆனால், இவற்றின் எண்ணிக்கை விவரங்கள் எதுவும் பதிவுசெய்யப்படவில்லை. மேலும், மாநிலத் தாவரப் பட்டியலிலோ, சமீபத்தில் வெளியான தாவர இனத் தொகுப்பிலோ பட்டியலிடப்படவில்லை. எங்களது ஆய்வின்படி தமிழ்நாட்டின் ஆனைமலை புலிகள் காப்பகத்தில் குறைந்தபட்சம் 40 மரங்கள் இருப்பதாகக் கண்டறியப்பட்டுள்ளது. இந்த மரங்கள் தரைமட்டத்திலிருந்து மலைப்பகுதியின் 733 மீட்டர் உயரம்வரை இருப்பதாகவும் கண்டறியப்பட்டுள்ளது. இந்த மரங்களை, அதன் பூர்வீக இடத்தில் பாதுகாக்க, ஆய்வுகள், பாதுகாப்பு முயற்சிகளை எடுக்குமாறு பரிந்துரைக்கப்படுகிறது.

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INTRODUCTION

The family Dipterocarpaceae includes a diverse group of tropical trees that form dominant stands with some of the tallest standing tree species in southern and southeastern Asian lowland tropical forests (Appanah & Turnbull 1998; Ashton 2014). About 500 species in 17 genera of Dipterocarpaceae are known around the world (Ashton 2003), of which five genera and 34 species, including 10 species in the type genus *Dipterocarpus*, occur in India (Kundu 2008). Within India, *Dipterocarpus* is distributed largely in lowland tropical forests of the north-east, the Andaman & Nicobar Islands, and the south-west in the Western Ghats (Brandis 1906). The two species endemic to India, *Dipterocarpus indicus* and *D. bourdillonii*, are both restricted to the Western Ghats in southwestern India (Ramesh & Pascal 1997; Sreekumar et al. 2021).

D. bourdillonii has been assessed as a Critically Endangered species by the IUCN Red List, with the global population currently estimated at under 250 mature individuals and the largest known subpopulation having less than 50 mature individuals (Deepu et al. 2021). The species is considered rare and has so far been recorded only in scattered locations in the states of Kerala, Karnataka, and Tamil Nadu, mainly on the western aspect of the Western Ghats mountain range of India (Ramesh & Pascal 1997; Swarupanandan et al. 2013; Sreekumar et al. 2021). It is reported to occur between 175 m and 600 m elevation in valleys along river courses (Jose et al. 2010; Puttaswamy et al. 2010). Within Tamil Nadu, *D. bourdillonii* occurrence has been reported from the Nilgiris and Megamalai hill ranges (Ramesh & Pascal 1997) but nothing is known of its population and associated species in the state. The present paper describes the occurrence of a population of *D. bourdillonii* in the Anamalai Tiger Reserve, in the Tamil Nadu Western Ghats.

METHODS

The field survey was carried out in the Anamalai Tiger Reserve (ATR), Tamil Nadu, India (core zone: 958 km², 10.216^{0}N, 76.816^{0}E – 10.566^{0}N, 77.416^{0}E) and the adjoining Valparai Plateau (220 km², 10.25^{0}N, 76.866^{0}E – 10.366^{0}N, 76.983^{0}E) in the Anamalai Hills. The Valparai Plateau is a landscape dominated by tea and coffee plantations with about 45 embedded rainforest fragments ranging in area from 1 ha to over 300 ha (Muthuramkumar et al. 2006; Mudappa & Raman 2007). As the focus of this study was on threatened and endangered tree species found in the mid-elevation tropical wet evergreen forest (tropical rainforest), the fieldwork was confined to the western parts of the Reserve in Valparai, Manamboli, and Ulandy Ranges that contain most of the remaining rainforests. The natural vegetation type falls mainly within the mid-elevation (700–1,400 m) tropical wet evergreen forest of the *Cullenia exarillata – Mesua ferrea – Palaquium ellipticum* type (Pascal 1988).

Between October 2020 and March 2022, 64 routes (29 sites) of 119.2 km total length were surveyed on foot, spanning an elevation range of 580 m to 2,000 m in the rainforests of the Anamalai Tiger Reserve and rainforest fragments in the Valparai Plateau. After two *D. bourdillonii* trees were first observed along one of the survey routes (11 km, walked on 30 January 2021) passing through the Ayyankulam area (Figure 1), the same area was subsequently explored covering 0.81 km and 2.63 km (in March–April 2021) and in four trails covering 3.31 km, 3.89 km, 3.0 km, and 4.1 km (in March 2022) recording additional individuals. The total length of 28.74 km of trails were tracked using a hand-held GPS (Garmin GPSMAP 64sc) and a checklist of all tree species encountered along the trail (10 m on either side) was recorded. Plant species were identified using available floras and field guides (Gamble & Fischer 1935; Pascal & Ramesh 1997; Page 2017) and based on the prior experience of the authors with floristic and ecological research in the region (Muthuramkumar et al. 2006; Page et al. 2010; Osuri et al. 2017, 2019; Page & Shanker 2018, 2020). Species names were updated with reference to Plants of the World Online, http://www.plantsoftheworldonline.org/ (POWO 2022).

At each of the 40 *D. bourdillonii* trees found during the survey, the following data centred on the tree were recorded: GPS coordinates and elevation (using GPS unit), girth at breast height (GBH, at 1.3 m, or higher in case of presence of buttresses), and tree height in metres measured with a rangefinder. For measurement of additional variables, a subset of 23 *D. bourdillonii* trees was chosen after excluding individuals that were less than about 30 m from previously-measured conspecifics (to ensure independence of samples). For these 23 trees, the following additional variables were measured keeping the focal tree as the centre: slope (flat, gentle, moderate, steep), canopy height (average height of trees in the immediate vicinity of focal tree measured with a rangefinder in metres), and canopy cover (0%, 1–25%, 26–50%, 51–75%, 76–100%). The number of *D. bourdillonii* seedlings (GBH <10 cm) and

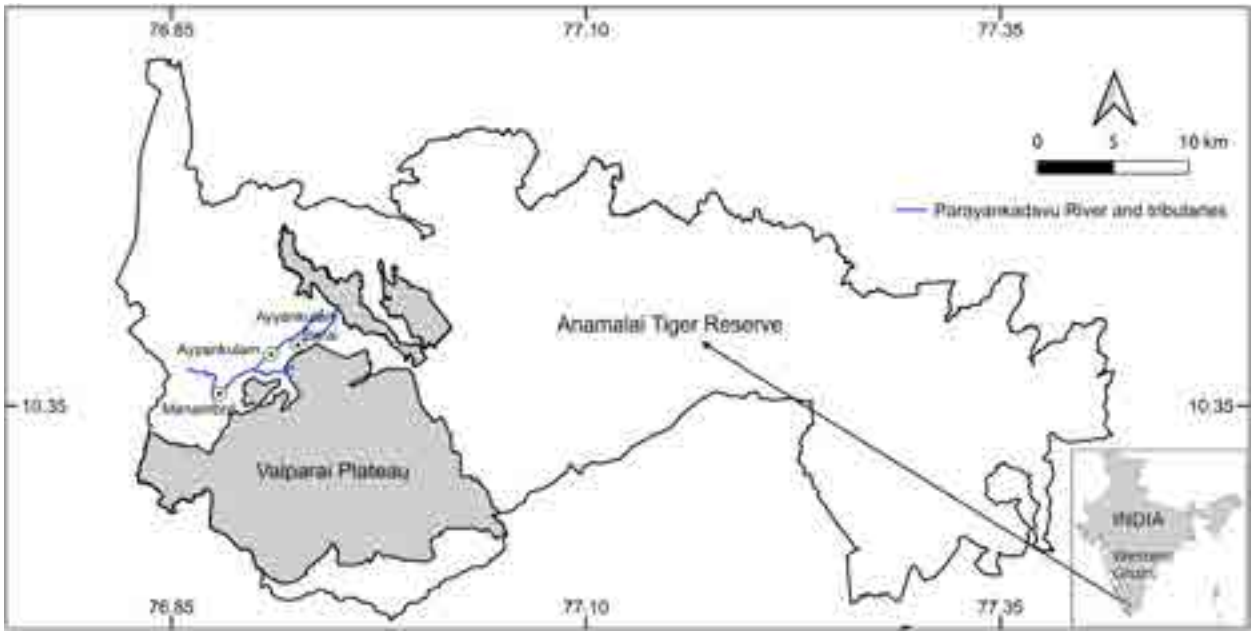

Figure 1. Map of Anamalai Tiger Reserve showing the main locations along the Parayankadavu River where *Dipterocarpus bourdillonii* was recorded.

saplings (GBH 10–30 cm) in a 5 m radius around each focal tree were also recorded. Observations on canopy shape, buttresses, and phenophase (leafing, flowering, fruiting) were noted. To record nearby tree species, point-centred quarter (PCQ) plots were placed keeping focal trees at the centre and the nearest individual tree >30 cm GBH in each of the four quarters was recorded, noting the species and GBH. As these were trees in the immediate vicinity of the focal trees, the frequency of different species was considered as indicative of species association with *D. bourdillonii*. Together, the survey trails enabled rapid coverage across wider areas to document species occurrence, while the PCQs around focal trees helped document tree species associated with *D. bourdillonii*.

Herbarium specimens were examined at the Madras Herbarium (MH), Botanical Survey of India, at Coimbatore, the Herbarium at the French Institute in Pondicherry (HIFP), the Herbarium of the Kerala Forest Research Institute (Sreekumar et al. 2021), Peechi (KFRI), and at the Forest Research Institute, Dehradun (DD). No specimens were available at the herbaria of the Botanical Survey of India in Pune (BSI). From select trees observed during this study, leaves, flowers, and maturing fruit were collected and photographed. These were subsequently used for preparing herbarium specimens and deposited into Herbarium JCB (Accession No.: JCB-1337) at the Centre for Ecological Sciences, Indian Institute of Science, Bengaluru. A sample of 11 maturing fruits, fallen on the ground in the vicinity of the trees, were individually measured for weight using a digital Ohaus scale, and nut length (along main longitudinal axis) and width (along two axes perpendicular to the longitudinal and to each other) were measured using Vernier calipers. The length and width of the two wings (enlarged sepals) of each of the fruits were also measured using Vernier calipers (except in the case of 1 fruit where 1 wing was broken, for which only width was measured and not the length). Data from the study are available on Zenodo (Page et al. 2022).

RESULTS

Tropical wet evergreen forest areas between 580 m and 700 m elevation were present only along six survey routes within the Manamboli Range in ATR. These routes were in the Ayyankulam-Manamboli area located along the Parayankadavu Ār (Ār = river) that flows into the Parambikulam Reservoir in neighbouring Kerala State (Figure 1). In 2021, 20 *Dipterocarpus bourdillonii* trees were recorded along three trails passing through two main locations along the Parayankadavu Ār within ATR: 13 trees at Ayyankulam (10.381^{0}N, 76.910^{0}E) and 7 trees at Ayyankulam Parai (10.386^{0}N, 76.926^{0}E), the latter about 2.4 km (1.8 km straight line distance) upstream from the former location. In March 2022, another 20 trees were recorded, including two trees at Ayyankulam

Parai and 18 along three of the four additional trails surveyed along the same river: Ayyankulam Parai to Ayyankulam (left bank 9; right bank 8), and Manamboli Powerhouse to Ayyankulam (left bank 1; right bank 0). *D. bourdillonii* was not recorded in any of the other 59 trails surveyed in Anamalai Tiger Reserve and Valparai Plateau.

The 40 *D. bourdillonii* trees were located at elevations between 627 m and 733 m and from the edge of the river to less than 100 m away from the river banks. Two tall trees of the species, when first noted on 30 January 2021 along the river banks at Ayyankulam, were flowering (Image 1). On two subsequent visits to the area, on 26 March 2021 (Ayyankulam) and 10 April 2021 (Ayyankulam Parai), fruiting trees were observed with different stages of fruit developments, a sample of which were measured (Table 1) and photographed (Image 2). In March 2022, subsequently, flowering trees and trees with immature fruits were also observed.

The 40 *D. bourdillonii* trees recorded averaged 375.4 cm in girth at breast height (range 90–622 cm) and 40.0 m in height (range 12–51.3 m, Table 1). In the PCQ plots centred on 23 individual *D. bourdillonii* trees, a total of 37 tree species (92 individual trees >30 cm GBH) were recorded, with the most frequently associated species being *Paracroton pendulus* (13 individuals), *Monoon fragrans* (8), *Cullenia exarillata* (8), and *Reinwardtiodendron anamalaiense* (5). In the vicinity of these *D. bourdillonii* trees, the average density of conspecific seedlings was higher than that of saplings, which were in turn higher than the density of *D. bourdillonii* trees (Table 1). Twelve (52%) of 23 trees were noted to be emergent and the remainder were canopy trees. Canopy shape was oval in 19/23 trees (remainder had spreading canopies) and most (20/23) were located at spots with 75–100% canopy cover (2 trees in spots with 51–75% canopy cover, 1 at <25% cover). While four trees were on flat terrain, the remainder were on gentle (7), moderate (6), or steep (6) slopes. Nine trees had buttresses.

Taxonomy

Dipterocarpus bourdillonii Brandis in Hook., Ic. Pl. t. 25. 1895; Gamble, Fl. Madras 81(58). 1915; K.P. Janardh. in B.D. Sharma & Sanjappa, Fl. India 3: 210. 1993; Subram., Fl. Thenmala Div. 27. 1995; Sasidh., Fl. Periyar Tiger Reserve 27. 1998; Anil Kumar et al., Fl. Pathanamthitta 74. 2005; K.P. Janardh. & W. Arisdason in P. Daniel, Fl. Kerala 1: 360. 2005.

Lofty, evergreen trees, up to 51 m tall. Young parts covered with tawny stellate pubescence; leaf buds obtuse, setose or woolly. Stipules large, amplexicaul, leaving an annular scar. Leaves simple, alternate; petiole 4–5.5 cm long, swollen at the apex, tomentose; lamina

Table 1. *Dipterocarpus bourdillonii* focal tree characteristics: number of conspecific seedlings, saplings, and trees, and fruit and seed measurements in the Anamalai Tiger Reserve, Tamil Nadu. N = number of trees (tree measurements) and number of fruits (fruit measurements).

Variable	Mean	Standard error	Minimum	Maximum	N
Tree measurements					
Girth at breast height (cm)	375.4	22.2	90	622	40
Tree height (m)	40.0	1.3	12	51.3	39†
Canopy height (m)	40.0	1.0	30	48.8	23#
Seedlings (number/78.5 m²)	0.9	0.3	0	6	23#
Saplings (number/78.5 m²)	0.2	0.1	0	2	23#
Trees (number/78.5 m²)	0.1	0.1	0	1	23#
Fruit measurements					
Mass of maturing fruit (g)	1.31	0.11	0.75	1.80	11
Nut length (cm)	2.20	0.03	2.10	2.40	11
Nut width 1 (cm)	1.28	0.02	1.15	1.40	11
Nut width 2 (cm)	1.20	0.03	1.10	1.40	11
Longer wing length (cm)	9.56	0.30	8	11	10
Longer wing width (cm)	1.84	0.10	1.3	2.3	11
Shorter wing length (cm)	9.18	0.26	7.8	10.5	10
Shorter wing width (cm)	1.79	0.12	1	2.3	11

†—missing data from 1 tree | #—focal trees >30 m from conspecifics.

Image 1. *Dipterocarpus bourdillonii* tree and leaves: a—view of emergent tree | b—abaxial surface of leaf | c—adaxial surface of leaf | d—view of basal portion of trunk | e—flowering branchlets. © NCF, CC-BY 4.0

ovate or obovate, 18–45 x 12–25 cm, coriaceous, abaxially stellate hairy, adaxially sparsely silky-villous, lateral vein 13–23 pairs, parallel, conspicuously raised abaxially, base rounded, subcordate or cuneate, margins undulate, ciliate, gradually or abruptly acuminate at apex. Flowers bisexual, in axillary racemes, 10 cm long, and 3-5 flowered. Calyx segments 5, 2 rather long and linear, 3 shorter and triangular. Petals pinkish and white, elliptic oblong, 3.5 cm long, densely pubescent outside, margin slightly upcurved, obtuse at apex. Stamens (27–)30; anthers linear to lanceolate, ca. 0.9 cm long, sagittate at base, coherent; connective appendages as long as anthers; filaments filiform, dilated at base. Ovary narrowly ovoid, sericeous, 3-loculed, with 2 ovules per locule; style finely terete, with long silky hairs on lower half. Nut ca. 2 cm in diam., ellipsoid, crowned by thickened, accrescent calyx lobes; calyx tube to 3.5 cm in diam., 5 winged; wing-like calyx segments 2, pinkish-red, linear-lanceolate, to 14 × 3 cm, leathery, 3-veined, rounded at apex (Table 1).

Flowering: January to March; fruiting: March–June.

Herbarium specimens examined: India, Tamil Nadu, Coimbatore District, Anamalai Tiger Reserve, Ayyankulam (10.380^{0}N & 76.909^{0}E, 628 m), 30 January 2021, coll. Srinivasan Kasinathan, Kshama Bhat, G. Moorthi, T. Sundarraj, T. R. Shankar Raman, and Navendu Page s.n. (Accession No.: JCB-1337).

Additional specimens examined: India, Kerala, Travancore, 1894, Brandis 2403 (K!); undated, 534 (MH!); Kollam District: Achankovil, 22 September 1977, N. Sasidharan 108 (KFRI!); 109 (KFRI!); Palakkad District, 550 m, 22 January 1980, P. Bhargavan 65660 (MH!); 350 m, 4 April 1983, P. Bhargavan 78309 (MH!); Ernakulam District: Anakulam, 14 March 1986, K.K.N. Nair 8079 (KFRI!); 7704 (KFRI!); Malayattoor, February 1936, Forest Ranger 160 (FRI!, 9x); March 1936, Forest Ranger 767 (FRI!, 2x), May 1937, Forest Ranger 74608 (FRI!), 10 February 1898, T.F. Bourdillon 918 (FRI!); Tamil Nadu, Nilgiris District, 11 February 1984, B.R. Ramesh 5521 (HIFP!).

The present study extends the known distribution of the Critically Endangered endemic *Dipterocarpus bourdillonii* to the Anamalai Tiger Reserve in Tamil Nadu. It also extends the known upper limit of the altitudinal range of the species to at least 733 m, higher than the range of 200–400 m reported from Kerala (Swarupanandan et al. 2013), and 176–271 m reported from Kodagu in Karnataka (Puttaswamy et al. 2010). The two MH herbarium specimens examined were from trees located at 350 m and 550 m elevation, while the BIOTIK website (Ramesh et al. 2010) reports the species may occur in low elevation wet evergreen forests up to 600 m (BIOTIK 2021). While *D. bourdillonii* has not been listed as occurring in Tamil Nadu in state floras (Gamble & Fischer 1935; Nair & Henry 1983; Matthew 1999; Narasimhan & Irwin 2021), there are two earlier reports from Tamil Nadu, from Nadugani Ghat area in western Nilgiris District (Ramesh & Pascal 1997) and a possible record in Megamalai Wildlife Sanctuary (V. Ravichandran, pers. comm. July 2022), but no additional details are available. Although the Ayyankulam area within the Anamalai Tiger Reserve falls within the zone of very high to excellent in terms of habitat suitability for *D. bourdillonii* as identified by species distribution modeling in an earlier study (Swarupanandan et al. 2013), the present report is the first to confirm the occurrence of *D. bourdillonii* in this area and is a new population record for the state.

DISCUSSION

The present report is also significant as it confirms the presence of a significant population (at least 40 mature trees) of *D. bourdillonii* in the Anamalai Hills. As in earlier studies, *D. bourdillonii* trees were confined to areas close to rivers on relatively flat to moderate slope. The trees were located mainly along the river between Ayyankulam and Ayyankulam Parai, both within the core area of the Anamalai Tiger Reserve, but the occurrence of one individual further downstream along the Parayankadavu Ār indicates there may be more individuals in the intervening area. Given that the species has an estimated global population of under 250 mature individuals, with less than 50 mature individuals in the largest known sub-population (Deepu et al. 2021), the Anamalai Hills population of least 40 mature individuals gains significance as an important site for in situ conservation of this Critically Endangered species.

Most (37) of the 40 trees observed were of large girth (>200 cm) and only few seedlings and saplings were recorded in their vicinity. The species has been reported to have intrinsically poor reproduction besides probably being affected by past selective logging (Swarupanandan et al. 2013). Future studies on population structure and regeneration of *D. bourdillonii* are required to assess the regeneration status in the study area.

In other parts of its distributional range, *D. bourdillonii* is reported to occur with species such as *Vateria indica*, *Turpinia malabarica*, *Dipterocarpus indicus*, *Humboldtia brunonis*, and *Nothopegia beddomei* (Pascal 1988; Puttaswamy et al. 2010; Swarupanandan et al. 2013). In

Image 2. *Dipterocarpus bourdillonii* flowers, fruits, and seedling: a–b—fresh fallen flowers | c—view of flower with sepal and petal partially removed | d—maturing fruits | e—seedlings showing tawny stellate pubescence on young parts. © NCF, CC-BY 4.0

the Anamalais, while *Paracroton pendulus* and *Monoon fragrans* were most frequent near *D. bourdillonii* trees, other lower elevation rainforest species such as *Vateria indica* and *Reinwardtiodendron anamalaiense* were also recorded in plots, besides species such as *Strombosia ceylanica* and *Anacolosa densiflora* in the Ayyankulam area. The expected natural vegetation types for this region include lower elevation (<700 m) tropical wet evergreen forest of the *Dipterocarpus indicus – Dipterocarpus bourdillonii – Strombosia ceylanica* type and medium elevation (700–1,400 m) tropical wet evergreen forest of the *Cullenia exarillata – Mesua ferrea – Palaquium ellipticum* type (Pascal 1988). While *Dipterocarpus indicus* was not recorded in the Ayyankulam Area during the present survey, it is the fifth most common tree species in the Varagaliar area (c. 6 km straight line distance) within ATR (Ayyappan & Parthasarathy 1999) and was also recorded there during the present survey.

The newly-discovered Anamalai population also showed some morphological peculiarities. The shape of the leaf apex of *D. bourdillonii* is described in the literature as shortly acuminate (Brandis 1906). On mature individuals in the Anamalai Hills, the leaves, particularly those at the top of the canopy exhibited an abruptly acuminate leaf apex, which may represent minor intra-specific variation.

Future surveys for *D. bourdillonii* should cover a wider altitudinal range (0–800 m) in evergreen forest areas along rivers. As the species can be clearly identified from flowers and fruits, carrying out surveys between January and April during the flowering and fruiting season is suggested. The existing population in the Ayyankulam area should continue to be protected, and in situ conservation efforts should focus on areas within the known ranges of this Critically Endangered species.

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COMMUNICATION

Checklist of the orchids of Nokrek Biosphere Reserve, Meghalaya, India

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Abstract: A study on the diversity and distribution of different orchid species in Nokrek Biosphere Reserve (NBR) was carried out from 2009 to 2015 with an objective to assess the threatened plants present in protected areas. A total of 127 species of orchids belonging to 56 genera were identified from NBR; out of which 94 are epiphytes or lithophytes, 32 are terrestrial, and one species is mycoheterotrophic. *Dendrobium* (21 spp.) is the most dominant genus in terms of the species composition, followed by *Bulbophyllum* (8 spp.), *Coelogyne* (8 spp.), *Liparis* (7 spp.), *Cymbidium* (5 spp.), and *Pinalia* (4 spp.). Other dominant genera include *Aerides*, *Agrostophyllum*, *Cleisostoma*, *Habenaria*, *Micropera*, *Paphiopedilum*, and *Pholidota* which were represented by three species each. A total of 10 genera were recorded that were represented by two species include *Acampe*, *Cryptochilus*, *Dendrolirium*, *Gastrochilus*, *Oberonia*, *Peristylus*, *Phalaenopsis*, *Pleione*, *Spathoglottis*, and *Vanda*. Of the recorded species from NBR, the *Gastrochilus calceolaris* is assessed by the IUCN Red List as 'Critically Endangered', *Paphiopedilum insigne* and *P. venustum* are 'Endangered', *P. Hirsutissimum* as 'Vulnerable', and *Dendrobium aphyllum* as 'Least Concern'. It has been observed that at the higher elevations, subtropical and temperate forests provide a conducive environment for the orchids to occupy a pristine ecosystem because the temperature and maximum humidity recorded in those areas is lower in comparison to lower regions. This research finding recommends the designation of Nokrek hill as a permanent orchid sanctuary for germplasm collection and conservation, as it could better guarantee the survival of threatened plants and reduce human interventions in the forested zone.

Keywords: Composition, conservation, diversity, Himalaya, Nokrek hill, Orchidaceae, threatened plants.

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Author contributions: Bikarma Singh carried out the fieldwork, identified species and wrote the manuscript. He also reviewed, analyzed, and gave critical comments for improving the quality of the manuscript. Sneha assisted with collection, species identification and proof correction.

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INTRODUCTION

Nokrek Biosphere Reserve (NBR) popularly called 'the Achik land' in the Garo language, located between 25.25–48°N and 90.22–90.50°E, was established on 13 September 1988 in the Garo district of Meghalaya State (Singh & Borthakur 2015). It occupies a geographic area of 820 km² in the state with 47.48 km² designated as Nokrek National Park. UNESCO added this biosphere reserve to its list in 2009 under Man & Biosphere (MAB) program, as it consists of three mountains, viz., Tura range, Arbella range, and Ranggira range (Singh 2015a,b). The well-recognized mountain peaks located in NBR includes Nokrek peak (1,412 m), followed by Arbella peak (999 m), Tura peak (872 m), and Ranggira peak (673 m); other important peaks are Meminram hill, Nengminjok hill, and Chitmomg hill (Singh et al. 2018). These mountainous belts are mainly composed of hilly granitic mass and compact block of hilly ranges having deep slopes and valleys with most of the ranges being more than 500 m. These mountain peaks are considered as an important source of several rivers and streams. The region is categorized as having a monsoon climate with temperature ranging 9.5–37.3°C. The climate as a whole is controlled by the south-west monsoon and seasonal winds; south-west and north-east monsoons are responsible for rainfall to the area ranging 3,900–6,800 mm/year (Singh et al. 2012a,b,c). It has been observed that the great heterogeniety in the ecologically rich ecosystem and the high range of altitudinal variations in the study area are responsible for the luxuriant, rich, and diverse vegetation of NBR (Singh 2015). Olson et al. (2001) categorized these mountain belts under the Indo-Malayan eco-region with the major vegetation types as the mixed tropical forests and subtropical forests (200–1,400 m), and small patches of temperate forests (above 1,400 m) at the higher mountains.

The Nokrek flora is the remnant of Indo-Malayan forests (Image 1), and the dense forests of these mountains provide a home to many narrowly endemic unique species of phytogeographical significance (Singh et al. 2011). The vegetation in many areas of the forests of Nokrek and adjoining areas has declined and plants are becoming threatened due to biotic pressure (Image 2). For instance, wild *Citrus indica* L., insectivorous plant *Nepenthes khasiana* Hook.f., the slipper orchids *Paphiopedilum* Pfitzer spp., Blue Vanda *Vanda coerulea* Griff. ex Lindl., which used to be common in Nokrek and Khasi mountains, are becoming rare and threatened due to illicit collection and destruction of virgin forests (Image 3). Considering the immense need for conservation of these unique species, the area needs research and protection from human interference.

Plant species diversity contributes to ecosystem health, and each species is like a thread holding together an ecosystem (Mir et al. 2022). Therefore, if a species disappears, an entire ecosystem can start to unravel. The rapid loss in orchid diversity and the changing pattern of forest compositions due to various biotic and abiotic factors in Meghalaya have necessitated the qualitative and quantitative assessment of vegetation. However, numbers of floristic studies on community dynamics and phytogeographic affinities have been conducted qualitatively as well as quantitatively in northeastern India (Singh 2015a); there are a few studies incorporating orchid diversity (Singh & Borthakur 2015). However, no studies are available that give a detailed account of orchid diversity of Nokrek as NBR is less explored from the floristic point of view. Therefore, this work (i) emphasizes the need to study and explore the diversity of orchid species in NBR, (ii) collect samples and identify the tree species where orchid plants grow, and (iii) identify the localities rich in orchid diversity for conservation and management for local use.

MATERIALS AND METHODS

Field Survey, Orchid Collection, and Identification

Eleven field surveys were carried out from 2009 to 2015 along 57 forest trails of NBR, including buffer and core zones. Nokrek peak, Tura peak, Ranggira peak, Daribokgre, Neingmandalgre, Rongrengre, Chokpot, and other similar adjoining areas were selected as prioritized areas for frequent field surveys and exploration of plant diversity. The living samples were collected for those non-flowering samples and as herbarium vouchers for both non-flowering and flowering samples. During the period of study, the live orchids collected were introduced in the greenhouse and orchidarium in the Botanical Survey of India (BSI) in Shillong for ex situ conservation and identification once they bore flowers. Flowering materials were then preserved as herbarium vouchers. All visible morphological characters were studies in the field and at the laboratory of ASSAM herbarium in BSI and Department of Botany, University of Gauhati, Assam. The collections were processed according to the standard herbarium specimen preparation techniques with slight modification as mentioned by Jain & Rao (1977) and Bridson & Forman (1989). Specimens were identified using the diagnostic characters described and the identification keys mentioned by Hooker (1895), Duthie (1906), Holtum

(1957), Seidenfaden & Arora (1982), Kataki et al. (1984), Kataki (1986), Deva & Naithani (1986), Chowdhery (1998), Bose et al. (1999), and Singh (2015). Comparative studies of collected vouchers were undertaken with housed orchid specimens at ASSAM herbarium in BSI, Shillong. Indian specimens deposited in herbaria abroad were also studied online including the Royal Botanic Gardens Kew Herbarium (K) for further verification. Scientific names adopted here are those accepted by the latest ICN nomenclature mentioned in 'The Plant List', 'Kew World Checklist of Selected Plant Families', and 'Plants of the World Online' accessed via the websites (available at http://www.theplantlist.org/; https://wcsp.science.kew.org; http://www.plantsoftheworldonline.org/). All studied herbarium vouchers were deposited in the herbarium of the Botanical Survey of India, Regional Centre, Shillong (acronym ASSAM), and at the herbarium of Gauhati University (HGU), Guwahati.

Presentation of the List of Orchids

All orchid species of the NBR are alphabetically presented genus-wise. The technical dichotomous key is prepared for all genera and species, and presented for easy identification of each species that belongs to a particular genus. The habit of each plant species was categorized as either epiphyte, terrestrial, or parasitic, followed by flower characters and colour, distribution range in Nokrek, and reported distribution in literature.

RESULTS AND DISCUSSION

Forest Characterization

Based on the plant species composition and consulting authentic published works (Champion & Seth 1968; FSI 2013; Singh et al. 2018), the forests of NBR were broadly grouped into four types, viz.: tropical forests, subtropical forests, riverine forests, and secondary forests. The tropical forests are important from the economic point of view as they are sources of medicine, timber, fodder, fuel, and provide shelter to the Achik tribe. Common tree species are *Artocarpus chama* Buch.-Ham., *Careya arborea* Roxb., *Dillenia indica* L., species of *Ficus* Tourn. ex L., *Garcinia* L., *Sterculia* L., *Syzygium* Gaertn., *Bombax ceiba* Burm.f., *Macaranga denticulata* (Blume) Mull.Arg., *Rhus chinensis* Mill., and many others. The subtropical forests are mostly confined to the Nokrek National Park so-called core zone, and the common tree species recorded while surveying and collecting orchids are species of *Terminalia* L., *Castanopsis* (D.Don) Spach, *Litsea* Lam., *Michelia* Kuntze, *Eurya acuminata* DC., *Trema orientale* (L.) Blume, *Croton joufra* Roxb., *Sterculia lanceoifolia* Roxb., *Pandanus odoratissimus* Jacq., and several other species. Riverine forests are found along the river Simsang, Didari, and Chibima, and major tree species are *Aglaia elaeagnoidea* (A.Juss.) Benth., *Saraca asoca* (Roxb.) W.J.de Wilde, *Saurauia armata* Kurz, *Ayenia grandifolia* (DC.) Christenh. & Byng (=*Byttneria grandifolia* DC.), *Zanthoxylum rhetsa* (Roxb.) DC., *Balakata baccata* (Roxb.) Esser (= *Sapium baccatum* Roxb.), *Parkia timoriana* (DC.) Merr., and several others. Jhum cultivation is the major practice. Secondary forests are formed due to cutting of virgin forests (Image 4). Common species recorded are *Macaranga denticulata* (Blume) Mull. Arg., *Eurya acuminate* DC., *Mikania micrantha* Kunth, *Callicarpa arborea* Roxb., *Mallotus roxburghianus* Mull.-Arg., *Ziziphus oenopolia* (L.) Mill., and several others. Different species of bamboo, banana, and cane are also a peculiar vegetation composition of Nokrek hills.

Orchid Composition and Analysis

A total of 127 orchids belongs to 56 genera were studied, of which 94 species were epiphytes or lithophytes, 32 terrestrial and one species mycoheterotrophic. Out of 56 genera, 33 are monotypic, *viz*., *Acanthophippium*, *Anoectochilus*, *Arundina*, *Brachycorythis*, *Calanthe*, *Ceratostylis*, *Cheirostylis*, *Corybas*, *Corymborkis*, *Crepidium*, *Cylindrolobus*, *Dienia*, *Diplomeris*, *Eria, Eriodes*, *Eulophia*, *Geodorum*, *Goodyera*, *Herminium*, *Herpysma*, *Luisia*, *Mycaranthes*, *Neogyna*, *Odontochilus*, *Otochilus*, *Papilionanthe*, *Porpax, Pteroceras*, *Rhynchostylis*, *Satyrium*, *Schoenorchis*, *Thelasis*, and *Thunia*. *Dendrobium* with 20 species is the dominant genus in terms of species composition, followed by *Bulbophyllum* (8 spp.), *Coelogyne* (8 spp.), *Liparis* (7 spp.), *Cymbidium* (5 spp.) and *Pinalia* (4 spp.). Other genera such as *Aerides*, *Agrostophyllum*, *Cleisostoma*, *Dendrolirium*, *Habenaria*, *Micropera, Paphiopedilum*, and *Pholidota* were represented by three species. A total of 10 genera recorded from Nokrek were represented by two species, which includes *Acampe*, *Cryptochilus*, *Gastrochilus*, *Oberonia*, *Peristylis*, *Phalaenopsis*, *Pleione*, *Spathoglottis* and *Vanda* (Figure 1).

First time inventorizations of orchids were undertaken from NBR and 32 plant species were recorded as new for Garo districts or western parts of Meghalaya mountains, and two new national records for India. It has been observed that the higher elevation in subtropical and temperate forests are condusive environment for the orchids to live because the temperature and higher humidity recorded in those areas are lower in comparison

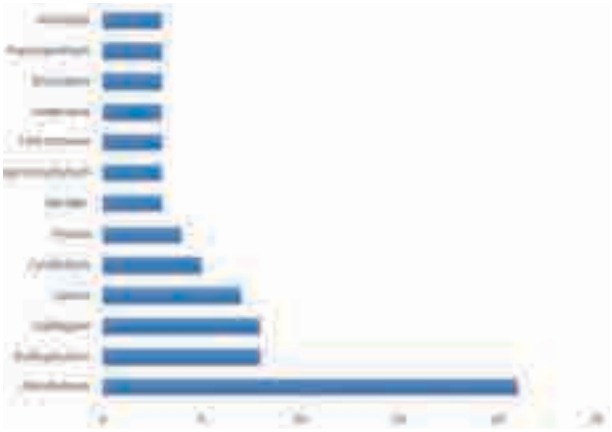

Figure 1. Generic diversity in Nokrek Biosphere Reserve.

to lower regions. During the study, the maximum orchid species collected were epiphytic or lithophytic and some terrestrials. The suitable climate coupled with soil as limiting factors allows the maximum orchid growth on trunks or hills layered with humus. From the ecological point of view, the species abundance was observed to be low and this is probably because the majority of plants were recorded as individual or minute in their natural growth.

MORPHOLOGY, ECOLOGY, AND DISTRIBUTION

1. *Acampe* Lindl.

The genus comprised of seven species distributed in southeastern Asia, tropical & subtropical Africa, Madagascar, and Islands of West Indian Ocean (http://www.plantsoftheworldonline.org/; Bose et al. 1999); six species in India (Gogoi et al. 2009); three species in Meghalaya (Kataki 1986), and two species in NBR.

Key to species

1a. Inflorescence panicled, equal to or longer than leaves; column with two short distinct horns ..... 1. *A. ochracea*

1b. Inflorescence sub-umbellate, much shorter than leaves; column without horns ... 2. *A. praemorsa*

1.1. ***Acampe ochracea* (Lindl.) Hochr. in Bull. New York Bot. Gard. 6: 270. 1910**. *Saccolabium ochraceum* Lindl. in Edwards's Bot. Reg. 28(Misc.): 2. 1842.

Note: Epiphytic plant of flower pale lemon yellow with irregular brown markings, on trunks of *Quercus griffithii* and *Catanopsis indica* in the tropical and subtropical forests of NBR with elevation range of 500–1,400 m. Flowering was recorded in mid-November to late December. The plant is rare and threatened due to the human ornamental needs in the study area. This species has a wide distribution in Bhutan, Cambodia, China, India (Assam, Arunachal Pradesh, Meghalaya, Sikkim), Laos, Nepal, Thailand, Myanmar, Laos, Sri Lanka, and Vietnam.

Specimen studied: Nokrek Peak (1,123 m), VNS & BS 116699 (ASSAM).

1.2. ***Acampe praemorsa* (Roxb.) Blatt. & McCann in J.B.N.H.S. 35: 495. 1932**. *Epidendrum praemorsum* Roxb. in Pl. Coromandel 1: 34. 1795.

Note: Epiphytic plant of flower yellow blotched with brown, on tree trunks of *Catanopsis indica* in the tropical and subtropical forests of Nokrek at 450–1,200 m. The flowering of this species recorded in October. Although this plant species is common in Meghalaya, this finding reports its occurrence only from Daribokgre, on way to Nokrek Peak, Bansamgre, and Chokpot in the NBR. The wide distribution of this species recorded from Bangladesh, Bhutan, China, India (Assam, Arunachal Pradesh, Meghalaya, Sikkim), Laos, Myanmar, Nepal, Thailand, and Vietnam.

Specimen studied: Daribokgre along Simsang river (874 m), VNS & BS 116700; other locality include Rongrengiri, Srinivasan 22222 (ASSAM).

2. *Acanthophippium* Blume

The genus comprises 13 species distributed in Southeast Asia from Sri Lanka, Nepal, and Japan in the world (http://www.plantsoftheworldonline.org; Chung et al. 2005); one species in Meghalaya and one species in NBR.

***Acanthophippium sylhetense* Lindl. in Gen. Sp. Orchid. Pl. 177. 1831.**

Note: Terrestrial plants of dull white flowers of yellow apex grow along with grasses in tree canopy area between the elevation ranges of 200–1,000 m in the study area. The flowering period of this species recorded between June and July. Distribution widely recorded from China, India (Arunachal Pradesh, Assam, Meghalaya, Manipur, Mizoram), Myanmar, and Thailand.

Specimen studied: Nokrek hills, MKV Rao 59274 (ASSAM).

3. *Aerides* Lour.

The genus comprises about 28 species (http://www.plantsoftheworldonline.org/) distributed in the world; 12 species in India (Bora & Kumar 2003), three species in Meghalaya (Kataki 1986), and three species in NBR.

Key to species

1a. Mid-lobe of lip narrow, turning upwards; spur ca 1.2 cm long, prominent, horn-like ..... 1. *A. odorata*

1b. Midlobe of lip broad, forward-pointing; spur short, inconspicuous 2

2a. Midlobe of lip cordate, apex emarginated-truncate ..... 2. *A. multiflora*

2b. Midlobe of lip triangular, apex acute .... 3. *A. rosea*

3.1. ***Aerides odorata*** **Lour. in Fl. Cochinch. 525. 1790. (Image 5)**

Note: Epiphytic Plant of flower white with pale pink flushed, on tree trunks in a subtropical forest in NBR between. The flowering season was recorded in mid-March to early June. This species is rare in the study site. It is widely recorded from Bhutan, Bangladesh, India (Assam, Meghalaya, Mizoram, Sikkim, Tripura), Laos, Myanmar, Philippines, Sumatra, Thailand, and Vietnam.

Specimen studied: Way to Nabokgre, VNS & BS 118277 (ASSAM).

3.2. ***Aerides multiflora*** **Roxb. in Pl. Coromandel 3: 68. 1820.**

Note: Pendent epiphytic plant of flower white to pinkish-purple,usually growing on tree trunks in both the open and the dense tropical and subtropical forests between the elevation range of 600–1,417 m. Flowering twigs of this species were seen in March. This species is extremely rare in Nokrek, and during the survey, we could not locate any site of occurrence, but while studying the housed specimens at ASSAM herbarium, two sheets of MKV Rao earlier collection were recorded from the study site. The plant is recorded from Bangladesh, Bhutan, India (Assam, Arunachal Pradesh, Meghalaya, Sikkim), Myanmar, Nepal, Thailand, and Vietnam.

Specimen studied: Gokha, MKVR 59292 (ASSAM); Way to Baghmara, MKVR 59328 (ASSAM).

3.3. ***Aerides rosea*** **Lodd. ex Lindl. & Paxton in Paxton's Fl. Gard. 2: 109. 1851. (Image 6)**

Note: Robust epiphytic plant of purple flowers arising from peduncle sheath recorded growing on the tree trunks between 700 and 1450m elevation in the study area. Flowering was recorded in August. Distribution recorded from Bhutan, India (Arunachal Pradesh, Assam, Meghalaya, Nagaland, Manipur), Myanmar, and Thailand.

Specimen studied: Nokrek hills, MKVR22464 (ASSAM).

4. *Agrostophyllum* Blume

The genus currently contains 135 species (http://www.plantsoftheworldonline.org/) distributed from the Seychelles to Samoa, New Guinea (Ormerod 2012), four species from Meghalaya, and three species in NBR.

Key to species

1a. Leaves more than 1.5 cm broad, epichile or lip broader than long, a transverse ridge dividing the hypochile from epichile .... 3. *A. planicaule*

1b. Leaves less than 1.3 cm broad, lip with a transverse callus on hypochile 2

2a. Stem clavate with few leaves on the upper part of the stem below which are large imbricate sheaths; capitula about 2 cm across .... 1. *A. brevipes*

2b. Stem with many leaves; capitula more than 3 cm across ..... 2. *A. callosum*

4.1. ***Agrostophyllum brevipes*** **King & Pantl. in Ann. Roy. Bot. Gard. (Calcutta) 8: 156. 1890.**

Note: Epiphytic plant of white flowers grows in subtropical forests between the elevation ranges of 1,300–1,480 m elevation in the study area forests. It flowering and fruiting period is between December and June. Wide distribution reported from India (Arunachal Pradesh, Assam, Meghalaya, Nagaland, Sikkim), Nepal, Sri Lanka, and Thailand.

Specimen studied: Nokrek hills, RN De 17137 (ASSAM).

4.2. ***Agrostophyllum callosum*** **Rchb.f. in B.Seemann, Fl. Vit. 296. 1868.**

Note: Terrestrial plant of reddish-pink flowers grows in subtropical forests at 900–1,480 m elevation in the study area. Distribution reported from Bhutan, China, India (Arunachal Pradesh, Assam, Meghalaya, Nagaland, Manipur, Mizoram, Sikkim), Nepal, Myanmar, and Thailand.

Specimen studied: Nokrek Peak, Das 46857 (ASSAM).

4.3. ***Agrostophyllum planicaule*** **(Wall. ex Lindl.) Rchb.f. in W.G.Walpers, Ann. Bot. Syst. 6: 909. 1864.** *Eria planicaulis* Wall. ex Lindl.). in Edwards's Bot. Reg. 26(Misc.): 8. 1840.

Note: Terrestrial Plant of white flowers grows in open as well as dense places along forest margin between the elevation ranges of 200–1,000 m in the Nokrek area. Distribution Bhutan, China, India (Arunachal Pradesh, Assam, Meghalaya, Nagaland, Manipur, Sikkim), Nepal,

Image 1. View of Nokrek Biosphere Reserve.

Image 3. Buttress formation of huge tree in core area of Nokrek.

Image 2. View of local hanging bridge in Nokrek Hills.

Image 4. View of traditional tree house in Nokrek hills for protecting jhum land.

Myanmar, Malaysia, and Thailand.

Specimen studied: Nokrek hills, VNS & BS35839 (ASSAM).

5. *Anoectochilus* Blume

The genus comprises 46 species (http://www.plantsoftheworldonline.org/) distributed from Sri Lanka and the Himalayan region throughout southeastern Asia to Oceania (Tian et al. 2008), six species in Meghalaya, and one species in NBR.

5.1 ***Anoectochilus roxburghii* (Wall.) Lindl. in J.F.Royle, Ill. Bot. Himal. Mts. 368. 1839.** *Chrysobaphus roxburghii* Wall. in Tent. Fl. Nepal. 37. 1826.

Note: Terrestrial plant of pale pink to white flower, occurring in shaded humus soil of the subtropical forests between the altitudes of 100–1,400 m. The flowering season recorded in the study area is from August to late September. The species is rare and is recorded for the first time from the Garo district of Meghalaya. Widely distribution recorded from Bangladesh, Bhutan, and India (Arunachal Pradesh, Sikkim, Assam, Meghalaya, Nagaland, Manipur, Mizoram).

Specimen studied: Nokrek, NPB 50096 (ASSAM).

6. *Arundina* Blume

The genus comprises two species (http://www.theplantlist.org) distributed in southern and southeastern Asia and both are found in India; one species from Meghalaya (Kataki 1986).

6.1 ***Arundina graminifolia* (D.Don.) Hochr. in Bull. New York Bot. Gard. 6: 270. 1910.** *Bletia graminifolia* D.Don in Prodr. Fl. Nepal. 29. 1825.

Note: Terrestrial plant of pale pinkish-purple flower, occasionally the plant is viviparous in nature in grassland, secondary forests and forest borders of the tropical and subtropical zone at 500–1,400 m. Flowering was observed in June and last till August. It is widely recorded from Bhutan, China, India (Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Tripura, Sikkim), Nepal, Myanmar, and Thailand.

Specimen studied: Way to Baghmara, MKVR 64516 (ASSAM).

7. *Brachycorythis* Lindl.

The genus was proposed by Lindley in 1938 and comprised of 37 species (http://www.plantsoftheworldonline.org/) distributed in tropical Asia, Africa, Australia, Madagascar, and Myanmar (Hoque & Huda 2008), five species have been reported from India (Bose et al. 1999), one species from Meghalaya, and one species in NBR.

7.1 ***Brachycorythis obcordata* (Lindl. ex Wall.) Summerh. in Kew Bull. 10: 243. 1955.** *Orchis obcordata* Lindl. ex Wall. in Prodr. Fl. Nepal. 23. 1825.

Note: Terrestrial plant of uniformly pink to pale purple flowers seen grows along with grasslands in forest borders at 1,000–1,400 m elevation in the study area. It flowers between May and September. Distribution recorded from Bhutan, China, India (Arunachal Pradesh, Meghalaya), Nepal, Myanmar, and Thailand.

Specimen studied: Sadhoa forest, Kanjilal 8190 (ASSAM).

8. *Bulbophyllum* Thouars

The genus is comprised of 2,058 species (http://www.plantsoftheworldonline.org/) distributed throughout the World; about 300 species in tropical regions (Kataki 1986); 37 species in Meghalaya, and eight species in NBR.

Key to species

1a. Pseudobulbs disc-like; stelidia linear, sharply pointed 2
1b. Pseudobulbs and stelidia otherwise 3
2a. Flowers reddish brown, mottled with yellow and lip purple ..... 8. *B. sarcophyllum*
2b. Flowers white with purple veined .... 7. *B. roseopictum*
3a. Inflorescence umbellate heads .... 4. *B. odoratissimum*
3b. Inflorescence not umbellate 4
4a. Inflorescence cylindric, densely many flowered 5
4b. Inflorescence lax raceme 6
5a. Peduncle laxly sheathed; peduncle more than 4 cm long; stelidia long ..... 1. *B. careyanum*
5b. Peduncle with dense, swollen sheaths throughout, peduncle less than 2 cm long; stelidia short ..... 2. *B. crassipes*
6a. Flowers reddish-purple to yellow blotched with reddish-purple, lip deep reddish-purple .... 6. *B. rolfei*
6b. Flowers yellowish-creamy, with or without red spots externally; lip yellow 7
7a. Leaves 8–20 cm long; petals serrate on margin ..... 3. *B. gymnopus*
7b. Leaves 6–10 cm long; petals entire on margin .... *B. reptans*

8.1. ***Bulbophyllum careyanum* (Hook.) Spreng. in Syst. Veg. 3: 732. 1826.** *Anisopetalum careyanum* Hook. in Exot. Fl. 2: t. 149. 1825.

Note: Epiphytic plant of flower orange-yellow spotted with red-brown or purple and lip yellow blotched with violet, recorded on a tree trunk in tropical forests of NBR between the altitude ranges of 400–800 m. Flowerings start in early October and continue till January. The species is recorded for the first time from the Garo district of Meghalaya. It is reported from Bhutan, India (Arunachal Pradesh, Meghalaya, Sikkim), Myanmar, Nepal, Thailand, and Vietnam.

Specimen studied: 6thMile area, VNS & BS 118464 (ASSAM).

8.2. ***Bulbophyllum crassipes*** **Hook.f. in Fl. Brit. India 5: 760. 1890. (Image 7)**

Note: Epiphytic plant of flower greenish-yellow, base spotted red-purple, grows on tree trunks in dense tropical forests along the river side. The flowering of this species was recorded in September and still flowering at the end of October or early November. Critically endangered in Nokrek, and is reported for the first time from the state of Meghalaya. Bhutan, China, India (Meghalaya, Sikkim), Malaysia, Myanmar, Thailand, and Vietnam.

Specimen studied: Near Rongrengiri (265m), VNS & BS118223 (ASSAM).

8.3. ***Bulbophyllum gymnopus*** **Hook.f. in Fl. Brit. India 5: 764. 1890.**

Note: Epiphytic plant of white flower, although bracts are slightly yellowish to brown, growing on tree trunks and branches covered with moss in subtropical forests at 1,200–1,400m. Flowering is usually recorded in December and continues till the end of January.Occasionally found in Nokrek. The species is reported from Bhutan, China, India (Arunachal Pradesh, Meghalaya, Sikkim), Myanmar, and Thailand.

Specimen studied: Daribokgre, VNS & BS 116708 (ASSAM).

8.4. ***Bulbophyllum odoratissimum*** **(Sm.) Lindl. ex Wall. in Numer. List. No. 1987. 1829.** *Stelis odoratissima* Sm. in A.Rees, Cycl. 34. No. 12. 1816.

Note: Usually epiphytic, occasionally lithophytic plant of white flower tipped with yellow, recorded growing on tree trunks of subtropical forests. The flowering period starts in June and ends in July. The species is extremely rare in Nokrek, only three localities were recorded while surveying both the core and buffer zones of the biosphere reserve. Bhutan, China, India (Arunachal Pradesh, Assam, Meghalaya, Nagaland, Sikkim), Myanmar, and Nepal.

Specimen studied: Sisubibra, VNS & BS 116705 (ASSAM); other localities are Nokrek Peak, VNS & BS 116613 (ASSAM) and Daribokgre, VNS & BS 114816 (ASSAM).

8.5. ***Bulbophyllum reptans*** **(Lindl.) Lindl. ex Wall. in Numer. List. No. 1988. 1829.***Tribrachia reptans* Lindl. in Coll. Bot. t. 41. 1826.

Note: Epiphytic or lithophytic plant yellowish-green with purple streaks flower and lip yellowish with red margin, recorded growing on tree trunks and on moss-covered rocks near stream or rivers in subtropical forests. The plant flowers in October and can be seen flowering till mid-November. Although this species is recorded from Shillong Peak of Meghalaya it is a new record for the Garo districts. This species is extremely rare in Nokrek and only recorded from the core zone near Nokrek Peak. Distribution of the species reported from India (Arunachal Pradesh, Assam, Meghalaya, Nagaland, Mizoram, Sikkim), Myanmar, and Thailand.

Specimen studied: Nokrek Peak, BS, VNS & BKS118501 (ASSAM).

8.6. ***Bulbophyllum rolfei*** **(Kuntze) Seidenf. in Dansk Bot. Ark. 33: 149. 1979.** *Phyllorkis rolfei* Kuntze in Revis. Gen. Pl. 2: 676. 1891.

Note: Epiphytic plant of reddish-purple flower with yellow blotched recorded growing on tree trunks in the tropical and subtropical forests. Flowering was recorded in August to October. Widely reported from Bhutan, China, India (Arunachal Pradesh, Assam, Meghalaya, Nagaland, Mizoram, Sikkim), and Nepal.

Specimen studied: Daribokgre near Simsang river, 114661 (ASSAM).

8.7. ***Bulbophyllum roseopictum*** **J.J.Verm., Schuit. & de Vogel in Phytotaxa 166. 105. 2014.**

Note: Epiphytic plant of white flowers with purple veined grows on the moss-laden stems, barks, and on tree trunks of subtropical forests at 900–1,450 m elevation in the study area. Its phenology period is between October and December. Distribution widely reported from China, India (Arunachal Pradesh, Meghalaya, Sikkim, Assam, Nagaland), Myanmar, and Thailand.

Specimen studied: Nokrek hills, GK Deka 35682 (ASSAM).

8.8. ***Bulbophyllum sarcophyllum*** **(King & Pantl.) J.J.Sm. in Bull. Jard. Bot. Buitenzong, ser. 2, 8: 27. 1912.** *Cirrhopetalum sarcophyllum* King & Pantl. in J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 64: 335. 1896.

Note: Epiphytic or lithophytic plant of flower reddish-brown, mottled with yellow and lip purple, recorded growing in shade on tree trunks in tropical and subtropical forests. The plant flowers in June. It is recorded rare in Meghalaya, and after the collection of Panigrahi from NBR. This species is not yet reported from other parts of the state. The species is reported from Bhutan, India (Arunachal Pradesh, Meghalaya, Sikkim), and Nepal.

Specimen studied: Tura Peak, GP22411 (ASSAM).

9. *Calanthe* R.Br.

The genus is represented by 214 species (http://www.plantsoftheworldonline.org/)widely distributed from tropical & subtropical Asia to the Pacific islands, tropical

Image 5. *Aerides odorata*.

Image 6. *Aerides rosea*.

Image 7. *Bulbophyllum crassipes*.

and southern Africa, Madagascar, Mexico, Panama, and northern South America (Zhai et al. 2013), 11 species in Meghalaya (Kataki 1986), and one species in NBR.

9.1. ***Calanthe biloba*** **Lindl. in Fol. Orchid. 6: 3. 1855.**

Note: Plant terrestrial of yellow flower spotted with purple brown, and lip pale violet, white at the base, grows in a shady area of subtropical forests. It flowers in September and in some other places of Meghalaya, it is recorded till November. The species is rare and threatened in the NBR. The distribution of the species is reported from Bhutan, China, India (Arunachal Pradesh, Assam, Meghalaya, Nagaland, Manipur, Sikkim), Myanmar, and Thailand.

Specimen studied: Sisubibra, ARKS 40557 (ASSAM); other locality is RF, MKVR 53311 (ASSAM).

10. *Ceratostylis* Blume

The genus comprises 153 species (http://www.plantsoftheworldonline.org/) distributed in Southern and

southeastern Asia to Indonesia and New Guinea (Pearce & Cribb 2002), three species from India, two species from Meghalaya (Kataki 1986), and one species in NBR.

10.1. ***Ceratostylis himalaica*** **Hook.f. in Fl. Brit. India 5: 826. 1890.**

Note: Epiphytes plant of pinkish-yellow flowers grows in the primary forests between the elevation ranges of 1,000–1,480 m in the study area. Flowering was recorded in May. Distribution of the species widely recorded from Bhutan, China, India (Meghalaya, Arunachal Pradesh, Assam, Nagaland, Manipur, Mizoram, Sikkim), Nepal, Thailand, and Myanmar.

Specimen studied: Nokrek peak, MKVR 64007 (ASSAM).

11. *Cheirostylis* Blume

The genus is represented by 55 species (http://www.plantsoftheworldonline.org/) distributed in tropical Africa, Southern & southeastern Asia, Japan, and Pacific Island to Australia (Bhattacharjee 2012), one species from Meghalaya, and one species in NBR.

11.1. ***Cheirostylis griffithii*** **Lindl. in J. Proc. Linn. Soc., Bot. 1: 188. 1857.**

Note: Terrestrial plant of white flowers found growing in the subtropical forests at 900–1,400 m elevation in the study area. Its flowering was recorded between May and August. Distribution reported from Bhutan, India (Meghalaya, Arunachal Pradesh, Assam, Nagaland), Nepal, Myanmar, and Thailand.

Specimen studied: Nokrek, PK Hajra 51876 (ASSAM).

12. *Cleisostoma* Blume

The genus comprises 96 species (http://www.plantsoftheworldonline.org/) distributed across the world in tropical and subtropical climate (Bose et al. 1999), 35 species in tropical Asia (Kataki 1986), 19 species in India (Gogoi et al. 2009), 10 species in Meghalaya, and three species in NBR.

Key to species

1a. Leave flat; pollinia with simple stipes .... 3. *C. subulatum*

1b. Leaves terete; pollia with complex strip 2

2a. Plant with dorsiventral leaves (sometimes V-shaped insection); inflorescence many-flowered long raceme; sepals and petals chocolate brown .... 2. *C. filiforme*

2b. Plant with terete leaves; inflorescence few-flowered short raceme; sepals and petals yellow with brown veins, spur narrow veins .... 1. *C. appendiculatum*

12.1. ***Cleisostoma appendiculatum*** **(Lindl.) Benth. & Hook.f. ex B.D. Jacks. in Index Kew. 1: 555. 1893.** *Aerides appendiculata* Lindl. in Gen. Sp. Orchid. Pl. 242. 1833.

Note: Epiphytic plant of yellow flower, growing on moss-covered tree trunks in the subtropical forests between the altitude ranges of 1,000–1,417 m. It flowers in July and ends in August. Rare in Nokrek hills of Meghalaya. India (Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim), Myanmar, and Thailand.

Specimen studied: Nokrek Hills, S Phukan 113011 (ASSAM); other locality is Danagiri, DB Deb 29295.

12.2. ***Cleisostoma filiforme*** **(Lindl.) Garay in Bot. Mus. Leafl. 23: 171. 1972.** *Sarcanthus filiformis* Lindl. Edmards's Bot. Reg. 28 (Misc.): 61. 1842.

Note: Epiphytic plant of purple flower with a yellow stripe at the centre, found to be growing on tree trunks in shady places in the tropical and subtropical forests. The plant flowers in April and continues till June. It is rare in the Nokrek, and recorded for the first time from the Garo districts, and is one of the most threatened plants of the state. After a repeated search in the study area, we could only locate two populations: one at the Sabokgre (subtropical area), and one at the Rongrenggre (tropical forests). Bhutan, China, India (Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Tripura, Sikkim), Nepal, Myanmar, and Thailand.

Specimen studied: Way to Sabokgre (1,026 m), VNS & BS118278 (ASSAM); other localities include Rongrenggre (295 m), VNS & BS 116760 (ASSAM).

12.3. ***Cleisostoma subulatum*** **Blume in Bijdr. Fl. Ned. Ind. 363. 1825.**

Note: Epiphytic plants of yellow to brown flowers, growing on tree trunks in the tropical and subtropical forests between the altitude ranges of 450–1,050 m. Flowering was recorded from May to June. During the scrutiny of ASSAM herbarium, the authors come across two unidentified sheets of MKV Rao, and after identification, it is a new record for Garo district. India (Arunachal Pradesh, Assam, Meghalaya, Nagaland, Mizoram, Sikkim), Myanmar, and Thailand.

Specimen studied: Nokrek Peak, MKVR 64609 (ASSAM).

13. *Coelogyne* Lindl.

The genus comprises of 210 species (http://www.

plantsoftheworldonline.org/), 34 species in India (Das & Jain 1980), 22 species in Meghalaya (Kataki 1986), and eight species in NBR.

Key to species

1a. Inflorescence with imbricate sterile bracts 2

1b. Inflorescence bare to the first flower, or rarely with 1 or a few sterile bracts; flowers opening simultaneously 4

2a. Rachis extending with new imbricate bracts to produce further annual sets of flowers 3

2b. Rachis producing a single set of flowers .... 1. *C. barbata*

3a. Lip mid-lobe nearly broadly oblong, 2 lamellae faint near the base of lip, elevated and prominent on mid-lobe ..... 8. C. *schultesii*

3b. Lip mid-lobe nearly elliptic, 2 lamellae terminating 2/3 onto mid-lobe ..... 5. *C. prolifera*

4a. Dorsal sepal forming a hood over the column, larger than lateral sepals and petals; lateral sepals and petals not widespread away from the column .. .. 4. *C. fuscescens*

4b. Dorsal sepal erect, away from the column; lateral sepals and petals widespread away from the column; sepals and petals of ca. equal length 5

5a Dorsal sepal and lateral sepals of ca. equal width, petals narrower 6

5b. Dorsal sepal, lateral sepals, and petals of ca. equal width; sepals, petals, and lip tending toward being fleshy 7

6a. Lip with mid-lobe large in relation to the overall size of flower, sometimes clawed; lip with margin tendingtowardbeingmembranous..... ..... 7. *C. suaveolens*

6b. Lip with mid-lobe not large relative to the overall size of flower; lip without evident claw; lip with margin tending toward being fleshy .... 3 *C. flaccida*

7a. Inflorescence hysteranthous .... 6. *C. punctulata*

7b. Inflorescence proteranthous or synanthous ... . 2. *C. corymbosa*

13.1. ***Coelogyne barbata*** **Lindl. ex Griff. in Itin. Pl. Khasyah Mts. 72. 1848.**

Note: Epiphytic or lithophytic plant of pure white flower grows on tree trunks in the tropical and subtropical forests. It flowers in September and continues flowering till December. Singh & Singh (2002) reported this species from Nokrek and treated under rare and endangered category. The plant is reported from Bhutan, India (Arunachal Pradesh, Assam, Manipur, Meghalaya, Nagaland, Sikkim, Mizoram), and Myanmar.

Specimen studied: Sisubibra, VNS & BS116706 (ASSAM).

13.2. ***Coelogyne corymbosa*** **Lindl. in Fol. Orchid. 5: 7. 1854.**

Note: Plant epiphytic or lithophytic plant of white flower bordered with orangish-red lip grows on tree trunks in the subtropical forests. The flowering of the plant was recorded in October–November. A sheet of vouchers is housed in ASSAM, but to date not reported from Garo hills, hence, is a new record for the Garo district. Widely reported from Bhutan, India (Arunachal Pradesh, Meghalaya, Nagaland, Manipur, Sikkim), Nepal, and Myanmar.

Specimen studied: Nokrek, GVSR 28188 (ASSAM).

13.3. ***Coelogyne flaccida*** **Lindl. in Gen. Sp. Orchid. Pl. 39. 1830. (Image 8)**

Note: Generally epiphytic plants on tree trunks, occasionally growing on moss-covered rocks (lithophytic) in dense places of tropical and subtropical forests at 700–1,400 m. It flowers from early March to the end of April. This species of plant is extremely rare, and threatened in the Nokrek due to illicit collection for ornamental purposes. Distributed in Bhutan, China, India (Arunachal Pradesh, Meghalaya, Nagaland, Manipur, Mizoram, Sikkim), Myanmar, and Thailand.

Specimen studied: Simsanggre to 15 km, VNS & BS 116786 (ASSAM).

13.4. ***Coelogyne fuscescens*** **Lindl. in Gen. Sp. Orchid. Pl. 41. 1830.**

Note: Epiphytic plant of yellow flowers found to be growing in dense primary subtropical forests at 1,000–1,400 m. Flowering was recorded in November and January. It is extremely rare in Nokrek, as authors could locate only two localities after repeated searches in the BR. It is reported from Bhutan, India (Arunachal Pradesh, Meghalaya, Mizoram, Sikkim), Nepal, and Myanmar.

Specimen studied: Daribokgre, VNS & BS114817 (ASSAM).

13.5. ***Coelogyne prolifera*** **Lindl. in Gen. Sp. Orchid. Pl. 40. 1830.**

Note: Epiphytic plant of yellow flower with lip brown-veined recorded growing on tree trunks of lofty trees in the subtropical forests. The plant flowers in early May and continues till June. It is rare in Nokrek forests and recorded for the first time from Garo hills. Bhutan, China,

India (Arunachal Pradesh, Assam, Meghalaya, Nagaland, Mizoram, Sikkim), Nepal, and Myanmar.

Specimen studied: Darugiri, MKVR 61442 (ASSAM).

13.6. ***Coelogyne punctulata*** **Lindl. in Coll. Bot. t. 33. 1824. (Image 9)**

Note: Epiphytic plant of white flower, and lip with two bright orangish-yellow spots on each lateral lobe. It is recorded *g*rowing on tree trunks in the subtropical forests between elevation ranges of 1,000–1,400 m, and flowering usually in February. It is rare and records for the first time from the Garo district. Bhutan, India (Arunachal Pradesh, Meghalaya, Manipur, Sikkim), Myanmar, and Nepal.

Specimen studied: Sellengiri, SDS 60130 (ASSAM).

13.7. ***Coelogyne suaveolens*** **(Lindl.) Hook.f. in Fl. Brit. India 5: 832. 1890.** *Pholidota suaveolens* Lindl. in Gard. Chron. 1856: 312. 1856.

Note: Epiphytic plant of white flower and lip with yellow spots, growing in shady places on tree trunks in the tropical and subtropical forests between the altitudinal gradient of 400–1,250 m. Flowering usually in May, and also occasionally recorded in June. Wide distribution of this species reported from India (Assam, Meghalaya, Arunachal Pradesh), Myanmar, and Thailand.

Specimen studied: Way to Khalakgre, VNS & BS 116716 (ASSAM); other localities include Rongrengiri, MKVR 59453 (ASSAM).

13.8. ***Coelogyne schultesii*** **S.K.Jain & S.Das in Proc. Indian Acad. Sci., B 87(5): 121. 1978. (Image 10)**

Note: Plant epiphytic plant of flower brownish-yellow or greenish to dark brown, and lip dark brown, on lofty trees, sometimes lithophytic on moss-covered rocks in the shady area of the tropical and subtropical forests between the elevations of 500–1,000 m. Its flowering period was recorded in January and continued till the end of March. The plant is rare and threatened in Nokrek. Distribution of the species recorded from Bhutan, India (Arunachal Pradesh, Assam, Meghalaya, Manipur, Nagaland, Sikkim), Myanmar, and Thailand.

Specimen studied: Sisubibra, VNS & BS116695 (ASSAM).

14. *Corybas* Salisb.

The genus of terrestrial orchids that comprised about 147 species (http://www.plantsoftheworldonline.org/) found from southern China and India to Australia, New Zealand, and western Pacific Islands (Chung & Hsu 2008), one species from Meghalaya, and one species in NBR.

Corybas himalaicus **(King & Pantl.) Schltr. in Repert. Spec. Nov. Regni Veg. 19: 19. 1923.** *Corysanthes himalaica* King & Pantl. in J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 65: 128. 1896.

Note: A terrestrial plant having white flowers grows along with grasses in subtropical vegetation at 1,000–1,480 m elevations in the study area. Flowering was recorded between June and July. The species is recorded from China and India (Sikkim, Meghalaya).

Specimen studied: Nokrek hills, Joseph 84079 (ASSAM).

15. *Corymborkis* Thouars

The genus is comprised of eight species (http://www.plantsoftheworldonline.org/) distributed across the world in tropic and subtropics, one species from Meghalaya, and one species in NBR.

15.1. ***Corymborkis veratrifolia*** **(Reinw.) Blume in Coll. Orchid. 125. 1859.** *Hysteria veratrifolia* Reinw. in Syll. Pl. Nov. 2: 5. 1825.

Note: Clump-forming terrestrial plant tubular fragrant white flowers, growing in the subtropical forests. It flowers usually in July. The plant is rare in Nokrek as well as in the state. The distribution of the species is recorded from China, India (Sikkim, Arunachal Pradesh, Assam, Meghalaya), Japan, Malaysia, Myanmar, and Thailand.

Specimen studied: Tura Hills, RND 22179 (ASSAM).

16. *Crepidium* Blume

The genus is represented by 291 species (http://www.plantsoftheworldonline.org/) throughout the world mostly in tropical and subtropical regions of Asia to the Pacific, six species from Meghalaya, and one species in NBR.

16.1. ***Crepidium acuminatum*** **(D.Don) Szlach. in Fragm. Florist. Geobot., Suppl. 3: 123. 1995.** *Malaxis acuminata* D.Don in Prodr. Fl. Nepal. 29. 1825.

Note: Terrestrial plant of greenish-yellow or slightly purple flowers grows in the primary forests in shaded moist places, often nearby streams and rivers at 200–1,300 m elevations in the study area. Its flowering starts in June and can be seen till the third week of August. Distribution in Bhutan, China, India (Arunachal Pradesh, Meghalaya, Sikkim, Assam, Nagaland, Manipur), Malaysia, Myanmar, Nepal, Sri Lanka, Thailand, and Vietnam.

Specimen studied: Sasatgiri, MKVR 53322 (ASSAM); other locaty include Nokrek range, MKVR 64415 (ASSAM).

17. *Cryptochilus* Wall.

The genus is represented by a total of eight species (http://www.plantsoftheworldonline.org/) distributed mostly in the southeastern Asian regions, two species from Meghalaya, and two species in NBR.

Key to species

1a. Red flowers ..... 1. *C. sanguineus*
1b. White flowers ..... 2. *C. strictus*

17.1. ***Cryptochilus sanguineus* Wall. in Tent. Fl. Napal. 36. 1824.**

Note: Epiphytic plant of a red flower, usually growing in the primary forests on tree trunks of the subtropical belt in shady places. Usually, they plant flowers in June and continues flowering till September in some places. The distribution of the species was widely reported from Bhutan, India (Arunachal Pradesh, Sikkim, Meghalaya, Nagaland, Mizoram), and Nepal.

Specimen studied: Nokrek, GKD 10156 (ASSAM).

17.2. ***Cryptochilus strictus* (Lindl.) Schuit., Y.P.Ng & H.A.Pedersen in Bot. J. Linn. Soc. 186: 195. 2018.** *Eria stricta* Lindl. in Coll. Bot. t. 41 B. 1826.

Note: Epiphytic plant of flower densely woolly-externally, white, flushed with pink and lips streaked with yellow, recorded growing on the tree trunks of tropical and subtropical forests between the elevation ranges of 700–1,400 m. This species is extremely rare in NBR. Its flowering can be seen between March and April. Distribution of the species recorded from Bhutan, India (Arunachal Pradesh, Nagaland, Meghalaya, Mizoram, Sikkim), and Thailand.

Specimen studied: Nokrek Peak (1,375 m), VNS & BS 114676 (ASSAM).

18. *Cylindrolobus* Blume

The genus is represented by 75 species (http://www.plantsoftheworldonline.org/) in its native range of southern China to tropical Asia and one species in NBR.

18.1. ***Cylindrolobus clavicaulis* (Wall. ex Lindl.) Rauschert in Feddes Repert. 94: 445. 1983.** *Eria clavicaulis* Wall. ex Lindl. in Edwards's Bot. Reg. 26(Misc.): 90. 1840.

Note: Epiphytic plant of white flowers, lips edged with pink, grows on tree trunks in the subtropical forests of the study area. Flowering of this plant species recorded in January. Occasional in the Nokrek hill range, however, its worldwide distribution recorded from China, India (Assam, Arunachal Pradesh, Meghalaya), Myanmar, Thailand, and Vietnam. (Note: This species can be distinguished from the inflorescence with 2 pedicelled flowers, and 2 yellow bracts. It can be separated from *E. marginatus* by their rachis pedicel, ovary, glabrous sepals, and lateral lobes bigger than the mid-lobe.).

Specimen studied: Sabokgre, VNS & BS 118275 (ASSAM).

19. *Cymbidium* Sw.

The genus is comprises 74 species (http://www.plantsoftheworldonline.org/) distributed in tropical and subtropical regions of Asia and Australia (Long et al. 2003), 18 species in India (Bora & Kumar 2003), 13 species in Meghalaya (Kataki 1986), and five species in NBR.

Key to species

1a. Pseudobulbs ovoid, bilaterally flattened; leaves 4–6, oblong, obtuse, unequal bilobed at apex, thick, rigid, erect ..... 1. *C. aloifolium*
1b. Pseudobulbs ovoid or fusiform; leaves 2–17, linear-elliptic, narrowly oblong, acute to mucronate, sessile, rigid 2
2a. Leaves 2–4, with long channeled petiole; inflorescence pendulous ..... 2. *C. devonianum*
2b. Leaves more than 5, petioles not channeled; inflorescence otherwise 3
3a. Leaves 5–9, linear-oblong, tapering to a fine tip; flowers spreading; margin ciliate ..... 4. *C. iridoides*
3b. Leaves more than 6, narrowly oblong to ovoid; flowers not spreading; margins not ciliate.....4
4a. Pseudobulbs ovoid to fusiform; leaves 6–17, narrowly oblong, mucronate; flowers white, not spreading ..... 3. *C. eburneum*
4b. Pseudobulbs small, ovoid to narrowly ovoid; leaves many, linear to linear-elliptic; flowers campanulate, pendent, pale lemon yellow .... 5. *C. longifolium*

19.1. ***Cymbidium aloifolium* (L.) Sw. in Nova Acta Regiae Soc. Sci. Upsal. 6: 73. 1799.** *Epidendrum aloifolium* L. Sp. Pl. 953. 1753.

Note: Epiphytic plant of flower yellow with purple mid-nerve on trunks of lofty trees usually recorded growing in the tropical and subtropical forests between the altitudinal ranges of 250–1,417 m. Flowering from May to July. Although this species is rare in the state, it is recorded very commonly in Nokrek. Distribution of this species reported from Bhutan, China, India (Arunachal Pradesh, Assam, Sikkim, Meghalaya, Nagaland, Mizoram), Myanmar, Nepal, Sri Lanka, and Thailand.

Specimen studied: Nokrek Peak (1,378 m), VNS & BS 116709 (ASSAM), others recorded localities include Rongrengiri, GP22626 (ASSAM) and Tura Hills, DBD29058 (ASSAM).

Image 8. *Coelogyne flaccida.*

Image 9. *Coelogyne punctulata*

Image 10. *Coelogyne schultesii.*

Image 11. *Cymbidium iridioides.*

Image 12. *Dendrobium anceps.*

Image 13. *Dendrobium aphyllum.*

19.2. ***Cymbidium devonianum*** **Paxton. in Paxton's Mag. Bot. 10: 97. 1843.**

Note: Epiphytic plant of flowers green with purple dots on tree trunks, occasionally lithophytic on moss-covered big rocks in dense under canopy layer in the subtropical forests above 1,000 m. Its flowering period was recorded from May to July. This plant species is again extremely rare in Nokrek as well as in the statebecause after long surveys, only two localities,Tura Hills and Cherrepunjee, are recorded so far from Meghalaya. It's a new record for the Garo districts. The species is reported from Bhutan, China, India (Arunachal Pradesh, Sikkim, Meghalaya, Manipur, Mizoram, Nagaland), Myanmar, Nepal, and Thailand.

Specimen studied: Tura Hills, DBD22629 (ASSAM).

19.3. ***Cymbidium eburneum*** **Lindl. in Edwards's Bot. Reg. 33: t. 67. 1847.**

Note: Plant epiphytic plant of pure white flower and midlobe has a yellow blotch, growing on tree trunks in the dense primary subtropical forests above 1050m. Its flowering period was recorded from March to May. It is very rare in Nokrek as well as in the state. The scrutiny of Herbarium recorded only two sheets: One of MKV Rao from Nokrek, and the other of T.M. Hynniewta from Jaintia hills housed in the ASSAM herbarium at Botanical Survey of India, recorded its rare location in Meghalaya. Widely distributed recorded from Bhutan, China, India (Arunachal Pradesh, Meghalaya, Mizoram, Nagaland, Sikkim), Nepal, and Myanmar.

Specimen studied: Nokrek hills, MKVR51864 (ASSAM).

19.4. ***Cymbidium iridioides*** **D.Don in Prodr. Fl. Nepal. 36. 1825. (Image 11)**

Note: Epiphytic plant of flowers yellow and lip red-spotted on tree trunks, sometimes occasionally recorded as lithophytic on moss-covered rocks under dense canopy layer in the subtropical forests. Flowering starts in early October and lasts till middle December. It is rare in Nokrek, and recorded for the first time from the state, and hence a new extended distribution of the species from Meghalaya. Bhutan, India (Arunachal Pradesh, Meghalaya (Present study), Mizoram, Nagaland, Sikkim), Myanmar, Nepal, and Thailand.

Specimen studied: Nokrek Peak, VNS & BS 116710 (ASSAM).

19.5. ***Cymbidium longifolium*** **D.Don in Prodr. Fl. Nepal. 36. 1825.**

Note: Epiphytic plant of purplish-brown flower with slightly yellowish lip, growing on tree trunks in the primary tropical and subtropical forests between the elevations range of 400–1,400 m. Flowering was recorded from October to November. Although this species is common in the state, it was rarely recorded in Nokrek, also a new record for the Garo district. Distribution of the species reported from Bhutan, China, India (Arunachal Pradesh, Meghalaya, Manipur, Nagaland, Sikkim), Myanmar, and Nepal.

Specimen studied: Tura Hills, DBD 22694 (ASSAM).

20. ***Dendrobium*** **Sw.**

This genus is the second-largest number of species in the Orchidaceae family and comprises 1,536 species (http://www.plantsoftheworldonline.org/) distributed in tropical and subtropical Asia to Oceania (Liu & Chen 2011), about 102 species in India (Gogoi 2011), 47 species in Meghalaya, and 20 species in NBR.

Key to species

1a. Plant with fusiform to clavate stems or pseudobulbs, often angled, sometimes compressed; leaves 1– 5, thick, nearly sheath-less, more or less, clustered at apex; leaf-sheaths insignificant 2

1b. Plant otherwise; leaves with distinct sheaths, often covering most of the internodes 6

2a. Pseudobulbs 1–leaved 3

2b. Pseudobulbs 2–5-leaved 4

3a. Pseudobulbs 7–10 cm long; inflorescence in many-flowered racemes; upper surface of the lip pubescent at base and centre only .... 14. *D. lindleyi*

3b. Pseudobulbs 3–5 cm long; inflorescence 1 to 2 flowered; whole upper surface of lip pubescent .. .. 13. *D. jenkinsii*

4a. Leaves close together on the many-angled stem 5

4b. Leaves lax on few angled stems .... 6. *D. chrysotoxum*

5a. Flowerspaleyellow.....7.*D.densiflorum*

5b. Flowers pale-mauve, turning into pure white on maturity ..... 9. *D. farmeri*

6a. Stems with at least some of the internodes either fleshy or swollen 7

6b. Stems compressed or wiry, without fleshy or swollen internodes 16

7a. Plant tufted, smaller ..... 8. *D. eriiflorum*

7b. Plant not tufted, larger 8

8a. Flowers 0.7–4.5 cm across .... 20. *D. transparens*

8b. Flowers more than 4.5 cm across 9

9a. Sepals and petals bright yellow to copper or

coral red 10
9b. Sepals and petals purple or white, cream or primrose yellow 11
10a. Operculum with warty surface .... 5. *D. chrysanthum*
10b. Operculum glabrous ..... 16. *D. ochreatum*
11a. Basal callus on lip splitting up in 3 keels entering about one-third into the disc ..... 3. *D. aphyllum*
11b. Basal callus on lip if any, fading into the disc without splitting up in keels 12
12a. Lip distinctly longer than dorsal sepal; one-flowered inflorescence ..... 17. *D. polyanthum*
12b. Lip not distinctly longer than dorsal sepal. Inflorescence more than one flower 13
13a. Flowers white, petals white; disk dark purple or yellow patch 14
13b. Petals light pink to purple; disk otherwise .... 19. *D. tortile*
14a. Disk dark purple patches ..... 15. *D. nobile*
14b. Disk yellow or brown patches 15
15a. Flowers large, single, disk yellow patch .... 11. *D. formosum*
15b. Flowers small, arise in the bunch, disk brown patch ..... 10. *D. fimbriatum*
16a. Leaves laterally compressed 17
16b. Leaves dorsiventral ..... 18. *D. salaccense*
17a. Flowers axillary ..... 2 *D. anceps*
17b. Flowers terminal or subterminal 18
18a. Inflorescence lateral from pseudobulb base .. .. 1. *D. acinaciforme*
18b. Inflorescence subterminal on the pseudobulb 19
19a. Inflorescence always abaxial; flowers pale yellow; midlobe of lip orange ..... 4. *D. calocephalum*
19b. Inflorescence abaxial or adaxial; flowers white; the tip of lip white ..... 12. *D. fugax*

20.1. ***Dendrobium acinaciforme*** **Roxb. in Fl. Ind. ed. 1832, 3: 487. 1832.**

Note: Epiphytic plant of pale yellow flowers with pink dots in the middle shortly clawed lip grows in the primary dense subtropical forests. The plant flowers usually in July and continues flowering till November. It is rare in the Nokrek and recorded for the first time from the Garo Hills. Widely distributed, reported from Bhutan, Cambodia, China, India (Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland), Laos, Myanmar, and Thailand.

Specimen studied: Danagiri, DBD 29242 (ASSAM).

20.2. ***Dendrobium anceps*** **Sw. in Kongl. Vetensk. Acad. Nya Handl. 21: 246. 1800. (Image 12)**

Note: Epiphytic plant of yellow flower with purple or pink-lined lip generally grows on tree trunks in the primary tropical and subtropical forests between the altitude gradient ranges of 300–1,400 m. Flowering is recorded usually from January to March. It is rare in Nokrek and recorded the first time from the Garo district. Distribution of this species reported from Bhutan, India (Arunachal Pradesh, Assam, Meghalaya, Manipur, Mizoram, Nagaland, Sikkim, Tripura), Myanmar, Thailand, and Nepal.

Specimen studied: Bansamgiri, VNS & BS 118223 (ASSAM).

20.3. ***Dendrobium aphyllum*** **(Roxb.) C.E.C.Fisch. in J.S.Gamble, Fl. Madras 1416. 1928.***Limodorum aphyllum* Roxb. in Pl. Coromandel 1: 34. 1795. **(Image 13)**

Note: Epiphytic plant, flowers white to pale purple, lip base with purple lines found to be growing on trunks of *Lagerstromea parviflora, Schima wallichii* in the tropical and subtropical forests. It flowers in early April also recorded flowering in September. Commonly found in the state, also recorded frequently in Nokrek. Distribution reported from Bangladesh, Bhutan, China, India (Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim), Laos, Nepal, Malaysia, Myanmar, Thailand, and Vietnam. (Note: Only 1 plant recorded in flowering condition, pure white flowers, from Rongrengre (312 m), and is the alba form of *Dendrobium aphyllum*.).

Specimen studied: Sisubibra, VNS & BS 116703 (ASSAM).

20.4. ***Dendrobium calocephalum*** **(Z.H.Tsi & S.C.Chen) Schuit. & Peter B.Adams in Muelleria 29: 66. 2011.** *Flickingeria calocephala* Z.H.Tsi & S.C.Chen in Acta Phytotax. Sin. 33. 203. 1995.

Note: Epiphytic plant of creamy to pale yellow flowers without any spots growing on tree trunks in tropical and subtropical forests at 400–1,480 m elevation; rare in NBR. Flowering recorded in June. The species is endemic to Indian regions and quite common in the northeastern states of India.

Specimen studied: Sisubibra, VNS & BS 116696 (ASSAM).

20.5. ***Dendrobium chrysanthum*** **Wall. ex Lindl. in Edwards's Bot. Reg. 15: t. 1299. 1830.**

Note: Epiphytic plant of golden yellow flowers having two maroon blotches on the lip, recorded growing on tree trunks in the tropical and subtropical forests

Image 14. *Dendrobium densiflorum.*

Image 16. *Dendrobium nobile.*

between the elevation ranges of 750–1,500 m. The plant flowers in September occasionally fruits in February. It is recorded for the first time from the Garo district of Meghalaya, hence a new record for the Garo hills. Distribution of the species reported from Bhutan, China, India (Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim), Laos, India, Myanmar, Nepal, Thailand, and Vietnam.

Specimen studied: Sisubibra, VNS & BS 116704 (ASSAM).

20.6. ***Dendrobium chrysotoxum*** **Lindl. In Edmards's Bot. Reg. 33: t. 19. 1847.**

Note: Epiphytic plant species are recorded growing on tree trunks in the tropical and subtropical forests. The species is rare in the Nokrek (Singh & Singh 2002). Wide distribution reported from Cambodia, India (Arunachal Pradesh, Meghalaya), Java, Laos, Myanmar, and Vietnam.

Specimen studied: Nokrek hills, RN De 17152 (ASSAM).

Image 15. *Dendrobium jenkinsii.*

Image 17. *Dendrolirium lasiopetalum.*

20.7. ***Dendrobium densiflorum*** **Lindl. in N.Wallich, Pl. Asiat. Rar. 1: 34. 1830.(Image 14)**

Note: Epiphytic plants of orange to yellow flowering, twigs usually recorded growing on tree trunks in the tropical and subtropical forests between the elevation ranges of 300–1,417 m. Flowering was recorded in March and continued till April. The plant is very common in all parts of the state, also the most threatened plant because of its ornamental use. Distribution widely reported from Bhutan Cambodia, China, India (Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim), Java, Myanmar, Laos, Nepal, Thailand, and Vietnam.

Specimen studied: Sisubibra, VNS & BS 116701 (ASSAM).

Note: Popularly known as 'Pineapple Orchid' for its

many compact yellow flowers on drooping racemes.

20.8. ***Dendrobium eriiflorum*** **Griff. in Ic. Pl. Asiat. 3: 316. 1851.**

Note: Epiphytic plant of flower yellow with purple streaks on lip grows on tree trunks of *Quercus griffithii, Castanopsis indica* in the tropical and subtropical forests at 500–1,400 m. It flowers in October and continues flowering till December, fruiting also recorded occasionally till to March. The plant is rare in the state, also recorded very rare in the Nokrek. The species is recorded for the first time from Garo hills and is a new record for the Garo district. The distribution of the species reported from Bhutan, India (Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland and Sikkim), India, Nepal, Myanmar, and Thailand.

Specimen studied: Nokrek hills, NPB 49922 (ASSAM).

20.9. ***Dendrobium farmeri*** **Paxton in Paxton's Mag. Bot. 15: 241. 1849.**

Note: Large epiphytic plant of white flowers with a yellow blotch at the centre of lip bordered by white, growing on tree trunks in the dense tropical and subtropical forests between the altitude gradients of 300–1,250 m. It flowers in April, sometimes the fruiting has been recorded in September and October. The plant is rare in the state, as well as in the Nokrek; it is recorded as new for the Garo districts. Distribution of the species reported from Bhutan, India (Arunachal Pradesh, Assam, Manipur, Meghalaya, Nagaland, Sikkim), Malaysia, Myanmar, Nepal, Thailand, and Vietnam.

Specimen studied: Nokrek hills, MMS 23530 (ASSAM).

20.10. ***Dendrobium fimbriatum*** **Hook. in Exot. Fl. 1: t. 71. 1823.**

Note: Pendant epiphytic plant with 3.5–5 cm across golden yellow flowers; growing on branches on big trees in the subtropical forests at elevations of 1,300–1,417 m. Its flowering can be seen from April to September. Wide distribution recorded from India (Arunachal Pradesh, Assam, Manipur, Meghalaya, Nagaland, Sikkim), and Myanmar.

Specimen studied: Nokrek Hills, C Deori 101135 (ASSAM).

20.11. ***Dendrobium formosum*** **Roxb. ex Lindl. in N.Wallich, Pl. Asiat. Rar. 1: 34. 1830.**

Note: Epiphytic plant of big white flowers of 6.5–11.5 cm diameter with a centre lip changes from yellow to orange after opening for about a week, delicately fragrant, grows on tree trunks in the open as well as in the dense forests of tropical and subtropical regions. Its flowering starts in October–December, fruiting in April–May. The plant is rare in Nokrek hills, recorded for the first time from Garo district. The distribution of the species is native to Indian regions, although recorded from Bhutan, India (Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Tripura), Malaysia, Myanmar, Nepal, Thailand, and Vietnam.

Specimen studied: Nokrek hills, on the way to Tura peak, DBD 29139 (ASSAM).

20.12. ***Dendrobium fugax*** **Rchb.f. in Gard. Chron. 1257. 1871.** *Flickingeria fugax* (Rchb.f.) Seidenf. in Dansk Bot. Ark. 34: 46. 1980.

Note: Epiphytic plant with creeping rhizome and white flowers recorded growing on tree trunks of subtropical forests at 500–1,400 m elevation in the study area. Its flowering can be seen between July and August. Distribution of the species recorded from India (throughout northeastern states), Myanmar, Thailand, Java, Ceylon.

Specimen studied: Nokrek Peak, VNS & BS 118587 (ASSAM)

Note: The flowers last one to two days only.

20.13. ***Dendrobium jenkinsii*** **Wall. ex Lindl. in Edwards's Bot. Reg. 25: t. 37. 1839. (Image 15)**

Note: Miniature epiphytic plantwith bright sulphur yellow flowers of about 1.5 cm diameter, growing on tree trunks in tropical and subtropical forests at 200–1,000 m. It usually starts flowering in February and continues flowering till the end of May in the study area. The plant is common in the Nokrek biosphere reserve. Distribution widely reported from Bhutan, China, India (Meghalaya, Sikkim), Myanmar, Thailand. Note: A very dwarf species among *Dendrobium* group.

Specimen studied: Rongrengre (298 m), VNS & BS 116768 (ASSAM).

20.14. ***Dendrobium lindleyi*** **Steud. in Nomencl. Bot., ed. 2, 1: 490. 1840.**

Note: Epiphytic plant of bright yellow flowers of faint, honey-like fragrance on pendent racemes, grows on tree trunks in the tropical and deciduous forests. Its flowering period is between April-June. The species is rare in the Nokrek hills, reported being a native species of southern and southeastern Asia. Distribution widely from China, India (Assam, Meghalaya, Sikkim), Myanmar, and Thailand. Note: the flower colour of the species is very similar to *Dendrobium jenkinsii* Wall. ex Lindl. but differs in mostly having an inflorescence with many flowers.

Specimen studied: Northern range of Nokrek hills, UK 6942 (ASSAM).

20.15. ***Dendrobium nobile*** **Lindl. in Gen. Sp. Orchid. Pl. 79. 1830. (Image 16)**

Note: Epiphytic as well as lithophytic plant, fragrant, waxy flowers, colour variable; the base of the petals is pale pink or white, grading into a stronger amethyst-purple towards the tip; the lip is velvety with a rich maroon-purple basal part, surrounded by a pale yellowish-white portion. The species were recorded from tropical deciduous and subtropical forests at 750–1,500 m at the foothills of Nokrek and surrounding areas. The flowering of this plant species could be seen continuing throughout the year. This plant species is rare in Nokrek (Singh & Singh 2002), and after repeated search in wild; the species could not be the location in the study area. Distribution of the species recorded from Bhutan, China, India (Arunachal Pradesh, Assam, Manipur, Meghalaya, Nagaland, Sikkim), Nepal, Myanmar, Nepal, Laos, Thailand, and Vietnam.

Specimen studied: Rongrengre, DBD 29127 (ASSAM).

20.16. ***Dendrobium ochreatum*** **Wall. ex Lindl. in Edwards's Bot. Reg. 21: t. 1756. 1835.**

Note: Epiphytic plant of flowers bright golden yellow, the lip has a dark red spot in the throat, long-lasting and fragrant, grows on tree trunks at high elevations above 1,000 m in the tropical and subtropical area. It flowers in April and May. The species is rare in Nokrek and collected after 50 years from the state of Meghalaya. The species is a native of northeastern India, also recorded from Myanmar, Thailand, and Vietnam.

Specimen studied: Daribokgre, VNS & BS 116702 (ASSAM).

20.17. ***Dendrobium polyanthum*** **Wall. ex Lindl. in Gen. Sp. Orchid. Pl. 81. 1830.** *Dendrobium cretaceun* Lindl. in Edwards's Bot. Reg. 33: t. 62. 1847.

Note: Pendulous epiphytic plant, white flowers with ciliate margin, grows on tree trunks in the subtropical forests between the elevations of 1,200–1,400 m.The flowering of the species was recorded in May and continued flowering till July. The plant is rare in the state, recorded for the first time from the Garo district of Meghalaya. India (Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, and Sikkim), Myanmar, and Thailand.

Specimen studied: Near Daribokgre (1,050 m), VNS & BS 114818B (ASSAM).

20.18. ***Dendrobium salaccense*** **(Blume) Lindl. in Gen. Sp. Orchid. Pl. 86. 1830.** *Grastidium salaccense* Blume in Bijdr. Fl. Ned. Ind. 333. 1825.

Note: Epiphytic plant of golden yellow flowers with lip purple, usually growing in shady places on tree trunks in the tropical and subtropical forests at 300–1,400 m. The plant flowers in March occasionally fruits in September. The distribution of the species reported from Bhutan, China, India (Assam, Arunachal Pradesh, Meghalaya, Mizoram, Sikkim, Tripura), and Nepal.

Specimen studied: Patalgiri to Todi river (596 m), VNS & BS 116834 (ASSAM); other localities includes Nabokgre, VNS & BS 118271 (ASSAM); Tura top, GP 225247 (ASSAM).

20.19. ***Dendrobium tortile*** **A.Cunn. in Gard. Chron. 797. 1847.**

Note: Epiphytic plant of flowers pink to mauve, scented, lips usually white with a delicate lining of the basic flower, petals and sepal twisted, recorded growing on moss-covered tree trunks in tropical forests. It flowers in May. The species are rare in the Nokrek biosphere reserve (Deori et al. 2009). Distribution mainly recorded from Bangladesh, India (Andaman Islands, Meghalaya), Malaysia, Myanmar, Thailand, Laos, and Vietnam.[The *D. tortile* reported as extinct because of its collection from Andamans in 1890 (Balakrishnana 1976), and no more collection after that, but reported by Deori (2009) after a gap of century from the Nokrek hills in Meghalaya. The growth of the species is similar to *D. nobile*, but differs in having petals and sepals twisted].

Specimen studied: Western range of Nokrek hills, Deori 116269 (ASSAM).

20.20. ***Dendrobium transparens*** **Wall. ex Lindl. in Gen. Sp. Orchid. Pl. 79. 1830.**

Note: Epiphytic plant species having white flowers tinged purplish-rose towards the tip, two to three in number, fragrant, recorded on tree trunks in tropical and subtropical forests at 600–1,300 m. It flowers in April–June, and the fruiting period is July–August. The species is rare in Nokrek as well as in Meghalaya and recorded for the first time from Garo district. Distribution widely recorded from Bhutan, Bangladesh, India (Arunachal Pradesh, Assam, Manipur, Mizoram, Meghalaya, Nagaland, Sikkim), Myanmar, and Nepal.

Specimen studied: Beyond Sisubibra, VNS & BS 116706 (ASSAM).

21. ***Dendrolirium*** **Blume**

The genus is represented by 12 species (http://www.

plantsoftheworldonline.org/) distributed from southern China to tropical Asia and three species in NBR.

Key to species

1a. Epiphytic plants with creeping rhizomes .... 1. *D. ferrugineum*

1b. Epiphytic or lithophytic plants without creeping rhizomes 2

2a. Flowering twigs including pedicels, sepals and ovary densely tomentose ..... 2. *D. fasiopetalum*

2b. Flowering twigs not densely tomentose, flowers bright orange ..... 3. *D. ornatum*

21.1. ***Dendrobium ferrugineum*** **(Lindl.) A.N.Rao in Bull. Arunachal Forest Res. 26: 103. 2010.***Eria ferruginea* Lindl. in Edwards's Bot. Reg. 25: t. 35. 1839.

Note: Epiphytic plant with creeping rhizome and pale white flower with a pink lip, grows on tree trunks in tropical and subtropical forests at 700–1,200 m. The flowering of the plant has been recorded in May–June. The species is rare in Nokrek as well as in Meghalaya state. Distribution of the species recorded from Bhutan, India (Assam, Arunachal Pradesh, Meghalaya), Myanmar.

Specimen studied: Sabogre, VNS & BS 118275 (ASSAM).

21.2. ***Dendrolirium lasiopetalum*** **(Willd.) S.C.Chen & J.J.Wood. in Fl. China 25: 351. 2009.** *Eria lasiopetala* (Willd.) Ormerod. in Opera Bot. 124: 22. 1995. *Aerides lasiopetala* Willd. in Sp. Pl., ed. 4, 4: 130. 1805. **(Image 17)**

Note: Epiphytic, occasionally, lithophytic species of plant found to be having white to yellow cottony hairy flowering twigs. The plant recorded growing on tree trunks along the riverside and moss-laden rocks in subtropical forests. The flowering period is between April and May, however fruiting recorded in August. This species is rare in the study area, common in the state of Meghalaya. Distribution widely recorded from Bhutan, Cambodia, China, India (Arunachal Pradesh, Assam, Manipur, Meghalaya, Nagaland, Sikkim), Laos, Myanmar, Nepal, Thailand, and Vietnam.

Specimen studied: Rongrengiri, VNS & BS 118280 (ASSAM).

21.3. ***Dendrolirium ornatum*** **Blume in Bijdr. Fl. Ned. Ind. 345. 1825.** *Eria ornata* (Blume) Lindl. in Gen. Sp. Orchid. Pl. 66. 1830.

Note: Epiphytic plant of bright orange flowers grows on tree trunks in shady places as well as in open areas of subtropical forests. It flowers in March–April. The species is rare in Nokrek hills, and its wide distribution is recorded from Borneo, India (Assam, Meghalaya, Sikkim), Malaysia, Sumatra, and Thailand.

Specimen studied: Way to Nabogre, VNS & BS 118277 (ASSAM).

22. *Dienia* Lindl.

The genus comprises six species (http://www.plantsoftheworldonline.org/) distributed in tropical and subtropical belts of southeastern Asian countries, one species in Meghalaya, and one species in NBR.

22.1. ***Dienia ophrydis*** **(J.Köenig) Seidenf. & Ormerod in Contr. Orchid Fl. Thailand 13: 18. 1997.***Epidendrum ophrydis* J.Köenig in A.J.Retzius, Observ. Bot. 6: 46. 1791.

Note: Usually terrestrial plants of purplish-red to greenish-yellow flowers growing in moist places along streamsides, sometimes epiphytic on tree trunks. Its flowering period is between June–August and fruiting in September–December. The species is recorded rarely in Nokrek hills, although common in the state of Meghalaya, but recorded for the first time from the Garo district. The wide distribution of this plant species is recorded from Australia, Bhutan, Cambodia, China, India (Meghalaya, Mizoram), Indonesia, Japan, Laos, Malaysia, Myanmar, Nepal, New Guinea, Philippines, Sri Lanka, Thailand, and Vietnam.

Note: The species can be easily identified based on unique flowers, which are always facing downwards, tepals curving inwards and lip with a typically large and deep lamina cavity.

Specimen studied: Way to Tura Peak, MKVR 63974 (ASSAM).

23. *Diplomeris* D.Don

The genus comprises of three species (http://www.plantsoftheworldonline.org/) distributed in southeastern Asian countries; one species from Meghalaya, and one species in NBR.

23.1. ***Diplomeris pulchella*** **D.Don in Prodr. Fl. Nepal. 26. 1825.**

Note: Terrestrial plant species were recorded growing in the primary forest in shaded humus-covered soil between the elevations of 200–800 m in the study area. Flowering was recorded between August and November. Distribution widely recorded from India (Arunachal Pradesh, Meghalaya), Nepal, Myanmar.

Specimen studied: Tura forest, RNDe 17145 (ASSAM).

24. *Eria* Lindl.

The genus is represented by 51 species (http://www.

plantsoftheworldonline.org/)distributed in tropical to the alpine climate in the world and one species in NBR.

24.1. ***Eria javanica*** **(Sw.) Blume in Rumphia 2: 23. 1836.** *Dendrobium javanicum* Sw. in Neues J. Bot. 1(1): 96. 1805.

Note: Lithophytic as well as epiphytic plants of fragrant white flowers growing on tree trunks in shady places as well as in open areas at 300–1,200 m. The flowering of the plant has been recorded in September–October. The species is rare in the Nokrek biosphere reserve. Distribution widely recorded from Bhutan, China, India (Assam, Meghalaya, Sikkim), Indonesia, Laos, Malaysia, Myanmar, Nepal, New Guinea, Philippines, and Thailand.

Specimen studied: NBR, near Rongrengiri (265 m), VNS & BS 118222 (ASSAM).

25. *Eriodes* Rolfe

The genus is represented by one species (http://www.theplantlist.org/) distributed and endemic to Southern and southeastern Asia, one species from Meghalaya, and one species in NBR.

25.1. ***Eriodes barbata*** **(Lindl.) Rolfe in Orchid Rev. 23: 326. 1915.***Tainia barbata* Lindl. in Gard. Chron. 68. 1857.

Note: Terrestrial plant of fragrant yellow flowers with red stripes grows along with grasses in tropical as well as in the subtropical forests at 600–1,200 m elevation in the study area. Distribution of the species recorded from China, India (Meghalaya, Mizoram), Myanmar, Thailand, and Vietnam.

Specimen studied: Nokrek hills, VNS & BS 114654 (ASSAM).

26. *Eulophia* R.Br. ex Lindl.

The genus is represented by 207 species (http://www.theplantlist.org/) distributed in tropical and subtropical regions of Asia and Africa (Srivastava 2004), 22 species reported from India (Bhattacharjee 1984), five species from Meghalaya.

26.1. ***Eulophia graminea*** **Lindl. in Gen. Sp. Orchid. Pl. 182. 1833.**

Note: Terrestrial plant of greenish flowers and veins dark green, white lips with purplish-red lamellae, growing in grassy places in open areas in the subtropical forests at 900–1,400 m. Flowering starts in April and continues till May, and the fruiting period is between May and June. Distribution of the species recorded from Bhutan, China, India (Assam, Arunachal Pradesh, Meghalaya), Indonesia, Japan, Laos, Malaysia, Myanmar, Nepal, Singapore, Sri Lanka, Thailand, and Vietnam.

Specimen studied: Nokrek hills, SDS 53021 (ASSAM).

27. *Gastrochilus* D.Don

The genus is represented by 64 species (http://www.plantsoftheworldonline.org/) distributed in the World, 12 species in India (Gogoi et al. 2009), nine species in Meghalaya (Kataki 1986), and two species in NBR.

Key to species

1a. The upper surface of epichile papillose; sepals and petals yellow with reddish-brown blotches .... 1. *G. calceolaris*

1b. The upper surface of epichile glabrous; sepals and petals light yellow with purplish-brown blotches a purple line around the sac ..... 2. *G. obliquus*

27.1. ***Gastrochilus calceolaris*** **(Buch.-Ham ex Sm.) D.Don in Prodr. Fl. Nepal. 32. 1825.** *Aerides calceolaris* Buch.-Ham. ex Sm. in A.Rees, Cycl. 39(1): No. 11. 1818.

Note: Epiphytic plant of pale green flowers having large reddish-brown spots grows on tree trunks in dense forests of tropical and subtropical regions between the elevations of 350–1,000 m. This species of the plant usually flowers in March and continues to have flowers till the end of April. The status in the study area is occasional and the distribution of the species reported from Bhutan, China, India (Arunachal Pradesh, Meghalaya, Sikkim), Nepal, Myanmar, and Thailand.

Specimen studied: Patalgiri, VNS & BS118273A (ASSAM).

27.2. ***Gastrochilus obliquus*** **(Lindl.) Kuntze in Revis. Gen. Pl. 2:661. 1891.** *Saccolabium obliquum* Lindl. in Gen. Sp. Orchid. Pl. 223. 1833.

Key to Varieties

1a. Sepals and petals densely spotted with bright red ..... 2a. var. *suavis*

1b. Sepals and petals with brownish-purple dots ..... 2b. var. *obliquus*

27.2a. ***Gastrochilus obliquus*** **var. *obliquus* in Wu & Hong. Fl. China 25: 1–570. 2009. (Image 18)**.

Note: A pendent epiphytic plant having a yellow flower with brownish-purple spots, and lip white with a patch of yellow with brown spots at the apex and column pink, grows in the tropical region of the study area. It flowers from October to December. Distribution recorded from northeastern India.

27.2b. ***Gastrochilus obliquus*** **var. *suavis* (Seidenf.) Z.H.Tsi. in Guihaia 16: 141. 1996.** *Gastrochilus suavis* Seidenf. in Opera Bot. 95. 298. 1988.

Image 18. *Gastrochilus obliquus* var *obliquus.*

Image 19. *Goodyera procera.*

Note: A pendent epiphytic plant having white flowers spotted with reddish-purple, pale yellow on the outer side, and lip white with a purple edge, and column purple, grows in both the tropical and subtropical region of the study area. It flowers October–December. The plant is rare in the study area and recorded only from the Sabogre region having a small population. Distribution recorded from northeastern India.

28. *Geodorum* Jackson

The genus comprises 12 species (http://www.theplantlist.org) distributed in tropical and subtropical environment (Gogoi et al. 2012), one species from Meghalaya, and one species in NBR.

28.1. ***Geodorum densiflorum* (Lam.) Schltr. in Repert. Spec. Nov. Regni Veg. Beih. 4. 259. 1919.** *Limodorum densiflorum* Lam. in Encycl. 3. 516. 1792.

Note: Terrestrial plant species enclosed by scarious sheaths having a white flower with yellow and purple marking, grows in dense as well as in open places of forest margins in tropical and subtropical forests at 450–1,100 m elevations. The flowering of the plant can be seen from April to May, however, fruiting can be seen from June to July. The species is widely distributed in Bhutan, China, India (Arunachal Pradesh, Meghalaya, Sikkim), Java, India, Myanmar, Nepal, and Thailand.

Specimen studied: Nokrek core forest, GK Deka 20423 (ASSAM).

29. *Goodyera* R.Br.

The genuscomprises 99 species (http://www.theplantlist.org) widely distributed in the tropical and subtropical environment across the world, six species from Meghalaya, and one species in NBR.

29.1. ***Goodyera procera* (Ker Gawl.) Hook. in Exot. Fl. 1: t. 39. 1823.***Neottia procera* Ker Gawl. in Bot. Reg. 8. t. 639. 1822. **(Image 19)**.

Note: Terrestrial plants with white flowers recorded growing along the forest borders in shaded moist soil especially near streams and rivers at 800–1,200 m elevation in the study area. Flowering can be seen in August, fruiting starts in September, and continues till the end of November. Distribution reported from Bhutan,

China, India (Arunachal Pradesh, Meghalaya, Sikkim, Assam, Nagaland, Mizoram, Tripura), India, Myanmar, Nepal, and Thailand.

Specimen studied: Nabokgre forest, VNS & BS 118276 (ASSAM); other localities includes Mandalgiri, BS, VNS & BKS 118544 (ASSAM); NokrekReserve, GK Deka 10115 (ASSAM).

30. *Habenaria* Willd.

The genus is comprised of 844 species (http://www.theplantlist.org) in the world, eight species from Meghalaya (Kataki 1986), and three species in NBR.

Key to species

1a. Lateral lobes of lip broad, rhombic or suborbicular, apical; margin serrate ..... 1 *H. dentata*

1b. Lateral lobes of lip narrow, not as above; margin never serrate 2

2a. Leaves 2–5, crowded above the base of stem, bright-green, conspicuously pale yellow margins .. .. 3. *H. marginata*

2b. Leaves 2 or 3, pale-green, not pale yellow at the margin ..... 2. *H. khasiana*

30.1. ***Habenaria dentata* (Sw.) Schltr. in Repert. Spec. Nov. Regni Veg. Beih. 4. 125. 1919.** *Orchis dentata* Sw. in Kongl. Vetensk. Acad. Nya Handl. 21. 207. 1800**.**

Note: Terrestrial plant of three leaves with white flowers having green veins; plant populations grows along the forest borders in shaded moist soil especially near streams and rivers at 800–1,200 m elevation. It flowers in September and bears fruit till October. Distribution reported from Bhutan, India (Arunachal Pradesh, Meghalaya, Sikkim, Assam, Nagaland, Mizoram, Tripura), Nepal, Bhutan, Myanmar, and Thailand.

Specimen studied: Nokrek Peak, MKVR 63928 (ASSAM).

30.2. ***Habenaria khasiana* Hook.f. in Brit. India. 6. 151. 1890.**

Note: Terrestrial plants with yellow flowers growing along the forest borders in shaded moist soil especially near streams and rivers at 1,000–1,400 m elevations. Flowering was recorded from July till August. It is rare in Nokrek, and distribution is widely reported from India (Meghalaya, Manipur, Mizoram) and Thailand.

Specimen studied: Way to Balphakram, MKV Rao 64082 (ASSAM); other locality include Tura forests, Balakrishnan42761 (ASSAM).

30.3. ***Habenaria marginata* Colebr. in W.J.Hooker, Exot. Fl. t. 136. 1824.**

Note: Terrestrial plants with yellow flowers growing along the forest borders in shaded moist soil especially near streams and rivers at 800–1,100 m elevations. It flowers between October and December. Distribution of the species recorded from India (throughout northeastern states), Bhutan, China, Myanmar, Nepal, and Thailand.

Specimen studied: Way to Baghmara from Tura, DB Deb 29138 (ASSAM).

31. *Herminium* R.Br.

The genus is comprised of 22 species (http://www.theplantlist.org) distributed in Europe and Asia, five species in Indian Himalaya, one species in Meghalaya, and one species in NBR.

31.1. ***Herminium lanceum* (Thunb. ex Sw.) Vuijk in Blumea 11. 228. 1961.** *Ophrys lancea* Thunb. ex Sw. in Kongl. Vetensk. Acad. Nya Handl. 21. 223. 1800.

Note: Terrestrial erect plant with pale green flowers grows along with the grasses in slopes at 900–1,450 m elevation in the study area. The plant starts flowering in June till August, and fruits start in August till November. The distribution has been reported from China, India (Arunachal Pradesh, Meghalaya, Sikkim, Assam, Nagaland, Mizoram, Tripura), Myanmar, Nepal, and Thailand.

Specimen studied: Nokrek hills, MKV Rao 63928A (ASSAM).

32. *Herpysma* Lindl.

The genus is represented by 1 species (http://www.theplantlist.org) endemic to Asia, one species from Meghalaya, and one species in NBR.

32.1. ***Herpysma longicaulis* Lindl. in Gen. Sp. Orchid. Pl. 506. 1840.**

Note: Terrestrial plant of white flowers tinged with orangish-red to pink grows along with the grasses in slopes at 900–1,450 m elevation. Flowering can be seen in April, however, fruiting can be recorded from September to November. It is rare in the biosphere reserve. Widely distributed in China, India (Meghalaya, Sikkim), Myanmar, and Thailand.

Specimen studied: Niengamandalgiri, VNS & BS 116896A (ASSAM).

33. *Liparis* L.C.Rich.

The genus comprises about 431 species (http://www.theplantlist.org) widely distributed in the tropical,

subtropical and temperate environment across the World; 260 species in tropical Asia (Singh 2015); 45 species in India (Gogoi et al. 2012); 17 species in Meghalaya (Kataki 1986), and seven species in NBR.

Key to species

1a. Leaves of the plant coriaceous and conduplicate; rachis not flattened 1
1b. Leaves otherwise; laterally flattened spike-like rachis, subtended by distichously arranged and basally imbricate bracts 4
2a. Plant with 1 leaf ..... 2. *L. cespitosa*
2b. Plant with 2 or more leaves 2
3a Plant tiny, pseudobulbs 1–1.5 cm .... 3. *L. delicatula*
3b Plant with pseudobulbs more than 1.5 cm long ..... 5. *L. nervosa*
4a. Plant with densely tufted tiny pseudobulbs; inflorescence laxly few flowered ..... 4. *L. luteola*
4b. Plant with long pseudobulbs; inflorescence densely many flowered 5
5a. Lip broader than long; scape broadly winged ..... 6. *L. stricklandia*
5b. Lip longer than broad; scape not winged 6
6a. Plant with 1 leaf ..... 1. *L. bootanensis*
6b. Plant with 2 or more leaves ..... 7. *L. viridiflora*

33.1. ***Liparis bootanensis*** **Griff. In Not. Pl. Asiat. 3. 278. 1851.**

Note:An epiphytic species grows on tree trunks in tropical and subtropical forests at 450–1,400 m elevation in shady areas. Flowering and fruiting can be seen between July and November. This plant species is rare in the study area. The distribution of the species is widely reported from Bhutan, China, India (throughout the regions), Nepal, Myanmar, Thailand, and India.

Specimen studied: Way to Baghmara, MKV Rao 53394 (ASSAM).

33.2. ***Liparis cespitosa*** **(Lam.) Lindl. Bot. Reg. 11. t. 882. 1825.** *Epidendrum caespitosum* Lam. in Encyl. 1. 187. 1783.

Note: Small epiphytic plant one-leaved with yellow flowers, grows on tree trunks in tropical and subtropical forests at 300–1,000 m elevation in the study area. Flowering has been recorded in August. Its occurrence in Nokrek is rare, however, the distribution of the species is reported from Bhutan, China, India (throughout the regions), Nepal, and India.

Specimen studied: Way to Sasatgiri, MKV Rao 53322A (ASSAM).

33.3. ***Liparis delicatula*** **Hook.f. in Fl. Brit. India. 5. 705. 1890.**

Note: Plant epiphytic with two leaves and greenish-white flowers grows on tree trunks in tropical and subtropical forests at 700–1,200 m. It flowers in August till the end of September. The plant is rare in the Nokrek hills. Distribution of the species is reported from Bhutan, China, India (Arunachal Pradesh, Meghalaya, Sikkim), and Nepal.

Specimen studied: Way to Sasatgiri, MKV Rao 53329 (ASSAM).

33.4. ***Liparis luteola*** **Lindl. in Gen. Sp. Orchid. Pl. 32. 1830.**

Note: Plant epiphytic with white flowers having ochre yellow. This species grows on tree trunks in tropical and subtropical forests at 700–1,200 m elevations. Flowering was recorded in September, and fruiting was seen between October and November. The plant is rare in the Nokrek range. Wide distribution reported from India (Arunachal Pradesh, Assam, Meghalaya, Sikkim), Myanmar, and Thailand.

Specimen studied: Nabokgre area, VNS & BS 118272; other locality include Simsangre to 15 km inside biosphere, VNS & BS 116790 (ASSAM).

33.5. ***Liparis nervosa*** **(Thunb.) Lindl. in Gen. Sp. Orchid. Pl. 26. 1830.** *Ophrys nervosa* Thunb. in J.A.Murray, Syst. Veg. ed. 14. 814. 1784.

Note: Terrestrial as well as epiphytic plant with purple flowers usually growing on tree trunks as well as in moist places on tree trunks in tropical and subtropical forests at 300–1,000 m. Its flowering was recorded in June–July. The population of this species is very low in Nokrek hills. Wide distribution of the species is reported from Bhutan, China, India (Arunachal Pradesh, Assam, Meghalaya, and Sikkim), Malaysia, and Thailand. Collected voucher: Way to Baghmara, MKVR 53324.

33.6. ***Liparis stricklandiana*** **Rchb.f. in Gard. Chron. n.s., 13. 232. 1880.**

Note: Epiphytic plant of two leaves and ovoid clustered pseudobulbs. The plant bears yellowish flowers in September and can flower till December. This species grows on tree trunks in tropical and subtropical forests at 200–1,100 m and its occurrence in Nokrek hills is rare. Distribution of this species reported from Bhutan, China, and India (Assam, Meghalaya, Arunachal Pradesh).

Specimen studied: Way to Chandigre, VNS & BS114798 (ASSAM).

33.7. ***Liparis viridiflora*** **(Blume) Lindl. in Gen Sp. Orchid. Pl. 31. 1830.** *Malaxis viridiflora* Blume in Bijdr. Fl. Ned. Ind. 392. 1825.

Note: Epiphytic or lithophytic plant, greenish yellow flowers recorded growing in tropical and subtropical forests at 400–1,200 m. It usually flowers from September till November and is very common in NBR. Wide distribution reported from Bhutan, China, India (throughout northeastern states), Java, Sri Lanka, and Vietnam.

Specimen studied: Niengmandalgiri, VNS & BS118211 (ASSAM); other localities include Patalgiri, VNS & BS118274 (ASSAM); along Simsanggiri, VNS & BS 114647 (ASSAM).

34. *Luisia* Gaud.

The genus is represented by 40 species (http://www.theplantlist.org) widely distributed in Asia and Australia, 16 species in India (Gogoi et al. 2012), five species in Meghalaya (Kataki 1986), and one species in NBR.

34.1. ***Luisia tristis*** **(G.Forst.) Hook.f. in Fl. Brit. India, 6. 25. 1890.** *Epidendrum triste* G.Forst. in Fl. Ins. Austr. 60. 1786**.**

Note:Epiphytic plant with yellowish-brown tinge and petals deeply purple growing on tree trunks in tropical and subtropical forests at 250–1,400 m elevation in the study area. The plant flowers from April to the end of June and the population is scarce in the Nokrek biosphere reserve. Wide distribution of the species recorded from Bangladesh, India (Arunachal Pradesh, Meghalaya, Sikkim, West Bengal), Malaysia, Sri Lanka, and Vietnam.

Specimen studied:Way to Sabokgre, VNS & BS 118278 (ASSAM).

35. *Micropera* Lindl.

The genus comprises of 21 species (http://www.theplantlist.org) widely distributed in tropical and subtropical environment across the world (Lucksom 2007), five species in India (Kataki 1986), three species in Meghalaya, and three species in NBR.

Key to species

1a. Inflorescence peduncle very short, flowers pale pink 2

1b. Inflorescence peduncle not very short, flowers brightly pink ..... 3. *M. rostrata*

2a. Stem pendent; flowers less than 1 cm across .. .. 1. *M. mannii*

2b. Stems erect; flowers more than 1 cm across ..... 2. *M. obtusa*

35.1. ***Micropera mannii*** **(Hook.f.) T.Tang & Wang in Acta Phytotax. Sin. 1: 94. 1951.***Sarochilus mannii* Hook.f. in Fl. Brit. India 6: 36. 1890.

Note: Epiphytic plant clothed with sheaths of fallen leaves and inflorescence with pale purple to white flowers grows on tree trunks in tropical and subtropical forests at 350–1,450 m elevation in the study area. Flowering occurs in June–July and the plant is rare in Nokrek and Tura hills. Distribution reported from Bhutan, India (Assam, Meghalaya, Sikkim), and Thailand.

Specimen studied: Ningmandalgre to Simsangre, VNS & BS116887 (ASSAM).

35.2. ***Micropera obtusa*** **(Lindl.) T.Tang & Wang in Acta Phytotax. Sin. 1. 94. 1951.** *Camarotis obtusa* Lindl. in Edward's Bot. Reg. 30 (Misc.). 73. 1844.

Note: Epiphytic creeping plant of pale purple to white flowers, found on trunks of trees in tropical and subtropical forests at 500–1,200 m elevation in the study area. Its flowering starts in June and ends in August. The population study revealed its occurrence is rare in the NBR. The wide distribution of the species is recorded from China, India (Arunachal Pradesh, Sikkim and Meghalaya), Myanmar, and Thailand.

Specimen studied: Nokrek range, MKVR 64112 (ASSAM).

35.3. ***Micropera rostrata*** **(Roxb.) N.P.Balakr. in J. Bombay Nat. Hist. Soc. 67. 66. 1970.***Aerides rostrata* Roxb. in Fl. Ind. ed. 1832, 3. 474. 1832.

Note:A plant epiphytic with pale purple or pink flowers grows on tree trunks in tropical and subtropical forests at 500–1,400 m elevation in the study area. This species flowers between May and June. The species is distributed occasionally in the Nokrek hills, however, wide distribution of the plant population is reported from China, India (Arunachal Pradesh, Meghalaya, Sikkim), and Thailand.

Specimen studied: Niengamandalgiri, VNS & BS 116887 (ASSAM).

36. *Mycaranthes* Blume

The genus is represented by 36 species (http://www.plantsoftheworldonline.org/) distributed from southcentral China to tropical Asia and one species in NBR.

36.1. ***Mycaranthes floribunda*** **(D.Don) S.C.Chen & J.J.Wood in Fl. China 25: 348. 2009.** *Dendrobium floribundum* D.Don in Prodr. Fl. Nepal. 34. 1825. *Eria paniculata* Lindl. in N.Wall., Pl. Asiat. Rar. 1: 32. 1830.

Note:Epiphytic as well as lithophytic plant recorded to have pale yellowish-green flowers with brownish-purple blotches on column and lip callus white. The plant recorded growing on tree trunks in shady places of tropical and subtropical forests at 750 –1,250 m elevation in the study area. It flowers between June and July. It is rare in the NBR and reported as new for the Garo Mountains of Meghalaya. Distribution widely recorded from Bhutan, India (Arunachal Pradesh, Assam, Manipur, Meghalaya, Nagaland, Sikkim), Cambodia, Laos, Myanmar, Nepal, and Thailand.

Specimen studied: Daribokgre, VNS & BS 114814 (ASSAM).

37. *Neogyna* Rchb.f.

The genus is represented by one species (http://www.theplantlist.org) endemic to Asia, one species from Meghalaya, and one species in NBR.

37.1. ***Neogyna gardneriana* (Lindl.) Rchb.f. in Bot. Zeitung (Berlin) 10. 931. 1852.** *Coelogyne gardneria* Lindl. N.Wallich, Pl. Asiat. Rar. 1. 33. 1830. **(Image 20).**

Note: Epiphytic plant of two leaves and yellow keeled white flowers usually grows on tree trunks in tropical and subtropical forests between the elevations of 500–1,400 m in the study area. It flowers between June and September. The population status is rare and endangered in the Nokrek hills. Wide distribution of the species reported from China, India (Arunachal Pradesh, Assam, Meghalaya, Sikkim), and Thailand.

Specimen studied: Nokrek hills, RN De s. n. (ASSAM).

38. *Oberonia* Lindl.

This genus is represented by 298 species (http://www.plantsoftheworldonline.org) widely distributed in tropical Asia and Australia (Bose et al. 1999), 50 species in India (Gogoi et al. 2012), 15 species in Meghalaya, and two species in NBR.

Key to species

1a. Lips distinctly 3-lobed ..... 1. *O. acaulis*

1b. Lips 2-lobed ..... 2. *rufilabris*

38.1. ***Oberonia acaulis* Griff. Not. Pl. Asiat. 3. 275. 1851. (Image 21)**

Note: Plant epiphyte of yellowish flowers rusty brown at the centre, grows on moss-laden tree trunks in tropical and subtropical forests at 600–1,200 m elevation in the study area. The flowering of the plant can be seen in July to August. It is rare in the Nokrek hills. Distribution of the species recorded from Cambodia, China, India (Arunachal Pradesh, Assam, Meghalaya, Sikkim), and Vietnam.

Specimen studied: Tura peak, MKV Rao 22530 (ASSAM).

38.2. ***Oberonia rufilabris* Lindl. in Sert. Orchid. t. 8.A. 1838.**

Note:Epiphytic plant of reddish-brown flowers found on huge tall trees in shady places in tropical and subtropical forests at 700–1,200 m elevation in the study area. The plant flowers in September and October. It is rare in the Nokrek hills. Distribution of this species reported from Cambodia, China, India (Sikkim, Meghalaya), Nepal, Thailand, and Vietnam.

Specimen studied: Tura hilltop, G Panigrahi 22537 (ASSAM).

39. *Odontochilus* Blume

The genus is represented by 56 species (http://www.plantsoftheworldonline.org) widely distributed in southern and southeastern Asia, seven species in India (Misra 2007), one species in Meghalaya, and one species in NBR.

39.1. ***Odontochilus lanceolatus* (Lindl.) Blume in Coll. Orchid. 80. 1859.***Anoectochilus lanceolatus* Lindl. in Gen. Sp. Orchid. Pl. 499. 1840.

Note: Terrestrial plant of flowers pale green tinged with brown and lip yellow, recorded growing in the primary forests in shaded humus soil, often on rotting wood between 1000 and 1400m elevations in the study area. Distribution recorded from India (Arunachal Pradesh, Assam, Sikkim, Meghalaya, Nagaland, Manipur, Mizoram, Sikkim) and Thailand.

Specimen studied: Nokrek hills, RN De 17142 (ASSAM).

40. *Otochilus* Lindl.

This genus is represented by five species (http://www.theplantlist.org) widely distributed throughout the world, four species in Meghalaya (Kataki 1986), and one species in NBR.

40.1. ***Otochilus albus* Lindl. in Gen. Sp. Orchid. Pl. 35. 1830.**

Note: Terrestrial plants with white flowers were recorded growing in the subtropical forests along forest margins at 1,000–1,480 m elevation in the study area. The flowering of this plant species could be seen between December and February. The wide distribution of the species reported from Bhutan, China, India (Sikkim, Arunachal Pradesh, Assam, Meghalaya, Nagaland, Manipur, Mizoram, Tripura), Nepal, Myanmar, Thailand,

and Malaysia.

Specimen studied: Nokrek hills, RN De 17193 (ASSAM).

41. *Paphiopedilum* Pfitzer

The genus commonly referred to as Lady's or Venus Slipper Orchid' comprised of 109 species (http://www.plantsoftheworldonline.org/) widely distributed in southern and southeastern Asia, and Philippines, nine species in India (Parveen et al. 2012), three species from Meghalaya (Kataki 1986), and three species in NBR.

Key to species

1a. Leaves elliptic-oblong, green with dark green motting on the ventral; dorsal sepal broadly ovate, greenish-white; petals with black warts; staminode semilunate ..... 3. *P. venustum*

1b. Leaves oblong, uniformly green; dorsal sepal orbicular, greenish-purple with blotches or dots; petals smooth, lacking wart; staminode quadrate or sub-quadrate 2

2a. Bracts half or more than the length of the pedicelled ovary; dorsal sepal purple blotched; petals not crisped ..... 2. *P. insigne*

2b. Bracts quarter or less than the length of the pedicelled ovary; dorsal sepal purple-spotted; petals crisped ..... 1. *P. hirsutissimum*

41.1. ***Paphiopedilum hirsutissimum* (Lindl. ex Hook.) Stein in Orchid.- Buch. 470. 1892.***Cypripedium hirsutissimum* Lindl. ex Hook. in Bot. Mag. 83. t. 4990. 1857.

Note:Terrestrial plant with greenish-purple flowers growing in the tropical and subtropical forests along forest margins and the well-drained area at 750–1,400 m elevations. Flowering was recorded in April and May. The wide distribution of the species recorded from India (Sikkim, Arunachal Pradesh, Meghalaya, Mizoram, Nagaland), Bhutan, China, Laos, Thailand, and Vietnam.

41.2. ***Paphiopedilum insigne* (Wall. ex Lindl.) Pfitzer in Jahrb. Wiss. Bot. 19. 159. 1888**. *Cypripedium insigne* Wall. ex Lindl. in Coll. Bot. t. 32. 1824. **(Image 22)**

Note: Terrestrial plant with a purplish white flowers growing in the tropical and subtropical forests along forest margins at 750–1,400 m elevation. It flowers between November and February. Wide distribution of the species recorded from India (Sikkim, Meghalaya), Bhutan, and China.

Specimen studied: Nokrek hills, RN De 17199 (ASSAM).

41.3. ***Paphiopedilum venustum* (Wall.ex Sims) Pfitzer in Jahrb. Wiss. Bot. 19. 165.** *Cypripedium venustum* Wall. ex Sims. in Bot. Mag. 47. t. 2129. 1820.

Note: Terrestrial plant with white flowers having maroon-black warts and yellow lip growing in primary forests, in marshy or wet streamsides in shaded places at 700–1,400 m elevations. Flowering was recorded between March and May. Wide distribution of the species recorded from India (Sikkim, Arunachal Pradesh, Meghalaya), Bhutan, China, Nepal, and Sri Lanka.

Specimen studied: Nokrek hills, RN De 17169 (ASSAM).

42. *Papilionanthe* Schltr.

The genus is represented by 10 species (http://www.plantsoftheworldonline.org/) widely distributed in the tropical, subtropical and temperate environments throughout the world, four species in India (Gogoi et al. 2009); three species in Meghalaya (Kataki 1986), and one species in NBR.

42.1. ***Papilionanthe teres* (Roxb.) Schltr. in Orchis 9. 78. 1915.***Dendrobium teres* Roxb. in Fl. Ind. ed. 1832. 3. 485. **(Image 23)**

Note:Climbing epiphytic plant with white flowers tinged with pink and yellowish to brown spur, inflorescence 2–5 flowers, grows primarily on tree trunks at 500–1,000 m elevations in tropical and subtropical forests. The flowering of this plant species is usually seen between May and June. This species found to be rare and threatened in Nokrek forests due to human ornamental needs. Wide distribution of the species recorded from India (throughout northeastern states), Bangladesh, Bhutan, Laos, Myanmar, Nepal, Thailand, and Vietnam.

43. *Peristylus* Benth. & Hook.f.

The genus comprises 103 species (http://www.plantsoftheworldonline.org/) widely distributed in Indo-Malesian regions (Goaverts 2008), 29 species in India (Tiwari et al. 2009), seven species from Meghalaya, and two species in NBR.

Key to species

1a. In flowering twigs, petal and lip are pure white ..... 1. *P. constrictus*

1b. In flowering twigs, petals and lip are yellowish-green, or creamy white ..... 2. *P. goodyroides*

43.1. ***Peristylus constrictus* (Lindl.) Lindl. in Gen. Sp. Orchid. Pl. 300. 1835.** *Herminium constrictum* Lindl. in Edwards Bot. Reg. 18. t. 1499. 1832.

Note: Terrestrial plant species with brown petals and

Image 20. *Neogyna gardneriana.*

Image 21. *Oberonia acaulis.*

Image 22. *Paphiopedilum insigne.*

Image 23. *Papilionanthe teres.*

white flowering twigs usually found to be growing in the subtropical forest between the elevations range of 1,200–1,500 m. The flowering season starts in June and ends in August. Wide distribution of species recorded from India (Assam, Meghalaya, Arunachal Pradesh, Sikkim), Bhutan, Cambodia, China, Myanmar, Nepal, Thailand, and Vietnam.

Specimen studied: Tura near Chithokgre-Chandmari, MKVR 64464 (ASSAM).

43.2. ***Peristylus goodyeroides*** **(D.Don) Lindl. in Gen. Sp. Orchid. Pl. 299. 1835.** *Habenaria goodyroides* D.Don in Prodr. Fl. Nepal. 25. 1825.

Note: Terrestrial plants with brown petals and white

flowers usually growing in the subtropical forest of 1,200–1,500 m elevation. The flowering season starts in June and ends in September. Wide distribution of species recorded from India (Assam, Meghalaya, Arunachal Pradesh, Sikkim), Bhutan, Cambodia, China, Myanmar, Nepal, Thailand, and Vietnam.

Specimen studied: Tura Peak, DB Deb 29220 (ASSAM).

44. *Phalaenopsis* Blume

The genus comprises 75 species (http://www.plantsoftheworldonline.org/) in the World, one species from Meghalaya, and two species in NBR.

Key to species

1a. Mid-lobe of lip anchor-shaped; lateral lobes of lip producing a raised tooth along the leading edge; petals conspicuously narrower than sepals; callus triseriate; sepals and petals pale yellow with dark brown spots and bars; lip slightly saccate at base created by folding ..... 2. *P. mannii*

1b. Mid-lobe of lip not anchor-shaped; lateral lobes of lip and petals not as above; callus biseriate; yellow flowers with dark maroon lip; lip not as above ..... 1. *P. difformis*

44.1. ***Phalaenopsis difformis* (Wall. ex Lindl.) Kocyan & Schuit. in Phytotaxa 161. 67. 2014.** *Aerides difformis* Wall. ex Lindl. in Gen. Sp. Orchid. Pl. 242. 1833.

Note: Epiphytic plant with stem covered by leaf sheaths and yellow flowers with dark maroon lip. It grows on tree trunks in tropical and subtropical forests at 350–1,400 m elevation in the study area and rare in the Nokrek hills. The flowering of the plant occurs in June–July. Wide distribution of the species reported from China, India (Assam, Arunachal Pradesh, Meghalaya, Mizoram, Nagaland, Tripura), Myanmar, Nepal, Thailand, and Vietnam.

Specimen studied: Nangalbibra, MKVR 64564 (ASSAM).

44.2. ***Phalaenopsis mannii* Rchb.f. in Gard. Chron. 1871. 902. 1871.** *Phalaenopsis boxallii* Rchb.f. in Gard. Chron. n.s. 19. 274. 1883. *Polychilos mannii* (Rchb.f.) in Malayan Nat. J. 36. 24. 1982.

Note: Epiphytic plants with many-flowered habitat on tree trunks of *Quercus* and *Castanopsis* trees; flowers yellowish with dark spots, growing in subtropical environment at 950–1,500 m elevations. The flowering of this species is usually seen in April and May. The species have been recorded wild from India (Assam, Meghalaya, West Bengal), China, Bhutan, Myanmar, Nepal, and Vietnam. This species is critically endangering at a faster rate in Nokrek BR.

Specimen studied: Darungiri RF, MKVR 61429 (ASSAM).

45. *Pholidota* Lindl. ex Hook.

The genus consists of 41 species (http://www.plantsoftheworldonline.org/) across the World, 10 species in India (Gogoi et al. 2009), seven species and two varieties in Meghalaya (Kataki 1986), and three species in NBR.

Key to species

1a. Pseudobulbs superposed; leaves linear-lanceolate; inflorescence few-flowered..1. *P. articulata*

1b. Pseudobulbs caespitose, leaves oblong-lanceolate, inflorescence long, densely flowered 2

2a. Mature leaves thick textured, coriaceous; floral bracts with many, dense fine veins ..... 2. *P. imbricata*

2b. Mature leaves thin textured, coriaceous; floral bracts with few coarse veins.....3. *P. pallida*

45.1. ***Pholidota articulata* Lindl. in Gen. Sp. Orchid. Pl. 38. 1830. (Image 24).**

Note: Epiphytic herbaceous plants with pseudobulbs, leaves usually two, and inflorescence always arise from new pseudobulb at the apex. Flowers white, slightly tinged with red, usually seen flowering in May to June and fruiting appears in December. Plants are seen growing on tree trunks of *Litsea* species in tropical and subtropical forests of Nokrek hills at 700–1,400 m. Wide distribution of this species is reported from India (Arunachal Pradesh, Assam, Meghalaya, Mizoram, Sikkim), Bhutan, Cambodia, China, Indonesia, Malaysia, Myanmar, Nepal, Thailand, and Vietnam.

Specimen studied:Daribokgre along Simsang river, VNS & BS 116698 (ASSAM); other localities includeRongrengiri, MKVR 59475 (ASSAM); Rongrengiri, DB Deb 29222 (ASSAM); Darugiri Tura road, MKVR 61363 (ASSAM).

45.2. ***Pholidota imbricata* Lindl.in Exot. Fl. 2. t. 138. 1825. (Image 25)**

Note: Epiphytic plants with creeping rhizomes and densely flowered inflorescence. Flowers usually white or slightly red-tinged, seen blooming in August and fruits start appearing in November. The luxuriant population of this species is found between the elevation range of 1,000–2,500 m in tropical and subtropical forests. Wide distribution of this species is reported from India (Arunachal Pradesh, Assam, Meghalaya, Nagaland, Manipur, Mizoram, Tripura), Australia, Bhutan,

Cambodia, China, Indonesia, Laos, Malaysia, Myanmar, Nepal, Pakistan, Thailand, and Vietnam.

Specimen studied: Rongrenggiri, MKVR 59456 (ASSAM).

45.3. ***Pholidota pallida*** **Lindl. In Edward's Bot. Reg. 21. t. 1777. 1835**.

Note: Epiphytic, occasionally lithophytes herbaceous plant species having papery leaflets and white flowering twigs. This species usually grows on tree trunks of *Terminallia bellerica, Lithocarpus dealbatus* and *Prunus* species between the elevation ranges of 800–2,000 m in tropical and subtropical forests. Flowers appear on tree trunks in May and June. This species is endangering in Nokrek hills at a faster rate due to illicit extraction for medicinal and ornamental purposes, however, a wide distribution of this species is reported from India (throughout northeastern states), Bhutan, China, Laos, Nepal, Thailand, and Vietnam.

Specimen studied: Nienga-Mandalgiri, VNS & BS 116891 (ASSAM); other locality include Rongrengiri, MKVR 53307.

46. *Pinalia* Lindl.

The genus is represented by 173 species (http://www.plantsoftheworldonline.org/) distributed in tropical and subtropical Asia to south-west Pacific and four species in NBR.

Key to species

1a. Pseudobulbs narrowly cylindric .... 2. *P. bractescens*

1b. Pseudobulbs ovoid, oblong or somewhat flattened or stem-like 2

2a. Inflorescence globose, capitate, 0.4-1 cm across ..... 3. *P. pumila*

2b. Inflorescence otherwise 3

3a. Inflorescence dense spike; flowers white to straw coloured with a slight purple tinge ..... 4. *P. spicata*

3b. Inflorescence lax spike; flowers yellowish green ..... 1. *P. apertiflora*

46.1. ***Pinalia apertiflora*** **(Summerh.) A.N.Rao in Bull. Arunachal Forest Res. 26: 103. 2010**. *Eria apertiflora* Summerh. in Bull. Misc. Inform. Kew 9. 1929.

Note: Tufted epiphytic plant of yellowish-green flowers growing on moss-covered branches of large trees in wet mixed subtropical forests at an elevation of 1000 m. Its initial flowering starts in January and continues till August. The species is rare in Nokrek and is first recorded from the Garo district of the Meghalaya. Distribution widely recorded from Bhutan, India (Assam, Arunachal Pradesh, Meghalaya), Myanmar, Thailand, and Vietnam.

Specimen studied: Nokrek Peak, VNS & BS 116610 (ASSAM).

Note: The species is allied to *E. bipunctata* Lindl., but can be distinguished by larger yellowish flower than that of smaller white flower.

46.2. ***Pinalia bractescens*** **(Lindl.) Kuntze in Revis. Gen. Pl. 2: 679. 1891.***Eria bractescens* Lindl. in Edwards's Bot. Reg. 27 (Misc.): 18. 1841. **(Image 26)**

Note: Plant epiphytic on tree trunks as well as lithophytic of white flowers on moss-covered rocks. The phenology period of the plant is between July and August. The species is common in Nokrek hills as well as in Meghalaya. The plant is native to Java and the Indian Peninsula, also extends its distribution in India (Arunachal Pradesh, Meghalaya, Sikkim), Nepal, and Thailand.

Specimen studied: Nokrek Peak, VNS & BS 116713 (ASSAM); other locality include Rongrenggri, GKD 35704 (ASSAM).

46.3. ***Pinalia pumila*** **(Lindl.) Kuntze in Revis. Gen. Pl. 2: 679. 1891.** *Eria pumila* Lindl. in Gen. Sp. Orchid. Pl. 68. 1830.

Note: Epiphytic plant species having minute flowers grows on tree trunks in tropical and subtropical forests at 700–1,400 m elevation in the study area. Flowering recorded in August. Distribution of the species reported from tropical India.

Specimen studied: Sabokgre, VNS & BS 118279 (ASSAM).

46.4. ***Pinalia spicata*** **(D.Don) S.C.Chen & J.J.Wood in Fl. China 25: 354. 2009.** *Octomeria spicata* D.Don in Prodr. Fl. Nepal. 31. 1825. *Eria spicata* (D.Don) Hand.-Mazz. in Symb. Sin. 7: 1353. 1936.

Note:Epiphytic plant recorded to have white to straw coloured flowers, with a slight purple tinge, grows on tree trunks in tropical and subtropical forests at 300–1,200 m elevation in the study area. Its flowering recorded between June and August. Distribution recorded from Bhutan, India (Meghalaya, Sikkim), Myanmar.

Specimen studied: Nokrek Peak, VNS & BS 116712 (ASSAM).

Note the species is similar to *Pinalia bractescens*. The major difference between the two is that the *P. bractescens* has two leaves at the apex of the pseudobulb, larger more open acute flowers with no fragrance, while, the *E. spicata* has four near the apex, sheathed leaves, and smaller, cupped flowers with fragrance.

47. *Pleione* D.Don

The genus is comprised of 24 species (http://www.plantsoftheworldonline.org) widely distributed in southern and southeast Asia, five species from Meghalaya (Kataki 1986), and two species in NBR.

Key to species

1a. Sheaths on pseudobulb warty; pseudobulb green, mottled purplish-brown; column 3.5–4.5 cm..... 2. *P. praecox*

1b. Sheaths on pseudobulb smooth; pseudobulb green; column 1.5–2 cm ..... 1. P. *maculata*

47.1. ***Pleione maculata* (Lindl.) Lindl.& Paxton in Paxton's Fl. Gard. 2. 5. 1851.***Coelogyne maculata* Gen. Sp. Orchid. Pl. 43. 1830.

Note: Epiphytic herbs with pyriform pseudobulbs, and inflorescence appears without leaves. Flowers are solitary, fragrant, and white with a slightly purplish lip and a yellow blotch at the center. Plant populations are found on tree trunks and mossy rocks in a subtropical environment between the elevation ranges of 1,200–1,400 m. Distribution of this species reported from India (Assam, Arunachal Pradesh, Meghalaya), Bhutan, China, Myanmar, Nepal, and Thailand.

Specimen studied: On way to Nienga-Mandalgiri, MKVR 53323 (ASSAM).

47.2. ***Pleione praecox* (Sm.) D.Don in Prodr. Fl. Nepal. 37. 1825.***Epidendrum praecox* Sm. in Exot. Bot. 2. 73. 1806.

Note: Epiphytic plants with purple-brown pseudobulbs and pink flowers with a yellow callus. This species can be seen in a subtropical environment between the elevation range of 1,200–1,500 m. This plant species was located in one place only in Nokrek hill and was not collected for samples considering the conservation of species. Therefore, plant photographs were taken as a record of the occurrence of this species in Nokrek biosphere reserve. The wide distribution of this species is recorded from India (Assam, Arunachal Pradesh, Meghalaya, Sikkim), Bangladesh, Bhutan, China, Laos, Myanmar, Nepal, Thailand, and Vietnam.

Specimen studied: Tura range, MKVR 53339 (ASSAM).

48. *Porpax* Lindl.

The genus is represented by 53 species (http://www.plantsoftheworldonline.org/) distributed mainly in tropical Africa, tropical and subtropical Asia to the south-west Pacific, one species in Meghalaya, and one species in NBR.

48.1 ***Porpax muscicola* (Lindl.) Schuit., Y.P. Ng & H.A. Pedersen in Bot. J. Linn. Soc. 186: 200. 2018**. *Dendrobium muscicola* Lindl. in Gen. Sp. Orchid. Pl. 75. 1830. *Conchidium muscicola* (Lindl.) Rauschert in Feddes Repert. 94: 444. 1983. *Eria muscicola* (Lindl.) Lindl. in J. Proc. Linn. Soc. Bot. 3: 47. 1858.

Note: Epiphytic plant species found to be growing on trees or lithophytic on rocks in evergreen broad-leaved forests in subtropical forests. Flowering can be seen between July–August and fruiting in October. This species is again extremely rare in the study area and recorded for the first time from the Garo district of Meghalaya. The distribution of the species Is widely reported from Bangladesh, Bhutan, China, India (Arunachal Pradesh, Assam, Meghalaya, Sikkim), Laos, Nepal, Myanmar, and Vietnam.

Specimen studied:On way to Balphakram near Chokpot, MKVR 53838 (ASSAM).

49. *Pteroceras* Hasselt ex Hassk.

The genus is comprised of 22 species (http://www.plantsoftheworldonline.org) widely distributed in tropical Asia, five species in India (Gogoi et al. 2012), one species in Meghalaya (Kataki 1986), and one species in NBR.

49.1 ***Pteroceras teres* (Blume) Holttum in Kew Bull. 14. 271. 1960**. *Dendrocolla teres* Blume in Bijdr. Fl. Ned. Ind. 289. 1825.

Note: Scandent epiphytic plants with light yellowish flower having several dark brown spots on petals, and also lip slightly bluish-pink with spots. This species is found flowering in June on tree trunks in tropical and subtropical forests. The altitudinal distribution of this species varies at 800–1,400 m in NBR, however, broad geographical distribution includes India (Arunachal Pradesh, Meghalaya, Sikkim), Myanmar, and Thailand. Field observation indicates the populations of this species are in the stage of critical endangerment in Nokrek due to medicinal importance and the Garos are extracting and selling in the local market as a source of income.

Specimen studied: Daribokgre along Simsang river, VNS & BS 116694 (ASSAM).

50. *Rhynchostylis* Blume

This genus is comprised of five species (http://www.plantsoftheworldonline.org)widely distributed in the Indo-Malayan regions to the Philippines (Bora & Kumar 2003), two species in India (Gogoi et al. 2009), one species in Meghalaya (Kataki 1986), and one species in NBR.

Image 24. *Pholidota articulata.*

Image 25. *Pholidota imbricata.*

Image 26. *Rhynchostylis retusa.*

Image 27. *Spathoglottis pubescens.*

50.1 ***Rhynchostylis retusa*** **(L.) Blume in Bijdr. Fl. Ned. Ind. 286. 1825.***Epidendrum retusum* L. in Sp. Pl. 953. 1753. **(Image 26)**

Note: Epiphytic herbs with densely flowered pendulous inflorescence growing on tree trunks. Flowers white with pink spots and purplish lip. This species prefers tropical and subtropical environments for its luxuriant growth and mostly occurs between the elevations of 500–1,500 m throughout Nokrek forest belts. The flowering of this species is usually recorded in April and May. This species is very common in NBR and its distribution from India (throughout the region, West Bengal, Jammu & Kashmir, Himachal Pradesh, Uttarakhand), is reported from throughout Asian countries.

Specimen studied: Sisubibra, VNS & BS 116697 (ASSAM); other locality include Rongrengiri, *MKV Rao* 59455 (ASSAM).

51. *Satyrium* Sw.

The genus is represented by 90 species (http://www.plantsoftheworldonline.org) widely distributed in tropical to alpine climate across the world, four species in India, one species from Meghalaya (Kataki 1986), and one species in NBR.

51.1. ***Satyrium nepalense* D.Don in Prodr. Fl. Nepal. 26. 1825.**

Note: Terrestrial herbs with tubers and purplish-rose flowers were found to be growing along forest margins between the elevation ranges of 1,000–3,000 m. The flowering of the plants can be seen in September and October. This species is endemic to Asia and wide distribution of this species reported from India (Arunachal Pradesh, Meghalaya, Sikkim), Bhutan, China, Myanmar, Nepal, and Sri Lanka.

Specimen studied: Tura Peak, DB Deb 4894 (ASSAM).

52. *Schoenorchis* Blume

The genus comprises 28 species (http://www.plantsoftheworldonline.org) across the world, 10 species in Himalaya regions (Kataki 1986), one species in Meghalaya (Kataki 1986), and one species in NBR.

52.1. ***Schoenorchis gemmata* (Lindl.) J.J.Sm. in Natuurk. Tijdschr. Ned. Indie 72.100.1912.***Saccolabium gemmatum* Lindl. in Edward's Bot. Reg. 24(Misc.). 50. 1838.

Note: Pendulous epiphytic plants with conduplicate leaves and purplish-red flowers with white apices prefer to grow on moss deposited trees in tropical and subtropical environments at 100–1,500 m. Flowering can be seen between April and June. This species is rare in Nokrek hills, however, wide distributionof this plant species is reported from India (Assam, Arunachal Pradesh, Meghalaya, Sikkim, West Bengal), Bhutan, China, Cambodia, Laos, Myanmar, Nepal, Thailand, and Vietnam.

Specimen studied: Daribokgre along Simsang river, VNS & BS 116693 (ASSAM).

53. *Spathoglottis* Blume

The genus is comprised of 41 species (http://www.plantsoftheworldonline.org) distributed in the diverse habitat of India, Philippines, southeastern Asia, New Guinea, New Caledonia, Solomon Islands, Borneo, and Australia (Singh 2015), two species from Meghalaya, and two species in NBR.

Key to species

1a. Flowers purplish, drooping, 2.5–3.5 cm across ... . 1. *S. plicata*

1b. Flowers golden yellow, erect, 2–2.5 cm across ... . 2. *S. pubescens*

53.1. ***Spathoglottis plicata* Blume in Bijdr. Fl. Ned. Ind. 401.1825.**

Note: Terrestrial herbs with ovoid pseudobulbs and purplish flowers were found to be growing in grasslands and along forest margins between the elevation ranges of 800–1,800 m. The flowering of the plants can be seen in August in Nokrek hills and is very rare in occurrence. Wide distribution of this species is reported from India (Arunachal Pradesh, Meghalaya), Australia, China, Indonesia, Japan, Malaysia, Pacific Islands, New Guinea, Philippines, Sri Lanka, Thailand, and Vietnam.

Specimen studied: Daribokgre vill. On way towards Khalakgre forest area, VNS & BS s.n. (ASSAM).

53.2. ***Spathoglottis pubescens* Lindl. in Gen. Sp. Orchid. Pl. 120. 1831. (Image 27)**

Note:Terrestrial herbs with dorsoventrally compressed pseudobulbs and yellow flowers with violet spotted lips. Flowers of this species can be seen in August and September. This species grows on hill slopes in the subtropical forest at 1,000–1,400 m in the study area of Nokrek forests. Wide distribution reported from India (Assam, Arunachal Pradesh, Meghalaya, Sikkim), Cambodia, China, Laos, Myanmar, Thailand, and Vietnam.

Specimen studied:On way to Balphakram, MKVR s.n. (ASSAM 53320).

This genus is represented by 24 species (http://www.theplantlist.org) widely distributed in the tropical and subtropical regions.

54. *Thelasis* Blume

The genus is comprised of 27 species (http://www.plantsoftheworldonline.org) distributed in tropical Asia and islands of Pacific Ocean (Singh 2015), four species in India (Gogoi et al. 2009), four species in Meghalaya (Gogoi et al. 2012), and one species in NBR.

54.1. ***Thelasis longifolia* Hook.f. in Fl. Brit. India 6.87. 1890.**

Note: Small epiphytic plants having conical-shaped pseudobulb and white coloured many flowered inflorescences. Flowering in plants appears in early summer and can also be seen till November. It prefers

to grow on tree trunks in tropical and subtropical forests between the elevation range of 500–1,400 m. It is rare in Nokrek Hills. Distribution of this species is reported from India (Assam, Meghalaya, Sikkim, West Bengal) and Bhutan.

Specimen studied: Rongrengiri, DB Deb 29220 (ASSAM).

55. *Thunia* Rchb.f.

This genus is represented by five species (http://www.plantsoftheworldonline.org) widely distributed in southern and southeastern Asian countries, four species in India (Kataki 1986), one species in Meghalaya (Kataki 1986), and one species in NBR.

55.1. ***Thunia alba* (Lindl.) Rchb.f. in Bot. Zeitung (Berlin) 10:764. 1852.(Image 28)**

Note: Plant epiphytic as well as terrestrial having large white flowers and yellow or orange dotted leaves. Flowers appear between March and May. It grows on tree trunks of *Mangifera indica* and *Schima wallichii* in tropical and subtropical forests. This species is occasionally found in the Nokrek biosphere reserve, but its wide distribution is reported from India (Assam, Arunachal Pradesh, Meghalaya), Bhutan, China, Nepal, Indonesia, Malaysia, Myanmar, Nepal, Thailand, and Vietnam.

Specimen studied: On way to Tura Peak, MKVR 53312 (ASSAM).

56. *Vanda* W.Jones ex R.Br.

The genus is comprised of 81 species (http://www.plantsoftheworldonline.org) widely distributed in tropical Asia to New Guinea and Australia, 14 species in India, six species in Meghalaya, and two species in NBR.

Key to species

1a. Inflorescence longer than the leaves, many-flowered; flowers blue ..... 1. *V. coerulea*

1b. Inflorescence shorter than leaves, few-flowered; flowers greenish-purple ..... 2. *V. cristata*

56.1. ***Vanda coerulea* Griff. ex Lindl. in Edward's Bot. Reg. 33. t. 30. 1847. (Image 29)**

Note: Epiphytic plants with many-flowered inflorescences. Flowering appears from September to October and flower size ranges 6–9 cm across with sepals and petals tessellated.This plant species is growing between the elevation ranges 750–1,400 m in Nokrek hills and usually appears on trunks of tall trees in humid places of tropical and subtropical forests. The wide distribution of this species is reported from India (Assam, Meghalaya, Arunachal Pradesh), Myanmar, and Thailand.

Image 28. *Thunia alba.*

Image 29. *Vanda caerulea.*

Specimen studied: Way to Chandigiri, BS 114797 (ASSAM).

56.2. ***Vanda cristata* Lindl. in Gen. Sp. Orchid. Pl. 216. 1833.**

Note: Epiphytic plants with creamy yellow coloured flowers. Lip usually found with spur. Flowers appear in May–June and grow on tree trunks of moist forest places. This species is rare in the NBR, however, its wide distribution is reported from India (Assam, Meghalaya, Sikkim; Orissa), Bhutan, Nepal, and Vietnam.

Specimen studied: Tura top, G Panigrahi 22523 (ASSAM).

CONCLUSION

Nokrek Biosphere Reserves exhibit a great diversity of both epiphytic and terrestrial orchids. A total of 56 genera having 127 species of orchids recorded from the tropical, subtropical and temperate forest ecosystems of locally called 'Achik land', which represents a remnant habitat of a unique class of Garo communities. While studying and scrutiny of published literature from Meghalaya on orchids, it has been observed that several species such as *Stereochilus hirtus* Lindl., *Smitianandia micrantha* (Lindl.) Holtt., *Taeniophyllum retrospiculutum* (King & Pantl.) King & Pantl., *Tainia minor* Hook.f., *Thrixspermum musiflorum* A.S.Rao & J.Joseph, *Trichotosia pulvinata* (Lindl.) Kranzlin, *Uncifera acuminata* Lindl., and *Vandopsis undulata* (Lindl.) J.J.Smith reported in the literature could not be located from the Nokrek hills after repeated search, nor could their herbarium samples be traced in renowned herbarium of India. Most of the orchids are indigenous to Nokrek hill which is now becoming threatened due to their application in the local traditional system of herbal medicine, therefore, there is an urgent need for conservation of this unique group of plant species to safeguard their existence in nature.

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COMMUNICATION

Morphological assessment and partial genome sequencing inferred from matK and rbcL genes of the plant *Tacca chantrieri*

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Abstract: *Tacca chantrieri* is a monotypic perennial plant belonging to the family Taccaceae. It is listed as an endangered species by different authors. The plant was found in Thorangtlang Wildlife Sanctuary, a protected area in Lunglei District, Mizoram. Although there is a record of its existence from the forests of Mizoram, there are no detailed studies based on morphology, partial or whole genome sequencing. Plant samples collected from Thorangtlang Wildlife Sanctuary were used for morphological assessment and partial genome sequencing of *mat*K and *rbc*L genes. This study provides information useful in making conservation decisions.

Keywords: Black Bat Flower, Endangered, genetics, genomics, herb, morphology, northeastern India.

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Author contributons: PCL and EVN conducted field studies, collected data, and wrote the manuscript. FL, VR, and JLP all gave valuable inputs. PCV analysed the data.

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INTRODUCTION

Tacca chantrieri Andre, or Black Bat Flower, belongs to the family Taccaceae (Fu & Jin 1992). The bractea of this particular species is very similar to that of bats, hence the common name Bat Flower. In local language, Mizo, it is called 'Thialkhasuak'. It is a perennial herb with underground rhizomes distributed mainly in tropical regions of Asia (Drenth 1972, 1976; Ding & Larsen 2000). The family Taccaceae tends to be divergent in the number of genera and species. According to Linn & Kuntz 2010, it is represented by two genera and about 13 species. Taccaceae comprises 10 species of pan-tropical distribution (Zhang & Li 2008) and comprised of one genus and 11 species (Ding et al. 2000). They are commonly found in the forest understorey, and a majority species are rare in the wild.

Black Bat Flower has a unique shape which mimics bats, with broad wings and numerous long dangling filaments with rich maroon black or deep purple color (Charoensub et al. 2008). It exhibits a low germination rate and can survive only under specific environmental conditions. As a result of its rapidly disappearing natural habitats and low germination rate, the species has become an endangered plant (Fu & Jin 1992).

Globally there are 10 species representing this genus, with nine confined to the Indo-Malaysian region. Beyond this region, only two species are found; an inclusive species: *T. leontopetaloides* distributed mainly from the Indo-Malaysian region to tropical Africa and the other species *T. parkeri*, the only native to South America. There are five species presently occurring in Malaysia, viz., *T. leontopetaloides, T. integrifolia, T. palmata, T. chantrieri*, and *T. bibracteata*. In both peninsular and eastern Malaysia *T. leontopetaloides, T. integrifolia,* and *T. palmata* are found whereas *T. chantrieri* is found only in the northern parts of peninsular Malaysia while *T. bibracteata* , a very rare plant is only found in Sarawak (Saw 1993).

Tacca chantrieri was first reported from Assam in 2015 as a new record from India (Baruah et al. 2015). Morphologically, *Tacca chantrieri* resembles *Tacca khanhhoaensis* which is assessed as Critically Endangered (CR) on the IUCN Red List Categories (IUCN 2012). To date, a study on reproductive biological observation of *Tacca* is still lacking (Faegri & van der Pijl 1971; Drenth 1972; Saw 1993). Mizoram is situated in the northeastern part of India along with its sister states of Manipur, Nagaland, Tripura, Arunachal Pradesh, Assam, and Meghalaya. It is abundantly furnished with dense forests and diverse species of flora and fauna but many areas of several regions are unexplored. Although a preliminary record of the plant's existence is recorded, there are no detailed studies based on its morphology, anatomy, and partial genomic sequencing. Due to exploitation and destruction of forests, the habitat of this species has diminished. *Tacca chantrieri* exhibits improvident floral arrangement and a high reproductive structure investment, which leads to highly suitable of it for out crossing thus possessing sapromyophilous (pollination by flies where the flower mimic rotting meat) syndrome of pollination (Drenth 1972; Saw 1993).

DNA bar coding based techniques such as DNA sequencing are the most relevant and innovative techniques which can analyze the genetic linkage and evolution of plants and species identification. CBOL (Consortium for the Barcode of Life) plant-working researchers suggest that rbcL and matK (the 2-locus) combination is the standard plant barcode based on the sequence attribute or trait, levels of species differentiation, and evaluation of resiliency. A brief reflection of Maturase K Gene in plant DNA barcoding and phylogenetics (Kar et al. 2015).

MATERIALS AND METHODS

The plant sample was collected from Thorangtlang Wildlife Sanctuary at an elevation of 500–550 m, where necessary investigation of *Tacca chantrieri* was done by field observation and measurement of observable morphological features and the state of its efflorescence within the natural habitat. The research analysis was conducted between September 2017 and December 2020. *Tacca chantrieri* prefers moist, shaded brushwood habitats (Image 1A,B). Plants are 2–4 feet tall with rhizomes imperfectly cylindrical, leaves are oblong or elliptic shape with caudate apex and attenuate base in various sizes and are green in color. Petiole slightly dark brown to black. Our study reveals that *T. chantrieri* bears inflorescence from late April to September and by October to November berries are ripened. T.S. and L.S. of both stems and leaves were observed under fluorescence microscope. The exposure of the anatomical studies for exceedingly large organs or tissues require to be dissected into tiny segments for microscopic observations. Section cutting or sectioning is the most stereotypic technique of studying microscopic anatomy or histology of large specimens (Karuppaiyan & Nandini 2016). Sections were stained using the double staining method, a technique involving a mixture of two contrasting dyes (safranin and methylene blue). These procedures can be used on

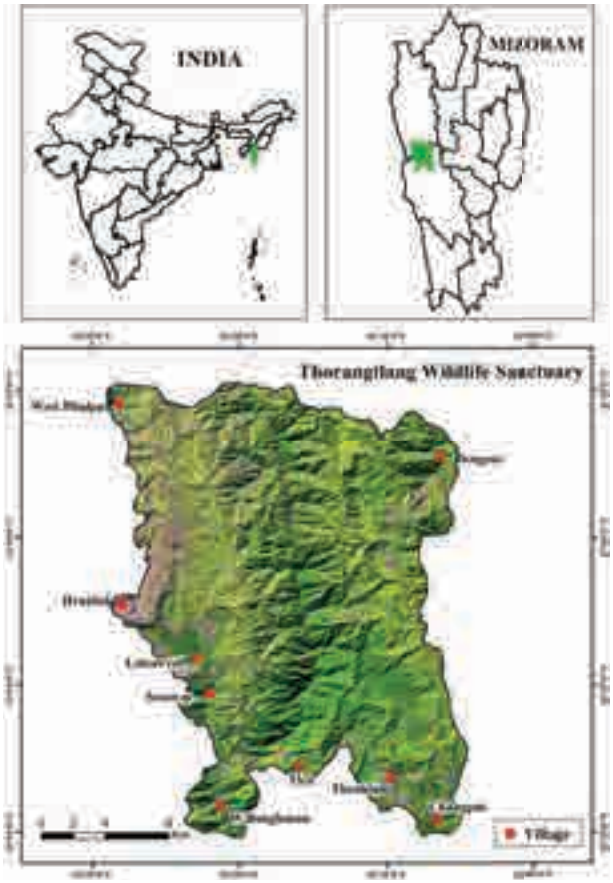

Figure 1. Study area: Thorangtlang Wildlife Sanctuary.

paraffin, paraplast, or historesin-embedded free hand and microtome sections. A section of young leaves was preserved in 70% alcohol which needs to undergo further partial genome sequencing process. Partial DNA sequencing was inferred from matK and rbcL genes. The length of DNA bands acquired from matK and rbcL genes are 635 and 675 respectively and are deposited in GenBank, NCBI with accession no MW289205 (matK) and MW289206 (rbcL).

DNA extraction, PCR amplification and sequencing

DNA isolation of the specimen was obtained from leaves and stems of *Tacca chantrieri* following the protocol recommended by White et al. (1990). For polymerase chain reaction (PCR) analysis, each DNA sample was diluted to the appropriate concentrations. A total reaction volume of 25 µl consisted of 12.5 µl Tag Master Mix (Takara), 9.5 µl of nucleus free water, 1 µl each of primers, and 1 µl of DNA sample. Maturase-K region was amplified using: Forward primer matK390F: 5'-CGATCTATTCATTCAATATTTC-3' and Reverse primer matK1326R: 5'-TCTAGCACACGAAAGTCGAAGT-3' with the following parameters; initial denaturation at 94 °C for 3 min, 35 cycles of 94 °C for 30 sec, 50 °C for 30 sec, and 72 °C for 45 sec, followed by the final elongation step at 72 °C for 7 min. RbcL region was amplified using: forward primer rbcL 1F: 5'-ATGTCACCACAAACAGAAAC-3' and reverse primer rbcL 724R: 5'-TCGCATGTACCCTGCAGTAGC-3' with the following parameters; initial denaturation at 95 °C for 4 min, followed by 35 cycles of 94 °C for 30 sec, 55 °C for 1 min, 72 °C for 1 min, followed by the final elongation step at 72 °C for 7 min (Bafeel et al. 2012).

The PCR products were electrophoresed on 0.8% (w/v) agarose gel in 1.0 x TAE buffer [containing 1 µl Safe DNA gel stain (Invitrogen, Thermo Fisher Scientific) per 20 ml of 10 gel] at 150 V for 20 minutes. The amplified PCR products were sequenced by Sanger's dideoxy method (Sanger et al. 1997) on ABI 3730XL automated sequencer (AgriGenome Labs Pvt. Ltd., Smart City Kochi, Kerala, India). Consensus sequences for contigs were trimmed and aligned using Bioedit sequence alignment editor (Hall 1999). Sequences were then compared to those in GenBank database using the BLASTn (Altschul et al. 1990) search tool for similarities. DNA sequence of matK and rbcL data of the studied species have been submitted to GenBank. The sequences were then aligned with Clustal W (Larkin et al. 2007) and the phylogenic tree was established using maximum likelihood in MEGAX. The bootstrap consensus tree inferred from 1,000 replicates was taken to represent the evolutionary history of the taxa analyzed. Branches corresponding to partitions reproduced in less than 50% bootstrap replicates were collapsed. The percentage of replicate trees in which the associated taxa clustered together in the bootstrap test (1,000 replicates) is shown next to the branches. Initial tree(s) for the heuristic search were obtained automatically by applying Neighhbor-Join and BioNJ algorithms to a matrix of pairwise distances estimated using the Tamura-Nei model, and then selecting the topology with superior log likelihood value. This analysis involved 12 nucleotide sequences.

Study Area

Thorangtlang Wildlife Sanctuary is situated about 245 km south of Aizawl, the state capital of Mizoram between 23.28°–23.19° North & 92.50°–92.62° East and 1,396 m at highest altitude falling in Lunglei District (Fig 1). The Sanctuary lies close to the Indo-Bangladesh border. It possesses both evergreen and semi-evergreen forests and its richness in wildlife is the most distinctive feature compared to other wildlife sanctuaries in the forests of Mizoram. Disastrous practices of events

like shifting cultivation and hunting from nine fringing villages leads to biotic pressure on flora and fauna.

RESULTS

Morphological and anatomical observations

Morphological evaluation was conducted primarily in its natural habitat. The morphological patterns of *Tacca chantrieri* plant was investigated intensively from September 2017 to December 2020. According to our observations, *Tacca* bears inflorescence from late April to September, and berries ripen from October to November. Plants are 2–4 feet tall, rhizomes imperfectly cylindrical, leaves oblong or elliptic shape having arcuate, reticulate, palmate, camptodromous and brochidodromous venation which measure 35–50cm x 14–20cm (Image 1E–G) and are green in color. Petiole 45–60 cm by 3–6 mm slightly dark brown to black (Image 1C). Inflorescence 2, up to 20–30 flowers comprising of involucral bracts (Image 1D).

Figure 2 depicts the schematic diagram of *Tacca chantrieri* inflorescence bearing numerous flowers along with its trailing-like filaments and leaves which resemble bats consequently giving the plant the common name Black Bat Flower. The inflorescence arrangements exhibit numerous flower stalks which spread from a common point, thus referred to as cymose umbellate inflorescence demarcated by the dark colored bracts and also consist of long trailing filamentous bracteoles. The flowers are nearly black, deep maroon or purple-red in color. The number of inflorescence per plant was two and in each of the two inflorescences 20–30 florets with around 25–30 long trailing like filaments were present. The inflorescence lasted for two to three weeks. The root of the plant is extensive and rhizomatous which is imperfectly cylindrical.

T.S. of the stem shows conductive collateral vascular bundles arranged in circular motion in which xylem protrudes towards the inner side and phloem projects outwards (Image 1K,L). The inner core mainly consists of the ground tissue. L.S. of stems of *Tacca* shows sieve tubes and sieve plate (Image 1I) T.S. of leaf shows a single layer of upper cuticle followed by epidermis which is transparent. Next to the epidermis are tightly packed rod-shaped cells known as mesophyll cells. Beneath the mesophyll cells, loosely bound spongy mesophyll cells are present. Stomatal pores (tiny pores) are present in some regions (Image 1J). The stomata present are anomocytic (Image 1M).

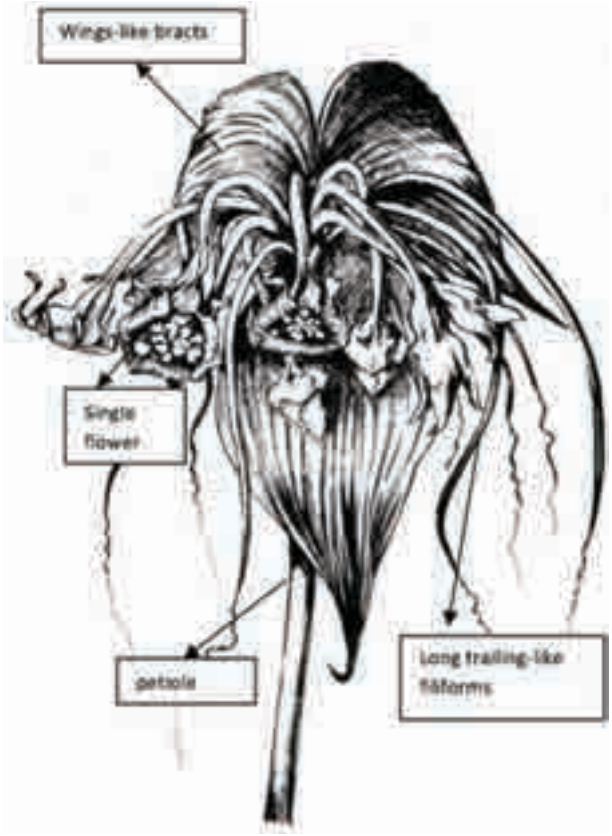

Figure 2. Schematic diagram of *Tacca chantrieri*. Illustrated by Vesper Lalrinawma.

Table 1. matK sequences.

Name of species	Accession Number
Tacca chantrieri	JQ733736
Tacca chantrieri	MH748936
Tacca reducta	MK153216
Tacca reducta	MK153205
Tacca palmata	MK153192
Tacca palmate	MK153200
Tacca bibracteata	MK153225
Trichopus sempervirens	KP083035
Tacca plantaginea	AY973842
Tacca maculate	MK153197
Tacca leontopetaloides	MK153196
Tacca leontopetaloides	MK153193
Tacca sumatrana	MK153224
Tacca havilandii	MK153210

Nucleotide analysis and Phylogeny

To construct phylogeny of major lineages, representative taxa of members from the major species

were chosen. Table 1 comprises all the taxa analyzed herein and their accession numbers.

The matK sequences of our specimen (MW289205) had 3 nucleotide differences with zero gap, from the two species of *Tacca chantieri* (JQ733736 and MH748926). The rbcL sequences (MW289206) of our specimen had 13 nucleotide differences with zero gap, from the species of *Tacca chantieri* (KX171420 and JN850578).

The evolutionary history was inferred using the maximum likelihood method and Tamura-Nei model base on the matK region (Figure 3). The final positioning for the merged sequences for the two regions (matK and rbcL) comprised of 897 base pairs.

In the phylogenetic tree (Figure 3), as expected, a close relationship between the specimens examined (MW289205 Voucher BMZU) and the two species of *Tacca chantieri* (JQ733736 and MH748926) was observed. The two species of *Tacca chantieri* (along with the specimen examined MW289205), form a distinct clade with a high support bootstrap value of 96 (Figure 3). Assessments of the two selected loci culminated in a well-supported phylogenetic tree. *T. leontopetaloides* and *T. maculata* formed the sister clade to all other Tacca species. *T. palmata, T. plantaginea* and *T. bracteata* form a clade with low support values (Figure 3). Section *Tacca* has been well supported based on the phylogeny shown by Zhang et al. (2001). This section is distinguished by its geophytic behavior, perennial leaves with decompound foliar blades, a long ascending peduncle, substantially more inflorescences, more than two inner segments, many threadlike floral bracteoles, and a low number of ovules per fruit. According to Tanaka (1954) and Li & Li (1997), the contemporary genetic diversity dispersal patterns of *Tacca chantrieri* populations are believed to be the result of a hypothetical evolutionary event involving vicariance from a single common ancestor and fragmentation of the species' historic geographic range. Genetic drift affects the genetic structure and increases differentiation among populations when populations are small and geographically and genetically distant from one another (Barrett & Kohn 1991; Ellstrand & Elam 1993). This highlights a shortage of gene flow between groups, which may be inadequate to combat genetic drift. Both morphological and phylogenetic analysis confirm that the specimen analysed (MW289205 Voucher BMZU) is identical to *Tacca chantrieri.*

DISCUSSION

The species *T. chantrieri*, though not included in the IUCN Red List, is still described by many authors as an endangered species as they are rare even in their wild habitats. *T. chantrieri* consists of several dark colored

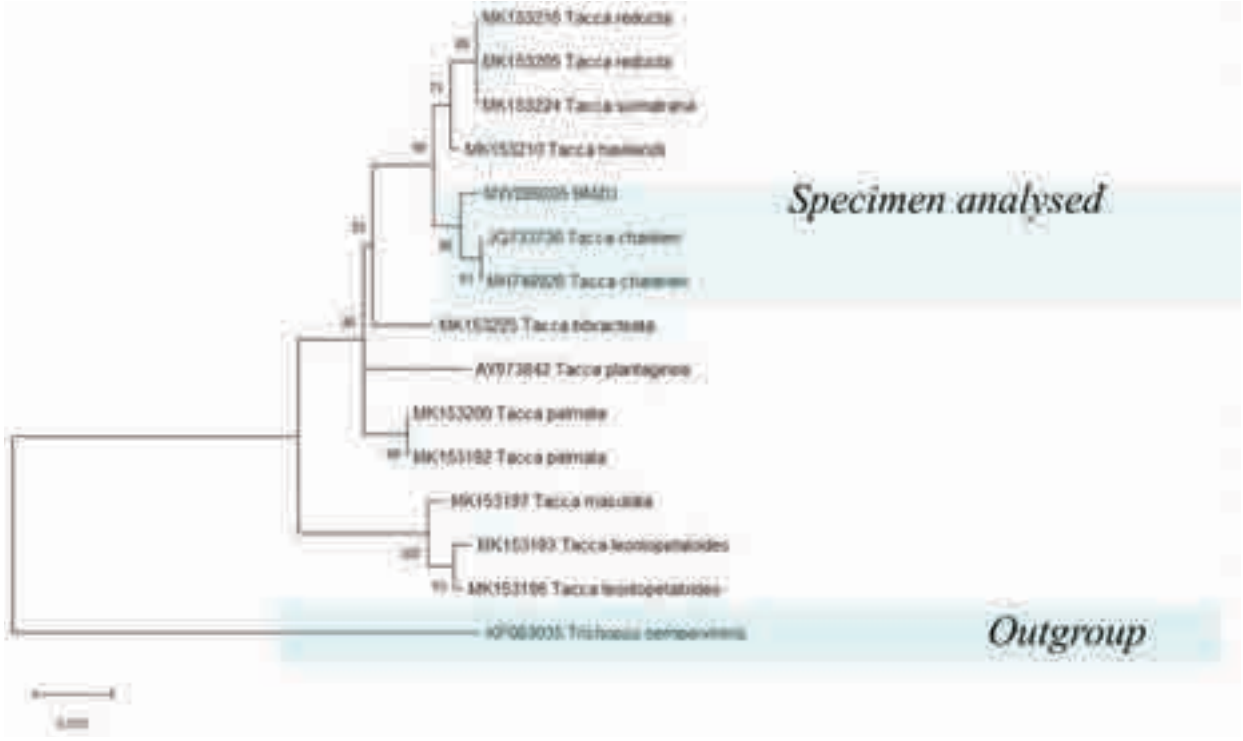

Figure 3. Phylogenetic tree.

Image 1. A,B—Habitat | C,D—Inflorescence | E–G—Leaves of *Tacca chantrieri*. © P.C. Lalbiaknii

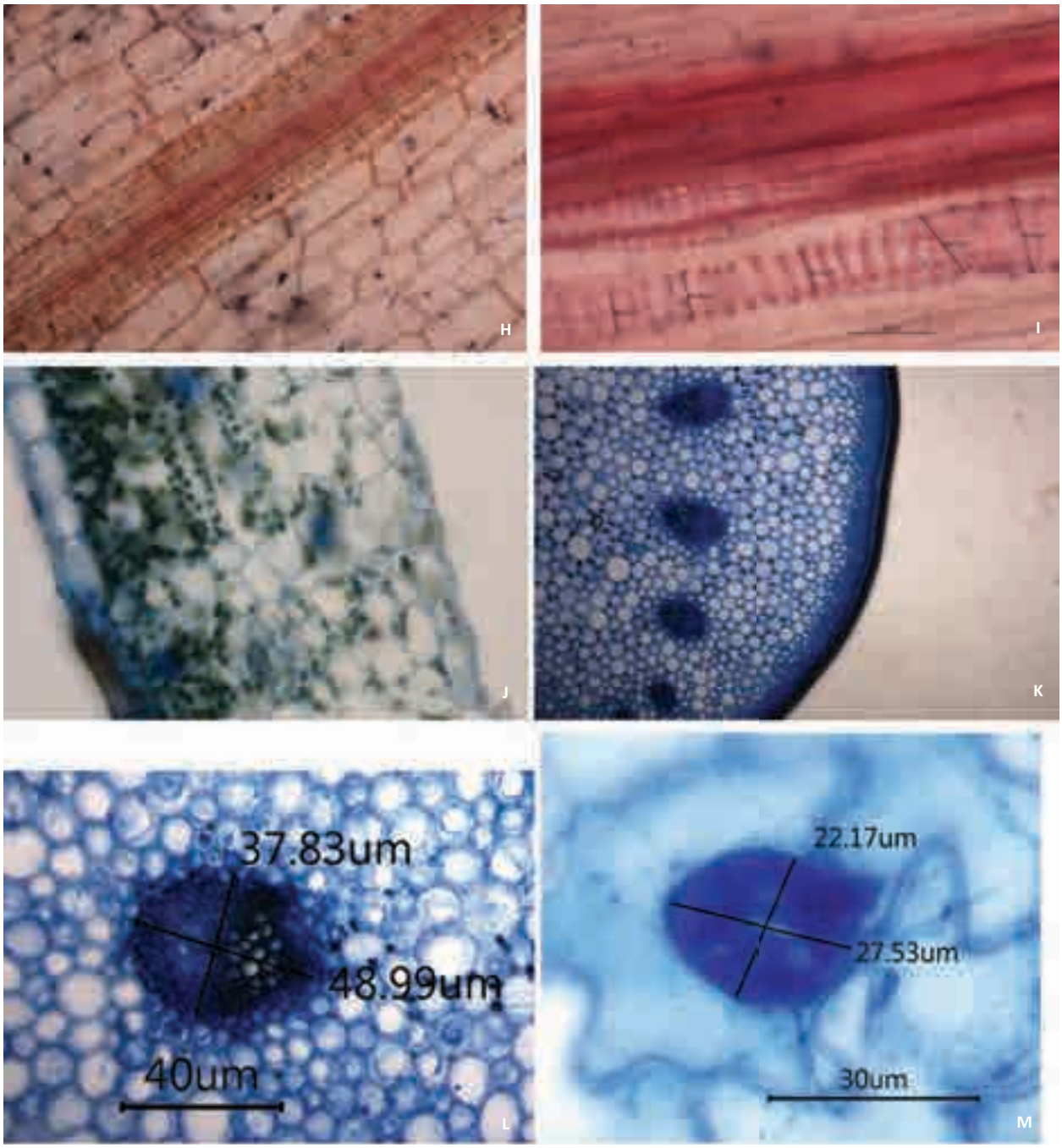

Image 1. H—L.S. of stem (40X) | I—L.S. of stem (40X) | J—T.S. of leaf (40X) | K—T.S. of stem (4X) | L—vascular bundle (40X) | M—single stomata. © P.C. Lalbiaknii

or maroon inflorescence with bracts and whisker like filiforms that makes it captivating. According to Zhang et al. (2005), it is a shade loving plant in its own natural habitat and florets are primarily self-pollinated and have several characteristics that encourage autonomous self-pollination. A potential explanation for its unusual inflorescence structure is that it aids in photosynthesis in the shady understory while also protecting the plant from herbivores. And due to the changes in the climatic conditions and landscape morphology of its native habitats it can be considered a rare, endangered or threatened species. The plant is very difficult to grow in an artificial or controlled environment, requiring specific temperature, moisture, and shade, and can take up to 11 to 12 months to germinate when cultivated by agriculturists. Hence, there is a significantly larger

potential for it to be developed as ornamental plants so as to conserve it from extinction. Apart from the species detailed, there might be many more species that are yet to be discovered in the unexplored terrains. So, it is imperative that we protect and conserve whatever species have been found regardless of their abundance and scarcity. Considering that habitat loss and overharvesting have been the primary cause of species endangerment, a central component of species recovery has been to establish a network of conservation areas and reserves that represent all the pertinent terrestrial and riparian natural communities. Species delineation provided by DNA-based techniques would provide important insights into the evolutionary biology and species diversity, but their versatility is limited in the apparent lack of multigene phylogenetic analysis. Future research in phylogenetic analysis will be critical in determining relevant perception to organise and better understand the basic similarities and differences between organisms, as well as other emergent properties of early life.

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SHORT COMMUNICATION

Conservation status of freshwater fishes reported from Tungabhadra Reservoir, Karnataka, India

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Abstract: Fishes constitute the major biomass of the aquatic ecosystem. The economy of the aquatic habitats is chiefly composed of fishes, crustaceans and molluscs inhabiting the given ecosystem. In the present investigation, an attempt was made to study the conservation status of the fishes that are naturally occurring in the Tungabhadra Reservoir located at Hospet, Vijayanagara district of Karnataka. The survey was spread across 12 months from June 2018 to May 2019. A total of 76 species, belonging to 50 genera and 20 families were recorded. As per the latest IUCN Red List, six Endangered, six Vulnerable, four Near Threatened, five Data Deficient and fifty four Least Concern fishes inhabit in TBR.

Keywords: Aquatic ecosystem, fish diversity, IUCN Red List, peninsular India, survey, Vijayanagara district.

India is endowed with vast aquatic resources possessing ecological heritage and rich biodiversity. Fishes inhabiting freshwater habitat are profoundly affected due to reduction in water flow, over fishing and increased water pollution. In order to maintain a healthy population of reservoir fisheries it is necessary to monitor water quality parameters, lake hydrobiology, periodic bioassay, and other environmental variables influencing the fish community (CIFRI 2008). Although, Tungabhadra Reservoir (TBR) is subjected to comprehensive fisheries studies, yet there is limited information available on fishes in the reservoir (Rao & Govind 1964; David et al. 1969; Govind 1969; Banerjee & Ray 1979). The TBR is located at 76.333^{0}E & 15.300^{0}N on the river Tungabhadra. It is one of the largest contributors of the river Krishna with an annual discharge of approximately 14,700 million m^3 of water at its confluence point, which holds 498m at the full reservoir level. It has an average water spread area of about 23,500 ha. The reservoir is located in northeastern Karnataka state and it supplies water to the neighbouring states. The reservoir produced 24 tonnes of fish in 1954–55 to 4,200 tonnes in 1981–82 to 25,638 metric tonnes in 2004–05. Carp seeds (Catla, Rohu and Fimbriatus) are nursed in the neighbouring fish seed farm and stocked at the rate of 4–5 million/ha until the larvae reach the fingerling size. These 70–80 mm fingerlings are stocked in the reservoir to enhance carp production.

Considering its fish diversity, a study was carried out between June 2018 and May 2019 to document fishes of TBR. The aim of this study is to understand fish diversity and explore their conservation status.

Materials and methods

The Tungabhadra Reservoir has many fish landing centres all along its periphery (Image 1). The fishes are caught using gill nets, cast nets, drag nets and giant alivi

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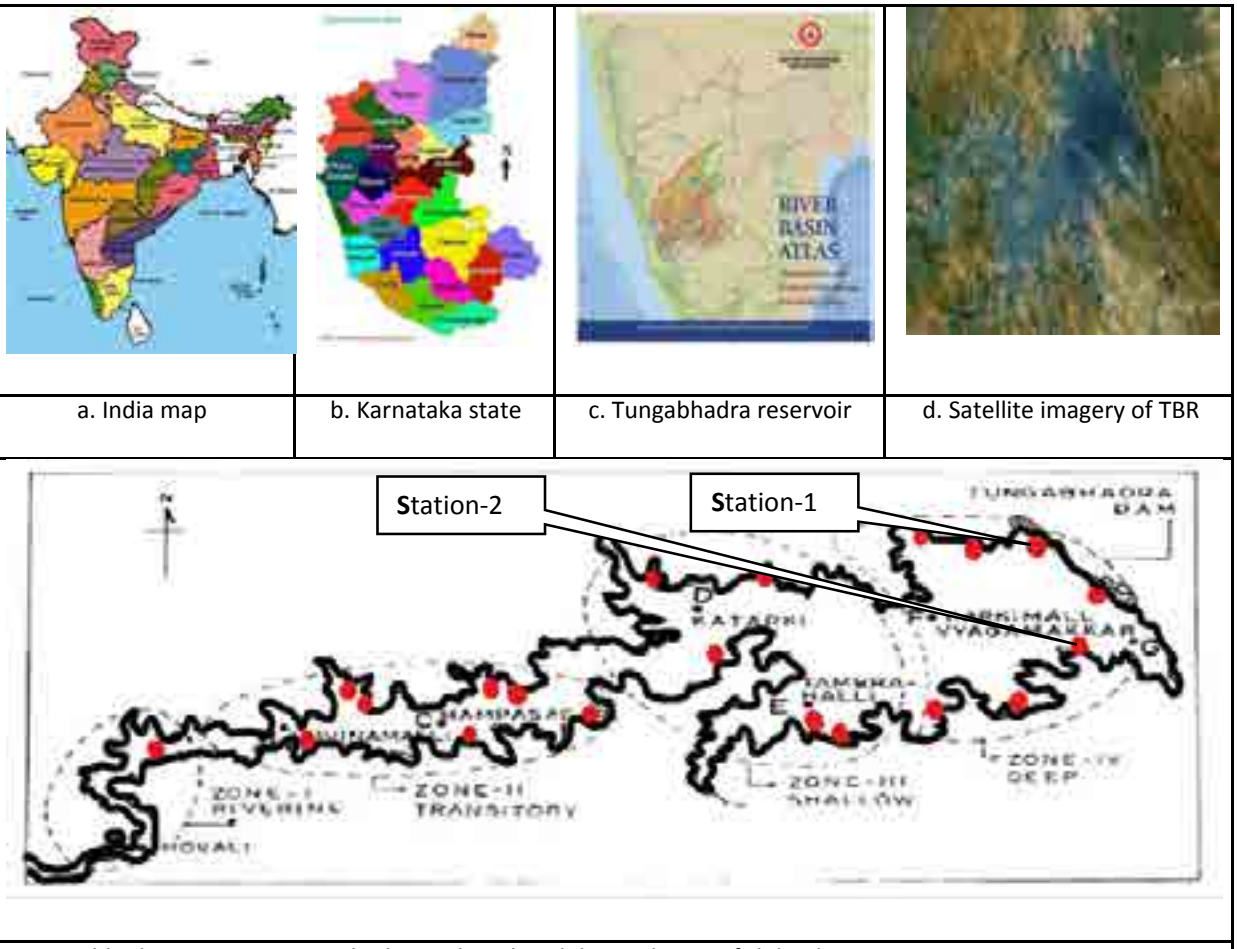

a. India map | b. Karnataka state | c. Tungabhadra reservoir | d. Satellite imagery of TBR

e. Tungabhadra reservoir water shed stretch with red dots indicating fish landing centres

Image 1. Map showing the location of Tungabhadra Reservoir (Image courtesy: Google).

seine net. The fish samples hauled during the catch at the two landing centres S-1 and S-2 in the zone-IV deep (Image 1) were collected and identified on site and others were brought to the laboratory for identification using the available taxonomic literatures (Day 1958; Jhingran 1991; Jayaram 2010) and open access fish base website (www.fishbase.org and Eschmeyer's Catalog of Fishes). Local fishermen and the faculty of the Zoology Department, Kuvempu University, Shankaraghatta and Vijayanagara Sri Krishnadevaraya University, Ballari were also consulted for fish species confirmation.

Results and Discussion

In the present investigation seventy six fishes belonging to 20 families were recorded from the reservoir. Among the recorded species, 40 species of fishes were represented from Cyprinidae family, five from Bagridae, four from Danionidae, three each from Ailiidae & Channidae, two species each belonged to Ambassidae, Balitoridae, Cobitidae, Mastacembellidae, Siluridae, & Sisoridae, and one each representative species from Anguillidae, Aplochelidae, Belonidae, Gobidae, Horabagridae, Nemachilidae, Notopteridae, Osphronemidae, & Pangassidae are depicted in Figure 1. David et al. (1974) reported that *Labeo fimbriatus, L. catla*, and *L. rohita* were part of the major fish composition in the TBR. A similar trend was observed in the present findings. It is attributed to the carp seed stocking in the reservoir on seasonal basis at the rate of 2–3 million fingerlings per hectare.

Among the species, *Cyprinus carpio* was exotic; *Labeo catla, L. fimbriatus, L. calbasu* were non-native to TBR, whereas native species such as *Cirrhinus cirrhosus, Hypselobarus jerdoni, Systomus sarana, Pethia ticto, Opsarius bendelisis, Devario aequipinnatus, Silonia childreni, Proeutropiichthys taakree, Wallago*

Table 1. IUCN Red List status of fishes encountered in Tungabhadra Reservoir during the study period.

	Family	Common name	Scientific name	Population trend	IUCN Red List (2019)
1	Ailiidae	Goongwaree Vacha	*Eutropiichthys goongwaree* Sykes, 1839	--	DD 2010
2	Ailiidae	Indian Taakree	*Proeutropiichthys taakree* (Sykes, 1839)	Decreasing	LC 2011
3	Ailiidae	White Cat Fish	*Silonia childreni* (Sykes, 1839)	Decreasing	EN 2010
4	Ambassidae	Elongate Glass Perchlet	*Chanda nama* Hamilton, 1822	Decreasing	LC 2010
5	Ambassidae	Indian Glassy Fish	*Parambassis ranga* (Hamilton, 1822)	Stable	LC 2011
6	Anguillidae	Indian Mottled Eel	*Anguilla bengalensis* (Grey, 1834)	--	NT 2019
7	Aplocheilidae	Striped Panchax	*Aplocheilus lineatus* (Valenciennes, 1846)	--	LC 2009
8	Bagridae	Giant River Cat Fish	*Sperata seenghala* (Sykes, 1839)	--	LC 2010
9	Bagridae	Giant Cat Fish	*Hemibagrus maydelli* (Rossel, 1964)	--	LC
10	Bagridae	Long-whiskered Catfish	*Sperata aor* (Hamilton, 1822)	--	LC 2011
11	Bagridae	Gangetic Mystus	*Mystus cavasius* (Hamilton, 1822)	Decreasing	LC 2009
12	Bagridae	Gogra rita	*Rita gogra* (Sykes, 1839)	Decreasing	LC2010
13	Balitoridae	Slender Stone Loach	*Balitora mysorensis* Hora, 1941	--	VU
14	Balitoridae	Dotted Loach	*Nemacheilus semiarmatus* (Day, 1867)	Stable	LC 2010
15	Belonidae	Gar Fish	*Xenentodon cancila* (Hamilton, 1822)	--	LC 2019
16	Channidae	Great Snake Head	*Channa marulius* (Hamilton, 1822)	--	LC 2009
17	Channidae	Snake-headed Murrel	*Channa striata* (Bloch, 1793)	Stable	LC 2019
18	Channidae	Spotted Snakehead	*Channa punctata* (Bloch, 1793)	Stable	LC 2019
19	Cobitidae	Zebra Loach	*Botia striata* Rao, 1920	--	EN 2011
20	Cobitidae	Common Spiny Loach	*Lepidocephalichthys thermalis* (Valenciennes, 1846)	Stable	LC 2019
21	Cyprinidae	Mola Carpet	*Amblypharyngodon mola* (Hamilton, 1822)	Stable	LC 2009
22	Cyprinidae	Catla	*Labeo catla* (Hamilton, 1822)	--	LC 2010
23	Cyprinidae	Mrigal Carp	*Cirrhinus cirrhosus* (Bloch, 1795)	Decreasing	VU 2011
24	Cyprinidae	Deccan White Carp	*Gymnostomus fulungee* (Sykes, 1839)	--	LC 2010
25	Cyprinidae	Mrigal	*Cirrhinus mrigal* (Hamilton, 1822)	Stable	LC 2010
26	Cyprinidae	Reba Carp	*Cirrhinus reba* (Hamilton, 1822)	Stable	LC 2010
27	Cyprinidae	Grass Carp	*Ctenopharyngodon idella* (Valenciennes, 1844)	--	Exotic and Not evaluated
28	Cyprinidae	Common Carp	*Cyprinus carpio* Linnaeus, 1758	--	Exotic, but globally VU 2008
29	Cyprinidae	Mullya Garra	*Garra mullya* (Skyes, 1839)	Stable	LC 2010
30	Cyprinidae	Minor Carp	*Labeo bata* (Hamilton, 1822)	--	LC 2011
31	Cyprinidae	Boga Labeo	*Labeo boga* (Hamilton, 1822)	--	LC 2010
32	Cyprinidae	Boggut Labeo	*Labeo boggut* (Sykes, 1839)	Stable	LC 2010
33	Cyprinidae	Calbasu	*Labeo calbasu* (Hamilton, 1822)	--	LC 2010
34	Cyprinidae	Finger Lipped Peninsula Carp	*Labeo fimbriatus* (Bloch, 1795)	--	LC 2011
35	Cyprinidae	Plymouth Carp	*Labeo kontius* (Jordon, 1849)	Decreasing	LC 2010
36	Cyprinidae	Pangusia Labeo	*Labeo pangusia* (Hamilton, 1822)	Decreasing	NT 2010
37	Cyprinidae	Bombay Labeo	*Labeo porcellus* (Haeckel, 1844)	Decreasing	LC 2010
38	Cyprinidae	Deccan Labeo	*Labeo potail* (Sykes, 1839)	Decreasing	EN 2011
39	Cyprinidae	Rohu	*Labeo rohita* (Hamilton, 1822)	--	LC 2010

	Family	Common name	Scientific name	Population trend	IUCN Red List (2019)
40	Cyprinidae	Ray-finned Fish	*Osteobrama peninsularis* Silas, 1952	--	DD 2011
41	Cyprinidae	Finescale Razorbelly Minnow	*Salmostoma phulo* (Hamilton, 1822)	--	LC 2009
42	Cyprinidae	Ray-finned Fish	*Osteobrama vigorsii* (Sykes, 1839)	Stable	LC 2011
43	Cyprinidae	Konti Barb	*Osteochilichthys thomassi* (Day, 1877)	--	LC 2011
44	Cyprinidae	Ray-finned Fish	*Puntius ambassis* (Day, 1869)	--	DD 2010
45	Cyprinidae	Scarlet Banded Barb	*Puntius amphibius* (Valenciennes, 1842)	--	DD 2010
46	Cyprinidae	Chola Barb	*Puntius chola* (Hamilton, 1822)	--	LC 2010
47	Cyprinidae	Jakkali	*Hypselobarbus jerdoni* (Day, 1870)	Decreasing	LC 2010
48	Cyprinidae	Long-snouted Barb	*Puntius dorsalis* (Jordon, 1849)	--	LC 2019
49	Cyprinidae	Kolus Barb	*Hypselobarbus kolus* (Sykes, 1839)	Decreasing	VU 2010
50	Cyprinidae	Narayan Barb	*Pethia narayani* (Hora, 1937)	--	LC 2010
51	Cyprinidae	Red Side Barb	*Puntius bimaculatus* (Bleeker, 1863)	Stable	LC 2019
52	Cyprinidae	Olive Barb	*Systomus sarana* (Hamilton, 1822)	--	LC 2010
53	Cyprinidae	Spot Fin Swamp Barb	*Puntius sophore* (Hamilton, 1822)	--	LC 2010
54	Cyprinidae	Ticto Barb	*Pethia ticto* (Hamilton, 1822)	--	LC 2010
55	Cyprinidae	Vatani Rohtee	*Rohtee ogilbii* Sykes, 1839	--	LC 2010
56	Cyprinidae	Salmostoma Phulo	*Salmophasia phulo* (Hamilton, 1822)	--	LC 2009
57	Cyprinidae	Nukta	*Schismatorhynchos nukta* (Sykes, 1839)	Decreasing	EN 2010
58	Cyprinidae	Sandkhol Carp	*Thynnichthys sandkhol* (Sykes, 1839)	Decreasing	EN 2010
59	Cyprinidae	Black Mahseer	*Tor khudree* (Sykes, 1839)	increasing	LC 2019
60	Cyprinidae	Musulla Barb	*Hypselobarbus mussullah* (Sykes, 1839)	Decreasing	EN 2010
61	Danionidae	Baril	*Opsarius bendelisis* (Hamilton, 1822)	--	LC
62	Danionidae	Silver Harchet Chela	*Chela cachius* (Hamilton, 1822)	--	LC 2010
63	Danionidae	Giant Danio	*Devario aequipinnatus* (McClelland, 1839)	--	LC 2010
64	Danionidae	Flying Barb	*Esomus danrica* (Hamilton, 1822)	Stable	LC 2007
65	Gobidae	Tank Gobi	*Glossogobius giuris* (Hamilton, 1822)	--	LC 2019
66	Horabagridae	Khavalchor Catfish	*Pachypterus khavalchor* (Kulkarni, 1952)	--	DD 2010
67	Mastacembellidae	Spiny Eel	*Mastacembelus armatus* (Lacepede, 1800)	Stable	LC 2019
68	Mastacembellidae	Barrel Spiny Eel	*Macrognathus pancalus* Hamilton, 1822	--	LC 2010
69	Nemacheilidae	Ray-finned Fish	*Indoreonectes evezardi* (Day, 1872)	--	LC 2010
70	Notopteridae	Bronze Featherback	*Notopterus notopterus* (Pallas, 1769)	Stable	LC 2019
71	Osphronemidae	Spiketail Paradise Fish	*Pseudosphromenus cupanus* (Cuvier, 1831)	Stable	LC 2019
72	Pangassidae	Pangas Cat Fish	*Pangassius pangassius* (Hamilton, 1822)	--	LC 2009
73	Siluridae	Butter Cat Fish	*Ompok bimaculatus* Bloch, 1794	--	NT 2009
74	Siluridae	Cat Fish	*Wallago attu* (Bloch & Schneider, 1801)	Decreasing	VU 2019
75	Sisoridae	Devil Cat Fish	*Bagarius bagarius* (Hamilton, 1822)	Decreasing	NT 2009
76	Sisoridae	Sucker Cat Fish	*Gagata itchkeea* (Sykes, 1839)	Decreasing	VU 2011

LC—Least Concern | EN—Endangered | NT—Near Threatened | VU—Vulnerable | DD—Data Deficient

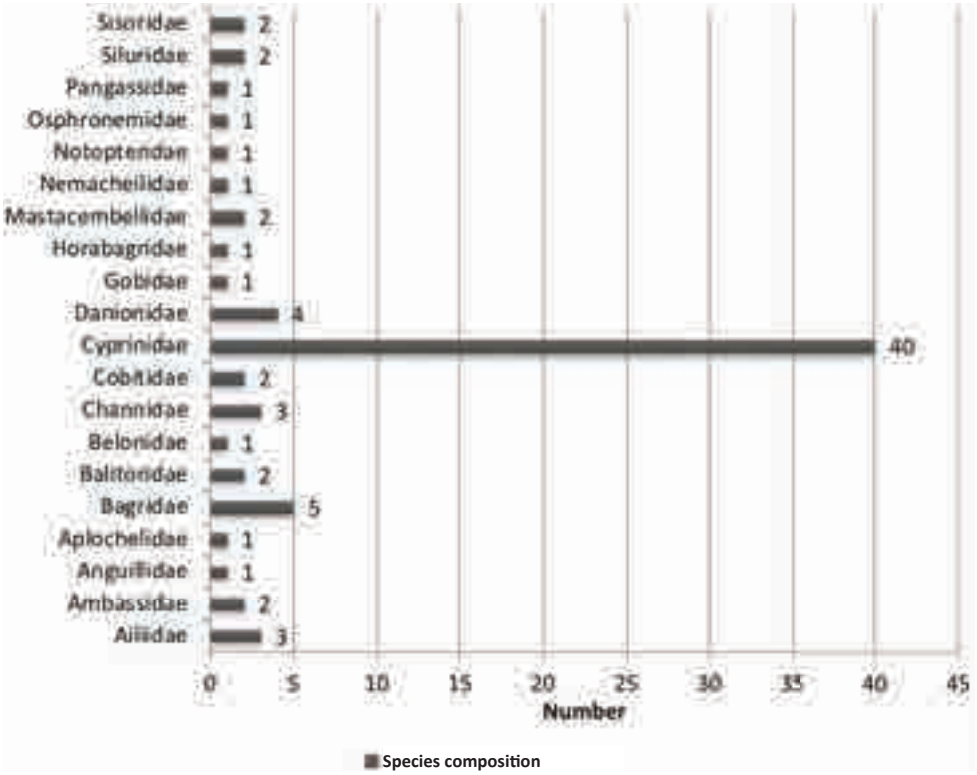

Figure 1. Family-wise species composition of fishes from Tungabhadra Reservoir.

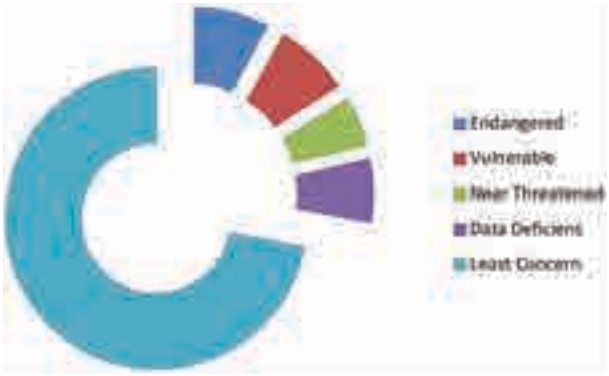

Figure 2. IUCN Red List status of fishes in Tungabhadra Reservoir during 2018–19.

attu, Mastacembelus armatus, Bagarius bagarius, Osteobrama vigorsii, and *Sperata seenghala* were recorded from all landing centers across the study period. The order of abundance of fishes was major carps > minor carps > cat fishes > small fishes. Kumar et al. (2006) observed a similar fish abundance trend in Geralsud Reservoir, Ranchi. As per the latest IUCN Red List, six Endangered, six Vulnerable, four Near Threatened, five Data Deficient, and 54 Least Concern (Figure 2). It also includes exotic species which are not evaluated. Details of the present conservation status of fishes inhabiting TBR are given in Table 1.

Conclusion

In the present study 76 species of freshwater fishes were recorded. As per the recent IUCN Red List, the conservation status of the fishes showed six Endangered, five Vulnerable, four Near Threatened, and five Data Deficient. Commercially important species were being reduced in certain landing centers along left flank of TBR and alien species were occupying the native species niches. To monitor the continuous potential fish yield of the reservoir, adequate release of carp seeds, utilizing the other vacant niches, monitoring the illegal fishing activities along the reservoir and continuous annual documentation of fish catches is necessary.

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SHORT COMMUNICATION

Species diversity and distribution of large centipedes (Chilopoda: Scolopendromorpha) from the biosphere reserve of the western Nghe An Province, Vietnam

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Abstract. A total of 12 scolopendromorph species from five genera and three families were recorded in three different habitats (wooden forest, mixed timber-bamboo forest, and bamboo forest) and at three elevation ranges (>1,000 m, 700–1,000 m, and <700 m) from the biosphere reserve of the western Nghe An Province. Eleven species were recorded for the first time in the area. Scolopendridae is the most diverse family with nine species. The number of species was highest at elevation <700 m (9 species), and lowest at 700–1,000 m (4). By habitat distribution, the bamboo forest had the lowest number of species (3).

Keywords. Arthropoda, bioinventory, biodiversity, pitfall trap, Scolopendridae, southeastern Asia.

The biosphere reserve west of Nghe An province contains two protected areas, Pu Mat National Park (= Pu Mat NP) and Pu Hoat Nature Reserve (= Pu Hoat NR), located in northern part of the Truong Son mountain range. The elevation of this area ranges 100–2,500 m, and the forested areas are mainly found at 800–1,500 m, and in valleys. The area's difficult topography has partly helped to limit deforestation and hunting for rare animals. Located in the tropical monsoon region, atmospheric circulation in this area is influenced by the Truong Son mountain range, and by westerly winds (Laotian wind) that create harsh, dry, hot weather in the summer (Vietnam Administration of Forestry 2013). These conditions have allowed high biodiversity in the area, with many endemic and rare species.

Although biodiversity surveys have been conducted in the area, studies of centipedes are limited. Tran et al. (2013) compiled a list of centipedes in Vietnam and reported the occurrence of several species in the eastern region of Nghe An (Vinh City), including *Rhysida nuda*, *Scolopendra dehaani* and *Scolopendra morsitans*. Only Vu et al. (2020) recorded *Otostigmus aculeatus* in Pu Mat NP.

In order to facilitate further studies in the future, this article provides a list of species belonging to the large centipede order Scolopendromorpha, along with assessments of the diversity and distribution of species recorded in the biosphere reserve west of Nghe An.

Materials and Methods

A total of 71 specimens of Scolopendromorpha were collected in 2018–2020 in Pu Mat NP and Pu Hoat NR. The specimens were collected in three different habitats: woody forest (WF), mixed wood-bamboo forest (WBF), bamboo forest (BF), and at three elevation

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ranges: below 700 m, 700–1,000 m and >1,000 m (Vu 2012). All of these habitats are less affected by humans. The organic surface layer in habitats is very thick, may be up to 15 cm. In the woody forest habitat, many trees are over 1 m in diameter.

Specimens were collected by pitfall trapping following the instruction of Mesibov & Churchill (2003). The traps were made of a 500 ml plastic cup. A total of 15 traps containing ethanol 75% were placed in each habitat, and were collected after 7–10 days. Centipedes were also gathered by leaf-sifting (Górny & Grüm 1993). This method uses a sieve with a diameter of 30 cm and a mesh of 1 cm to remove the upper matter (leaves, twigs). The remaining matter after falling through the sieve was collected to find animals. Centipedes were also manually collected by hand sorting and digging. Centipede specimens were searched directly under decaying vegetation, stumps, rotting trunks, dry bark, and rocks.

Specimens were identified according to the references of Attems (1930), Bonato et al. (2011), Schileyko (1992, 1995, 2007, 2020), Siriwut et al. (2016, 2018). Ecological indices including the number of species, Shanon-Weaver H', uniformnity J' were calculated using the software Primer ver. 7.0 for each habitat type. Similarity index was calculated using the software R ver. 4.0.4.

All specimens were preserved in 75% ethanol and kept at Vietnam-Russia Tropical Center (VRTC), Vietnam.

Results

Species composition and taxon diversity

We recorded 12 species belonging to five genera and three families in the study area (Table 1). Of these only *Otostigmus aculeatus* has been recorded from previous studies (Vu et al. 2020). Thus, our results contribute 11 new records to the centipede fauna of the biosphere reserve west of Nghe An. It also increases the total number of species recorded in Nghe An to 15 species (Tran et al. 2013).

Table 1 shows that BF habitat has the lowest diversity with only three species (three genera, three families) recorded. The WBF and WF habitats had the same number of recorded species (seven species, four genera, three families). Only *Scolopocryptops rubiginosus* was recorded in all three habitats. *Otostigmus multidens*, *Otostigmus scaber* and *Cryptops doriae* were recorded in two habitats, the rest were only recorded in one habitat.

The distribution of large centipedes according to the altitude shows they were concentrated mainly below 700 m (nine species, four genera, three families), followed by >1,000 m (six species, three genera, two families), with the lowest diversity at 700–1,000 m (four species, three varieties, three families). *Otostigmus scaber* was the only species recorded at all three different altitudes. *Scolopocryptops rubiginosus*, *Scolopocryptops* sp., *Scolopendra subspinipes*, *Otostigmus astenus*, and *Cryptops doriae* were recorded at two different elevations. *Scolopendra dawydoffi* was only recorded above 1,000 m; the other species were only recorded below 700 m. Although there have been initial results on the distribution by altitude in the study area, the results cannot fully represent the distribution of large centipedes, because the study area has a very complex terrain making it difficult to collect samples. Therefore, additional studies are needed.

Taxon diversity

Of the three families recorded, Scolopendridae was recorded with the highest species diversity (nine species, accounting for 75% of the total species; three genera, accounting for 60% of the total genera); Scolopocryptopidae has recorded with only two species (accounting for 17% of total species) in one genus (20% of total genera); Cryptopidae was recorded with just one species (accounting for 8.3%) (Table 2). With this result, it can be seen that the family Scolopendridae considerably dominates in the study region. This is similar to the previous studies by Le et al. (2021) at Phia Oac - Phia Den National Park and Nguyen et al. (2019) at Hoang Lien National Park.

Biological indices

Table 3 presents the results of the analysis of biological indicators, in which the H' index was highest in the WBF habitat (2,148), followed by WF (1,934) and finally BF (1,673). Therefore, WBF biodiversity was quite good (2<H'<3) while WF and BF were medium (1<H'<2). For the J' index, it shows that WBF and BF were similar with 0.9329 and 0.9335, respectively. And the J' index was lowest in WF, with 0.8801. With these values, it was shown that habitats have large differences in the number of individuals obtained between species.

According to the results of NMDS analysis, the habitats as well as the elevations were quite different in species composition recorded in the study area, as shown by the distance between each other in the Figure 1,2. Along with that was the close relationship of the species with different habitats and altitudes, specifically *Otostigmus astenus* with WF habitat, *Rhysida* sp. with WBF habitat and *Cryptops doriae* with BF habitat (Figure 1). *Scolopendra dawydoffi, Scolopocryptops rubiginosus, Scolopocryptops* sp. closely related to altitudes above

Table 1. Species composition and distribution of scolopendromorphs in the biosphere reserve west of Nghe An province.

	WF	WBF	BF	<700	700–1,000	>1,000
Family Scolopocryptopidae Pocock, 1896						
Genus *Scolopocryptops* Newport, 1844						
Scolopocryptops rubiginosus L. Koch, 1878	+	+	+		+	+
Scolopocryptops sp.	+				+	+
Family Scolopendridae Pocock, 1895						
Genus *Scolopendra* Linnaeus, 1758						
Scolopendra subspinipes Leach, 1815	+			+		+
Scolopendra dawydoffi Kronmüller, 2012	+					+
Genus *Otostigmus* Porat, 1876						
Otostigmus astenus (Kohlrausch, 1878)	+			+		+
Otostigmus multidens Schileyko, 1995		+	+	+		
Otostigmus scaber Porat, 1876	+	+		+	+	+
Otostigmus amballae Chamberlin, 1913		+		+		
Otostigmus aculeatus Haase, 1887		+		+		
Genus *Rhysida* Wood, 1862						
Rhysida immarginata Porat, 1876		+		+		
Rhysida sp.		+		+		
Family Cryptopidae Rausch, 1881						
Genus *Cryptops* Leach, 1815						
Cryptops doriae Pocock, 1891	+		+	+	+	
Total number of individuals	30	28	13	40	11	20
Total species	7	7	3	9	4	6

WF—Wood forest | WBF—Wood-bamboo mixed forest | BF—Bamboo forest | +—present.

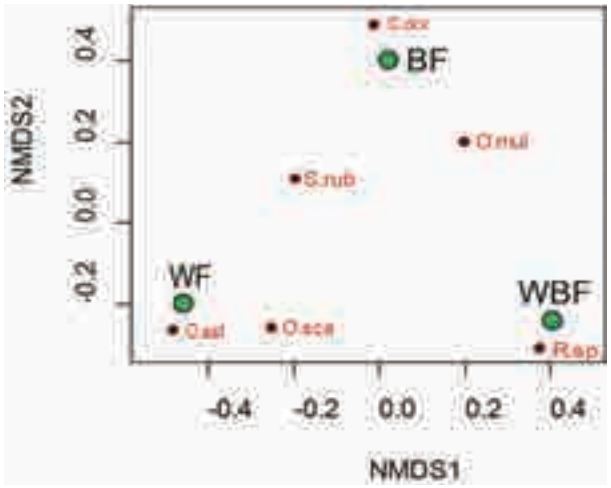

Figure 1. Non-metric multidimensional scaling (NMDS) analysis by habitat: S.rub—*Scolopocryptops rubiginosus* | O.ast—*Otostigmus astenus* | O.mul—*Otostigmus multidens* | O.sca—*Otostigmus scaber* | C.dor—*Cryptops doriae* | R.sp.—*Rhysida* sp.

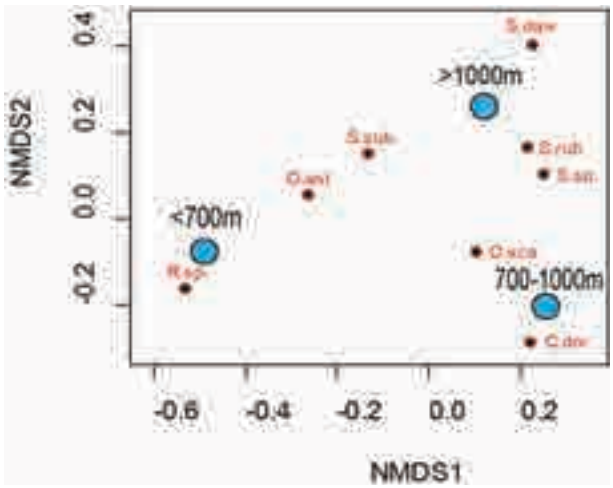

Figure 2. Non-metric multidimensional scaling (NMDS) analysis by Elevation: S.sub—*Scolopendra subinosus* | S.daw—*Scolopendra dawydoffi* | S.rub—*Scolopocryptops rubiginosus* | S.sp.—*Scolopocryptops* sp. | O.ast—*Otostigmus astenus* | O.sca—*Otostigmus scaber* | C.dor—*Cryptops doriae* | R.sp.—*Rhysida* sp.

Table 2. Taxon diversity of scolopendromorphs in the biosphere reserve west of Nghe An province.

Taxa	Genus		Species	
	Amount	Ratio	Amount	Ratio
Scolopendridae	1	20.00	9	75.00
Scolopocrypidae	3	60.00	2	16.67
Cryptopidae	1	20.00	1	8.33
Total	**5**	**100.00**	**12**	**100.00**

Table 3. Diversity index and uniformity index by habitat in the biosphere reserve west of Nghe An province.

Habitat	Amount		Index	
	Species	Individual	J'	H'
WF	9	29	0.8801	1.934
WBF	10	31	0.9329	2.148
BF	6	11	0.9335	1.673

WF—Wood forest | WBF—Wood-bamboo mixed forest | BF—Bamboo forest.

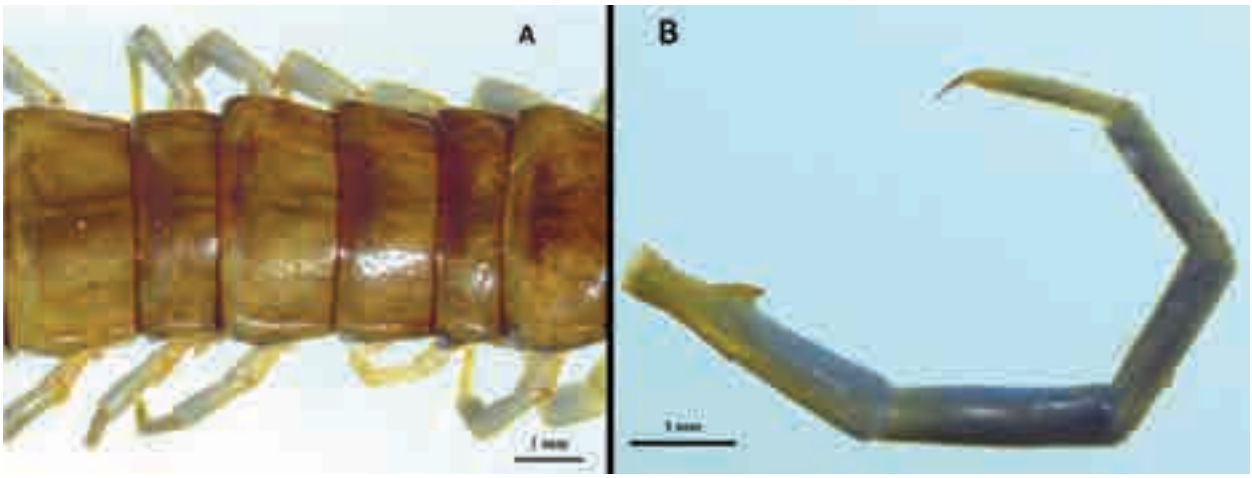

Image 1. *Scolopocryptops* sp. (specimen SVR.PH.048): A—Tergites | B—Ultimate.

1,000 m, while *Rhysida* sp. closely related to altitudes below 700 m, *Otostigmus scaber, Cryptops doriae* more closely related to altitude 700–1,000 m.

Discussion

With 12 recorded species, the diversity of large centipedes in the Biosphere Reserve West of Nghe An is similar to other regions, such as Hoang Lien, Thuong Tien, Xuan Nha (each with 12 recorded species) (Nguyen et al. 2018, 2019a, b), but is lower than Ta Xua, Phia Oac - Phia Den with 15 and 18 species, respectively (Tran et al. 2018; Le et al. 2021). Due to the complicated weather conditions and terrain of the study area, this study was conducted only at altitudes from 200 to 1,300 m, the species diversity of that area has not been fully understood. Additional studies are needed for high mountains (above 1,600 m) and in different seasons.

The results also show that Scolopendridae is the most common family in Vietnam, with the highest species diversity and superiority to other families, in which the genus *Otostigmus* is still the genus with the highest number of recorded species. This result is also consistent with the report of Tran et al. (2013) and Vu et al. (2020).

The genus *Scolopocryptops* was recorded at altitudes of over 700 m in the study area, specifically, specimens were collected at altitudes from 900–1,200 m. This complements the identification that *Scolopocryptops* species in Vietnam are temperate species, only recorded in cool climatic regions (Le et al. 2021). *Scolopocryptops* sp. has different characteristics from those known in Vietnam (*S. rubiginosus*, *S. spinicaudus*, and *S. melanotoma*) which are quite obvious in the tergites and ultimate legs (Image 1). With these other diagnosis, it may be a new record for the large centipede fauna in Vietnam. To be able to confirm this with certainty, further studies are needed.

Scolopendra dawydoffi, was formerly known as *Scolopendra subspinipes cingulatoides* (Attem, 1938; Schileyko 2007). However, Siriwut et al. (2016) combined both morphological and molecular analysis to confirm that this is an independent species. In Vietnam, it has been recorded in some areas such as Ha Giang, Hanoi, Thai Nguyen, and Ha Tinh (Attem 1938; Schileyko 2007).

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SHORT COMMUNICATION

Eremotermes neoparadoxalis Ahmad, 1955 (Isoptera: Termitidae: Amitermitinae) a new record from Haryana, India

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Abstract: We report a new record of *Eremotermes neoparadoxalis* from Haryana, India. *Eremotermes* Silvestri, 1911 is a highly dispersed genus epitomized by 10 species, six of which have been reported in India, including *E. paradoxalis* in Harayana. Taxonomic descriptions provided with illustrations of general morphology and measurements of body length, head length with and without mandibles, body pigmentation, antennae segments, tibial spur, tarsal segments, head width, and body width. These keys along with photographs are prepared for both soldier and worker castes of *E. neoparadoxalis*.

Keywords: Antennae segments, blattaria, caste, morphological characters, phenotypic characters, pronotum, tarsal segment, tibial spur, termite.

Termites (Order: Blattaria; Infraorder: Isoptera) are highly useful insects in many ecosystems (Engel et al. 2009; Pranesh & Harini 2015; Effowe et al. 2021), where they consume cellulose-rich plant matter and facilitate recycling of waste products (Wood & Sands 1978). They also support the growth of forests and microbes while constructing their mounds (Lee & Wood 1971; Eggleton et al. 2002; Davies et al. 2014). *Eremotermes* (subfamily Amitermitinae) are found in many localities worldwide (Oriental, Ethiopian and Palaearctic zoogeographical regions), and in India they are known from the Oriental Region (Krishna et al. 2013). Ten species of *Eremotermes* are reported globally, of which six occur in India: *dehraduni*, *fletcheri*, *madrasicus*, *neoparadoxalis*, *paradoxalis*, and *sanyuktae*, while three occur in southern India: *paradoxalis*, *madrasicus*, and *fletchreri* (Chhotani 1997; Ranjith & Kalleshwaraswamy 2021), five in Gujarat and Rajasthan: *dehraduni*, *fletcheri*, *neoparadoxalis*, *paradoxalis*, and *sanyuktae* (Rathore & Bhattacharyya 2004), and only *paradoxalis* from Haryana (Poonia 2019). The present report deals with *Eremotermes neoparadoxalis* as a new record trapped from dung cake in Palwal (Hodal), Haryana.

Methods

Surveys were conducted throughout southern Haryana, where most vegetation is in agricultural lands and *Acacia* forest. The sample of *E. neoparadoxalis* was collected from Hodal (Palwal), Haryana, India in July 2020. The area of sample collection is 27.40 °N & 77.36 °E (Figure 1; Image 1). Around 50 individuals of the soldier and worker castes were collected from a dung cake with the help of forceps, and preserved in 70% ethanol (Gupta & Kakkar 2015). For the taxonomic description photographs were captured using an Olympus CX41 microscope and Olympus Camedia C-7070 wide zoom

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Competing interests: The authors declare no competing interests.

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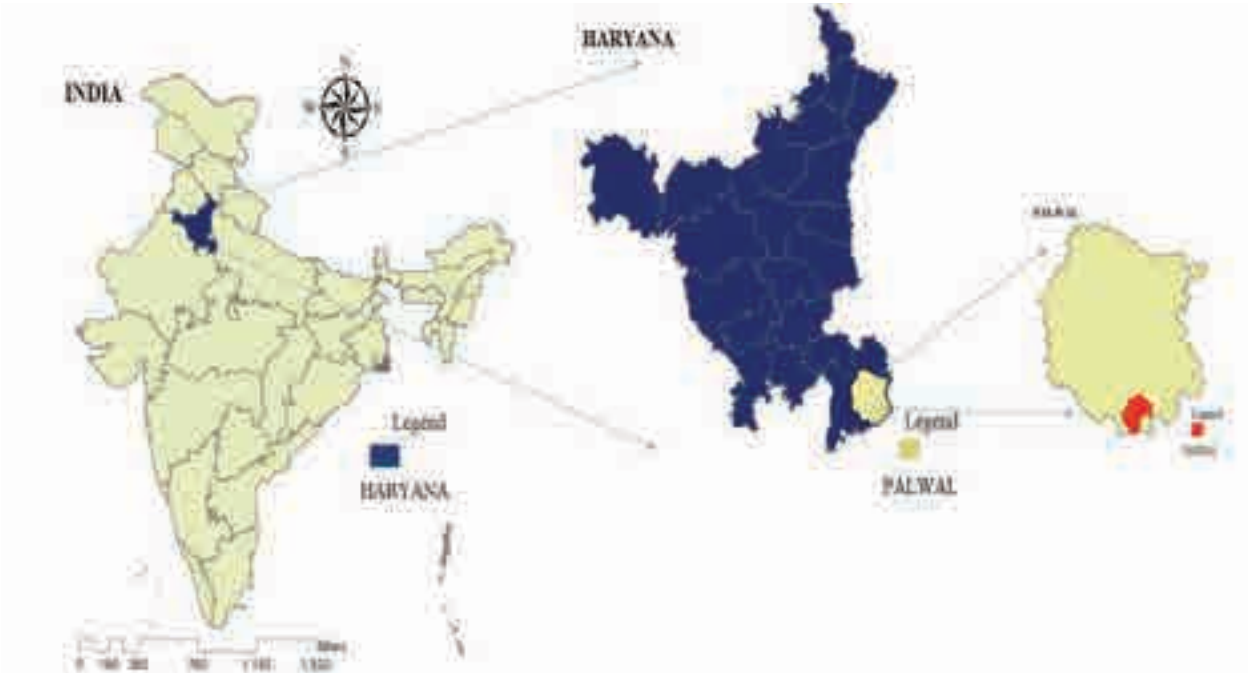

Figure 1. Study site.

digital camera. Termite characterization was done using taxonomic keys (Chhotani 1997; Rathore & Bhattacharyya 2004; Mahapatro et al. 2018) (Table 1).

Phenotypic characters assessed were:

· Head: Shape, color, size, width and length of head with and without mandibles (Table 1)

· Antennae: Number and size of the segments

· Mandible: Shape, length, arrangement of marginal teeth and size (Table 1)

· Labrum: Hyaline tip and its shape

· Legs: Tibial spur and number of tarsi segments

· Body: Color, length and width

Results and Discussion

A total of 37 termite species were reported from Haryana (Poonia 2019). This diversity was hierarchically listed under 11 genera, six subfamilies (Macrotermitinae, Angulitermitinae, Amitermitinae, Coptotermitinae, Heterotermitinae, and Apicotermitinae) and three families (Termitidae, Rhinotermitidae, and Kalotermitidae). *Eremotermes* was previously only represented by *paradoxalis* in Haryana (Krishna et al. 2013; Poonia 2019), and we now include *neoparadoxalis*. This species is mostly found in dry zones (Roonwal & Bose 1978). For the species identification mean and standard deviation were calculated on five individuals of both castes (soldier and worker). Species of the genus *Eremotermes* generally look alike; consequently, differences among species are noticed by different sizes of antennal segments of 3rd, 4th, and 5th in worker castes (Chhotani 1997).

Keys for genus and species of *Eremotermes*

Genus: *Eremotermes* Silvestri (Head with short projected front protuberance. Mandibles thin, long, and somewhat incurved apically) (Image 2)

Species:

1(2) Mandibles comparative to head longer, index mandible-length/head-length 1.12–1.23. Mandibular tooth weak or indistinct .... *neoparadoxalis*

2(1) Mandibles comparative to head shorter, index mandible-length/head-length 0.78–1.07 Mandibular tooth prominent

3(4) Mandibles almost straight; concavity on outer margin of mandibles very weak or absent ..... *madrasicus*

4(3) Mandibles appreciably curved; concavity on outer margin strong

5(6) Larger species: Head-length to base of mandibles 0.94–1.105, head-width 0.81–0.85 mm. Mandible-length equal to or slightly more than head-length, index mandible-length/head-length 1.0– 1.07 ..... *fletcheri*

6(5) Smaller species: Head-length to base of mandibles 0.80–0.95, head-width 0.68–0.80 mm.

Mandible-length generally less than head length, index mandible-length/head-length 0.78–0.98
7(8) Frontal protuberance prominent and frons very steeply inclined in front. Head thick, height/width index 0.81–0.93. Mandibles strongly incurved at apices ..... *dehraduni*
8(7) Frontal protuberance a little weaker and frons somewhat less so steeply inclined in front. Head thinner, height/width index 0.66–0.87. Mandibles weakly incurved at apices ..... *paradoxalis*

Species: *neoparadoxalis* (Mandibles with weak tooth and comparatively longer than the head)

***Eremotermes neoparadoxalis* Ahmad**

1955. Ahmad, Biologia, Lahore, 1(2): 252–253. S only. Holotype: S, in PU, Lahore. Type-locality: Shahdadpur, Sind, Pakistan.

1969. Roonwal and Bose, Rec. Zool. Surv. India, 61(3 & 4): 440, 446.

1974. Akhtar, Pakistan J. Zool., 6(1 & 2): 103. 1976. Akhtar, Pakistan J. Zool., 8(2): 163–165.

1977. Roonwal, In: Natural Resources of Rajasthan (Ed Roonwal): 375: 3.

2013. Krishna, et al., Bull. Am. Mus. Nat. Hist., 6: 2129–2137.

This species is a small-sized termite. Body length is ranged in between 3.5–4.1 in soldier caste and 3.4–3.8 in worker caste (Table 1). Diagnostic features, measurements, distribution and remarks of the soldier and worker castes of *E. neoparadoxalis* (Image 2) were described as follows:

Diagnostic features:

Soldier caste: Head capsule is light yellow, rectangular to oval-shaped. Body is yellowish-white and mandibles are reddish-brown. Mandibles are sabre-shaped, less incurved, pointed and strongly incurved outer marginally. There is a minute tooth present little behind the middle on both the mandibles. Pronotum is saddle-shaped where labrum is smaller and pointed in shape (Image 2).

Worker Caste: Head capsule is straw-colored and sub-square shaped whereas body is paler. Mandibles are similar as imago caste (Image 2). Pronotum is saddle-shaped; its anterior margin weakly or generally not notched and posterior margin straight.

Measurements (Table 1) (mm):

More description:

Soldier: Tarsal segments: 4, Tibial spur ratio: 3:2:2, Antennae segments: 14, 3rd shortest and sub-equal to or a little longer than 4; 5 longer and broader than 4 (Image 2).

Worker: Tarsal segments: 4, Tibial spur ratio: 3:2:2, Antennae: 14 segmented; segment 3, 4, 5 sub-equal (Image 2).

Distribution: India: Haryana (Nuh), Delhi, Gujarat (Dangs, Banaskantha, Valsad, Sabarkantha), Rajasthan (Bikaner, Jaisalmer, Barmer, Jodhpur, Jaipur) and Pakistan.

Image 1. Location of sample collected site. © Bhanupriya.

Table 1. Morphometric analysis of termite's body parts (in mm) *Eremotermes neoparadoxalis*.

	Parameters (mm)	Soldier		Worker	
		Range	Mean±SD	Range	Mean±SD
1	Total body length	3.5–4.1	3.84±0.215	3.4–3.8	3.64±0.16
2	Head length without mandibles	0.7–0.85	0.77±0.06	0.5–0.65	0.56±0.058
3	Head + mandibles length	1.6–1.9	1.75±0.109	0.7–0.9	0.81±0.08
4	Mandibles length	0.8–0.9	0.86±0.04	0.2–0.35	0.27±0.06
5	Tooth distance	0.3–0.37	0.33±0.027	-	-
6	Head width	0.6–0.9	0.73±0.107	0.65–0.75	0.69±0.037
7	Body width	0.6–0.75	0.67±0.06	0.6–0.8	0.7±0.07

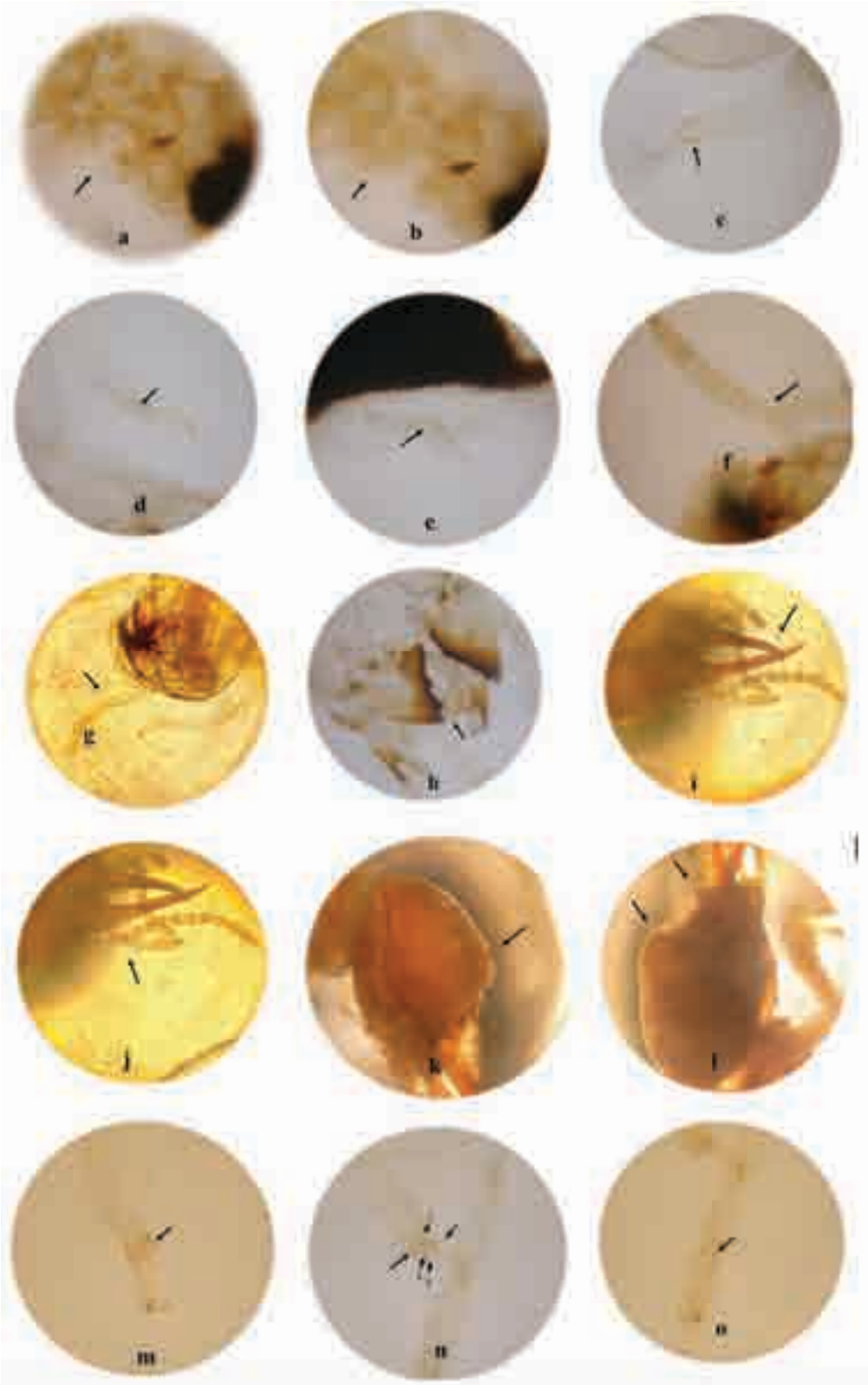

Image 2. Worker caste: a—Pronotum: saddle-shaped | b—Dorsal view of pronotum | c—Foreleg with three tibial spur | d—Mid leg with two tibial spur | e—Hind-leg with two tibial spur | f & g—14 segmented antennae, with 3rd, 4th, and 5th segments are sub-equal in sized and 3+4 = 2nd segment | h—shape of the mandibles;
Soldier caste: i—Mandible with prominent tooth and tooth distance | j—Antennae 14-segmented with 4th short segment | k—Dorsal view of head | l—Head with frontal protuberance and a pointed labrum | m—Foreleg with three tibial spur | n—Mid leg with two tibial spur and tarsal segments (4) | o—Hind-leg with two tibial spur. © Bhanupriya.

Remarks: In India, this species is relatively rare but generally found in Gujarat and Rajasthan. As a new record, this species is stated first time from the study site Palwal (Hodal), Haryana. This is a soil-borne species, commonly collected from damaged wooden structures, dung cake and forests as well as harvested fields (Sharma et al. 1975; Chhotani 1997; Saha & Basak 2011). The present record of this species is collected from dung cake.

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SHORT COMMUNICATION

New state records of longhorn beetles (Insecta: Coleoptera: Cerambycidae) from Meghalaya, India

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Abstract: We report the range extension of 11 species of Cerambycidae fauna into Meghalaya, northeastern India, based on our studies on the unidentified specimens of longhorn beetles deposited in the National Zoological Collection of the Zoological Survey of India, Shillong. These 11 species under 11 genera, nine tribes, and three subfamilies increases the known Cerambycidae diversity in Meghalaya from 81 species to 92 species.

Keywords: Additional distribution records, Mawsmai cave, Nongkhyllem, northeastern India, Shillong.

The longhorn beetles (Family Cerambycidae) are one of the most spectacular insect groups due to their strikingly long antennae and colourful elytra. However, the records of longhorn beetles from northeastern India are very poor, despite the region being located in the confluence of two biodiversity hotspots (the Himalaya and the Indo-Burma), with probably many species yet to be documented from this region. Our knowledge on the Indian longhorn beetles are largely enhanced by the works of Kariyanna (2016) and Kariyanna et al. (2017). The earliest known work on the cerambycid beetles of Meghalaya dates back to Breuning (1938). However, since then, no further addition was made to our knowledge on this group of insects from the State. It was in the 21st century that voluminous work on the cerambycid fauna of Meghalaya was made by Mukhopadhyay & Biswas (2000) where they reported 71 species. So far, a total of 81 species under 53 genera of 28 tribes under three subfamilies are known from the State of Meghalaya (Mitra et al. 2016).

Herein, we examine the cerambycid beetles specimens deposited in the National Zoological Collections (NZC) of Zoological Survey of India (ZSI), Shillong, Meghalaya

Material and Methods

The Cerambycidae specimens present in the backlog collections of ZSI, Shillong are identified. The identification is based on the morphological characters. Classification and the distribution records were followed after Kumawat et al. (2015) and Kariyanna et al. (2017), respectively. The specimens are photographed using a Nikon D300s DSLR camera and registered in the NZC of ZSI, Shillong. The museum catalogue numbers are provided under the respective species account. The known distribution ranges of these identified species are

Editor: Anonymity requested.

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Competing interests: The authors declare no competing interests.

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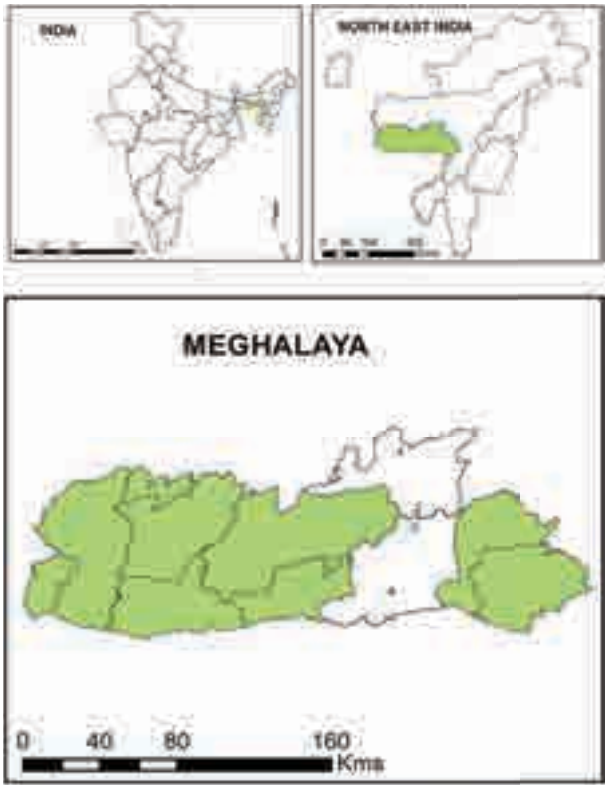

Figure 1. A map of Meghalaya showing the collection localities marked in blue: 1—Lailad, Nongkhyllem WS | 2—Umaim | 3—Shillong | 4—Mawsmai, Sohra (=Cherrapunjee).

also mentioned. The collection details of the specimens are arranged in the following order: number of specimen(s) denoted as ex., collection location, date of collection, collector's name, museum catalogue number of ZSI, Shillong.

Results

Family Cerambycidae

Subfamily Cerambycinae

Tribe Callidiopini

1. *Stenodryas apicalis* (Gahan, 1893) [Image 1E]

1893. *Nyphasia apicalis* Gahan, *The Annals and Magazine of Natural History, London*, Series 6, 11(65): 378

1984. *Stenodryas apicalis* Holzschuh, *Entomologica Basiliensa*, 9: 347.

Material examined: 01 ex., India, Meghalaya, East Khasi Hills, 3rd Mile, Upper Shillong, 02 June 2020, P. Burathoki, Reg. No. I/COL/NERC-224.

Diagnostic Characters: Small sized (L 14 mm, B 5 mm); red-brown in colour; eyes large; antenna 11 segmented, longer than body, segment 3–6 with acute spine; pronotum globular, longer than broad; elytra elongated, slender; femur abruptly bulged at apex, tarsal claw less than 90^0 angle.

Distribution: India (Chhattisgarh, Karnataka, Madhya Pradesh, Meghalaya, & West Bengal) and Nepal.

Tribe Cerambycini

2. *Trirachys holosericeus* (Fabricius, 1787) [Image 1B]

1787. *Ceramryx holosericeus* Fabricius, *Mantissa Insectorum sistens eorum species nuper detectas adiectis characteribus genericis, differentiis specificis, emendationibus, Observationibus*. 1. C.G. Proft, Copenhagen: 135.

2017. *Trirachys holosericeus* Vitali et al. *Les Cahiers Magellanes*, N.S. 26: 46.

Material examined: 01 ex., India, Meghalaya, East Khasi Hills, Mawsmai Cave, Cherrapunjee, 01 November 2011, B. Saikia, Reg. No. I/COL/NERC-40.

Diagnostic Characters: Medium sized (L 27 mm, B 7 mm); chocolate brown in colour; antennae apical portion broken. Pronotum with irregular folds and heterogeneous sparse punctures dorsally & lateral to median elevation with very coarse longitudinal folds; elytra long and slender; femur flat.

Distribution: India (Arunachal Pradesh, Jammu & Kashmir, Maharashtra, & Meghalaya); China; Indonesia; Laos; Myanmar; Thailand; Sri Lanka; and Vietnam.

***3. Xoanodera regularis* Gahan, 1890 [Image 1C]**

1890. *Xoanodera regularis* Gahan, *The Annals and Magazine of Natural History*, London, Series 6, **5** (25): 52.

Material examined: 01 ex., India, Meghalaya, East Khasi Hills district, Mawsmai Cave, Cherrapunjee, 01 November 2011, B. Saikia, Reg. No. I/COL/NERC-36.

Diagnostic Characters: Medium sized (L 20 mm, B 7 mm); antenna 11-segmented; pronotum is as long as broad, with one thorn laterally. Elytra greyish in colour with streaks of brown shades near the scutellum and roundish dark spots mid-dorsolaterally.

Distribution: India (Assam, Meghalaya, & West Bengal); Cambodia; China; Laos; Myanmar; Nepal; and Vietnam.

Tribe Xystrocerini

4. *Xystrocera globosa* (Olivier, 1795) [Image 1D]

1795. *Cerambix globosus* Olivier, *Imprimerie de Lanneau*, Paris, 4: 27

1834. *Xystrocera globosa* Audinet-Serville, *Annales de la Société Entomologique de France*, Paris, 1(3): 70

Material examined: 01 ex., India, Meghalaya, East Khasi Hills district, Mawsmai Cave, Cherrapunjee, 01

November 2011, B. Saikia, Reg. No. I/COL/NERC-38; 02 exs. Meghalaya, East Khasi Hills district, ZSI Campus, Shillong 17 May 2017, I. Imam Coll. Reg. No. I/COL/NERC-39.

Diagnostic Characters: Medium sized (L 24 mm, B 6 mm); antenna 10-segmented, spur on the first sengment; pronotum globular with dark coloured border dorsally, centrally brown; elytra long and elongated, brown in colour with a single dark colour longitudinal stripe on each elytra; femur bulged.

Distribution: India (Arunachal Pradesh, Assam, Karnataka, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Tamil Nadu, & West Bengal); Australia; Egypt; Hawaiian France Is.; Indonesia; Japan; Madagascar; Malaysia; Mauritius; Myanmar; the Philippines; Puerto Rico; Sri Lanka; and Thailand.

Subfamily Lamiinae

Tribe Apomecynini

5. *Apomecyna histrio* (Fabricius, 1793) [Image 1A]

1793. *Lamia histrio* Fabricius, *Entomologia systematic emendata et aucta*. 1(2). Hafniae Impensis Christ Gottl Proft, Copenhagen: 288.

1960. *Apomecyna (Apomecyna) histrio* Breuning *Verlag des Museums G. Frey, Tutzing bei München,* 3: 131

Material examined: 01 ex., India, Meghalaya, East Khasi Hills district, Shillong, Risa Colony, 27 August 2020, B. Saikia, Reg. No. I/COL/NERC-223.

Diagnostic Characters: Small sized (L 10 mm, B 3 mm); dark brown in color; head roundish; antenna 11 segmented, 3rd and 4th segment large; pronotum cylindrical, with a mid dorsal line of whitish spots; elytra elongated, covered in dense longitudinal punctures, decorated with yellow spots.

Distribution: India (Arunachal Pradesh, Chhattisgarh, Madhya Pradesh, Meghalaya, Sikkim, Tamil Nadu, & West Bengal); Australia; China; Indonesia; Japan; Korea; Laos; Mongolia; Pakistan; the Philippines; and Russia.

Tribe Batocerini

6. *Batocera horsfieldi* (Hope, 1839) [Image 1F]

1839. *Lamia horsfieldii* Hope, *Proceedings of the Linnean Society of London*, 1: 42.

1948. *Batocera horsfieldi* m. *flavicans* Breuning, *Bulletin du Musée Royal d'Histoire Naturelle de Belgique, Bruxelles,* 24(38): 15.

Material examined: 01 ex., India, Meghalaya, East Khasi Hills district, ZSI Campus, Shillong 17 May 2017, B. Saikia, Reg. No. I/COL/NERC-47; 01 ex. Meghalaya, East Khasi Hills district, Mawsmai Cave, Cherrapunjee, 01 November 2011, B. Saikia Coll. Reg. No. I/COL/NERC-49.

Diagnostic Characters: Body large, broad and robust (L 54 mm, B 20 mm); antenna 11-segmented, 3rd the longest; pronotum is as long as broad with a pair of thorn on lateral side, a pair of prominent yellow marks in the middle; scutellum tongue shaped, whitish in colour; elytra slaty-grey in colour, anterior portion with dark dots and whitish patches, mid to posterior portion with irregular and large whitish patches.

Distribution: India (Arunachal Pradesh, Himachal Pradesh, Meghalaya, & Sikkim); China; Japan; Korea; Myanmar; Nepal; and Vietnam.

Tribe Dorcaschematini

7. *Olenecamptus indianus* (Thomson, 1857) [Image 2G]

1857. *Authades indianus* Thomson, *Archives Entomologiques*, Paris, 1: 192

1943. *Olenecamptus indianus* Breuning & Itzinger, *Attidella Società Italiana di Scienze Naturali e del Museo Civico di Storia Naturale in Milano*, 82: 48.

Material examined: 01 ex., India, Meghalaya, Ri-Bhoi district, Nongkhyllem Wildlife Sanctuary, Forest IB, Lailad, 10 May 2017, B. Saikia, Reg. No. I/COL/NERC-50.

Diagnostic Characters: Body slander and elongated (L 24 mm, B 5 mm); antenna 11-segmented. 3rd segment the largest. Body brown in color with irregular yellow patches on the elytra. Pronotum longer than broad.

Distribution: India (Arunachal Pradesh, Meghalaya, Sikkim, Uttarakhand, & West Bengal); China; Japan; Laos; Myanmar; Nepal; Sri Lanka; and Vietnam.

Tribe Lamiini

8. *Anoplophora stanleyana* Hope, 1839 [Image 2H]

1839. *Anoplophora stanleyana* Hope, *Proceedings of the Linnean Society of London*, 1: 43.

Material examined: 01 ex., India, Meghalaya, Ri-Bhoi district, BSI Experimental Garden, Barapani, 04 August 2020, V.D. Hegde Coll. Reg. No. I/COL/NERC-218.

Diagnostic Characters: Body large, robust and (L 40 mm, B 15 mm), antenna 11-segmented, 3rd segment the longest, segments of antenna pale blue with black apical portion; protonotum with a pair of thorns placed laterally; elytra large and robust, dark in colour marked with irregular shaped bright ocean-blue coloured spots.

Distribution: India (Nagaland, Meghalaya, Sikkim, & West Bengal); Bhutan; China; Indochina; Myanmar; and Vietnam.

Remark: Kariyanna et al. (2017) included Assam under its distribution as they included Naga Hills as one of the known localities. However, post the bifurcation of erstwhile Assam, Naga Hills now comes under the state

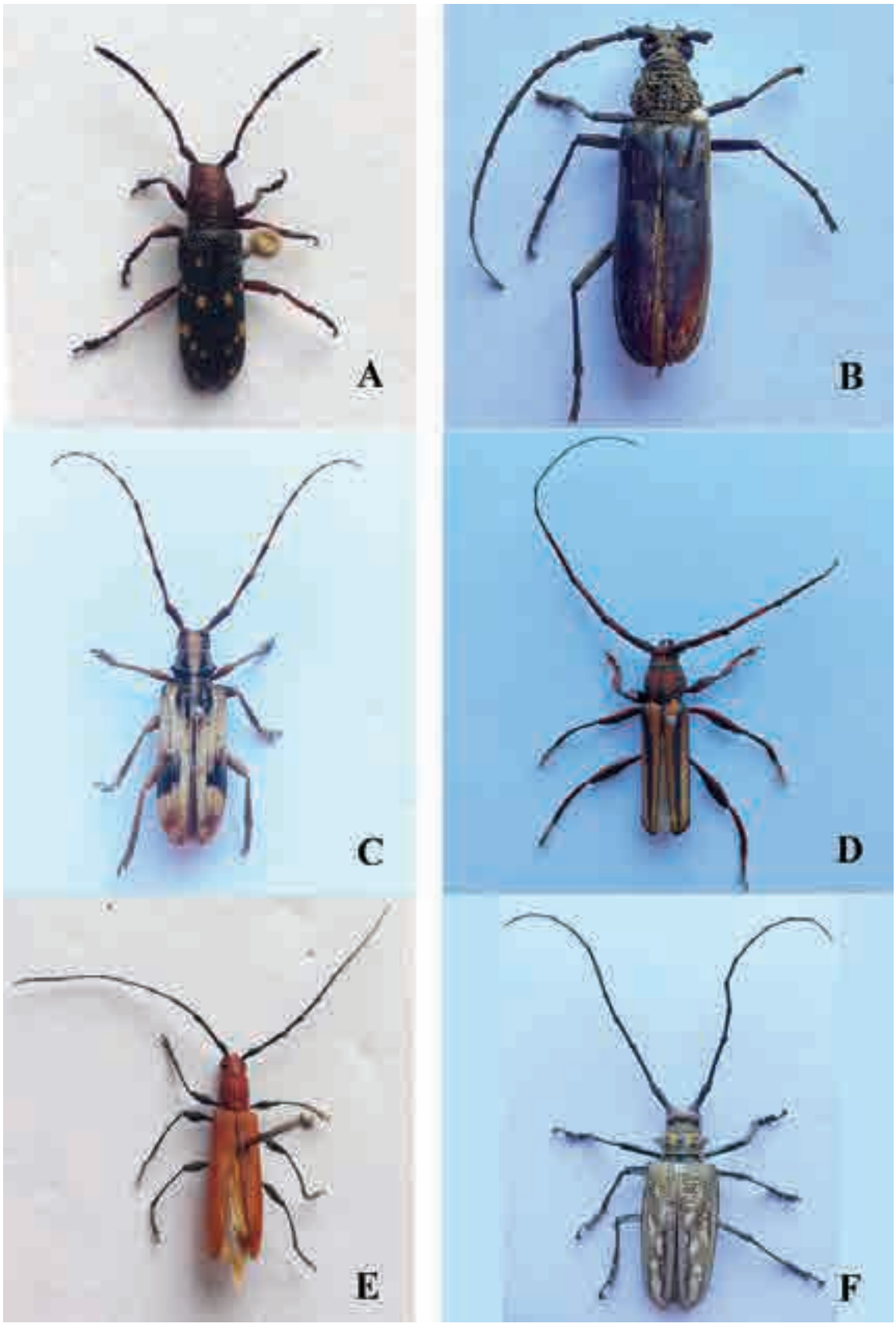

Image 1. Cerambycidae of Meghalaya: A—*Apomecyna histrio* | B—*Trirachys holosericeus* | C—*Xoanodera regularis* | D—*Xystrocera globosa* | E—*Stenodryas apicalis* | F—*Batocera horsfieldi*.

of Nagaland. As such, there is no further report of this species from Assam.

***9. Sarothrocera* cf. *lowii* White, 1846 [Image 2I]**

1846. *Sarothrocera lowii* White, *The Annals and Magazine of Natural History, London, Series* **18**, 7 (116): 47.

Material examined: 02 exs., India, Meghalaya, East Khasi Hills district, Mawsmai Cave, Cherrapunjee, 01 November 2011, B. Saikia, Reg. No. I/COL/NERC-52.

Diagnostic Characters: Medium sized (L 22 mm, B 11 mm), light brown in color; scutellum tongue shaped; pronotum broader with spur on the lateral side; antenna 11 segmented and serrated.

Distribution: India (Arunachal Pradesh & Meghalaya); Malaysia; Myanmar; and Thailand.

Subfamily Prioninae

Tribe Aegosomatini

10. *Baralipton maculosum* Thomson, 1857 [Image 2J]

1857. *Baralipton maculosum* Thomson, *Archives Entomologiques*, Paris, 1: 342.

Material examined: 01 ex., India, Meghalaya, East Khasi Hills district, Mawsmai Cave, Cherrapunjee, 01 November 2011, B. Saikia, Reg. No. I/COL/NERC-41; 02 exs. Meghalaya, East Khasi Hills district, ZSI Campus, Shillong, 04 June 2017, I. Imam, Reg. No. I/COL/NERC-42.

Diagnostic Characters: Large and elongated body (L 41 mm, B 12 mm); antenna 11-segmented, 3rd segment the longest. The terminal part of each antennal segment is marked with black; pronotum broad, covered with yellowish-brown pubescence and a pair of prominent black triangular shape in the middle, lateral sides of the pronotum with a thorn. Elytra brown in colour with two pairs of dark brown patches, longitudinal ridges.

Distribution: India (Arunachal Pradesh, Nagaland, Meghalaya, Sikkim, & West Bengal); China; Laos; Myanmar; Thailand; and Vietnam.

Remark: Kariyanna et al. (2017) included Assam under its distribution as they included Patkai Mts. as one of the known localities. However, post the bifurcation of erstwhile Assam, Patkai Mountains now comes under the state of Nagaland; although Mitra et al. (2017) have reported this from Assam.

Tribe Prionini

11. ***Prionomma atratum* (Gmelin, 1790) [Image 2K]**

1790. *Cerambyx (Prionus) atratus* Gmelin, *Caroli a Linné Systema Naturæ per Regna tria Naturae*, Classis V. Insecta. 1 (4). 13th Edition. G.E. Beer, Leipzig: 1818.

1910. *Prionomma (Prionomma) atratum* Lameere, *Annales de la Société Entomologique de Belgique, Bruxelles*, 54(8): 280.

Material examined: 01 ex., India, Meghalaya, East Khasi Hills district, Mawsmai Cave, Cherrapunjee, 01 November 2011, B. Saikia, Reg. No. I/COL/NERC-43.

Diagnostic Characters: Body large and robust (L 42 mm, B 17 mm); antennae broken; pronotum broad with a pair of medially raised bulge and a mid-dorsal groove, laterally a pair of thorns; scutellum tongue shaped; elytra dark brown, longitudinal ridges present.

Distribution: India (Arunachal Pradesh, Chhattisgarh, Madhya Pradesh, Maharashtra, Meghalaya, Odisha, & Tamil Nadu) and Sri Lanka.

Discussion

Kariyanna et al. (2017) reported 1,536 species of longhorn beetles from India including 592 species from northeastern India. In Meghalaya, only 81 species of longhorn beetles were recorded prior to this report, wherein we are reporting 11 new records of longhorn beetles from the State. Hence, with this finding, the current cerembycid fauna of Meghalaya stands at 92 species. Despite being an economic pest, there is a general lack of research thrust in this group of insects as highlighted by the limited number of known species from the Region and as well as from the State.

Kariyanna et al. (2017) included Assam under the distribution range of *Baralipton maculosum* and *Anoplophora stanleyana*. A perusal of the report by Kariyanna et al. (2017) reveals that *B. maculosum* is known from Patkai Mountains while *A. stanleyana* is known from Naga Hills, due to which Assam was erroneously included in their distribution range, as both the locations were a part of the erstwhile undivided Assam. However, with the bifurcation of the erstwhile Assam which had resulted in the creation of Nagaland State in 1963, the new state included both Patkai Mountains and Naga Hills within its jurisdiction; hence, the occurrence of these above species in Assam is erroneous.

The specimens reported herein were collected from four localities: forest near Mawsmai Cave in Cherrapunjee (=Sohra) and some forests patches of Shillong, both the areas located in East Khasi Hills District, Umiam, and Nongkhyllem Wildlife Sanctuary and around, in Ri-Bhoi District of the State. The State being largely a producer of different varieties of fruits, especially citrus fruits, there is a high probability of occurrence of many undocumented species of longhorn beetles. Further extensive surveys, particularly into the protected areas

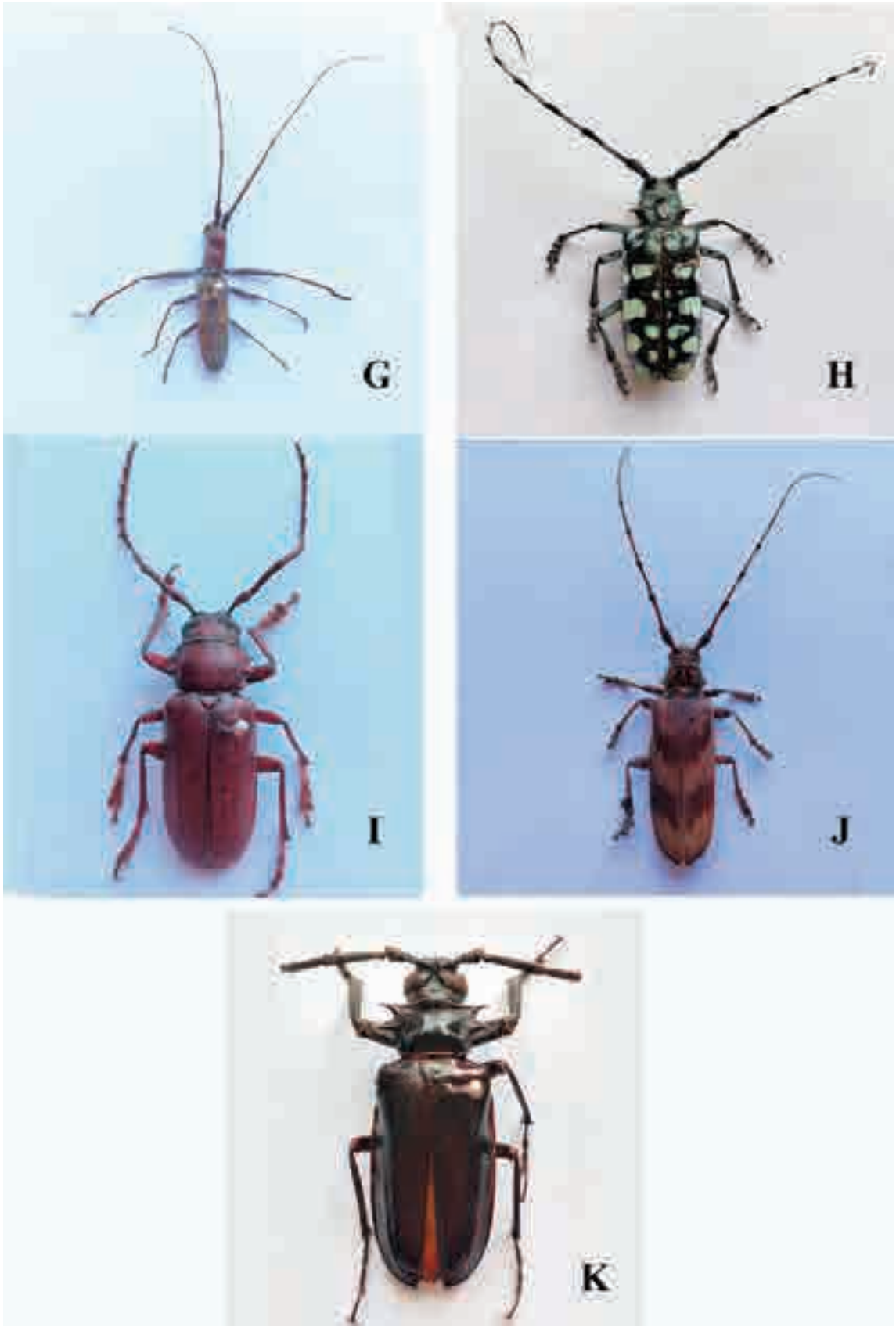

Image 2. Cerambycidae of Meghalaya: G—*Olenecamptus indianus* | H—*Anoplophora stanleyana* | I—*Sarothrocera lowii* | J—*Baralipton maculosum* | K—*Prionomma atratum*.

of the State has the potential to enhance our knowledge on the diversity of this group of beetles.

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SHORT COMMUNICATION

Range extension of lesser-known orchids to the Nilgiris of Tamil Nadu, India

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Abstract: The present paper records the extended distribution of orchids, viz., *Oberonia chandrasekharanii* V.J.Nair, V.S.Ramach. & R.Ansari, *Peristylus plantagineus* (Lindl.) Lindl., *Porpax exilis* (Hook.f.) Schuit., Y.P.Ng & H.A.Pedersen, and *P. jerdoniana* (Wight) Rolfe, to the Nilgiris of Tamil Nadu.

Keywords: Endemics, epiphytes, new record, Orchidaceae, *Porpax*, Western Ghats.

Orchids, one of the highly evolved or advanced flowering groups in the Plant Kingdom are known for their shape, structure, colour and everlasting flowers. The diversity of orchids is extensive; they are distributed all the way from tropics to alpine meadows with varied habits for their survival like epiphytes, lithophytes, saprophytes, and terrestrials. "The Orchids of India" accounts with 1,256 taxa belonging to 155 genera with 307 endemic species; while the Western Ghats is represented by 305 species under 75 genera among which 128 species are endemic to the region; whereas from Tamil Nadu state, 215 species under 62 genera are documented of which 92 species are endemic (Singh et al. 2019). From the Nilgiris district of Tamil Nadu 113 species were reported by Sharma et al. (1977), later Joseph (1982) documented 116 species under 49 genera. Recently, Jeevith et al. (2019) recorded 37 species belonging to 23 genera from the shola and grasslands of the Nilgiris.

Naturally, plants distribute or migrate through seed dispersal by various kinds of agents, viz., wind, water, insects, birds, and animals. Sometimes, their dispersion is enhanced through environmental disasters like cyclone, flood, torrential rain, causing translocation to an extended distance or range extension. Thus, previously distributed floral elements grow with the new associations. The regional flora workers should significantly document the new invasion of native or exotic species. It facilitates to compare the floristic assessment of an area on different time periods.

Although the flora handbook and pictorial guide of the Nilgiris is available, its flora is being continuously updated by new distribution records (Kiruthika et al. 2018; Kaliamoorthy & Saravanan 2019). The present paper highlights the range extension of four lesser-known orchids from the Nilgiris district of Tamil Nadu. Each species is supplemented with description, photographs, and other relevant details for easy identification (Image 1).

Editor: Anonymity requested.

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Materials and Methods

Study area

The Nilgiris district of Tamil Nadu is geo-positioned between 11.2–11.61^{0}N latitude and 76.5–76.91^{0}E longitude and ranging in altitude between 300 to 2,637 m. It lies phytogeographically in the Western Ghats covering total forest cover with 1,731.01 km^2 of which 466.72 km^2, 629.85 km^2, and 634.44 km^2 area with dense forest, moderate dense forest, and open forest respectively (India State Forest Report 2019). The hilly district is surrounded by Karnataka in the north, Kerala in the west, Coimbatore in the south, and Erode in the east.

Methods

After studying the indigenous medicinal plants in the Nilgiris district of Tamil Nadu (2016–2018), the authors collected a few species of orchids. The survey was supported with recording the field data, geo position and photograph of the species. The orchids were identified and studied using national and regional flora (Ansari & Balakrishnan 1990; Kumar & Manilal 1994; Fischer 1928, 2004; Misra 2007; Singh et al. 2019) and specimen examined in CAL, FRC, MH, and virtual herbarium of K. The voucher specimens are deposited at PSGR Krishnammal College for Women, Coimbatore, Tamil Nadu.

Taxonomic Treatment

1. *Oberonia chandrasekharanii* V.J.Nair, V.S.Ramach. & R.Ansari, Blumea 28: 361. 1983; C.S. Kumar & Manilal, Cat. Indian Orch. 81. 1994; S. Misra, Orchids India 309. 2007; S.K. Singh et al., Orchids of India - A pictorial guide 382. 2019; Ganesan et al. Endemic Flora of Western Ghats – Anamalais 1: 182. 2019. (Image 2).

Epiphytes up to 38 cm long. Acaulescent. Leaves ca. 15.0 x 1.5 cm, articulate at base, ensiform, acute. Scape ca. 9.0 x 0.6 cm, flattened. Inflorescence raceme, ca. 22 cm long, verticils. Flowers ca. 2 x 1 mm, pale brownish, pedicelled. Bracts ca. 2.0 x 1.25 mm ovate or lanceolate, acuminate, irregularly denticulate along margins, gland-dotted. Sepals & petals reflexed, sparsely gland-dotted; dorsal sepal ca. 1.25 x 1.0 mm, ovate-oblong, obtuse, entire; lateral sepals ca. 1.25 x 1.0 mm, ovate-oblong, obtuse, induplicate. Petals ca. 1.25 x 0.5 mm, linear, denticulate, distantly denticulate along margins. Lip antrorse, ca. 1.5 x 2.0 mm, semi-orbicular or reniform in outline, papillose, gland-dotted, 3-lobed; lateral lobes cuneate and auriform, folded upwards round the column by the proximal end; midlobe ca. 0.5 x 0.75 mm, 2-lobuled with a broad sinus in between; lobules orbicular; disc ovate, concave and sac-like. Pedicel with ovary ca. 2 mm long. Column ca. 0.39 x 0.45 mm, cylindric; clinandrium apical, orbicular, winged around; operculum sub-orbicular, rounded; rostellum retuse, shorter than the clinandrial wings; stigma sub-orbicular, saccate. Pollinia ca. 0.3 x 0.18 mm, obovoid.

Flowering & Fruiting: July–October.

Habitat: The species is distributed in the Wilson Plantation of Eucalyptus sp.

Specimen examined: 81B (PSGR Krishnammal College for Women), 15.vii.2017, India, Tamil Nadu, Nilgiris district, Wilson Plantation – Naduvattam, 11.491339^{0}N & 76.525112^{0}E, 1,515 m, coll. K. Kiruthika & M. Sulaiman.

Distribution: India (Karnataka, Kerala & Tamil Nadu).

Note: *Oberonia chandrasekharanii* can be easily identified from other *Oberonia* species by papilose nature of lip. Recently, the species has been reported from the Anamalai hills of Tamil Nadu (Ganesan et al. 2019). More than 20 individuals of the species observed in Wilson Plantation, Naduvattam.

2. *Peristylus plantagineus* (Lindl.) Lindl., Gen. Sp. Orchid. Pl. 300. 1835; C.E.C. Fisch. in Gamble, Fl. Madras 3(8): 1475. 1928; J.Joseph & R.Ansari in A.N.Henry et al., Fl. Tamil Nadu, Ind. Ser. I: Analy. 3: 22. 1989; C.S. Kumar & Manilal, Cat. Indian Orch. 83. 1994; C.E.C. Fisch., Flora of the Anamalai Hills 2nd reprint 176. 2004; S. Misra, Orchids India 312. 2007; S.K. Singh et al., Orchids of India - A pictorial guide 421. 2019. *Herminium plantagineum* Lindl., Edwards's Bot. Reg. 18: t. 1499. 1832. *Habenaria wightii* Trimen, Syst. Cat. Fl. Pl. Ceylon: 91. 1885; Hook.f., Fl. Brit. India 6: 162. 1890. (Image 3).

Terrestrial up to 90 cm tall. Tuber 2, 2–3 cm long, oblong or ellipsoidal, terete. Stem 25–30 x 1.5–4.0 mm, erect, terete, glabrous, sheaths broad, tubular, acuminate. Leaves 3–8, 6–15 x 2–5 cm, clustered about middle of stem, closely sheathing at the base, sessile, broadly elliptic to elliptic-ovate, acute, entire, minutely papillose, mid-nerve prominent, 5–7-veined. Inflorescence a raceme, terminal spike, 9–22 cm long, erect, densely many flowered; peduncle 4–10 cm long, bracteate; stem bracts 1.5–2.0 x 0.4–0.6 cm, ovate-lanceolate, acuminate, entire, papillose, glabrous, dirty brownish-green with a yellow margin. Flowers greenish-white, 5–7 mm long, sessile, resupinate. Bracts 9–14 x 2–3 mm, pale brownish-green, lanceolate, longer than the pedicel and ovary, lanceolate, acuminate, 1-nerved. Sepals sub-smilar, very minutely denticulate, glabrous, strongly 1-nerved; dorsal sepals 2.0–4.5 x 2.0–3.0 mm, concave, oblong-ovate, obtuse, forming a hood with petals; lateral sepals 2.5–5.0 x 1.5–2.5 mm, spreading,

Image 1. a,b—*Oberonia chandrasekharanii* (Habit & Inflorescence along with labellum of the flower) | c,d—*Peristylus plantagineus* (Habit & Inflorescence) | e,f—*Porpax exilis* (Habit & Flowers close view) | g,h—*P. jerdoniana* (Habit & flower close view). © M. Sulaiman.

Image 2. *Oberonia chandrasekharanii* herbarium sheet preserved at PSGRKCW.

Image 3. *Peristylus plantagineus* herbarium sheet preserved at PSGRKCW.

oblong, margins incurved, often overlapping, sub-oblong, apex at acute. Petals 2.5–4.0 x 2.0–3.0 mm long, obliquely oblong-elliptic, obtuse, entire, glabrous, glands dotted, 1-nerved. Lip 2.0–3.5 x 2.0–3.5 mm, smaller than the lateral sepals, faintly white, gland-dotted, broadly ovate, oblong, obtuse, shortly 3-lobed, base of the lip sub-concave, 3-nerved, mid nerve running straight from the base to the apex, the two lateral ones slightly sinuate, meeting below the apex at to form a loop across the mid-nerve; spur much shorter than sepals. Column short, pale green. Anther rounded, short recurved; tubes, divergent at the base; pollinia 2, clavate, caudicles very small with a small orbicular gland. Stigmatic lobes short, stout convex. Pedicel with ovary ca. 10 x 2 mm, stout, curved at apex, ribbed.

Flowering & Fruiting: July–December.

Habitat: Tropical evergreen forests and grasslands.

Specimen examined: 39A (PSGR Krishnammal College for Women), 28.viii.2016, India, Tamil Nadu, Nilgiris district, Allurkoodamoola – Gudalur, 11.51723^{0}N & 76.519669^{0}E, 964 m, coll. K. Kiruthika & M. Sulaiman.

Distribution: India (Chhattisgarh, Odisha, West Bengal, Madhya Pradesh, Andhra Pradesh, Gujarat, Maharashtra, Goa, Karnataka, Kerala, & Tamil Nadu), Nepal, and Sri Lanka.

Note: *Peristylus plantagineus* can be easily recognised by having obscurely lobed lip and long floral bracts which exceed to the pedicle and ovary. It is found growing under moist Bamboo forests in Allurkoodamoola, Gudalur and previously recorded only from Anamalai and Tirunelveli hills of Tamil Nadu.

3. *Porpax exilis* (Hook.f.) Schuit., Y.P.Ng & H.A.Pedersen, Bot. J. Linn. Soc. 186: 199. 2018. *Eria exilis* Hook.f., Hooker's Icon. Pl. 19: t. 2074. 1891; C.E.C. Fisch. in Gamble, Fl. Madras 3(8): 1425. 1928; C.S. Kumar & Manilal, Cat. Indian Orch. 73. 1994; S. Misra, Orchids India 297. 2007; Karuppusamy & Ravichandran, Biosci. Disc. 4(1):12. 2013; S.K. Singh et al., Orchids of India - A pictorial guide 261. 2019. *Porpax chandrasekharanii* Bhargavan & C.N. Mohanan, Curr. Sci. 51: 990. 1982. *Eria chandrasekharanii* (Bhargavan & C.N. Mohanan) C.S.Kumar & Manilal, Taxon 35: 720. 1986. (Image 4).

Epiphytic, up to 3 cm tall. Pseudobulbs 0.3–1.0 cm across, 0.1–0.2 cm thick, button like, dorsi-ventrally compressed pushing the apex at to a lateral position,

always in pair or triplet, with white epidermal venation; scape 1.5–2.8 cm long, arise from the side of matured pseudobulbs. Leaves 2, 1.0–2.5 x 0.4–0.9 cm, deciduous, from the top of the scape, sub-opposite, unequal, obovate-elliptic to oblanceolate-oblong, entire, minutely serrulate towards apex, acuminate-apiculate, 7–9-veined, base sheathing, channeled, articulate, leaves fall before flowering. Inflorescence a raceme, 1.5–2.5 cm long, laxly 5–16-flowered, glabrous; peduncles slender, erect, terete, base at covered by the sheathing leaf-bases and sheath; rachis 1.0–1.3 cm long, slender, strongly flexuous. Flowers minute, 2.5–4.0 mm long, not fully opening, glabrous, white to greenish-yellow, lip purple. Bracts 1.0–1.5 x 1.0–1.5 mm, persistent, equal or shorter than pedicel and ovary, clasping, membranous, ovoid, cymbiform, entire, acuminate, 1-veined. Dorsal sepal *ca.* 2.0 x 1.2 mm, ovate-oblong, entire, obtuse, 1-veined; lateral sepals 2.0–2.2 x 1.5–2.0 mm, ovate, falcate, entire, sub-acute to obtuse, 1-veined; mentum *ca.* 1.0 x 1.5 mm, saccate, broadly orbicular, curved outwards. Petals 1.3–1.8 x 0.5–0.7 mm, elliptic-lanceolate, falcate, entire, acute, 1-veined. Lip 1.5–1.8 x 0.8–0.9 mm, enclosed within the lateral sepals and mentum, simple, fleshy, conduplicate, strongly recurved at the middle, entire to slightly undulate, 3-veined, veins ending well behind the apex; disc with 2-oblong calli along the margins from base to apex. Column 0.3–0.5 mm long, erect; foot 1.2–1.5 mm long, elongated, curved; clinandrium widely 2-grooved; rostellum reflexed, tongue-shaped; stigmatic cavity orbicular. Anther ca. 0.3 x 0.4 mm, broadly orbicular, slightly emarginate, 2-lobed, each lobe 4-chambered; pollinia 8, in 4 unequal pairs, *ca.* 0.2 mm long, oblong-clavate, united by caudicles. Pedicel with ovary 1–1.15 mm long, slightly curved. Capsules 2.5–5.0 mm long, broadly ovate to obpyriform, ridged.

Image 4. *Porpax exilis* herbarium sheet preserved at PSGRKCW.

Flowering & Fruiting: January–May

Habitat: *Porpax exilis* is found in colonies on the host of *Litsea* sp.; it is associated with *Pinalia mysorensis* (Lindl.) Kuntze Lindl. and *Bulbophyllum* sp. in the tropical evergreen forests.

Specimen examined: 166 (PSGR Krishnammal College for Women), 16.i.2017, India, Tamil Nadu, Nilgiris district, Puliyambara – Gudalur, 11.503091^{0}N & 76.416058^{0}E, 975 m, coll. K. Kiruthika & M. Sulaiman.

Distribution: India (Maharashtra, Goa, Karnataka, Kerala & Tamil Nadu).

4. *Porpax jerdoniana* (Wight) Rolfe, Orchid Rev. 16: 8. 1908; C.E.C. Fisch. in Gamble, Fl. Madras 3(8): 1422. 1928; J.Joseph & R.Ansari in A.N.Henry et al. Fl. Tamil Nadu, Ind. Ser. I: Analy. 3: 23. 1989; C.S. Kumar & Manilal, Cat. Indian Orch. 84. 1994; S. Misra, Orchids India 315. 2007; Uthayakumari Kalavathy, Taxonomic studies of the Monocots of Tirunelveli hills 71. 2004. S.K. Singh et al., Orchids of India - A pictorial guide 457. 2019. *Lichenora jerdoniana* Wight, Icon. Pl. Ind. Orient. 5: t. 1738. 1851. *Eria lichenora* Lindl., J. Proc. Linn. Soc., Bot. 3: 46. 1858; Hook.f., Fl. Brit. India 5: 787. 1890. (Image 5).

Epiphytes. Pseudobulb 0.5–1.0 cm diam., discoid, enclosed by reticulated sheath. Leaves 1.5–2.0 x 1.0–1.5 cm, 2-per pseudobulb, pale brown or green, orbicular or ovate, hairy on both surfaces, with reticulate veins and persistent during flowering. Flowers 1–2, reddish-brown, arise between leaves, sessile. Sepals connate, tube 2-lipped, lobes unequal, oblong, pubescent; dorsal sepal ca 1.5 x 1.0 mm; lateral sepals ca 2 x 1 mm, fused. Petals ca 2.0 x 0.7 mm, linear, fused, obtuse, 3-veined. Lip ovate-cordate, sides toothed, tip subulate, gland dotted. Anther 2-celled, ca. 1.5 x 1.0 mm, orbicular; pollinia 8, ca. 0.8 mm long clavate, waxy. Pedicel with ovary 3–4 cm long, densely hairy.

Flowering & Fruiting: July–October.

Habitat: The species is found growing on *Careya arborea* trees in association with *Dendrobium*

Image 5. *Porpax jerdoniana* herbarium sheet preserved at PSGRKCW.

macrostachyum in tropical evergreen forests.

Specimen examined: 81A (PSGR Krishnammal College for Women), 14.vii.2017, India, Tamil Nadu, Nilgiris district, Nadugani – Gudalur, 11.477477^{0}N & 76.419929^{0}E, 876 m, coll. K. Kiruthika & M. Sulaiman.

Distribution: India (Maharashtra, Goa, Karnataka, Kerala, Tamil Nadu, Andaman & Nicobar Islands).

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NOTE

Opportunistic sighting of a Sperm Whale *Physeter macrocephalus* Linnaeus, 1758 in Lakshadweep Archipelago

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The Sperm Whale *Physeter macrocephalus* Linnaeus, 1758 is a large-sized toothed marine mammal belonging to the order Cetartiodactyla and family Physeteridae. It is the only living species of the genus *Physeter* (Mittermeier & Wilson 2014). It is the world's largest toothed whale having the biggest brain of any animal species (Marino 2004). This species is characterised by a very large and rounded head which hold large quantities of a waxy substance known as spermaceti; the blowhole opens at angle from the left side of nasal passage; body colour is deep black to brownish-gray above with white markings around lips; instead of a dorsal fin, this species has distinct thick, low, and triangular humps (Jefferson et al. 1993; Menon 2014). It may live alone, or in small groups of 20–40 individuals or more in greater than 1,000 m deep oceans and undertake extensive migration (Taylor et al. 2019). Their distribution range is from Antarctic and cold-temperate waters (Northern hemisphere) to tropical waters (Mittermeier & Wilson 2014). In India, this species has been recorded all along the coastal states of Gujarat, Karnataka, Kerala, Tamil Nadu, Puducherry, Andhra Pradesh, Lakshadweep Islands, and Andaman & Nicobar Islands (Kumarran 2012; Marine Mammals of India database 2022).

Recently, the Government of India declared three protected areas in the Lakshadweep archipelago. Among these, Pitti Island (Pitti Islet) is the one where Zoological Survey of India conducted a marine faunal exploration under MoEFCC-ZSI in-house activity during February 2022. During the survey period, a single Sperm Whale was observed while partially breaching through the water surface on 7 February 2022 at 0853 h (Beaufort Sea state 1). It was recorded between Kavaratti and Pitti Island (10.653^{0}N & 72.598^{0}E). Based on the distinctive large rounded head (Image 1a), an angled bushy blow of water from the left side of its nose (Image 1b) and the thick and triangular hump on the back (Image 1c), the whale was confirmed as *Physeter macrocephalus* Linnaeus, 1758. However, the size of the whale and its behaviour except breaching could not be ascertained as it was

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Image 1. Sperm Whale from the Lakshadweep archipelago: a—the large rounded head | b—an angled bushy blow of water opens from the left side of its nose | c—thick and triangular hump on the back. © N. Marimuthu.

observed at a distance of about 500 m.

Although the Sperm Whale ranges worldwide, their record in Lakshadweep coasts is limited. From 1890 to 2018, there are 10 records of Sperm Whale reported from Kalpeni and Chetlat Islands of the Lakshadweep archipelago, of which eight records are strandings (James 1990; James & Panicker 1994; Pande et al. 2009). After 2009, only a stranding report was documented without locality information from Lakshadweep (a fisherman record) in 2018 (Marine Mammals of India database 2022). Here, we report an opportunistic sighting of a Sperm Whale from Pitti Island of Lakshadweep archipelago. Pitti Island lies within the Indian Ocean Cetacean Sanctuary (IOCS). Sperm Whales occur in the IOCS which is a potential feeding and calving ground (De Boer et al. 2003).

Besides the common threats from natural and anthropogenic impact, the illegal ambergris (a solid waxy substance that originates from the digestive system of Sperm Whale) trade is considered as a major threat to this species (Anonymous 2021, 2022; Raveendran 2022). Due to rafting behavior at the surface between deep dives, it is also more vulnerable to vessel strikes (NOAA Fisheries 2022). Thus, this species is classified as 'Vulnerable' globally by the IUCN Red List of Threatened Species (2022) and listed under Appendix I of the CITES and Schedule II of the Indian Wildlife (Protection) Act, 1972. Increased survey efforts could aid in monitoring whales and other cetaceans in exclusive economic zone (EEZ) of India. Further this observation indicates that opportunistic data from such efforts could also be beneficial for framing conservations strategies under Schedule- I of the Indian Wildlife (Protection) Act, 1972.

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NOTE

An unusual morph of *Naja naja* (Linnaeus, 1758) (Squamata: Serpentes) from Goa, India

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Pigmentation serves a protective role in many animals, including snakes, it functions in camouflage, warning, mimicry or thermoregulation (Bechtel 1978; Krecsák 2008). Body coloration is a multifunctional trait often characterized by sophisticated variation (Kemp et al. 2005; Bury et al. 2020). Therefore, discontinuous phenotypes are generally thought to bear fitness costs as a result of the primary functions of a given color variation having been lost (Bury et al. 2020). The maintenance of such phenotypes within populations, i.e., color polymorphism, thus represents an interesting evolutionary phenomenon (Forsman 1995; Forsman et al. 2008; Bury et al. 2020). Melanistic individuals exhibit an increased amount of dark pigmentation, a possible adaptive hypothesis for melanism in snakes is protection against sun damage (Lorioux et al. 2008; Jablonski & Kautman 2017).

Melanism is an example of color polymorphism in which a phenotype is characterized by over concentration of melanin compared to the typical color (Trullas et al. 2007; Bury et al. 2020). In small vertebrates, melanistic individuals are known to bear an elevated risk of predation (Andren & Nilson 1981; Bury et al. 2020). In the past few years there has been an increase in the reports of abnormal colorations among Indian serpents, which includes cases of albinism and leucism (Devkota et al. 2020; Deshmukh et al. 2020; Mukherjee & Mohan 2021). The spectacled cobra *Naja naja* is a large, venomous snake distributed throughout most of India except the far north-east, altitudes above 2,000 m, and the Andaman & Nicobar Islands (Daniel 2002; Das 2002; Whitaker & Captain 2004; Whitaker & Martin 2015).

On 27 May 2021, an abnormal looking *N. naja* was rescued at Modelo wado, Assonora (15.618^{0}N, 73.897^{0}E), Goa at 1005 h. The snake was initially sighted by an elderly woman who then reported it to other members of the family, who called the rescuer. The snake was brownish black in colour on dorsal side and brownish grey on ventral side (Image 1), eye with visible eye ball (Image 2) and with a scarcely visible spectacle mark on the hood (Image 3). Ventral scales were counted as per Dowling (1951). The unsexed individual possessed 187 ventral scales, 25 undivided subcaudal scales and an undivided anal plate. Dorsal scales at neck: mid-body: tail, were in 24:21:15 rows, respectively. Nasal scale 1 on each side separated by a pair of pre frontals, 1 frontal, 2 parietals and 2+3 temporal scales on each side, supralabials 7 on right and 8 on left with 3rd & 4th supralabial contacting the

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Image 1. Full body view of *Naja naja* rescued at Modelo wado, Assonora, Goa. © Durgesh Singh.

eye, infralabials 8 on right and 9 on left, cuneate scale is present on both the sides, 1 preocular, 3 postocular and 1 supra ocular (Image 2). After recording the meristic data, the specimen was handed over to the Goa Forest Department to be released in a suitable habitat.

The snake was identified to be Spectacled Cobra *Naja naja.* The ventral scale count was in the range provided by Captain & Whitaker (2004) but the observed subcaudal scale count for complete tail was below the normally recorded range for *N. naja*. Such black color morph individuals are been recorded in northwestern region of India where such morphs are said to be common (Whitaker & Martin 2015; Litschka-Loen et al. 2019). The snake being rescued from a locality where no major transportation activity occurs reduces the chances of snake being transported from the region where they are commonly found. Observed pigmentation is the first reported case of melanism from this region and appropriate documentation of these types of individuals will farther our understanding of this phenomenon in *N. naja*.

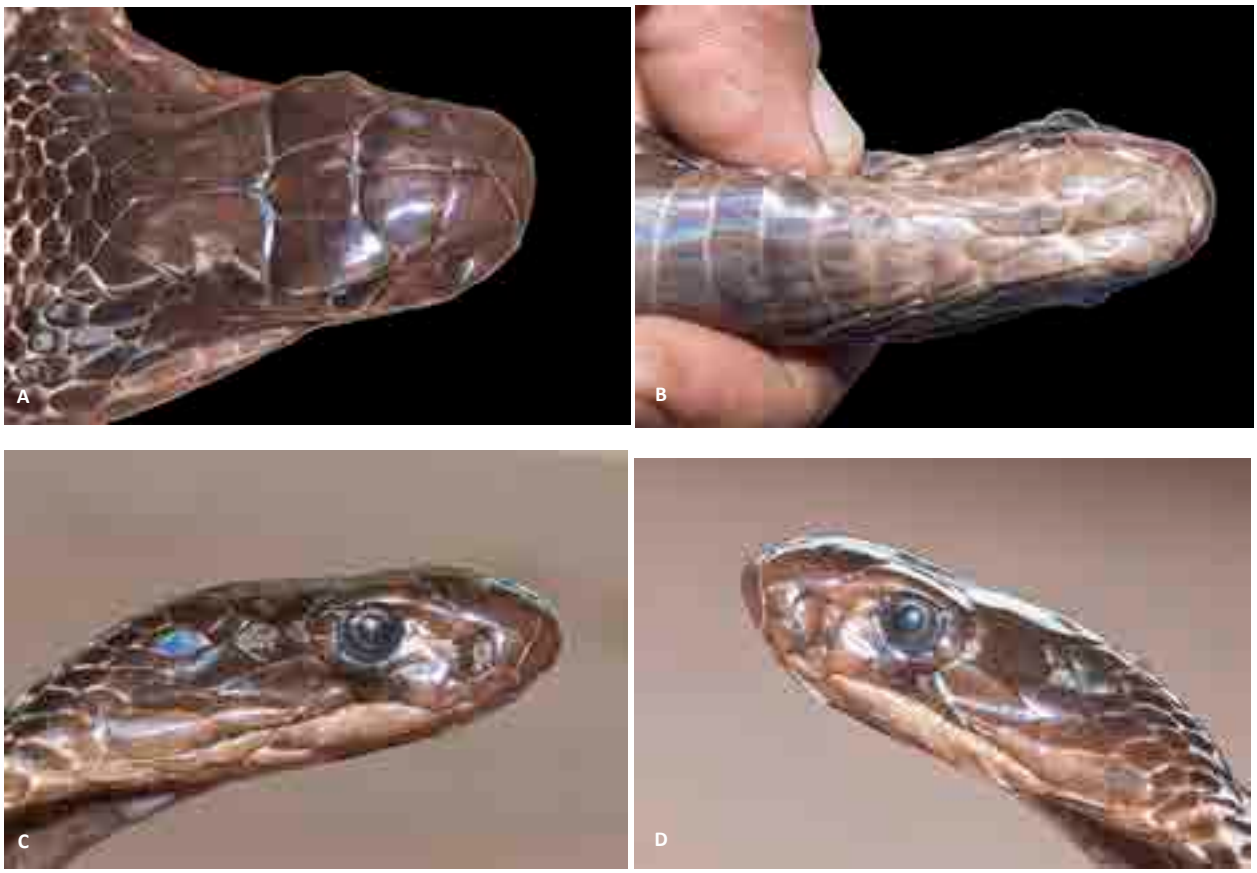

Image 2. A—Dorsal head portrait | B—Ventral head portrait | C—Right lateral head portrait | D—Left lateral head portrait of *Naja naja* rescued from Modelo wado, Assonora, Goa on 27 May 2021 at 1005 h. © Mayur Gawas.

Image 3. *Naja naja* hood: A—Dorsal view | B—Ventral view. © Durgesh Singh.

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Drape Fin Barb *Oreichthys crenuchoides* (Schäfer, 2009) (Cypriniformes: Cyprinidae) a new fish species report for Nepal

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With more than 6,000 rivers, Nepal is one of the most biodiverse rich countries in terms of freshwater fish diversity (Shrestha 2008; Khatri et al. 2020). To date, a total of 240 species of fish have been reported from Nepal (Froese & Pauly 2021). Of the 240, 118 species were recorded from the Morang District that adjoins with Jhapa District in the west (Subba et al. 2017). Kharel (2013) conducted an extensive survey of fishes in the Budoholi Wetland in Jhapa District and recorded 43 species of fish. Globally, the big-sized freshwater fishes have declined by 94%, and 30% of all freshwater fish species are threatened with extinction according to the International Union for Conservation of Nature (IUCN) Red List (World Wildlife Fund 2021).

The Budoholi Wetland ('Budo Holi') is formed by the old course of the Aduwa River and is irregularly extended from the north-west inlet to the south-east in the outlet (Rai et al. 2006). The wetland is located in Arjundhara Municipality-9 (26.6739^{0}N, 88.0146^{0}E; 148 m) of Jhapa District in southeastern Nepal (Image 1) and is managed by Martyrs Memorial Park under the Sukhani Martyrs Memorial Foundation (SUMMEF). Once this wetland was a marshy area but it became a lacustrine habitat due to the construction of the dam by the Park. Just below the outlet of the main body of water, a natural pond occurs, which is popularly known as the Turtle Rescue and Conservation Centre (TRCC) Natural Lake (Image 2). This natural pond has luxuriant aquatic flora and fauna and is strictly protected for rearing softshell turtles by TRCC. The maximum depth of the pond is 100 cm, which has a muddy substrate, and sunlight that penetrates to the bottom.

During the fish survey, two sets of foldable umbrella fishing traps, with six sides that each have a hole in them were used to trap fish in the natural pond. Chopped pieces of chicken and puffed rice were used as bait in the trap. On 10 September 2021 the traps were set by submerging them in the pond and kept there overnight. Except for one specimen, all the fish captured in the traps were identified using standard identification keys for Nepali fish species (Shrestha 2008; Froese & Pauly 2021).

The unknown specimen was identified as Drape Fin Barb *Oreichthys crenuchoides* (Image 3) in consultation with ichthyologists and available ichthyology literature from adjacent areas of neighbouring India. This small cyprinid fish was first described by Schäfer (2009) from the Jorai River in West Bengal, India. The total length (TL) of the captured specimen was measured as 47 mm,

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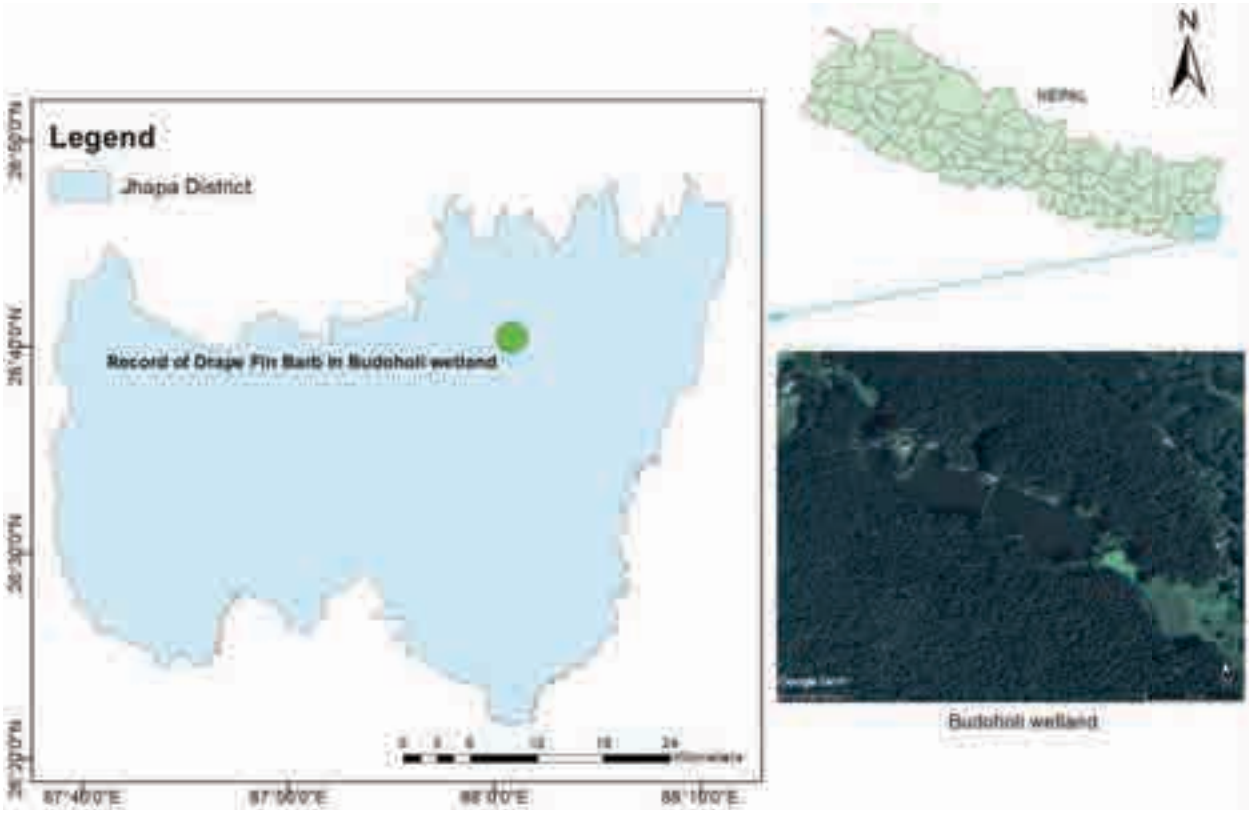

Image 1. Map showing *Oreichthys crenuchoides* recorded location in Jhapa District in southeastern Nepal. The inset image is the Google map of Budoholi Wetland.

Image 2. Habitat of *Oreichthys crenuchoides* in Budoholi Wetland of Martyrs Memorial Park, Arjundhara Municipality in Jhapa District, Nepal. © Tapil Prakash Rai.

which is the largest known specimen to date (Schäfer 2009). It has a prominent dorsal fin, the snout is blunt with a large black blotch at the base of the caudal fin, and the black spot or blotch on the anal fin is absent. Drape Fin Barbs typically have 11–13 rows of pores on the cheeks, 17–19 + 2 scales in longitudinal series, and seven scales in transverse series (Schäfer 2009).

Drape Fin Barbs are considered 'Data Deficient' according to the IUCN Red List (Ng 2010) and this record from Nepal will help in better understanding its spatial distribution. Habitat loss, water pollution, and excessive fish harvesting are the main threats observed in the study area.

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Image 3. *Oreichthys crenuchoides* recorded in Budoholi Wetland of Arjundhara Municipality in Jhapa District, Nepal. © Tapil Prakash Rai.

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New distribution record of *Gazalina chrysolopha* Kollar, 1844 (Lepidoptera: Notodontidae) in the Trans-Himalayan region of western Nepal

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Gazalina chrysolopha Kollar, 1844 is a moth belonging to the family Notodontidae. Genus *Gazalina* was described by Walker in 1865 which contributes a total of three species with other two *G. apsara* and G. *transversa*, to the moth inventory of Nepal (Smith 2010). Haruta (1993) collected *G. chrysolopha* from Godawari (1,600 m) south-east of Kathmandu. During another expedition, this moth was recorded from Dagchu (2,880 m) and Jiri (2,340 m) in eastern Nepal (Haruta 1994). Hampson (1892) described the northwestern Himalaya and Sikkim as their major habitat. The caterpillar of *G. chrysolopha* is a major pest of the oak forest causing heavy defoliation (Rahaman 1992). It has been found to defoliate the shade tree (*Alnus nepalensis*) of large cardamom so severely that it exposes the undergrowing cardamom to excess sunshine, frost, and other weather conditions (Srivastava 2003). Amongst three *Gazalina* species in Nepal, *G. chrysolopha* remains the strongest suspect to cause of corneal melting eye disease called Seasonal Hyperacute Panuveitis (SHAPU), reported only in Nepal (Upadhyay et al. 2020; Gurung et al. 2021). Monsoon season is considered the favorable period for the completion of their biological cycle (Gurung et al. 2021). As a result, the species prefer areas that get regular monsoons like western regions of Nepal such as Kaski and its neighboring districts causing the disease SHAPU in most (Upadhyay et al. 2020).

During an opportunistic survey on 28–29 August 2021, 10 individuals of *G. chrysolopha* were recorded in the Mustang district (28.770°N & 83.727°E, 2,885 m). The district is also a part of a trans-Himalayan region that falls under the Annapurna Conservation Area (ACA). Moths were observed nearby light sources in the daytime in resting position on a wall, window glass, and partially damaged wings on the ground. Capturing of moth was not done to avoid any risk of contamination due to lack of proper equipment and photographed in a natural position to observe wing mark patterns. Identification was based on Hampson (1892) and Haruta (1993). *G. chrysolopha* differs from other sibling species in the fore wing having an indistinct sub-basal black line: a streak along median nervure; two slightly waved medial oblique lines beyond which the veins are black; the thorax and collar are tinged with fulvous (Hampson

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Image 1,2. *Gazalina chrysolopha* observed nearby light sources on window glass and walls. © Ashant Dewan.

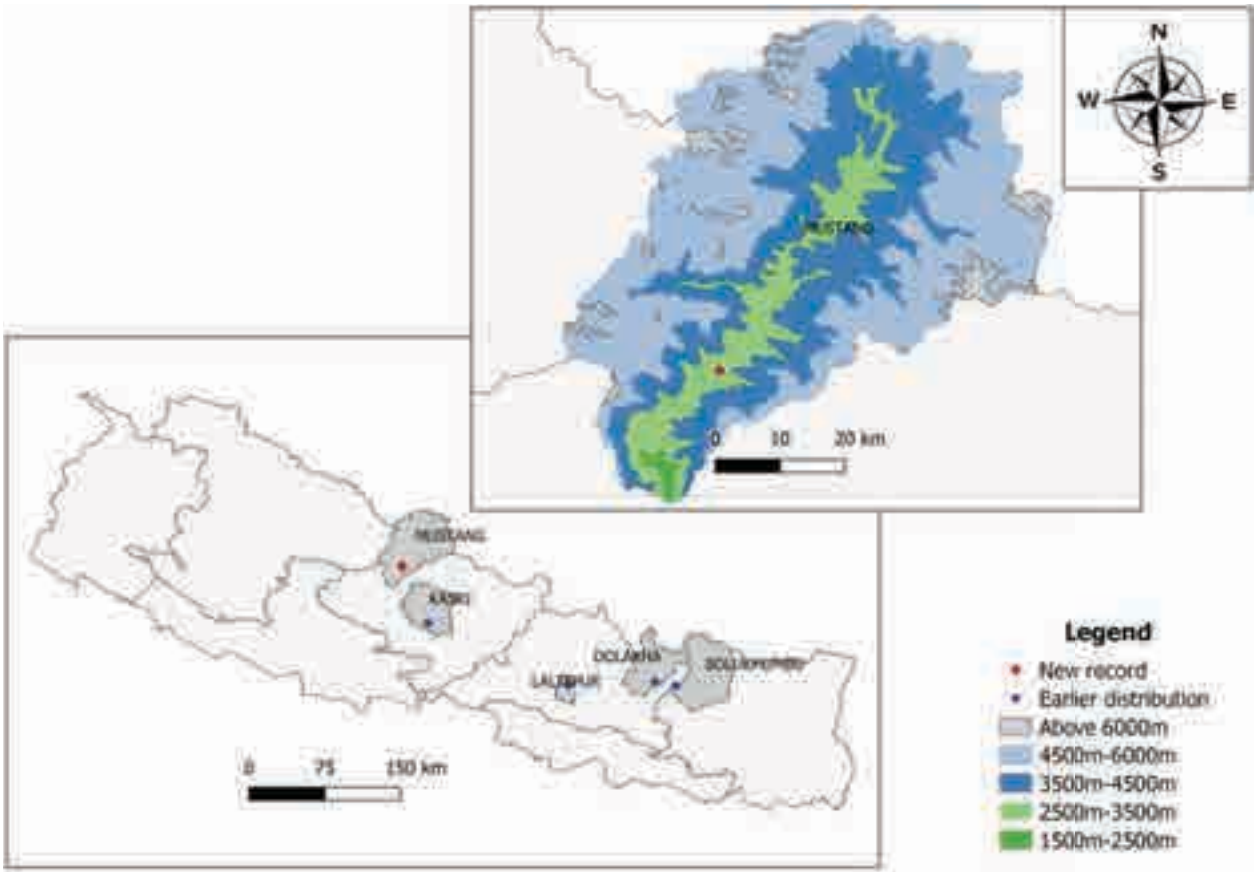

Image 3. Distribution record of *Gazalina chrysolopha* in Nepal. A red square indicates a new record in the Trans-Himalayan region of Mustang, western Nepal.

1892), whereas the females of these moths have a golden brown tuft of spines on their abdomen (Clements 1951; Manandhar et al. 2018).

The landscape was typical trans-Himalayan terrain with dry stony and sandy habitat scattered with grassy clumps, pine shrubs, and few cultivated land with apple trees. The finding of a moth in this region set forth the change in current distribution range, host, and habitat preference behaviors. Extending of study site with proper field equipment (light traps) could result in a complete inventory and distribution of overall moth species. Besides this, the possibility of an outbreak of SHAPU diseases cannot be denied. Timely awareness program is required in the area to prevent the spread of disease.

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NOTE

First record of *Xanthia* (*Cirrhia*) *icteritia* (Hufnagel, 1766) (Noctuidae: Xyleninae) from India

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Xanthia Ochsenheimer, 1816 is a genus of moth belong to the family Noctuidae and often tabbed with a common name 'Swallow'. *Xanthia* Ochsenheimer, 1816 is the synonym of the genus *Cirrhia* Hübner, 1821. Poole (1989) included *Xanthia* Billberg, 1820; *Cirrhia* Hübner, 1821; *Citria* Hübner, 1821; *Mellinia* Hübner, 1821; *Euthemonia* Gistl, 1848; and *Tiliacea* Tutt, 1896 as junior synonyms of *Xanthia* Ochsenheimer, 1816. Ronkay et al. (2001) combined the genus *Xanthia* with the genus *Cirrhia* Hübner and treated them as subgenera of *Xanthia*.

In the present study, we report the presence of *Xanthia* (*Cirrhia*) *icteritia* in Union territory of Jammu & Kashmir, India. A single male *Xanthia* (*Cirrhia*) *icteritia* (Image 1) was photographed and collected on 20 September 2021 in Tehsil Herman, district Shopian of Kashmir Division (Union territory of Jammu & Kashmir), at 1,596 m (33.705^{0}N, 74.940^{0}E) (Image 1). The specimen was identified based on the morphological and genitalia characters provided in the published literature: Hampson (1894), Parrack & Bay (1986), Mehl & Thiele (1995), Lafontaine & Mikkola (2003), Saldaitis et al. (2011), Sivasankaran et al. (2011), Tarauş & Okyar (2016), Sanyal et al. (2018), Kovtun (2019), and Dar et al. (2020).

The wingspan of individual is 3.7 cm (Image 2) with forewing pale yellow and slightly hooked. The costal end of the median shade, and the subbasal costal blotch prominently dark brown; the dark blotch at base is reniform with a pale centre; the fringe yellow; head and shoulders pale yellow; hindwing whitish: an irregular diffuse median fascia between median and postmedian lines; a subterminal costal blotch; a dotted subterminal line and a faintly outlined oval (Image 3).

The genitalia of the specimen was prepared using KOH in 135°C by clearing the apex of the abdomen for several minutes. The abdomen was transferred to glycerin for further examination after rinsing the KOH with distilled water. After examination, we observed the well-developed, medium and slender uncus of the male genitalia of the species. Tegumen broad, bearing prominent penicula. Juxta shield shaped. Valvae elongated and slender, sclerotized; clasper and ampulla also well sclerotized; corona moderately developed. Vinculum V-shaped. Aedeagus stout, vesica bearing a large scobanate cornutus and a micro cornuti (Image 4). The collected specimen along with its genitalia is deposited in the museum of the Division of Taxonomy and Biodiversity at the Entomology Research Institute, Loyola College Chennai, India with specimen voucher

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Image 1. Map of Shopian District showing location of collection site. (Source: Maps of India, Google maps).

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Major tree species around the site were *Populus deltoides, Juglans regia, Robinia pseudoacacia, Ulmus* sp., *Salix* sp., and *Malus* sp. (Riyaz et al., 2021). The temperature was recorded as 25ºC and the habitat mostly consists of agricultural lands with annual precipitation of 660 mm and average temperature of 13ºC (Riyaz & Reshi 2021).

Xanthia (*Cirrhia*) *icteritia* (Hufnagel, 1766), is distributed across Europe to Central Asia including Japan and Korea (GBIF Secretariat 2021). In Europe, *Xanthia* (*Cirrhia*) *icteritia* is very common in United Kingdom and adjoining countries except for the furthest south (https://ukmoths.org.uk/species/cirrhia-icteritia/adult/).

Based on the previous observations with similar habitats, the authors propose a tentative area of occurrence for this species to the entire area of Kashmir and northern parts of Jammu division of the Union territory of Jammu & Kashmir in India. The authors expect the possibility of the species to occur in northern parts of Pakistan. The IUCN Red List assessment of this species on the GeoCAT website based on the present identification, type locality and two other possible locations showed the species to be Least Concern with extent of occurrence of 2,449,522.018 km^2. This record is significant and important, as it constitutes the first

Image 2. Mounted specimen of *Xanthia* (*Cirrhia*) *icteritia*. (Mounted and stretched by Muzafar Riyaz).

proven evidence of the occurrence of *Xanthia* (*Cirrhia*) *icteritia* Hufnagel, 1766 (synonym of *Xanthia icteritia* Hufnagel, 1766) in the Indian subcontinent making it a

Image 3. Live photograph of the *Xanthia* (*Cirrhia*) *icteritia*. © Muzafar Riyaz.

Image 4. Male genitalia and aedeagus of *Xanthia* (*Cirrhia*) *icteritia*. (Uncus well developed, juxta shield shaped vinculum V-shaped. aedeagus stout). (Genitalia isolated by K. Sivasankaran and photogrpahed by Muzafar Riyaz).

notable range extension for the species into the political boundary of India.

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NOTE

First report of the mymarid genus *Proarescon* Huber (Hymenoptera: Chalcidoidea: Mymaridae) from India

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Members of the family Mymaridae are called fairyflies and are generally egg parasitoids (except two species) attacking eggs of agriculturally important insects (for details refer Huber (1986) & Huber et al. (2006)). This family is represented by 1,490 described species under 119 genera globally (Noyes 2019) of which only 39 genera and 232 species are known from India (Athithya & Manickavasagam 2022a). Surveys are being conducted across India to locate other mymarid fauna reported elsewhere but not from India. One such survey uncovered *Proarescon primitivus* (Huber) which is being reported here for the first time from India.

Since 2010, we have been conducting surveys specifically for recovering chalcidoid parasitoids from Western Ghats of Kerala state. Parasitoids were collected using yellow pan traps and pitfall traps and mymarids were sorted out and stored in 70% alcohol at -20 ^{0}C. Mymarids were subsequently diagnosed after dissection following Noyes (1982) and Huber (2015). After mounting, images of the mounted parts were captured using a DMC 2900 camera linked to a Leica DM750 phase contrast microscope. The united Zip software was used to obtain stacked images which were further processed using Adobe Photoshop version 7.0.

Proarescon primitivus (Huber) (Image 1a–d): (Type species: *Borneomymar primitivum* Huber, 2002). Later *primitivum* was transferred from *Borneomymar* to a new genus *Proarescon* by Huber (2017) and the species was named as *P. primitivus*. Members belonging to the genus *Proarescon* (Huber) can be diagnosed using the characters: 1. Funicle 8-segmented; 2. clava entire and gradually narrowing apically to a point (Image 1b); 3. Fore wing microtrichia more densely spaced except for an oval area along posterior margin (Image 1c,d).

Proarescon is represented only by two species globally (*P. primitivus* and *P. similis* Huber, 2017) of which the species in study belongs to *P. primitivus* that can be diagnosed using the characters: clava 3.3 times as long as wide, with ventral margin almost straight, cubital line in fore wing extending proximally almost to level of proximal macrochaeta (Image 1a).

Material examined: 08.v.2019, two females with Entomology Department, Annamalai University (EDAU/Mym41/2022). One female on slide under five coverslips, another female on slide under two cover slips, labelled, India: Kerala, Western Ghats (10.77N; 77.06E), pitfall trap, forest floor, coll. Prasanth.

Distribution: India (new record); Indonesia (Huber

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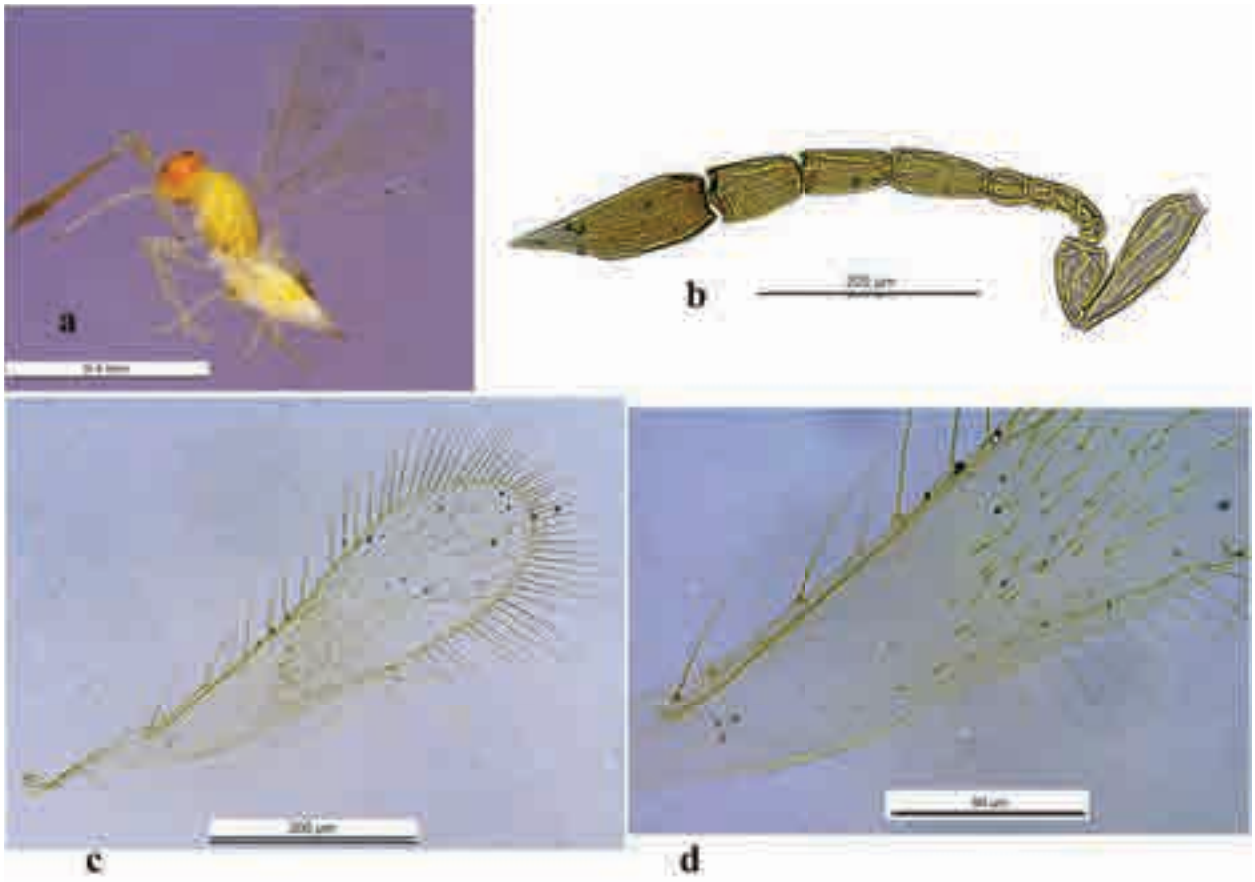

Image 1a–d. *Proarescon primitivus* female: a—Habitus | b—Antenna | c—Fore wing | d—Base of fore wing magnified. © Authors.

2002) and Thailand (Huber 2017).

Recently Athithya & Manickavasagam (2022b) proposed a key to diagnose the generic group initially, followed by diagnosing the particular genus within that generic group to reduce misidentification. In this key, *Proarescon* fits in *Arescon* group of genera under couplet 4. Now this genus group is known by two genera (*Arescon* and *Proarescon*). However, *Proarescon* can be differentiated from *Arescon* as shown in generic diagnosis (in *Arescon*, funicle 6-segmented, clava entire but not narrowing to a pointed apex and fore wing microtrichia bare to densely setose but without a specific oval area in the posterior margin).

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Article

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