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continued on the back inside cover

Caption: Both the Old World and New World birds and fish are not only beautiful but also tell us about the status of their habitats. And as people, we can learn more from them about the world we live in. Watercolour artwork by Anita Menon, Yellow Train School, Coimbatore.

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ARTICLE

Appearances are deceptive: molecular phylogeny recovers the Scaly Gecko *Hemidactylus scabriceps* (Reptilia: Squamata: Gekkonidae) as a member of a scansorial and rupicolous clade

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Abstract: We reassess the systematics of *Hemidactylus scabriceps*, a recently rediscovered and poorly known gecko, and elucidate its phylogenetic position using molecular data for the first time. Contrary to previous speculations prompted by its morphological resemblance to other terrestrial *Hemidactylus*, our phylogenetic analyses recovered *H. scabriceps* to be a part of a clade consisting of the large-bodied, rock-dwelling *Hemidactylus* – the *H. prashadi* group. *Hemidactylus scabriceps* also shows high levels of intraspecific genetic divergence, indicative of cryptic diversity. We also confirm the synonymy of the monotypic genus *Lophopholis* (erected for *H. scabriceps*) with *Hemidactylus*. We elaborate on the morphology of the type specimen and other recent voucher specimens, and compare it with sister species and other ground-dwelling *Hemidactylus* in peninsular India. Species distribution of this 'outlier' clade member has been modeled using MaxEnt. These exercises confirm that it is primarily a smooth-scaled, plain-dwelling, terrestrial species unlike other members in its clade. This unexpected pattern of genetic alliance and contrasting body form plus habitat associations further underscores the unstudied complexity of peninsular India's geological history. Historical denudation of rock formations could have driven evolution of some of these otherwise rupicolous, scansorial gekkonids into smaller terrestrial lizards.

Keywords: Clade member, distribution modeling, habitat associations, Indian dry zone, morphology, phylogenetic position, rock dwelling.

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INTRODUCTION

Hemidactylus Oken, 1817 is one of the most speciose gekkonid genera in the world, with about 150 congeners currently recognized, of which around 34 are found in India (Carranza & Arnold 2006; Giri & Bauer 2008; Bauer et al. 2010; Uetz & Hošek 2018; Chaitanya et al. 2018). The Indian *Hemidactylus* are part of a tropical Asian radiation, and consist of five major clades - *H. prashadi, H. flaviviridis, H. brookii, H. frenatus* and *H. platyurus* groups (Bansal & Karanth 2010). Of these, the *H. brookii* group encompasses all the thus-far sampled ground-dwelling *Hemidactylus* that are found in central and peninsular India (Bansal & Karanth 2010; 2013). Previous studies show that the ground dwelling clade of geckos are sister to *H. brookii*, the clade that consists of five currently recognized terrestrial species namely *H. reticulatus* Beddome, 1870, *H. albofasciatus* Grandison & Soman, 1963, *H. satarensis* Giri & Bauer, 2008, *H. imbricatus* Bauer, Giri, Greenbaum, Jackman, Dharne & Shouche, 2008, *H. gracilis* Blanford, 1870 (Bansal & Karanth 2010). *Hemidactylus scabriceps* was considered to be closely related to the ground-dwelling *Hemidactylus* due to its superficial morphological similarities such as a reduced subdigital scansorial apparatus, imbricate tail scales, reduced subcaudal scales and a terrestrial lifestyle (Bauer et al. 2010). Similar assumptions were made for *Dravidogecko anamallensis* (Günther, 1875) which was later resolved and found to be sister to the Indian *Hemidactylus* radiation (Bansal & Karanth 2013). In the past, *H. scabriceps* has been misidentified on many occasions with other marginally co-occurring terrestrial congeners such as *H. reticulatus*, despite its distinctive scalation (Ganesh et al. 2017).

Annandale (1906) originally described this species as *Teratolepis scabriceps* based on its imbricate scalation, as the second congener next to *T. fasciatus* (currently *H. imbricatus*, after Bauer et al. 2008). Later, a new monotypic genus *Lophopholis* was erected by Smith & Deraniyagala, 1934 to accommodate this species as it was considered quite unique (Smith 1935). Parker & Taylor (1942) reassigned the species back to *Teratolepis* along with various other African geckos such as *H. isolepis* and *H. ophiolepis*, attributing this generic transfer to the imbricate scalation. Due to the similarity of *H. scabriceps* with other oriental *Teratolepis* and *Hemidactylus* geckos, it was called the 'Oriental imbricate-scaled *Hemidactylus*'. Subsequently, the generic allocation of this species was debated and later the genus *Lophopholis* was synonymized with *Hemidactylus* by Loveridge (1947). Furthermore, Bauer et al. (2008) synonymized the genus *Teratolepis* with *Hemidactylus* based on a multilocus molecular phylogeny and mentioned the possible close relationship of *H. scabriceps* with *H. imbricatus* (Image 5), along with other small-bodied, ground-dwelling endemic geckos such as *H. albofasciatus, H. gracillis* and *H. reticulatus*, which themselves are genetically-tested clade members (Bansal & Karanth 2010).

Since its description, *H. scabriceps* was not re-sighted for 104 years till an uncollected specimen was reported from Mayiladuthurai in the Coromandel Coastal Plains (Ganesh & Chandramouli 2010). More recently, Ganesh et al. (2017) dug up some obscure publications reporting this species under a wrong name, described a series of preserved specimens including its hemipenal morphology, provided natural history notes and mapped its locality based on newer fieldwork. *Hemidactylus scabriceps*, however, still remains an intriguing gecko for both Indian and Sri Lankan herpetologists due to its assumed rarity and unknown phylogenetic relationships, since it is underrepresented and poorly sampled (Bauer et al. 2010). In this paper, we provide for the first time data on its phylogenetic position, elaborate on its morphology, habitat associations and distribution.

MATERIALS AND METHODS

Specimens of *H. scabriceps* were opportunistically collected from three ecoregions: Coimbatore plateau, Thanjavur delta and Kalakad foothills, abutting Western Ghats in peninsular India. The specimens were deposited in the collections of BNHS (Bombay Natural History Society, Mumbai), IISc - CES (Indian Institute of Science, Bengaluru - Center for Ecological studies), and IISER (Indian Institute of Science, Education and Research, Thiruvananthapuram). Tissue samples were collected from the tail tips and liver of the specimens and sent for molecular analysis and sequencing at the Indian Institute of Science (IISc), Bengaluru and Osmania University, Hyderabad. The geographic coordinates of the localities were obtained from Garmin 62 GPS. Other comparative materials, including the type specimens, were examined at the Natural History Museum, London (BMNH).

Morphological analysis

Morphological and meristic data were collected following methods described by Giri & Bauer (2008) and Mahony (2009) with Mitutoyo™ digital calipers (to the nearest 0.1mm). The following measurements were taken from collected specimens and the museum types: snout vent length (SVL; from tip of snout to vent), trunk

length (TRL; distance from axilla to groin measured from posterior edge of forelimb insertion to anterior edge of hind limb insertion), body width (BW; maximum width of body), crus length (CL; from base of heel to knee); tail length (TL; from below vent to tip of tail), tail width (TW; measured at widest point of tail near the tail base); head length (HL; distance between retroarticular process of jaw and snout-tip), head width (HW; maximum width of head), head height (HH; maximum height of head, from occiput to underside of jaws), forearm length (FL; from base of palm to elbow); ear length (EL; longest dimension of ear); orbital diameter (OD; greatest diameter of orbit), nares to eye distance (NE; shortest distance between anterior most point of eye and nostril), snout to eye distance (SE; distance between anterior most point of eye and tip of snout), eye to ear distance (EE; distance from anterior edge of ear opening to posterior corner of eye), internarial distance (IN; distance between nares), interorbital distance (IO; shortest distance between left and right supraciliary scale rows). Scale counts and external observations of morphology, meristic characters were made using a Wild M5 dissecting microscope.

Species distribution modeling

Species distribution modeling was carried out using MaxEnt v.3.3 (Phillips et al. 2006), which is based on maximum entropy modeling. MaxEnt, a machine learning program that estimates the probable species distribution based on constraints of the environment. It uses presence-only data for prediction and studies show that it has good success rate for small sample sizes compared to other SDMs (Elith et al. 2006; Wisz et al. 2008). We have considered 21 environmental variables - the 19 bioclimatic layers, one topographic layer representing elevation (Hijmans et al. 2005) and one vegetation layer-NDVI (NRSC, ISRO). The 13 location points used in the model were obtained from the recent collections, literature which includes historical points Adayar (13.0012^{0}N & 80.2565^{0}E), and Maricukatte (8.588^{0}N & 79.933^{0}E). The environmental layers were derived from globally interpolated datasets observed from climate stations around the world. All the layers are of approximately 1,000m resolution, clipped for the Indian subcontinent including Sri Lanka and projected on WGS84 Lat-Long map datum. The layers were subjected to a multicollinearity test and 10 bioclimatic variables that were least correlated (Pearson's correlation coefficient r<0.85) were selected for the distribution modeling.

MaxEnt program with following changes was used in the model: auto feature for environmental variables was selected. The random test percentage was set to 20%, making the training percentage 75%. The regularization multiplier and maximum number of background points for sampling was kept at 1 and 10,000 respectively. With subsampling as replicating model, 15 replicates were used. Maximum iterations were set to 5,000, with 10^{-5} as convergence threshold with threshold rule of 10 percentile training presence as it relatively better at predicting suitable habitat for endemic species (Escalante et al. 2013). The logistic output of the model shows the suitability of the habitat, graded over a range of 0 to 1.

Molecular analysis

Genomic DNA was isolated from 95–100 % ethanol preserved liver tissue sample using phenol: chloroform: isoamyl alcohol reagent (25:24:1 v/v) as described by Sambrook & Russell (2001). Two partial mitochondrial markers, cytochrome *b* (cyt *b*) and NADH dehydrogenase 2 (ND2) along with two nuclear markers, Recombination Activation Gene 1 (RAG-1), Phosducin (PDC) were used to infer the phylogeny of *H. scabriceps* (see Agarwal et al. 2011). These molecular markers were useful for resolving the phylogenetic relationships at deeper nodes. Primers and PCR conditions used were as described in Bauer et al. (2008). PCR products were purified and sequences were obtained commercially from Bioserve Biotechnologies, Hyderabad, India. All PCR amplifications were carried out in 25µL reaction volumes, with 12.5µL of the 2X PCR master mix (Thermo Scientific), 0.5µL forward primer, 0.5µL reverse primer (10 pm/ µL concentration each) and 2µL template DNA added and the final volume was adjusted with nuclease-free water. Reactions were carried out with Thermo Scientific Mastercycler gradient thermocycler. The sequence integrity was analyzed by BLAST tool (Altschul et al. 1997), processed and submitted to NCBI GenBank under the accession numbers given in Table 3 (Appendix 1).

Phylogenetic analysis

The mitochondrial genes cyt *b* (379 bp), ND2 (981 bp) and the nuclear genes PDC (400 bp) and RAG-1 (1000 bp) sequences of representative members of major, well supported *Hemidactylus* groups - *H. flaviviridis, H. brookii, H. prashadi* and *H. frenatus* (Bansal & Karanth 2010, 2013; Murthy et al. 2015; Giri et al. 2017; Chaitanya et al. 2018) were downloaded from GenBank (accession numbers listed in Table 3 in the appendix). Sequences were aligned with default gap penalties using ClustalW (Thompson et al. 1994) in MEGA 7.0. (Tamura et al.

2011). Protein-coding genes were translated to amino acids to check for the reading frame and premature stop codons. Uncorrected pairwise distances were calculated using the inbuilt program in MEGA.

Sequences of the members of the *H. brookii* sensu lato group that were published prior to the revisions of the group (Mahony 2011; Lajmi et al. 2016) were labeled as *H. brookii* due to the inability to trace and identify the specimens from which the sequences were derived. The same revision, however, shows that the group including the ground-dwelling *Hemidactylus* is monophyletic and is sister to the *H. frenatus* group. Hence, the *H. brookii* epithet is used here indicating individuals that may represent *H. murrayi, H. gleadowi, H. treutleri, H. kushmorensis* or *H. parvimaculatus* (Lanfear et al. 2012).

We used Partition Finder 2.1.1 to pick the partitions and best substitution model for the analysis. The concatenated gene dataset (cyt *b*, ND2, PDC and RAG1) comprise a total of 2760 bp. We built a maximum likelihood (ML) tree in RAxML HPC 7.4.2 through RAxMLGUI v1.3.1 (Silvestro & Michalak 2012) by running ML + thorough bootstrap for 10 runs and 1000 repetitions.

RESULTS

Molecular phylogeny and relationships

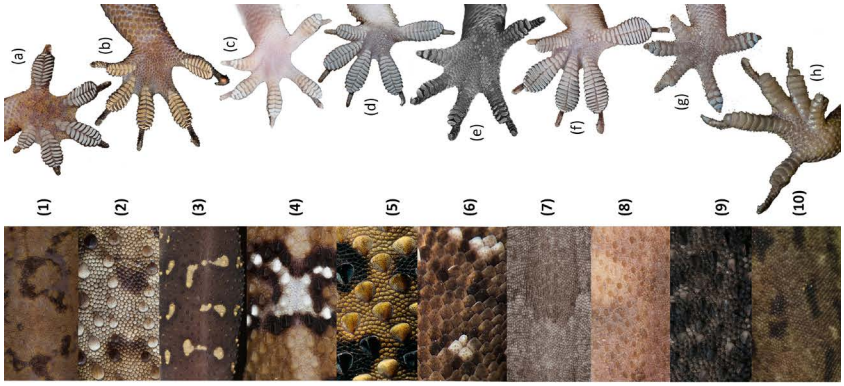
Our tree (Image 1) recovered *H. scabriceps* as member of a clade containing *H. triedrus* of peninsular Indian plains, *H. lankae* of Sri Lankan plains, *H. maculatus* of the northern Western Ghats, *H. prashadi* of central Western Ghats, *H. acanthopholis* and *H. vanam* of southern Western Ghats, *H. hunae* of Sri Lankan hill tracts, *H. graniticolus* of southern Eastern Ghats, *H. sushilduttai* and *H. kangenerensis* of northern Eastern Ghats and Chota Nagpur plateau, and more closely with *H. depressus* of Sri Lanka.

From a broader perspective, the ML analyses on the concatenated dataset with sequence lengths of 2760 bp yielded a tree (Image 1) of similar topology to previous studies (Chaitanya et al. 2018). Comparing tree topologies from prior works corroborated the integrity of our trees. *Dravidogecko anamallensis* is sister to all Indian *Hemidactylus* that consists of four well-supported groups, *H. flaviviridis, H. brookii, H. prashadi* and *H. frenatus* (Bansal & Karanth 2010; 2013). As previously known, *H. brookii* sensu lato is sister to the *H. frenatus* group; while *H. scabriceps* falls within the *H. prashadi* group (support seen in tree). The relationship of *H. scabriceps* with other rock-dwelling Indian and Sri Lankan *Hemidactylus* is strongly supported in our tree.

From a species-specific viewpoint, the pairwise distance matrix revealed 6% divergence in the cyt *b* gene between the two individuals of *H. scabriceps* sampled from different localities (Thanjavur and Coimbatore). The genetic distance between *H. scabriceps* and other species of the *H. prashadi* and *H. brooki* clades are given in Table 1. The high genetic divergence between the populations sampled may indicate that *H. scabriceps* could be a potential species complex that requires further study.

Morphology and body configurations (n=7, in mm) (Images 2 & 3)

A small-sized *Hemidactylus* (30.1–41.3); head short (9.6–13.8); distinct from neck; head broader (4.3–7.4) than high (3.9-6.9); forehead flat; snout (3.5–4.6) longer than orbital diameter (1.0–2.7); snout concave; covered with heterogeneous granular scales; scales on head keeled; small warty scales on parietal region intermixed with granular scales; scales largest on canthal region, size similar to tubercles on parietal region; pupil vertically elliptical with sharp crenellated edges, supraciliaries large when compared to scales on canthal region; pointed posteriorly; becoming smaller and less pointed towards posterior; spinose posteriorly; nostrils close to snout-tip (2.8–3.0), moderately wide (1.3–2.7), fairly close to eye (2.3–3.5); ear opening small (0.2–1.5); orbital diameter slightly smaller than orbit to ear distance; eyes distant from each other (1.4–3.8); rostral large; subrectangular to pentagonal in shape; in contact with nostril and the 1st supralabial, medial groove dorsally, extending more than half the length of the rostral depth; supralabials 7/7 (left/right); infralabials 6/6 (left/right); mental triangular; two pairs of post mentals, inner pair in contact with mental and each other, outer pair not in contact with each other; a pair of smaller chin shields in contact with the outer postmentals followed by elongated shields in two rows in contact with the infralabials; no chin shields posterior to the postmentals; a row of smaller, slightly elongated scales with slightly pentagonal scales wedged in the intersection of the postmental scales; gular covered with small granular scales; trunk of moderate size (13.1–20.7); body slightly depressed, oval in cross-section, dorsolateral fold weak to indistinct; dorsum covered with mildly keeled, imbricate scales with no tubercles; granular scales from head gradually changing into sub-imbricate scales on nape and imbricate scales towards torso; mild keels on dorsal scales distinct, gradually disappearing towards ventral scales, scales at paravertebral line comparatively smaller than other



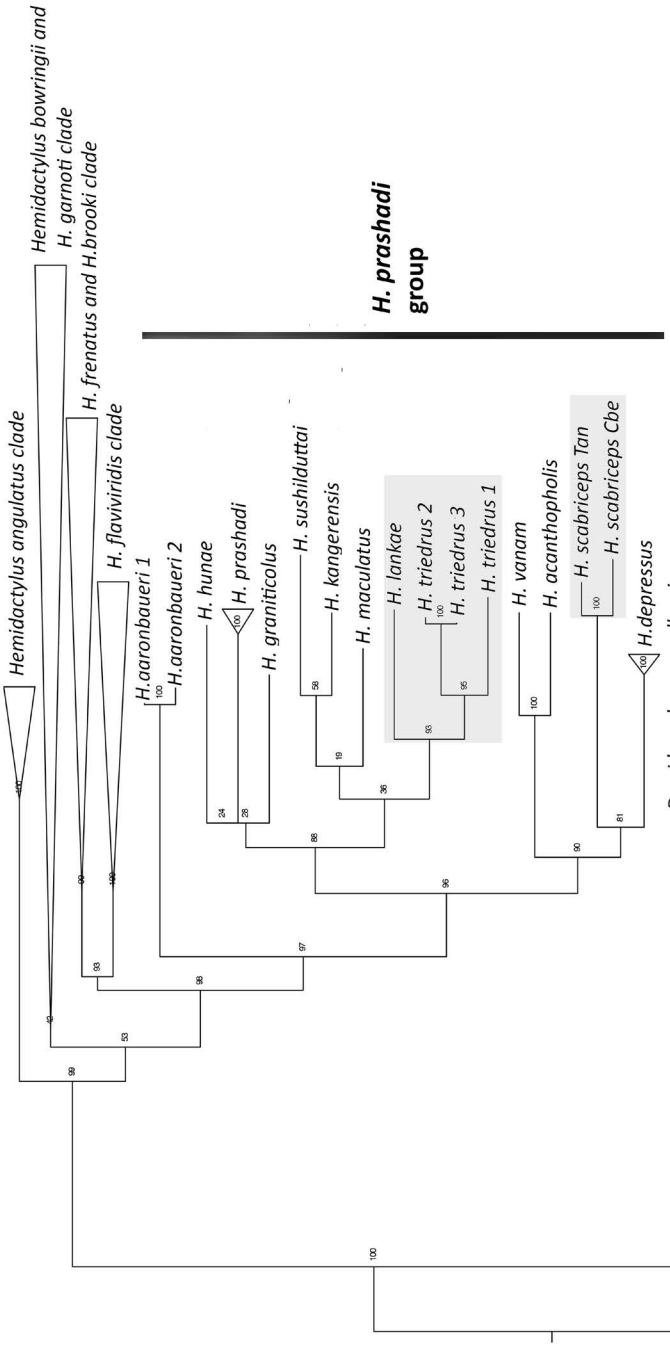


Image 1. ML tree constructed using cyt *b*, ND2 mitochondrial sequences and RAG1, PDC nuclear sequences representing the Indian groups of *Hemidactylus*. Bootstrap support values are mentioned in the nodes. Specimens of *Hemidactylus scabriceps* are suffixed with the location collected from (Cbe–Coimbatore and Tan-Thanjavur). The taxa highlighted in grey denote the plains dwelling taxa. A visual comparison of Dorsal scale images of representative clades are as follows: (1) *H. depressus*, (2) *H. graniticolus*, (3) *H. prashadi*, (4) *H. triedrus*, (5) *H. maculatus*, (6) *H. scabriceps*, (7) *H. giganteus*, (8) *H. brookii*, (9) *H.gracilis*, (10) *D. anamallensis*. A visual comparison of Lamellar morphology of representative clade members as follows: (a) *H. depressus*, (b) *H. prashadi*, (c) *H. triedrus*, (d) *H. maculatus*, (e) *H. scabriceps*, (f) *H. giganteus*, (g) *H. brookii*, (h) *H.gracilis*, (i) *D. anamallensis*

Table 1. Percentage values of uncorrected pairwise divergence (*p*-distance) for the cyt *b*, RAG-1, PDC and ND2 genes between the closely related congeners of *H. scabriceps* and morphologically similar members of *H. prashadi* and *H. brookii* clades. The percentage divergence of cyt *b* gene between the two specimens of *H. scabriceps* used in this study is 6.3 %.

Pairwise genetic distance with *H. scabriceps* from Coimbatore	ND2 distances	RAG-1 distances	PDC distances	cyt *b* distances
*H. scabriceps (Tanj)**	-	0.4	2.1	6.3
H. prashadi	13.8	1.4	2.5	15.3
H. maculatus	17.5	2.5	2.5	15.3
H. kangerensis	-	-	-	18.8
H. depressus	8.8	1.8	3.8	18.2
H. vanam	-	1.4	2.5	19.3
H. sushilduttai	-	-	-	17.0
H. graniticolus	-	1.8	3.0	19.3
H. hunae	15.0	1.8	3.0	21.6
H. triedrus ^	11.2	2.2	2.1	18.8
H. lankae #	11.2	2.2	2.5	18.2
H. acanthopholis	12.5	1.8	3.0	19.9
H. reticulatus				24.4
H. albofasciatus				19.9
H. gracilis		4.7	5.5	22.2
H. imbricatus	21.3	3.9	6.4	22.7
H. parvimaculatus	16.2	3.6	5.1	21.1

Foot notes: * - intraspecific distance; ^ - syntopic clade-member in peninsular India; # - syntopic clade-member in Sri Lanka.

Table 2. A comparison of synapomorphic morphological characters that is convergent to *H. scabriceps* with the ground-dwelling *Hemidactylus* clade and the *H. prashadi* clade. Note the commonly shared characters of *H. scabriceps* with both the ground dwelling *Hemidactylus* and the *H. prashadi* clade.

Species	Series of white spots/ dotted line	Series of black stripes in the infralabials and gular
H. scabriceps	Present	Present
H. prashadi	Present	Absent
H. parvimaculatus	Present	Absent
H. maculatus	Present	Absent
H. kangerensis	Present	Absent
H. sushilduttai	Present	Absent
H. graniticolus	Present	Absent
H. hunae	Present	Absent
H. triedrus	Present	Absent
H. lankae	Present	Absent
H. acanthopholis	Present	Absent
H. reticulatus	Absent	Present
H. albofasciatus	Absent	Present
H. gracilis	Absent	Present
H. imbricatus	Absent	Present

dorsal scales; ventral scales imbricate till femoral region; slightly smaller, rounded sub-imbricate scales posterior to femoral region; preanofemoral pores 2–4 on each side separated by 1–2 pore-less scales; forelimbs slender, covered with small, imbricate scales reducing in size and sub-imbricate to granular scales ventrally, forelimbs moderate, crus (5.4–6.7) longer than forearm (4.0–5.1); hindlimbs slender, covered with imbricate scales both ventrally and dorsally; dorsal part of manus and pes covered with small granular scales; digits short, free, with interdigital webbing absent, a distinct short curved claw present in all the digit tips; all digits with initial few lamellae divided, other lamellae fused; lamellar formula of manus 4-6-5-5-5 and pes 5-7-8-8-5; basal lamellae narrow; tail fairly long, (21.2–43.2) subequal to body length, robust and thickset in width (3.2–4.9); blunt at tip, round in cross section, covered with imbricate scales subequal to size of scales on dorsum, tubercles absent; dorsum light brown with dark brown bands extending from above the dorsolateral fold region sometimes forming 'x's along the body from nape to vent region with large white spots or scales sometimes forming stripes across the body found; smaller white and black spots intermixed with the light brown parts of the body; head covered with dark and light-colored spots, labials characterized with a black patch forming a stripe pattern throughout the labials, sometimes extending into stripes in the gular region; venter dirty white, rarely with small black dots; mental shields with small black blotches; manus and pes darker beneath.

Distribution and niche modeling

Hemidactylus scabriceps has so far been recorded from the dry, low-elevation plains of Tamil Nadu ranging from 10 to 380 m (Image 4). In the Coromandel Coastal Plains this species is known from Adayar (in Madras) near Palar Bay, southwards to Mannampandal near Cauvery Delta, further down in Ramanathapuram and Thoothukudi north and south of the Palk Strait, respectively. Apart from the earlier records we sighted this species from Thitai (11.083^{0}N & 77.031^{0}E; 44m) in Thanjavur Delta region, Kalapatti (11.083^{0}N & 77.0317^{0}E, 385m) further westwards in the Coimbatore Plateau, south in Pottal (8.644^{0}N & 77.484^{0}E, 77m) just east of Tirunelveli foothills and Mariccukatte (Marichchukkaddi) in Sri Lanka (8.580^{0}N & 79.946^{0}E).

The input for species distribution modeling are nine least correlated bioclim variables, altitude and NDVI layers with 13 sample locations of the species. The

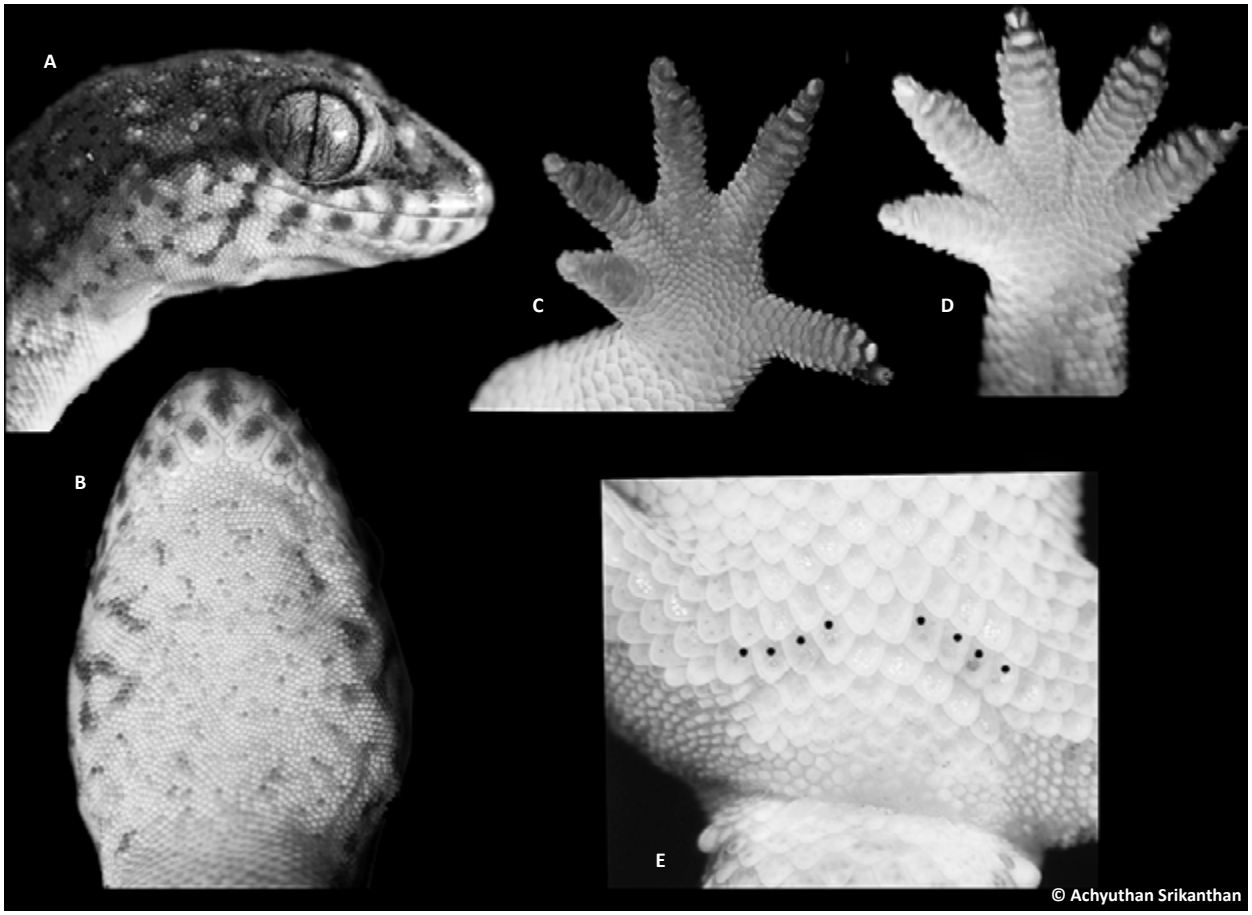


Image 2 & 3. (Above) Image (in life) of BNHS 2421 (Below) (A) Head lateral showing labials and eye, (B) Mentum, (C) Lamellae of the left manus, (D) Lamellae of the left pes and (E) Preanal pores of BNHS 2421

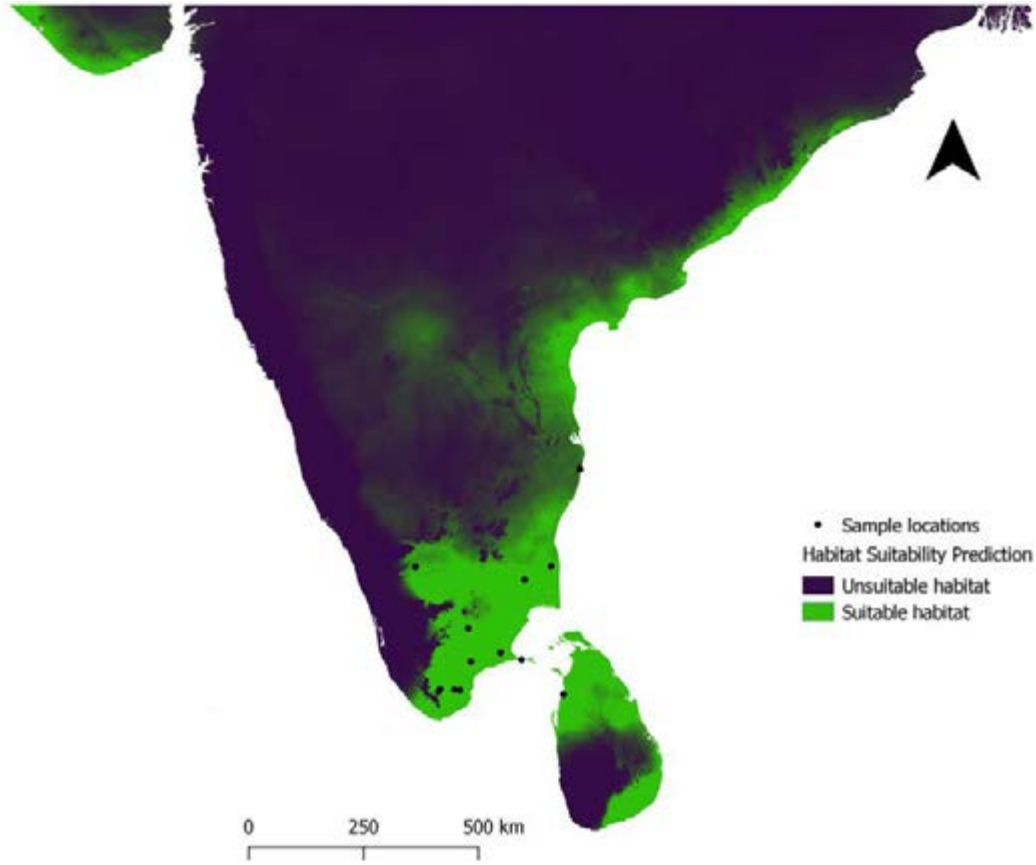


Image 4. Habitat Suitability Map projected based on MaxEnt modeling of *H. scabriceps* occurrences (both previously published and new) in India and Sri Lanka, revealing dry-zone plains (green shade) abutting Coromandel Coast, Cauvery flood-plains and dry peneplain of Sri Lanka as its realised range.

Image 5. Habitat spectrum of *H. scabriceps* in India (left) rocky habitat from the most inland locality Kalapatti, Coimbatore; (right) sandy habitat of *H. scabriceps* from the most coastal locality Mandapam, Rameshwaram.

logistic output of the model shows the suitability of the habitat, graded over a range of 0–1. A binary map is created indicating suitable and unsuitable habitat for occurrence of *H. scabriceps*. A threshold of 0.3491 was selected to classify the suitability which is the average value of the threshold rule used for the MaxEnt model. The AUC for the run/model is above 0.9 showing high goodness of fit. The AUC value of the model is 0.987

indicating that the resultant model is reliable.

The relative contribution (approx.) of the environmental variables to the MaxEnt model is as shown in Table 4. It is observed that the following variables are the major contributors to the model - bio2 (mean diurnal temperature range), bio12 (Annual Precipitation) and alt12 (altitude) signifying that the habitat most suitable for *H. scabriceps* is low altitudes, less rainfall and relatively less change in maximum and minimum temperature with annual mean temperature of approximately around 28.5^{0}C.

As per the output of MaxEnt modeling (Image 4), *H. scabriceps* is predicted to be distributed from the far south of Tamil Nadu (including Tirunelveli and Tuticorin) northwest till about Coimbatore, northeastwards till about Madras (currently Chennai), with high possibilities of being present in dry parts of northern Sri Lanka. This species is possibly confined to this range within the dry parts of Tamil Nadu, Kerala and Sri Lanka, bound by the Western and Eastern Ghats; and the highlands in central Sri Lanka.

DISCUSSION

Hemidactylus scabriceps is a member of a clade comprising large-bodied, rock-dwelling, scansorial geckos, although it has a small terrestrial body-build and is found in low-elevation plains that are not dominated by rock formations. Our new molecular phylogenetic analyses provide a radically different and contrasting relationship for *Hemidactylus scabriceps,* as shown in Image 1. To untangle this complex interplay between morphology, habitat associations / distribution and genetic relationships, we herein elaborate on these three seemingly disparate features and discuss their dynamics in light of potential evolutionary trajectories that might have acted upon this species shaping it into what it is now.

The morphological characterization and ecological data of our new individuals are for the most part in conformity with literature reports (Annandale 1906; Smith 1935; Ganesh & Chandramouli 2010; Ganesh et al. 2017). Another important facet of morphology of *H. scabriceps* is the persistence of transverse series of white spots / dotted lines across the trunk, typical of all the known members of *H. prashadi* group and absent in *H. albofasciatus, H. imbricatus, H. reticulatus* and *H. sataraensis* (Smith 1935; Bauer et al. 2008; Giri & Bauer 2008). We postulate that the white spots and barred pattern on the back are a synapomorphy of the *H. prashadi* clade, present either bold or diffuse in all of its members. Based on our phylogeny we postulate that the under-developed or rudimentary claws and digits in general, along with the partial fusion of digital lamellae of *H. scabriceps,* are ecologically derived traits consequent upon a strictly terrestrial lifestyle. Similar to the phenotypically biased taxonomic allocations that taxa from the *H. brookii* clade have had, the current study confirms that the genus *Lophopholis*, originally erected for *H. scabriceps*, is actually a synonym of *Hemidactylus* (also see Bauer et al. 2008).

We observed this species in grassland/ dry thorn scrub jungle dominated by palmyra trees, in coconut grove and paddy fields. The species is strictly nocturnal, found resting under rocks during the day, preferably on mounds of gravel under moderately large rocks. It was repeatedly observed to be in a 's' shaped position under rocks and trying to stay still and not trying to get away while the rock was disturbed. This behavior was also observed in *H. reticulatus* (Ganesh et al. 2017; this work) and *H. sataraensis* (see Bauer & Giri 2008). It is also common for *H. scabriceps* to be found in sympatry with *H. triedrus* (Image 8). Some specimens were also found inside termite-eaten and weathered palm and coconut logs, leaves and fruits. This species was observed to be highly territorial. Two individual male specimens in the same vicinity showed territorial behavior, circling each other making chirping calls to each other (the only time the species was heard vocalizing) with a raised waving tail, stretched legs and arched body, and trying to bite at the neck of opponent male. Individuals were found to occur at quite a distance from one another (15–20 m). Thus our observations on the microhabitat associations of *H. scabriceps* along with previously published notes (Ganesh & Chandramouli 2010; Ganesh et al. 2017) do attest its strictly terrestrial lifestyle.

We found some of our adult male individuals to have either 2 or 4 pores on a single side, whereas it usually numbers 3 (Ganesh et al. 2017). Such variations in characters of diagnostic importance in gecko taxonomy, coupled with high levels (6% in cyt *b*) of inter-individual genetic divergence point out to the possibility of cryptic speciation within this complex. It is also noteworthy to highlight that though the original description (Annandale 1906) and subsequent expanded characterizations, both historical (Smith 1935) and recent (Ganesh & Chandramouli 2010; Ganesh et al. 2017) of this species still stems from Coromandel Coastal Plains population, except for the sole record of a specimen from near Madurai (see Ganesh et al. 2017).

Thus the current study describes previously

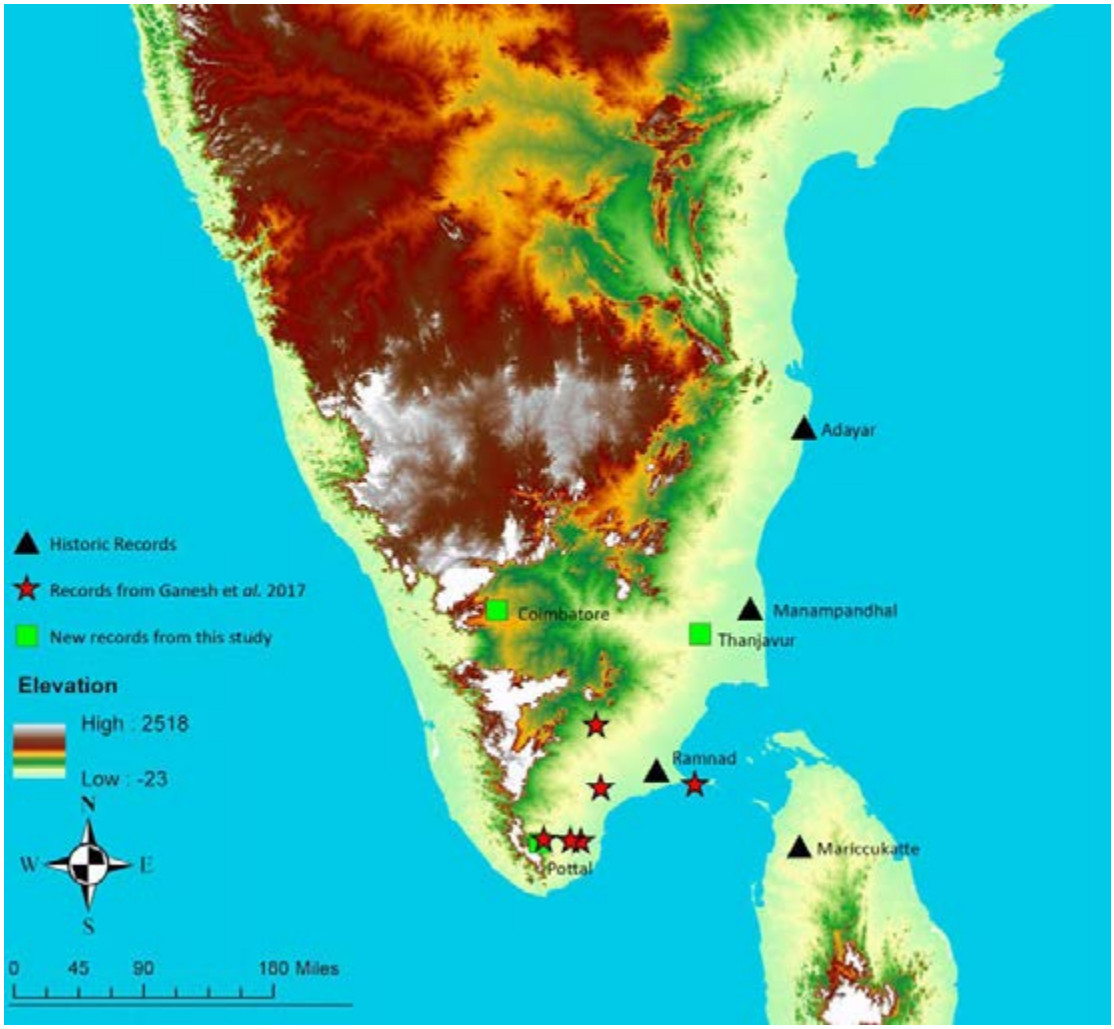


Image 6. Distribution of *H. scabriceps.* Black triangle denotes historical records before 1935 - (type locality) Ramnad by Anandale, 1906; P.E.P Deraniyagala (Mariccukatte, Sri Lanka), D.W. Devanasan (Adayar, Madras (Chennai); red star denotes records from Ganesh et al. (2017) and green squares denote new records used in this study.

Image 7. *Hemidactylus imbricatus* (captive individual) in life, the species with which *H. scabriceps* was originally considered congeneric during its description; illustrating the homoplasy

Table 3. List of specimens used for the molecular analysis and genetic comparison with the museum numbers, localities and GenBank accession numbers. Highlighted species are the samples used in this study.

Species	Museum No.	Locality	cyt *b*	ND2	RAG-1	PDC
Cyrtodactylus ayeyarwadyensis	CAS 216446	Myanmar, Rakhine State, Than Dawe District	EU268380	JX440526	JX440685	JX440634
Cyrtodactylus consobrinus	LLG 4062	-	EU268381	EU268349	EU268288	EU268318
Cyrtodactylus loriae	FK 7709	Papua New Guinea: Milne Bay, Bunisi	EU268382	EU268350	EU268289	EU268319
Hemidactylus scabriceps	BNHS 2421	Kalapatti, Coimbatore, Tamil Nadu	KX902971	*	KX902973	KX902972
Hemidactylus scabriceps	VPC-GK-029	Tanjore, Tamil Nadu	KX902975	BankIt2106186	KX902977	KX902976
Hemidactylus brasilianus	MZUSP 92493	Brazil, Piauí, Parque Nacional Serra das Confusões	EU268383	EU268351	EU268290	EU268320
Hemidactylus imbricatus 1	JS11	Pakistan (captive specimen)	EU268385	EU268353	EU268292	EU268322
Hemidactylus imbricatus 2	JFBM2	Pakistan (captive specimen)	EU268386	EU268354	EU268293	EU268323
Hemidactylus flaviviridis 1	FMNH 245515	Pakistan, Punjab Province	EU268387	EU268355	EU268294	EU268324
Hemidactylus flaviviridis 2	ID 7626	India, Rajasthan, Kuldhara	EU268388	EU268356	EU268295	EU268325
Hemidactylus flaviviridis 3	ID 7640	India, Rajasthan, Jaisalmer	HM559596	HM559628	HM559694	HM559661
Hemidactylus frenatus 1	AMB 7411	Sri Lanka, Pidipitiya 1	EU268389	EU268357	EU268296	EU268326
Hemidactylus frenatus 2	LLG 6745	Malaysia, Pulau Pinang, Empangon Air Hitam 2	EU268390	EU268358	EU268297	EU268327
Hemidactylus frenatus 3	AMB 7420	Sri Lanka, Rathegala 3	EU268391	EU268359	EU268298	EU268328
Hemidactylus frenatus 4	LLG 4871	Malaysia, Pahang, Bukit Bakong 4	GQ375289	GQ458049	GQ375308	GQ375301
Hemidactylus frenatus 5	CES07035	India, Tamil Nadu, Valparai 5	HM595655		HM622356	HM622371
Hemidactylus turcicus	LSUMZ H-1981	USA, Louisiana, Baton Rouge	EU268392	EU268392	EU268299	EU268329
Hemidactylus karenorum	CAS 210670	Myanmar, Mandalay Division, Kyaukpadaung Township, Popa	EU268394	EU268362	EU268301	EU268331
Hemidactylus garnotii 3	CAS 215549	Myanmar, Sagaing Division, Mon Ywa District 3	HM559597	HM559631	HM559697	HM559664
Hemidactylus garnotii 2	CAS 222276	Myanmar, Mon State, Kyaihto Township, Kyait Hti Yo 2	EU268396	EU268364	EU268303	EU268333
Hemidactylus garnotii 1	CAS 223286	Myanmar, Rakhine State, Taung Gok Township, Ma Ei Ywa 1	EU268395	EU268363	EU268302	EU268332
Hemidactylus brookii 1	LLG6754		EU268397.1	EU268365.1	EU268304.1	
Hemidactylus brookii 2	LLG6755		EU268398.1	EU268366.1	EU268305.1	
Hemidactylus angulatus 1	MVZ 245438	Nigeria, Togo Hills, Nkwanta	EU268399	EU268367	EU268306	EU268336
Hemidactylus angulatus 2	EBG 746	Guinea, Daniah River at Koulete River	HM559588	HM559620	HM559686	HM559653
Hemidactylus palaichthus	LSUMZ 12421	Brazil, Roraima State	EU268400	EU268368	EU268307	EU268337
Hemidactylus greefii	CAS 219044	São Tome and Principe, São Tome Island, Praia da Mutamba	EU268401	EU268369	EU268308	EU268338
Hemidactylus fasciatus 1	WRB no number	Gabon, Rabi 1	EU268402	EU268370	EU268309	EU268339
Hemidactylus fasciatus 2	CAS 207777	Equatorial Guinea, Bioko Island, 3.6 km N of Luba 2	EU268403	EU268371	EU268310	EU268340
Hemidactylus bowringii 1			EU268405.1	EU268373.1	EU268312.1	
Hemidactylus bowringii 2			EU268406.1	EU268374.1	EU268313.1	
Hemidactylus robustus 1	MVZ 248437	Pakistan, Thatta District, 40km S of Mipur Sakro 1	EU268408	EU268376	EU268315	EU268345
Hemidactylus robustus 2	FMNH 245519	Pakistan, Baluchistan Province, Gwadar Division, Makran 2	HM559610	EU054287	EU054271	EU054255
Hemidactylus robustus 3	MVZ 234374	Iran, Lorestan Province, 99km SW (by road) of KhorramAbah 3	HM559611	HM559644	HM559710	HM559677
Hemidactylus reticulatus 1	AMB 5730	India, Tamil Nadu, Vellore 1	EU268410	—	—	—

Species	Museum No.	Locality	cyt *b*	ND2	RAG-1	PDC
Hemidactylus reticulatus 2	CES07016	India, Karnataka, Pavgada 2	HM595669	—	—	—
Hemidactylus reticulatus 3	CES06024	India, Karnataka, Bangalore 3	HM595670	—	—	—
Hemidactylus parvimaculatus 1	AMB 7475	Sri Lanka, Kandy 1	GQ375290	GQ458055	GQ375309	GQ375302
Hemidactylus parvimaculatus 2	ADS36	Sri Lanka, Kartivu 2	GQ375291	GQ458053	GQ375310	GQ375303
Hemidactylus parvimaculatus 3	AMB 7466	Sri Lanka, Mampuri 3	GQ375292	GQ458056	GQ375311	GQ375304
Hemidactylus craspedotus	LLG 5613	Malaysia, Perak, Temengor	HM559586	HM559618	HM559684	HM559651
Hemidactylus platyurus 1	KU 304111	Philippines, Lubang Id., Occidental Mindoro Prov., Lubang 1	HM559587	HM559619	HM559685	HM559652
Hemidactylus depressus 1	ADS 29A	Sri Lanka, Galkotte 1	HM559589	HM559621	HM559687	HM559654
Hemidactylus depressus 2	ADS 69A	Sri Lanka, Kuruwekotha 2	HM559590	HM559622	HM559688	HM559655
Hemidactylus depressus 3	AMB 7440	Sri Lanka, Dumbulayala 3	HM559591	HM559623	HM559689	HM559656
Hemidactylus depressus 4	AMB 7445	Sri Lanka, Ritigala 4	HM559592	HM559624	HM559690	HM559657
Hemidactylus depressus 5	AMB 7481	Sri Lanka, Matale 5	HM559593	HM559625	HM559691	HM559658
Hemidactylus depressus 6	AMB 7524	Sri Lanka, Galle 6	HM559594	HM559626	HM559692	HM559659
Hemidactylus giganteus 1	JB03	India (captive specimen) 1	HM559598	HM559632	HM559698	HM559665
Hemidactylus giganteus 2	CES08013	India, Karnataka, Hampi 2	HM595657		HM622357	HM622372
Hemidactylus haitianus 1	AMB 4188	Dominican Republic, Santo Domingo 1	HM559599	HM559633	HM559699	HM559666
Hemidactylus haitianus 2	AMB 4189	Dominican Republic, Santo Domingo 2	HM559600	HM559634	HM559700	HM559667
Hemidactylus leschenaultii 1	AMB 7443	Sri Lanka, Polonnaruwa 1	HM559601	HM559635	HM559701	HM559668
Hemidactylus leschenaultii 2	JB05	India (captive specimen) 2	HM559602	HM559636	HM559702	HM559669
Hemidactylus leschenaultii 3	CES07041	India, Tamil Nadu, Chidambaram 3	HM595662		HM622360	
Hemidactylus longicephalus	CAS 218939	São Tomé et Principe, São Tomé	HM559603	HM559637	HM559703	HM559670
Hemidactylus mabouia 1	AMB 8301	South Africa, Limpopo Prov., nr. Huntleigh 1	HM559604	HM559638	HM559704	HM559671
Hemidactylus mabouia 2	YPM 14798	USA, Florida, Monroe Co., Little Torch Key 2	HM559605	HM559639	HM559705	HM559672
Hemidactylus hunae	AMB 7416	Sri Lanka, Pitakumbura	HM559606	HM559640	HM559706	HM559673
Hemidactylus maculatus	BNHS1516	India, Maharashtra, Raigad District, Zirad	HM559607	HM559641	HM559707	HM559674
Hemidactylus prashadi 1	CES07037	India, Maharashtra, Ratnagiri 1	HM595666	—	—	—
Hemidactylus prashadi 2	CES06170	India, Karnataka, Udupi 2	HM595667	—	—	—
Hemidactylus prashadi 3	CES07040	India, Karnataka, Castle Rock 3	HM595668		HM622364	HM622378
Hemidactylus prashadi 4	JB02	India (captive specimen) 4	HM559608	HM559643	HM559708	HM559675
Hemidactylus prashadi 5	JB30	India (captive specimen) 5	HM559609	HM559644	HM559709	HM559676
Hemidactylus lankae	AMB 7453	Sri Lanka, nr. Medavachchiya	HM559615	HM559648	HM559714	HM559681
Hemidactylus triedrus 1	JB09	India (captive specimen) 1	HM559616	HM559649	HM559715	HM559682
Hemidactylus triedrus 2	JB08	Pakistan (captive specimen) 2	HM559617	HM559650	HM559716	HM559683
Hemidactylus triedrus 3	CES07007	India, Karnataka, Ramnagar 3	HM595673	—	HM622365	HM622379
Hemidactylus aaronbaueri 1	CES08022	India, Maharashtra, Pune 1	HM595640	—	—	—
Hemidactylus aaronbaueri 2	CES08016	India, Maharashtra, Raigad District 2	HM595641		HM622352	HM622367
Hemidactylus albofasciatus 1	CES07038	India, Maharashtra, Sindhudurg District, Malvan 1	HM595642	—	—	—
Hemidactylus albofasciatus 2	CES08018	India, Maharashtra, Sindhudurg District, Malvan 2	HM595643	—	—	—
Dravidogecko anamallensis	CES08029	India, Kerala, Eravikulam,	HM595644		HM622353	HM622368

Species	Museum No.	Locality	cyt *b*	ND2	RAG-1	PDC
Hemidactylus gracilis	CES07039	India, Maharashtra, Pune	HM595660	—	HM622359	HM622374
Hemidactylus persicus	CES08027	India, Rajasthan, Jaisalmer	HM595665	—	HM622362	HM622376
Hemidactylus yajurvedi 1	CES12006	Kanker, Chhattisgarh, India 1	KT601564	—	KT601569	KT601566
Hemidactylus yajurvedi 2	CES12007	Kanker, Chhattisgarh, India 2	KT601565	—	KT601568	KT601567
Hemidactylus treutleri	CES06108	India, Telangana, Hyderabad	KU720681	—	KU720742	
Hemidactylus graniticolus	CES08028	India, Tamil Nadu, Nilgiri Hills	HM595664	—	HM622361	HM622375
Hemidactylus vanam	BNHS2329	India, Tamil Nadu, Meghamalai	MG711527.1	MG711532.1	MG711540.1	MG711535.1
Hemidactylus sushilduttai	ESV 112	Simhachalam, Visakhapatnam District, Andhra Pradesh, India	MF668228.1			
Hemidactylus kangerensis	BNHS 2486	Kanger Valley National Park, Bastar District, Chhattisgarh	KY938009.1			
Hemidactylus acanthopholis	CES17066	Tamil Nadu, India	MG711526.1	MG711531.1	MG711539.1	MG711534.1

*accession number pending

Table 4. Analysis of variable contributions of *H. scabriceps* Maxent model. The names of the variables are as follows: _bio3_28 = Isothermality, _bio2_28 = Mean diurnal range, _bio1_28 = Annual mean temperature, _bio15_28 = Precipitation seasonality, _bio14_28 = Precipitation seasonality, _bio19_28 = Precipitation of coldest quarter, _bio18_28 = Precipitation of the warmest quarter, _bio8_28 = Mean temperature of the wettest quarter and _bio12_28 = Annual temperature

Variable	Percent contribution	Permutation importance
bio2	43.5	49.3
bio12	23	26.5
alt	11.9	20.5
bio1	9.7	2.9
bio18	6.5	0
bio3	4.8	0.2
veg	0.5	0.3
bio19	0.1	0
bio14	0.1	0.1
bio8	0	0.1

Image 8. A field photograph taken in Tuticorin showing syntopic sighting of *H. scabriceps* (bottom) and *H. triedrus* (top).

unsampled populations from Coimbatore near the foothills of the Western Ghats, a different ecoregion altogether. Even here, we observed fine-scale landscape partitioning between *H. scabriceps* and the ecologically similar *H. reticulatus* (see Ganesh et al. 2017). This makes *H. scabriceps* the only member of *H. prashadi* clade to be distributed exclusively in a primarily sandy alluvial plains terrain not dominated by rock outcrops. The loose occurrence of individuals of *H. scabriceps* at some distance between each other was observed to be similar to other *Hemidactylus* species such as *H. mabouia* (see Regalado 2003). Our niche distribution model shows an indication that rivers Cauvery and Amaravathi (a tributary of Cauvery) could be geographic barriers between the Coimbatore plateau population and the Cauvery delta and Palk Strait populations, which might explain the high genetic divergence between the individuals sampled from these distinct populations.

Other ground-dwelling *Hemidactylus* occur both in the *H. prashadi* and the *H. brookii* clades. In the *H. prashadi* clade, in as far as is known, only *H. triedrus* is terrestrial and is currently known to be distributed in most of the dry zones of peninsular India including the transitional zones of the Western Ghats. From the *H. brookii* clade, *H. reticulatus* is a similarly distributed terrestrial species, closely associated with rocky habitats. *Hemidactylus gracillis* has its close affinities with black soil throughout its distribution in central India and northern peninsular India, while *H. albofasciatus* and *H. satarensis* are distributed in parts of the northern Western Ghats occupying rocky plateaus. *Hemidactylus scabriceps* occupies the dry zone of Tamil Nadu and northern Sri Lanka (rainfall <1,000mm/year), restricting itself to the grasslands of the alluvial plains and sandy

regions in Northern Sri Lanka and towards the east of Tamil Nadu and red soils towards its west in the Tamil Nadu uplands till the foothills of the Western Ghats. The rocky outcrops in Tamil Nadu (both Eastern and Western Ghats), though interrupted by *H. scabriceps* habitat, are occupied by *H. reticulatus.* Both the Western and Eastern Ghats in the west and north respectively restrict *H. scabriceps* within Tamil Nadu. Informed by our MaxEnt analysis, we hypothesize that the farthest inland locality of *H. scabriceps* disclosed herein (Coimbatore) is inhabited by this species largely because of the deep erosion of the plateau created by the Cauvery River system, engraving a low, alluvial, plains ecosystem into the table-land, much far west than in other nearby parts of the peninsula. This scenario is comparable to the Moyar Gorge being an important biogeographic barrier for terrestrial lizards such as *Sitana* sp. that are predominantly plateau dwelling (Deepak & Karanth 2018). *Hemidactylus scabriceps* also shows the contrast of shared fauna between the dry zones of Tamil Nadu and Sri Lanka (Guptha et al. 2015; Deepak et al. 2016; Deepak & Karanth 2018).

Our findings have a direct bearing on the evolutionary history of this species. The inferred trees from the current work showed strong support for the previously known groups—*H. prashadi, H. flaviviridis, H. brookii, H. frenatus* and *H. platyurus.* From our study, it is also revealed that *H. scabriceps* belongs to the *H. prashadi* group (recognized by Bansal & Karanth 2010). The reduced subdigital scansoral apparatus, imbricate tail scales, imbricate dorsal scales, reduced subcaudal scales and a terrestrial lifestyle are traits that seem to be visually convergent within sub-groups of *Hemidactylus* geckos both from Africa (*H. isolepis, H. ophiolepis*) and India (*H. imbricatus*) (Bauer et al. 2008). The ground dwelling clade of geckos that share similar traits was previously known to be sister to the *H. brookii* group of geckos and *H. scabriceps* was assumed to be related to this group (Bauer et al. 2008). Our phylogenetic analysis reveals that *H. scabriceps* is related to the large rock dwelling clade of geckos contrary to what was previously assumed prompted by morphological similarity.

The unexpected and contrasting genetic relationship of the morphologically and ecologically discordant *H. scabriceps* and *H. prashadi* group underscores the complexity of peninsular India's geological history. Previous studies on peninsular India's terrestrial lizard species have all revealed such discordant patterns of genetic alliance and eco-morphology. Agarwal & Karanth's (2015) molecular phylogenetic analyses revealed that the fat-bodied, forest-floor dwelling taxa '*Geckoella*' is actually a part of primarily scansorial and rupicolous *Cyrtodactylus* radiation. Deepak et al.'s (2015) study on '*Brachysaura*' *minor* also points out a similar structure, i.e. the short body form and completely terrestrial habits of that taxon, contrary to its arboreal congeners in the genus *Calotes*, is nothing but a result of reduction in tree cover and other associated landscape changes (Stromberg 2011; Ponton et al. 2012). Similarly, the Miocene landscape changes such as aridification of the Indian sub-continent has shown large influence on lizard groups such as *Cyrtodactylus*, *Ophisops*, *Sitana* and *Sarada* in the Indian subcontinent (Agarwal & Karanth 2015; Agarwal & Ramakrishnan 2017; Deepak & Karanth 2018). Similar to the phenotypically biased taxonomic allocations the above taxa have had, the current study confirms that the genus *Lophopholis*, originally erected for *H. scabriceps*, is actually a synonym of *Hemidactylus* (also see Bauer et al. 2008).

Although previous studies on other peninsular Indian lizard taxa have revealed such unexpected yet consistent patterns of genetic and eco-morphological discordance, such an instance within the better-studied Indian *Hemidactylus* radiation (Bansal & Karanth 2010; 2013; Bauer et al. 2008, 2010) exhibiting this sharp a contrast is without precedent. This is particularly intriguing, especially when another member of the *H. prashadi* clade, *H. triedrus,* occurring in areas inhabited by *H. scabriceps* (see Smith 1935) can afford to survive in sandy low-elevation alluvial tracts without changing its body form too much. But it must be borne in mind that though *H. triedrus* occurs in plains habitat it could still scale vertical rock surfaces when such formations are present within its range, whereas *H. scabriceps* cannot (Ganesh et al. 2017; this work). Additionally, in most of the range of *H. scabriceps*, there are no other strictly-terrestrial geckoes, neither *Hemidactylus* nor other genera (Smith 1935; Somaweera & Somaweera 2009; Ganesh et al. 2017; this work), thereby throwing open prospects of an empty niche for a potential species to exploit. Thus the current work brings to light a case of so far hidden historical competition between a eurytopic (*H. triedrus, H. lankae*) versus a stenotopic (*H. scabriceps*) clade member. These species are geographically sympatric (Image 6), in India and Sri Lanka respectively, genetically related but morphologically very different (see Image 1). This sharp discordance amply illustrates the complex interplay of historical landscape changes, eco-morphological reactions and resource-use competition.

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Appendix 1. *Hemidactylus scabriceps* material examined

Syntype: BMNH 1946.8.22.40, adult female, Ramnad, Madras District (=Ramnad, Tamil Nadu, India), collected by Col. Annandale, 1906.

BMNH 1920.12.14.2, adult female, Adiyar, Madras (= Chennai, Tamil Nadu, India), collected by D.W. Devanesan, 1920.

BMNH 1933.11.24.1, adult male, Mariccukatti, Northern Province, Ceylon (= Sri Lanka), collected by P.E.P. Deraniyagala, 1934.

CESL 503 & CESL 504, Adult male and female, Kalakad, Tamil Nadu, India, Collected by Saunak Pal, 2012.

BNHS 2421, Adult Male, Kalapatti, Coimbatore, Tamil Nadu, India, Collected by Achyuthan, N. Srikanthan and Chethan Kumar Gandla, 2014.

VPC-GK-029 (IISER, Thiruvananthapuram), Adult male, Thanjavur, Tamil Nadu, India, collected by Gopal Murali, 2014.

Author Details: Achyuthan N. Srikanthan is currently working with the Indian Institute of Science, studying the ecomorphology and evolutionary osteology and specialized integument microstructure characterisation of the amphibian and reptile groups. G. Chethan Kumar is currently working in Wildlife Forensic and Conservation Genetics laboratory, Wildlife Institute of India, Dehradun, solving cases related to morphology and DNA evidences. His research includes, studying reptiles, amphibians and mammalian fauna of India. His primary research interest includes documenting herpetofaunal diversity of under-explored eco-regions, ecology and characterization of species by both classical and molecular approaches. Aishwarya J. Urs works on Geographic Information Systems (GIS) developing models and maps for wildlife biology and related fields. Dr. S.R. Ganesh is working as Deputy Director & Scientist at the Chennai Snake Park, conducting research on reptiles and amphibians of Southern India. His research themes include documenting diversity of under-explored eco-regions, updating and refining species characterizations and elucidating modern day distribution patterns with respect to southern India's herpetofauna.

Author Contributions: NSA, GCK conducted fieldwork and did the morphological as well as genetic analyses. AJU conducted mapping analysis. SRG led the writing with inputs from NSA, GCK and AJU. All the authors equally contributed in refining the manuscript drafts and approved the final version.

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Foraging and roosting ecology of the Lesser Dog-faced Fruit Bat *Cynopterus brachyotis* (Mammalia: Chiroptera: Pteropodidae) in southern India

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Abstract: The Lesser Dog-faced Fruit Bat *Cynopterus brachyotis* was found at higher elevations but since there is a paucity of reports on its distribution and habitat selection, an inventory was made at four locations in the Eastern and Western Ghats of southern India where the elevation ranged from 200–1,500 m. The *C. brachyotis* roosts were distributed between 600–1,500 m. Day roosts were found at an elevation of about 1,000m in Sirumalai and Yercaud Hill stations. Mist-netting studies, however, revealed that *C. brachyotis* was widely distributed at different elevations ranging from 600–1,500 m. Moreover, through a radio-telemetry study, we determined that the males foraged at shorter distances from the day roost, whereas the females commuted longer distances and used more than one foraging area. The male bats' time of emergence is significantly less than females; in addition, males frequently return to their day-roost and made several short foraging flights spaced randomly throughout the night. These observations suggest that some type of territoriality is associated with their roost, which appears to be the basis of social organization in *C. brachyotis*. Overall, this study provides detailed information about the foraging and roosting ecology of *C. brachyotis* in southern India.

Keywords: *Cynopterus brachyotis*, Eastern Ghats, Fruit Bat, habitat use, mist netting, radio-telemetry, Western Ghats.

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Author Contribution: Study design (TK and SK); field work, data collection and analysis (TK); photography and manuscript writing (TK and SK), manuscript correction and revision (TK).

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Ministry of Environment, Forest & Climate Change

DEPARTMENT OF BIOTECHNOLOGY
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INTRODUCTION

The Lesser Dog-faced Fruit Bat *Cynopterus brachyotis* is a group-living, frugivorous, yinpterochiropteran bat, distributed throughout Southeast Asia (Corbet & Hill 1992; Bates & Harrison 1997; Simmons 2015). It is commonly found at higher elevations of the tropical evergreen forests (Lim 1966; Francis 1994; Balasingh et al. 1999). In India, it is reported from a few pockets in the Western and Eastern Ghats (Balasingh et al. 1999). The behaviours of *C. brachyotis* such as tent construction (Kunz et al. 1994; Tan et al. 1997), pollination and seed dispersal (Phua & Corlett 1989), food habits (Tan et al. 1998) and hind limb motion (Cheney et al. 2014) were studied in detail and most of the studies had been carried out in the Southeast Asian countries like Myanmar, Thailand (Bumrungsri & Racey 2007; Bumrungsri et al. 2007), peninsular Malaysia and the Philippines (Lim 1966; Francis 1994; Zubaid 1994). The available data suggest that this is one of the poorly studied species in the Indian subcontinent. Especially, knowledge about distribution, abundance and habitat selection in southern India is still rather incomplete and also little is known about their dispersal patterns, sex ratio, breeding behaviour and social structure. Moreover, this species is dwindling due to increased human interference so that traditional roosts have been drastically reduced as a consequence of tree felling and there is a need for a greater understanding of the species' occurrence and roosting habits. Therefore, the main aim of the present study was to evaluate the foraging and roosting ecology of the Lesser Dog-faced Fruit Bat *C. brachyotis* in southern India.

MATERIALS AND METHODS

Study area

We conducted this study on a monthly basis for a total of 24 months from April 2007 to March 2009 in four different hill regions: Sirumalai (10.1942^{0}N & 77.9967^{0}E), Kodaikkanal (10.2381^{0}N & 77.4892^{0}E), Megamalai (High Wavy Mountains; 9.6461^{0}N & 77.4013^{0}E), and Yercaud (11.7753^{0}N & 78.2093^{0}E; Fig. 1). The study was carried out at different elevations ranging between 200m and 1,500m. In addition, the day roosts of *C. brachyotis* in Sirumalai and Yercaud hill regions were surveyed during October and November 2015 and March and April 2016.

Sampling method (Mist-netting)

Bats were captured using nylon mist nets of 9m x 2.6m with a mesh size of 38mm (Avinet-Dryden, New York, USA) from different altitudes of the above mentioned study areas (Image 1). Mist netting was done from a height of 200–1,500 m. At each altitude, we mainly concentrated on three locations, which had most roosting resources and high food resources for bats. Each location was measured approximately 0.1km in diameter and separated by a minimum of 1km from the closest location. The maximum distance between the locations was about 5km. Since, forest fragments were small and limited to areas too steep and inaccessible for coffee, tea and banana cultivation, it was impossible to find distant capture locations within fragments in four different hill regions. Every month mist netting was carried over a period of nearly 24 months. Mist netting was carried out for 24 nights per elevation (8 nights per location) totaling 168 nights (2,016 night hours) for seven elevations (200–400; 400–600; 600–800; 800–1,000; 1,000–1,200; 1,200–1,400; 1,400–1,500 m) from dusk to dawn. The mist nets were placed away from illuminated areas to avoid visual detection by bats. Mist nets covered a height of up to 4m from the ground. They were erected about half an hour before sunset and removed at 06:00hr. Mist nets were open all night long (12 hours), under different climatic conditions, like new and full moon phases and even during rainy nights. The sampling effort was calculated in net-hours, one net-hour corresponding to one mist net (9x2.6 m, 38mm mesh) opened for one hour [one 9x2.6 m net open for 1h equal to 1 mist-net-hour (mnh)]. Each night, we used one net, resulting in a total sampling effort of 288 net-hours for each elevation, totally 2,016 net-hours for seven elevations in each hill. In order to identify the relative abundance of *C. brachyotis* (excluding recapture) in four different hill regions, we calculated relative capture rates (number of captured individuals/ mist net-hour) for each hill station. Bats caught in mist nets were removed immediately with gloved hands and placed in cloth bags (Gaisler 1973). The morphological measurements such as body mass and length of forearm were measured using a spring balance (Avinet-Dryden, USA) and a Vernier caliper, respectively and also for each bat, species, sex, age were identified, marked and released (Elangovan et al. 2003); a large number of bats were captured within a short duration, they were placed in a holding cage to avoid stress. All the captured bats were marked with a color-coded bead necklace. Ten colored beads (5mm) were used for marking the bats with each color denoting a number from 0–9 (Balasingh et al. 1992). We used three beads for each necklace. Thus, all possible sequential arrangements of the beads

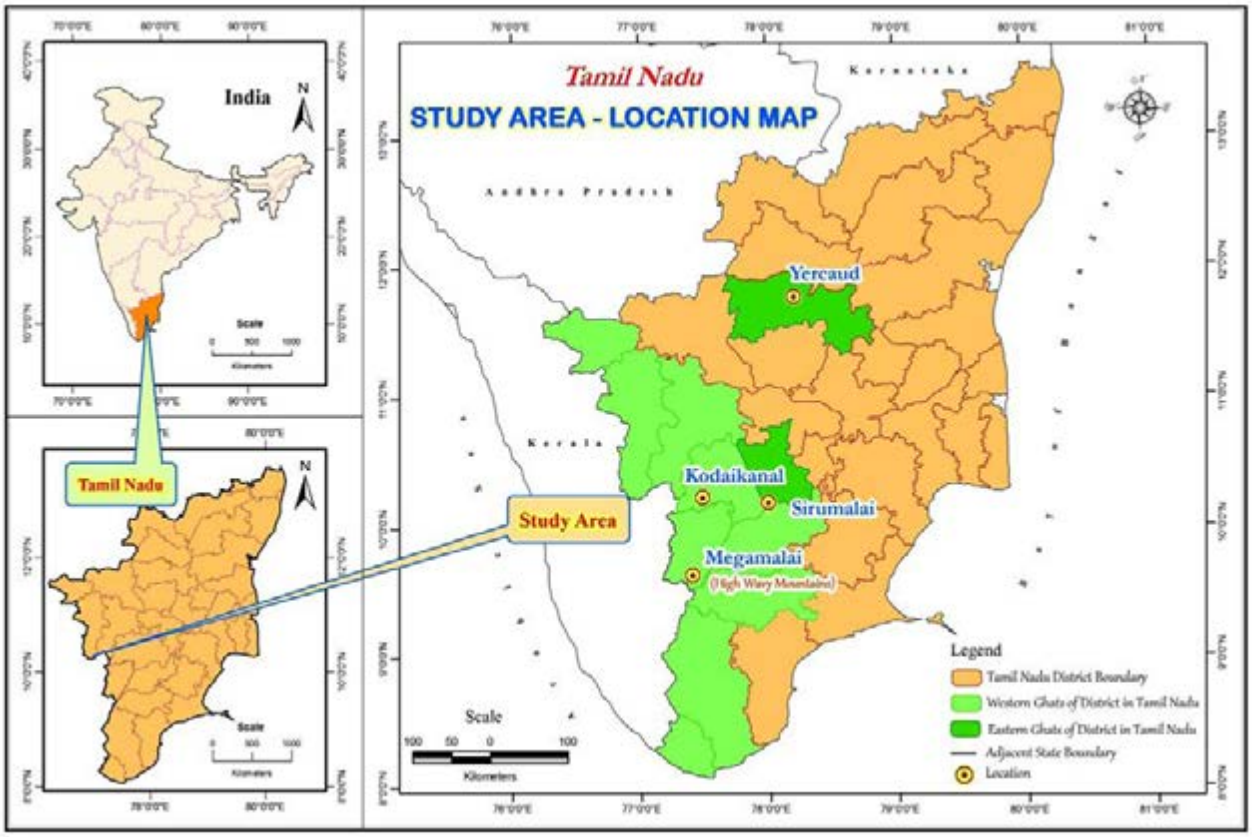

Figure 1. Map shows the location of four different hill regions (study areas) in southern peninsula of India.

Image 1. Closer views of *C. brachyotis* (a & b) captured in the study areas.

provided up to 999 unique tags. The necklace was secured around the bat's neck, by crimping the sleeved copper ring with long-nose pliers. We have used this type of tagging for various studies and have observed no apparent detrimental effects on bats (Gopukumar et al. 2003; 2005; Karuppudurai et al. 2008). After marking, all individuals were released at the site of capture. These markings allowed us to identify individuals and determine their past roosting locations. No bats were injured, killed or retained as specimens during this study.

Radio-telemetry studies

In addition to mark-recapture studies, a radio-telemetry study was conducted during September and October 2008 in Yercaud Hill station. For this study, four bats (2 females and 2 males) of *C. brachyotis* were selected within the study area. The bats were captured at the time of emergence using mist nets and each bat was fitted with a transmitter (Model BD-2, Holohil Systems Ltd., Carp, Ontario, Canada). The weight of the transmitter was 1.5g with a transmission range of 400–500 m, which was mounted over an aluminium collar covered with reflective tape. The reflective tape allowed us to locate the bat within the dense foliage using a torchlight. The transmitter along with the collar was less than 5% of adult body mass. Bats fitted with radio collars were released within 3h of capture, but were not intensely monitored until the following night. Two tracking groups monitored the radio-tagged bat using Merlin receivers and collapsible 3-element Yagi antennae (Customs Electronics, Urbana, Illinois, USA). While, one unit tracked the bat in the foraging area, the other unit stationed near the day roost monitored the bat activity at the roost. In addition, the activity of the bat at the roost was observed using a red torch (>640 nm). We rarely lost radio contact with the focal animal. If radio contact was broken with a moving bat, contact usually was re-established within 20min by walking towards the bearing of disappearance. A change in pulse rate according to the orientation of the antenna allowed us to determine whether the bat was flying or roosting. The constant beep signals were considered as 'rest' and variable singles were considered as 'flying'. We defined foraging time as the period between emergence from the roost at dusk and return to the roost at dawn. 'Foraging bouts' are defined as the period during which a bat flew continuously between leaving the roost and returning to the same roost. The number of foraging bouts and time spent in the day roost during night hours by male and female *C. brachyotis* was analysed by t-tests. Values are expressed as mean ± SD throughout the text.

RESULTS

Mist-netting studies

Over the course of mist netting survey at four different hills, a total of 362 *C. brachyotis*, were captured (Table 1). Of the 362 *C. brachyotis*, about 41 individuals (11.3%) were recaptured (23 adult females, 11 adult males, five young females, and two young males). Adult females (56.1%) were recaptured more frequently followed by adult males, young females and young males and accounted for 26.8%, 12.2% and 4.9% respectively. In general, more adult females and males were recaptured at nearby elevations but occasionally adult females were recaptured in distant elevations than males. For example, in Kodaikkanal hill station, one tagged adult female was captured at an elevation of 1,400–1,500 m but was originally captured and tagged at an elevation of 800–1,000 m.

Among the four different hills, the Sirumalai hill region accounted for 22.4%, of bats, the Kodaikkanal hill station accounted for 28.2% of bats, the Megamalai (High Wavy Mountains) accounted for 26.2% and Yercaud accounted for 23.2% of the total bats (Table 1). There was no significant difference found among the total number of *C. brachyotis* captured at different elevations in four different hill stations (ANOVA: $F_{3, 24} = 0.08$, $P = 0.97$), and also there was no significant difference among the total *C. brachyotis* mark-recaptured at four different hill stations (ANOVA: $F_{3, 24} = 0.33$, $P = 0.80$). To identify the abundance of *C. brachyotis* (excluding recapture) in four different hill stations, we conducted a total of 2,016 mist-net-hours in each hill station. In Sirumalai Hill station a total of 81 *C. brachyotis* were captured with a capture rate of 0.040 bats per net-hour. In Kodaikkanal Hill station a total of 102 bats were captured, which corresponds to a capture rate of 0.051 bats per net-hour, in Megamalai a total of 95 bats were captured, with a capture rate of 0.047 bats per net-hour and in Yercaud 84 bats were captured, which corresponds to a capture rate of 0.042 bats per net-hour.

Table 1. Total number of *C. brachyotis* and other bat species captured at four different hill stations in southern Western Ghats. Value in parentheses is percentage (%) of bats captured in each species.

Study areas / Bat species	Sirumalai (1,600m)	Kodaikkanal (2,133m)	Megamalai (1,500m)	Yercaud (1,623m)	Total number of bats
C. brachyotis	81 (22.4)	102 (28.2)	95 (26.2)	84 (23.2)	362 (61.3)
C. sphinx	107 (49.1)	86 (39.4)	14 (6.4)	11 (5.0)	218 (38.7)
R. leschenaulti	3 (33.3)	4 (44.4)	2 (22.2)	0 (0.0)	9 (1.5)
M. spasma	0 (0.0)	0 (0.0)	2 (100)	0 (0.0)	2 (0.3)

In addition, a total of 229 bats of another three species were captured. All species captured were common bats (Table 1). Two species of fruit-eating bats, *Cynopterus sphinx* (218), *Rousettus leschenaultii* (9), and one species of insect-eating bat *Megaderma spasma* (2). Our study species *C. brachyotis* accounted for 61.3% of all bats captured. Other three bat species *C. sphinx*, *R. leschenaulti* and *M. spasma*, accounted for 38.7%, 1.5% and 0.3%, respectively. Overall, members of the *C. brachyotis* (61.3%) and *C. sphinx* (38.7%) were captured most frequently (Table 1). There was no significant difference among the total bats captured at four different hill stations (ANOVA: $F_{3, 12} = 0.27$, $P = 0.84$).

Distribution, abundance and roosting ecology of *C. brachyotis*

The distribution and abundance of *C. brachyotis* survey was carried out at different elevations starting from 200–1,500 m. More *C. brachyotis* were captured and observed in higher elevation (600–1,500 m; Fig. 2) and stayed only in higher elevations in southern India. In contrast, the *C. sphinx* was captured both in higher and lower elevations but the capture rate was lower in higher elevation and higher in lower elevation. We distinguished *C. brachyotis* from *C. sphinx* on the basis of four morphological characters like forearm length, body mass, ear length and pelage colour (Image 1). The mean forearm length (61.6±1.7 mm) and mean body mass (32.3±2.5 g) of *C. brachyotis* were significantly lower than the mean forearm length (68.5±2.2 mm) and body mass (47.2±3.8 g) of *C. sphinx* (forearm length of *C. brachyotis* vs. *C. sphinx; t* = -23.902, *P*<0.05; body mass of *C. brachyotis* vs. *C. sphinx; t* = -19.852, *P*<0.05). The mean ear size of *C. brachyotis* (16.9±0.72 mm) was significantly smaller compared with mean ear size of *C. sphinx* (20.2±1.1 mm; *t* = -15.041, *P*<0.05). The dorsum of *C. brachyotis* is cinnamon brown compared with the darker olive black of *C. sphinx* (Image 1).

The day roosts of *C. brachyotis* were located at an elevation of above 1,000m in Sirumalai and Yercaud hill stations (Image 2). In these study areas, *C. brachyotis* constructed tents in the pepper plant (*Piper nigrum* L.), leaves of banana tree (*Musa acuminata*) and in the cavities of Indian Banyan tree (*Ficus benghalensis*) which were observed. At Yercaud, a day roost consisting of 10 *C. brachyotis* were found in the roof of an abandoned building (Image 2f). Recent direct observation of day-roosts revealed that *C. brachyotis* completely abandon the pepper plant (*P. nigrum* L.) and leaves of banana tree (*M. acuminata*) tents. The cavity of Indian Banyan tree (*F. benghalensis*), however, was still used as a day roost.

Radio-telemetry studies

In the radio-telemetry study, four bats (2 males and 2 females) were radio-tagged in order to estimate the number and type of foraging areas used by *C. brachyotis* (defined as the localities within which bats were found, presumably feeding, during a large proportion of the night) and patterns of nightly behaviour by individual bats. Each locality has different habitats interspersed

Image 2. Variety of day roosts used by *C. brachyotis* in southern Western Ghats (a) Indian Banyan tree (*F. benghalensis*), (b) a closer view of the tree cavity, (c) a group of *C. brachyotis* roosting in the tree hollow, (d) Pepper plant (*P. nigrum* L.), (e) a closer view of bat roost, and (f) a group of *C. brachyotis* roosting in the roof of an abandoned building. © Authors

Table 2. Tracking summary of radio collared male and female bats of *C. brachyotis* in Yercaud Hill region.

Bat code	Observed days	No. of day roosts used	No. of night roosts used	Cause for end of observation
M1	16	1	3	Transmitter recovered
M2	10	1	1	Transmitter loss
F1	5	1	2	Transmitter loss
F2	14	2	1	Bat disappeared

Table 3. Number of foraging areas used by radio tagged bats in the study area. Value in parentheses is distance(s) to foraging areas from the day roosts (km).+ used; - not used

Bate code	No. of Foraging areas					
	1	2	3	4	5	6
M1	+ (0.2)	+ (0.6)	+ (0.9)	+ (1.2)	+ (2.0)	- (4.0)
M2	+ (0.1)	+ (0.8)	+ (0.4)	+ (1.1)	- (2.4)	- (4.5)
F1	- (0.8)	- (1.0)	+ (0.5)	+ (1.5)	+ (2.8)	+ (5.2)
F2	- (1.0)	+ (1.2)	+ (0.8)	- (2.0)	+ (3.0)	+ (6.0)

with coffee plantations, orange groves, pepper plants and banana trees and the localities are separated from the day roosts by one kilometer. The male (M1 and M2) and female (F1 and F2) bats were successfully tracked for 16, 10, 5 and 14 days respectively and their day roosts were also located successfully (Image 3). The female bat (F2) was roosting in the pepper plant (*P. nigrum* L; Image 3a,b) and the male bat (M1) was roosting in the banana tree (*M. acuminata;* Image 3c). Interestingly, the male bats used a maximum of three night roosts. Conversely, the female bats used a maximum of two night roosts. All the male bats used a single day roost and female bat F1 used a single day roost while female F2 used 2-day roosts (Table 2). The male bat returned to its day roost (modified leaves of banana tree) regularly, however, female bats changed their day roost frequently to either pepper plants and/or a cavity in an Indian banyan tree. The male and female bats used 5 and 6 different foraging areas, respectively (Table 3). The foraging site one was used exclusively by male bats and site 6 was used exclusively by female bats. The male bats foraged ca. 4–4.5 km and the female bats foraged 5–6 km from the day roosts. Female bats travelled longer distances and used more foraging areas (Table 3).

The male and female bats foraged at different areas. Throughout the study, male bats made many visits to its day roosts and thus it spent significantly less time in foraging. There was significant difference in the mean number of foraging bouts/night between male (7.6±1.1) and female (2.2±0.8, n=5 nights) bats (t = 6.65, P<0.05; Fig. 3) and also there was significant difference in the mean time spent in the day roost/night between males (223±80.7 min) and females (554±100.2 min, n=5 nights) (t = 4.97, P<0.05; Fig. 4).

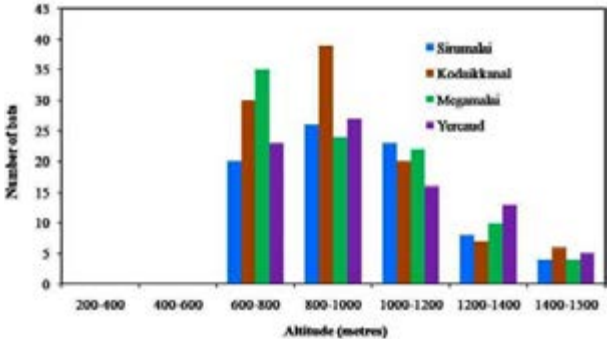

Figure 2. Altitudinal variation in the abundance and distribution of *C. brachyotis* in southern Western Ghats. None of the *C. brachyotis* were captured in lower elevations (200–600 m) and more bats were captured only in higher elevations (600–1,500 m).

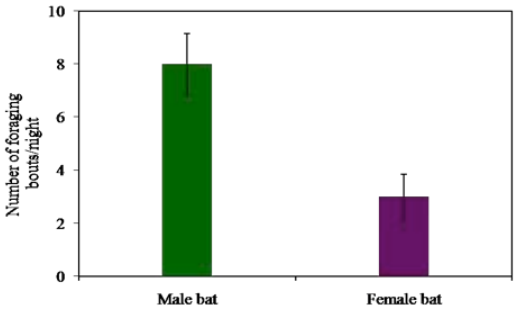

Figure 3. Number of foraging bouts by male and female bats/night.

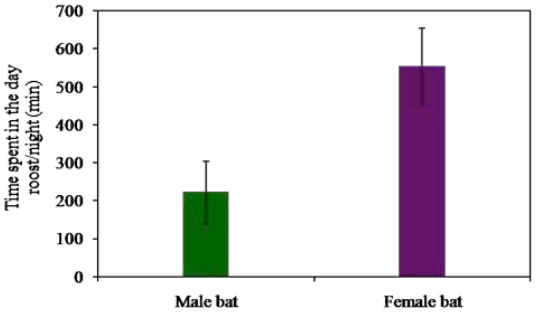

Figure 4. Time spent in the day roost by male and female bats during night hours.

DISCUSSION

Diversity and richness of *C. brachyotis* in southern India

Our study provides detailed information about the distribution, abundance and number of foraging areas of *C. brachyotis* in peninsular India. Day roosts of *C. brachyotis* were located at an elevation of about 1000m and distributed at different elevations that ranges from 600–1,500 m in all selected hill stations to avoid biotic and abiotic disturbance (Brooke et al. 2000; Baskaran et al. 2016). These observations, suggest that *C. brachyotis* occur at higher elevations in southern India, whereas, in Southeast Asia *C. brachyotis* prefers to stay in the plains (Kunz et al. 1994; Tan et al. 1997). In contrast, the Indian Short-nosed Fruit Bat *C. sphinx* were captured both in higher and lower elevations but the capture rate of *C. sphinx* was lower in the higher elevation. Most fruit bats are known to play a crucial role in reforestation through seed dispersal. Previous studies showed that *C. brachyotis* modified leaves of palm trees to construct tents which were then used as day roosts and/or feeding roosts (Tan et al. 1997). In this study, we observed that *C. brachyotis* modifies the pepper plant, leaves of the banana plant, and also used cavities in the Indian banyan tree as day roosts (TK-personal observation). Our recent day roost observations clearly revealed that modified pepper plant and banana tree roosts were completely abandoned by *C. brachyotis* in Sirumalai and Yercaud hill stations. The reasons for decrease in the bat population and roost sites appear to be increased human interference by way of cultivation. Traditional roosts have been drastically reduced as a consequence of tree felling (TK-personal observation).

Feeding behaviour

Previous studies suggest that the fruit bat *C. brachyotis* feeds on fruits of 54 plant species, leaves of 14 species and the stamens of four species. Its role as a seed disperser has been documented in other Southeast Asian countries (Marshall 1983; Phau & Corlett 1989). In the present study, we observed that *C. brachyotis* mainly feed on several fruits, especially banana, jackfruit, orange and coffee. The feeding roosts were usually within 100m of the fruiting tree. Occasionally fruits were carried too far (2–3 km). In our study areas, the most favoured day-roost in the hills was the pepper plant, which sometimes supported colonies of 10 or more bats. In our field studies, most of the mist-netted bats were *C. brachyotis* flying at 2–5 m from the ground. The foraging pattern was observed indirectly from the rate of capture at every hour from dusk to dawn by mist netting. The peak foraging activity occurred between 21:30–23:00 hr with a small peak at 04.30–05.30 hr showing a dominant unimodal pattern of foraging activity in *C. brachyotis*. The second small peak cannot be considered as foraging activity as it may represent a return from the foraging areas. Generally, bimodal activity patterns are characteristic of almost all insectivorous species and some fruit eating bats (Fleming 1982; Elangovan et al. 1999; Stephenraj et al. 2010). In contrast, unimodal patterns are dominant among frugivorous and nectarivorous species (Fleming & Heithaus 1986). From our indirect observations, the unimodal pattern of foraging activity was observed in *C. brachyotis*, however, further systematic studies are required to determine the pattern of foraging activity.

Roosting Ecology

Radio-telemetry studies showed that bats left their day roosts shortly after sunset and flew to foraging areas while they began to search for ripe fruits. The harvested fruit is transported to the night roost for consumption. These 'night roosts' might promote digestion and energy conservation, offer retreat from predators, serve as centers for information transfer about the location of fruit patches and facilitate social interaction (Morrison 1978; Kunz 1982; Fleming 1988). Throughout our study one male bat was found to have high night roost fidelity. A banana tree was used as a night roost constantly. The regular travel path exhibited by this bat between its day roost and foraging area may be attributed to the constancy of resource availability. Such trap-lining behaviour (repeated sequential visits to a series of feeding or foraging locations) minimizes commuting search distance and energy cost. But the other tagged bats of both sexes used more than one night roost. High risk of predation may be attributed for the usage of more night roosts. It seems clear that male *C. brachyotis* restrict their foraging areas close to the day roost, whereas, females commute longer distances and utilized several foraging areas. Since, the male is involved in tent construction, harem formation, and defense, a foraging area a short distance away would facilitate harem defense strategies near the day roost (Fleming 1988). These observations of short distance foraging flights of males are consistent with the earlier reports on the activity of harem males in *C. sphinx*, *Artibeus jamaicensis, Phyllostomus hastatus*, *Carollia perspicillata*, and *Balionycteris maculata* (Morrison 1978; Fleming 1988; Balasingh et al. 1995; Bhat & Kunz, 1995; Marimuthu et al. 1998; Gopukumar et al. 1999; Hodgkison et al. 2003; Karuppudurai et al. 2008). This

Image 3. Day roosts used by radio-tagged male and female bats of *C. brachyotis* (a) modified Pepper plant (*P. nigrum* L.) roost (long view), (b) a radio collared female bat roosting in the Pepper plant roost (close view), and (c) a radio collared male bat roosting in the leaves of Banana tree (*M. acuminata*) (transmitters and bats are indicated by arrows). © Authors

suggests that some type of territoriality is associated with shelter, which appears to be the basis of social organization of bats (Kunz et al. 1998).

Foraging behaviour of male and female *C. brachyotis*

Female bats travel long distances (ca. 6km). Besides, they change their primary foraging area in an unpredictable fashion as observed in *C. perspicillata* (Kunz 1982). Since not every foraging area contains the same potential food resources, one reason for such unpredictable 'shuttles' might increase dietary diversity. The foraging areas of females are isolated whereas the foraging areas of males are overlapping. Since the day roost of most of the males lie within a rich food patch, overlapping of foraging areas is likely to arise (our unpublished data). The exact reasons why female *C. brachyotis* commute longer distances, spend more time foraging and utilize several foraging areas are not clearly known. One of the reasons for long distance commuting by females might be searching for potential male tent roosts and to assess the harem male's parental ability. Recent studies reported the importance of female choice especially in highly mobile animals with harem mating systems (Clutton-Brock 1989; McComb 1991). Female *Saccopteryx bilineata* actively select their roosting location and are highly mobile; some females shift roosting territories during the course of a day and some disperse to other colonies (Heckel et al. 1999). In addition, earlier studies in *C. sphinx* reported fluctuations in the harem size on a day-to-day basis, indicating that females periodically shifted their tents (Balasingh et al. 1995; Karuppudurai & Sripathi 2010). Similarly, the polygynous bats *A. jamaicensis* (Ortega et al. 2003), *P. hastatus* (McCracken & Bradbury 1977), *Desmodus rotundus* (Wilkinson 1985), and *S. bilineata* (Heckel et al. 1999) shifted their roosting sites. Our radio-telemetry studies lend support to these observations. In the present study, one female bat used more than one day roost and also shifted her day roosts frequently. Overall, male and female *C. brachyotis* differed in their foraging

areas and behaviour, as it has been shown for many other bat species like *Rousettus aegyptiacus* (Barclay & Jacobs 2011), *Myotis daubentonii* (Ngamprasertwong et al. 2014), and *Nycticeius humeralis* (Istvanko 2015). An extension of molecular genetics techniques to behavioural ecology might help in understanding the behavioural ecology of *C. brachyotis*. For example, how the behavioural phenotypes are controlled by genes, how they interact with other genes, what is the molecular and genetic basis of their allelic variation, and how this variation behaves with respect to the environment.

CONCLUSION

The present study describes the distribution, relative abundance and number of foraging areas of *C. brachyotis* in four different hill stations in the southern Western Ghats. These findings provides additional knowledge of the behavioural ecology of fruit bats in the Western Ghats, southern India in order to improve habitat suitability models, define critical habitat, and direct land management policies. There is little information about this species in the Indian subcontinent especially in the Western Ghats. Hence, this study provides detailed information about the habitat selection of *C. brachyotis* and is useful in bringing out new information about this species and also gives more information about the *altitudinal* preference and plant animal interaction in the forest area. The understanding of habitat selection of *C. brachyotis* can contribute valuable guidelines for proper conservation and management and is also helpful for formulating bat conservation strategies. Further studies, however, are needed to determine the dispersal patterns, sex ratio, mating strategy and genetic diversity of *C. brachyotis* over the long term using behavioural and molecular techniques.

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COMMUNICATION

Diversity and status of avifauna in man-made sacred ponds of Kurukshetra, India

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Abstract: Located in the Trans-Gangetic Plains of India, Kurukshetra is dotted with a number of man-made, perennial, sacred ponds of great historical and religious importance. These wetlands also serve as important wintering and stopover sites for birds coming from the Palearctic region. Surveys were conducted from April 2014 to March 2015 to record the diversity and status of avifauna in four sacred ponds of Kurukshetra. Point counts and direct observations were used to record the bird species. A total of 126 bird species of 98 genera belonging to 45 families and 16 orders were identified, of which 41 were winter migrants, six were summer migrants, and 79 were residents. Anatidae (n=15) was the most common family, followed by Ardeidae (n=8), and Motacillidae and Muscicapidae (n=7 each). Based on the guilds, 37 species were carnivorous, 36 omnivorous, 29 insectivorous, six herbivorous, six frugivorous, five granivorous, four insectivorous/nectarivorous, and three piscivorous. Of the species recorded, five species are classified as Near Threatened and one species as Vulnerable in the IUCN Red List of Threatened Species; nine species are listed in Appendix II of Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and six species are included in Schedule I of the Indian Wildlife (Protection) Act, 1972. We hope that this study will provide a baseline for future research on monitoring the population and seasonal changes in the bird assemblage of sacred ponds.

Keywords: Avifauna, diversity, India, Kurukshetra, sacred ponds, status.

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INTRODUCTION

Wetlands are the most productive biomes in the world (Kumar et al. 2005) and provide the transitional link between aquatic and terrestrial habitats (Torell et al. 2001; Zedler & Kercher 2005). They have specific ecological characteristics, functions, and values, occupying about 6% of the earth's surface (Maltby & Turner 1983; Green 1996; Getzner 2002) and providing habitat to a wide array of flora and fauna (Buckton 2007). Wetlands are, thus, often considered as treasuries of biodiversity within a region or a landscape (Gopal & Sah 1993; Surana et al. 2007). Birds constitute an important component of the biotic community of wetland ecosystems as they occupy several trophic levels in the food web of wetlands and form the terminal links in many aquatic food chains (Custer & Osborn 1977). Because of their high mobility, birds respond quickly to changes in their habitats (Morrison 1986); they are, thus, valuable indicators of the ecological health, productivity, trophic structure, human disturbance, and contamination of wetland ecosystems (Custer & Osborn 1977; Subramanya 1996).

India, with its varied topography and climatic regimes, supports diverse and unique wetland habitats that occupy an estimated area of 15.26 million hectares (Panigrahy et al. 2012). Apart from natural wetlands, which support 20% of the known biodiversity of India (Kumar et al. 2005), there are a large number of man-made wetlands that also support rich flora and fauna. It is estimated that there are 5,55,557 small-sized wetlands (<2.25 ha) in the form of village tanks/ponds in India (Panigrahy et al. 2012). These wetlands provide suitable habitats and food resources for a wide variety of birds (Stewart 2007; Ali et al. 2013). Of the 1,263 bird species reported from India (Praveen et al. 2016), 310 species are known to be dependent on wetlands (Kumar et al. 2005). Wetlands in India, as elsewhere, however, are under tremendous anthropogenic pressures including encroachment of wetland habitat, unsustainable harvesting of resources, industrial pollution, poisoning, agricultural runoff, eutrophication, siltation, and invasion of alien species (Prasad et al. 2002). These impacts can lead to population declines and changes in community structure of birds (Kler 2002; Verma et al. 2004; Reginald et al. 2007).

Biodiversity inventories or checklists serve as repositories of baseline information on species occurrences, biogeography, and their conservation status (Chandra & Gajbe 2005). They are essential tools for developing our knowledge and understanding of biodiversity, and often the first step to evolve an appropriate long-term conservation strategy for birds and their habitats (Kumar et al. 2005; Badola & Aitken 2010).

Located in the Trans-Gangetic Plains of India, the landscape of Kurukshetra is dotted with a number of perennial, man-made, sacred wetlands of great historical and religious importance. A large number of pilgrims and tourists visit these sacred tanks to take a holy dip and perform religious ceremonies. These wetlands are also potentially important for birds, not only because they provide foraging, roosting, and breeding habitats for resident species, but also for their role as stopover sites or wintering areas for several migrants of the Palearctic region (Kumar et al. 2016). The avifauna of these sacred wetlands, however, remains poorly known. Lack of adequate information on bird species inhabiting wetlands greatly limits the development and establishment of effective conservation strategies. The present study was hence undertaken to make an inventory of bird species that inhabit sacred ponds of Kurukshetra in the Trans-Gangetic Plains of India along with their conservation and residential status.

MATERIALS AND METHODS

Study area

The present study was carried out in four religious ponds: namely, Brahma Sarovar, Jyoti Sarovar, Baan Ganga, and Sannihit Sarovar located in and around Kurukshetra (29.866–30.200 ^{0}N & 76.416–77.066 ^{0}E), Haryana, in the Trans-Gangetic Plains of India (Fig. 1, Table 1). These ponds are surrounded by human habitations and agricultural fields. The surrounding agriculture fields, with wheat and paddy as main crops, provide extra foraging space and food for certain wetland bird species. The study area, experiencing sub-tropical climate, has three seasons: rainy (July–September), cool-and-dry (October–February), and the hot-and-dry (March–June); temperature ranges from 3–45 ^{0}C and annual rainfall averages to 582mm. The wetlands support many types of macrophytes that may be grouped into marginal, submerged, floating, and emergent categories, of which *Eichhornia crassipes* (a deadly invasive) is the dominant free-floating, *Hydrilla verticillata* the dominant submerged, and *Cynodon dactylon* the dominant marginal species in the wetlands. Various tree species like Jamun *Syzygium cumini,* Mango *Mangifera indica*, *Alstonia* sp., Acacia *Acacia nilotica* & *Acacia arabica*, Neem *Azadirachta indica*, Jujube

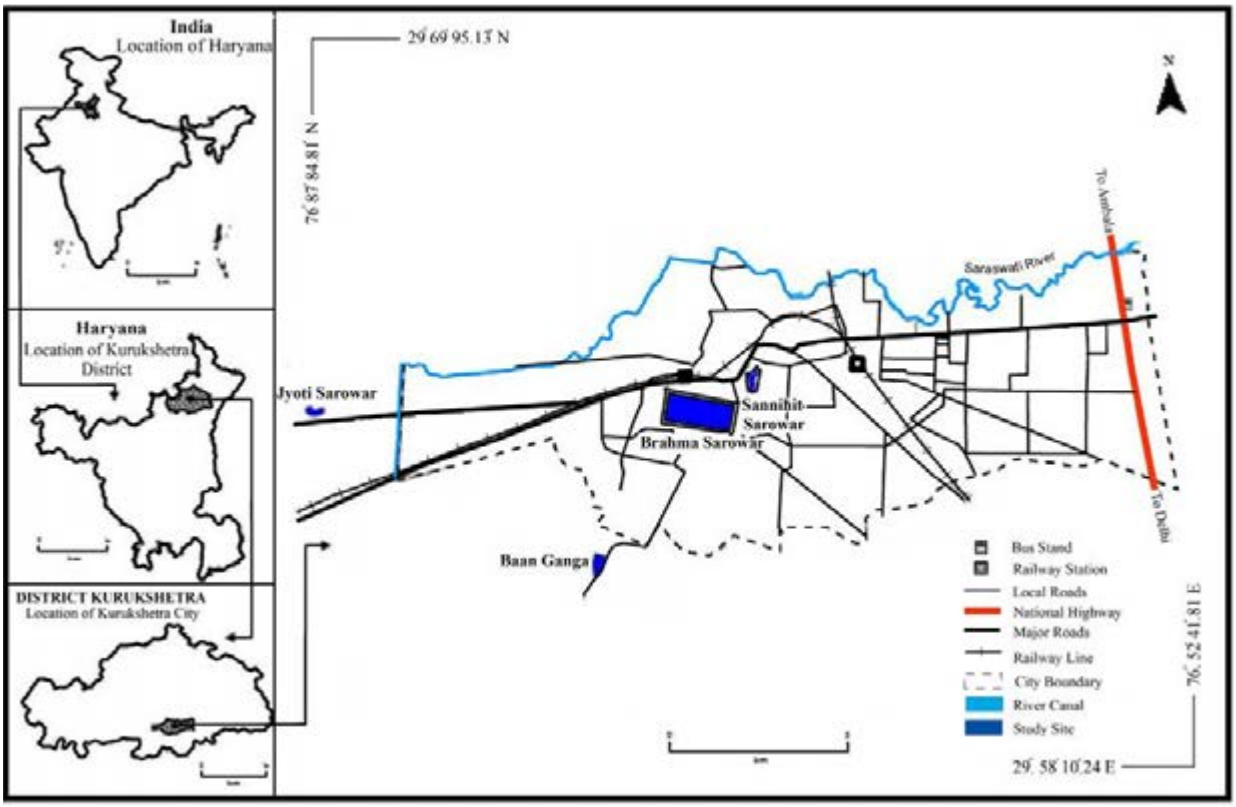

Figure 1. Location of selected study sites

Table 1. Summary of general characteristics of selected sacred ponds

	Sacred Pond	Coordinates	Elevation (m)	General Features
1.	Brahma Sarovar	29.950^{0}N & 76.816^{0}E	245	Rich, healthy, and robust perennial pond situated in the heart of Kurukshetra city; one of largest man-made bathing tanks in Asia; divided into two sections,namely, Eastern and Western Brahma Sarovar. The size of Eastern and Western Brahma Sarovar is 548.64× 457.20×4.57 m and 457.20×457.20×4.57 m, respectively; edged with 6.09m wide platforms, stairs, and a 12.19m wide parikrama. Bathing platforms with protective railings have been constructed along the periphery of the tank. Exclusive separate and covered bathing areas have been constructed for use of women pilgrims. The water in the tank is replenished using water from Bhakra irrigation canal. A large number of pilgrims and tourists take holy dips in the tank on auspicious days of the new moon and solar eclipse. To add scenic beauty, the sarovar is decorated on the periphery with lush green lawns, floral beds, and huge trees with thick and dense canopy, which serve as roosting and nesting sites for birds.
2.	Jyoti Sarovar	29.950^{0}N & 76.766^{0}E	253	Perennial, a series of three closely located ponds at the outskirts of Jyotisar village; one is used by the tourists and local people for holy dip. Size of Jyoti Sarovar is 393.7x196.8 x 3.7m. The second is used for lotus cultivation, is mainly fed by direct precipitation and run-off from surroundings, is recharged during summer through a feeder canal,and is surrounded by large marshy swamp fed by local village sewage; third is used for cattle drinking and bathing. Both the second and third ponds are heavily infested with water hyacinth.
3.	Baan Ganga	29.933^{0}N & 76.800^{0}E	254	Perennial, man-made, religious pond located at the outskirts of Dayalpur Village. Size of of Baan Ganga is 258.20x127.6x 3.7m. It is mainly fed by direct precipitation and run-off from surroundings, and is recharged during summer through field channels. The tank is flanked by rural human habituations and agricultural fields. In the vicinity of the sacred pond, there is a rural pond used for cattle drinking and bathing, washing of vehicles, and other domestic purposes.
4.	Sannihit Sarovar	29.950^{0}N & 76.833^{0}E	244	Perennial, man-made sacred pond in the heart of Kurukshetra city about 1km from Brahma Sarovar, 457.20x137.16 m in size, surrounded by urban human habitation; used by pilgrims for bathing and 'pinddaan'.

Zizyphus jujube, Wild Senna *Cassia tora*, Banyan Tree *Ficus benghalensis*, Bodhi Tree or Peepal *Ficus religiosa*, and the Indian Rosewood *Dalbergia sissoo* at the banks or in the surroundings of the ponds provide suitable roosting and nesting sites for various bird species. The ponds are also surrounded by Mesquite *Prosopis juliflora*, a deadly invasive shrub, and the non-native *Eucalyptus* sp.

Data collection

Bird surveys were conducted at two-week intervals in all the ponds from April 2014 to March 2015, following the point count method (Bibby et al. 2000). Six to 10 vantage points, at least 250m apart, were selected at the perimeter of each pond, and each point location was surveyed 24 times during the entire study period. The observer waited for a few minutes after arrival at each station before beginning to count. This allowed the birds to settle down following the observer's arrival and 10–20 minutes were spent at each point surveying the birds. Birds were counted directly, aided by 7x35 Nikon binoculars, during hours of peak activity 0600–1000 hr and 1600–1800 hr. In addition to these regular surveys, opportunistic records were also collected during other time periods of the day by walking at a slow pace along the bank of selected ponds and recording the species observed. Field guides (Grimmett et al. 1999; Kazmierczak & Perlo 2000) were used for field identification. Taxonomy and nomenclature follow Praveen et al. (2016). For residential status, birds were categorised as resident, winter visitor, and summer visitor on the basis of their presence in the study area (Ali & Ripley 1987). Feeding guilds were classified on the basis of direct observations and available literature (Ali & Ripley 1987; Grimmett et al. 1999). For national and global conservation status of recorded avifauna, we followed IWPA (1972), CITES (2012), and IUCN (2017). The relative abundance (RA) of families was calculated using the following formula as per Torre-Cuadros et al. (2007):

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

RESULTS AND DISCUSSION

A total of 126 species of birds belonging to 98 genera, distributed among 45 families and 16 orders were recorded from four sacred ponds of Kurukshetra during the study period (Table 2, Images 1–102). Of these, 62 species were wetland-associated and the rest were terrestrial. Of all species recorded, 31 (24.60%) were observed from all the four sacred wetlands, and 95 (75.39%) were recorded from some specific wetlands alone (Table 2). Passeriformes had the highest diversity with 46 species and 17 families (Fig. 2). The proportion of species richness of birds by family varied from 0.79–11.90%. Anatidae, the richest family represented by 15 species, accounted for 11.90% of the total bird species in the study area (Table 3). Apodidae, Burhinidae, Rostratulidae, Strigidae, Bucerotidae, Upupidae, Picidae, Meropidae, Coraciidae, Campephagidae, Dicruridae, Nectariniidae, Ploceidae, Passeridae, Pycnonotidae,

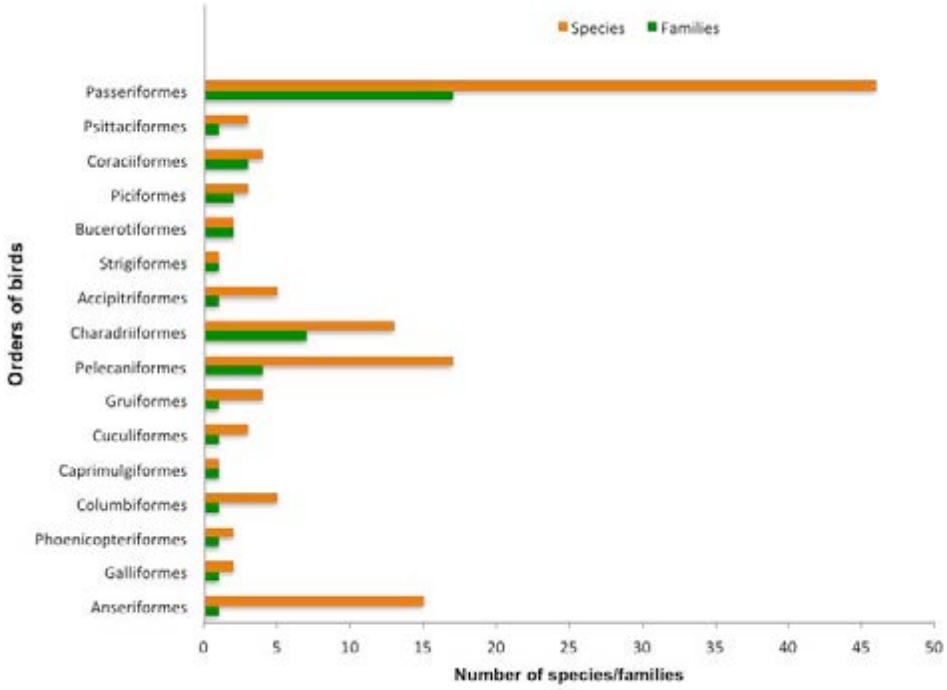

Figure 2. Composition of avian community in sacred ponds of Kurukshetra, India

Zosteropidae, and Timaliidae were poorly represented families with a single species in each. Similarly, Gupta & Kumar(2009) recorded 110 bird species belonging to 41 families and 14 orders from different habitats of Kurukshetra. For comparison, Alfred et al. (2001) reported 216 wetland bird species from various wetland habitats in the much more expansive Sub-Himalayan Terai and Indo-Gangetic Plains of northern India. Ducks and geese (Anatidae) are the most copious and remarkable winter migrants to the Indian-subcontinent, and constitute about 85% of the migrant bird populations (Alfred et al. 2001). These results are in confirmation with findings of earlier workers who have reported Anatidae to be the most dominant family among bird communities in different wetland habitats of Haryana in northern India (Kumar & Gupta 2009, 2013; Tak et al. 2010; Kumar et al. 2016).

Of the 126 species identified, 41 were winter migrants, six were summer migrants, and 79 were residents. The occurrence of a considerable number of winter migratory species can be attributed partly to the study area being on the Central Asian Flyway and serving as a wintering and stopover site for migratory birds that breed in the Palearctic region (Kumar et al. 2016). These migratory birds form a major component of the aquatic bird populations in various wetland habitats of northern India (Alfred et al. 2001; Manral et al. 2013; Kumar et al. 2016). We observed that the majority of the winter migrants stayed in the sacred wetlands from November to February. The summer visitors, including Cotton Teal *Nettapus coromandelianus*, Lesser Whistling Duck *Dendrocygna javanica*, Comb Duck *Sarkidiornis melanotos*, Pied Cuckoo *Clamator jacobinus*, Pheasant-tailed Jacana *Hydrophasianus chirurgus*, and Greater Painted-snipe *Rostratula benghalensis* were spotted during summer season (April–August) in the study area. Little Cormorant *Microcarbo niger* and Black-winged Stilt *Himantopus himantopus*, being common resident species, were recorded in and around the wetlands throughout the year, but their populations augmented due to the influx of migrant birds during the winter season.

Wetland characteristics like size, water depth, quality of water, trophic structure, and presence of suitable roosting and nursery sites influence the abundance and diversity of birds (Wiens 1989; Mukherjee et al. 2002; Ma et al. 2010). During the study period, species richness was recorded to be the highest at Jyoti Sarovar (n=107), followed by Brahma Sarovar (n=88), Baan Ganga (n=53), and Sannihit Sarovar (n=34). Generally, habitats with a complex architecture generate greater

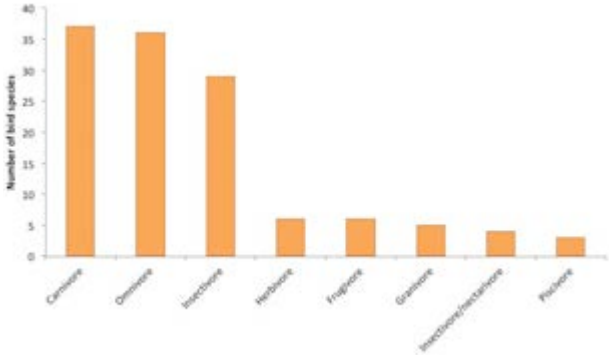

Figure 3. Guild-based classification of avian species recorded in sacred ponds of Kurukshetra, India

resources for birds, allowing the persistence of a greater number of species and guilds than in less complex habitats (MacArthur & MacArthur 1961; Tews et al. 2004; Codesido et al. 2013). In the present study, Jyoti Sarovar wetland, along with the adjacent rural pond, marshy area, and irrigated crop fields, provided a mosaic of habitats leading to multiple and variety of alternative food sources for the birds, and thus registered highest species richness (Aynalem & Bekele 2008). Brahma Sarovar and Sannihit Sarovar, being located in urban areas of the Kurukshetra City, are more exposed to local people and tourists. As a result, bird activities like feeding, nesting, hiding, and breeding are affected at these sites.

The quality and quantity of food available is the major factor that determines the spatio-temporal distribution and relative abundance of birds in a given habitat (Wiens 1989; Ma et al. 2010; Jha 2013). The different species of birds occupying a particular feeding guild and space have evolved specialized foraging strategies to explore and obtain food resources efficiently and thereby to reduce competition (Nudds & Bowlby 1984). As far as foraging habits of the bird community in the study area are concerned, eight major feeding guilds were identified (Fig. 3). This representation of major trophic guilds in the area indicated that the area holds a wide spectrum of food resources for birds. The carnivore guild was the most abundant one with 37 species followed by omnivore (36), insectivore (29), herbivore (six), frugivore (six), granivore (five), insectivore/nectarivore (four), and piscivore (three). Due to their specialized diet and low availability of preferable food resources, the nectarivores and piscivores are generally less represented (Wiens 1989). The diversity of avifauna in the study area may be due to the presence of a wide spectrum of food niches, which reduced food competition among different species (Jose & Zacharias 2003). About half of the recorded bird

species were those associated with wetland habitats, such as ducks, herons, egrets, cormorants, jacanas, grebes, kingfishers, and storks, which were observed to feed on aquatic organisms (worms, insects, snails, fish, and amphibians) at various water depths available in the wetlands and adjoining paddy fields and marshy area.

Bronze-winged Jacana *Metopidius indicus* and Pheasant-tailed Jacana *Hydrophasianus chirurgus* were spotted at Jyoti Sarovar alone, the only pond with lotuses. The vegetation cover of lotuses provides suitable feeding, nesting, and breeding habitat for herons, moorhens, and jacanas. Purple Swamphen *Porphyrio porphyrio*, a common resident species, was observed only in weedy marsh areas flanking the sacred pond of Jyoti Sarovar, where there were frequent human activities; this bird species may be a bio-indicator of enhanced weed infestation and increased vegetation cover in the wetlands of Haryana (Kumar et al. 2016). Waders, shorebirds, Purple Moorhen, and wagtails were also observed foraging in the irrigated wheat and paddy fields flanking the sacred ponds in rural habitats (Jyoti Sarovar and Baan Ganga). This observation is consistent with earlier reports, where foraging by aquatic birds outside the wetlands in surrounding agriculture fields has been recorded (Lane & Fujioka 1998; Mukherjee et al. 2002; Urfi 2003; Jha 2013; Kumar et al. 2016).

Among the recorded avifauna, five species, namely, Painted Stork *Mycteria leucocephala*, Black-necked Stork *Ephippiorhynchus asiaticus*, Black-headed Ibis *Threskiornis melanocephalus*, River Tern *Sterna aurantia*, and Alexandrine Parakeet *Psittacula eupatria* are listed as Near Threatened, and one species, Common Pochard *Aythya ferina*, as Vulnerable in the IUCN Red List (IUCN 2017). All the remaining species (n=120) are placed in the Least Concern category in the Red List of IUCN (2017). Additionally, nine species are included in Appendix-II of CITES (2012). Six species, including five species of Accipitridae and one of Phasianidae, are considered nationally threatened as these are listed under Schedule-I of the Indian Wildlife (Protection) Act, 1972.

Significant records

Painted Stork - Near Threatened: A winter migrant in the study area was recorded in a small flock (4–8 individuals) only at Jyoti Sarovar during winter months (December–January). The birds were often recorded roosting on large trees at the bank of the wetland.

Black-necked Stork - Near Threatened: A lone male individual was recorded foraging in the mud-flat adjacent to Jyoti Sarovar on 25January 2015. This species is very widely but thinly distributed in India, with the northern and northwestern regions forming its main strongholds (Rahmani 1989).

Black-headed Ibis - Near Threatened: A resident wader species (Kumar et al. 2016) was recorded in small loose groups (1–4 individuals) only at Jyoti Sarovar throughout the study period. It was often observed foraging with other waders at the margins of the pond, and mudflats and paddy fields adjoining the sacred wetland.

River Tern - Near Threatened: A common resident species in the study area (Kumar et al. 2016) was recorded as 1–7 scattered individuals at all the four sacred ponds throughout the study period.

Alexandrine Parakeet - Near Threatened: A resident species in the study area was recorded in small groups of 5–10 individuals. The birds were frequently observed roosting on trees at banks of all the ponds.

Common Pochard - Vulnerable: This is a common winter visitor in India (Grimmett et al. 1999). The species was recorded in flocks of 6–50 individuals during winter months (November–March) in Brahma Sarovar only.

Comb Duck - Appendix II of CITES: A resident species in the Indian subcontinent with local movements (Grimmett et al. 1999) was recorded only at Jyoti Sarovar in a pair during summer (May 2014).

In addition to the cultural and religious legacy of the region, the presence of significant numbers of migratory species as well as those with conservation priorities underlines the importance of these sacred wetlands as important bird habitats in Haryana. It is evident from the present study that if some attention is provided to these sacred wetlands, these could be developed as a good site for harbouring avifauna and as a haven for bird-watchers. Our efforts contributed towards filling biological information gaps in the region; continuing studies will allow monitoring of the population and seasonal changes in the bird assemblage.

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Table 2. Checklist and status of avifauna recorded in sacred ponds of Kurukshetra in the Trans-Gangetic Plains, India

	Order/family/common name	Scientific name	Residential status	Feeding guild	Conservation status			Sacred pond				Image
					IUCN (2017)	CITES (2012)	IWPA (1972)	BS	JS	BG	SS	
	ANSERIFORMES Anatidae (15)											
1	Lesser Whistling Duck	*Dendrocygna javanica* (Horsfield, 1821)	SM	O	LC	-	IV	×	✓	×	×	1
2	Common Shelduck	*Tadorna tadorna* (Linnaeus, 1758)	WM	O	LC	-	IV	✓	×	×	×	
3	Ruddy Shelduck	*Tadorna ferruginea* (Pallas, 1764)	WM	O	LC	-	IV	✓	×	×	×	2
4	Red Crested Pochard	*Netta rufina* (Pallas, 1773)	WM	H	LC	-	IV	✓	×	×	×	3
5	Common Pochard	*Aythya ferina* (Linnaeus, 1758)	WM	O	VU	-	IV	✓	×	×	×	4
6	Tufted Duck	*Aythya fuligula* (Linnaeus, 1758)	WM	H	LC	-	IV	✓	×	×	×	5
7	Northern Shoveler	*Spatula clypeata* (Linnaeus, 1758)	WM	O	LC	-	IV	✓	✓	×	×	6
8	Gadwall	*Mareca strepera* (Linnaeus, 1758)	WM	H	LC	-	IV	✓	✓	×	×	7
9	Eurasian Wigeon	*Mareca penelope* (Linnaeus, 1758)	WM	H	LC	-	IV	✓	×	×	×	
10	Indian Spot-billed Duck	*Anas poecilorhyncha* Forster, 1781	WM	H	LC	-	IV	✓	✓	×	×	8
11	Mallard	*Anas platyrhynchos* Linnaeus, 1758	WM	H	LC	-	IV	✓	✓	×	×	9
12	Northern Pintail	*Anas acuta* Linnaeus, 1758	WM	O	LC	-	IV	✓	×	×	×	10
13	Common Teal	*Anas crecca* Linnaeus, 1758	WM	O	LC	-	IV	✓	✓	×	×	11
14	Comb Duck	*Sarkidiornis melanotos* (Pennant, 1769)	SM	O	LC	II	IV	×	✓	×	×	12
15	Cotton Teal	*Nettapus coromandelianus* (Gmelin, 1789)	SM	O	LC	-	IV	×	✓	×	×	13
	GALLIFORMES Phasianidae (2)											
16	Indian Peafowl	*Pavo cristatus* Linnaeus, 1758	R	O	LC	-	I	✓	×	×	×	14
17	Grey Francolin	*Francolinus pondicerianus* (Gmelin, 1789)	R	O	LC	-	IV	✓	✓	×	×	
	PHOENICOPTERIFORMES Podicipedidae (2)											
18	Little Grebe	*Tachybaptus ruficollis* (Pallas, 1764)	R	C	LC	-	IV	✓	✓	✓	×	15
19	Great Crested Grebe	*Podiceps cristatus* (Linnaeus, 1758)	WM	C	LC	-	IV	✓	×	×	×	16
	COLUMBIFORMES Columbidae (5)											
20	Rock Pigeon	*Columba livia* Gmelin, 1789	R	G	LC	-	IV	✓	✓	✓	✓	17
21	Spotted Dove	*Spilopelia chinensis* (Scopoli, 1786)	R	G	LC	-	IV	✓	✓	✓	✓	18
22	Eurasian Collared Dove	*Streptopelia decaocto* Frivaldszky, 1838	R	G	LC	-	IV	✓	✓	✓	✓	19
23	Laughing Dove	*Spilopelia senegalensis* (Linnaeus, 1766)	R	G	LC	-	IV	✓	✓	✓	×	20
24	Yellow-legged Green Pigeon	*Treron phoenicopterus* (Latham, 1790)	R	F	LC	-	IV	✓	✓	✓	✓	21
	CAPRIMULGIFORMES Apodidae (1)											
25	Indian House Swift	*Apus affinis* (Gray, 1830)	R	In	LC	-	IV	×	✓	✓	×	
	CUCULIFORMES Cuculidae (3)											
26	Pied Cuckoo	*Clamator jacobinus* (Boddaert, 1783)	SM	In	LC	-	IV	✓	×	✓	×	
27	Asian Koel	*Eudynamys scolopaceus* (Linnaeus, 1758)	R	O	LC	-	IV	✓	✓	✓	✓	22

	Order/family/common name	Scientific name	Residential status	Feeding guild	Conservation status			Sacred pond				Image
					IUCN (2017)	CITES (2012)	IWPA (1972)	BS	JS	BG	SS	
28	Greater Coucal	*Centropus sinensis* (Stephens, 1815)	R	C	LC	-	IV	✓	✓	✓	✓	23
	GRUIFORMES Rallidae (4)											
29	White-breasted Waterhen	*Amaurornis phoenicurus* (Pennant, 1769)	R	O	LC	-	IV	✓	✓	✓	✓	24
30	Purple Swamphen	*Porphyrio porphyrio* (Linnaeus, 1758)	R	O	LC	-	IV	×	✓	×	×	25
31	Common Moorhen	*Gallinula chloropus* (Linnaeus, 1758)	WM	O	LC	-	IV	✓	✓	✓	✓	26
32	Common Coot	*Fulica atra* Linnaeus, 1758	WM	O	LC	-	IV	✓	✓	✓	✓	27
	PELECANIFORMES Ciconiidae (3)											
33	Painted Stork	*Mycteria leucocephala* (Pennant, 1769)	WM	C	NT	-	IV	×	✓	×	×	28
34	Asian Openbill	*Anastomus oscitans* (Boddaert, 1783)	WM	C	LC	-	IV	×	✓	×	×	29
35	Black-necked Stork	*Ephippiorhynchus asiaticus* (Latham, 1790)	WM	C	NT	-	IV	×	✓	×	×	
	Ardeidae (8)											
36	Black-crowned Night-Heron	*Nycticorax nycticorax* (Linnaeus, 1758)	R	C	LC	-	IV	✓	✓	✓	×	30
37	Indian Pond Heron	*Ardeola grayii* (Sykes, 1832)	R	C	LC	-	IV	✓	✓	✓	✓	31
38	Cattle Egret	*Bubulcus ibis* (Linnaeus, 1758)	R	C	LC	-	IV	✓	✓	✓	✓	32
39	Grey Heron	*Ardea cinerea* Linnaeus, 1758	R	C	LC	-	IV	×	✓	×	×	33
40	Purple heron	*Ardea purpurea* Linnaeus, 1766	R	C	LC	-	IV	✓	✓	×	×	34
41	Great Egret	*Ardea alba* Linnaeus, 1758	WM	C	LC	-	IV	✓	✓	✓	×	35
42	Intermediate Egret	*Ardea intermedia* Wagler, 1829	WM	C	LC	-	IV	✓	✓	✓	×	36
43	Little Egret	*Egretta garzetta* (Linnaeus, 1766)	R	C	LC	-	IV	✓	✓	✓	✓	37
	Threskiornithidae (3)											
44	Black-headed Ibis	*Threskiornis melanocephalus* (Latham, 1790)	R	C	NT	-	IV	×	✓	×	×	38
45	Indian Black Ibis	*Pseudibis papillosa* (Temminck, 1824)	R	C	LC	-	IV	×	✓	×	×	39
46	Glossy Ibis	*Plegadis falcinellus* (Linnaeus, 1766)	R	C	LC	-	IV	×	✓	×	×	40
	Phalacrocoracidae (3)											
47	Little Cormorant	*Microcarbo niger* (Vieillot, 1817)	R	C	LC	-	IV	✓	✓	✓	✓	41
48	Great Cormorant	*Phalacrocorax carbo* (Linnaeus, 1758)	WM	C	LC	-	IV	✓	✓	×	✓	42
49	Indian Cormorant	*Phalacrocorax fuscicollis* Stephens, 1826	WM	P	LC	-	IV	✓	✓	×	✓	43
	CHARADRIIFORMES Burhinidae (1)											
50	Eurasian Thick-knee	*Burhinus oedicnemus* (Linnaeus, 1758)	R	O	LC	-	IV	×	✓	×	×	44
	Recurvirostridae (2)											
51	Pied Avocet	*Recurvirostra avosetta* Linnaeus, 1758	WM	C	LC	-	IV	×	✓	×	×	45
52	Black-winged stilt	*Himantopus himantopus* (Linnaeus, 1758)	R	C	LC	-	IV	✓	✓	✓	×	46
	Charadriidae (2)											
53	Red-wattled Lapwing	*Vanellus indicus* (Boddaert, 1783)	R	C	LC	-	IV	✓	✓	✓	✓	47

	Order/family/common name	Scientific name	Residential status	Feeding guild	Conservation status			Sacred pond				Image
					IUCN (2017)	CITES (2012)	IWPA (1972)	BS	JS	BG	SS	
54	White-tailed Lapwing	*Vanellus leucurus* (Lichtenstein, 1823)	WM	C	LC	-	IV	×	✓	×	×	48
	Rostratulidae (1)											
55	Greater Painted-Snipe	*Rostratula benghalensis* (Linnaeus, 1758)	SM	O	LC	-	IV	×	✓	×	×	
	Jacanidae (2)											
56	Pheasant-tailed Jacana	*Hydrophasianus chirurgus* (Scopoli, 1786)	SM	O	LC	-	IV	×	✓	×	×	49
57	Bronze-winged Jacana	*Metopidius indicus* (Latham, 1790)	R	O	LC	-	IV	×	✓	×	×	50
	Scolopacidae (3)											
58	Common Sandpiper	*Actitis hypoleucos* Linnaeus, 1758	WM	C	LC	-	IV	✓	✓	×	×	51
59	Common Greenshank	*Tringa nebularia* (Gunnerus, 1767)	WM	C	LC	-	IV	×	✓	×	×	52
60	Common Redshank	*Tringa totanus* (Linnaeus, 1758)	WM	C	LC	-	IV	×	✓	×	×	53
	Laridae (2)											
61	Pallas's Gull	*Larus ichthyaetus* Pallas, 1773	WM	C	LC	-	IV	✓	×	×	×	
62	River Tern	*Sterna aurantia* Gray, 1831	R	P	NT	-	IV	✓	✓	×	×	54
	ACCIPITRIFORMES Accipitridae (5)											
63	Black-winged Kite	*Elanus caeruleus* (Desfontaines, 1789)	R	C	LC	II	I	×	✓	×	✓	55
64	Oriental Honey Buzzard	*Pernis ptilorhynchus* (Temminck, 1821)	R	C	LC	II	I	✓	✓	×	×	
65	Shikra	*Accipiter badius* (Gmelin, 1788)	R	C	LC	II	I	✓	✓	✓	×	56
66	Brahminy Kite	*Haliastur Indus* (Boddaert, 1783)	R	C	LC	II	I	✓	✓	×	×	57
67	Black Kite	*Milvus migrans* (Boddaert, 1783)	R	C	LC	II	I	✓	✓	✓	✓	58
	STRIGIFORMES Strigidae (1)											
68	Spotted Owlet	*Athene brama* (Temminck, 1821)	R	C	LC	II	IV	✓	✓	✓	×	59
	BUCEROTIFORMES Bcerotidae (1)											
69	Indian Grey Hornbill	*Ocyceros birostris* (Scopoli, 1786)	R	O	LC	-	IV	✓	✓	✓	✓	60
	Upupidae (1)											
70	Common Hoopoe	*Upupa epops* Linnaeus, 1758	R	In	LC	-	IV	×	✓	✓	×	61
	PICIFORMES Picidae (1)											
71	Lesser Golden-backed Woodpecker	*Dinopium benghalense* (Linnaeus, 1758)	R	In	LC	-	IV	✓	✓	×	×	62
	Ramphastidae (2)											
72	Brown-headed Barbet	*Psilopogon zeylanicus* (Gmelin, 1788)	R	F	LC	-	IV	✓	✓	✓	×	63
73	Coppersmith Barbet	*Psilopogon haemacephalus* (Muller, 1776)	R	F	LC	-	IV	✓	✓	×	×	64
	CORACIIFORMES Meropidae (1)											
74	Green Bee-eater	*Merops orientalis* Latham, 1802	R	In	LC	-	IV	✓	✓	✓	✓	65
	Coraciidae (1)											
75	Indian Roller	*Coracias benghalensis* (Linnaeus, 1758)	R	C	LC	-	IV	×	✓	✓	×	66
	Alcedinidae (2)											

	Order/family/common name	Scientific name	Residential status	Feeding guild	Conservation status			Sacred pond				Image
					IUCN (2017)	CITES (2012)	IWPA (1972)	BS	JS	BG	SS	
76	Pied Kingfisher	*Ceryle rudis* (Linnaeus, 1758)	R	P	LC	-	IV	✓	×	×	×	
77	White-throated Kingfisher	*Halcyon smyrnensis* (Linnaeus, 1758)	R	C	LC	-	IV	✓	✓	✓	✓	67
	PSITTACIFORMES Psittaculidae (3)											
78	Slaty-headed Parakeet	*Psittacula himalayana* (Lesson, 1832)	WM	F	LC	II	IV	✓	×	×	×	
79	Alexandrine Parakeet	*Psittacula eupatria* (Linnaeus, 1766)	R	F	NT	II	IV	✓	✓	✓	✓	68
80	Rose-ringed Parakeet	*Psittacula krameri* (Scopoli, 1769)	R	F	LC	-	IV	✓	✓	✓	✓	69
	PASSERIFORMES Campephagidae (1)											
81	Scarlet Minivet	*Pericrocotus flammeus* (Forster, 1781*)*	WM	In	LC	-	IV	✓	×	×	×	
	Dicruridae (1)											
82	Black Drongo	*Dicrurus macrocercus* Vieillot, 1817	R	In	LC	-	IV	✓	✓	✓	✓	70
	Laniidae (2)											
83	Bay-backed Shrike	*Lanius vittatus* Valenciennes, 1826	R	C	LC	-	IV	×	✓	×	×	
84	Long-tailed Shrike	*Lanius schach* Linnaeus, 1758	R	C	LC	-	IV	×	✓	×	×	71
	Corvidae (3)											
85	Rufous Treepie	*Dendrocitta vagabunda* (Latham, 1790)	R	O	LC	-	IV	✓	✓	✓	✓	72
86	House Crow	*Corvus splendens* Vieillot, 1817	R	O	LC	-	V	✓	✓	✓	✓	73
87	Large-billed Crow	*Corvus macrorhynchos* Wagler, 1827	WM	O	LC	-	IV	✓	✓	✓	✓	74
	Nectariniidae (1)											
88	Purple Sunbird	*Cinnyris asiaticus* (Latham, 1790)	R	In/N	LC	-	IV	✓	✓	✓	✓	75
	Ploceidae (1)											
89	Baya Weaver	*Ploceus philippinus* (Linnaeus, 1766)	R	O	LC	-	IV	✓	✓	✓	×	76
	Estrildidae (2)											
90	Indian Silverbill	*Euodice malabarica* (Linnaeus, 1758)	R	G	LC	III	IV	×	✓	×	×	77
91	Scaly-breasted Munia	*Lonchura punctulata* (Linnaeus, 1758)	R	O	LC	-	IV	✓	✓	×	×	78
	Passeridae (1)											
92	House Sparrow	*Passer domesticus* (Linnaeus, 1758)	R	O	LC	-	IV	×	✓	✓	×	79
	Motacillidae (7)											
93	Tree Pipit	*Anthus trivialis* (Linnaeus, 1758)	WM	In	LC	-	IV	×	✓	×	×	
94	Paddyfield Pipit	*Anthus rufulus* Vieillot, 1818	R	In	LC	-	IV	×	✓	×	×	80
95	Western Yellow Wagtail	*Motacilla flava* Linnaeus, 1758	WM	In	LC	-	IV	×	✓	×	×	81
96	Grey Wagtail	*Motacilla cinerea* Tunstall, 1771	WM	In	LC	-	IV	×	✓	×	×	82
97	Citrine Wagtail	*Motacilla citreola* Pallas, 1776	WM	In	LC	-	IV	×	✓	×	×	83
98	White-browed Wagtail	*Motacilla maderaspatensis* Gmelin, 1789	R	In	LC	-	IV	✓	✓	✓	✓	
99	White Wagtail	*Motacilla alba* Linnaeus, 1758	WM	In	LC	-	IV	✓	✓	✓	✓	84
	Cisticolidae (4)											
100	Zitting Cisticola	*Cisticola juncidis* (Rafinesque, 1810)	R	In	LC	-	IV	✓	✓	✓	×	

	Order/family/common name	Scientific name	Residential status	Feeding guild	Conservation status			Sacred pond				Image
					IUCN (2017)	CITES (2012)	IWPA (1972)	BS	JS	BG	SS	
101	Ashy Prinia	*Prinia socialis* Sykes, 1832	R	In/N	LC	-	IV	✓	✓	✓	×	85
102	Plain Prinia	*Prinia inornata* Sykes, 1832	R	In	LC	-	IV	×	✓	×	×	86
103	Common Tailorbird	*Orthotomus sutorius* (Pennant, 1769)	R	In/N	LC	-	IV	✓	✓	✓	×	87
	Hirundinidae (6)											
104	Northern House Martin	*Delichon urbicum* (Linnaeus, 1758)	R	In	LC	-	IV	×	✓	×	×	
105	Wire-tailed Swallow	*Hirundo smithii* Leach, 1818	R	In	LC	-	IV	✓	✓	×	×	88
106	Barn Swallow	*Hirundo rustica* Linnaeus, 1758	R	In	LC	-	IV	✓	×	×	×	
107	Eurasian Crag-Martin	*Ptyonoprogne rupestris* (Scopoli, 1769)	R	In	LC	-	IV	✓	×	×	×	
108	Plain Martin	*Riparia paludicola* (Vieillot, 1817)	R	In	LC	-	IV	✓	×	×	×	
109	Sand Martin	*Riparia riparia* (Linnaeus, 1758)	R	In	LC	-	IV	✓	×	×	×	
	Pycnonotidae (1)											
110	Red vented Bulbul	*Pycnonotus cafer* (Linnaeus, 1766)	R	O	LC	-	IV	✓	✓	✓	✓	89
	Zosteropidae (1)											
111	Oriental White-eye	*Zosterops palpebrosus* (Temminck, 1824)	R	In/N	LC	-	IV	✓	✓	×	×	90
	Timaliidae (1)											
112	White-browed Scimitar Babbler	*Pomatorhinus schisticeps* Hodgson, 1836	WM	O	LC	-	IV	×	✓	×	×	
	Leiothrichidae (3)											
113	Large Grey Babbler	*Argya malcolmi* (Sykes, 1832)	R	O	LC	-	IV	✓	✓	×	×	91
114	Common Babbler	*Argya caudata* (Dumont, 1823)	R	O	LC	-	IV	✓	✓	✓	✓	
115	Jungle Babbler	*Turdoides striata* (Dumont, 1823)	R	O	LC	-	IV	✓	✓	×	×	92
	Sturnidae (4)											
116	Asian Pied Starling	*Gracupica contra* (Linnaeus, 1758)	R	O	LC	-	IV	✓	✓	✓	×	93
117	Brahminy Starling	*Sturnia pagodarum* (Gmelin, 1789)	R	O	LC	-	IV	✓	✓	✓	×	94
118	Common Myna	*Acridotheres tristis* (Linnaeus, 1766)	R	O	LC	-	IV	✓	✓	✓	✓	95
119	Bank Myna	*Acridotheres ginginianus* (Latham, 1790)	R	O	LC	-	IV	✓	✓	✓	×	96
	Muscicapidae (7)											
120	Indian Robin	*Saxicoloides fulicatus* (Linnaeus, 1766)	R	In	LC	-	IV	✓	✓	✓	×	97
121	Oriental Magpie Robin	*Copsychus saularis* (Linnaeus, 1758)	R	In	LC	-	IV	✓	✓	✓	✓	98
122	Verditer Flycatcher	*Eumyias thalassinus* Swainson, 1838	WM	In	LC	-	IV	✓	×	×	×	
123	Bluethroat	*Cyanecula svecica* (Linnaeus, 1758)	WM	In	LC	-	IV	×	✓	×	×	99
124	Red-breasted Flycatcher	*Ficedula parva* (Bechstein, 1792)	WM	In	LC	-	IV	×	✓	×	×	100
125	Common Stonechat	*Saxicola torquatus* (Linnaeus, 1766)	WM	In	LC	-	IV	×	✓	×	×	101
126	Brown Rock Chat	*Oenanthe fusca* (Blyth, 1851)	R	In	LC	-	IV	✓	✓	×	×	102

IUCN: International Union for Conservation of Nature and Natural Resources; CITES: Convention on International Trade in Endangered Species of Wild Fauna and Flora; IPWA: Indian Wildlife Protection Act; R: Resident; SM: Summer migrant; WM: Winter migrant; LC: Least concern species; NT: Near threatened species; VU: Vulnerable species; I: Schedule- I species of IWPA (high priority species); IV: Schedule - IV species of IWPA (relatively low priority species); BS - Brahma Sarovar; JS - Jyoti Sarovar; BG - Baan Ganga, Dayalpur; SS - Sannihit Sarovar; C-Carnivore; H-Herbivore; In - Insectivore; O - Omnivore; N - Nectarivore; F - Fruigivore; G - Grainivore; P - Piscivore; ✓ - Species recorded in the habitat; × - Species not recorded in the habitat.

Table 3. Relative diversity of various avian families in sacred ponds of Kurukshetra, India

Order	Family	No. of species recorded	Relative abundance (%)
Anseriformes	Anatidae	15	11.90
Galliformes	Phasianidae	2	1.59
Phoenicopteriformes	Podicipedidae	2	1.8
Columbiformes	Columbidae	5	3.96
Caprimulgiformes	Apodidae	1	0.79
Cuculiformes	Cuculidae	3	2.38
Gruiformes	Rallidae	4	3.17
Pelecaniformes	Ciconiidae	3	2.38
	Ardeidae	8	6.34
	Threskiornithidae	3	2.38
	Phalacrocoracidae	3	2.38
Charadriiformes	Burhinidae	1	0.79
	Recurvirostridae	2	1.59
	Charadriidae	2	1.59
	Rostratulidae	1	0.79
	Jacanidae	2	1.59
	Scolopacidae	3	2.38
	Laridae	2	1.59
Accipitriformes	Accipitridae	5	3.96
Strigiformes	Strigidae	1	0.79
Bucerotiformes	Bucerotidae	1	0.79
	Upupidae	1	0.79
Piciformes	Picidae	1	0.79
	Ramphastidae	2	1.59
Coraciiformes	Meropidae	1	0.79
	Coraciidae	1	0.79
	Alcedinidae	2	1.59
Psittaciformes	Psittaculidae	3	2.38
Passeriformes	Campephagidae	1	0.79
	Dicruridae	1	0.79
	Laniidae	2	1.59
	Corvidae	3	2.38
	Nectariniidae	1	0.79
	Ploceidae	1	0.79
	Estrildidae	2	1.59
	Passeridae	1	0.79
	Motacillidae	7	5.55
	Cisticolidae	4	3.17
	Hirundinidae	6	4.76
	Pycnonotidae	1	0.79
	Zosteropidae	1	0.79
	Timaliidae	1	0.79
	Leiothrichidae	3	2.38
	Sturnidae	4	3.17
	Muscicapidae	7	5.55

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Image 1. Lesser Whistling Duck

Image 2. Ruddy Shelduck

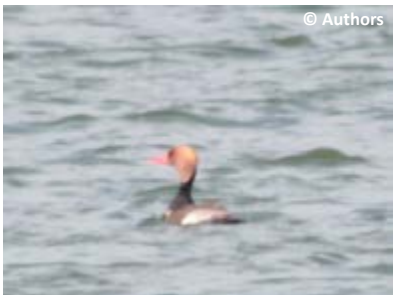

Image 3. Red Crested Pochard

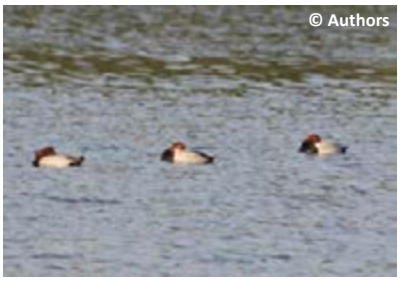

Image 4. Common Pochard

Image 5. Tufted Duck

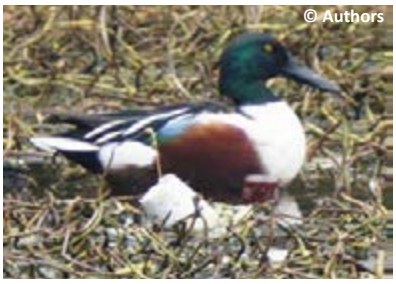

Image 6. Northern Shoveler

Image 7. Gadwall

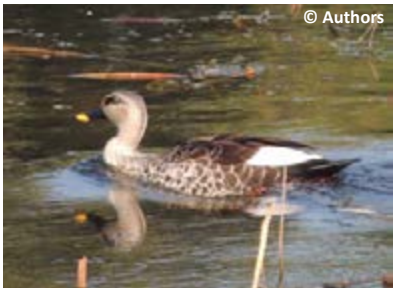

Image 8. Indian Spot-billed Duck

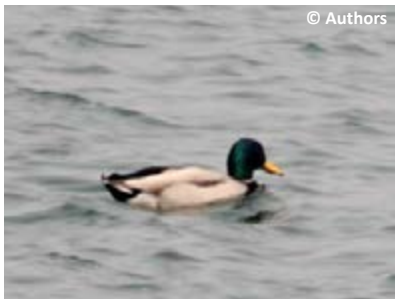

Image 9. Mallard

Image 10. Northern Pintail

Image 11. Common Teal

Image 12. Comb Duck

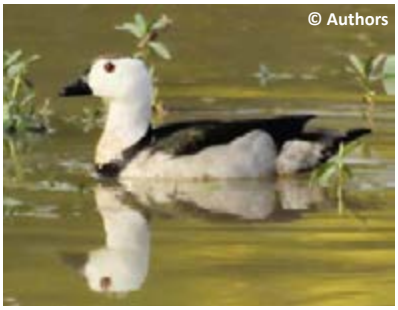

Image 13. Cotton Teal

Image 14. Indian Peafowl

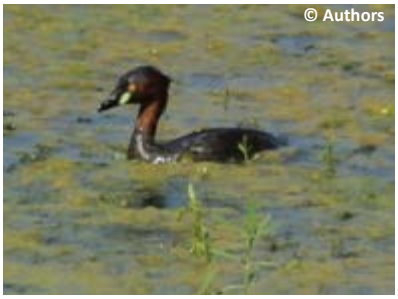

Image 15. Little Grebe

Image 16. Great Crested Grebe

Image 17. Rock Pigeon

Image 18. Spotted Dove

Image 19. Eurasian Collared Dove

Image 20. Laughing Dove

Image 21. Yellow-legged Green Pigeon

Image 22. Asian Koel

Image 23. Greater Coucal

Image 24. White-breasted Waterhen

Image 25. Purple Swamphen

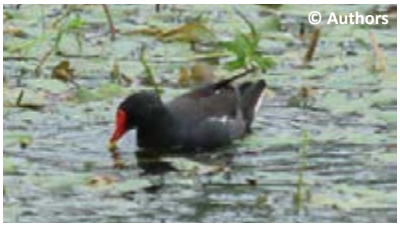

Image 26. Common Moorhen

Image 27. Common Coot

Image 28. Painted Stork

Image 29. Asian Openbill

Image 30. Black-crowned Night Heron

Image 31. Indian Pond Heron

Image 32. Cattle Egret

Image 33. Grey Heron

Image 34. Purple heron

Image 35. Great Egret

Image 36. Intermediate Egret

Image 37. Little Egret

Image 38. Black-headed Ibis

Image 39. Indian Black Ibis

Image 40. Glossy Ibis

Image 41. Little Cormorant

Image 44. Eurasian Thick-knee

Image 47. Red-wattled Lapwing

Image 50. Bronze-winged Jacana

Image 42. Great Cormorant

Image 45. Pied Avocet

Image 48. White-tailed Lapwing

Image 51. Common Sandpiper

Image 43. Indian Cormorant

Image 46. Black-winged Stilt

Image 49. Pheasant-tailed Jacana

Image 52. Common Greenshank

Image 53. Common Redshank

Image 54. River Tern

Image 55. Black-winged Kite

Image 56. Shikra

Image 57. Brahminy Kite

Image 58. Black Kite

Image 59. Spotted Owlet

Image 60. Indian Grey Hornbill

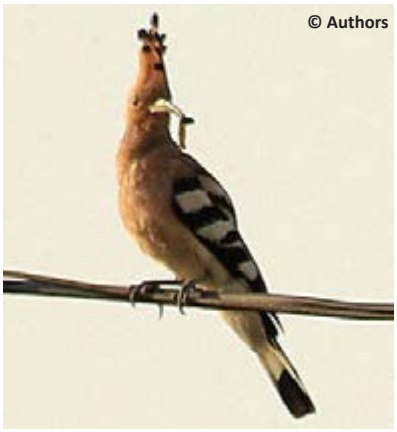

Image 61. Common Hoopoe

Image 62. Lesser Golden-backed Woodpecker

Image 63. Brown-headed Barbet

Image 64. Coppersmith Barbet

Image 65. Green Bee-eater

Image 66. Indian Roller

Image 67. White-throated Kingfisher

Image 70. Black Drongo

Image 73. House Crow

Image 76. Baya Weaver

Image 68. Alexandrine Parakeet

Image 71. Long-tailed Shrike

Image 74. Large-billed Crow

Image 77. Indian Silverbill

Image 69. Rose-ringed Parakeet

Image 72. Rufous Treepie

Image 75. Purple Sunbird

Image 78. Scaly-breasted Munia

Image 79. House Sparrow

Image 80. Paddyfield Pipit

Image 81. Western Yellow Wagtail

Image 82. Grey Wagtail

Image 83. Citrine Wagtail

Image 84. White Wagtail

Image 85. Ashy Prinia

Image 86. Plain Prinia

Image 87. Common Tailorbird

Image 88. Wire-tailed Swallow

Image 89. Red vented Bulbul

Image 90. Oriental White-eye

Image 91. Large Grey Babbler

Image 92. Jungle Babbler

Image 95. Common Myna

Image 98. Oriental Magpie Robin

Image 101. Common Stonechat

Image 93. Asian Pied Starling

Image 96. Bank Myna

Image 99. Bluethroat

Image 102. Brown Rock Chat

Image 94. Brahminy Starling

Image 97. Indian Robin

Image 100. Red-breasted Flycatcher

COMMUNICATION

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OPEN ACCESS

Diversity and distribution of freshwater turtles (Reptilia: Testudines) in Goa, India

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Abstract: Freshwater turtles symbolize a key component of biodiversity in aquatic ecosystems. Of the 356 living species of turtles and tortoises in the world, 34 species are recorded from India. The number of freshwater turtle and tortoise species found in the state of Goa, however, is debatable. No study specific to the Goa region has been carried out on freshwater turtles. Therefore, baseline data on diversity and distribution of freshwater turtles is scanty. The present study was conducted to address this lacuna in knowledge, which will further aid in identifying threats to the population of freshwater turtles and in devising appropriate methods for their conservation. The diversity and distribution of freshwater turtles was investigated in 186 sites in Goa from June 2012 to May 2015. A total of 337 specimens of two native and one introduced species of freshwater turtles belonging to three families—Trionychidae (Indian Flap-shell Turtle *Lissemys puncata*), Geomydidae (Indian Black Turtle *Melanochelys trijuga*) and Emydidae (Red-eared Slider *Trachemys scripta elegans*)— were identified. *Melanochelys trijuga* (52.23%) was the most widely and abundantly distributed species, and was recorded from 132 sites. *L. punctata* (46.88%) was recorded from 113 sites, while *T. scripta elegans* (0.89%) was rare and was recorded from only two sites. While *Melanochelys trijuga* is generalized in habitat selection, making it the widely distributed species in the State of Goa, *L. punctata* is more specific in habitat selection thus restricting its range to coastal, middle-level plateau and the foothills of Western Ghats.

Keywords: Distribution, diversity, freshwater, Goa, invasive, turtle.

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Author Contribuion: TJ has contributed in the field work and writing of the manuscript; NS has contributed in the field work; SKS has contributed in the final editing of the manuscript.

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INTRODUCTION

Freshwater turtles are a key component of biodiversity in aquatic ecosystems, aiding other animals and plants by scavenging on dead animals and plants in the aquatic ecosystem. They not only form the major component of freshwater biomass but also participate in the aquatic food web and assists the co-dependent species thus helping in the energentic operation of the ecosystem. Without turtles, aquatic ecosystems would progressively degrade in ways yet to be understood, and would undergo loss of biodiversity (Iverson 1982; Congdon & Gibbons 1989).

Turtles belong to the order Chelonia/Testudines, sub-order Cryptodira of class Reptilia, and comprise of 14 identified families. These include freshwater turtles (Family: Geomydidae and Trionychidae), marine turtles (Family: Cheloniidae and Dermochelyidae), and land tortoises (Family: Testudinidae) (Fritz & Havas 2007). Rhodin et al. (2017) and Stanford et al. (2018) reported 356 living species of turtles and tortoises found in different habitats of the world. India hosts the richest diversity of turtles in the world (Iverson 1992) with 34 species of Chelonians—25 freshwater, five marine, and four land tortoises (Fritz & Havas 2007).

Three species of Testudines, namely, *Nilssonia leithii, Vijayachelys silvatica*, and *Indotestudo travancorica* (tortoise) are endemic to India. *Vijayachelys silvatica* and *Indotestudo travancorica* are endemic to the Western Ghats, whereas *Nilssonia leithii* is endemic to peninsular India (Deepak & Vasudevan 2009). The number of freshwater turtle and tortoise species found in Goa, however, is debatable as some authors (Tikader & Sharma 1985) reported the presence of two species, *Lissemys punctata punctata* and *Melanochelys trijuga trijuga*, in Goa and have stated *Nilssonia leithii* and *Geochelon elegans* to be distributed in peninsular india. Pradhan (2008) reports the presence of four species in Goa: three freshwater species, namely, *Nilssonia leithii, Lissemys punctata punctata*, and *Melanochelys trijuga*, and one tortoise *Geochelone elegans*. Murthy & Das (2009) reported the presence of specimens of two species in the collection of Zoological Survey of India, namely, *Lissemys punctata punctata* and *Melanochelys trijuga trijuga* from few localities in Goa while others (Srivastava & Nigam 2009) reported the presence of only one species in Goa, namely, *Lissemys punctata punctata*.

Studies on freshwater turtle specific to the Goa region are scanty; therefore, baseline data on the existence and distribution of freshwater turtles is deficient. For managing and conserving natural habitats, information on the distribution of a species is imperative (Rubin et al. 1998). The present study was conducted to address this lacuna in knowledge, which will further aid in identifying threats to turtle populations and in devising appropriate methods for their conservation.

MATERIALS AND METHODS

Study Area

Goa is the smallest state in India and is located along its central-west coast (Fig. 1). It is situated at the latitude 15.29932^{0}N and longitude 74.123996^{0}E. The mountainous region of the Sahyadris in the east, the middle-level plateaus in the centre, and the low-lying river basins along with the coastal plains form are the three main physical divisions (Rao 1985–86) of this region. The average rainfall is 2500–3000 mm. The mean daily temperature is around 30^{0}C and the maximum temperature is 36^{0}C. The climate is humid throughout the year, with humidity level ranging from 75%–95% in the monsoon. The main feature of the climate is the southwest monsoon that occurs between June and September. Champion & Seth (1968) classified the major forest types of Goa into west coast tropical evergreen, west coast semi-evergreen, and southern moist deciduous forest.

Methods

Potential sites (rivers, wetlands, streams, ponds, agricultural lands, and forest areas) were visited and transect walks were carried out to observe turtles in the wild throughout the geographical region of Goa; 186 sites (Table 1) were surveyed across Goa as shown in Fig. 1. The sites were randomly selected and were readily accessible. The study was conducted from June 2012 to May 2015 across seasons (summer: March–May, monsoon: June–August, post-monsoon: September–November, and winter: December–February) following the methodology of Akbar et al. (2006). Active searches in the undergrowth were carried out using visual encounter method (Litzgus & Mousseau 2004). Basking turtles were observed and directly counted. Dip net was used for the capture of turtles (Spinks et al. 2003). Netted animals were counted, their species identified, and then released back into the same water. All freshwater turtles encountered during the study were identified up to species level following Smith (1933), Tikader & Sharma (1985), and Das (1985, 2008). The exact location and altitude of the area were recorded using GPS (geographical positioning system) to depict the pattern of distribution of freshwater turtles.

Potentially suitable habitats were also identified. In sites where no turtles were captured or encountered, it was assumed that the site had no turtles or that they occurred at very low densities (Lin et al. 2010). Turtles captured opportunistically by local volunteers were also considered.

The distribution of all three species in seven different habitats was tested using two-way ANOVA. The seasonal encounter of the three species across seasons (summer, monsoon, post-monsoon, and winter) was tested using two-way ANOVA. A difference of $p<0.05$ was regarded as statistically significant. All the calculations were carried out using Microsoft Excel 2010.

RESULTS

During the survey conducted from June 2012 to May 2015, a total of 337 individuals (334 individuals of native species and three individuals of introduced species) of three species of freshwater turtles belonging to three families, viz., Trionychidae (Indian Flap-shell Turtle *Lissemys puncata*), Geomydidae (Indian Black Turtle *Melanochelys trijuga*) and Emydidae (the invasive Red-eared Slider *Trachemys scripta elegans*) were recorded. *Melanochelys trijuga* (Image 1) was the most abundant species and comprised of 52.23% (n=176) of the total individuals encountered, followed by *L. punctata* (Image 2) comprising of 46.88% (n=158), and *T. scripta elegans* (Image 3) comprising of 0.89% (n=3).

Of the 186 sites surveyed, freshwater turtles were encountered at 181 sites. *Melanochelys trijuga* was the

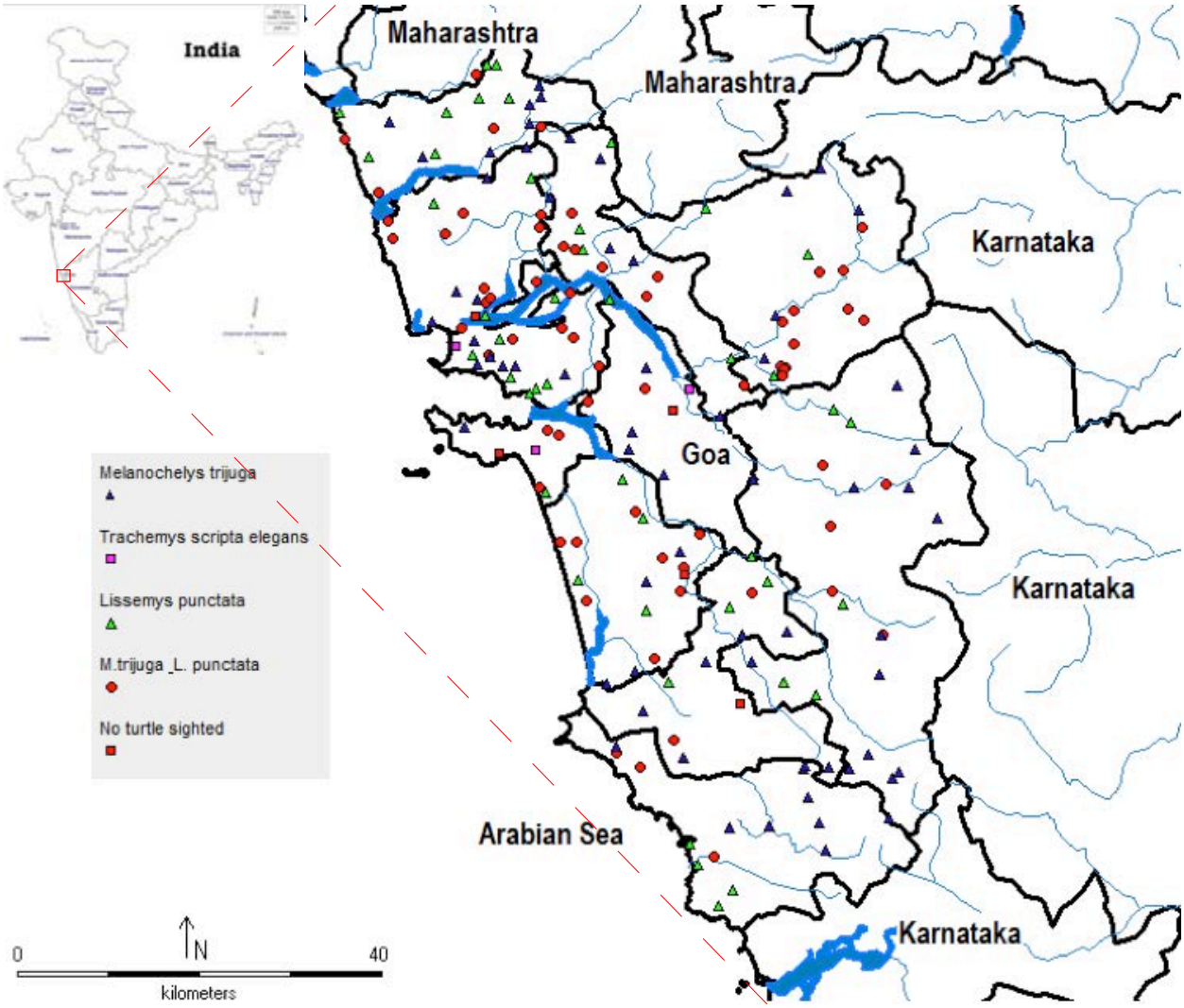

Figure 1. Map of Goa, India, showing the distribution of *Melanochelys trijuga, Lissemys punctata*, and *Trachemys scripta elegans*

Image 1. *Melanochelys trijuga*

Image 2. *Lissemys punctata*

Image 3. *Trachemys scripta elegans*

most widely distributed species and was recorded from 132 sites, followed by *L. punctata*, which was reported from 113 sites, and *T. scripta elegans*, which was rare and was reported from only three sites. At 67 sites both *M. trijuga* and *L. punctata* were recorded (Fig. 1).

It was observed that freshwater turtles exhibit nocturnal habits and are active mostly during night, dusk, and dawn. A few individuals were also found while crossing the road. During the day hours, they mostly remain submerged in water, bury themselves in soil, or stay hidden in crevices and moist leaf litter. It was observed that *M. trijuga* was distributed throughout the state of Goa. *L. punctata* was recorded in all terrains except rocky habitats and mountainous regions (Western Ghats). *Melanochelys trijuga* was recorded in slow- and fast-moving rivers and ditches at low and high elevations, in wetlands, agricultural lands, ponds and streams on plains, plateaus, and mountainous areas, and in artificial drainages in urban areas. *L. punctata* was encountered in slow-moving waters, wetlands, agriculture lands, ponds, and streams on plains. *Trachemys scripta elegans* was encountered in a pond (Taleigao, Tiswadi Taluka), a residential area (Upasnagar, Marmugoa Taluka), and in a river (Khandepar, Ponda Taluka). The number of turtles of all the three species found in different habitat types is given in Fig. 2. ANOVA showed that the distribution of freshwater turtles in different habitats was highly significant (df=12, F=4.23, p=0.00024).

Distribution of turtles varied with seasons. During monsoon they were encountered at all 180 sites, whereas in summer and winter they were observed at only 50 and 72 sites, respectively. The highest number of individuals was encountered during monsoon season (Fig. 3). ANOVA showed that the encounter of freshwater turtles varied significantly with seasons (df=6, F=1.44, p=0.24).

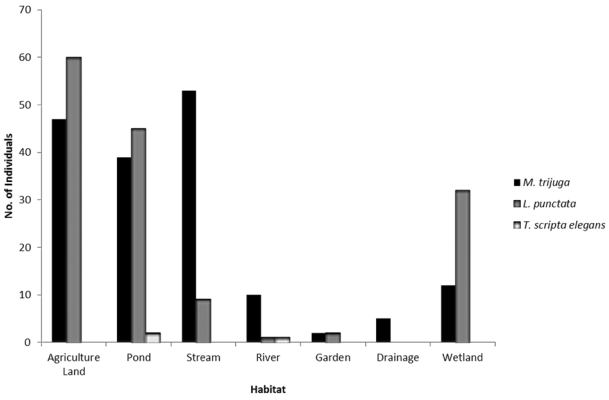

Figure 2. Graph showing the total number of individuals of *Melanochelys trijuga, Lissemys punctata*, and *Trachemys scripta elegans* found in different habitat types

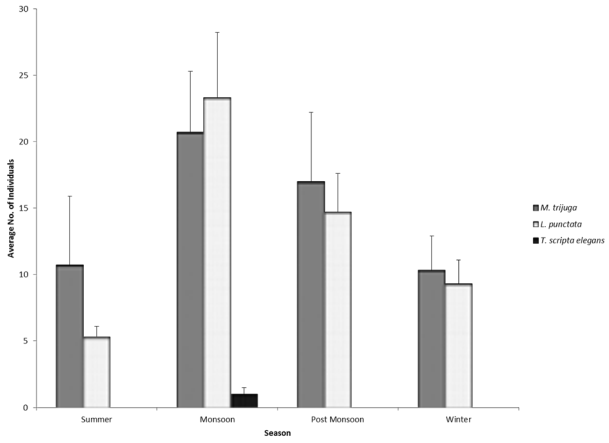

Figure 3. Graph showing the total number of individuals of *Melanochelys trijuga, Lissemys punctata*, and *Trachemys scripta elegans* during different seasons

DISCUSSION

Reptile species inhabit distinct microhabitats and are not randomly distributed in space (Heatwole 1982). The findings with respect to the two native species augment to that of Murthy & Das (2009) and Tikader & Sharma (1985). The presence of *Nilssonia leithii*, however, was not reported during the present study. The presence of *T. scripta elegans* was recorded for the first time in the state of Goa. Trachemys scripta elegans a native of Mississippi Valley area (Pendlebury 2006) was imported to other countries in pet trade (Pendlebury 2006), which eventually led to illegal trade (Pupins 2007). Its impact on the native turtle species in Goa, however, needs to be investigated.

It was observed that *M. trijuga* and *L. punctata* were widely distributed and occupied all potential habitats (agricultural fields, ponds, wetlands, gardens, drainages, rivers, and streams) across the State of Goa. Similar habitats were reported by Tikader & Sharma (1985) for both the species and by Hoassain et al. (2008) for *L. punctata*. *Lissemys punctata*, however, was not reported from the hilly areas of the Western Ghats during the present study and *M. trijuga* occupied all the possible habitats, including drainages, in the urban setup. *M. trijuga* was found to be the most abundant species (52.22%), followed by *L. punctata* (46.88%) and *T. scripta elegans*, which was the rarest (0.89%). *Lissemys punctata* preferred agricultural fields (37.97%), ponds (28.48%), and wetlands (20.25%), and was rarely sighted in streams (5.69%), gardens (1.27%), and rivers (0.63%).

Table 1. List of Site and habitat surveyed; Road*- Indicates road passing through paddy fields; Road# - Indicates road passing through forests; Road@ - Indicates road passing through wetland; '□' Indicates sites where no turtles were encountered

Taluka / Site No.	Name of Locality	Habitat	Latitude	Longitude
Pernem				
1	Korgao	Pond	15°42'28.94"N	73°45'11.83"E
2	Chandel	Wetland	15°43'39.30"N	73°53'49.57"E
3	Kondalwada	Pond	15°42'41.26"N	73°4814.66"E
4	Tuvem	Agriculture land	15°40'9.92"N	73°47'35.01"E
5	Mandrem	Wetland	15°40'2.13"N	73°43'32.34"E
6	Morjim	Agriculture land	15°37'53.80"N	73°44'5.15"E
7	Parse	Pond	15°37'52.55"N	73°44'3.75"E
8	Dadachiwadi	Stream	15°41'45.93"N	73°50'59.66"E
9	Hasapur	Pond	15°44'21.3"N	73°53'54.71"E
10	Harmal	Wetland	15°41'2.32"N	73°42'32.95"E
11	Vadnem	Drainage	15°43'7.39"N	73°53'13.54"E
12	Varkhand	Stream	15°43'31.90"N	73° 50'7.00"E
13	Ugvem	Agriculture land	15°44'57.55"N	73°56'0.40"E
14	Keri	Pond	15°42'57.55"N	73°49'57.78"E
16	Vajri	River	15°42'3.14"N	73°53'9.26"E
16	Mopa	Agriculture land	15°45'30.75"N	73°51'13.38"E
17	Tamboxem	Road*	15°45'30.51"N	73° 56'38.02"E
18	Shemecheadvan	Agriculture land	15°43'37.24"N	73°56'59.07"E
19	Dhargal	Pond	15°40'19.08"N	73°50'46.90"E
Bardez				
20	Kanka	Agriculture land	15°35'26.98"N	73°48'09.97"E
21	Kuchelim	Stream	15°36'40.91"N	73°49'09.46"E
22	Quitla	Agriculture land	15°32'09.33"N	73°50'26.80"E
23	Pilern	Road@	15°32'00.22"N	73°48'49.26"E
24	Revora	Wetland	15°39'24.44"N	73°50'38.67"E
25	Porvorim	Drainage	15°31'31.90"N	73°50'05.01"E
26	Haliwada	Stream	15°31'18.01"N	73°50'32.14"E
27	Virlosa	Agriculture land	15°30'37.38"N	73°50'31.62"E
28	Badem	Pond	15°31'39.09"N	73°50'47.85"E
29	Shivolim	Road*	15°37'16.12"N	73°47'27.65"E
30	Anjuna	Pond	15°35'06.84"N	73°44'57.84"E
31	Caisua	Pond	15°36'14.34"N	73°44'40.85"E
32	Nerul	Stream	15°35'06.84"N	73°44'57.84"E
33	Assagao	Stream□	15°30'26.82"N	73°49'55.67"E
Tiswadi				
34	Shirdona	Wetland	15°26'49.61"N	73°52'03..91"E
35	Carambolim	Wetland	15°29'12.75"N	73°55'47.82"E
36	Malar,Divar	Agriculture land	15°31'40.28"N	73°54'45.87"E
37	Campal	Garden	15°29'50.95"N	73°49'08.24"E
38	Bhatlem	Stream	15°29'02.49"N	73°49'48.56"E
39	Aggasaim	Agriculture land	15°26'08.89"N	73°53'34.08"E
40	St.Cruz	Agriculture land	15°28'09.72"N	73°50'43.29"E
41	Kalapur	Agriculture land	15°28'04.23"N	73°50'48.03"E
42	Carambolim Lake	Wetland	15°29'49.01"N	73°55'07.89"E
43	Amaral Band	Agriculture land	15°28'12.20"N	73°49'43.56"E
44	Taleigao	Agriculture land	15°28'40.20"N	73°48'45.81"E
45	Dongrim	Stream	15°27'02.77"N	73°55'16.96"E
46	Neura	Road*	15°26'26.82"N	73°54'15.13"E
47	Chorao	Agriculture land	15°32'36.11"N	73°53'32.03"E
48	Divar	Pond	15°31'52.79"N	73°55'34.02"E
49	Bambolim	Agriculture land	15°27'33.28"N	73°51'36.93"E
50	Goa Velha	Agriculture land	15°25'36.93"N	73°53'12.37"E
51	Merces	Agriculture land	15°29'10.88"N	73°51'22.53"E
52	Chimbel	Pond	15°29'06.36"N	73°52'08.58"E
53	Curca	Wetland	15°27'32.11"N	73°52'22.42"E
54	Goa University Campus	Road*	15°27'39.18"N	73°50'04.56"E
Bicholim				
55	Mayem	Stream	15°34'29.88"N	73°55'53.02"E
56	Pilgao	Pond	15°33'24.60"N	73°57'30.28"E
57	Kumbharwada, Mayem	Wetland	15°34'38.96"N	73°55'13.78"E
58	Mayem lake	Pond	15°34'30.42"N	73°56'21.11"E
59	Poira	Wetland	15°35'46.46"N	73°53'47.05"E
60	Menkurem	Pond	15°41'51.66"N	73°53'49.47"E
61	Sarvan	Pond	15°34'33.74"N	73°57'58.38"E
62	Navelim	Agriculture land	15°31'41.16 N	74°00'6.80"E
63	Kudnem	Pond	15°32'51.34"N	74°00'51.45"E
64	Sal	Agriculture land	15°41'12.21"N	73°55'34.95"E
65	Latambarcem	Agriculture land	15°39'56.55"N	73°57'06.95"E
66	Pirna	Agriculture land	15°40'33.33"N	73°52'59.62"E
67	Advalpal	Agriculture land	15°38'47.18"N	73°53'16.97"E
68	Mulgao	Agriculture land	15°36'39.10"N	73°55'38.58"E
69	Asnora	River	15°37'37.07"N	73°54'25.85"E
70	Bordem	Wetland	15°35'42.14"N	73°56'06.69"E
71	Karapur	Pond	15°33'47.68"N	73°59'25.13"E
72	Shirgao	Agriculture land	15°36'18.98"N	73°54'01.94"E
Sattari				

Taluka / Site No.	Name of Locality	Habitat	Latitude	Longitude
73	Kumthal	Stream	15°30′58.20″N	74°12′12.31″E
74	Velge	Road+	15°30′52.62″N	74°08′54.71″E
75	Gulelim	Stream	15°27′17.73″N	74°08′17.41″E
76	Paikul	Pond	15°26′55.16″N	74°07′48.72″E
77	Shel	Pond	15°27′33.53″N	74°08′11.93″E
78	Melaulim	Agriculture land	15°27′24.88″N	74°08′28.23″E
79	Nanus	Road*	15°30′32.55″N	74°44′57.84″E
80	Sheldobar	Pond	15°35′06.84″N	74°07′53.39″E
81	Shel-Dhadyar	Pond	15°27′21.30″N	74°08′22.66″E
82	Paikul (Ragada)	River	15°28′02.37″N	74°07′12.03″E
83	Shel-Melaulim	Pond	15°27′23.33″N	74°08′25.10″E
84	Khotodem	Agriculture land	15°28′49.31″N	74°08′53.62″E
85	Khadki	River	15°30′11.88″N	74°8′13.49″E
86	Bramhakarmali	Wetland	15°34′13.22″N	74°09′46.79″E
87	Sathre	Stream	15°36′54.55″N	74°12′49.42″E
88	Ivrem	Stream	15°38′02.72″N	74°08′52.22″E
89	Surla	Stream	15°39′54.15″N	74°10′18.37″E
90	Derode	Pond	15°35′47.42″N	74°12′59.92″E
91	Caranzole	Pond	15°30′15.65″N	74°13′09.00″E
92	Dhave	Agriculture land	15°33′10.57″N	73°10′28.50″E
93	Ushte	Agriculture land	15°33′16.41″N	74°11′54.68″E
94	Gotelim	Wetland	15°36′55.25″N	74°03′39.90″E
Ponda				
95	Bondla	Pond	15°26′24.70″N	74°06′02.95″E
96	Ganjem	River	15°28′02.22″N	74°05′15.25″E
97	Keri	Agriculture land	15°27′24.62″N	74°00′10.24″E
98	Khandepar	River	15°26′06.19″N	74°02′44.61″E
99	Kundai	Agriculture land	15°27′30.94″N	73°57′19.74″E
100	Usgao	River	15°24′35.98″N	74°04′33.07″E
101	Talaulim	Road*	15°22′39.16″N	73°59′02.06″E
102	Kavale	Stream	15°23′37.65″N	73°59′17.33″E
103	Dabal	Stream	15°20′47.49″N	74°06′35.17″E
104	Palem	Agriculture land	15°21′03.89″N	74°01′13.26″E
105	Madkai	Agriculture land	15°25′25.63″N	73°56′39.30″E
106	Priol	Stream	15°26′11.07″N	74°00′02.64″E
107	Khandola	Agriculture land	15°31′31.57″N	73°57′56.04″E
108	Borim	Pond	15°21′03.99″N	74°01′12.67″E
109	Kurti	Agriculture land□	15°24′49.50″N	73°01′49.25″E
Marmugoa				
110	Upasnagar	Pond	15°22′25.67″N	73°53′33.12″E
111	Vasco	Road@	15°23′52.08″N	73°49′15.57″E
112	Casaulim	Wetland	15°20′19.25″N	73°53′45.35″E

Taluka / Site No.	Name of Locality	Habitat	Latitude	Longitude
113	Arrosim	Wetland	15°20′00.63″N	73°54′07.05″E
114	Issorcim	Wetland□	15°22′14.80″N	73°51′31.74″E
115	Cortalim	Agriculture land	15°23′25.95 N	73°54′53.96″E
116	Sancoale	Pond	15°23′42.92″N	73°54′14.95″E
Dharbandora				
117	Sonaulim	River	15°18′44.10″N	74°17′49.86″E
118	Sacordem	Agriculture land	15°24′58.82″N	74°11′17.93″E
119	Campsite, Mollem	River	15°20′29.09″N	74°15′08.66″E
120	Satpal	Agriculture land	15°24′10.87″N	74°12′21.78″E
121	Sunset point, Mollem	Stream	15°24′13.47″N	74°15′59.32″E
122	Tambdisurla	Stream	15°26′23.20″N	74°15′08.97″E
123	Collem	Pond	15°20′27.26″N	74°14′28.46″E
124	Shigao	Agriculture land	15°20′17.10″N	74°12′32.50″E
Salcete				
125	Varca	Agriculture land	15°13′28.04″N	73°56′29.37″E
126	Betul	Stream	15°08′32.65″N	73°57′48.54″E
127	Velim	Agriculture land	15°09′24.51″N	73°58′03.25″E
128	Maina-Curtorim	Wetland	15°16′05.46″N	74°01′04.76″E
129	Raia	Pond	15°18′51.85″N	73°59′30.52″E
130	Rachol	Pond	15°18′26.45″N	74°06′00.96″E
131	Chandor	Agriculture land	15°15′28. 48″N	74°02′21.49″E
132	Caurim	Agriculture land□	15°14′59.31″N	74°02′26.62″E
133	Guirdolim	Road*	15°16′28.16″N	74°02′12.04″E
134	Loutolim	Road*	15°20′42.98″N	73°58′44.96″E
135	Seraulim	Pond	15°17′01.40″N	73°55′57.34″E
136	Macazana	Agriculture land	15°17′28.01″N	74°03′18.00″E
137	Sao Jose De Areal	Stream	15°14′38.23″N	74°00′08.19″E
138	Colva	Wetland	15°17′10.32″N	73°54′58.20″E
139	Benaulim	Pond	15°14′45.93″N	73°56′03.82″E
140	Sarzora	Road*	15°12′57.50″N	74°00′07.20″E
Sanguem				
141	Verle	Agriculture land	15°02′48.24″N	74°14′50.73″E
142	Kalem	Pond	15°17′57.12″N	74°11′09.72″E
143	Ugem	Pond	15°14′04.96″N	74°11′10.70″E
144	Bhati	Pond	15°11′30.56″N	74°14′11.98″E
145	Savordem	Road*	15°11′09.33″N	74°06′27.15″E
146	Valkini	Agriculture land	15°13′18.81″N	74°11′50.65″E
147	Savri	Stream	15°04′20.38″N	74°13′24.70″E
148	Tudov	Stream	15°03′34.55″N	74°15′15.76″E
149	Saljini	Stream	15°00′30.99″N	74°14′40.96″E

Taluka / Site No.	Name of Locality	Habitat	Latitude	Longitude
150	Nundem	Stream	15°32′07.67″N	74°12′06.41″E
151	Rivona	Stream	15°09′52.89″N	74°06′29.21″E
152	Curpe	Agriculture land	15°07′53.07″N	74°10′14.37″E
153	Colomb	Agriculture land	15°08′35.76″N	74°08′23.52″E
154	Sangod	Agriculture land	15°21′36.38″N	74°10′40.83″E
155	Shigone	Pond	15°09′05.70″N	74°14′03.47″E
156	Naiquini	Agriculture land	15°11′32.61″N	74°14′16.52″E
Quepem				
157	Bali	Stream	15°08′36.31″N	74°01′28.68″E
158	Shirvoi	Agriculture land	15°11′29.42″N	74°05′52.90″E
159	Morpirla	Stream	15°06′55.07″N	73°59′56.07″E
160	Paroda	Pond	15°14′01.78″N	74°02′11.43″E
161	Fatorda	Wetland	15°09′20.26″N	73°59′30.85″E
162	Kunkolim	Agriculture land	15°10′03.75″N	74°00′35.62″E
163	Maina	Agriculture land□	15°07′18.35″N	74°05′45.78″E
164	Tilamol	Agriculture land	15°13′04.36″N	74°05′07.62″E
165	Cacora	Road*	15°14′39.30″N	74°07′22.86″E
166	Curchorem	Road*	15°13′56.64″N	74°06′29.00″E
167	Cavrem	Stream	15°09′52.99″N	74°04′05.47″E
168	Padi	Agriculture land	15°05′11.34″N	74°01′44.48″E
169	Mangal	Agriculture land	15°03′34.15″N	74°11′03.71″E
170	Barcem	Stream	15°04′11.83″N	74°02′19.83″E
171	Molkornem	Stream	15°11′42.07″N	74°08′31.60″E
Canacona				
172	Aave	Stream	15°01′44.86″N	73°09′47.95″E
173	Eda	Stream	15°00′13.06″N	74°10′27.06″E
174	Agonda	Agriculture land	15°02′59.68″N	73°59′46.54″E
175	Shirtvoti, Khola	Stream	15°04'43.03''N	73°58'33.06''E
176	Khola	Stream	15°04′49.24″N	73°58′16.55″E
177	Loliem	Agriculture land	14°56′13.10″N	74°05′20.46″E
178	Galgibag	Wetland	14°58′16.49″N	74°04′08.04″E
179	Talpan	Pond	14°59′02.69″N	74°02′42.52″E
180	Dhantali	Stream	14°58′34.71″N	74°10′51.90″E
181	Bamanbudo	Stream	15°03′28.88″N	74°09′29.47″E
182	Ambeghat	Road#	15°03′40.53″N	74°09′37.16″E
183	Mashem	Wetland	14°57′47.02″N	74°03′15.04″E
184	Bhatpal	River	14°59′55.26″N	74°05′09.26″E
185	Gaodongrim	Stream	15°00′32.89″N	74°07′31.68″E
186	Polem	Pond	14°55′15.92″N	74°04′25.47″E

No individuals of *L. punctata* were found in drainages. The highest encounters of *L. punctata* were in agricultural fields and the lowest were in rivers and gardens. This suggests that *L. punctata* prefers marshy areas and stagnant waters that might assist in burrowing, which provides protection from predators. This also elucidates their absence in hilly regions where the stream beds consist mostly of pebbles and rocks that possibly will not serve as good refuge grounds. Hossain et al. (2008) reported that marshlands and agricultural fields were the most preferred habitats of *L. punctata*, followed by ponds, streams, and lakes.

On the contrary, *M. trijuga* preferred streams (30.11%), agricultural lands (26.7%), and ponds (22.16%) followed by wetlands (6.81%), rivers (5.68%), drainages (2.84%), and gardens (1.14%). This suggests that *M. trijuga* can acclimatize to all habitat types. The distribution of all the three species in different habitats was highly significant.

The encounter of freshwater turtles in different seasons was significant when tested statistically. Highest numbers of individuals were encountered in monsoon and post-monsoon season, which may be attributed to favorable climatic conditions and rich prey base, as compared to summer and winter, when the resources required for survival are limited, thus restricting the distribution of species. Similar observations were made in other groups of reptiles such as snakes by Sawant et al. (2010). Thus, the present study reports the presence of three species of freshwater turtles in Goa, namely, *M. trijuga, L. punctata*, and *T. scripta elegnas*. *Melanochelys trijuga* is generalized in habitat selection thus making it the most widely distributed species in the state of Goa and *L. punctata* is more specific in habitat selection thus restricting its range to coastal, middle-level plateau, and foothills of Western Ghats.

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COMMUNICATION

Breeding behaviour of the Coromandel Damselfly *Ceriagrion coromandelianum* (Fabricius) (Zygoptera: Coenagrionidae) in central India: copulation

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OPEN ACCESS

Abstract: The Coromandel Damselfly *Ceriagrion coromandelianum* can be easily identified because of its bright yellow abdomen, greenish thorax and eyes. In females, the abdomen is darker with light brown colouration extending to dark brown towards the terminal end. The documentation of the reproductive behaviour of *Ceriagrion coromandelianum* was carried out at the botanical garden of Hislop College, Nagpur, India. The males of *C. coromandelianum* arrive early in the morning by 07:00hr at the ovipositing site. They belong to "sit and wait" type of mate-location. While perched and waiting for the female to arrive they at times exhibit abdominal bobbing, and oviposition posture. The territorial area of male *C. coromandelianum* is very small, within a range of about 45cm around his perch. There is no precopulatory courtship display and the male move toward the arriving receptive female and directly tries to form a tandem link. The other males of the group follow the pair. The tandem pair flies towards the safety of the surrounding vegetation to copulate. Before copulation, the male fills his penis vesicle with sperm material by the process of "intra male sperm translocation" which lasts for 30±8 seconds. The female curves her abdomen ventrally forward so that her gonopore which is located between the eighth and ninth sternite comes to lie before the secondary copulatory apparatus of the male and forms a strong genital link, to form the copulatory wheel. The copulation duration can be long (34–55 min) or short (12–15 min). Two stages of copulation depending upon the pumping movement of the couple can be differentiated. During the first stage, the male rhythmically and forcefully depresses and stretches the first two abdominal segments, vigorously pumping the penis inside the female vagina which accounts for 72% of the copulation duration. The second stage starts with rapid short thrusting movement which are not forceful but exhibit shallow movements of the first two abdominal segment of the male. The tandem pairs after copulation may directly move for oviposition or settle around the surrounding foliage and exhibit "post-copulatory resting" (PCR) behaviour. It is noted that 23.3% females immediately commence oviposition, 53.4% exhibit brief, while 23.3% display prolonged PCR behaviour.

Keywords: Intra male sperm translocation, mate-location, post-copulatory resting.

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Authors Contribution: Nilesh R. Thaokar and Payal R. Verma contributed in field work and documentation of the oviposition behaviour. Raymond J. Andrew set up the project and evaluated the findings.

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INTRODUCTION

In Odonata, the mating system has the following components—encounter, recognition, copulation, sperm transfer and oviposition. The encounter for a majority of odonates is near the oviposition site and is therefore the water body (Waage 1984). Encounter leads to territoriality and aggressive interaction between males. Recognition of sex and species is based predominantly on visual signals (Mokrushov & Frantsevich 1976). In many odonates the phenomena of male courtship follows recognition during which the female can exhibit "refusal display" to unwelcome approaches by male. Courtship leads to pre-copulatory tandem formation where the male grasps the female's thorax and head with his anal appendages. Intra-male sperm translocation generally occurs during tandem and is followed by copulation. Copulation is achieved by the "wheel" formation where the female's genital aperture is secured to the male's secondary genitalia. Copulation in Odonata is unique among pterygote insects since the primary genitalia of the two sexes do not meet during sperm transfer (Carle 1982; Matsuda 1976). Sperm competition occurs widely among insects and the discovery that the odonate penis both inseminates the female and displaces rival sperm (Waage 1986) has indeed proved to be an invaluable aid in interpreting odonate reproductive behaviour (Corbet 1999). Sperm competition as found in Odonata benefits the female by reducing their energy expenditure, lowering risk of harassment from conspecific males and predators, survival of genetic diversity of progeny and fertility backup.

MATERIAL AND METHOD

The documentation of the reproductive behaviour of *Ceriagrion coromandelianum* was carried out at the botanical garden of Hislop College, Nagpur, (21.166^{0}N & 79.033^{0}E) where small underground cement tubs are used to grow macrophytes. The garden houses aquatic plants in a large circular tub surrounded by six smaller circular tubs followed by a row of three rectangular cement containers. These tubs contain free floating *Nymphaea nouchali, Lemna paucicostata* and submerged *Hydrilla verticillata.* The tubs are surrounded by grasses and bushes of flowering plants (*Mussaenda laxa, Chrozophora* sp., *Catharanthus roseus, Phyllanthus amarus, Ageratum conyzoides, Bougainvillea* sp.) (Images 1 a,b). Post-noon this area is in shadow of the college building. Adult *C. coromandelianum* are found

Image 1. The study site: Location of oviposition sites at the Botanical garden of Hislop College, Nagpur.

almost all round the year breeding in these water-bodies.

To study the reproductive behaviour of *C. coromandelianum,* field observations were carried out mostly during the months of August to November and March to May from 2008–2013. These observations were carried out in the morning and/or afternoon and the reproductive behaviour was documented, noted and/or photographed, videotaped while the duration of different behaviour was timed with a stop-watch.

RESULTS

On a typical breeding day, the males of *C. coromandelianum* arrive early in the morning by 7am and move between the bushes and grasses around the ovipositing site (water tubs). Within an hour, they can be spotted perched all around the bushes surrounding the water-body. The male belong to "sit and wait" type of mate-location. They occupy a base perch which is about 10–60 cm above the ground and not more than 120cm away from the water tubs. The base perch is commonly a floating/emerging water plant or any other object on water or shrubs and grasses bordering the water-body. While perched and waiting for the female to arrive, they at times exhibit two peculiar behaviors. The first is "abdominal bobbing" when a wave of motion

passes from the first to the last abdominal segment while the second is copying the "oviposition posture of the female" when the male bends the abdomen down along the fourth-fifth segment (Image 2 a,b).

Territoriality

The territorial area is determined by the range of distance beyond which the resident territorial male does not respond to an intruder. The territorial area of male *C. coromandelianum* is very small. It gets disturbed only if an intruder comes within a range of about 45cm near his perch. Many a times, two to three males can be seen perched within a vicinity of 120cm.

Whenever an intruder (conspecific or heterospecific male or any other insect) enters his territory, the resident male flies behind the intruder, follows it up to around 600cm and chasing it away. The male returns to his territory either at the same base perch or a few inches around it. If the intruder persists in his territory, then the resident male moves to a new perch about 70–120 cm away but returns as soon as the intruder leaves. If the intruder (generally a conspecific male) is persistent, he chases the resident male away from the ovipositing site into the surrounding bushes. The male later moves to a new location around the water-body. The territorial male also undertakes small patrolling flights. This flight is of not more than 500cm from his perch. The female arrives from 07:30hr onwards (upto noon) when most of the male have demarcated their territory.

Precopulatory behaviour

The males move toward the arriving receptive female when she is at a distance of 70cm from the water body. The males follow the female and directly try to form a tandem link. This link is also formed when the female has entered the oviposition site and is settled on a low lying bush. There is no precopulatory courtship display. It is a common site to find 2–3 males following a female to form a link. Although there is no visible fight amongst the males, the quickest male holds the female just below the head with his anal appendages and forms the tandem linkage. The other males of the group follow the pair but do not try to physically dislodge the male. Once the link is formed, the remaining males may follow the pair keeping a distance of 6–12 cm. The tandem pair moves away from the water-body and flies towards the safety of the surrounding vegetation where they form the copulatory wheel. Before forming the copulatory wheel, the male charges his penis with sperm material by the process of "intra male sperm translocation".

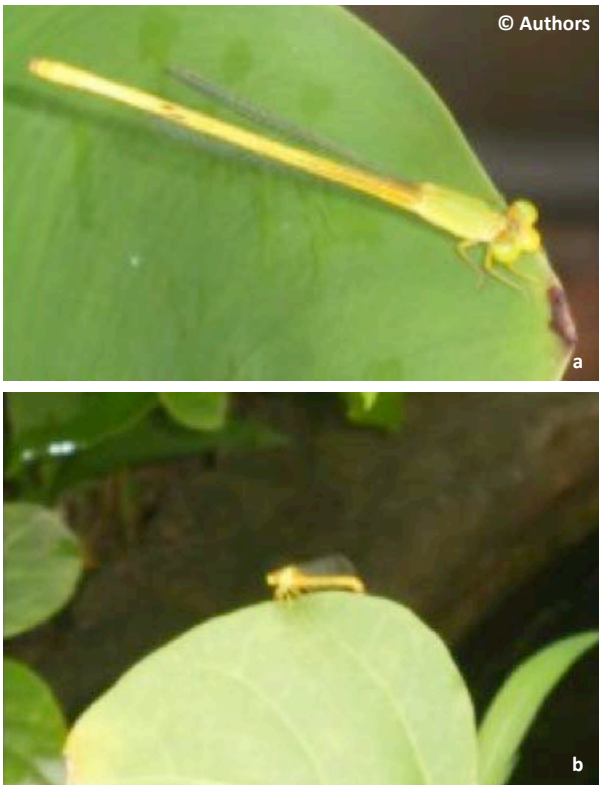

Image 2. *Ceriagrion coromandelianum* male at his perch (a) and (b) exhibiting oviposition posture along the rim of the leaf blade

Intra male sperm translocation

The male transfers the sperm material from the sperm sac which is located in the ninth abdominal segment to the penis of the secondary copulatory apparatus located on the second abdominal segment. The male gonopore and paired coxites of the primary genitalia located on ninth abdominal sternum and penis vesicle of the secondary copulatory apparatus play a key role during this process of intra male sperm translocation (IMST). During this translocation, the position of the male is precarious, since it has to grip the substrate with his legs, hold the female with his terminal anal appendages and curve and bend the abdomen to bring the gonopore in contact with the penis vesicle with the female suspended vertically. The female hangs passively with folded wings and the abdomen is either straight or slightly curved inwards. IMST in *C. coromandelianum* lasts for 30+8 seconds (N=28). During this translocation, the male's gonopore pumps sperm material in the penis vesicle which acts as a sperm reservoir during copulation.

Copulatory wheel

After IMST, the female curves the abdomen ventrally forward so that her gonopore which is located between

Table 1. Duration (in minutes) of copulation observed in 10 pairs of *Ceriagrion coromandelianum*.

	1	2	3	4	5	6	7	8	9	10	Total	Mean	SD	SE
Stage I	34	34	25	25	27	22	12	12	13	8	215	21.5	9.62	3.21
Stage II	21	7	15	10	8	12	3	2	1	4	83	8.3	6.36	2.12
Total	55	41	40	37	36	34	15	14	14	12	298	29.3	14.93	4.97

the eighth and ninth sternite comes to lie before the secondary copulatory apparatus of the male and forms a strong genital link, in the form of a copulatory wheel. The wheel is always formed when the male is holding a supporting substrate and never in flight. Copulation takes place within 5m around the oviposition site and not more than 500cm above ground level. Copulation lasts for 29.3±4 m (N=10, Max - 55 min: Min - 12 min, SD - 14.93).

Copulation

Copulation of *C. coromandelianum* is initiated when the male starts pumping the penis inside the female's vagina. Two types of pumping movement can be differentiated (which can be observed from a distance) by recording the variation in the periodic movements of the first two abdominal segments of the male, the change in the shape of the copulatory wheel and the pressure exerted on the head of the female by the anal appendages of the male.

During the first stage, i.e., stage I, the male rhythmically and forcefully depresses and stretches the first two abdominal segments, vigorously pumping the penis inside the female genitalia. At this stage, there is a rapid and energetic movement of the male's abdomen which in turn exerts heavy pressure on the females head held by the anal appendages. The female's head generally wobbles with every thrusting movement. This movement is interspaced with very short (<14 seconds) resting periods when there is no movement of the abdomen. This stage lasts for 21.5±3 min (N = 10, Max - 34 min: Min- 8 min, SD - 9.62) and covers 72% of the copulation duration.

The Stage II starts with rapid short thrusting movement which are not forceful as found in Stage I. Along with the rhythmic but shallow movements of the first two abdominal segment of the male, the third abdominal segment too exhibits periodic synchronised movements. The abdomen of male exhibit angular bending along the fourth- seventh abdominal segment. The frequency of movements decrease until all movements stop and the couple is immobile. This is followed by the breaking of the copulatory wheel, when

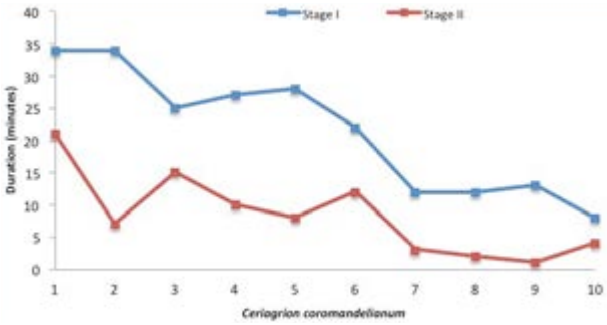

Figure 1. *Ceriagrion coromandelianum* copulation. Duration (in minutes) of Stages I and II.

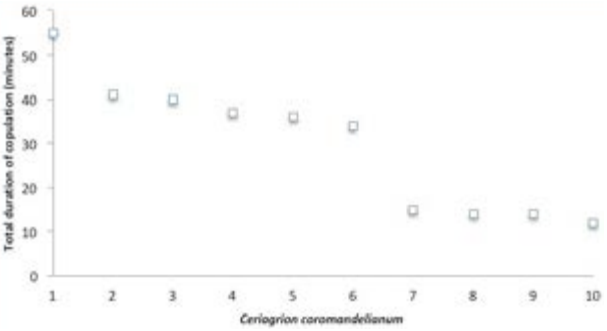

Figure 2. *Ceriagrion coromandelianum* copulation. Total duration (in minutes).

Table 2. *Ceriagrion coromandelianum* post copulation. Duration (in seconds) of post copulatory resting behavior.

Sno	PCR	Sno	PCR	Sno	PCR
1	0	11	184	21	249
2	0	12	185	22	253
3	0	13	187	23	253
4	0	14	196	24	577
5	0	15	208	25	590
6	0	16	221	26	602
7	34	17	226	27	628
8	136	18	229	28	632
9	152	19	232	29	650
10	174	20	244	30	652

Image 3. *Ceriagrion coromandelianum* - Copulation. Stage I (a,b), Stage II (c,d).

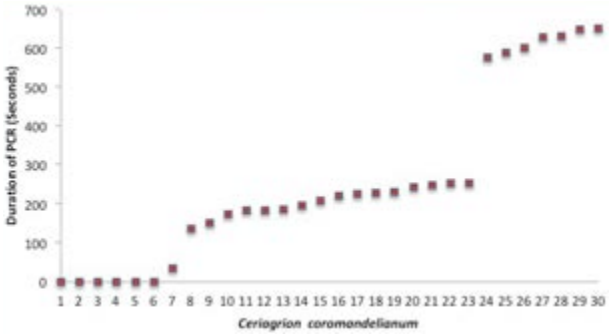

Figure 3. *Ceriagrion coromandelianum* post copulation. Graphical representation of post-copulatory resting (PCR) behavior (in ascending order).

the female extricates her genitalia from the secondary copulatory apparatus of the male. This stage lasts for 8.3±2 min (N = 10, Max - 21 min: Min. - 1 min, SD - 6.36). The duration of Stage I is always greater than Stage II (Image 3a–d; Table 1; Fig. 1).

The copulation duration can be long (34–55 min) or short (12–15 min) distinctly divided into division. The long copulation which clocks between 55 to 34 minutes and short copulation which completes between 15 to 12 minutes (Fig. 2)

Post copulatory resting behaviour

The tandem pairs after copulation may directly move for oviposition or settle around the surrounding foliage and exhibit "post-copulatory resting" (PCR) behavior (Image 4 a,b,c). After monitoring and timing the PCR behavior of 30 pairs, it is found that PCR can be divided into three types. In Type-1, the pair directly moves for oviposition immediately after copulation. In Type-2, the PCR is brief (208±90 sec) and in Type-3 the PCR is prolonged (619±11 sec). Post copulation, 23.3% females immediately commence oviposition, 53.4% exhibit brief, while 23.3% display prolonged PCR behavior (Table 2, Fig. 3).

DISCUSSION

Habitat selection based on the oviposition site is practiced by females and by males of many species of Odonata for which the oviposition site, that is mostly a water-body, forms the focus for reproductive activity (Corbet 1999). The choice of such sites mostly depend upon the plant community present in and around the water-body and therefore a link between the odonate and composition and structure of vegetation is evident in most odonates (Buchwald 1991). *Ceriagrion coromandelianum* is one of the most common damselflies from the Indian sub-continent found around banks of large and small perennial and weedy ponds and lakes and small garden tanks or any shallow water body with profuse growth of vegetation with floating and/or submerged vegetation (Fraser 1933; Andrew et al. 2008). *C. coromandelianum* is found breeding year around in the small tanks and tubs of the college botanical garden used for the propagation of aquatic macrophytes (*Nymphaea nouchali, Hydrilla verticillata*, *Lemna paucicostata*). These plants are used as substrate for egg deposition by this endophytic species. In a few odonate species, copulation occurs away from the oviposition site during roosting and foraging (Fincke 1987; Miller 1987a).

In Odonata, territoriality is functionally related to site attachment and aggressive behaviour to protect the territory. The area defended by a territorial male in Odonata varies from 1800m (*Hemianax papuensis*) to 0.2m (*Copera marginipes*) (Furtado 1974; Rowe 1987). Prasad (1990) and Sharma (2009) observed that the male of *C. coromandelianum* selects a small oval/ circular territory (40–80 cm radius) and defends this area against any intrusion by other males by abdominal raising display (threat display) but Srivastava & Babu (1985) found lack of territoriality in this species. In the present investigation, it is found that the territoriality area of *C. coromandelianum* is small (Max - 45cm radius) but not a single case of threat display was detected. The "sit and wait" type search mode behaviour of male as found in *C. coromandelianum* is also found in the damselfly *Ceriagrion melanurum* (Mizuta 1988) *Enallagma nigridorsum* (Samway 1994) and the

Image 4. *Ceriagrion coromandelianum* exhibiting "Post Copulatory Resting" behaviour.

gomphid, *Onychogomphus forcipatus unguiculatus* (Miller & Miller 1985). The male odonate may seize the female while she is flying or perched and often while she is ovipositing. *C. coromandelianum* always seize the female in flight and never when she is perched or ovipositing. *Pantala flavescens* executes tandem formation and wheel formation always in flight followed by oviposition (R.J. Andrew pers. obs. 2010–2017), while some odonates form the wheel in air and then perch to complete copulation (Sakagami et al. 1974; Miller & Miller 1989). In *C. coromandelianum* wheel formation is achieved in perched condition. According to Corbet (1999) long bodied odonates will always perch for copulation.

Copulation in most zygopteran species is divided into two to three stages. The first stage, *i.e.* Stage I can cover upto 95% of the total duration (*Nososcticta kalumburu* Thompson, 1990) while in *C. coromandelianum* it covers 72%. In *Enallagma cyathigerum* the Stage II and Stage III is brief whereas in *C. coromandelianum* the Stage II and Stage III cannot be differentiated as reported in many other zygopterans (Cordero & Miller 1992; Tajima & Watanabe 2014). During Stage I the penis removes the pre-deposited sperm of previous mating from the sperm storage organ of the female and during Stage II the now empty sperm storage organs are inseminated (Waage 1982, 1984, 1986, 1988; Miller 1987a,b; Corbet 1999; Andrew 2001; Cordero-Rivera et al. 2004; Cordoba-Aguilar 2010; Tajima & Watanabe 2014). During the present investigation it is found that in *C. coromandelianum* the copulation duration is divided into short copulation which completes between 12–15 minutes and long copulation of 34–55 minutes. The probable reason for this variation is the condition of female. While copulating with virgin females and/or females with a smaller amount of sperm in their storage organs the male needs less time to displace sperm and therefore the Stage I gets over quickly which reduces the copulation duration.

In Odonata, more than 50 species exhibit post copulatory resting (PCR) behaviour, which in damselflies can fluctuate from 01 (*Calopteryx maculata* Meek & Herman, 1990) to 180 minutes (*Argia vivida*, Conrad & Pritchard 1988). Srivastava & Babu (1985) reported that PCR by *C. coromandelianum* is for 50–60 seconds followed by post copulatory flights in tandem for 54–90 minutes; such short post copulatory flights were not recorded in the present study. Prasad (1990) and Sharma (2009) observed that PCR occurs for about six minutes in this species. In the present study it is found that *C. coromandelianum* PCR is clearly differentiated into two categories, the brief PCR ranges from 136–253 seconds while the prolonged one from 577–652 seconds. Disturbance during copulation, temperature and sunlight are few factors that may increase the duration of PCR, but in the present study no specific relationship between these factors and the duration of PCR is noticed. As postulated by Miller & Miller (1989) "sperm handling" appears to be the only feasible reason for PCR in *C. coromandelianum*. Perhaps it implies that there is variation in the PCR of virgin and non-virgin females or maybe, long copulation leads to prolonged PCR as found in *Orthetrum caledonicum* (Alcock 1988).

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The status assessment of *Corynandra viscosa* subsp. *nagarjunakondensis* (Magnoliopsida: Cleomaceae), endemic to Nagarjunakonda, Andhra Pradesh, India

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Abstract: *Corynandra viscosa* subsp. *nagarjunakondensis* (Cleomaceae), a flowering plant taxon endemic to Nagarjunkonda of Krishna River Valley, Andhra Pradesh, southern India was assessed for its ecological status. The distribution of this species was mapped, population estimated and the impending threats ascertained. The extent of its area of spread is primarily limited by the water body (Nagarjunasagar) created by the impounding waters when a dam was constructed across the River Krishna at the site of its occurrence. The extent of occurrence (EOO) and the area of occupancy (AOO) of this taxon were estimated to be 0.20 km² and 0.31 km², respectively. The threat assessment places the taxon in the Critically Endangered [B1ab(iii)] category.

Keywords: Ecological impact of dam, endemism, threat assessment.

Telugu Abstract: వామింట కుటుంబానికి (Cleomaceae) చెందిన పుష్పించే మొక్క కొరి సేంద్ర విస్కోసా ఉపజాతి నాగార్జునకొండ సెన్సిస్ (*Corynandra viscosa* subsp. *nagarjunakondensis*) ను దక్షిణ భారతదేశ రాష్ట్రమైన ఆంధ్రప్ర దేశ్‌లోని కృష్ణానది పరివాహక ప్రాంతములో నాగార్జునకొండ వద్ద గుర్తించి వర్ణించడం జరిగినది. ప్రపంచంలో ఈ ప్రాంతానికే పరిమితమైన ఈ ఉపజాతి మొక్క యొక్క విస్తరణ, వ్యాప్తి, లభ్యత, పర్యావరణ సంబంధమైన స్థితిని పరిశోధించడం జరిగినది మరియు ఆసన్నమయ్యే ప్రమాదాలను కూడా గుర్తించడం జరిగినది. కృష్ణానదిపై ఆనకట్ట కట్టడం ద్వారా నిల్వ అయిన నీరు నాగార్జునకొండ ద్వీపం ఏర్పడడానికి కారణమైనందున ఈ ఉపజాతి మొక్కల యొక్క వ్యాప్తి నాగార్జునకొండకు మాత్రమే పరిమితమైనవి. ఈ వర్గం మొక్క యొక్క విస్తృతి (EOO) మరియు విస్తీర్ణ ఉపస్థితి (AOO) ను 0.2 చ.కి.మి మరియు 0.31 చ.కి.మి గా గణించడం జరిగినది. ఈ మొక్కల యొక్క లభ్యత, విస్తృతిపై ఆసన్నమయ్యే ప్రమాదాలను అధ్యయనం చేయగా ఈ వర్గం మొక్కలు సవిమర్శకంగా త్వరగా అంతరించిపోయే (Critically Endangered (B1ab(iii)) ప్రమాద స్థితిలో ఉన్నట్లుగా గుర్తించడమైనది. నాగార్జునకొండ ప్రముఖ పర్యాటక స్థలంగా అభివృద్ధి చెందుతున్న దృష్ట్యా ఆంధ్రప్రదేశ్ రాష్ట్రం ఈ ఉపజాతి మొక్కలను పరిరక్షించడానికి తగు తక్షణ చర్యలు తీసుకోవలసివుంది.

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Author Contribution: VHR did the field work and IUCN assessment, VVR is overall in-charge of the work and responsible for the pest report, ABR did the herbarium work, and VSR contributed to the taxonomic assessment.

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INTRODUCTION

The concept of endemism is useful in quantifying the biological uniqueness of an area (Peterson & Watson 1998). High endemism usually occurs in areas that have been isolated for a long time, such as islands or isolated forest fragments. Islands are known centers of range-restricted species and show high levels of endemism **(**Whittaker & Fernández-Palacios 2007**).** Furthermore, islands are centers of past as well as imminent species extinction (Ricketts et al. 2005). Of late, many species globally have attained endangered category as assessed by the IUCN. If the present trend of intensive human activity continues, it is likely that many more species on our planet will either fall under this category or simply disappear. Preventing these extinctions must be part of a global strategy to reduce biodiversity loss (Ricketts et al. 2005). With so many species at risk of extinction in the near future, efforts to conserve plant biodiversity has to be on apriority basis and through site-specific action. Unfortunately, the efforts are undermined in many a country by lack of comprehensive inventories on one hand and the political will on the other. In India, many species which are endemic or alleged to be endemic from recent discoveries and descriptions, need to be assessed for their threat status.

Sundararaghavan (1988) described *Cleome viscosa* var. *nagarjunakondens* based on the collection made by K. Thothathri on 13 July 1961 from Nagarjunakonda Hills, Guntur District, Andhra Pradesh, India. Pullaiah et al. (2000: 55) provided an account of this taxon citing Sundararaghavan (1993: 318), which was a reproduction of the 'protologue'. In both these accounts, the taxon was stated to be endemic. Rao et al. (2001) did not report this taxon from Nalgonda District, Telangana. But it is curious to note that Pullaiah & Rao (2002), in their account of Cleomaceae for Eastern Ghats of India, have not included this taxon despite the fact that the type locality falls under Eastern Ghat Hill Ranges while they cited the specimens of Capparaceae (e.g., *Capparis sepiaria* from Nagarjunakonda, another collection of K. Thothathri 9727 [CAL] cf. p.70) from the same habitat. Pullaiah (2015: 70), however, records this taxon for Telangana State even though its extant populations are found on Nagarjunakonda Island, which is no longer the territory under Telangana State with effect from June 2014. There was no further collection or specific study conducted since its description. Therefore, the present study attempts to provide a detailed description of *Cleome viscosa* var. *nagarjunakondensis* based on the live specimens, map the distribution, estimate the population, and ascertain the threats.

Taxonomic status

Cleome viscosa var. *nagarjunakondensis* Sundararagh. is considered a synonym of *Cleome viscosa* L. by www.plantlist.org, which generally deals with species taxonomy and not below its rank and does not update the accepted names instantly/regularly (last update 2012-03-23); however, the experts on the genus *Cleome* (Cochrane & Iltis 2014) consider it not only as an accepted taxon under *Corynandra* but as a subspecies with which we agree and assess its status accordingly.

The study area

The Nagarjunakonda is a historic Buddhist Village, located at 16.516^{0}N and 79.233^{0}E in a perimeter of 4.31km^2 in the Krishna River valley in Guntur District of Andhra Pradesh, India. The valley went under water when a tall masonry dam was built across the river Krishna in the 1960s (Image 1 A–C). The reservoir, so-named Nagarjunasagar, has created the island Nagarjunakonda. It is now a tourist spot known for the historic Buddhist town. It is one of India's richest Buddhist sites known in ancient times as Sri Parvata (Barua 2016). The island receives rainfall that ranges from 381–508 mm per annum which is relatively low. The temperature goes up to 49^{0}C during summer (May–June) though the annual temperature ranges from 21–48^{0}C. The soil is of red-gravel with intermingled patches of black soil, particularly restricted to the limestone belt. The vegetation on the flat terrain comprises largely of herbs, shrubs and open canopy trees (Image 1 D). There are exotic trees planted around the archeological buildings in the visitor's zone.

METHODS

Field trips were undertaken regularly during 2012 to 2014 to record the floral component during the pre- and post-monsoon seasons. All elevations, habitats and vegetation types of Nagarjunakonda were mapped. After knowing the terrain, the study area was divided into 100×100 m grids. Four quadrats were selected at random from each grid. The quadrat size used was 1×1m for herbs and grasses. The relevant field data about the habitat, altitude, habit and phenology of the plant species fallen into the quadrats were recorded. The plant species were identified using the Flora of Guntur District (Pullaiah et al. 2000).

For the threat assessment under Criterion B, GeoCAT,

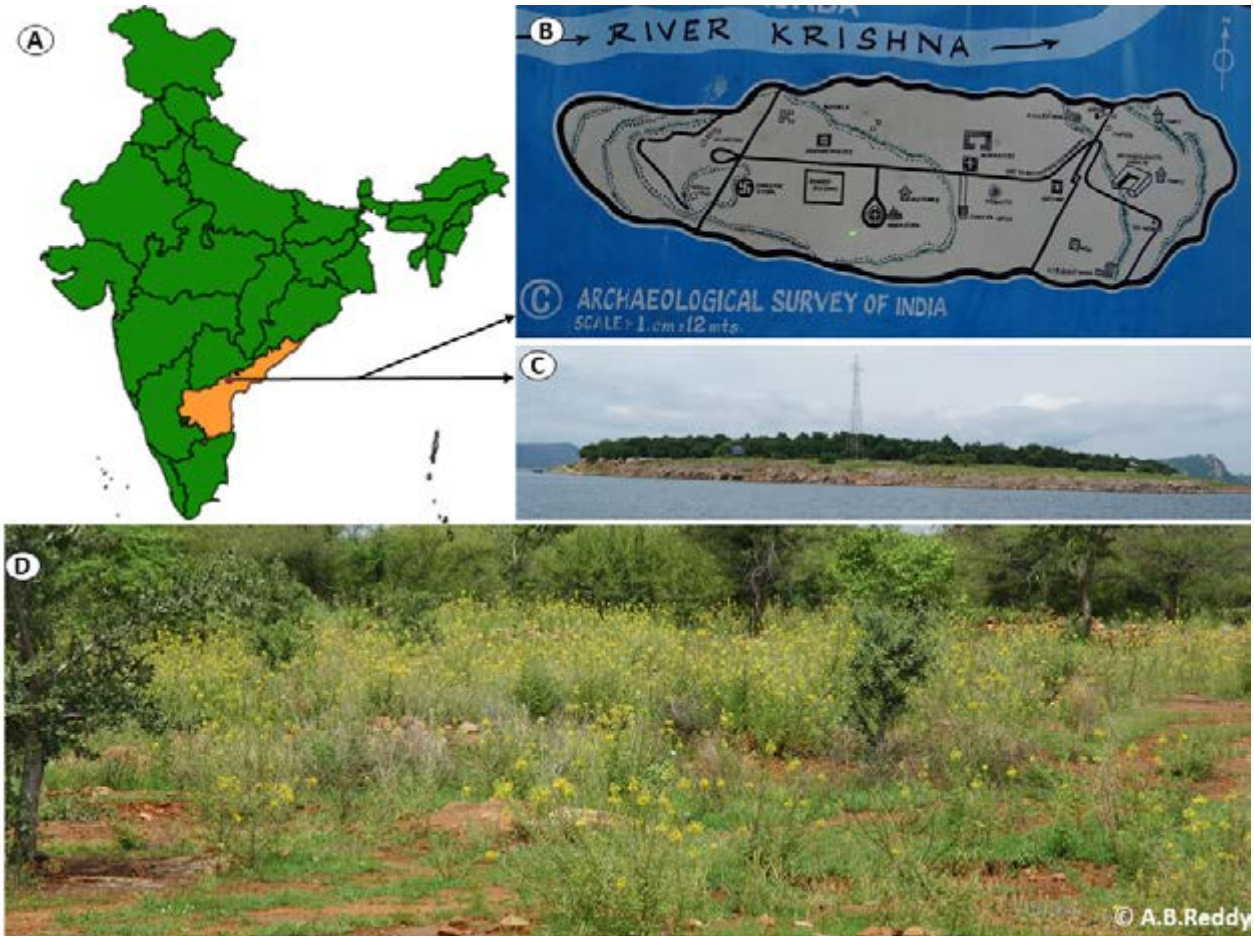

Image 1. Study area. (A) India; (B) Map of Nagarjunkonda Island; (C) Panoramic view of Nagarjunkonda; (D) Preferred habitat of *Corynandra viscosa* subsp. *nagarjunakondensis*.

an open source browser-based tool was used to perform the rapid geospatial analysis for red-listing the taxa of interest. This tool was developed to utilize spatially referenced primary occurrence data for the analysis of two aspects of the geographic range of a taxon: EOO - Extent of Occurrence and AOO - Area of Occupancy (Maes et al. 2015). The AOO is defined as the area within its 'extent of occurrence' which is occupied by a taxon, excluding the cases of vagrancy. The result is an intuitive environment for web-based GIS and conservation analysis algorithms. Analyses were done and visualized instantly. The tool provides an indication of the threat rating subjected to meeting the full requirements of the assessment criteria in a transparent, repeatable and rapid way through a user-friendly environment (Bachman et al. 2011). The standard IUCN Ver. 3.1 sampling methodology (IUCN 2013) was employed for determining the AOO.

RESULTS AND DISCUSSION

(i) Vegetation of Nagarjunakonda Island

Thothathri (1964) explored the Nagarjunakonda Valley and the surroundings, and reported 251 species representing 156 genera and 45 families of Angiospermae (Tracheophyta: Magnoliopsida). The present study recorded for the group, 193 species of 139 genera pertaining to 58 families from Nagarjunakonda Island. As per the growth forms, there are 39 (20.2%) tree species, 21 (10.8%) shrubs, 103 (53.5%) herbs, and 30 (15.5%) climbers. The vegetation is largely of dry deciduous type.

(ii) Taxonomic Status

Since Linnaeus (1753) described *Cleome viscosa*, it formed the basionym for several new combinations at generic level. It was because the genus *Cleome* L. with about 200 species (Kers 2003) has been conceived and circumscribed differently by later workers, leading to the creation of a number of segregate genera. The

www.theplantlist.org accepts the name *Cleome viscosa* L. whereas the www.tropicos.org considers *Polanisia viscosa* (L.) DC. to be the legitimate name. When this manuscript was written and submitted, the www.catalogueoflife.org viewed the name *Coynandra viscosa* (L.) Cochrane & Iltis as the accepted name and the same website now (since 31 May 2018) replaced that name with *Arivela viscosa* (L.) Raf. Conversely, these websites post these plant names in current use or currently accepted; however, this particular species has features distinct from *Cleome* L., sensu stricto. Now, the recent experts on *Cleome*, who use molecular evidence, assign *Cleome viscosa* either to *Corynandra* (Cochrane & Iltis 2014) or *Arivela* (Barrett et al. 2017), thus considering it distinct from *Cleome* proper. Nonetheless, when there are no major generic differences between these two genera *Corynandra* Schrad. ex Spreng. (1827) and *Arevila* Raf. (1838), the former gets priority being the older name.

The genus *Corynandra* Schrad. ex Spreng. (1827) was resurrected as the earlier name for *Arevila* Raf. (1838) which was recently taken up by Zhang & Tucker (2008). This segregate genus *Corynandra* is characterized by closed-imbricate aestivation of the flowers, higher number of stamens (10-100 plus), adaxial filaments apophysate, capsules sessile and erect with persistent valves that dehisce from the distal end and the seeds with open cleft, and largely of Old World distribution (Cochrane & Iltis 2014). Accordingly, the common weedy species of *Cleome* found in India such as *C. aspera* Koenig ex DC., *C. chelidonii* L.f., *C. felina* L.f., *C. simplicifolia* (Cambess.)Hook.f. & Thomson and *C. viscosa* L., fall under *Corynandra* (Cochrane & Iltis 2014; Barrett et al. 2017). Rafinesque (1838) and Barrett et al. (2017), however, consider *Cleome viscosa* L. as *Arevila viscosa* (L.)Raf. The authors of the present paper do not endorse this particular assessment because the morphological characters used by Barrett et al. (2017) are overlapping to distinguish clearly the Indo-Australian Cleomaceae, the delimitation of the genera *Areocleome*, *Arivela* and *Corynandra*. Even otherwise, *Cleome viscosa* is atypical. It has closed imbricate aestivation, the number of stamens, apophysate filaments and sessile erect capsules of *Areocleome* but differs from it in the apical dehiscence of capsules and seeds with open cleft and without elaiosome. It resembles *Arevila* in yellow flowers, closed imbricate aestivation, number of stamens which are filiform, sessile erect capsules and transversely ridged seed and differing in possessing apophysate filaments, apical dehiscence of capsules and non-eliosomic seeds; however, it resembles *Corynandra* in all the characters used to circumscribe the genus. Therefore, the taxon under assessment has to be called as follows:

Corynandra viscosa (L.) Cochrane & Iltis in Novon 23(1): 24. 2014. *Cleome viscosa* L., Sp. Pl. 2: 672. 1753. *Sinapiastrum viscosum* (L.) Moench, Suppl. Meth.: 83. 1802. *Polanisia viscosa* (L.)DC., Prodr. 1: 242. 1824. *Arivela viscosa*(L.) Raf., Sylva. Tellur.: 110. 1838.

Corynandra viscosa subsp. ***nagarjunakondensis*** (Sundararagh.) Cochrane in Novon 23(1): 25. 2014. *Cleome viscosa* var. *nagarjunakondensi*s Sundararagh. in Bull. Bot. Surv. India 28: 187. 1986 [publ.1988] et Flora India 2: 318.1993; Pullaiah et al., Fl. Guntur Distr. 55. 2000.

(iii) Taxon Description

Erect herbs up to 1.2m tall; woody and sparingly branched from base, viscid, clothed with glandular and eglandular trichomes, foetid. Leaves 3–5(7)-foliolate with petiole up to 4.5cm long at base; leaflets obovate, rhomboid or elliptic-oblong (variable in shape and size), 0.6–3.0 x 0.2–1.5cm, middle leaflet the largest, cuneate, ciliate, apex acute, lateral nerves 5–7 pairs; petiolule 0.5–2.5 mm. Inflorescence lax, few-flowered elongated racemes or terminal corymbs; bracts foliaceous. Flowers solitary and axillary, largely hermaphroditic (Image 2A), a few either with vestigial gynoecium (Image 2B) or staminate (Image 2C); creamy, 2–2.5 cm across; pedicels up to 2.8cm, elongating up to 4cm in fruit. Sepals 4, glandular pubescent, elliptic-lanceolate, 8–12 x 2.5–4.0 mm, acute. Petals 4, subequal, prominently veined, oblong to obovate, cuneate, apex rounded, outer pair 2.0–2-5 x 0.8–1.0 cm, inner pair 1.8–2.0 x 0.6–0.8 cm (incl. 5–6 mm long claw). Stamens 36-40, dimorphic, adaxial ones apophysate; filaments 1.5–2.0 cm long; anthers 2.0–2.8 mm. Ovary sessile, linear-oblong, 1.0–1.4 cm, glandular hairy; style slender, puberulous, 0.8–1.0 cm long, elongating up to 2cm in capsules; stigma capitate. Capsules linear-oblong, 6.0–8.5 x 0.4–0.5 cm (including persistent style), terete, tapering at both ends, obliquely striate, ribs glandular. Seeds many, 1.5–1.6 mm across, dark brown, glabrous, with fine longitudinal striations, concentric ribs faint, cleft closed or with a narrow opening, non-elaeosomic (the description in the protologue is retained to the extent where there is no variation found).

Illustration: Sundararaghavan (1988: 187): Plate III; Figures 1–8; Present study: Image 2.

Type: India, Nagarjunakonda Hills, 200m altitude, 13.vii.1961, K. Thothathri 9616 (Holotype 9616A; Isotype 9616B-D, CAL).

Note: There are two specimens of *Cleome viscosa*

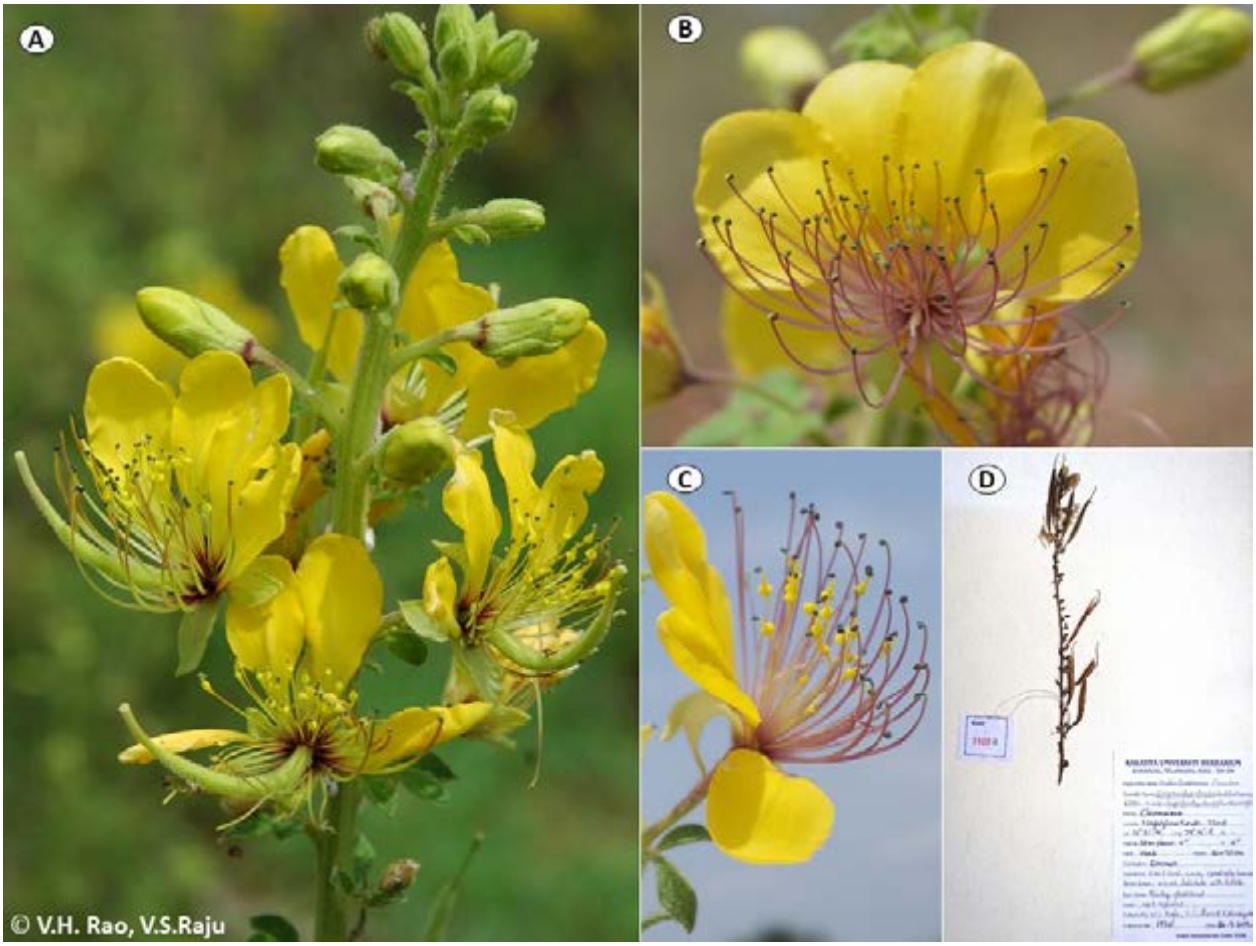

Image 2. *Corynandra viscosa* subsp. *nagarjunakondensis*. (A) Inflorescence with the hermaphroditic flowers (note the insect on the flower bud and the adaxial apophysate [yellow swellings below the anthers] filaments); (B) Flower with vestigial gynoecium; (C) Staminate flower; (D) Voucher specimen (V.S. Raju, S. Suthari & R. Kandagatla 1920 at KUW).

collected by K.C. Jacob on September 7, 1924 proximate to the type locality, i.e., Madinapad Reserve Forest, Guntur District, Andhra Pradesh. These specimens were preserved in MH as *Cleome viscosa* L. with the Madras Herbarium South India Flora acc. no.17458. These were selected by Sundararaghavan (1988) to serve as paratype (A, B). The digital images of specimens were assigned the numbers MH00155624 and MH00155625 by MH. It is not clear from Sundararaghavan (1988), which he assigned A or B. Of these, the latter sheet has two specimens pasted on it. We, therefore, designate the former as A and the latter B; however, it is to be mentioned that these specimens do not exactly compare with those from the type locality bearing relatively shorter, not so conspicuously long stigmas. Moreover, Sundaragahavan has wrongly mentioned the type collection number (at thousand digit) of K. Thothathri as '6616' when his other collections from the habitat of the field trip bear collection numbers in 'nine thousand' series. This was rightly pointed out by Cochrane & Iltis (2014: 25). Furthermore, the present study reports in this subspecies, for the first time, the presence of staminate flowers and functionally male flowers with vestigial gynoecium.

Ex siccatae: India, Andhra Pradesh, Guntur District, Nagarjunakonda: 14.ix.2011, A.B. Reddy & P.H. Rao 5056 (BSID); 24.ix.2013, V.S. Raju, S. Suthari & R. Kandagatla 1920 (KUW); 25.vi.2017, V.S. Raju, V.H. Rao & S. Gurappa 4901(KUW).

Flowering & Fruiting: June–September.

Distribution: Asia, India, Andhra Pradesh, Krishna River valley, Guntur District.

(iv) Threat Status

The Assessment: The taxon was not found under closed canopy forests but prefers open scrub of rocky landscape at elevations 196–210 m. After mapping the distribution of *Corynandra viscosa* subsp. *nagarjunakondensis*, the habitat Nagarjunakonda Island

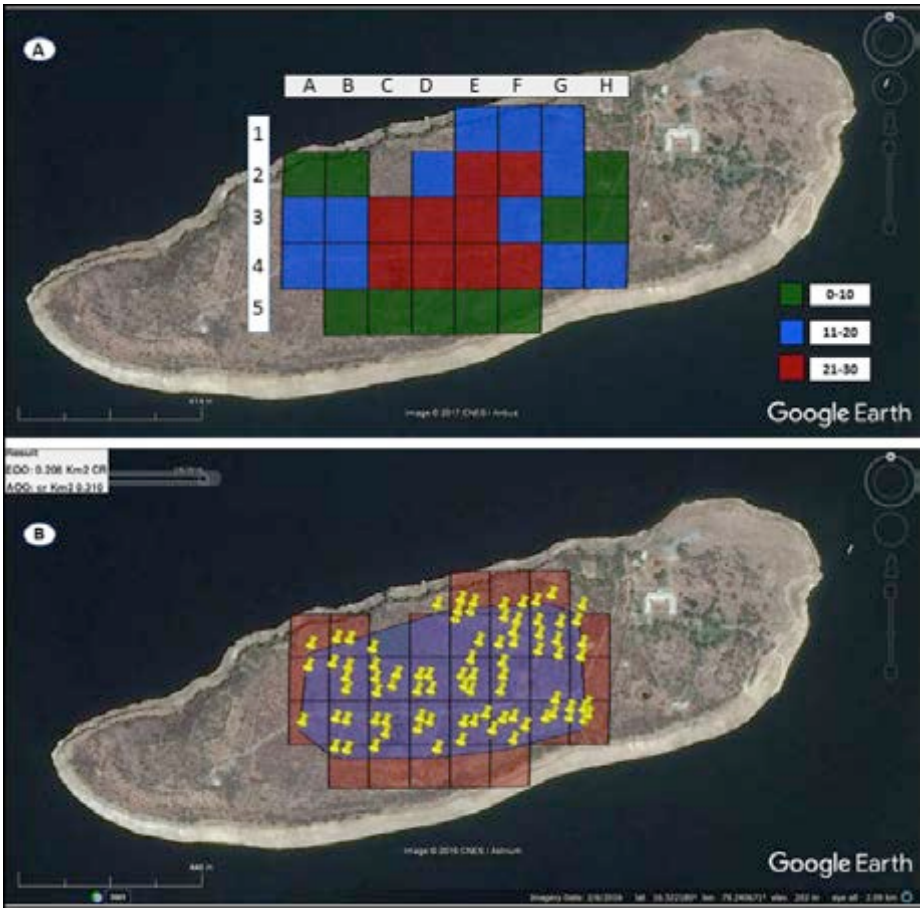

Image 3. Nagarjunakond Island. (A) Grid-wise categorization of population density in the Island; (B) Area surveyed for the occurrence of target species. Minimum Convex Polygon - Polygon Area: 100m², perimeter 0.31km (blue - EOO; red - AOO).

was stratified into 31 grids, each with 100m². The occurrence of this taxon was listed in each grid which had four quadrats of 1m² area. The population in each of these quadrats was determined. The sites of the taxon occurrence was recorded by GPS to estimate the extent of occurrence (EOO) and the area of occupancy (AOO).

A total of 124 quadrats of 1×1 m size were laid in 31 grids of 100×100 m size, and recorded 458 individuals of *Corynandra viscosa* subsp. *nagarjunakondensis.* The average population count among the grids varied between 1.5-7.50 individuals. Based on the population, the grids were divided into three categories (Image 3A) with a class interval of 10, viz.: Category-I (0–10), Category-II (11–20) and Category-III (21–30). Among the class intervals, maximum percent occurrence was noticed in Category-II with 12 grids, followed by Category-I with 10 grids and III with nine grids. The nine grids, namely C-3 and 4, D-3 and 4, E-2, 3 and 4 and F-2 and 4 (Image 3B) showed greater density of the taxon (columns were designated as A–H and rows as 1–5).

IUCN Red List Assessment

The conservation status of the taxon *Corynandra viscosa* subsp. *nargarjunakondensis* which has not been done so far is presently taken-up using the latest IUCN Red List Criteria (Version 3.1; IUCN 2001/2013). Opportunistic data are increasingly used for estimating trends and geographic range sizes. Geographic ranges are determined using: (i) marginal occurrences, (ii) habitat distributions, (iii) range-wide occurrences, (iv) species distribution modeling (including site-occupancy models), and (v) process-based modeling (Maes et al. 2015). The criterion B of the IUCN is used to evaluate a taxon based on its the geographic range in the form of either B1 (EOO) and/or B2 (AOO), leading to assigning the threat category Critically Endangered, Endangered or Vulnerable. EOO and AOO reflect two different processes and represent respectively the spread of extinction risk and vulnerability due to a restricted range and, therefore, useful to estimate both criteria in Red List assessments. In Britain, the combined use of EOO and AOO resulted in the highest Red List category (76%) while in Flanders this was the case for AOO (86%) (Maes et al. 2015). The

re-assessment of *Leucopogon spectabilis* yielded an estimated EOO of 14.8km^2 and AOO of 32km^2 and the values for *Tetratheca aphylla* subsp. *aphylla* were 35km^2 for EOO and 52km^2 for AOO (Bioscope Environmental 2016). For *Murdannia saddlepeakensis*, Tagore et al. (2016: 9492) showed the larger area for AOO (red) and smaller for EOO (blue) in Figure 1, as can be seen in our study (Image 3); however, they have provided only the value of EOO (1.8 km^2), but not the AOO.

Since the estimated values of EOO and AOO are 0.20 km^2 and 0.31 km^2 respectively, the taxon under assessment falls under the Critically Endangered category. The conditions such as the population being confined to a single location [of (Ba)] and the (i) extent of occurrence (EOO <100km^2); (ii) area of occupancy (AOO <10km^2); (iii) area, extent and/or quality of habitat (elaborated below); (iv) number of locations or subpopulations not found further; and (v) the number of mature individuals about 500 [of B(b)] are the conditions which qualify *Corynandra viscosa* subsp. *nagarjunakondenis* to B1ab(iii) of the above category.

A declining population was observed/inferred (sub-criterion b of B) in terms of the biotic interference on the habitat - where there is a tourism and impact of trekking on the Island, which in fact, comes under category II of protected areas. Forest fire is the other serious threat along with the alien plant invasion. Increased burn frequencies can, therefore, progressively exclude the fire-vulnerable species and increase the pyrophytes. Above all, *Corynandra viscosa* subsp. *nagarjunakondensis* was found severely infested with papaya mealybug (*Paracoccus marginatus* Williams & Granara de Willink: Pseudococcidae, Hemiptera). The papaya mealybug is a small, polyphagous, sucking insect with pest status that attacks several genera of host plants, including the economically important tropical fruits, vegetables and ornamentals. Infestation of the mealybug appeared as clusters of cotton-like masses on the aboveground portion of plants, more so the inflorescence (Image 4 A-C). Both the immature and adult mealybugs suck

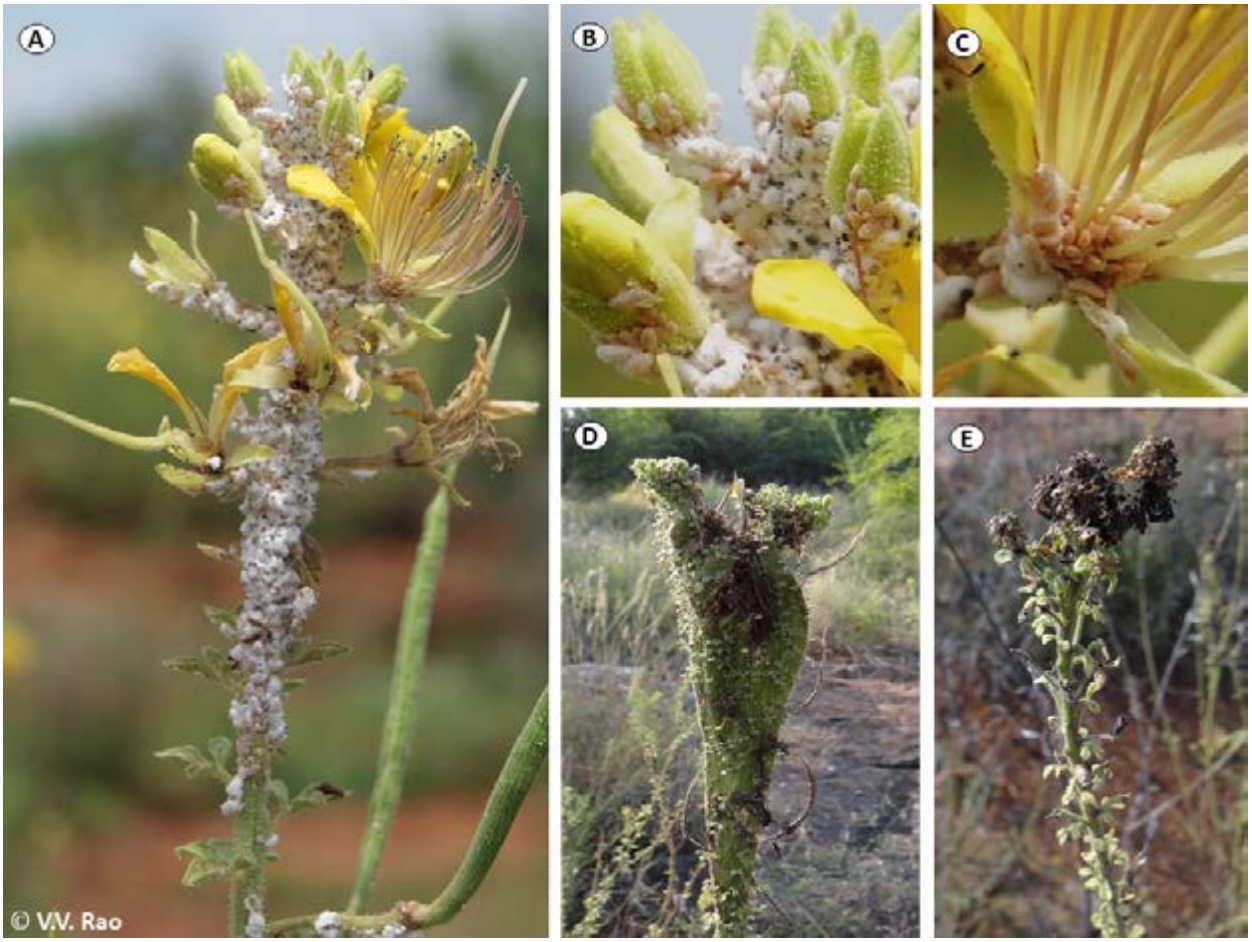

Image 4. *Corynandra viscosa* subsp. *nagarjunakondensis* infested with the Papaya mealybug (*Paracoccus marginatus*): (A) Inflorescence; (B) Flower buds; (C) Colonization on flower; (D) Abnormal growth of shoot due to insect attack; (E) Another kind of deformation of shoot apex.

the sap of the plant and weaken it. Consequently, the leaves become wrinkled, yellowish and wither while the seeds do not develop fully (Image 4 D-E). The honey dew excreted by the bug and the associated black sooty mold formation further impairs the photosynthetic efficiency of the affected plants (Tanwar et al. 2010). This insect, if unchecked, may expedite the decline of the population in the near future.

CONCLUSION

The Nagarjunakonda Island has a unique environment, with vulnerabilities. It harbours small seasonal populations of *Corynandra viscosa* subsp. *nagarjunakondensis* whose luxuriance depends on critical amounts and timing of moisture availability. Tourism promotion by the Andhra Pradesh State Government and the accompanied infrastructure development is a serious threat. Protection of this small precarious habitat and its native biota are essential for the long-term conservation of this taxon. It can come with political will and/or the enforcement of wildlife and biodiversity acts.

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Short Communication

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New records of termites (Blattodea: Termitidae: Syntermitinae) from Colombia

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Abstract: Eight species of termite from the Amazon and Orinoquia regions, belonging to four genera of the subfamily Syntermitinae, are recorded for the first time in Colombia. The species are *Cornitermes cumulans* (Kollar, 1832), *Cornitermes pilosus* Holmgren, 1906, *Cornitermes ovatus* Emerson, 1952, *Cornitermes snyderi* Emerson, 1952, *Mapinguaritermes peruanus* (Holmgren, 1906), *Rhynchotermes amazonensis* Constantini & Cancello, 2016, *Rhynchotermes perarmatus* (Snyder, 1925), and *Uncitermes teevani* (Emerson, 1925). Diagnostic characteristics and geographic distributions for the recorded species are provided, with detailed photographs of the soldier caste. The diversity and distribution of indigenous termite species in Colombia are documented.

Keywords: Amazon, Colombian Llanos, *Cornitermes*, *Mapinguaritermes*, neotropical, Orinoco, *Rhynchotermes*, savannas, termites, *Uncitermes*.

Resumen: Ocho especies de termitas de las regiones de la Amazonía y Orinoquía, pertenecientes a cuatro géneros de la subfamilia Syntermitinae, son registradas por primera vez para Colombia. Las especies son: *Cornitermes cumulans* (Kollar, 1832), *Cornitermes pilosus* Holmgren, 1906, *Cornitermes ovatus* Emerson, 1952, *Cornitermes snyderi* Emerson, 1952, *Mapinguaritermes peruanus* (Holmgren, 1906), *Rhynchotermes amazonensis* Constantini & Cancello, 2016, *Rhynchotermes perarmatus* (Snyder,1925), and *Uncitermes teevani* (Emerson, 1925). El presente estudio provee los caracteres diagnósticos y la distribución geográfica de las ocho especies estudiadas con fotografías detalladas del soldado. Este trabajo contribuye a documentar la diversidad y la distribución de especies de termitas nativas de Colombia.

Termites are insects of ecological importance in the dynamics of ecosystems that contribute to the biological processes of organic matter decomposition and mineralisation (Lewis 2009). Brazil is documented as the site of greatest termite diversity in the Neotropics (Constantino 2005), whereas Colombian termite fauna is much less well characterised and under-represented in the literature, due to a lack of sampling, taxonomic expertise and fewer investigative studies (Constantino 2002).

The first list of Colombian Termitidae genera, based on material deposited in entomological collections, was compiled in 2005 (Vargas-Niño et al. 2005), but a species list has not yet been published. Previous studies on termites in Colombia have focused on plantations and crops (Galvis 1985; Gutiérrez et al. 2004; Pinzón et al. 2012; Abadía et al. 2013), while natural ecosystems that possess higher species richness have received less attention (Morales-Castaño & Medina 2009; Casalla et al. 2016; Pinzón et al. 2017). Herein, we report eight

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Termitidae species from four genera in Colombia for the first time, thereby expanding our knowledge of termite species occurring in this country.

Materials and Methods

Species of the Syntermitinae subfamily deposited in the Colección Entomológica Forestal CEFUD "Universidad Francisco José de Caldas" and the Colección de Artrópodos Terrestres de la Amazonia Colombiana CATAC (Instituto Amazónico de Investigaciones Científicas SINCHI) were identified to species level based on the morphology of the soldier caste using the taxonomic keys of Emerson (1952), Rocha et al. (2012), and Constantini & Cancello (2016).

Results and Discussion

Four genera and eight Termitidae species are recorded for the first time in Colombia (Figs. 1–4 & Images 1–8). These are the Syntermitinae: *Cornitermes cumulans* (Kollar, 1832), *Cornitermes pilosus* Holmgren, 1906, *Cornitermes ovatus* Emerson, 1952, *Cornitermes snyderi* Emerson, 1952, *Mapinguaritermes peruanus* (Holmgren, 1906), *Rhynchotermes amazonensis* Constantini & Cancello, 2016, *Rhynchotermes perarmatus* (Snyder, 1925), and *Uncitermes teevani* (Emerson, 1925).

Cornitermes cumulans (Kollar, 1832)

Specimens examined: CEFUD 2014-602, 02.xii.2014, 7 individuals, Colombia, Meta, Puerto Gaitán, Planas (4.17935^{0}N & 71.27439^{0}W), coll. D. Castro, id. P. Pinzón & 7 ind. CEFUD 2014-626B, 09.xii.2014, 4 individuals, Colombia, Meta, Puerto Gaitán, Planas (4.17955^{0}N & 71.27450^{0}W), coll. J. Vega, id. P. Pinzón.

Diagnostic features: The head is yellowish, the pronotum is a little lighter than the head, the length of the head with mandibles is 3.29–4.31 mm, the width of the head is 1.85–2.62 mm and the head is sparsely covered with bristles and numerous relatively long hairs about half the length of the bristles. Antennae have 15-16 articles, the labrum has distinct side angles greater than a right angle (Image 1d) and the front margin of the pronotum is not emarginate and does not have a shallow emargination (modified from Emerson 1952).

Distribution: This species has been recorded in Brazil, Argentina and Paraguay (Krishna et al. 2013). This is the first record for a country in the north of South America, although restricted to Orinoquia in Colombia.

Notes: Workers and soldiers were collected from gallery forest during the rainy season and found only in epigeous monticules.

Cornitermes pilosus Holmgren, 1906

Specimens examined: CEFUD 2014-617, 11.vi.2014, 20 individuals, Colombia, Meta, Puerto Gaitán, Planas (4.17923^{0}N & 71.27462^{0}W), coll. D. Castro, id. P. Pinzón. CEFUD 2014-170, 27.vi. 2014, 4 individuals, Colombia, Meta, Puerto Gaitán, Planas (4.17963^{0}N & 71.27397^{0}W), coll. J. Vega, id. P. Pinzón.

Diagnostic features: The head has numerous long bristles on the upper side and a dense contrasting mat of short hairs on the upper and under sides. The postmentum is covered with shorts hairs, the length of the head with mandibles is 4.00–5.00 mm and the width of the head is 2.06–2.76 mm. The frontal tube is relatively short and depressed in profile. The labrum is rounded and bluntly pointed with lateral angles, and the margins from the base of the median white lobe to the lateral angles are straight (Image 2D). Antennae have 15 articles, and the second, third and fourth are approximately equal (adapted from Emerson 1952).

Distribution: This species has been recorded only in Brazil (Araujo 1977; Constantino 1998; Fontes 1998). In Colombia, it was only recorded in Puerto Gaitán, Meta.

Notes: Workers and soldiers were collected from

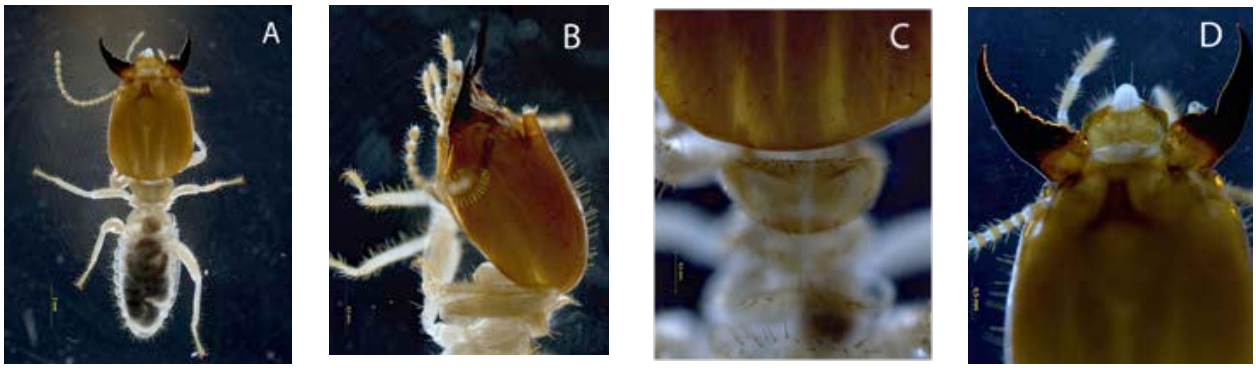

Image 1. *Cornitermes cumulans* (Kollar, 1832)
A - Dorsal view; B - Head lateral view; C - Pronotum; D - Labrum and mandibles. © W. Garcia, 2017.

gallery forest during dry and rainy seasons. Samples were obtained from dry branches and epigeous monticules.

***Cornitermes ovatus* Emerson, 1952**

Specimens examined: CEFUD 2014-165, 11.vi.2014, 1 individual, Colombia, Meta, Puerto Gaitán, Planas (4.17977^{0}N & 71.27399^{0}W), coll. D. Castro, id. P. Pinzón. CEFUD 2014-294, 27.vi.2014, 6 individuals, Colombia, Meta, Puerto Gaitán, Planas (4.15875^{0}N & 71.23913^{0}W), coll. D. Castro, id. P. Pinzón. CEFUD 2014-336, 29.vi.2014, 4 individuals, Colombia, Meta, Puerto Gaitán, Planas (4.15148°N & 71.24068°W), coll. J. Vega, id. P. Pinzón. CEFUD 2014-572A, 21.xi.2014, 2 individuals, Colombia, Meta, Puerto Gaitán, Planas (4.17977^{0}N & 71.27399^{0}W), coll. D. Castro, id. P. Pinzón. CEFUD 2014-632, 10.xii.2014, 4 individuals, Colombia, Meta, Puerto Gaitán, Planas

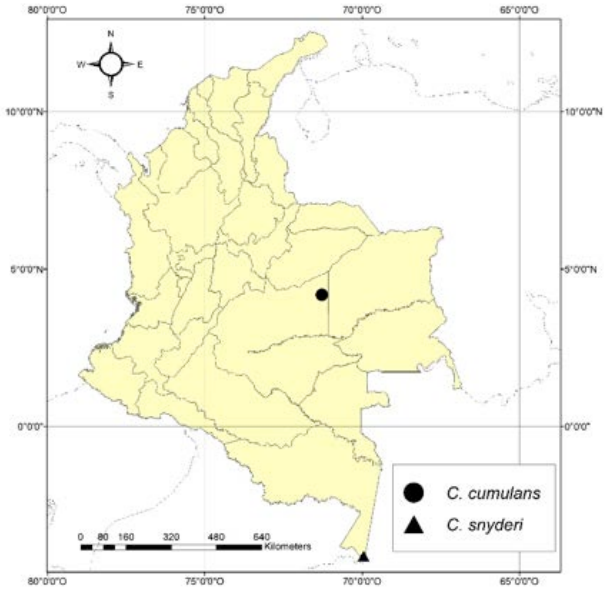

Figure 1. Distribution map of *Cornitermes cumulans* and *Cornitermes snyderi*.

Figure 2. Distribution map of *Cornitermes pilosus* and *Cornitermes ovatus*.

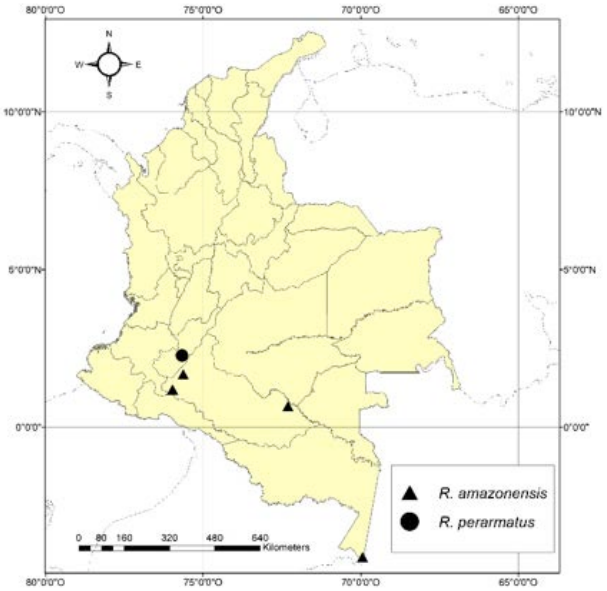

Figure 3. Distribution map of *Rhynchotermes amazonensis* and *Rhynchotermes perarmatus*.

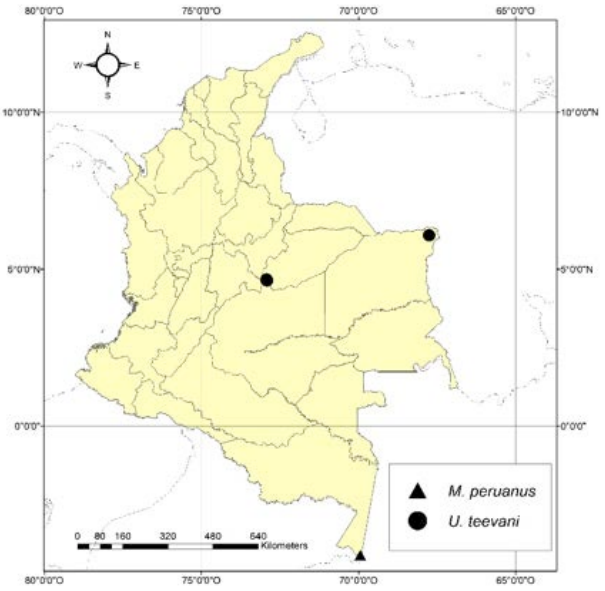

Figure 4. Distribution map of *Mapinguaritermes peruanus* and *Uncitermes teevani*.

(4.17963^{0}N & 71.27450^{0}W), coll. D. Castro, id. P. Pinzón. CEFUD 2014-639, 12.xii.2014, 6 individuals, Colombia, Meta, Puerto Gaitán, Planas (4.17971^{0}N & 71.27477^{0}W), coll. J. Vega, id. P. Pinzón. CEFUD 2014-681, 20.xii.2014, 6 individuals, Colombia, Meta, Puerto Gaitán, Planas (4.15870^{0}N & 71.23914^{0}W), coll. D. Castro, id. P. Pinzón. CEFUD 2009.6.3, 15.x.2014, 16 individuals, Colombia, Meta, Puerto López (4.25555^{0}N & 72.56889^{0}W), coll. P. Pinzón, id. P. Pinzón.

Diagnostic features: The head has numerous bristles on top and a few underneath, and has a mat of contrasting short hairs. The head is light reddish-brown, the length of the head with mandibles is 5.08–5.30 mm and the width of the head is 2.98–3.20 mm. The pronotum has numerous bristles and a few short hairs (Image 3c). Antennae have 15 articles. The sides of the labrum are obtusely pointed or rounded, and the angles at the junction of the white median lobe are distinct (Image 3B) (adapted from Emerson 1952).

Distribution: This species has been previously recorded in Brazil (Krishna et al. 2013). In Colombia, it was recorded in two localities of the Meta Department.

Notes: Workers and soldiers were collected from gallery forests during dry and rainy seasons. Samples were obtained from dry branches, epigeous monticules and soil.

***Cornitermes snyderi* Emerson, 1952**

Specimens examined: CATAC 1230, 23.vi.2017, 11 individuals, Colombia, Amazonas, Leticia, Tanimboca Natural Reserve (4.12094^{0}S & 69.95547^{0}W), coll. D. Castro, id. D. Castro. CATAC 1231, 23.vi.2017, 1 individual, Colombia, Amazonas, Leticia, Tanimboca Natural Reserve (4.12094^{0}S & 69.95547^{0}W), coll. D. Castro, id. D. Castro.

Diagnostic features: The head is dark yellow and subrectangular, and has numerous bristles and some shorter hair. The length of the head and mandibles is 2.74-3.47 mm, and the width is 1.50-1.85 mm. The pronotum is yellow with a number of bristles and a few shorts hairs on the posterior half. Antennae have 15 articles. The labrum has somewhat blunt lateral angles, and the margin between the lateral angles and the base of the median white tip is slightly concave or nearly straight (adapted from Emerson 1952).

Distribution: This species has been reported in Bolivia (Emerson 1952), as well as northeastern (Bandeira & Vasconcellos 1999), central-western (da Cunha et al. 2006) and Amazon (Constantino & Cancello 1992; Fontes 1998) regions of Brazil.

Notes: Workers and soldiers were collected from 20cm depth soil samples in a secondary forest.

***Mapinguaritermes peruanus* (Holmgren, 1906)**

Specimens examined: CATAC 633, 26.xi.2015, 38 individuals, Colombia, Amazonas, Leticia, Tacana River (4.161916^{0}S & 69.9569^{0}W), coll. C. Peña, id. D. Castro. CATAC 976, 22.viii.2017, 23 individuals, Colombia, Amazonas, Leticia, Cerca Viva Natural Reserve (4.12075^{0}S & 69.94469^{0}W), coll. D. Castro, id. D. Castro.

Diagnostic features: The head capsule is oval in the dorsal view, and the frontal tube is conical, almost parallel with the base of the head capsule and approximately four-fifths of its length in profile. Bristles on the head are sparse, varying in number, but never fewer than 15. The frontal tube always has bristles, at least until the middle of the proximal region. Antennae have 14 articles (adapted description of Rocha et al. 2012).

Distribution: This species has been recorded in Peru and Brazil (Holmgren 1912; Mathews 1977) and is distributed in the Amazon region (Rocha et al. 2012). In Colombia, two records of this species were found 11km from the city of Leticia in the Amazonas Department, at the Natural Reserve Cerca Viva and the Tacana River.

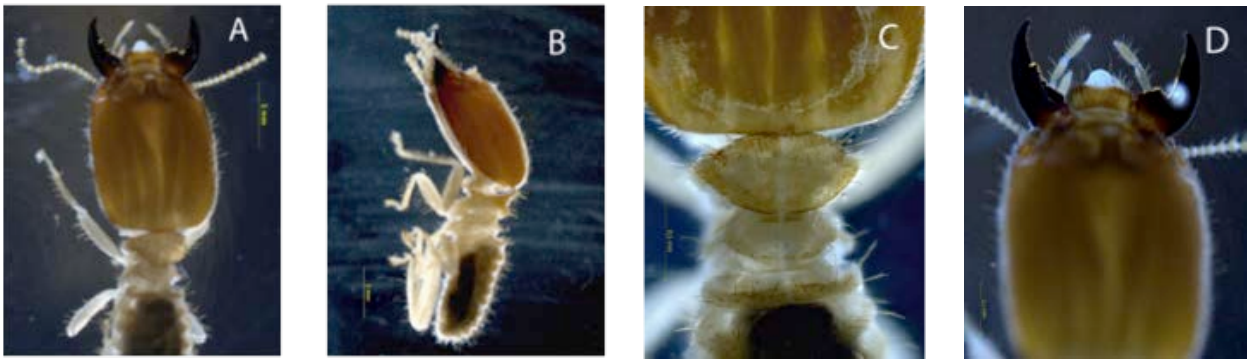

Image 2. *Cornitermes pilosus* Holmgren, 1906
A - Dorsal view; B - Lateral view; C - Pronotum; D - Labrum and mandibles. © W. Garcia, 2017.

Notes: Workers and soldiers were collected from primary and secondary forest in Leticia, close to the Amazon River. They were collected from soil samples in a secondary forest, and also from anthropogenic soil (terra preta) in secondary forests at a depth from 0 to 10 cm.

***Rhynchotermes amazonensis* Constantini & Cancello, 2016**

Specimens examined: CATAC 1752, 3.x.2015, 12 individuals, Colombia, Amazonas, Puerto Santander, Aduche (0.66202^{0}N & 72.31061^{0}W), coll. C. Peña, id. D. Castro. CATAC 965, 4.ix.2015, 1 individual, Colombia, Amazonas, Leticia (4.16916^{0}S & 69.9569^{0}W), coll. C. Peña, id. D. Castro. CATAC 1764, 20.ix.2016, 19 individuals, Colombia, Caquetá, Florencia, Caldas (1.67638^{0}S & 75.63294^{0}W), coll. C. Peña, id. D. Castro. CATAC 1245, 15.iii.2016, 5 individuals, Colombia, Caquetá, Florencia, Caldas (1.67638^{0}S & 75.63294^{0}W), coll. C. Peña, id. D. Castro.

Diagnostic features: This species is dimorphic. The head of major soldiers is slightly constricted behind the antennae. In profile, the dorsal margin of the head and the margin of the frontal tube are concave, the length of the head to the lateral base of the mandibles is 0.67–0.85 mm and the width of the head is 0.82–0.92 mm. Mandibles are strongly curved, with a serrated inner margin. The forecoxa process is subcylindrical, and antennae articles are long (adapted from Constantini & Cancello 2016).

Distribution: This species has previously been recorded only in Brazil (Constantini & Cancello 2016) in an Amazonian forest. In Colombia, it was recorded in two departments of the Amazonian region: Caquetá and Amazonas.

Notes: Workers and soldiers were collected from soil samples in a primary forest and from anthropogenic soil samples (terra preta) in the indigenous community of Aduche (Puerto Santander, Amazonas). They were found in soil samples taken from a depth of 0-20 cm.

***Rhynchotermes perarmatus* (Snyder, 1925)**

Specimens examined: CEFUD 2103, 26.ix.2015, 1 individual, Colombia, Huila, El Agrado (2.2675^{0}N & 75.6733^{0}W), coll. S. Angel, id. P. Pinzón.

Diagnostic features: The head is short, pear-shaped, with a very elongated nasus that is curved downward and gradually attenuated toward the apex, and subcylindrical. The length of the head and nasus is 2.50–2.60 mm, and the width of the head is 0.65–0.67 mm. The mandibles are larger than the head, and clearly visible in the dorsal view when closed (adapted

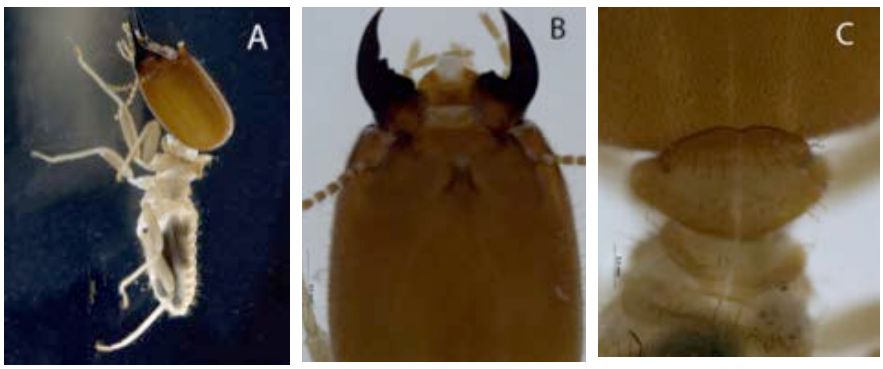

Image 3. *Cornitermes ovatus* Emerson, 1952
A - Lateral view; B - Head, labrum and mandibles; C - Pronotum.
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Image 4. *Cornitermes snyderi* Emerson, 1952
A - Dorsal view; B - Lateral view; C - Labrum and mandibles.
© D. Castro, 2018.

from Snyder 1925 and Constantini & Cancello 2016).

Distribution: This species has been recorded in Panama, Honduras, Costa Rica, Guatemala, Ecuador and Belize (Snyder 1925; Snyder 1949; Becker 1953; Araujo 1977). In Colombia, the species was found in a dry forest region of the Huila Department.

Notes: Constantino (1998) reported that this species is distributed from Belize to Ecuador, but there is no published evidence of any report for Colombia. Only a single soldier was collected.

***Uncitermes teevani* (Emerson, 1925)**

Specimens examined: CEFUD 2014-1119, 16.xi.2014, 10 individuals, Colombia, Vichada, Puerto Carreño, (6.07666^{0}N, 67.75000^{0}W), coll. P. Pinzón, id. P. Pinzón. CEFUD 2015-747, 2.ii.2015, 20 individuals, Colombia, Casanare, Villanueva, Refocosta (4.64277^{0}N & 72.92222^{0}W), coll. P. Pinzón, id. P. Pinzón. CEFUD 2015-863, 30.i.2015, 28 individuals, Colombia, Casanare, Villanueva, Refocosta (4.63566^{0}N & 72.90805^{0}W), coll. P. Pinzón, id. P. Pinzón. CEFUD 2015-2202, 12.v.2015, 20 individuals, Colombia, Casanare, Villanueva, Refocosta (4.66627^{0}N & 72.92302^{0}W), coll. P. Pinzón, id. P. Pinzón.

Diagnostic features: Soldiers of this species have a rounded head capsule (in the dorsal view), and the head has a few sparse bristles. The frontal tube is conical and glabrous, and the same length as the base of the head capsule, and forms an almost 45^0 angle with the base of the head (in profile). Antennae have 15 articles. The enteric valve of workers has major ridges that are slightly dilated at the apex (Image 8C), and all are decorated with curved spines (Rocha et al. 2012).

Image 5. *Mapinguaritermes peruanus* (Holmgren, 1906)
A - Dorsal view; B - Lateral view. © D. Castro, 2018.

Distribution: This species is restricted to tropical regions of South America. It has been recorded in Bolivia, Brazil, French Guyana, Guyana, Venezuela and Ecuador (Snyder 1949; Constantino 1998; Davies 2002; Carrijo et al. 2016). In Colombia, these first records were restricted to the Colombian Orinoquia.

Notes: Workers and soldiers were collected from

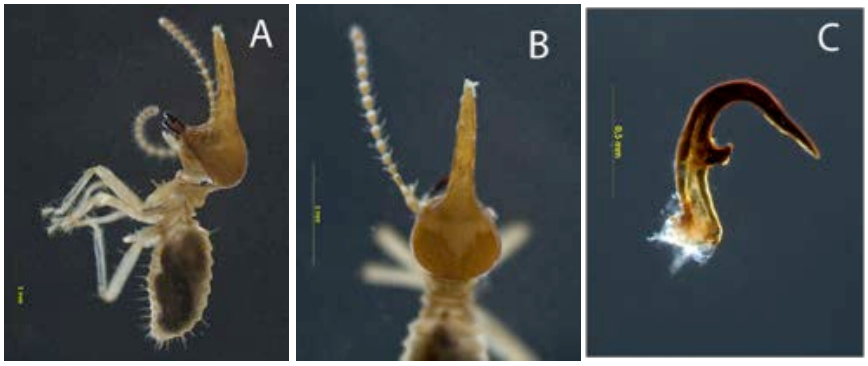

Image 6. Rhynchotermes amazonensis Constantini & Cancello (2016)
A - Lateral view; B - Dorsal view;
C - Mandible soldier. © D. Castro, 2018.

Image 7. Rhynchotermes perarmatus (Snyder, 1925)
A - Dorsal view; B - Lateral view:
C - Mandibles. © W. Garcia, 2017.

Image 8. *Uncitermes teevani* (Emerson, 1925)
A - Lateral view;
B - Dorsal view;
C - Worker enteric valve.

gallery forest during dry and rainy seasons.

Discussion

Termite genera and species records from the Orinoco and Amazon regions of Colombia, where most of our records are from, are mainly the result of studies focusing on economically important agricultural and forest species (Sánchez 2011; Sterling et al. 2011; Lores & Pinzón 2011; Pinzón et al. 2012), and samples from these regions are scarce in Colombian collections (Vargas-Niño et al. 2005; Morales-Castaño & Medina 2009). Termite diversity in riparian forests in these regions is poorly studied, despite the presence of ecologically important species (Decaëns et al. 2006; Pinzón et al. 2017).

The records presented in the present work expand the known distribution of *Cornitermes*, extending from Panama to northern Argentina. Two species of this genus have been previously listed in Colombia (Krishna et al. 2013), and the present study expands this to six records. By contrast, the genus *Rhynchotermes* is known to be restricted to the north of South America (Constantini & Cancello 2016), and we herein add two new records, *R. perarmatus* from a region of dry forest and *R. amazonensis* from a tropical humid forest. Thus, three species are now known to occur in Colombia, including the previous record of *R. bulbinasus* Scheffrahn in the northern savannas (Scheffrahn 2010). The genera *Uncitermes* and *Mapinguaritermes* were previously known to occur in geographical regions sharing ecological similarities, such as the Brazilian northeast and Venezuelan Orinoco Llanos (Rocha et al. 2012; Carrijo et al. 2016). Herein, we enlarge their known distribution to include the Colombian Oriental Llanos. To conclude, the new records of eight species expand the known geographical distribution of termite genera, and species previously known to occur in Brazil, Paraguay, Bolivia, Argentina, Ecuador, Guyana, Venezuela and Peru (Krishna et al. 2013) have now been identified in Colombia for the first time.

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Short Communication

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New reports of thrips (Thysanoptera: Terebrantia: Thripidae) from India

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Abstract: The presence of three species of thrips, namely *Asprothrips bimaculatus* Michel & Ryckewaert, *Plesiothrips perplexus* (Beach), and *Pseudodendrothrips darci* (Girault), has been reported here for the first time from India, collected during a thrips survey carried out at Agartala in Tripura and Valparai in Tamil Nadu. Among them, *A. bimaculatus* and *P. darci* belong to the subfamily Dendrothripinae, and *P. perplexus* comes under Thripinae. Diagnosis and illustration for the above three terebrantians are given along with the images for the respective species.

Keywords: *Asprothrips bimaculatus, Plesiothrips perplexus, Pseudodendrothrips darci,* new reports, Thysanoptera.

The suborder Terebrantia includes eight families, of which thrips belonging to the families Aeolothripidae, Melanthripidae, Merothripidae, Stenurothripidae and Thripidae have been collected and recorded from India. Among them, Thripidae is the biggest family, represented by a large number of economically important species. A recent appraisal of this family in India reflects the presence of 307 species in 105 genera (Rachana & Varatharajan 2017). While analysing the diverse species in terms of their practical attributes, it is apparently evident that the functional dynamics of thrips have gained momentum in recent years; their involvement in diverse aspects like pollination, gall induction, predation, and vector potential besides agricultural pests, have been realized (Mound 2005), in addition to being a bio-indicator to pollutants like heavy metals and radio active nucleotides (Daniela et al. 2011). Owing to their wide range of feeding habits and habitat diversity, it becomes imperative to undertake a periodical survey of these minute insects from varied habitats and micro-niches. Attempts made in such routine surveys resulted in the collection of three species which are newly recorded for India. This paper reports the occurrence of *Asprothrips bimaculatus*, *Pseudodendrothrips darci* and *Plesiothrips perplexus* in India for the first time, of which the former two species belong to the subfamily Dendrothripinae, while *P. perplexus* comes under the subfamily Thripinae. The diagnostic features of each species have been described below along with their photographic images.

The genus *Asprothrips* was erected by Crawford in 1938, with *A. raui* as type species, and currently comprises

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eight described species worldwide (ThripsWiki - accessed on 25 May 2018). Nevertheless, as of now only two species are known from India (Rachana & Varatharajan 2017). The genus *Asprothrips* can be easily diagnosed by its reticulate body with a complex sculpture; head transverse with anterior margin recessed, 3-segmented maxillary palp; metathoraxic endofurca lyre-shaped, extending to mesosternal furca; all tarsi usually 2-segmented; fore wing apex with 2 long apical setae; median pair of setae (S1 setae) on abdominal tergites II to VI shorter than distance between basal pores; males with or without pore plate on abdominal sternites (Tong et al. 2016).

The genus *Plesiothrips,* erected by Hood in 1915, comprises 17 described species worldwide (Thripswiki accessed on 25 May 2018), but existence of any individual of *Plesiothrips* has not been recorded previously in India. The genus is characterised by the presence of a pair of dorso-apical setae on the first antennal segment, which is unique among New World Thripinae. Moreover, the anterior ocellus is situated anterior to frontal margin of compound eyes; and females have a highly reduced ovipositor, without reaching the apex of abdomen. Males have unusually small antennal segment III and greatly enlarged segments IV–VI with numerous long setae; tergite IX bears a pair of drepanae and sternites III and IV bear a pair of circular pore plates (Mound et al. 2016).

Pseudodendrothrips Schmutz is a genus comprising leaf-feeding thrips of the subfamily Dendrothripinae under Thripidae. Its members are comparatively smaller than other thripids, and a majority of them are very pale in colour. The abdominal tergites bear transverse striae, with longitudinal ridge-like sculpture lines laterally; the metanotum has linear sculpture medially, with the median setae far behind the anterior margin. The antennae are eight to nine-segmented; segment VI entire or subdivided, the sensorium on VI and VII arising close to the base of these segments. The anterior marginal cilia of the forewing arise near the costal margin; the hind tarsi are exceptionally elongate with two stout spatulate setae ventro-laterally (Mound 1999).

Material and Methods

Extensive random taxonomic surveys were conducted during 3–10 March 2016 and 17–20 April 2016, respectively at Agartala in Tripura and Valparai in Tamil Nadu. Specimens were collected at random by gentle tapping of plant parts on the board and laying yellow pan water traps at the canopy level of the plants at specific localities with dense and diverse crops. The collected specimens were preserved in collection fluid (nine parts 10% alcohol + one part glacial acetic acid + one ml Triton X-100 in 1000ml of the mixture). Specimens were balsam mounted for permanent preservation (Ananthakrishnan & Sen 1980) and they were subsequently sorted out and identified with the help of standard keys (Mound 1999; Mound et al. 2016; Tong et al. 2016). The images of all the three species were photographed with the help of a binocular research microscope.

Results

***Asprothrips bimaculatus* Michel & Ryckewaert**

Material studied: ICAR/NBAIR/THYS/162-166, 4 females, 17.iv.2016, India, Tamil Nadu, Valparai, Yellow pan trap, coll. Rameshkumar Anandan. All specimens have been deposited in the National Bureau of Agricultural Insect Resources (ICAR-NBAIR), Bengaluru, India.

Diagnosis: Female Macroptera (Image 1): Body bicoloured, head and thorax brown, abdomen white with two brown patches on tergite VI, antennal segments I–II brown, III–V white, VI brown distally, VII–VIII brown; fore and mid legs brown, hind legs white; forewings brown with basal area white. Ocellar setae pair I absent, pair II close to the margin of compound eyes, pair III within the ocellar triangle; four pairs of postocular setae. Antennal segment III pedicellate, VI with two long sense cones, almost reaching the apex of segment VIII. Pronotum reticulate with internal markings, except in discal area. Mesonotum with transverse lines, anterior campaniform sensilla present, median setae pair situated far from posterior margin. Metanotum reticulate medially, campaniform sensilla present. Hind tibiae with two stout apical setae. Tergite sculptured laterally, bearing spine-like microtrichia, tergites VII–VIII with posteromarginal

Image 1. *Asprothrips bimaculatus* Michel & Ryckewaert

comb bearing median row of small denticulations.

Asprothrips navsariensis and *A. indicus* have been reported from India (Rachana & Varatharajan 2017). Newly reported species can be distinguished from *A. navsariensis* and *A. indicus* by having bicoloured body, two brown patches on tergite VI of abdomen and brown forewings with basal white area.

Distribution: India (Tamil Nadu) (new record); Martinique (Michel & Ryckewaert 2014); Malaysia (ThripsWiki 2017); China (Tong et al. 2016).

***Plesiothrips perplexus* (Beach)**

Material studied: ICAR/NBAIR/THYS/110-112, 2 females, 06.iii.2016, India, Tripura, Agartala, Yellow pan trap, coll. Prashanth Mohanraj. All specimens have been deposited in the National Bureau of Agricultural Insect Resources (ICAR-NBAIR), Bengaluru, India.

Diagnosis: Female Macroptera (Image 2): Head and thorax brown; abdomen light yellow, segments IX and X darker; antennae brown, 7-segmented; segment III light yellow, IV light brown, segments III and IV with forked sense cones, IV longer than III. Head produced anteriorly to form a triangular area; anterior ocellus on this triangular area, anterior to frontal margin of compound eyes; interocellar setae situated just above the inner side of posterior ocelli. Cheeks curved behind protuberant compound eyes. Pronotum as long as head, slightly wider than head; two pairs of long posteroangular setae, three pairs of posteromarginal setae. Forewing slender, upper vein with 13 + 2 setae. Posterior margin of tergite VIII without marginal comb, tergite X with a complete median split. Sternites without discal setae.

Distribution: India (Tripura) (new record); Taiwan (Chen 1979); USA, California, Texas, Mexico, Australia (Mirab-balou et al. 2011).

***Pseudodendrothrips darci* (Girault)**

Material studied: ICAR/NBAIR/THYS/127-131, 4 females, 06.iii.2016, India, Tripura, Agartala, Yellow pan trap, coll. Prashanth Mohanraj. All specimens have been deposited in the National Bureau of Agricultural Insect Resources (ICAR-NBAIR), Bengaluru, India.

Diagnosis: Female Macroptera (Image 3): Body white; interantennal projection brown; pronotum having paired longitudinal brown markings sublaterally with a transverse dark line interrupted at middle; pterothorax shaded laterally; antennal segment II darkest, remaining segments shaded, IV–VI white at base; forewing including clavus light brown but apex paler. Head with three pairs of ocellar setae, ocellar setae I anterolateral to first ocellus, ocellar setae III within ocellar triangle; antennae with nine segments, III and IV with a long and forked sense cone each. Pronotum with closely spaced transverse striae; four pairs of posteromarginal setae. First vein of forewing with three setae basally and three distally, second vein without setae; wing apex with a terminal seta. Abdominal tergite I sculptured medially, median setae wider apart than their length; tergites II–VIII with long median setae and close together; VIII with long marginal comb of microtrichia, VI–VII with few similar microtrichia medially; II–VII laterally with

Image 2. *Plesiothrips perplexus* (Beach)

Image 3. *Pseudodendrothrips darci* (Girault)

numerous short linear ridges between transverse sculpture lines; sternites with transverse lines of sculpture, bearing three pairs of relatively long marginal setae.

The presence of a pair of longitudinal brown markings on the pronotum is characteristic of *Pseudodendrothrips bhattii* and *P. darci,* being absent in rest of the members of this genus (Mound 1999). These two species are difficult to distinguish, but unpublished observations of Masami Masumoto (Masami Masumoto, in litt., 05 April 2017) state that *P. bhattii* is devoid of a dark line on pronotum, differentiating it from *P. darci*.

Distribution: India (Tripura) (new record), Australia (Mound 1999).

Discussion

The present report on the occurrence of three terebrantian species, namely *Asprothrips bimaculatus, Plesiothrips perplexus* and *Pseudodendrothrips darci* in India adds a new dimension to the faunistic wealth of the country. Since the eight known species of *Asprothrips* are all described from Asia, the present study shares the view that they appear to be Asian in origin. In this context, the present collection of *A. bimaculatus* from India corroborates the above view. Further, it is also evident from the tendency of widespread occurrence of *A. seminigricornis* in greenhouses of several countries (Mound 1999) and a conspicuous distribution pattern of *A. bimaculatus* between the Caribbean region and Asia (Tong et al. 2016) that the members of this genus can move far and wide from Asia. With respect to *Plesiothrips,* it is known that members of this genus are invariably confined to the New World, except for *P. perplexus* that has become widely spread across the tropics and sub-tropics on grassy weeds. There were, however, no reports pertaining to genus *Plesiothrips,* nor occurrence of *P. perplexus* in India. Hence our findings take the credit of recording the genus *Plesiothrips* in India for the first time. Although the present report is based on thrips collection at random from diverse habitats and agro-ecosystems, chances of these species becoming active on crops are appreciably high by virtue of the fact that members of the genus *Asprothrips* have already been recorded from the leaves of turmeric and arrow root (Ananthakrishnan 1984). Similarly, the dendrothripine *P. darci* has been described as a pest of *Ficus* species in northern Australia (Mound 1999). Therefore, the present study not only highlights the new record of these thrips in India, but indicates the need for further study to monitor these herbivores so that they do not attain the status of a pest.

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Short Communication

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New records of earthworm fauna (Oligochaeta: Glossoscolecidae and Megascolecidae) collected from Satkosia-Baisipalli Wildlife Sanctuary of Odisha, India

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Abstract: A survey work was conducted in Satkoshia-Baisapalli Wildlife Sanctuary in Odisha, India, where altogether 10 earthworm species were collected. Out of these, four species—*Pontoscolex corethrurus* (Müller, 1856), *Metaphire houlleti* (Perrier, 1872), *Perionyx bainii* Stephenson, 1915, *Perionyx barotensis* Julka & Paliwal 1993—are reported for the first time after the original description and is proved to be a new record for the state of Odisha.

Keywords: Earthworms, *Metaphire houlleti,* new record, Odisha, *Perionyx bainii, Perionyx barotensis, Pontoscolex corethrurus*, taxonomic.

Extensive areas in Indian forest reserves are still unexplored and have never been sampled for earthworms. To estimate earthworm biodiversity correctly, the majority of species in the country are yet to be found and described. Consequently, new locations should be sampled, which represents a great challenge, since there are few researchers working in this area. With this view Satkoshia-Baisapalli Wildlife Sanctuaries in Odisha, India were selected for earthworm faunal survey (Image 1). These twin reserves are the meeting point of two bio-geographic regions of India, the Deccan peninsula and the Eastern Ghats, contributing immense earthworm diversity in that area. The landscape is hilly and the general elevation is around 350m from sea level. The climate of the region is tropical resulting in high summer temperatures. The Satkoshia gorge of the river Mahanadi and the reserve has tremendous genetic and ecological importance.

The first record of earthworms from Odisha was published by Michaelsen (1910). The work was followed by Stephenson and he described several species (1914, 1915, 1916, 1917, 1921, 1923, 1926). Subsequently, many other scientists presented data about earthworms from Odisha, viz., Julka (1976, 1978), Patra & Dash (1973), Das & Patra (1977), Senapati & Dash (1979, 1981, 1982, 1983), Dash & Senapati (1980), Senapati et al. (1979), Senapati (1980). Thirty species are described by Julka et al. (1987). Blakemore (2006) made a checklist of earthworms of Odisha and Goswami et al. (2013) worked on taxonomical records of earthworms from Odisha. The aim of the present paper is to report on these collections, including four new records from Odisha (Fig. 1).

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Materials and Methods

Live earthworm were narcotised in 70% alcohol and then washed and preserved in 10% formalin with proper labeling. The specimens were studied under the Leica EZ4 microscopic binocular. All the studied specimens are deposited at the National Zoological Collection of Zoological Survey of India, Kolkata. The registration numbers are mentioned in material examined. GPS with elevation, temperature and pH were recorded during the collection. Photographs were taken by Leica EZ4HD to specify the identified characters.

Taxonomic description

I. Family: Glossoscolecidae

1. Genus *Pontoscolex* Schmarda, 1861

(1) *Pontoscolex corethrurus* (Muller, 1856)

II. Family: Megascolecidae

2. Genus *Metaphire* Sims & Easton, 1972

(2) *Metaphire houlleti* (Perrier, 1872)

3. Genus *Perionyx* Perrier, 1872

(3) *Perionyx bainii* Stephenson, 1915

(4) *Perionyx barotensis* Julka & Paliwal, 1993

Systematic Accounts

I. Family Glossoscolecidae

1. Genus *Pontoscolex* Schmarda 1861

(1) *Pontoscolex corethrurus* (Muller) (Image 2)

1856. *Lumbricus corethrurus* Muller, Abhandl. Naturgesch. Ges. Halle, 4:26.

1897. *Pontoscolex corethrurus*: Michaelsen, Mitt. Mus. Hamburg, 14: 247

Diagnosis: Length 45–100 mm.; diameter 2-4 mm. Segments 60-230. Dorsal side is reddish brown and ventral side is colourless. Dorsal pore absent. Prostomium elongated like a long thin proboscis while it moves. Clitellum saddle shaped, covering 14–22. Setae lumbricine, i.e., 8 per segment in regular rows, but in the tail region setae rows enlarged and becomes alternative in adjacent segments i.e., quincunx arrangement. Male pores (20/21) and 3 pairs spermathecal pores (6/7-8/9) are minute. Female pore is a transverse slit at left side of mid ventral line at AB, in front of intersegmental furrow 14/15.

Distribution: India (Odisha, Andaman Islands, Andhra Pradesh, Gujarat, Karnataka, Kerala, Maharashtra, Tamil

Image 1. Study area - different locations in Satkoshia-Baisipalli Wildlife Sanctuary in Odisha

Nadu, West Bengal), Africa, Australia, Belize, Indonesia, Iran, Madagascar, Mexico, Myanmar, Pakistan, Sri Lanka, South America, Thailand, USA.

Type locality: Itajahy, Brazil.

Material examined: An4112/1 ZSI, 17exs., 26.i. 2016, Tarva, Pampasar range of Satkoshia, 20.70081^{0}N & 84.83843^{0}E, coll. R. Goswami.

Remarks: This species make the soil hard and compact.

II. Family Megascolecidae

2. Genus *Metaphire* Sims & Easton, 1972

(2) *Metaphire houlleti* (Perrier, 1872) (Image 3)

1872. *Perichaeta houlleti*, Perrier, Nouv. archs. Mus. Hist. nat. Paris, 8: 99.

1900. *Pheretima houlleti* (in part), Michaelsen, Tierreich, 10: 273.

1982. *Metaphire houlleti*, Julka, Rec. Zool. Surv. India, 80: 142.

Diagnosis: Length 60–105 mm, diameter 2–3 mm, segments 95–100. Colour brownish on dorsal side. Prostomium epilobic, tongue open. Combined & paired male and prostatic pores. Female pore single on xiv. Spermathecal pores paired in 6/7/8/9. External genital markings absent.

Distribution: India (Odisha, Andaman & Nicobar Islands, Himachal Pradesh, Jammu & Kashmir, Karnataka, Kerala, West Bengal), Australia, Bahamas, Bangladesh, Caroline Islands, China, Cuba, Fiji, France, French Guiana, Indonesia, Madagascar, Malay Peninsula, Myanmar, Nepal, Pakistan, Philippines, Salvador, Sierra Leone, Singapore, Sri Lanka, Thailand, USA (Florida), Vietnam.

Type locality: Kolkata, West Bengal, India.

Material examined: An4105/1 ZSI, 7exs., 26.i.2016, Hatibari mundasai -1 of Satkoshia, 20.6197^{0}N & 84.80745^{0}E, coll. R. Goswami. An4114/1 ZSI, 19exs., 27.i.2016, Chotakei, Purnakote range of Satkoshia, 20.63511^{0}N & 84.88006^{0}E, coll. R. Goswami.

Remarks: The origin of this species is in Southeast Asia.

3. Genus *Perionyx* Perrier 1872

(3) *Perionyx bainii* Stephenson, 1915 (Image 4)

1915. *Perionyx bainii* Stephenson, Mem. Indian Mus., 6: 72

Diagnosis: Length 50–65 mm, diameter 3–3.5 mm, segments 84–100. Colour bluish purple, pale ventrally. Prostomium epilobic, tongue open. Clitellum annular, xiii-xvii. Paired male and prostatic pores are combined in the xviii segment. 7–10 penial setae present to each pore in the median. Spermathecal pores in 7/8/9 in large transverse slits.

Distribution: India (Odisha, Himachal Pradesh, Uttar Pradesh).

Material examined: AnSZ 161 ZSI 3 exs., 20.i.16, Kuanria dam-2 of Baisipalli, 20.34698^{0}N & 84.80726^{0}E, coll. R. Goswami.

(4) *Perionyx barotensis* Julka & Paliwal 1993 (Image 5)

1993. *Perionyx barotensis* Julka & Paliwal, J. Bom. Nat. His. Soc. 90(3): 461–462.

Diagnosis: Length 70–90 mm, diameter 2–3 mm, segments 103–125. Colour bluish purple, pale ventrally. Prostomium epilobic. Tongue open. Clitellum annular, xiii-xvii. Transversely elliptical male genital area on xviii.

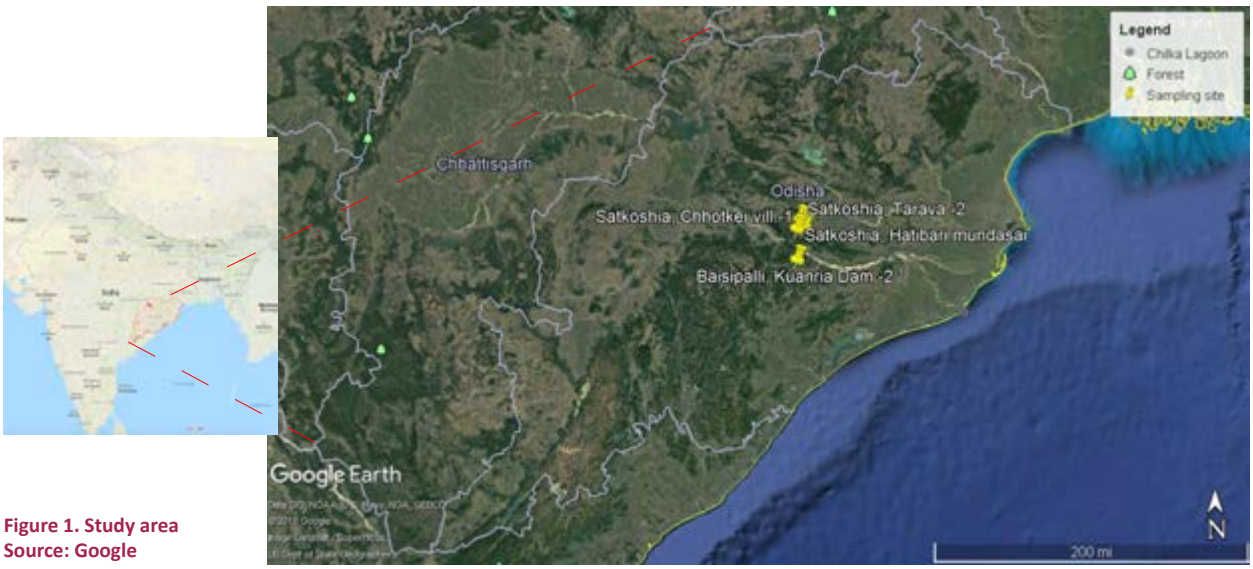

Figure 1. Study area
Source: Google

Image 2. Prostomium and genital organs of *Pontoscolex corethrurus*

Image 3. Prostomium and genital organs of *Metophire houlleti*

Image 4. Prostomium and genital organs of *Perionyx bainii*

Image 5. Prostomium and genital organs of *Perionyx barotensis*

Male pores and minute prostatic pores are combined. Paired, minute spermathecal pores on 7/8/9.

Distribution: India: Odisha, Himachal Pradesh, Uttar Pradesh.

Material examined: AnSZ173 ZSI, 1 ex., 20.i.16, Kuanria dam of Baisipalli, 20.34698^{0}N & 84.80726^{0}E coll. R. Goswami; An4105/19 ZSI, exs., 26.i.16, Hatibari mundasai -1of Satkoshia, 20.61966^{0}N & 84.80733^{0}E, coll. R. Goswami.

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Table 1. The location, different edaphic factors, and new record species of earthworms in different collecting spots.

Camp name & WS Range	Date	Collection Area	GPS	No. of Earthworm exs	pH	Temp at ºC	Elevation (Feet)	Name of the species
Satkoshia (Pampasar Range)	26.i.16	Tarava -2	20.70081^{0}N & 84.83843^{0}E	17	7.17	22.3	13	*Pontoscolex corethrurus* (Muller, 1856)
Satkoshia (Tikarpada Range)	26.i.16	Hatibari mundasai -1	20.6197^{0}N & 84.80745^{0}E	7	7.16	21.2	45	*Metaphire houlleti* (Perrier, 1872)
	26.1.16	Hatibari mundasai-2	20.61966^{0}N & 84.80733^{0}E	1	7.15	21.5	45	*Metaphire houlleti* (Perrier, 1872)
Satkoshia (Pampasar Range)	26.1.16	Tarava -1	20.70068^{0}N & 84.8386^{0}E	1	7.19	22.4	13	*Metaphire houlleti* (Perrier, 1872)
Satkoshia, Purunakote Range (Chhotkei)	27.1.16	Chhotkei vill.-1	20.63511^{0}N & 84.88006^{0}E	19	7.37	23.5	25	*Metaphire houlleti* (Perrier, 1872)
Baisipalli- Kuanria (Banigocha west Range)	20.1.16	Kuanria Dam -2	20.34698^{0}N & 84.80726^{0}E	3	7.5	23.3	11	*Perionyx bainii* Stephenson, 1915
Baisipalli- Kuanria (Banigocha west Range)	20.1.16	Kuanria Dam -2	20.34698^{0}N & 84.80726^{0}E	1	7.5	23.3	11	*Perionyx barotensis* Julka & Paliwal, 1993
Satkoshia (Tikarpada Range)	26.1.16	Hatibari mundasai -1	20.61966^{0}N & 84.80733^{0}E	9	7.15	21.5	45	*Perionyx barotensis* Julka & Paliwal, 1993

Key to the identification of earthworms of the new records

1. Setae 8 on each segment in 4 pairs throughout the body 2
1′. Setae numerous or, more than 8 on each segment throughout the body 3
2. Setae on posterior segments arranged in irregular rows, alternating between dorsal and ventral positions ... *Pontoscolex corethrurus*
3. Nephridia astomate, gizzard between7/8 and 9/10, male pores within copulatory pouches 4
3′. Nephridia stomate, colour usually reddish to violet; gizzard vestigial in segment v or vi 5
4. Invaginated spermathecal pores recognizable internally by the presence of stalked glands. Genital markings, when present, small and in the vicinity of spermathecal pores ..... *Metaphire houlleti*
5. Male pores are longitudinal slits, each overhung by a small tubercle. A group of penial setae present to each male pore .... *Perionyx bainii*
5′. Male pores and minute prostatic pores are combined. Male genital field without penial setae ..... *Perionyx barotensis*

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SHORT COMMUNICATION

Diversity and endemism of butterflies of montane forests of Eravikulam National Park in the Western Ghats, India

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OPEN ACCESS

Abstract: In a study on the diversity and abundance of butterflies of montane forests of Eravikulam National Park in the Western Ghats, southern India, 85 species of butterflies belonging to six families were recorded. This include eight species of butterflies that are endemic to the Western Ghats and one Near-Threatened species according to IUCN Red List of Threatened Species. The family Nymphalidae, the brush-footed butterflies, was the major group of butterflies seen in the montane forests of Eravikulam National Park.

Keywords: Biodiversity hotspot, conservation, Hesperiidae, IUCN, Lycaenidae, Nymphalidae, Papilionidae, Pieridae, Riodinidae.

The Western Ghats is one of the biodiversity hot spots of the world (Myers et al. 2000). This region is rich in endemism including butterflies and has been of great interest for biogeography. The natural habitats in the Western Ghats is under tremendous pressure from the biotic influences (Jha et al. 2000; Mittermeier et al. 1998). Butterflies are suitable for biodiversity studies, because their taxonomy and geographic distribution are better understood compared to many other taxonomic groups (Pandhye et al. 2012). Butterflies are also regarded as good indicators of habitat quality as many species exhibit habitat preferences and seasonality (Larsen 1988; Kunte 1997). Butterflies are sensitive biota, which get severely affected by environmental variations and changes in forest structure (Pollard 1991). India has around 1,501 species of butterflies, out of which 336 species have been reported from the Western Ghats (Kunte et al. 2018). Of the 336 species of butterflies of the Western Ghats, 316 species have been reported from Kerala (Palot et al. 2012).

Although quite a few studies have been done on the butterflies of the Western Ghats (Gaonkar 1996; Kunte 2000, 2008; Kehimkar 2008; Padhye et al. 2012), very little is known about the butterflies of the montane habitats of the southern Western Ghats. Some of the earlier documentation on butterfly fauna from the Western Ghats include—100 species from Silent Valley National Park (Mathew & Rahamathulla 1993), 124 species from Parambikulam Wildlife Sanctuary (Sudheendrakumar et al. 2000), 75 species from Siruvani Reserve Forests (Arun

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2003), 73 species from Shendurney Wildlife Sanctuary (Mathew et al. 2004), 74 species from Peechi-Vazhani Wildlife Sanctuary (Mathew et al. 2005), 24 species from Kalakkad-Mundanthurai Tiger Reserve (Ambrose & Raj 2005), 75 species from Anaikatty Reserve Forests (Eswaran & Pramod 2005), 53 species from Neyyar Wildlife Sanctuary (Mathew et al. 2007), and 282 species from the Kerala part of Nilgiri Biosphere Reserve (Mathew 2016). A checklist of butterflies of Western Ghats reported 834 species of plants as larval host plants of 320 butterflies (Nitin et al. 2018). In this paper we give an account of the butterfly fauna of the montane forests of Eravikulam National Park, based on a four-month long study done in 2014.

Study Area

Eravikulam National Park (ENP) (Fig. 1) is located between 10.08333–10.33333 ^{0}N & 77.00–77.16 ^{0}E in Idukki District of Kerala. The ENP forms part of the Munnar Hills, a part of the High Ranges of Western Ghats, which has six protected areas, viz., Anamudi Shola National Park, Pampadum Shola National Park, Mathikettan Shola National Park, Chinnar Wildlife Sanctuary, Kurinjimala Wildlife Sanctuary, and ENP; it is contiguous with the Palni Hills and Anamalai Hills. The ENP has an extent of 97km^2 and the terrain is undulating with grassland and shola, the stunted high altitude evergreen forests, as the dominant vegetation.

Climate: Eravikulam has a tropical montane climate. The average annual rainfall is about 5,000–6,500 mm. The area receives both south-west as well as north-east monsoons. The mean monthly minimum temperature is 11.9^{0}C, while the mean monthly maximum temperature is 22.5^{0}C. The altitude of ENP ranges from 1,800–2,695 m, typical of a montane landscape and the highest peak is Anamudi (2,695m).

Vegetation: The major plant communities found within ENP are grasslands, shrub lands, and forests. The terrain above 2,000m is covered primarily by grasslands (~60%), about 25% by shola forests, 8% by southern sub-tropfical hill forest, and 7% by shrubs (Menon 2001).

Methods

The study was conducted from September 2014 to December 2014. The whole of the study area was divided into nine blocks based on topography and drainage (Table 1) and five days each were spent on each of these blocks. At each basecamp two to three hour long transects were walked in the morning from 10:00–13:00 hr. No afternoon transects could be done because of the unfavourable weather conditions, such as mist, cloud and northeastern monsoon rains. During these transect walks, the butterflies were identified to the species level and the number of individuals were counted. Attempt was also made to photo-document every species of butterflies sighted. The butterflies were identified using the field guides of Kunte (2000) and Kehimkar (2008), and for taxonomy and nomenclature,

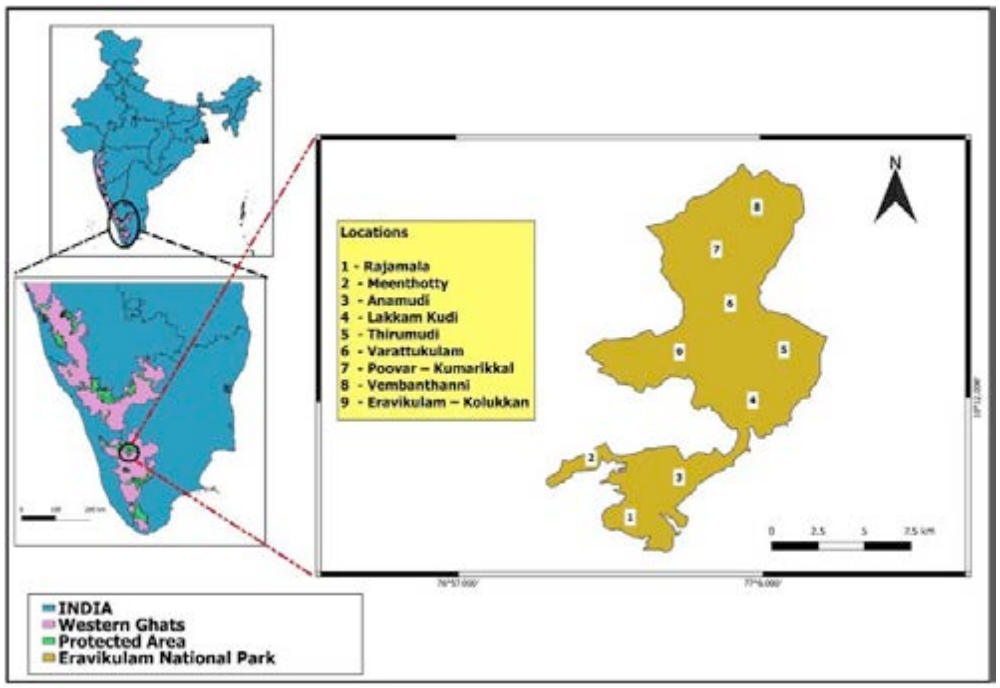

Figure 1. Location map of Eravikulam National Park

Table 1. Basecamp details of the study locations at Eravikulam National Park (modified after Praveen & Nameer 2015)

Camps	Altitude (m)	Habitats
Rajamala	1,750	Shola, grasslands, rocky out-crops and shrubs, adjacent to tea plantations
Meenthotty	1,950	Shola, grasslands, rocky out-crops, adjacent to tea plantations and tribal settlements
Anamudi	2,150	Shola, grasslands, adjacent to tea plantations
Lakkam Kudi	1,450	Shola, grasslands, adjacent to tea plantations, coffee plantation and tribal settlements
Thirumudi	1,625	Shola, grasslands, adjacent to tribal settlements
Varattukulam	2,100	Shola, grasslands, adjacent to degraded grasslands
Poovar - Kumarikkal	2,125	Shola, grasslands
Vembanthanni	2,125	Shola, grasslands
Eravikulam - Kolukkan	2,180	Shola, grasslands

we followed Kunte et al. (2018).

The abundance of the butterflies was calculated using the following method, species observed 80–100 % of the survey days were categorized as very common (VC), 60–80 % as common (C), 40–60 % as occasional (O), 20–40 % as rare (R) and below 20% as very rare (VR) (after Aneesh et al. 2013).

Results

A total of 85 species of butterflies belonging to six families such as, Papilionidae (10 species), Pieridae (15), Nymphalidae (36), Riodinidae (1), Lycaenidae (9), and Hesperiidae (14) (Table 2) were identified from the montane habitat of ENP. This included eight species that are endemic to the Western Ghats. They are Sahyadri Birdwing *Troides minos*, Nilgiri Clouded Yellow *Colias nilagiriensis*, Red-disc Bushbrown *Heteropsis oculus*, Nilgiri Four-ring *Ypthima chenui*, Palni Four-ring *Ypthima ypthimoides*, Palni Fritillary *Argynnis castetsi*, Nilgiri Tiger *Parantica nilgiriensis* and Striped Hedge Hopper *Baracus subditus*. The proportion between the endemic and non-endemic species of butterflies in the different basecamps are given in Fig 2. The basecamps such as Meenthotty, Rajamala, Anamudi and Eravikulam-Kolukkan recorded the greatest proportion of the endemic butterflies at ENP, while the Lakkam Kudi basecamp recorded the greatest proportion of the non-endemic species of butterflies. While the basecamps that recorded the greatest proportion of endemic butterflies were all within the core zone of the ENP, the Lakkam Kudi basecamp is very close to human habitation and the elevation is also the lowest. The Palni Four-ring found to be the most abundant species among endemic species was found in ENP.

Highest species diversity was observed in Lakkam Kudi area (51 species), followed by Poovar-Kumarikkal (47), Eravikulam-Kolukkan (45), Vembanthanni (43), Thirumudi (41), Anamudi (37), Varattukulam (33), Rajamala (29) and Meenthotty (13) (Fig. 3). The relative abundance of the butterflies was highest in the family Nymphalidae (57.6%), followed by Pieridae (25%) and Papilionidae (10.4%). The other three butterfly families account for the remaining 7% of the butterflies of ENP (Fig. 4).

The only threatened species of butterfly recorded as per the IUCN category was the Nilgiri Tiger *Parantica nilgiriensis*. It belonged to the Near Threatened category (Lepidoptera Specialist Group 1996). The relative abundance study revealed that 27.05% of species of butterflies belonged to very rare (VR) followed by

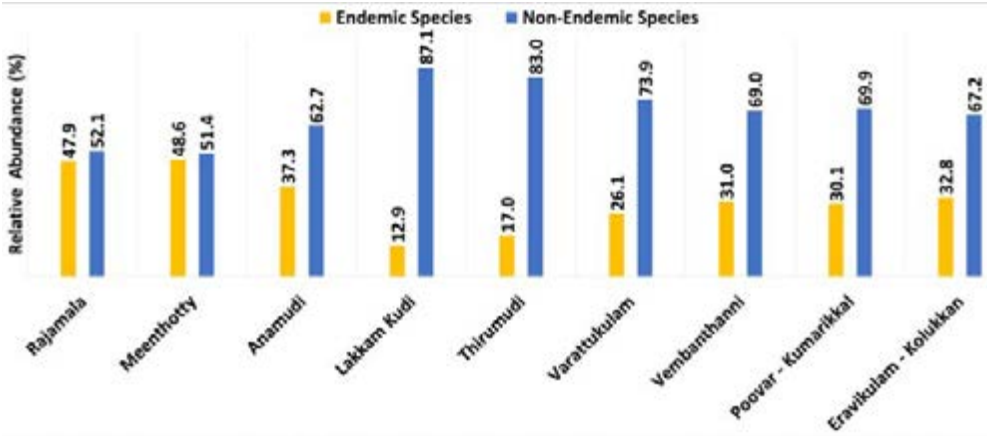

Figure 2. Percentage relative abundance of endemic and non-endemic species of butterflies in different study locations of Eravikulam National Park

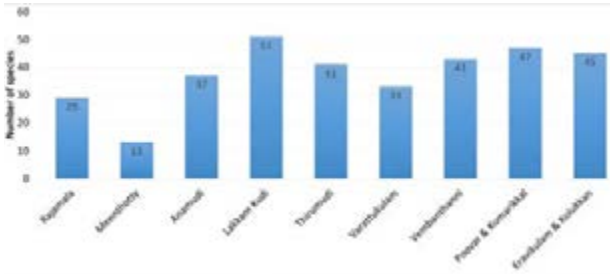

Figure 3. Species richness of butterflies in different study locations of Eravikulam National Park

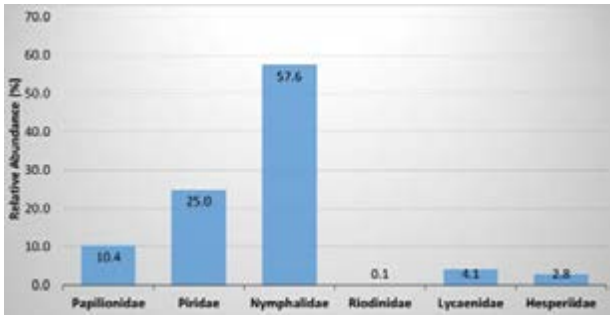

Figure 4. Relative abundance of families of butterflies in Eravikulam National Park

28.24% of species that were rare (R) (Table 2).

This is the first ever documentation of the butterflies of a montane habitat in the Western Ghats, which highlights the significance of these habitats on the conservation of high altitude, endemic butterflies of the Western Ghats.

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Table 2. Checklist of butterflies of Eravikulam National Park

Common English name/Family	Scientific name	Species authority	Image number	Abundance
Family Papilionidae				
Sahyadri Birdwing*	*Troides minos*	Cramer, 1779	1	O
Common Rose	*Pachliopta aristolochiae*	Fabricius, 1775	2	VR
Crimson Rose	*Pachliopta hector*	Linnaeus, 1758	3	O
Common Bluebottle	*Graphium sarpedon*	Linnaeus, 1758	4	VC
Tailed Jay	*Graphium agamemnon*	Linnaeus, 1758	5	R
Lime Swallowtail	*Papilio demoleus*	Linnaeus, 1758	6	O
Red Helen	*Papilio helenus*	Linnaeus, 1758	7	C
Common Mormon	*Papilio polytes*	Linnaeus, 1758	8	C
Blue Mormon	*Papilio polymnestor*	Cramer, 1775	9	C
Paris Peacock	*Papilio paris*	Linnaeus, 1758	10	O
Family Pieridae				
Lemon Emigrant	*Catopsilia pomona*	Fabricius, 1775	11	C
Mottled Emigrant	*Catopsilia pyranthe*	Linnaeus, 1758	12	O
Spotless Grass Yellow	*Eurema laeta*	Boisduval, 1836	13	VC
One-spot Grass Yellow	*Eurema andersoni*	Moore, 1886	14	VR
Common Grass Yellow	*Eurema hecabe*	Linnaeus, 1758	15	O
Three-spot Grass Yellow	*Eurema blanda*	Boisduval, 1836	16	R
Nilgiri Clouded Yellow*	*Colias nilagiriensis*	Felder & Felder, 1859		VR
Indian Jezebel	*Delias eucharis*	Drury, 1773	17	R
Asian Cabbage White	*Pieris canidia*	Linnaeus, 1768	18	VC
Common Gull	*Cepora nerissa*	Fabricius, 1775	19	R
Lesser Gull	*Cepora nadina*	Lucas, 1852		VR
Pioneer	*Belenois aurota*	Fabricius, 1793	20	C
Common Albatross	*Appias albina*	Boisduval, 1836	21	C
Yellow Orange-tip	*Ixias pyrene*	Linnaeus, 1764	22	O
Great Orange-tip	*Hebomoia glaucippe*	Linnaeus, 1758		C
Family Nymphalidae				
Common Evening Brown	*Melanitis leda*	Linnaeus, 1758	23	VR
Common Treebrown	*Lethe rohria*	Fabricius, 1787	24	R
Tamil Bushbrown	*Mycalesis subdita*	Moore, 1892	25	R
Red-disc Bushbrown*	*Telinga oculus*	Marshall, 1880	26	VC
Common Four-ring	*Ypthima huebneri*	Kirby, 1871	27	O
Common Five-ring	*Ypthima baldus*	Fabricius, 1775	28	C
Nilgiri Four-ring*	*Ypthima chenu*	Guérin-Méneville, 1843	29	R
Palni Four-ring*	*Ypthima ypthimoides*	Moore, 1881	30	VC
Tawny Coster	*Acraea terpsicore*	Linnaeus, 1758	31	O
Rustic	*Cupha erymanthis*	Drury, 1773	32	R
Common Leopard	*Phalanta phalantha*	Drury, 1773	33	R
Palni Fritillary*	*Argynnis castetsi*	Oberthür, 1891	34	R
Common Sailer	*Neptis hylas*	Linnaeus, 1758	35	O
Commander	*Moduza procris*	Cramer, 1777	36	VR
Clipper	*Parthenos sylvia*	Cramer, 1775	37	VR
Angled Castor	*Ariadne ariadne*	Linnaeus, 1763	38	O
Common Castor	*Ariadne merione*	Cramer, 1777		VR

Common English name/Family	Scientific name	Species authority	Image number	Abundance
Map Butterfly	*Cyrestis thyodamas*	Doyère, 1840	39	R
Common Beak	*Libythea lepita*	Moore, 1857	40	O
Yellow Pansy	*Junonia hierta*	Fabricius, 1798	41	O
Lemon Pansy	*Junonia lemonias*	Linnaeus, 1758	42	R
Chocolate Pansy	*Junonia iphita*	Cramer, 1779	43	R
Painted Lady	*Vanessa cardui*	Linnaeus, 1758	44	R
Indian Red Admiral	*Vanessa indica*	Herbst, 1794	45	VR
Blue Admiral	*Kaniska canace*	Linnaeus, 1763	46	R
Great Eggfly	*Hypolimnas bolina*	Linnaeus, 1758	47	O
Danaid Eggfly	*Hypolimnas misippus*	Linnaeus, 1764	48	VR
Glassy Tiger	*Parantica aglea*	Stoll, 1782	49	R
Nilgiri Tiger*	*Parantica nilgiriensis*	Moore, 1877	50	VC
Blue Tiger	*Tirumala limniace*	Cramer, 1775	51	VC
Dark Blue Tiger	*Tirumala septentrionis*	Butler, 1874	52	VC
Plain Tiger	*Danaus chrysippus*	Linnaeus, 1758	53	R
Striped Tiger	*Danaus genutia*	Cramer 1779	54	R
Common Crow	*Euploea core*	Cramer, 1780	55	C
Double-branded Crow	*Euploea sylvester*	Fabricius, 1793	56	O
King Crow	*Euploea klugii*	Moore, 1857	57	O
Family Riodinidae				
Double-banded Judy	*Abisara bifasciata*	Moore, 1877	58	VR
Family Lycaenidae				
White Hedge Blue	*Udara akasa*	Horsfield, 1828	59	C
Common Hedge Blue	*Acytolepis puspa*	Horsfield, 1828	60	VR
Pale Grass Blue	*Pseudozizeeria maha*	Kollar, 1844	61	R
Tiny Grass Blue	*Zizula hylax*	Fabricius, 1775	62	VR
Oriental Grass Jewel	*Freyeria putli*	Kollar, 1844		VR
Forget-me-not	*Catochrysops strabo*	Fabricius, 1793	63	R
Pea Blue	*Lampides boeticus*	Linnaeus, 1767	64	C
Common Cerulean	*Jamides celeno*	Cramer, 1775	65	R
Common Lineblue	*Prosotas nora*	Felder, 1860	66	VR
Family Hesperiidae				
Common Banded Awl	*Hasora chromus*	Cramer, 1780	67	VR
Common Awlking	*Choaspes benjaminii*	Guérin-Méneville, 1843		VR
Water Snow Flat	*Tagiades litigiosa*	Möschler, 1878	68	R
Common Yellow-breasted Flat	*Gerosis bhagava*	Moore, 1865	69	VR
Fulvous Pied Flat	*Pseudocoladenia dan*	Fabricius, 1787		VR
Dingy Scrub Hopper	*Aeromachus dubius*	Elwes & Edwards, 1897	70	C
Restricted Demon	*Notocrypta curvifascia*	Felder & Felder, 1862	71	VR
Striped Hedge Hopper*	*Baracus subditus*	Moore, [1884]	72	O
Giant Redeye	*Gangara thyrsis*	Fabricius, 1775		VR
Rounded Palm-redeye	*Erionota torus*	Evans, 1941	73	VR
Tawny-spotted Grass Dart	*Taractrocera ceramas*	Hewitson, 1868	74	O
Dark Palm-Dart	*Telicota bambusae*	Moore, 1878	75	R
Oriental Variable Swift	*Parnara bada*	Moore, 1878		R
Blank Swift	*Caltoris kumara*	Moore, 1878	76	VR

Image 1. Sahyadri Birdwing *Troides minos*

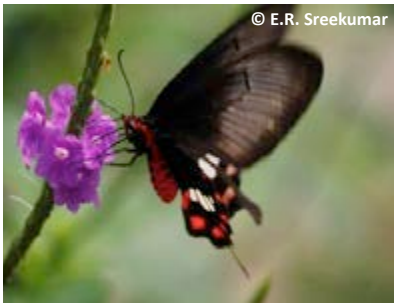

Image 2. Common Rose *Pachliopta aristolochiae*

Image 3. Crimson Rose *Pachliopta hector*

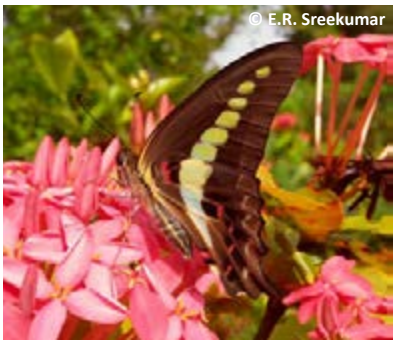

Image 4. Common Bluebottle *Graphium sarpedon*

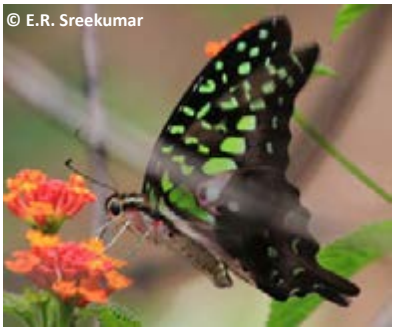

Image 5. Tailed Jay *Graphium agamemnon*

Image 6. Lime Swallowtail *Papilio demoleus*

Image 7. Red Helen *Papilio helenus*

Image 8. Common Mormon *Papilio polytes*

Image 9. Blue Mormon *Papilio polymnestor*

Image 10. Paris Peacock *Papilio paris*

Image 11. Lemon Emigrant *Catopsilia pomona*

Image 12. Mottled Emigrant *Catopsilia pyranthe*

Image 13. Spotless Grass Yellow *Eurema laeta*

Image 14. One-spot Grass Yellow *Eurema andersoni*

Image 15. Common Grass Yellow *Eurema hecabe*

Image 16. Three-spot Grass Yellow *Eurema blanda*

Image 18. Indian Jezebel *Delias eucharis*

Image 18. Asian Cabbage White *Pieris canidia*

Image 19. Common Gull *Cepora nerissa*

Image 20. Pioneer *Belenois aurota*

Image 21. Common Albatross *Appias albina*

Image 22. Yellow Orange-tip *Ixias pyrene*

Image 23. Common Evening Brown *Melanitis leda*

Image 24. Common Treebrown *Lethe rohria*

Image 25. Tamil Bushbrown *Mycalesis subdita*

Image 26. Red-disc Bushbrown *Telinga oculus*

Image 27. Common Four-ring *Ypthima huebneri*

Image 28. Common Five-ring *Ypthima baldus*

Image 29. Nilgiri Four-ring *Ypthima chenu*

Image 30. Palni Four-ring *Ypthima ypthimoides*

Image 31. Tawny Coster *Acraea terpsicore*

Image 32. Rustic *Cupha erymanthis*

Image 33. Common Leopard *Phalanta phalantha*

Image 34. Palni Fritillary *Argynnis castetsi*

Image 35. Common Sailer *Neptis hylas*

Image 36. Commander *Moduza procris*

Image 37. Clipper *Parthenos sylvia*

Image 38. Angled Castor *Ariadne ariadne*

Image 39. Map Butterfly *Cyrestis thyodamas*

Image 40. Common Beak *Libythea lepita*

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Image 44. Painted Lady *Vanessa cardui*

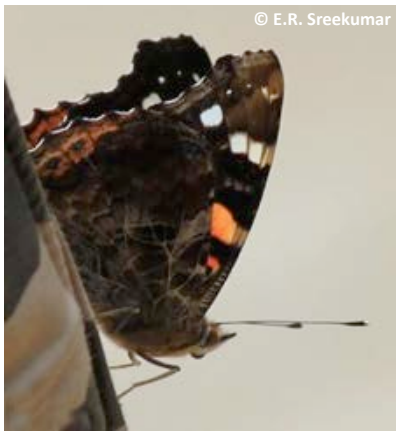

Image 45. Indian Red Admiral *Vanessa indica*

Image 46. Blue Admiral *Kaniska canace*

Image 47. Great Eggfly *Hypolimnas bolina*

Image 48. Danaid Eggfly *Hypolimnas misippus*

Image 49. Glassy Tiger *Parantica aglea*

Image 50. Nilgiri Tiger *Parantica nilgiriensis*

Image 51. Blue Tiger *Tirumala limniace*

Image 52. Dark Blue Tiger *Tirumala septentrionis*

Image 53. Plain Tiger *Danaus chrysippus*

Image 54. Striped Tiger *Danaus genutia*

Image 55. Common Crow *Euploea core*

Image 56. Double-branded Crow *Euploea sylvester*

Image 57. King Crow *Euploea klugii*

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Image 59. White Hedge Blue *Udara akasa*

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Image 71. Restricted Demon *Notocrypta curvifascia*

Image 72. Striped Hedge Hopper *Baracus subditus*

Image 73. Rounded Palm-redeye *Erionota torus*

Image 74. Tawny-spotted Grass Dart *Taractrocera ceramas*

Image 75. Dark Palm-Dart *Telicota bambusae*

Image 76. Blank Swift *Caltoris kumara*

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SHORT COMMUNICATION

Angiosperm diversity of Sonbhadra District, Uttar Pradesh: a checklist

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OPEN ACCESS

Abstract: The present study provides a taxonomic account of the angiosperms of Sonbhadra District in Uttar Pradesh. The district, which comes under the Vindhyan region of Uttar Pradesh, is one of the richest areas in the state as far as plant diversity is concerned. It is spread over about 6788km² of geographical area, which constitutes about 36% forest cover on highly undulated land. The extensive survey of the area conducted during 2011–2016, critical examination of previous collections housed at various herbaria, and review of published literature have resulted in a total of 705 species belonging to 459 genera under 110 families. Out of these, 541 species (76.73%) under 354 genera (77.12%) and 89 families (80.90%) belong to dicots, and 164 species (23.26%) under 105 genera (23.26%) and 21 families (19.09%) to monocots. The present enumeration of the species also includes about 78 species cultivated in the area for various purposes. Fabaceae (110 spp.) comprises of the maximum number of species, followed by Poaceae (89 spp.), Asteraceae (38 spp.), Cyperaceae (33 spp.), and Malvaceae (33 spp.). Some of the largest genera in the area are *Cyperus* (14 spp.), *Ipomoea* (9 spp.), *Solanum* (9 spp.), *Ficus* (9 spp.), *Crotalaria* (7 spp.), *Desmodium* (7 spp.), *Bauhinia* (6 spp.), *Hibiscus* (6 spp.), *Fimbristylis* (6 spp.), *Acacia* (5 spp.), etc. The entire forest is chiefly dominated by trees such as *Acacia catechu* (L.f.) Willd., *Boswellia serrata* Roxb. ex Colebr., *Butea monosperma* (Lam.) Taub., *Hardwickia binata* Roxb., and *Shorea robusta* Gaertn.

Keywords: Floristic diversity, Vindhyan region, Sonbhadra District, Uttar Pradesh.

The floristic account provides lots of information of plant wealth of an area, which may be beneficial for university students, botanists, researchers, NGOs, naturalists, environmental engineers, forest managers, conservation biologists, and policy makers. Knowledge of floristic composition and structure of forest is also useful in identifying ecologically and economically important plants, analysing their diversities, and protecting threatened plants (Addo-Fordjour et al. 2009). In the past, many important floristic accounts have been published for several states, districts, and biogeographic regions of India and abroad. In addition to general flora of Uttar Pradesh (Duthie 1903–1929; Kanjilal 1966; Rau 1969; Uniyal et al. 1999; Chaudhary et al. 2016), several works related to different districts, national parks, and sanctuaries have also been produced by many (Kanjilal 1933; Srivastava 1938; Singh 1969; Srivastava 1976; Sharma & Pandey 1984; Sharma & Dhakre 1995; Verma & Ranjan 1995; Singh 1997; Saini

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2005; Singh & Khanuja 2006; Kumar et al. 2015). The floristic account of Sonbhadra District of Uttar Pradesh, however, is still unexplored in spite of its rich diversity. The production of state flora will be easier, once all the district floras are worked out systematically. Hence, there is a need for proper inventory and documentation of all plants available in Sonbhadra District with their up to date taxonomic information. Since the area is very rich in minerals and forest resources, many industries and factories of different kinds have been set up here. Therefore, the present study will also be very important for a comparative study of the plants of the area in future and also to examine the effects of industrial pollutants on them.

Although the district has not been thoroughly inventoried earlier, the reference on the plants of the study area is available in Bhattacharyya (1963, 1964) and Srivastava (1955) wherein the plants of erstwhile Mirzapur District have been dealt with. In these studies, about 460 species have been listed including about 130 species from the study area. In addition, a few scattered works chiefly pertaining to ethnobotanical and medicinal plants have been carried out in the area (Singh et al. 2002; Chaudhary 2010; Singh et al. 2010; Singh et al. 2012; Singh & Dubey 2012; Mishra et al. 2012). Recently, Kushwaha et al. (2016 a, b) have thoroughly studied the family Cucurbitaceae of the area and have also presented a preliminary overview of angiospermic plants. Hence, the present work is the first study of its kind from the study area after its recognition as a district.

Materials and Methods

In this study, 12 field tours in different seasons were conducted between 2011–2016 to survey the area. The plant materials were collected either in flowering or fruiting or in both stages with detailed information such as habit, habitat, colour of flowers and fruits, shape and size of trees, nature of bark of trees, GPS information, conservation status, etc. The herbarium specimens were prepared following the standard procedure outlined by Lawrence (1951) and Jain & Rao (1977). The identification of species was done with the help of different floras and important taxonomic works (Hooker 1872–1897; Duthie 1903–1929; Brandis 1906; Singh 1997) and also after matching with the authentic specimens housed at various Indian herbaria such as Botanical Survey of India, Allahabad (BSA), Botanical Survey of India, Dehra Dun (BSD), Botanical Survey of India, Kolkata (CAL), Forest Research Institute, Dehra Dun (DD), and National Botanical Research Institute, Lucknow (LWG). All specimens collected in the present study have been deposited at LWG for future records. In the present treatment, each species was furnished with the correct recent name following websites such as The International Plant Names Index (IPNI), Germplasm Resources Information Network (GRIN), International Legume Database and Information Service (ILDIS), The Plantlist, Wikipedia, and Tropicos, along with habit, distribution and reference to voucher specimens. The families, genera, and species within the genus have been arranged alphabetically in the list. All photographs included in the study have been take by first author (AKK).

Study Area

Uttar Pradesh, one of the largest states of India with an area of about 240,928km^2, has been divided into 75 districts. Its forest cover, however, is about 16,583km^2, which is only 6.88% of its total geographical area (Forest Survey of India, 2011). In the present study, Sonbhadra District was selected for the floristic study to know the plant wealth of the area (Fig. 1; Image 1). Sonbhadra District was carved out from the district Mirzapur on 4 March 1989. It is the second largest district of the state comprising of about 6788km^2 geographical area. It lies between 23° 51'54" N–24° 46'18" N and 82° 40'24" E–83°33'15" E at elevations ranging from 315–485 m. The temperature of the area varies from 32°C–42°C in the summer and 2°C–15°C in the winter. This district is situated in the extreme southeast of the state, and is bounded by Mirzapur District in the northwest, Chandauli District in the north, Kaimur and Rohtas districts of Bihar in the northeast, Garhwa District of Jharkhand State in the east, Koriya and Surguja districts of Chhattisgarh State in the south, and Singrauli District of Madhya Pradesh in the west. The district occupies 36.79% (i.e., 3,782.86km^2) forest cover of the total geographical area of the state. The topography of the area is uneven due to the presence of hillocks. The area that comes under the Vindhyan plateau of the state has tropical dry deciduous forest (Singh & Dubey 2012).

Results and Discussion

The whole of the area is covered with natural scrubby jungle and thick forests. Almost the entire plateau exhibits a uniform horizontal stratification of rocks. The top of the plateau is unsuitable for the growth of broad-leaved plants and, is represented by uniform scrubby dry vegetation. The broad-leaved plants are generally seen on the slopes of the plateau. Overall, the entire forest is mixed dry deciduous, but evergreen trees are frequently seen in ravines. The data collected from

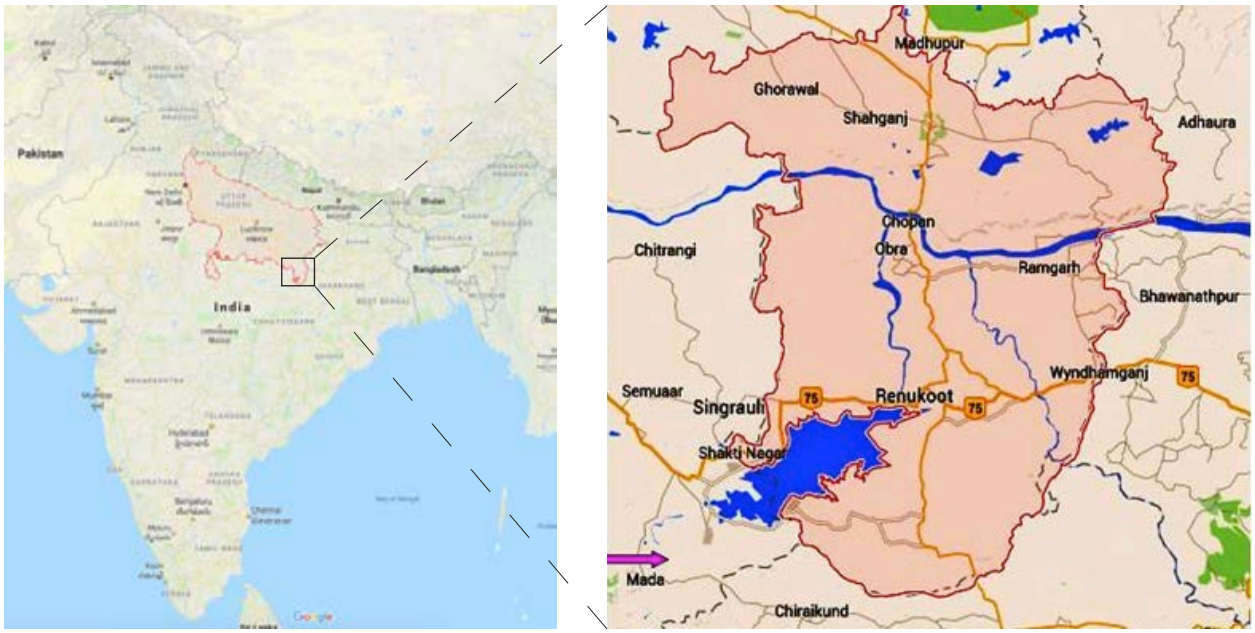

Figure 1. Study site: Sonbhadra District Uttar Pradesh. Source: India map from Google and Sonbhadra map from: https://www.google.co.in/maps/place/Sonbhadra,+Uttar+Pradesh.

Image 1. General views of the Sonbhadra District (a - hillock; b - miscellaneous forest; c - river; d - deciduous forest; e - lake; f - *Hardwickia binata* Roxb. forest).

field and herbarium studies reveal that the entire area contains about 705 species under 459 genera and 110 families including 78 cultivated ones that have been planted in the area for different purposes (Table 1; Images 2–3). Out of these, 541 species (76.73%) under 354 genera (77.12%) and 89 families (80.90%) belong to dicots and 164 species (23.26%) under 105 genera (22.87%) and 21 families (19.09%) to monocots (Fig. 2). The family Fabaceae has the maximum number of species (52 Genera, 110 species), followed by Poaceae (63 Genera, 89 species), Asteraceae (32 Genera, 38 species), Malvaceae (15 Genera, 33 species), Cyperaceae (9 Genera, 33 species), Cucurbitaceae (11 Genera, 20 species), Acanthaceae (11 Genera, 17 species),

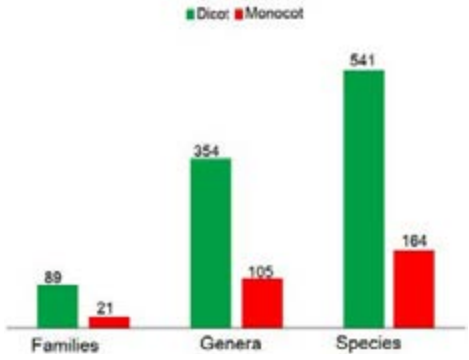

Figure 2. Analysis of Dicot and Monocot taxa.

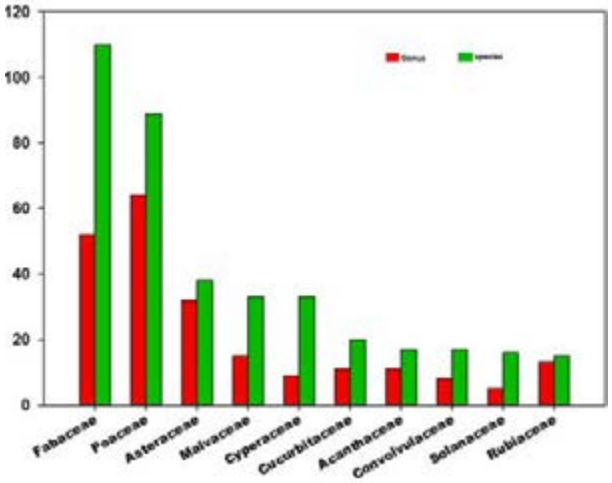

Figure 3. Largest families.

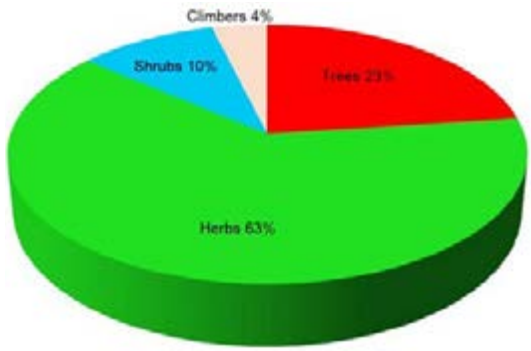

Figure 4. Different life forms of species.

Convolvulaceae (8 Genera, 17 species), Solanaceae (5 Genera, 16 species), and Rubiaceae (13 Genera, 15 species) (Fig. 3). Some of the dominant genera in the forest are *Cyperus* (14 spp.), *Ipomoea* (9 spp.), *Solanum* (9 spp.), *Ficus* (9 spp.), *Crotalaria* (7 spp.), *Desmodium* (7 spp.), *Bauhinia* (6 spp.), *Hibiscus* (6 spp.), *Fimbristylis* (6 spp.), *Acacia* (5 spp.), etc. Among all plants, 443 species (62.70%) are herbs, 163 species (23.12%) are trees, 75 species (10.21 %) are shrubs, and 29 species (3.97 %) are climbers (Fig. 4).

According to a revised classification of forest type in India by Champion & Seth (1968), the forest type of Sonbhadra District is tropical dry deciduous. The whole area of the district has an interesting diversity of flora and vegetation due to variable plains, slopes, hills, and climate, represented by dry deciduous vegetation, natural scrub jungle, patches of grasses, and thick forest. The whole area of the district is covered with rich plant diversity with trees at the top layer, shrubs at the middle layer, and herbs, climbers, and twiners at the ground level.

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Table 1. List of the plants of Sonbhadra District.

Family	Taxa	Growth form	Remarks	Collection reference
	DICOT			
Acanthaceae	*Adhatoda zeylanica* Medik.	Shrub	Native	Kushwaha 304140 (LWG)
	Andrographis echioides (L.) Nees	Herb	Native	Panigrahi 12006 (BSA)
	Andrographis paniculata (Burm. f.) Wall. ex Nees	Herb	Native	Kushwaha 304101 (LWG)
	Barleria cristata L.	Shrub	Native	Kushwaha 254593 (LWG)
	Barleria prionitis L.	Shrub	Native	Kushwaha 254285 (LWG)
	Dipteracanthus prostratus (Poir.) Nees	Herb	Native	Panigrahi 12221 (BSA)
	Elytraria acaulis (L.f.) Lindau	Herb	Native	Kushwaha 304137 (LWG)
	Hemigraphis hirta (Vahl) T.Anderson	Herb	Native	Kushwaha 304195 (LWG)
	Hygrophila auriculata (Schumach.) Heine	Herb	Native	Panigrahi 9676 (BSA)
	Hygrophila erecta (Burm.f.) Hochr.	Herb	Native	Panigrahi 2059 (BSA)
	Hygrophila polysperma (Roxb.) T.Anderson	Herb	Native	Panigrahi 13417 (BSA)
	Justicia diffusa Willd.	Herb	Native	Panigrahi 20504 (BSA)
	Justicia prostrata Schltdl. ex Nees	Herb	Native	Panigrahi 8451 (BSA)
	Justicia quinqueangularis K.D.Koenig ex Roxb.	Herb	Native	Panigrahi 2247 (BSA)
	Peristrophe bicalyculata (Retz.) Nees	Herb	Native	Kushwaha 259263(LWG)
	Ruellia suffruticosa Roxb.	Shrub	Native	Mishra 9935 (BSA)
	Rungia pectinata (L.) Nees	Herb	Native	Kushwaha 259237(LWG)
Aizoaceae	*Glinus oppositifolius* (L.) Aug. DC.	Herb	Native	Singh at al. EBH 249 (LWG)
	Trianthema portulacastrum L	Herb	Native	Kushwaha 304102 (LWG)
Ampelidaceae	*Ampelocissus latifolia* (Roxb.) Planch.	Climber	Native	Mishra 9736 (BSA)
Amranthaceae	*Achyranthes aspera* L.	Herb	Native	Kushwaha 264710 (LWG)
	Aerva lanata (L.) Juss.	Herb	Native	Kushwaha 254359 (LWG)
	Allmania nodiflora (L.) R.Br. ex Wight	Herb	Native	Panigrahi 12590 (BSA)
	Alternanthera ficoidea (L.) Sm.	Herb	Native	Kushwaha 254289 (LWG)
	Alternanthera paronychioides A.St.-Hil.	Herb	Alien	Kushwaha 254690 (LWG)
	Alternanthera sessilis (L.) R.Br. ex DC.	Herb	Native	Kushwaha 259235 (LWG)
	Amaranthus spinosus L.	Herb	Native	Kushwaha 254691 (LWG)
	Amaranthus tricolor L.	Herb	Native	Panigrahi 12631 (BSA)
	Amaranthus viridis L.	Herb	Native	Kushwaha 254700 (LWG)
	Celosia argentea L.	Herb	Alien	Kushwaha 245695 (LWG)
	Digera muricata (L.) Mart.	Herb	Alien	Kushwaha 245692 (LWG)
	Nothosaerva brachiata (L.) Wight	Herb	Native	Kushwaha 304104 (LWG)
Anacardiaceae	*Buchanania cochinchinensis* (Lour.) M.R. Almeida	Tree	Native	Kushwaha 259255 (LWG)
	Lannea coromandelica (Houtt.) Merr.	Tree	Native	Kushwaha 259825 (LWG)
	Mangifera indica L.	Tree	Cultivated	Kushwaha 259801 (LWG)
	Semecarpus anacardium L.f.	Tree	Native	Kushwaha 259810 (LWG)
Annonaceae	*Annona squmosa* L.	Tree	Cultivated	Kushwaha 254696 (LWG)
	Miliusa tomentosa (Roxb.) Sinclair	Tree	Native	Kushwaha 259852 (LWG)
	Polyalthia longifolia (Sonn.) Thw.	Tree	Cultivated	Kushwaha 254699 (LWG)
	Polyalthia suberosa (Roxb.) Thwaites	Tree	Native	Kushwaha 259881 (LWG)
Apiaceae	*Anethum graveolens* L.	Herb	Cultivated	Singh & Party EBH489 (LWG)
	Centella asiatica (L.) Urban	Herb	Native	Kushwaha 259883 (LWG)
	Coriandrum sativum L.	Herb	Cultivated	Kushwaha 259878 (LWG)

Family	Taxa	Growth form	Remarks	Collection reference
Apocynaceae	*Alstonia scholaris* (L.) R. Br.	Tree	Cultivated	Kushwaha 254697 (LWG)
	Calotropis gigantea (L.) R. Br.	Small tree	Native	Kushwaha 304106 (LWG)
	Calotropis procera (Aiton) Dryand.	Shrub	Native	Kushwaha 259285 (LWG)
	Carissa carandas L.	Small tree	Cultivated	Kushwaha 259812 (LWG)
	Cascabela thevetia (L.) Lippold	Tree	Cultivated	Kushwaha 259819 (LWG)
	Carissa spinarum L.	Shrub	Native	Kushwaha 254363 (LWG)
	Catharanthus pusillus (Murray) G.Don	Herb	Native	Panigrahi 12587 (BSA)
	Holarrhena pubescens Wall. ex G.Don	Tree	Native	Kushwaha 259298 (LWG)
	Ichnocarpus frutescens (L.) W.T.Aiton	Climber	Native	Kushwaha 259849 (LWG)
	Oxystelma esculentum (L.f.) Sm.	Climber	Native	Kushwaha 304108 (LWG)
	Tabernaemontana divaricata (L.) R.Br. ex Roem. & Schult	Tree	Cultivated	Kushwaha 259824 (LWG)
	Wrightia arborea (Dennst.) Mabberley	Small tree	Native	Kushwaha 304118 (LWG)
	Wrightia tinctoria R.Br.	Tree	Native	Kushwaha 254509 (LWG)
	Plumeria rubra L.	Tree	Cultivated	Kushwaha 304122 (LWG)
	Plumeria alba L.	Small tree	Cultivated	Kushwaha 304127 (LWG)
Aristolochiaceae	*Aristolochia indica* L.	Herb	Native	Kushwaha 304131 (LWG)
Asclepiadaceae	*Ceropegia hirsuta* Wight & Arn.	Climber	Native	Panigrahi 12577 (BSA)
	Cryptolepis dubia (Burm.f.) M.R.Almeida	Climber	Native	Panigrahi 9971 (BSA)
	Gymnema rivulare Schltr.	Climber	Native	Panigrahi 9660 (BSA)
	Hemidesmus indicus (L.) R. Br. ex Schult.	Herb	Native	Singh & Party EBH735 (LWG)
	Marsdenia tenacissima (Roxb.) Moon	Woody climber	Native	Mishra 9960 (BSA)
	Telosma pallida (Roxb.) W. G. Craib	Shrub	Native	Panigrahi 12380 (BSA)
Asteraceae	*Acanthospermum hispidum* DC.	Herb	Alien	Panigrahi 12329 (BSA)
	Acilepis aspera (Buch.-Ham.) H.Rob.	Herb	Native	Panigrahi 12083 (BSA)
	Acmella calva (DC.) Jansen	Herb	Native	Kushwaha 304197 (LWG)
	Ageratum conyzoides (L.) L.	Herb	Alien	Kushwaha 304198 (LWG)
	Artemisia nilagirica (C.B.Clarke) Pamp.	Herb	Native	Panigrahi 12422 (BSA)
	Bidens pilosa L.	Herb	Alien	Panigrahi 1090 (BSA)
	Blainvillea acmella (L.) Philipson	Herb	Alien	Kushwaha 259259 (LWG)
	Blumea lacera DC.	Herb	Alien	Panigrahi 13707 (BSA)
	Blumea axillaris (Lam.) DC.	Herb	Native	Kushwaha 259817 (LWG)
	Blumea fistulosa (Roxb.) Kurz	Herb	Native	Panigrahi 12051 (BSA)
	Blumea laciniata (Wall. ex Roxb.) DC.	Herb	Native	Panigrahi 13738 (BSA)
	Blumea oxyodonta DC.	Herb	Native	Kushwaha 304199 (LWG)
	Caesulia axillaris Roxb.	Herb	Native	Panigrahi 12559 (BSA)
	Carthamus oxyacantha M.Bieb.	Herb	Native	Panigrahi 12027 (BSA)
	Chrysanthellum indicum DC.	Herb	Native	Kushwaha 304191 (LWG)
	Conyza leucantha (D.Don) Ludlow & P.H.Raven	Herb	Native	Panigrahi 13644 (BSA)
	Cyanthillium cinereum (L.) H.Rob.	Herb	Native	Panigrahi 12065 (BSA)
	Cyathocline purpurea (Buch.-Ham. ex D.Don) Kuntze	Herb	Native	Kushwaha 259815 (LWG)
	Echinops echinatus Roxb.	Herb	Alien	Kushwaha 259286 (LWG)
	Eclipta prostrata L.	Herb	Alien	Kushwaha 254361 (LWG)
	Elephantopus scaber L.	Herb	Native	Kushwaha 264709 (LWG)
	Emilia sonchifolia (L.) DC. ex DC.	Herb	Alien	Panigrahi 9692 (BSA)
	Gnaphalium polycaulon Pers.	Herb	Alien	Kushwaha 254290 (LWG)

Family	Taxa	Growth form	Remarks	Collection reference
	Gnaphalium indicum L.	Herb	Native	Koul & Party 47388 (LWG)
	Grangea maderaspatana (L.) Poir.	Herb	Alien	Panigrahi 12623 (BSA)
	Helichrysum indicum (L.) Grierson	Herb	Native	Panigrahi 13428 (BSA)
	Ixeris polycephala Cass.	Herb	Native	Srivastava & Party (LWG)
	Launaea acaulis (Roxb.) Babc. ex Kerr.	Herb	Native	Kushwaha 304192 (LWG)
	Launaea procumbens (Roxb.) Ramaya & Rajgopal	Herb	Native	Kushwaha 304196 (LWG)
	Parthenium hysterophorus L.	Herb	Alien	Kushwaha 254364 (LWG)
	Pentanema indicum (L.) Ling	Herb	Native	Panigrahi 9614 (BSA)
	Pluchea indica (L.) Less.	Herb	Native	Kushwaha 259838 (LWG)
	Pulicaria crispa Sch.Bip.	Herb	Native	Panigrahi 9621 (BSA)
	Sonchus asper (L.) Hill	Herb	Alien	Kushwaha 254279 (LWG)
	Sphaeranthus indicus L.	Herb	Native	Kushwaha 259805 (LWG)
	Tagetes erecta L.	Herb	Native	Singh & Party EBH 487 (LWG)
	Tridax procumbens (L.) L.	Herb	Alien	Kushwaha 254597 (LWG)
	Xanthium strumarium L.	Herb	Alien	Kushwaha 259773 (LWG)
Basellaceae	*Basella alba* L.	Climber	Native	Kushwaha 304200 (LWG)
Bignoniaceae	*Handroanthus impetiginosus* (Mart. ex DC.) Mattos	Tree	Cultivated	Kushwaha 254292 (LWG)
	Fernandoa adenophylla (Wall. ex G. Don) Steenis	Tree	Cultivated	Kushwaha 254694 (LWG)
	Jacaranda mimosifolia D. Don	Tree	Cultivated	Kushwaha 259867 (LWG)
	Kigelia africana (Lam.) Benth.	Tree	Cultivated	Kushwaha 254293 (LWG)
	Tabebuia rosea DC.	Tree	Cultivated	Kushwaha 259867 (LWG)
	Tecoma stans (L.) Juss. ex Kunth	Tree	Cultivated	Kushwaha 259820 (LWG)
Bombacaceae	*Bombax ceiba* L.	Tree	Native	Kushwaha 259807 (LWG)
Boraginaceae	*Cordia dichotoma* G. Forst.	Tree	Native	Kushwaha 259761 (LWG)
	Ehretia laevis Roxb.	Tree	Native	Kushwaha 259813 (LWG)
	Heliotropium indicum L.	Herb	Native	Kushwaha 259764 (LWG)
	Heliotropium ovalifolium Forssk.	Herb	Native	Mishra 9798 (BSA)
	Heliotropium supinum L.	Herb	Native	Panigrahi 9631 (BSA)
	Trichodesma indicum (L.) Lehm.	Herb	Native	Kushwaha 259808 (LWG)
Brassicaceae	*Brassica nigra* (L.) K.Koch	Shrub	Cultivated	Kushwaha 259766 (LWG)
	Brassica rapa L. subsp. *campestris* (L.) Clapham	Herb	Cultivated	Kushwaha 254264 (LWG)
	Eruca vesicari (L.) Cav.	Herb	Native	Panigrahi 13911 (LWG)
	Raphanus sativus L.	Herb	Cultivated	Kushwaha 254266 (LWG)
Burseraceae	*Boswellia serrata* Roxb. ex Colebr.	Tree	Native	Kushwaha 259773 (LWG)
Caryophyllaceae	*Polycarpaea corymbosa* (L.) Lam.	Herb	Native	Panigrahi 2220 (BSA)
	Polycarpon prostratum (Forssk.) Asch. & Schweinf.	Herb	Native	Mishra 9807 (BSA)
	Spergula arvensis L.	Herb	Native	Panigrahi 12630 (BSA)
	Vaccaria hispanica (Mill.) Rauschert	Herb	Native	Kushwaha 259767 (LWG)
Cactaceae	*Opuntia dillenii* (Ker Gawl.) Haw.	Shrub	Native	Singh & Saha EBH 585 (LWG)
	Opuntia cochenillifera (L.) Mill.	Shrub	Native	Kushwaha 254267 (LWG)
	Opuntia stricta (Haw.) Haw.	Shrub	Alien	Kushwaha 254293 (LWG)
Campanulaceae	*Lobelia alsinoides* Lam.	Herb	Native	Kushwaha 259768 (LWG)
Cannabaceae	*Cannabis sativa* L.	Shrub	Native	Kushwaha 254269 (LWG)
	Celtis australs L.	Tree	Native	Kushwaha 259769 (LWG)
	Celtis tetrandra Roxb.	Tree	Native	Kushwaha 254272 (LWG)

Family	Taxa	Growth form	Remarks	Collection reference
	Trema orientalis (L.) Blume	Tree	Native	Panigrahi & Prasad 2695 (BSA)
Capparidaceae	*Capparis zeylanica* L.	Shrub	Native	Kushwaha 259809 (LWG)
Casuarinaceae	*Casuarina equisetifolia* L.	Tree	Native	Kushwaha 259882 (LWG)
Celastraceae	*Cassine glauca* (Rottb.) Kuntze	Tree	Native	Panigrahi 13648 (BSA)
	Celastrus paniculatus Willd.	Shrub	Native	Singh & Party 9336 (LWG)
Ceratophyllaceae	*Ceratophyllum demersum* L.	Herb	Native	Kushwaha 259770 (LWG)
Chenopodiaceae	*Chenopodium murale* L.	Herb	Native	Kushwaha 254273 (LWG)
	Chenopodium album L.	Herb	Native	Kushwaha 259771 (LWG)
	Dysphania ambrosioides (L.) Mosyakin & Clemants	Herb	Native	Kushwaha 254265 (LWG)
Cleomaceae	*Cleome gynandra* L.	Herb	Alien	Panigrahi 13574 (BSA)
	Cleome viscosa L.	Herb	Alien	Panigrahi 13724 (BSA)
Combretaceae	*Anogeissus acuminata* (Roxb. ex DC.) Wall. ex Guillem. & Perr.	Tree	Native	Kushwaha 254326 (LWG)
	Anogeissus latifolia (Roxb. ex DC.) Wall. ex Guillem. & Perr.	Tree	Native	Kushwaha 254510 (LWG)
	Terminalia elliptica Willd	Tree	Native	Kushwaha 254328 (LWG)
	Terminalia arjuna (Roxb. ex DC.) Wight & Arn.	Tree	Native	Kushwaha 254457 (LWG)
	Terminalia bellirica (Gaertn.) Roxb.	Tree	Native	Kushwaha 254475 (LWG)
Convolvulaceae	*Convolvulus arvensis* L.	Herb	Native	Kushwaha 259292 (LWG)
	Cuscuta reflexa Roxb.	Climber	Alien	Kushwaha 254270 (LWG)
	Erycibe paniculata Roxb.	Woody climber	Native	Panigrahi 2260 (BSA)
	Evolvulus alsinoides (L.) L.	Herb	Native	Mishra 9794 (BSA)
	Evolvulus nummularius (L.) L.	Herb	Alien	Kushwaha 259848 (LWG)
	Ipomoea aquatica Forssk.	Herb	Native	Panigrahi 2240 (BSA)
	Ipomoea batatas (L.) Lam.	Climber	Cultivated	Kushwaha 259772 (LWG)
	Ipomoea cairica (L.) Sweet	Climber	Native	Kushwaha 259291 (LWG)
	Ipomoea carnea Jacq.	Shrub	Alien	Kushwaha 254356 (LWG)
	Ipomoea dichroa Choisy	Climber	Native	Panigrahi 12537 (BSA)
	Ipomoea nil (L.) Roth	Climber	Native	Panigrahi 12382 (BSA)
	Ipomoea obscura (L.) Ker Gawl.	Herb	Alien	Kushwaha 254271 (LWG)
	Ipomoea pes-tigridis L.	Herb	Alien	Kushwaha 259775 (LWG)
	Ipomoea quamoclit L.	Herb	Alien	Kushwaha 254277 (LWG)
	Merremia hederacea (Burm. f.) Hallier f.	Herb	Native	Kushwaha 259781 (LWG)
	Operculina turpethum (L.) Silva Manso	Climber	Native	Kushwaha 254278 (LWG)
	Porana paniculata Roxb.	Climber	Native	Mishra 2237 (BSA)
Cornaceae	*Alangium salviifolium* (L.f.) Wangerin	Tree	Native	Kushwaha 254274 (LWG)
Cucurbitaceae	*Benincasa hispida* (Thunb.) Cogn.	Climber	Cultivated	Kushwaha 254303 (LWG)
	Cayaponia laciniosa (L.) C.Jeffrey	Climber	Native	Kushwaha 254396 (LWG)
	Citrullus colocynthis (L.) Schrad.	Herb	Native	Kushwaha 259885 (LWG)
	Citrullus lanatus (Thunb.) Matsumara & Nakai	Herb	Cultivated	Kushwaha 254445 (LWG)
	Coccinia grandis (L.) Voigt	Herb	Native	Kushwaha 259880 (LWG)
	Cucumis sativus L.	Herb	Native	Kushwaha 254302 (LWG)
	Cucumis melo L.	Herb	Cultivated	Kushwaha 254423 (LWG)
	Cucumis melo L. subsp. *agrestis* (Naudin) Pangalo	Herb	Cultivated	Kushwaha 259273 (LWG)
	Cucurbita maxima Duch.	Herb	Cultivated	Kushwaha 254596 (LWG)
	Diplocyclos palmatus (L.) C. Jeffrey	Herb	Native	Kushwaha 254396 (LWG)
	Lagenaria siceraria (Molina) Standl.	Herb	Cultivated	Kushwaha 254280 (LWG)

Family	Taxa	Growth form	Remarks	Collection reference
	Luffa hermaphrodita Singh & Bandhari	Herb	Cultivated	Kushwaha 254431 (LWG)
	Luffa acutangula (L.) Roxb.	Herb	Cultivated	Kushwaha 254320 (LWG)
	Luffa cylindrica (L.) M.Roem.	Herb	Cultivated	Kushwaha 259802 (LWG)
	Momordica charantia L.	Herb	Cultivated	Kushwaha 254433 (LWG)
	Momordica dioica Roxb. ex Willd.	Herb	Native	Kushwaha 254304 (LWG)
	Mukia maderaspatana (L.) M.Roem.	Herb	Cultivated	Kushwaha 254310 (LWG)
	Trichosanthes cucumerina L.	Climber	Cultivated	Kushwaha 254429 (LWG)
	Trichosanthes cucumerina L. var. *anguina* (L.) Haines	Climber	Native	Kushwaha 254437 (LWG)
	Trichosanthes dioica Roxb.	Herb	Cultivated	Kushwaha 254426 (LWG)
Dipterocarpaceae	*Shorea robusta* Gaertn.	Tree	Native	Kushwaha 259826 (LWG)
Ebenaceae	*Diospyros melanoxylon* Roxb.	Small tree	Native	Kushwaha 254523 (LWG)
	Diospyros montana Roxb.	Small tree	Native	Kushwaha 254487 (LWG)
Elatinaceae	*Bergia ammannioides* Roxb. ex Roth	Herb	Native	Shrivastava 21670 (LWG)
Euphorbiaceae	*Acalypha ciliata* Forssk.	Herb	Native	Panigrahi 12233 (BSA)
	Baliospermum solanifolium (Burm.) Suresh	Shrub	Native	Panigrahi 12634 (BSA)
	Chrozophora rottleri (Geiseler) A.Juss. ex Spreng.	Herb	Alien	Kushwaha 304194 (LWG)
	Croton bonplandianus Baill.	Herb	Alien	Kushwaha 254352 (LWG)
	Euphorbia hirta L.	Herb	Native	Kushwaha 304189 (LWG)
	Euphorbia hypericifolia L.	Herb	Native	Panigrahi 13413 (BSA)
	Euphorbia prostrata Aiton	Herb	Native	Kushwaha 304193 (LWG)
	Jatropha gossypiifolia L.	Shrub	Native	Kushwaha 304190 (LWG)
	Mallotus nudiflorus (L.) Kulju & Welzen	Tree	Native	Kushwaha 254294 (LWG)
	Mallotus philippensis (Lam.) Müll.Arg.	Tree	Native	Kushwaha 2598621 (LWG)
	Microstachys chamaelea (L.) Müll.Arg.	Herb	Native	Panigrahi 2017 (BSA)
	Ricinus communis L.	Shrub	Native	Kushwaha 304188 (LWG)
Fabaceae-Caesalpinioideae	*Bauhinia malabarica* Roxb.	Tree	Native	Kushwaha 254378 (LWG)
	Bauhinia purpurea L.	Tree	Native	Kushwaha 259242 (LWG)
	Bauhinia racemosa Lam.	Tree	Native	Kushwaha 259251 (LWG)
	Bauhinia semla Wunderlin	Tree	Native	Kushwaha & Chaudhary 259831 (LWG)
	Bauhinia vahlii Wight & Arn.	Tree	Native	Panigrahi 13825 (BSA)
	Bauhinia variegata L.	Tree	Native	Kushwaha 259263 (LWG)
	Cassia fistula L.	Tree	Native	Kushwaha 254376 (LWG)
	Chamaecrista absus (L.) H.S.Irwin & Barneby	Tree	Native	Chaudhary & Kushwaha 259265 (LWG)
	Chamaecrista mimosoides (L.) Greene	Herb	Native	Panigrahi 12208 (BSA)
	Delonix regia (Hook.) Raf.	Tree	Cultivated	Chaudhary & Kushwaha 259855 (LWG)
	Hardwickia binata Roxb.	Tree	Native	Kushwaha 254324 (LWG)
	Parkinsonia aculeata L.	Small tree	Native	Kushwaha 259261 (LWG)
	Peltophorum pterocarpum (DC.) K.Heyne	Tree	Cultivated	Kushwaha 254297 (LWG)
	Piliostigma malabaricum (Roxb.) Benth.	Tree	Native	Kushwaha & Srivastava 259261 (LWG)
	Senna alata (L.) Roxb.	Shrub	Alien	Kushwaha 254298 (LWG)
	Senna occidentalis (L.) Link	Herb	Native	Panigrahi 12357 (BSA)
	Senna siamea (Lam.) H.S.Irwin & Barneby	Tree	Native	Kushwaha 259260 (LWG)
	Senna tora (L.) Roxb.	Herb	Alien	Kushwaha 254340 (LWG)

Family	Taxa	Growth form	Remarks	Collection reference
Fabaceae-Mimosoideae	*Acacia auriculiformis* Benth.	Tree	Cultivated	Kushwaha 254373 (LWG)
	Acacia catechu (L.f.) Willd.	Tree	Native	Kushwaha 254366 (LWG)
	Acacia nilotica (L.) Delile	Tree	Native	Kushwaha 259294 (LWG)
	Acacia pinnata Link	Tree	Native	Chaudhary & Kushwaha 259294 (LWG)
	Acacia torta (Roxb.) Craib	Shrub	Native	Panigrahi 4131 (BSA)
	Albizia lebbeck (L.) Benth.	Tree	Native	Kushwaha 264785 (LWG)
	Albizia procera (Roxb.) Benth.	Tree	Native	Kushwaha 254288 (LWG)
	Albizia odoratissima (L.f.) Benth.	Tree	Native	Panigrahi 13538 (BSA)
	Dichrostachys cinerea (L.) Wight & Arn.	Tree	Native	Kushwaha 254295 (LWG)
	Leucaena leucocephala (Lam.) de Wit	Tree	Alien	Kushwaha 254504 (LWG)
	Mimosa himalayana Gamble	Small tree	Native	Panigrahi 13929 (BSA)
	Mimosa rubicaulis Lam.	Small tree	Native	Panigrahi 13771 (BSA)
	Pithecellobium dulce (Roxb.) Benth.	Tree	Native	Kushwaha 259834 (LWG)
	Prosopis cineraria (L.) Druce	Tree	Native	Kushwaha 259862 (LWG)
	Prosopis juliflora (Sw.) DC.	Small tree	Alien	Kushwaha 259290 (LWG)
Fabaceae-Papilionoideae	*Abrus precatorius* L.	Climber	Native	Singh & Party 9335 (LWG)
	Aeschynomene indica L.	Herb	Native	Panigrahi 12268 (BSA)
	Atylosia scarabaeoides (L.) Benth.	Herb	Native	Kushwaha 264734 (LWG)
	Alhagi maurorum Medik.	Shrub	Native	Kushwaha 304144 (LWG)
	Alysicarpus bupleurifolius (L.) DC.	Herb	Native	Kushwaha 304109 (LWG)
	Alysicarpus glumaceus (Vahl) DC.	Herb	Native	Panigrahi 13596 (BSA)
	Alysicarpus hamosus Edgew.	Herb	Native	Panigrahi 13936 (BSA)
	Alysicarpus monilifer (L.) DC.	Herb	Native	Mishra 9896 (BSA)
	Alysicarpus vaginalis (L.) DC.	Herb	Native	Kushwaha 264724 (LWG)
	Butea monosperma (Lam.) Taub.	Tree	Native	Kushwaha 259287 (LWG)
	Cajanus cajan (L.) Millsp.	Shrub	Cultivated	Kushwaha 259287 (LWG)
	Cajanus platycarpus (Benth.) Maesen	Herb	Native	Singh at al. EBH 513 (LWG)
	Cajanus scarabaeoides (L.) Thouars	Herb	Native	Panigrahi 12288 (BSA)
	Cicer arietinum L.	Herb	Cultivated	Singh at al. EBH 601 (LWG)
	Clitoria ternatea L.	Herb	Native	Panigrahi 13837 (BSA)
	Codariocalyx motorius (Houtt.) H.Ohashi	Shrub	Native	Panigrahi 11129 (BSA)
	Crotalaria albida Roth	Shrub	Native	Kushwaha 254517 (LWG)
	Crotalaria spectabilis Roth	Herb	Native	Kushwaha 304119 (LWG)
	Crotalaria juncea L.	Shrub	Cultivated	Singh & Party EHB 518 (LWG)
	Crotalaria medicaginea Lam.	Herb	Native	Kushwaha 264702 (LWG)
	Crotalaria mysorensis Roth	Herb	Native	Chaudhary & Dutt 264702 (LWG)
	Crotalaria prostrata Willd.	Herb	Native	Kushwaha 264737 (LWG)
	Crotalaria quinquefolia L.	Herb	Native	Chaudhary & Dutt 264717 (LWG)
	Daldergia sisso DC.	Tree	Native	Kushwaha 259296 (LWG)
	Dalbergia lanceolaria L.f.	Tree	Native	Kushwaha & Bajpai 259296 (LWG)
	Dalbergia latifolia Roxb.	Tree	Native	Mishra 9817 (BSA)
	Desmodium oojenenensis (Roxb.) H. Ohasi	Tree	Native	Kushwaha 259276 (LWG)
	Desmodium dichotomum (Willd.) DC.	Herb	Native	Kushwaha 259879 (LWG)

Family	Taxa	Growth form	Remarks	Collection reference
	Desmodium polycarpum (Poir.) DC.	Herb	Native	Kushwaha 254338 (LWG)
	Desmodium gangeticum (L.) DC.	Herb	Native	Kushwaha 259811 (LWG)
	Desmodium heterocarpon (L.) DC.	Shrub	Native	Kushwaha & Srivastava 259811 (LWG)
	Desmodium triflorum (L.) DC.	Shrub	Native	Panigrahi 3633 (BSA)
	Desmodium velutinum (willd.) DC.	Herb	Native	Kushwaha 264756 (LWG)
	Erythrina stricta Roxb.	Tree	Native	Kushwaha 254441 (LWG)
	Erythrina suberosa Roxb.	Herb	Native	Kushwaha 254441 (LWG)
	Flemingia strobilifera (L.) W.T.Aiton	Shrub	Native	Panigrahi 8427 (BSA)
	Indigofera astragalina DC.	Tree	Native	Chaudhary & Kushwaha 259246 (LWG)
	Indigofera cassioides DC.	Tree	Native	Panigrahi 13769 (BSA)
	Indigofera hirsuta L.	Herb	Native	Panigrahi 8496 (BSA)
	Indigofera linifolia (L.f.) Retz.	Herb	Alien	Kushwaha 264790 (LWG)
	Indigofera linnaei Ali	Shrub	Alien	Chaudhary & Dutt 264790 (LWG)
	Indigofera tinctoria L.	Shrub	Native	Panigrahi 12397 (BSA)
	Indigofera trita L.f.	Herb	Native	Panigrahi 13516 (BSA)
	Lablab purpureus (L.) Sweet	Herb	Cultivated	Kushwaha 259803 (LWG)
	Lathyrus aphaca L.	Herb	Native	Singh at al. 9344 (LWG)
	Lathyrus sativus L.	Herb	Native	Singh 1867 (LWG)
	Medicago polymorpha L.	Herb	Native	Kushwaha 254375 (LWG)
	Melilotus indicus (L.) All.	Herb	Native	Panigrahi 9651 (BSA)
	Millettia extensa (Benth.) Baker	Herb	Native	Panigrahi 13929 (BSA)
	Millettia peguensis Ali	Tree	Native	Kushwaha 254296 (LWG)
	Mucuna pruriens (L.) DC.	Climber	Native	Kushwaha 264705 (LWG)
	Phyllodium pulchellum (L.) Desv.	Shrub	Native	Chaudhary & Dutt 264705 (LWG)
	Pongamia pinnata (L.) Pierre	Tree	Native	Kushwaha 254693 (LWG)
	Pterocarpus marsupium Roxb.	Tree	Native	Kushwaha 259253 (LWG)
	Rhynchosia capitata (Roth) DC.	Herb	Native	Panigrahi 12346 (BSA)
	Rhynchosia minima (L.) DC.	Herb	Native	Panigrahi 12357 (BSA)
	Sesbania bispinosa (Jacq.) W.Wight	Herb	Alien	Kushwaha 254340 (LWG)
	Sesbania sesban (L.) Merr.	Shrub	Native	Panigrahi 13892 (BSA)
	Smithia conferta Sm.	Herb	Native	Panigrahi 13694 (BSA)
	Tephrosia pumila (Lam.) Pers.	Herb	Native	Panigrahi 13883 (BSA)
	Tephrosia purpurea (L.) Pers.	Herb	Native	Kushwaha 254365 (LWG)
	Tephrosia strigosa (Dalzell) Santapau & Maheshw.	Herb	Native	Kushwaha 254365 (LWG)
	Teramnus labialis (L.f.) Spreng.	Herb	Native	Panigrahi 13742 (BSA)
	Trifolium alexandrinum L.	Herb	Native	Panigrahi 13742 (BSA)
	Trigonella foenum-graecum L.	Herb	Cultivated	Panigrahi 12098 (BSA)
	Uraria lagopodoides (L.) DC.	Herb	Native	Panigrahi 13654 (BSA)
	Uraria lagopus var. *neglecta* (Prain) H.Ohashi	Herb	Native	Panigrahi 13654 (BSA)
	Uraria picta (Jacq.) DC.	Herb	Native	Kushwaha 254401 (LWG)
	Vicia hirsuta (L.) Gray	Herb	Native	Panigrahi 9626 (BSA)
	Vicia sativa L.	Herb	Native	Singh & Saha EBH 600 (LWG)
	Vigna aconitifolia (Jacq.) Marechal	Herb	Native	Panigrahi 12321 (BSA)

Family	Taxa	Growth form	Remarks	Collection reference
	Vigna mungo (L.) Hepper	Herb	Cultivated	Kushwaha 254358 (LWG)
	Vigna radiata (L.) R.Wilczek	Herb	Cultivated	Kushwaha 264755 (LWG)
	Vigna trilobata (L.) Verdc.	Herb	Native	Panigrahi 2236 (BSA)
	Vigna umbellata (Thunb.) Ohwi & H.Ohashi	Herb	Cultivated	Panigrahi 12496
	Zornia gibbosa Span.	Herb	Native	Panigrahi 12317 (BSA)
	Zornia glochidiata DC.	Herb	Native	Chaudhary & Datt 264748 (LWG)
Gesneriaceae	*Didymocarpus pygmaeus* C.B.Clarke	Herb	Native	Panigrahi 12231 (BSA)
Gentianaceae	*Canscora alata* (Roth) Wall.	Herb	Native	Kushwaha 259821 (LWG)
	Canscora diffusa (Vahl) R.Br. ex Roem. & Schult.	Herb	Native	Kushwaha 264792 (LWG)
	Hoppea dichotoma Willd.	Herb	Native	Kushwaha 264792 (LWG)
	Swertia ciliata (D. Don ex G. Don) B.L. Burtt	Herb	Native	Panigrahi 2097 (BSA)
Hydrophyllaceae	*Hydrolea zeylanica* (L.) Vahl	Herb	Native	Panigrahi 13860 (BSA)
Lamiaceae	*Anisomeles indica* (L.) Kuntze	Herb	Native	Panigrahi 13680 (BSA)
	Hyptis suaveolens (L.) Poit.	Herb	Alien	Kushwaha 259256 (LWG)
	Leonotis nepetifolia (L.) R.Br.	Herb	Alien	Panigrahi 2232 (BSA)
	Leucas aspera (Willd.) Link	Herb	Native	Panigrahi 12067 (BSA)
	Leucas cephalotes (Roth) Spreng.	Herb	Native	Kushwaha 254500 (LWG)
	Ocimum americanum L.	Herb	Alien	Kushwaha 254343 (LWG)
	Ocimum basilicum L.	Herb	Native	Kushwaha 254499 (LWG)
	Ocimum tenuiflorum L.	Herb	Native	Kushwaha 259274 (LWG)
	Orthosiphon pallidus Royle ex Benth.	Herb	Native	Kushwaha 259274 (LWG)
	Premna herbacea Roxb.	Herb	Native	Panigrahi 2098 (BSA)
	Salvia plebeia R.Br.	Herb	Native	Kushwaha 254498 (LWG)
Lauraceae	*Litsea glutinosa* (Lour.) C.B. Rob.	Tree	Native	Kushwaha 254598 (LWG)
	Litsea monopetala (Roxb.) Pers.	Tree	Native	Kushwaha 254496 (LWG)
Lecythidaceae	*Barringtonia acutangula* (L.) Gaertn.	Tree	Native	Mishra 9831 (BSA)
	Careya arborea Roxb.	Tree	Native	Singh & Party 7631 (LWG)
Lentibulariaceae	*Utricularia aurea* Lour.	Herb	Native	Panigrahi 13486 (BSA)
Linaceae	*Linum usitatissimum* L.	Herb	Cultivated	Kushwaha 304124 (LWG)
Linderniaceae	*Lindernia anagallis* (Burm.f.) Pennell	Herb	Native	Kushwaha 304111 (LWG)
	Lindernia ciliata (Colsm.) Pennell	Herb	Native	Kushwaha 304114 (LWG)
	Lindernia crustacea (L.) F.Muell.	Herb	Native	Kushwaha 304145 (LWG)
Loranthaceae	*Dendrophthoe falcata* (L.f.) Ettingsh.	Shrub	Native	Panigrahi 9682 (BSA)
	Loranthus philippinensis Cham. & Schlecht., extract	Shrub	Native	Panigrahi 13527 (BSA)
	Taxillus tomentosus Tiegh.	Shrub	Native	Panigrahi 12036 (BSA)
Lythraceae	*Ammannia baccifera* L.	Herb	Native	Kushwaha 304146 (LWG)
	Ammannia multiflora Roxb.	Herb	Native	Panigrahi 12573 (BSA)
	Lagerstroemia indica L.	Shrub	Native	Kushwaha 254299 (LWG)
	Lagerstroemia parviflora Roxb.	Tree	Native	Kushwaha 259264 (LWG)
	Lagerstroemia speciosa (L.) Pers.	Tree	Cultivated	Kushwaha 254300 (LWG)
	Lawsonia inermis L.	Shrub	Native	Singh 1878 (LWG)
	Rotala indica (Willd.) Koehne	Herb	Native	Kushwaha 304147 (LWG)
	Trapa natans L.	Herb	Native	Kushwaha 304150 (LWG)
	Woodfordia floribunda Salisb.	Shrub	Native	Panigrahi 1864 (BSA)
	Woodfordia fruticosa (L.) Kurz	Shrub	Native	Kushwaha 259832 (LWG)

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Malvaceae	*Abelmoschus manihot* (L.) Medik.	Herb	Native	Kushwaha 304151 (LWG)
	Abelmoschus moschatus Medik.	Herb	Cultivated	Kushwaha 304139 (LWG)
	Abelmoschus crinitus Wall.	Shrub	Cultivated	Singh & Party EBH 7626 (LWG)
	Abelmoschus esculentus (L.) Moench	Shrub	Cultivated	Maheshwari & Saha EBH 733 (LWG)
	Abutilon ramosum (Cav.) Guill. & Perr.	Shrub	Native	Kushwaha 304152 (LWG)
	Abutilon indicum (L.) Sweet	Shrub	Native	Kushwaha 259275 (LWG)
	Byttneria herbacea Roxb.	Shrub	Native	Chaudhary & Datt 264723 (LWG)
	Ceiba pentandra (L.) Gaertn.	Tree	Cultivated	Kushwaha 259889 (LWG)
	Corchorus aestuans L.	Herb	Alien	Kushwaha 264769 (LWG)
	Corchorus capsularis L.	Herb	Native	Kushwaha 264769 (LWG)
	Corchorus tridens L.	Herb	Alien	Kushwaha 259890 (LWG)
	Corchorus olitorius L.	Herb	Native	Panigrahi 13877 (BSA)
	Grewia asiatica L.	Tree	Native	Kushwaha 304153 (LWG)
	Grewia hirsuta Vahl	Tree	Native	Kushwaha 264760 (LWG)
	Grewia tiliifolia Vahl	Tree	Native	Kushwaha 264760 (LWG)
	Hibiscus cannabinus L.	Shrub	Native	Panigrahi 12602 (BSA)
	Hibiscus lobatus (Murray) Kuntze	Herb	Native	Mishra 9950 (BSA)
	Hibiscus micranthus L.f.	Shrub	Native	Panigrahi 13937 (BSA)
	Hibiscus mutabilis L.	Shrub	Native	Kushwaha 304154 (LWG)
	Hibiscus panduriformis Burm.f.	Shrub	Native	Panigrahi 13878 (BSA)
	Hibiscus sabdariffa L.	Herb	Native	Singh & Party EBH 545 (LWG)
	Kydia calycina Roxb.	Tree	Native	Panigrahi 12480 (BSA)
	Malvastrum coromandelianum (L.) Garcke	Herb	Alien	Kushwaha 304142 (LWG)
	Pavonia cancellata (L.) Cav.	Herb	Native	Panigrahi 2698 (BSA)
	Pterospermum acerifolium (L.) Willd.	Tree	Native	Kushwaha 259893 (LWG)
	Sida cordata (Burm.f.) Borss.Waalk.	Shrub	Native	Kushwaha 259236 (LWG)
	Sida cordifolia L.	Shrub	Native	Shrivastava 21670 (LWG)
	Sida spinosa L.	Herb	Native	Panigrahi 9612 (BSA)
	Sida acuta Burm.f.	Herb	Alien	Panigrahi 13518 (BSA)
	Sida rhombifolia L.	Herb	Native	Saha & Party EBH246 (LWG)
	Thespesia populnea (L.) Sol. ex Corrêa	Tree	Native	Kushwaha 259894 (LWG)
	Triumfetta pentandra A. Rich.	Shrub	Native	Kushwaha 264706 (LWG)
	Urena lobata L.	Herb	Alien	Kushwaha 259264 (LWG)
Martyniaceae	*Martynia annua* L.	Herb	Alien	Kushwaha 264775 (LWG)
Meliaceae	*Azadirachta indica* A. Juss.	Tree	Native	Kushwaha 259282 (LWG)
	Melia azedarach L.	Tree	Native	Kushwaha 259863 (LWG)
	Soymida febrifuga (Roxb.) A. Juss.	Tree	Native	Kushwaha 259217 (LWG)
	Toona ciliata M. Roem.	Tree	Native	Kushwaha 259271 (LWG)
Menispermaceae	*Cissampelos pareira* L.	Shrub	Native	Kushwaha 254331 (LWG)
	Cocculus diversifolius DC.	Climber	Native	Kushwaha 304148 (LWG)
	Cocculus hirsutus (L.) W.Theob.	Climber	Native	Kushwaha 259288 (LWG)
	Tinospora cordifolia (Willd.) Miers	Climber	Native	Kushwaha 304155 (LWG)
Menyanthaceae	*Nymphoides cristata* (Roxb.) Kuntze	Herb	Native	Kushwaha 304149 (LWG)
Moraceae	*Artocarpus heterophyllus* Lam.	Tree	Cultivated	Kushwaha 254494(LWG)

Family	Taxa	Growth form	Remarks	Collection reference
	Artocarpus lacucha Buch.-Ham	Tree	Cultivated	Kushwaha 304156 (LWG)
	Ficus benghalensis L.	Tree	Native	Kushwaha 254533 (LWG)
	Ficus benjamina L.	Small tree	Cultivated	Kushwaha 254281 (LWG)
	Ficus elastica Roxb. ex Hornem	Tree	Cultivated	Kushwaha 259895 (LWG)
	Ficus hispida L.f.	Tree	Native	Kushwaha 304157 (LWG)
	Ficus palmata Forssk.	Small tree	Native	Kushwaha 304158 (LWG)
	Ficus pumila L.	Climber	Native	Kushwaha 304163 (LWG)
	Ficus racemosa L.	Tree	Native	Kushwaha 254286 (LWG)
	Ficus religiosa L.	Tree	Native	Kushwaha 254351 (LWG)
	Ficus virens Aiton	Tree	Native	Kushwaha 254282 (LWG)
	Morus alba L.	Tree	Cultivated	Kushwaha 254287 (LWG)
	Morus indica L.	Tree	Native	Kushwaha 254284 (LWG)
	Streblus asper Lour.	Tree	Native	Kushwaha 254291 (LWG)
Moringaceae	*Moringa oleifera* Lam.	Tree	Cultivated	Kushwaha 304165 (LWG)
Myrsinaceae	*Embelia tsjeriam-cottam* (Roem. & Schult.) A.DC.	Tree	Native	Panigrahi 4126 (BSA)
Myrtaceae	*Callistemon citrinus* (Curtis) Skeels	Tree	Cultivated	Kushwaha 304159 (LWG)
	Eucalyptus tereticornis Sm.	Tree	Cultivated	Kushwaha 304161 (LWG)
	Psidium guajava L.	Tree	Cultivated	Kushwaha 254357 (LWG)
	Syzygium cumini (L.) Skeels	Tree	Native	Kushwaha 264775 (LWG)
	Syzygium salicifolium (Wight) J.Graham	Tree	Native	Kushwaha 254493 (LWG)
Nyctaginaceae	*Boerhavia diffusa* L.	Herb	Native	Singh 9364 (LWG)
	Boerhavia chinensis (L.) Rottb.	Herb	Native	Kushwaha 304162 (LWG)
	Boerhavia repens L.	Herb	Native	Panigrahi 13731 (BSA)
	Bougainvillea glabra Choisy in DC.	Shrub	Cultivated	Kushwaha 304164 (LWG)
	Mirabilis jalapa L.	Herb	Alien	Kushwaha 259897 (LWG)
Nymphaeceae	*Nymphaea nouchali* Burm. f.	Herb	Native	Kushwaha 304170 (LWG)
	Nymphaea pubescens Willd.	Herb	Native	Kushwaha 304160 (LWG)
Olacaceae	*Olaxscandens* Roxb.	Shrub	Native	Panigrahi 2669 (BSA)
Oleaceae	*Jasminum multiflorum* (Burm. f.) Andrews	Shrub	Native	Kushwaha 304166 (LWG)
	Jasminum arborescens Roxb.	Shrub	Native	Mishra 9904 (BSA)
	Nyctanthes arbor-tristis L.	Small tree	Native	Kushwaha 254413 (LWG)
Onagraceae	*Ludwigia octovalis* (Jacq.) P.H.Raven	Herb	Native	Panigrahi 12651 (BSA)
	Ludwigia perennis L.	Herb	Native	Panigrahi 13751 (BSA)
Orobanchaceae	*Orobanche aegyptiaca* Pers.	Herb	Native	Kushwaha 304171 (LWG)
Oxalidaceae	*Averrhoa carambola* L.	Tree	Cultivated	Kushwaha 304175 (LWG)
	Biophytum reinwardtii (Zucc.) Klotzsch	Herb	Native	Kushwaha 259783 (LWG)
	Biophytum sensitivum (L.) DC.	Herb	Native	Kushwaha 264732 (LWG)
	Oxalis corniculata L.	Herb	Alien	Kushwaha 254463 (LWG)
Papaveraceae	*Argemone mexicana* L.	Herb	Alien	Kushwaha 304169 (LWG)
	Fumaria indica (Hausskn.) Pugsley	Herb	Native	Kushwaha 304176 (LWG)
Pedaliaceae	*Sesamum mulayanum* N.C.Nair	Herb	Native	Kushwaha 254329 (LWG)
	Sesamum indicum L.	Herb	Cultivated	Panigrahi 13803 (BSA)
Phyllanthaceae	*Bridelia retusa* (L.) A. Juss.	Tree	Native	Mishra 9993 (BSA)
	Cleistanthus collinus (Roxb.) Benth. ex Hook.f.	Tree	Native	Kushwaha 304178 (LWG)
	Flueggea virosa (Roxb. ex Willd.) Royle	Shrub	Native	Kushwaha 264712 (LWG)

Family	Taxa	Growth form	Remarks	Collection reference
	Phyllanthus emblica L.	Tree	Native	Kushwaha 264733 (LWG)
	Phyllanthus urinaria L.	Herb	Native	Panigrahi 6556 (BSA)
	Phyllanthus virgatus G. Forst.	Herb	Native	Kushwaha 304172 (LWG)
	Phyllanthus reticulatus Poir.	Small tree	Native	Kushwaha 254313 (LWG)
Plantaginaceae	*Lindenbergia indica* Vatke	Herb	Native	Panigrahi 13921 (BSA)
	Scoparia dulcis L.	Herb	Alien	Mishra 9754 (BSA)
Plumbaginaceae	*Plumbago zeylanica* L.	Herb	Native	Kushwaha 304145 (LWG)
Putranjivaceae	*Putranjiva roxburghii* Wall.	Tree	Native	Kushwaha 259898 (LWG)
Polygalaceae	*Polygala chinensis* L.	Herb	Native	Mishra 9964 (BSA)
	Polygala longifolia Poir.	Herb	Native	Panigrahi 12070 (BSA)
	Polygala arvensis Willd.	Herb	Native	Kushwaha 304173 (LWG)
Polygonaceae	*Antigonon leptopus* Hook. & Arn.	Climber	Alien	Kushwaha 304167 (LWG)
	Persicaria barbata (L.) H.Hara	Herb	Native	Kushwaha 304177 (LWG)
	Persicaria hydropiper (L.) Delarbre	Herb	Native	Kushwaha 304181 (LWG)
	Polygonum aviculare L.	Herb	Native	Kushwaha 259804 (LWG)
	Polygonum plebeium R.Br.	Herb	Native	Kushwaha 254467 (LWG)
	Rumex dentatus L.	Herb	Native	Kushwaha 304179 (LWG)
Portulacaceae	*Portulaca oleracea* L.	Herb	Alien	Kushwaha 254464 (LWG)
Primulaceae	*Anagallis arvensis* L.	Herb	Native	Kushwaha 254470 (LWG)
Punicaceae	*Punica granatum* L.	Small tree	Cultivated	Kushwaha 254402 (LWG)
Ranunculaceae	*Ranunculus sceleratus* L.	Herb	Native	Kushwaha 254469 (LWG)
	Ranunculus scleratoides Perfil. ex Ovczinn.	Herb	Native	Kushwaha 304174 (LWG)
Rhamnaceae	*Ventilago maderaspatana* Gaertn.	Tree	Native	Saha & Party EBH257 (LWG)
	Ziziphus nummularia (Burm.f.) Wight & Arn.	Small tree	Native	Kushwaha 254446 (LWG)
	Ziziphus oenopolia (L.) Mill.	Small tree	Native	Kushwaha 254325 (LWG)
	Ziziphus jujuba Mill.	Small tree	Native	Kushwaha 254470 (LWG)
	Ziziphus xylopyrus (Retz.) Willd.	Small tree	Native	Kushwaha 254316 (LWG)
Rubiaceae	*Catunaregam longispina* (Link) Tirveng.	Small tree	Native	Panigrahi & Prasad 9979 (BSA)
	Ceriscoides turgida (Roxb.) Tirveng.	Tree	Native	Kushwaha 259840 (LWG)
	Dentella repens (L.) J.R.Forst. & G.Forst.	Herb	Native	Mishra 9801 (BSA)
	Gardenia latifolia Aiton	Tree	Native	Kushwaha 259822 (LWG)
	Haldina cordifolia (Roxb.) Ridsdale	Tree	Native	Kushwaha 259270 (LWG)
	Knoxia sumatrensis (Retz.) DC.	Herb	Native	Panigrahi 12490 (BSA)
	Mitragyna parvifolia (Roxb.) Korth	Tree	Native	Kushwaha 259842 (LWG)
	Neolamarckia cadamba (Roxb.) Bosser	Tree	Cultivated	Kushwaha 259899 (LWG)
	Spermadictyon suaveolens Roxb.	Herb	Native	Panigrahi 13593 (BSA)
	Oldenlandia diffusa (Willd.) Roxb.	Herb	Native	Kushwaha 254471 (LWG)
	Oldenlandia corymbosa L.	Herb	Native	Kushwaha 304168 (LWG)
	Oldenlandia herbacea (L.) Roxb.	Herb	Native	Panigrahi 12596 (BSA)
	Spermacoce articularis L.f.	Herb	Native	Panigrahi 12565 (BSA)
	Tamilnadia uliginosa (Retz.) Tirveng. & Sastre	Small tree	Native	Mishra 9979 (BSA)
	Wendlandia heynei (Schult.) Santapau & Merchant	Tree	Native	Kushwaha 259267 (LWG)
Rutaceae	*Aegle marmelos* (L.) Corrêa	Tree	Native	Kushwaha 254474 (LWG)
	Citrus limon (L.) Osbeck	Tree	Cultivated	Kushwaha 254468 (LWG)
	Citrus medica L.	Tree	Cultivated	Kushwaha 254491 (LWG)

Family	Taxa	Growth form	Remarks	Collection reference
	Glycosmis pentaphylla (Retz.) DC.	Shrubs	Native	Kushwaha 259900 (LWG)
	Hesperethusa crenulata (Roxb.) M. Roem.	Tree	Native	Panigrahi 13588 (BSA)
	Limonia acidissima Groff	Tree	Native	Kushwaha 254497 (LWG)
	Murraya koenigii (L.) Spreng.	Tree	Native	Kushwaha 259853 (LWG)
	Murraya paniculata (L.) Jack	Tree	Native	Kushwaha 254471 (LWG)
Salicaceae	*Casearia tomentosa* Roxb.	Tree	Native	Kushwaha 254465 (LWG)
	Flacourtia indica (Burm.f.) Merr.	Tree	Native	Kushwaha 259830 (LWG)
Sapindaceae	*Sapindus emarginatus* Vahl	Tree	Native	Maheshwari & Saha EBH 821 (LWG)
	Schleichera oleosa (Lour.) Merr.	Tree	Native	Kushwaha 259823 (LWG)
Sapotaceae	*Madhuca longifolia* (J.Koenig ex L.) J.F.Macbr.	Tree	Native	Kushwaha 254360 (LWG)
Scrophulariaceae	*Bacopa monnieri* (L.) Wettst.	Herb	Native	Kushwaha 254472 (LWG)
	Centranthera nepalensis D.Don	Herb	Native	Kushwaha 254466 (LWG)
	Kickxia ramosissima (Wall.) Janch.	Herb	Native	Panigrahi 13421 (BSA)
	Limnophila heterophylla (Roxb.) Benth.	Herb	Native	Panigrahi 9668 (BSA)
	Limnophila indica (L.) Druce	Herb	Native	Panigrahi 12354 (BSA)
	Mazus pumilus (Burm.f.) Steenis	Herb	Native	Panigrahi 12094 (BSA)
	Mecardonia procumbens (Mill.) Small	Herb	Native	Kushwaha 254399 (LWG)
	Scoparia dulcis L.	Herb	Native	Panigrahi 9684 (BSA)
	Veronica anagallis L.	Herb	Native	Panigrahi 12635 (BSA)
Simaroubaceae	*Ailanthus excelsa* Roxb.	Tree	Native	Kushwaha 259854 (LWG)
Solanaceae	*Datura innoxia* Mill.	Herb	Alien	Kushwaha 254473 (LWG)
	Datura metel L.	Shrub	Alien	Kushwaha 259284 (LWG)
	Lycopersicon lycopersicum (L.) H.Karst.	Shrub	Native	Kushwaha 254480 (LWG)
	Nicotiana plumbaginifolia Viv.	Herb	Alien	Kushwaha 254476 (LWG)
	Nicotiana tabacum L.	Herb	Native	Kushwaha 259854 (LWG)
	Physalis minima L.	Herb	Native	Kushwaha 254337 (LWG)
	Physalis peruviana L.	Herb	Native	Kushwaha 254477 (LWG)
	Solanum americanum Mill.	Herb	Alien	Kushwaha 254481 (LWG)
	Solanum incanum L.	Herb	Native	Kushwaha 254484 (LWG)
	Solanum lycopersicum L.	Shrub	Native	Kushwaha 254479 (LWG)
	Solanum melongena L.	Herb	Native	Kushwaha 254482 (LWG)
	Solanum nigrum L.	Herb	Native	Kushwaha 254489 (LWG)
	Solanum surattense Burm. f.	Herb	Native	Kushwaha 259254 (LWG)
	Solanum viarum Dunal	Herb	Alien	Kushwaha 254478 (LWG)
	Solanum virginianum L.	Herb	Native	Kushwaha 304183 (LWG)
	Solanum tuberosum L.	Herb	Alien	Kushwaha 304186 (LWG)
Sterculiaceae	*Byttneria herbacea* Roxb.	Herb	Native	Panigrahi 12517 (BSA)
	Eriolaena hookeriana Wight & Arn.	Tree	Native	Mishra 9882 (BSA)
	Firmiana simplex (L.) W.Wight	Tree	Native	Panigrahi 12027 (BSA)
	Helicteres isora L.	Shrub	Native	Kushwaha 304184 (LWG)
	Melochia corchorifolia L.	Herb	Native	Kushwaha 254483 (LWG)
	Sterculia villosa Roxb.	Tree	Native	Kushwaha 259857 (LWG)
	Waltheria indica L.	Herb	Native	Kushwaha 259248 (LWG)
Ulmaceae	*Holoptelea integrifolia* (Roxb.) Planch.	Tree	Native	Kushwaha 259856 (LWG)
	Parasponica rugosa Blume	Tree	Native	Kushwaha 259865 (LWG)

Family	Taxa	Growth form	Remarks	Collection reference
Verbenaceae	*Clerodendrum phlomidis* L.f.	Shrub	Native	Kushwaha 304185 (LWG)
	Lantana camara L.	Shrub	Alien	Kushwaha 254423 (LWG)
	Lippia javanica (Burm.f.) Spreng.	Shrub	Native	Kushwaha 304187 (LWG)
	Phyla nodiflora (L.) Greene	Shrub	Native	Mishra 9750 (BSA)
	Tectona grandis L.	Tree	Cultivated	Kushwaha 304182 (LWG)
Violaceae	*Hybanthus enneaspermus* (L.) F.Muell.	Herb	Native	Mishra 9913 (BSA)
	Hybanthus linearifolius (Vahl) Urb.	Herb	Native	Srivastava 21664 (LWG)
Vitaceae	*Ampelopsis glandulosa* (Wall.) Momiy.	Climber	Native	Kushwaha 259218 (LWG)
	Cayratia trifolia (L.) Domin	Climber	Native	Panigrahi 11167 (BSA)
	Leea asiatica (L.) Ridsdale	Shrub	Native	Kushwaha 304185 (LWG)
	MONOCOT			
Alismataceae	*Sagittaria sagittifolia* L.	Herb	Native	Kushwaha 254615 (LWG)
Amaryllidaceae	*Crinum asiaticum* L.	Herb	Native	Kushwaha 304103 (LWG)
Aponogetonaceae	*Aponogeton crispus* Thunb.	Herb	Native	Kushwaha 304115 (LWG)
	Aponogeton natans (L.) Engl. & K.Krause	Herb	Native	Panigrahi 3677 (BSA)
Araceae	*Alocasia macrorrhizos* (L.) G. Don	Herb	Native	Kushwaha 304117 (LWG)
	Amorphophallus paeoniifolius (Dennst.) Nicolson	Herb	Native	Kushwaha 304107 (LWG)
	Colocasia esculenta (L.) Schott	Herb	Cultivated	Kushwaha 304120 (LWG)
	Pistia stratiotes L.	Herb	Alien	Kushwaha 304124 (LWG)
	Remusatia vivipara (Roxb.) Schott	Herb	Native	Kushwaha 254453(LWG)
Arecaceae	*Phoenix acaulis* Roxb.	Shrub	Native	Kushwaha 304116 (LWG)
	Phoenix rupicola T.Anderson	Tree	Native	Kushwaha 304121 (LWG)
Asparagaceae	*Asparagus racemosus* Willd.	Shrub	Native	Kushwaha 304125 (LWG)
Colchicaceae	*Gloriosa superba* L.	Shrub	Native	Kushwaha 254333 (LWG)
Commelinaceae	*Commelina benghalensis* L.	Herb	Native	Kushwaha 304126 (LWG)
	Commelina caroliniana Walter	Herb	Native	Panigrahi 13763 (BSA)
	Commelina diffusa Burm.f.	Herb	Native	Panigrahi 9671 (BSA)
	Commelina paludosa Blume	Herb	Native	Panigrahi 12582 (BSA)
	Cyanotis axillaris (L.) D.Don ex Sweet	Herb	Native	Kushwaha 304128 (LWG)
	Murdannia malabarica (L.) G.Brückn.	Herb	Native	Panigrahi 13752 (BSA)
	Murdannia nudiflora (L.) Brenan	Herb	Native	Kushwaha 304130 (LWG)
Cyperaceae	*Courtoisina cyperoides* (Roxb.) Soják	Herb	Native	Panigrahi 13463 (BSA)
	Cyperus compactus Retz.	Herb	Native	Panigrahi 3690 (BSA)
	Cyperus compressus L.	Herb	Native	Mishra 9863 (BSA)
	Cyperus cyperoides (L.) Kuntze	Herb	Native	Panigrahi 12594 (BSA)
	Cyperus difformis L.	Herb	Alien	Mishra 9868 (BSA)
	Cyperus exaltatus Retz.	Herb	Native	Panigrahi 13494 (BSA)
	Cyperus iria L.	Herb	Alien	Kushwaha 254380 (LWG)
	Cyperus glomeratus L.	Herb	Native	Kushwaha 254654 (LWG)
	Cyperus leucocephalus Retz.	Herb	Native	Mishra 9944 (BSA)
	Cyperus malaccensis Lam.	Herb	Native	Kushwaha 254635 (LWG)
	Cyperus michelianus subsp. *pygmaeus* (Rottb.) Asch. & Graebn.	Herb	Native	Panigrahi 12560 (BSA)
	Cyperus niveus Retz.	Herb	Native	Mishra 9908 (BSA)
	Cyperus pangorei Rottb.	Herb	Native	Kushwaha 254350 (LWG)
	Cyperus rotundus L.	Herb	Native	Kushwaha 254667 (LWG)

Family	Taxa	Growth form	Remarks	Collection reference
	Cyperus tenuispica Steud.	Herb	Native	Panigrahi 13904 (BSA)
	Eleocharis geniculata (L.) Roem. & Schult.	Herb	Native	Kushwaha 254642 (LWG)
	Eleocharis palustris (L.) Roem. & Schult	Herb	Native	Panigrahi 3681 (BSA)
	Eleocharis quinqueflora (Hartmann) O.Schwarz	Herb	Native	Kushwaha 254627 (LWG)
	Fimbristylis bisumbellata (Forssk.) Bubani	Herb	Native	Kushwaha 254485 (LWG)
	Fimbristylis dichotoma (L.) Vahl	Herb	Native	Mishra 9761 (BSA)
	Fimbristylis falcata (Vahl) Kunth	Herb	Native	Mishra 9992 (BSA)
	Fimbristylis miliacea (L.) Vahl	Herb	Native	Mishra 9811 (BSA)
	Fimbristylis squarrosa Vahl	Herb	Native	Mishra 9813 (BSA)
	Fimbristylis tetragona R.Br.	Herb	Native	Panigrahi 13832 (BSA)
	Fuirena ciliaris (L.) Roxb.	Herb	Native	Panigrahi 13711 (BSA)
	Kyllinga brevifolia Rottb.	Herb	Native	Kushwaha 264777 (LWG)
	Pycreus flavidus (Retz.) T.Koyama	Herb	Native	Mishra 9818 (BSA)
	Pycreus polystachyos (Rottb.) P.Beauv.	Herb	Native	Mishra 9874 (BSA)
	Pycreus pumilus (L.) Nees	Herb	Native	Mishra 9908 (BSA)
	Schoenoplectiella articulata (L.) Lye	Herb	Native	Kushwaha 254614 (LWG)
	Schoenoplectiella juncoides (Roxb.) Lye	Herb	Native	Mishra 9823 (BSA)
	Scirpus supinus L.	Herb	Native	Panigrahi 13668 (BSA)
	Scleria levis Retz.	Herb	Native	Panigrahi & Prasad 2035 (BSA)
Eriocaulaceae	*Eriocaulon guinguangulare* Linn	Herb	Native	Panigrahi 2638 (BSA)
Hydrocharitaceae	*Blyxa aubertii* Rich.	Herb	Native	Kushwaha 254486 (LWG)
	Hydrilla verticillata (L.f.) Royle	Herb	Native	Kushwaha 304132 (LWG)
	Najas minor All.	Herb	Native	Panigrahi 2636 (BSA)
	Vallisneria spiralis L.	Herb	Native	Kushwaha 304185 (LWG)
Lemnaceae	*Lemna aequinoctialis* Welw.	Herb	Native	Kushwaha 304129 (LWG)
	Wolffia microscopica (Griff.) Kurz	Herb	Native	Kushwaha 304133 (LWG)
Musaceae	*Musa balbisiana* Colla	Large Shrub	Cultivated	Kushwaha 304135 (LWG)
Orchidaceae	*Vanda tessellata* (Roxb.) Hook. ex G.Don	Herb	Native	Kushwaha 304136 (LWG)
	Zeuxine strateumatica (L.) Schltr.	Herb	Native	Kushwaha 304138 (LWG)
Poaceae	*Alloteropsis cimicina* (L.) Stapf	Herb	Native	Panigrahi 13856 (BSA)
	Andropogon fastigiatus Sw.	Herb	Native	Panigrahi 13807 (BSA)
	Apluda mutica L.	Herb	Native	Kushwaha 264766 (LWG)
	Apocopis vaginata Hack.	Herb	Native	Mishra 9909 (BSA)
	Arundo donax L.	Shrubs	Native	Kushwaha 254772 (LWG)
	Aristida adscensionis L.	Herb	Native	Panigrahi 12464 (BSA)
	Aristida funiculata Trin. & Rupr.	Herb	Native	Panigrahi & Prasad 2048 (BSA)
	Aristida redacta Stapf	Herb	Native	Panigrahi 9693 (BSA)
	Aristida setacea Retz.	Herb	Native	Panigrahi 3614 (BSA)
	Arthraxon hispidus (Thunb.) Makino	Herb	Native	Kushwaha 264727 (LWG)
	Arthraxon lancifolius (Trin.) Hochst.	Herb	Native	Panigrahi 8494 (BSA)
	Arthraxon prionodes (Steud.) Dandy	Herb	Native	Panigrahi 11125 (BSA)
	Avena sativa L.	Herb	Native	Kushwaha 254611 (LWG)
	Arundinella setosa Trin.	Herb	Native	Panigrahi 3513 (BSA)
	Bothriochloa pertusa (L.) A.Camus	Herb	Native	Mishra 9869 (BSA)
	Bambusa bambos (L.) Voss	Tree	Native	Kushwaha 254283 (LWG)
	Chloris virgata Sw.	Herb	Native	Kushwaha 254503 (LWG)

Family	Taxa	Growth form	Remarks	Collection reference
	Chrysopogon fulvus (Spreng.) Chiov.	Herb	Native	Kushwaha 254526 (LWG)
	Coix aquatica Roxb.	Herb	Native	Kushwaha 254490 (LWG)
	Cymbopogon martini (Roxb.) W.Watson	Herb	Native	Panigrahi 8499 (BSA)
	Cynodon dactylon (L.) Pers.	Herb	Native	Kushwaha 254607 (LWG)
	Dactyloctenium aegyptium (L.) Willd.	Herb	Native	Kushwaha 254665 (LWG)
	Dendrocalamus strictus (Roxb.) Nees	Herb	Native	Panigrari & Prasad 2037 (BSA)
	Desmostachya bipinnata (L.) Stapf	Herb	Native	Kushwaha 254625 (LWG)
	Dichanthium annulatum (Forssk.) Stapf	Herb	Native	Kushwaha 254454 (LWG)
	Digitaria bicornis (Lam.) Roem. & Schult.	Herb	Native	Panigrahi 20590 (BSA)
	Digitaria ciliaris (Retz.) Koeler	Herb	Native	Kushwaha 254490 (LWG)
	Digitaria longiflora (Retz.) Pers.	Herb	Native	Mishra 9774 (BSA)
	Digitaria stricta Roth	Herb	Native	Panigrahi 9665 (BSA)
	Dimeria ornithopoda Trin.	Herb	Native	Panigrahi 12330 (BSA)
	Echinochloa colona (L.) Link	Herb	Alien	Panigrahi 12063 (BSA)
	Echinochloa crus-galli (L.) P.Beauv.	Herb	Alien	Mishra 9779 (BSA)
	Echinochloa stagnina (Retz.) P.Beauv.	Herb	Native	Mishra 9947 (BSA)
	Eleusine indica (L.) Gaertn.	Herb	Native	Kushwaha 254601 (LWG)
	Enteropogon dolichostachyus (Lag.) Keng	Herb	Native	Kushwaha 254522 (LWG)
	Eragrostis amabilis (L.) Wight & Arn.	Herb	Native	Kushwaha 254623 (LWG)
	Eragrostis japonica (Thunb.) Trin.	Herb	Native	Kushwaha 254459 (LWG)
	Eragrostis pilosa (L.) P.Beauv.	Herb	Native	Kushwaha 264728 (LWG)
	Eragrostis tremula Hochst. ex Steud.	Herb	Native	Kushwaha 264796 (LWG)
	Eragrostis unioloides (Retz.) Nees ex Steud.	Herb	Native	Kushwaha 264730 (LWG)
	Eremopogon foveolatus (Delile) Stapf	Herb	Native	Panigrahi 12299 (BSA)
	Eulalia trispicata (Schult.) Henrard	Herb	Native	Panigrahi 4122 (BSA)
	Eulaliopsis binata (Retz.) C.E.Hubb.	Herb	Native	Panigrahi 12371 (BSA)
	Hackelochloa granularis (L.) Kuntze	Herb	Native	Panigrahi 13743 (BSA)
	Hemarthria compressa (L.f.) R.Br.	Herb	Native	Panigrahi 12420 (BSA)
	Heteropogon contortus (L.) P.Beauv. ex Roem. & Schult.	Herb	Native	Kushwaha 264742 (LWG)
	Hordeum vulgare L.	Herb	Cultivated	Kushwaha 304110 (LWG)
	Hygroryza aristata (Retz.) Nees ex Wight & Arn.	Herb	Native	Kushwaha 254492 (LWG)
	Imperata cylindrica (L.) Raeusch.	Herb	Native	Panigrahi 12407 (BSA)
	Isachne globosa (Thunb.) Kuntze	Herb	Native	Panigrahi 8467 (BSA)
	Ischaemum rugosum Salisb.	Herb	Native	Panigrahi 4060 (BSA)
	Iseilema laxum Hack.	Herb	Native	Mishra 9726 (BSA)
	Leptochloa chinensis (L.) Nees	Herb	Native	Panigrahi 4121 (BSA)
	Leptochloa panicea (Retz.) Ohwi	Herb	Native	Kushwaha 254488 (LWG)
	Melanocenchris jacquemontii Jaub. & Spach	Herb	Native	Panigrahi & Prasad 3041 (BSA)
	Ophiuros exaltatus (L.) Kuntze	Herb	Native	Kushwaha 254309 (LWG)
	Oplismenus hirtellus (L.) P.Beauv.	Herb	Native	Kushwaha 254221 (LWG)
	Oryza glaberrima Steud.	Herb	Native	Panigrahi 12030 (BSA)
	Oryza rufipogon Griff.	Herb	Cultivated	Panigrahi 13402 (BSA)
	Oryza sativa L.	Herb	Cultivated	Kushwaha 304112 (LWG)
	Panicum notatum Retz.	Herb	Native	Panigrahi 13641 (BSA)
	Panicum paludosum Roxb.	Herb	Native	Panigrahi 12062 (BSA)

Family	Taxa	Growth form	Remarks	Collection reference
	Paspalidium flavidum (Retz.) A.Camus	Herb	Native	Panigrahi 12229 (BSA)
	Paspalum scrobiculatum L.	Herb	Native	Mishra 9770 (BSA)
	Pennisetum glaucum (L.) R.Br.	Herb	Native	Panigrahi 12477 (BSA)
	Pennisetum pedicellatum Trin.	Herb	Native	Kushwaha 254513 (LWG)
	Perotis indica (L.) Kuntze	Herb	Native	Mishra 9867 (BSA)
	Phalaris minor Retz.	Herb	Native	Kushwaha 254631 (LWG)
	Pogonatherum paniceum (Lam.) Hack.	Herb	Native	Panigrahi 4061 (BSA)
	Polypogon monspeliensis (L.) Desf.	Herb	Native	Kushwaha 254606 (LWG)
	Pseudoraphis spinescens (R.Br.) Vickery	Herb	Native	Panigrahi 2027 (BSA)
	Pseudosorghum fasciculare (Roxb.) A.Camus	Herb	Native	Panigrahi 13775 (BSA)
	Saccharum bengalense Retz.	Herb	Native	Panigrahi 13475 (BSA)
	Saccharum spontaneum L.	Herb	Alien	Panigrahi 12659 (BSA)
	Sacciolepis interrupta (Willd.) Stapf	Herb	Native	Panigrahi 13616 (BSA)
	Sacciolepis myosuroides (R.Br.) A.Camus	Herb	Native	Panigrahi & Prasad 2918 (BSA)
	Schizachyrium brevifolium (Sw.) Buse	Herb	Native	Panigrahi & Prasad 2520 (BSA)
	Schizachyrium exile (Hochst.) Pilg.	Herb	Native	Panigrahi 13606 (BSA)
	Schoenefeldia gracilis Kunth	Herb	Native	Panigrahi 9625 (BSA)
	Sehima nervosum (Rottler) Stapf	Herb	Native	Panigrahi & Prasad 2071 (BSA)
	Setaria intermedia Roem. & Schult.	Herb	Native	Panigrahi 12552 (BSA)
	Setaria pumila (Poir.) Roem. & Schult.	Herb	Native	Kushwaha 264788 (LWG)
	Setaria verticillata (L.) P.Beauv.	Herb	Native	Panigrahi 13886 (BSA)
	Sorghum bicolor (L.) Moench	Herb	Cultivated	Kushwaha 254453 (LWG)
	Themeda quadrivalvis (L.) Kuntze	Herb	Native	Kushwaha 254514 (LWG)
	Thysanolaena latifolia (Roxb. ex Hornem.) Honda	Herb	Native	Panigrahi 12664 (BSA)
	Tragus racemosus (L.) All.	Herb	Native	Panigrahi & Prasad 3674 (BSA)
	Triticum aestivum L.	Herb	Cultivated	Kushwaha 304113 (LWG)
	Urochloa panicoides P.Beauv.	Herb	Native	Singh & Saha EBH 506 (LWG)
Pontederiaceae	*Eichhornia crassipes* (Mart.) Solms	Herb	Alien	Kushwaha 254400 (LWG)
	Monochoria vaginalis (Burm.f.) C.Presl	Herb	Alien	Kushwaha 304141 (LWG)
Potamogetonaceae	*Potamogeton crispus* L.	Herb	Native	Kushwaha 304185 (LWG)
	Potamogeton nodosus Poir.	Herb	Native	Panigrahi 13708 (BSA)
Smilacaceae	*Smilax guianensis* Vitman	Herb	Native	Panigrahi 13675 (BSA)
Typhaceae	*Typha domingensis* Pers.	Herb	Native	Kushwaha 254641 (LWG)
	Typha elephantina Roxb.	Herb	Native	Panigrahi 12086 (BSA)
Xanthorrhoeaceae	*Asphodelus tenuifolius* Cav.	Herb	Native	Panigrahi 12655 (BSA)
Zingiberaceae	*Cheilocostus speciosus* (J. Koenig.) C. D. Specht	Herb	Native	Kushwaha 304134 (LWG)
	Curcuma aromatica Salisb.	Herb	Cultivated	Kushwaha 304143 (LWG)
	Curcuma longa L.	Herb	Cultivated	Kushwaha 304105 (LWG)
	Zingiber officinale Roscoe	Herb	Native	Kushwaha 254282 (LWG)

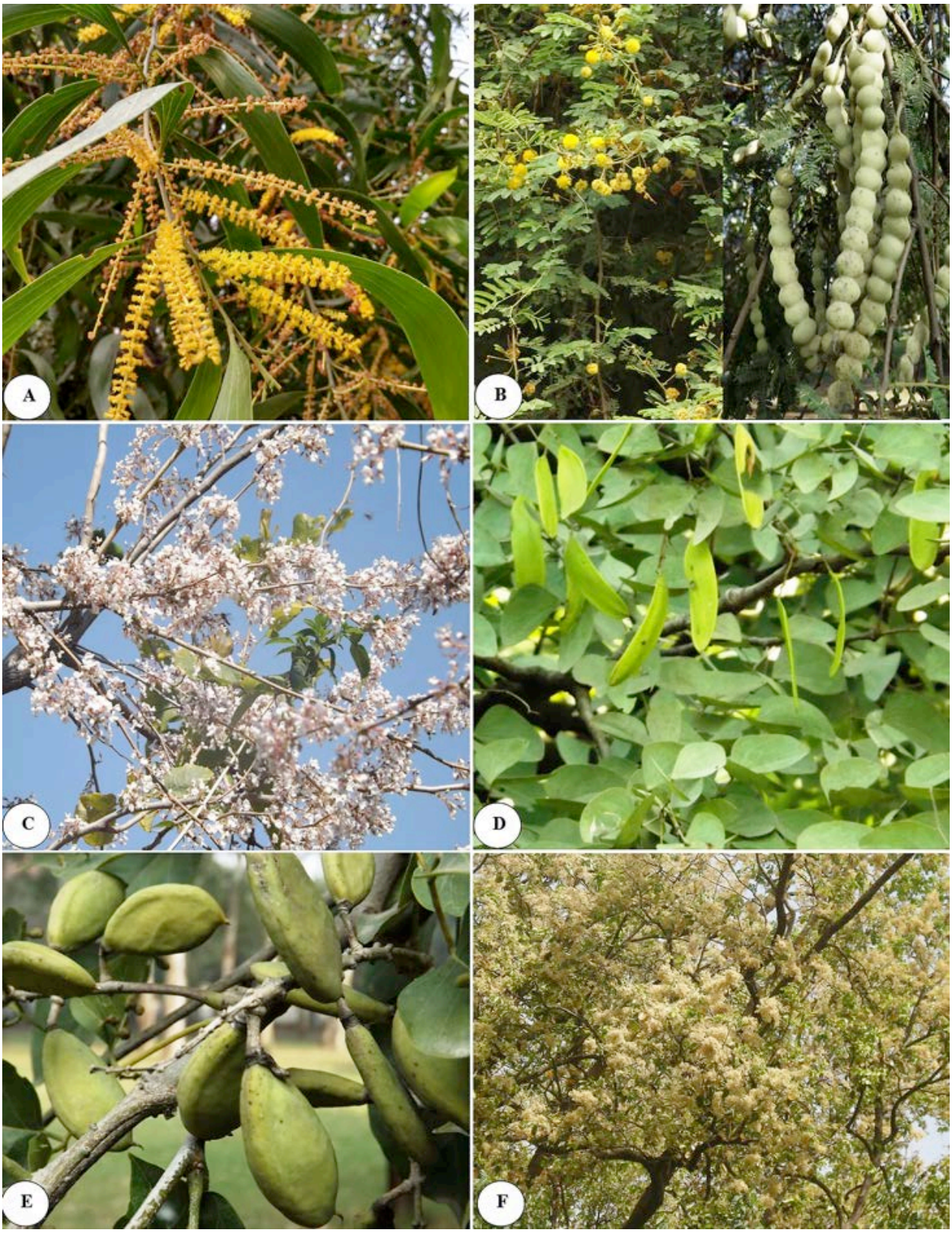

Image 2. A - *Acacia auriculiformis* Benth.; B - *Acacia nilotica* (L.) Delile; C - *Desmodium oojenenensis* (Roxb.) H. Ohasi; D - *Hardwickia binata* Roxb.; E - *Pongamia pinnata* (L.) Pierre; F - *Shorea robusta* Gaertn.

Image 3. A - *Commelina benghalensis* L.; B - *Gloriosa superba* L.; C - *Monochoria vaginalis* (Burm. f.) C. Presl; D - *Pistia stratiotes* L.; E - *Sagittaria sagittifolia* L. i; F -*Typha domingensis* Pers.

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Contribution to the Macromycetes of West Bengal, India: 23–27

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Abstract: The present article reports five heterobasidiomycetous taxa, viz., *Dacryopinax spathularia* (Dacrymycetaceae), *Exidia glandulosa*, *Pseudohydnum gelatinosum* (Exidiaceae), *Tremella fuciformis*, and *T. mesenterica* (Tremellaceae), based on collections made from West Bengal, India, with their morpho-anatomical details. *Dacryopinax spathularia* is reported from Odisha and Uttar Pradesh while *Tremella fuciformis* and *T. mesenterica* are reported from Chhattisgarh.

Keywords: Heterobasidiomycetes, jelly fungi, taxonomy, West Bengal.

Five jelly fungi were collected from different corners of West Bengal, India, and are reported herein with detailed morpho-taxonomic details.

The state of West Bengal has a wide range of phytogeographic regions extending from the coastal areas (of Bay of Bengal) to the subalpine regions of the eastern Himalaya. Each of these regions is unique in terms of various ecological conditions such as temperature, humidity, salinity, rainfall, altitude, edaphic factors, etc. that provide a wide range of habitats for the luxuriant growth of different types of macromycetes.

The 'jelly fungi' belong to the class Heterobasidiomycetes, characterized by the presence of greatly swollen gelatinous basidiocarps, basidia that lobed and often divided by transverse, oblique or longitudinal septa, and prominent sterigma (Webster & Weber 2007). Most of the jelly-fungi are saprotrophs that preferably grow on dead and decaying plant parts. The present manuscript reports five Heterobasidiomycetous fungi viz., *Dacryopinax spathularia* (Schwein.) G.W. Martin, *Exidia glandulosa* (Bull.) Fr., *Pseudohydnum gelatinosum* (Scop.) P. Karst., *Tremella fuciformis* Berk., and *Tremella mesenterica* Retz. with their morphological details. This is a series of our earlier works dealing with the exploration of macromycetes diversity of West Bengal (Acharya et al. 2017a,b,c; Tarafder et al. 2017).

Materials and methods

The specimens were collected during field trips in monsoon seasons (2010–2017) from corners of West Bengal, India. Macro-morphological and ecological features of each collection were noted in the field and subsequently photographed. The colour codes

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and terms used were in accordance with Kornerup & Wanscher (1978). Microscopic features were obtained from freehand sections of dried specimens by mounting with 10% KOH, Congo red and Melzer's reagent with the help of Carl Zeiss AX10 Imager A1 phase contrast microscope. Measurements of 30 basidiospores of each of the specimens were examined. Q value denotes length/breadth ratios of basidiospores and the mean value is underlined. Identification was done with the help of standard literature (Spears 1957; McNabb 1965; Ellis & Ellis 1990; Zhishu et al. 1993; Kuo 2006, 2007, 2008a,b; Pippola & Kotiranta 2008; Shirouzu et al. 2009). The voucher specimens were deposited in the Calcutta University Herbarium (CUH).

Taxonomy

***Dacryopinax spathularia* (Schwein.) G.W. Martin**

Lloydia 11: 116 (1948) (Fig. 1, Image 1a)

Fruit body 3–9 mm high. Pileus 1–5 mm diam., flabellate to petaloid, cartilaginous, brownish orange (6C8, 7C6) to reddish-orange (7B7) when fresh, turns reddish orange (7A8-B7-C7) all over on drying, surface covered with cortical hairs coloured white (1A1), margins sinuate to undulating. Stipe 1–1.5 mm broad, slender, cylindrical, white (1A1) to grey (7B1) when fresh, becoming grey (6B1) on drying, surface covered with cortical hairs coloured white (1A1). Odour mushroomy.

Basidiospores (7–)8–8.7–9.5(–11) × 3.5–3.7–4.5 µm, Q=1.6–2.3–3.0, cylindrical, curved, thin-walled, greyish beige (4C2) to grey (4C1), inamyloid,1-septate at maturity, short apiculate, oil granule present when viewed with KOH. Basidia 13–20 × 1.5–3.5 µm, bifurcate, having typical tuning-fork like structure, thin-walled, hyaline, 2-spored; sterigmata 7–22 × 2.5–3.5 µm, cylindrical. Pro-basidia 19.5–30.5 × 3.5–4.5 µm, clavate to cylindrical with basal septa, becoming bifurcate at maturity. Hymenium unilateral, smooth to slightly wavy. Marginal hyphae 11–27 × 4–6 µm, solitary or fasciculate, cylindrical, smooth, straight or flexuous, sometimes branched, thick-walled, septate, hyaline to brownish grey (5C2) with KOH. Internal hyphae 2.5–3.5 µm broad, cylindrical, smooth, thin-walled, branched, septate, hyaline to pale yellow (4A3) when viewed with KOH; clamp-connections absent.

Habit and habitat: Caespitose, gregarious or arranged in rows, on dead and decayed dicotyledonous woods.

Specimens examined: CUH AM175, 11.viii.2010, 22.44917^{0}N & 88.18500^{0}E, elevation 3m, Kakdwip, South 24-Pargana, West Bengal, India, coll. P. Pradhan & A.K. Dutta; CUH AM184, 18.viii.2011, 21.87611^{0}N & 88.39138^{0}E, elevation 8.5m, Sonarpur, South 24-Pargana, West Bengal, India, coll. A.K. Dutta & P. Pradhan; CUH AM187, 17.ix.2011, 22.36250^{0}N & 88.87666^{0}E, elevation 6m, Sandeshkhali, South 24-Pargana, West Bengal, India, coll. A.K. Dutta & P. Pradhan; CUH AM169, 31.vii.2010, 22.21472^{0}N & 88.90555^{0}E, elevation 4m, Chotomollakhali, Gosaba block, South 24-Pargana, West Bengal, India, coll. P. Pradhan; CUH AM172, 31.vii.2010, 22.22333^{0}N & 88.91388^{0}E, elevation 4m, Amtali, South 24-Pargana, West Bengal, India, coll. S. Chatterjee & S. Chandra; CUH AM168, 31.vii.2010, 22.19805^{0}N & 88.71388^{0}E, elevation 6m, Basanti, South 24-Pargana, West Bengal, India, coll. K. Acharya; CUH AM349, 09.vii.2015, 22.58666^{0}N & 88.41472^{0}E, elevation 4m, Central Park, Kolkata, West Bengal, India, coll. K. Acharya & A.K. Dutta & S. Paloi; CUH AM528, 14.viii.2017, 22.88305^{0}N & 88.76361^{0}E, elevation 6m, Gobardanga, North 24-Pargana, West Bengal, India, coll. K. Acharya; CUH AM544, 14.vii.2017, 26.32194^{0}N & 88.43638^{0}E, elevation 37m, Debi Bari, Cooch Behar, India, coll. K. Acharya; CUH AM 541, 16.vii.2017, 26.32194^{0}N & 88.43638^{0}E, elevation 37m, Debi Bari, Cooch Behar,

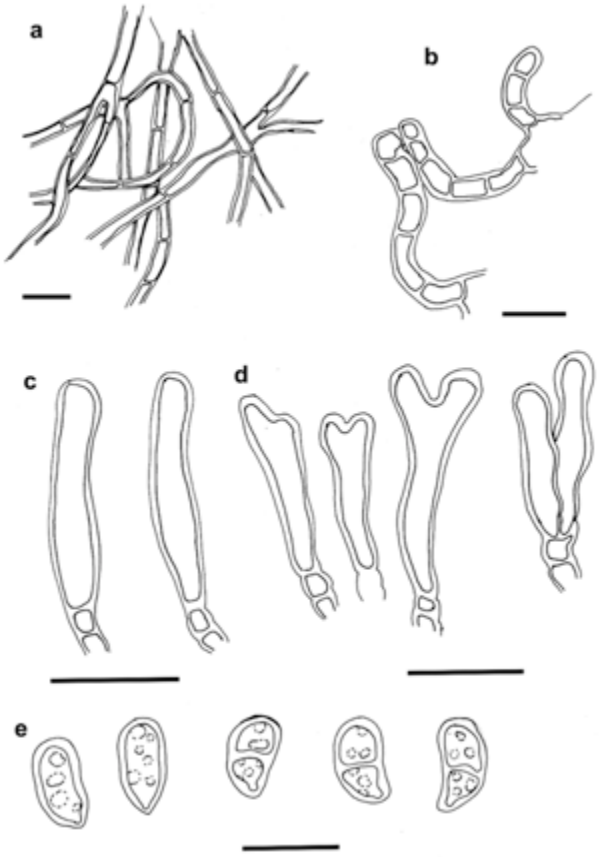

Figure 1. *Dacryopinax spathularia*: a - Internal hyphae, b - Marginal hyphae, c - Pro-basidia, d - Basidia, e - Basidiospores. Scale = 10µm.

India, coll. K. Acharya.

Remarks: *Dacryopinax spathularia* is well characterised by its spathulate fruit body coloured yellow-orange; presence of thick-walled, cylindrical marginal hyphae; absence of inflated vesicles and hyphal pegs in the abhymenium; and presence of 0–1 septate basidiospores (McNabb 1965; Shirouzu et al. 2009). This is a widely distributed taxon and previously been reported from Japan, North America, and China etc. (McNabb 1965; Zhishu et al. 1993; Shirouzu et al. 2009). It was reported from Rajamunda, Odisha, growing on logs of *Shorea robusta* (Tiwari et al. 2013). The species was also recorded on wood from Saharanpur, Uttar Pradesh (Butler & Bisby 1931). The present collection matches well with the description made from North America (McNabb 1965); however, according to Shirouzu et al. (2009), basidiospores of the specimen from Japan were found to be sub-globose to reniform, while the Indian specimen showed mostly cylindrical basidiospores with the range varying from oblong to bacilliform (Q=1.6–3.0). The specimen reported from China was found to have 1–2 septate basidiospores at maturity, but the basidiospores of our collection showed one septation at maturity.

Among morphologically similar taxa: *Dacryopinax indacocheae* has foliose fruit body coloured tan and presence of inflated vesicles (McNabb 1965); *Dacryopinax formosus* primarily differs by the presence of hyphal pegs in abhymenium layer; *Dacryopinax aurantiaca* differs by its dingy white to cream or pallid tan-coloured stipe and abhymenial surface, and considerably longer basidiospores (up to 13.5 × 5 µm); *Dacryopinax elegans* has larger fruitbody (12–50 mm) coloured deep amber-brown to black-brown, thick-walled basidiospores with 3-septations at maturity. *Dacryopinax yungensis* differs by the presence of inflated vesicle-like cells in cortical layer, and comparatively larger (11–14 × 4.5–6.5 µm), 3-septate basidiospores.

Exidia glandulosa (Bull.) Fr.

Syst. mycol. (Lundae) 2(1): 224 (1822) (Fig. 2, Image 1b)

Fruit body 22–25 mm long, 10–16 mm broad, turbinate, fleshy, gelatinous, irregularly folded to cerebriform, reddish brown (8E5) to dark brown (8F4) to black when fresh, becoming greyish brown (8F3) to black, hard, crust-like when dry, surface with dot-like glands. Odour mushroomy.

Basidiospores 11–13.1–13.5(–15) × (4.5–)5–5.6(–6.5) µm, Q=1.5–2.4–3.2, oblong to cylindric, allantoid, dark brown (7F5) at maturity, smooth, inamyloid, oil granules present with KOH. Phragmobasidia 11–17 × 8–12 µm,

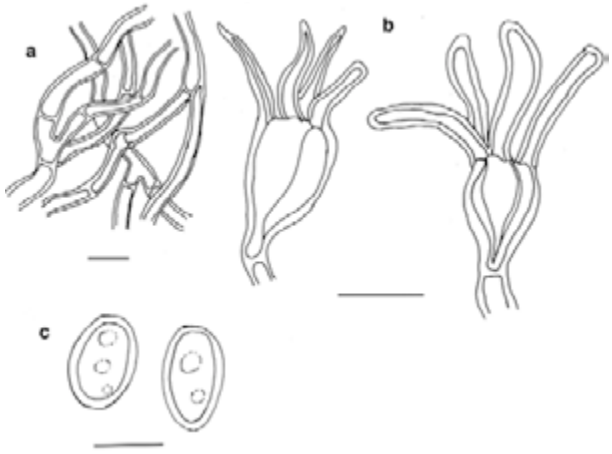

Figure 2. ***Exidia glandulosa*****: a - Hyphae, b - Basidia, c - Basidiospores. Scale = 10µm.**

globose to ellipsoid, hyaline, smooth, longitudinal, cruciate septate, 2–4 spored, basally stalked; stalk of basidia 7–14.5 × 1.8–3.5 µm, septate, hyaline, smooth; sterigmata 14–54 × 3.5–5.5 µm, hyaline. Hyphae 2–5.5 µm broad, smooth, with clamp-connections.

Habit and habitat: Gregarious to confluent, growing on dead and decayed dicotyledonous woods.

Specimen examined: CUH AM 219, 10.viii.2013, 22.27972^{0}N & 88.45472^{0}E, elevation 8m, Gocharan, South 24-Parganas, West Bengal, India, coll. A.K. Dutta & P. Pradhan.

Remarks: Characteristic features of *Exidia glandulosa* includes the presence of brown to black turbinate, gelatinous fruit bodies that often coalescing together to form masses, dotted by minute glandular structures, cruciate septate, stalked basidia and allantoid basidiospores. The Indian collection nicely matches with the description of Ellis & Ellis (1990); however, the habitat of our collection was other dead dicotyledonous wood as compared to the Britain collection that was reported to be oak and hazel. It was reported from Nilgiris, Tamil Nadu (Montagne 1842). Among morphologically similar taxa: *Exidia plana* differs by its effused fruit body (Roberts 2001) that lacks dot-like glands on its surface. *Exidia truncata* Fr. has fruit bodies that are not confluent and remain largely free from the substrate, and larger basidiospores (14–22 × 5–7 µm; Ellis & Ellis 1990). *Exidia saccharina* differs in having caramel to dark brown fruit bodies lying flat on the substrate (Ellis & Ellis 1990). *Exidia recisa* differs by its amber to dark brown coloured fruit bodies that are not confluent and becomes flabby and drooping when old (Ellis & Ellis 1990).

***Pseudohydnum gelatinosum* (Scop.) P. Karst**

Not. Sällsk. Fauna et Fl. Fenn. Förh. 9: 374 (1868)

(Fig. 3, Image 1c)

Fruit body 21–39 mm high. Pileus 14–28 mm, fan-shaped, glossy, gelatinous, dull red (8C3) to reddish-brown (9D4) when fresh, becoming dark brown (8F4) when dry, hard, cartilaginous; lower hymenial surface covered with dense, soft teeth or spines, teeth 1–3 mm long, white (9A1). Stipe 15–18 × 7–13 mm, lateral, reddish brown (9D4) when fresh, becoming dark brown (8F4) on drying.

Basidiospores (5–)6–7.2(–9) × (5–)6–6.8(–7.5) µm, Q=1–1.1–1.3, globose to sub-globose, hyaline, apiculate, smooth, thin-walled, oil granules present when viewed with KOH. Basidia 11–15 × 7–11 µm, globose to sub-globose or ellipsoid, hyaline, thin-walled, inamyloid, smooth, 2–4 septate (cruciate), oil granules present when viewed with KOH, basally stalked, stalk 5–29 × 2–3.5 µm, 2–4 spored; sterigmata 5–25 × 2–4 µm, 1-septate, sometimes bearing bifurcation near the tip, smooth. Hyphae 2.5–4.5 µm broad, smooth, hyaline, branched, thin-walled, clamp-connections present. Hymenium unilateral, wavy due to the presence of teeth.

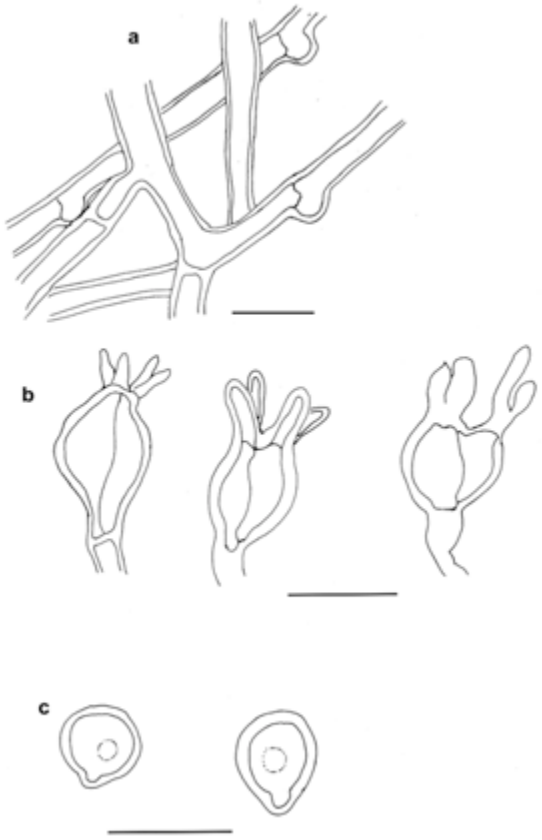

Figure 3. *Pseudohydnum gelatinosum*: a - Hyphae, b - Basidia, c - Basidiospores. Scale = 10µm.

Habit and habitat: Solitary to scattered, on humus mixed soil.

Specimen examined: CUH AM197, 22.viii.2012, 27.01805^{0}N & 88.56472^{0}E, elevation 1697m, Lolaygaon, Darjeeling District, West Bengal, India, coll. A.K. Dutta & P. Pradhan.

Remarks: The presence of characters like a glossy, fan-shaped, gelatinous pileus with the lower (hymenial) fertile surface covered with dense, white soft teeth or spines can easily identify *Pseudohydnum gelatinosum* in the field (Ellis & Ellis 1990). It is distinct from other taxa in being the only toothed member of the jelly fungi (Emberger 2008).

Pseudohydnum gelatinosum has been previously reported from India (Das 2009). The present collection shows little smaller cap (14–28 mm vs. 40–90 mm) and larger basidiospores (5–9 × 5–7.5 µm vs. 5–6 × 4–5.5 µm). Apparently, *Dacryopinax elegans* resembles the present taxon with regard to colour, structure, and texture but is easily distinguished from it when the lower part of pileus is examined (Kuo 2015).

***Tremella fuciformis* Berk.**

Hooker's J. Bot. Kew Gard. Misc. 8: 277 (1856)

(Fig. 4, Image 1d)

Fruit body 43–63 mm long and 35–42 mm broad, white (1A1), firm gelatinous, translucent, mucilaginous when fresh, becoming horny, thin, grey (3B1) to yellowish-grey (3B2) coloured when dry, repeatedly lobed or forked with margins flexuous to folded, sessile. Odour slightly fishy.

Basidiospores (6–) 6.5–8.4–9(–10) × (5–)5.5–6(–7) µm, Q=1.1–1.3–1.5, subglobose to broadly ellipsoid, smooth, hyaline, inamyloid, apiculate, with 1 oil guttule. Phragmobasidia 11–14 × 6.5–10 µm, subglobose, becoming longitudinally cruciate septate, 2–4 septate at maturity, thin-walled, hyaline, oil granules visible when mounted with KOH, 4-spored; sterigmata 10–33 × 2–4 µm, cylindrical. Conidia 8–15 ×6–9 µm, subglobose to broadly ellipsoid, smooth, hyaline. Swollen cells 11–20 × 6–11 µm, globose to subglobose to ellipsoid, abundant, hyaline, oil granules present when viewed with KOH. Hyphae 2.5–5.5 µm broad, hyaline, thin walled, branched, clamp-connections present.

Habit and habitat: Solitary, on dead and decayed dicotyledonous wood.

Specimens examined: CUH AM536, 14.viii.2017, 22.88305^{0}N & 88.76361^{0}E, elevation 6m, Gobardanga, North 24 Parganas, West Bengal, India, coll. K. Acharya; CUH AM543, 14.vii.2017, 26.32194^{0}N & 88.43638^{0}E, elevation 37m, Debi Bari, Cooch Behar, India, coll. K.

Image 1. Habit of mature fruit bodies of a - *Dacryopinax spathularia*, b - *Exidia glandulosa*, c - *Pseudohydnum gelatinosum*, d - *Tremella fuciformis*, e - *Tremella mesenterica*.

Acharya.

Remarks: *Tremella fuciformis* is characterised by its pure white, translucent, gelatinous fruit bodies with lobed margins, and the presence of cruciate-septate phragmobasidia (Speairs 1957). It has previously been reported from several countries such as China, Brazil, and North America (Burt 1921; Olive et al. 1948; Speairs 1957; Zhishu et al. 1993). The Chinese specimen differs from the present collection in having slightly smaller basidiospore (5–7 µm diam.); however, the present specimen was found to be identical to the description made from Brazil and North America (Burt 1921; Olive et al. 1948; Speairs 1957). From India it was reported growing on logs of *Shorea robusta* from West Bengal (Banerjee 1947) and Jagdalpur, Chhattisgarh; on *Pterocarpus marsupium* and from Keshkalghat, Chhattisgarh (Tiwari et al. 2013).

Tremella fuciformis is morphologically similar to *T. reticulata*; however, *T. reticulata* grows on the ground or on very rotten stumps and it differs by having a larger (up to 80mm long and 150mm broad), erect, reticulated fruit body that is irregularly forked upwards giving rise to tapered tips (Speairs 1957; Kuo 2008a).

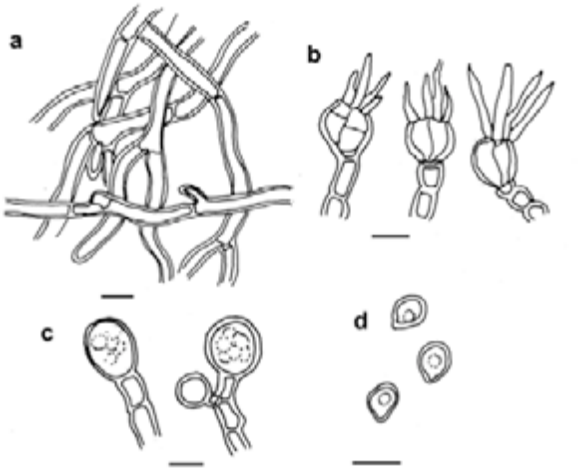

Figure 4. ***Tremella fuciformis*****: a - Hyphae, b, - Basidia, c - Swollen cells, d - Basidiospores. Scale = 10µm.**

Tremella mesenterica **Retz.**

K. svenska Vetensk-Akad. Handl., ser. 1 30: 249 (1769)

(Fig. 5, Image 1e)

Fruit body 18–33 × 13–30 mm, folded into lobes, cerebriform, gelatinous, light yellow (4A5) when fresh, becoming orange (5A6) to greyish orange (5B6), horny and crust-like when dry. Sessile. Odour mushroomy.

Basidiospores 14–16–18 × 14–15–16.5 µm, Q=1–1.1–1.2, globose to sub-globose, smooth, hyaline to pale yellowish (3A3), apiculate, oil granules visible with KOH. Phragmobasidia 25–29 × 22–27 µm, globose to sub-globose, 2–4 celled, longitudinally or obliquely (cruciate) 4-septate at maturity, thin-walled, hyaline to pale yellowish (3A3), inamyloid, smooth, oil granules present when viewed with KOH, 4-spored; sterigmata 18–144 × 4.5–6.5 µm. Conidia not observed. Swollen cells 14–33 × 11–27 µm, sub-globose to ellipsoid to oblong, terminal or sub-terminal, stalked, smooth, hyaline. Hyphae 2–5 µm broad, thin-walled, branched, hyaline to pale yellow (3A3), clamp-connections present.

Habit and habitat: Solitary to caespitose, on dead and decayed dicotyledonous wood.

Specimens examined: CUH AM538, 10.viii.2017, 22.78638^{0}N & 88.35500^{0}E, elevation 17m, Barrackpore, North 24-Pargana, West Bengal, India, coll. K. Acharya; CUH AM545, 16.vii.2016, 23.40083^{0}N & 88.50138^{0}E, elevation 20m, Krishnanagar, Nadia, West Bengal, India, coll. K. Acharya.

Remarks: Distinguishing features of *Tremella mesenterica* includes a bright yellow, lobed, cerebriform fruit body, presence of cruciate septate phragmobasidia with much longer sterigmata (Ellis & Ellis 1990; Pippola & Kotiranta 2008). The specimen of our collection

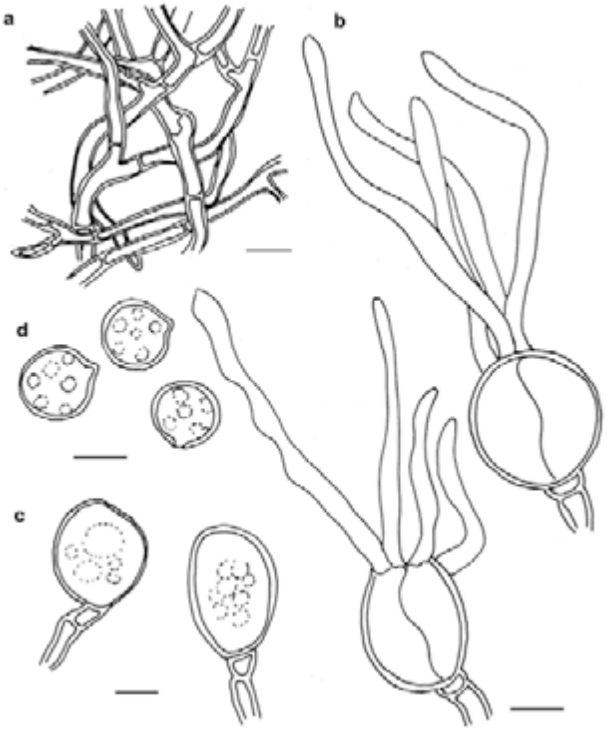

Figure 5. ***Tremella mesenterica*****: a - Hyphae, b - Basidia, c - Swollen cells, d - Basidiospores. Scale = 10µm.**

is similar in characters with the one described from Finland (Pippola & Kotiranta 2008) except having slightly longer sterigmata and presence of distinct oil droplets in basidia and sterigmata. From India, it was reported from Jagdalpur, Chhattisgarh, growing on logs of *Shorea robusta* (Tiwari et al. 2013).

With regard to the colouration and size of the fruit body, *Tremella mesenterica* is similar to *T. aurantia* (Pippola & Kotiranta 2008). However, *T. aurantia* differs from *T. mesenterica* in having rather smaller basidiospores (5.5–9 × 4.5–7 µm) and basidia (ca. 9–13 µm wide) (Pippola & Kotiranta 2008).

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Animal-fungal interactions 2: first report of mycophagy by the Eastern European Hedgehog *Erinaceus concolor* Martin, 1837 (Mammalia: Eulipotyphla: Erinaceidae)

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The fungal species frequently eaten by small mammals often fruit below ground (hypogeous fungi) and have evolved a dependence on animals for their spore dispersal (Maser et al. 1978, 2008; Cazares & Trappe 1994; Trappe & Claridge 2005; Vernes & Dunn 2009; Elliott & Trappe 2018). The digging required to excavate these fungi enhances soil aeration and allows for better water penetration and soil hydration (Flemming et al. 2013). Most fungi consumed by animals are mycorrhizal and serve important functions as symbionts in soil nutrient acquisition and exchanges with plants (Maser et al. 1978; Colgan & Claridge 2002; Schickmann et al. 2012). Many small mammals depend on hypogeous fungi as a staple food, and numerous larger animals opportunistically feed on them (Fogel & Trappe 1978; Claridge & Trappe 2005).

Fungi contain important dietary components such as water, essential amino acids, protein, fat, carbohydrates, and crude fiber (Hussain & Al-Ruqaie 1999; Claridge & Trappe 2005; Wallis et al. 2012). Fungi appear in a wide array of animals' diets around the world (Fogel & Trappe 1978; Blaschke & Bäumler 1989; Claridge & May 1994; Hanson et al. 2003; Schickmann et al. 2012). Despite the prevalence and importance of fungi as animal food, mycophagy has been understudied/unreported even among otherwise well-researched animal species. For example, we provide the first confirmed documentation of mycophagy by *Erinaceus concolor* (Martin), the Eastern European Hedgehog. This small mammal has been frequently reported to eat insects, snakes, and plant matter (Özen 2006). Naem et al. (2015) note that "…mushrooms may supplement the diet" of the West European Hedgehog, *E. europaeus* (L.); but their evidence for this statement is unclear and the species of mushrooms are not indicated. New Zealand has a diversity of hypogeous fungi and a large population of invasive hedgehogs, *E. europaeus*, that likely consume local fungi, but this has yet to be confirmed (Wood et al. 2015). As part of this study we conducted microscopic examinations of 30 scats collected from *E. europaeus* in New Zealand and we found no fungal spores. These scats were collected by collaborators and we were unable to determine if many fungi were fruiting during

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the sampling period.

Santana et al. (2010) mention African Four-toed Hedgehogs, *Atelerix albiventris* (Wagner), eating fungi, but it was not recorded how this or the species of fungus consumed was determined. Skinner & Chimimba (2005) mention fungi in the diet of the southern African Hedgehog *A. frontalis* (A. Smith), but we were unable to determine the original source of their report, and they do not indicate the identity of the fungi consumed. Members of the hedgehog genera *Hemiechinus*, *Mesechinus*, and *Paraechinus* have either had inadequate seasonal dietary studies or insufficient microscopic examination of fecal or stomach samples to determine their mycophagist status.

During mycological fieldwork in March and April 2014 in Muğla-Ula, Turkey, we encountered an Eastern European Hedgehog. *Erinaceus concolor* (Image 1a) crossing the road in a plantation of Umbrella Pine *Pinus pinea* (L.). The understory was predominantly Kermes Oak *Quercus coccifera* (L.), and *Cistus* spp. accompanied by a diverse ectomycorrhizal fungal community. Our interest in mycophagy and hypogeous fungal spore dispersal led us to wait and collect a fecal sample from the animal. The fecal sample we collected was dried and once at the laboratory, several small pieces were placed with forceps into drops of ethanol on microscope slides. After several minutes the ethanol evaporated and the structures softened. Then water and a cover slip were added and the slide studied with a binocular compound microscope at × 100, × 400, and × 1000 magnification. Additional slides were mounted in Meltzer's reagent to test for taxonomically diagnostic staining reactions of fungal structures; all tests were nonresponsive. Micrographs were taken in water. Percentage volume of fungal material in the slide mounts was estimated by visual scanning. To increase sample size we attempted to find additional individuals to collect scats by spotlighting, but the thick understory and brief time at the site prevented success.

Pieces of fungal tissue and masses of spores composed at least 90% of the Turkish fecal sample. The fungal tissues were characteristic of the false truffle genus *Rhizopogon* (Image 1b). Fungal surveys in the area where the *E. concolor* was found revealed prolific fruitings of *Rhizopogon vulgaris* (Image 1b).

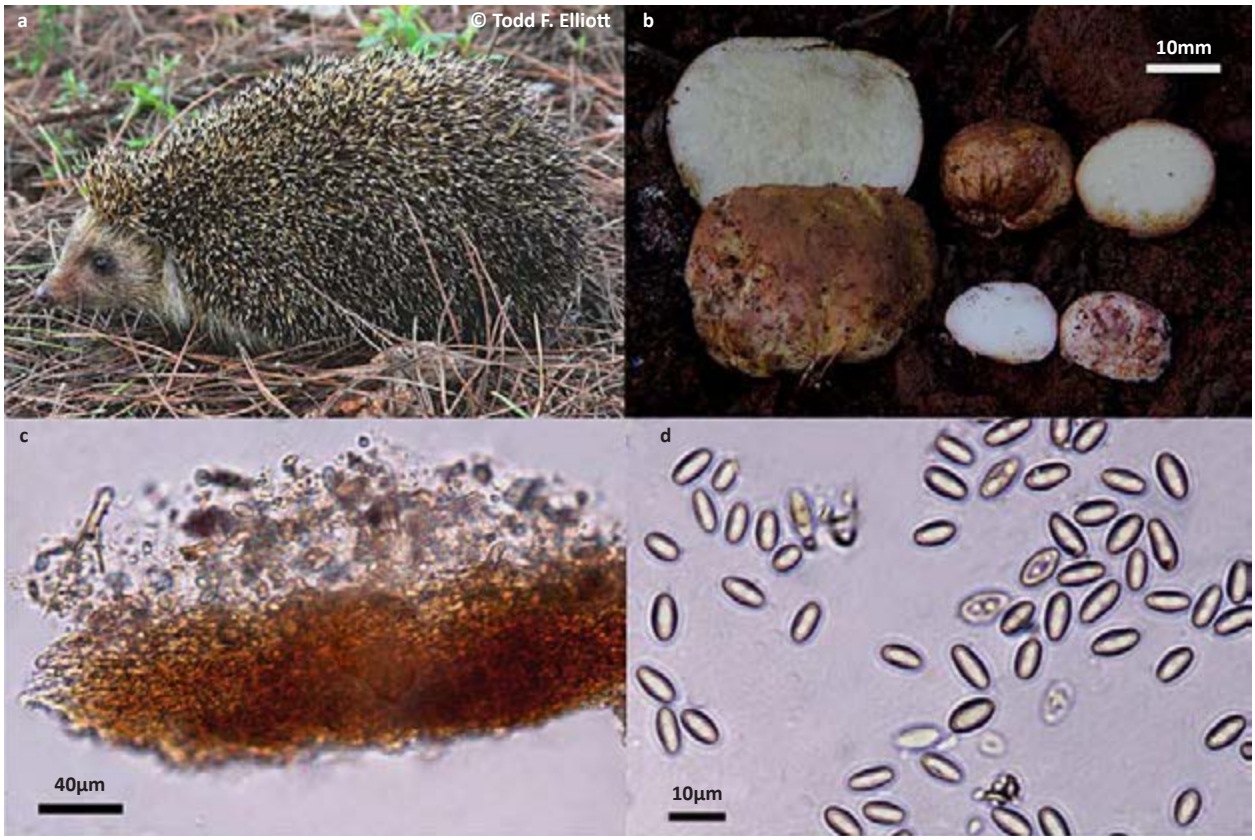

Image 1. a - The Eastern European Hedgehog that was the source of the fecal sample examined; b - Fruiting bodies of the false truffle *Rhizopogon vulgaris* found near where the hedgehog was foraging, surface and cross-sectional views; c - Piece of *R. vulgaris* peridium extracted from hedgehog fecal sample; d - Spores of *R. vulgaris* that comprised the majority of the hedgehog fecal sample.

This observation provides strong evidence of gaps in our understanding of the dietary behavior of this and other species of hedgehogs. Historically, the use and importance of fungi has been frequently overlooked in animal dietary studies, and that is likely true for hedgehogs. We had one fecal sample from one individual, insufficient for broad conclusions on behavior and dietary preferences of *E. concolor* or related species, but the large volumes of spores and chunks of fungal tissue in the sample examined (Image 1 c,d) indicate preferential or opportunistic consumption of *Rhizopogon vulgaris* over other food sources. Our estimate of 90% fungus by volume in the scat sampled shows that Eastern European Hedgehogs are opportunistic or possibly preferential mycophagists and we encourage researchers working on this and other species of hedgehogs to apply similar methods to test that hypothesis.

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Note

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Rostral anomaly in a juvenile Spiny Butterfly Ray *Gymnura altavela* (Linnaeus, 1758) (Elasmobranchii: Myliobatiformes: Gymnuridae) from the Canary Islands

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The Spiny Butterfly Ray *Gymnura altavela* (Linnaeus, 1758) has an amphi-Atlantic distribution, and occurs in its eastern range along the coasts of Portugal and Spain, over Morocco to Angola, the Mediterranean Sea, Black Sea, Madeira, and the Canary Islands (Ebert & Stehmann 2013; Yokota et al. 2016). It has been assessed globally as Vulnerable on the IUCN Red List (Vooren et al. 2007) and as Critically Endangered (Dulvy et al. 2016) for the European distribution. The first record of an anomaly in this species was described by Narváez & Osaer (2016) for an adult female observed in 2007 and 2008 in the northwest of the Island of Gran Canaria (Canary Islands, Spain). This observation was also remarkable for its similarity, prominent in sex, shape, location, and texture, with the partial lack of the disc in way of the rostrum in the Long-tailed Butterfly Ray *G. poecilura* from the western Indo-Pacific (Suresh & Raffi 2012).

On 29 July 2017, an unusual juvenile female *G. altavela* (41cm disc width) was observed during a visual census at 10.9m depth and 22^{0}C water temperature in the Special Area of Conservation 'Playa del Cabrón' (ES7010053, 27.8709^{0}N & 15.3822^{0}W, Gran Canaria, Canary Islands). The right pectoral fin was not fused to the braincase, causing an opening in the anterior part of the disc from the rostral ridge to the posterior margin of the eye and a free lobe. The epidermis pigmentation was absent at the proximal part of this lobe, presenting a similar appearance in colour and texture as the white epidermis from the ventral side (Image 1). The inflated peritoneal cavity of the individual may suggest a full stomach and adaption to its abnormality for successful predation (Image 1b). The species was identified following the descriptions from Yokota et al. (2016). The juvenile maturity phase was inferred from the reported size ranges in neonates (34–39 cm disc width) for the distribution off Syria (Alkusairy et al. 2014), and the maximum recorded disc width of 31.3 cm for embryos was inferred from the distribution off Tunisia (Capapé et al. 1992).

The present communication is the first record of this anomaly type in a juvenile *G. altavela*, and the second instance reported in this species and in the Canary Islands. Both cases were observed in the island of Gran Canaria, but in different regions (eastern versus northwestern) and with a 10-year time lapse. In addition, they have similar morphologic aspects, with differences limited to the extent in lack of the disc (posterior margin of the eye versus posterior margin of the spiracle) and the opening

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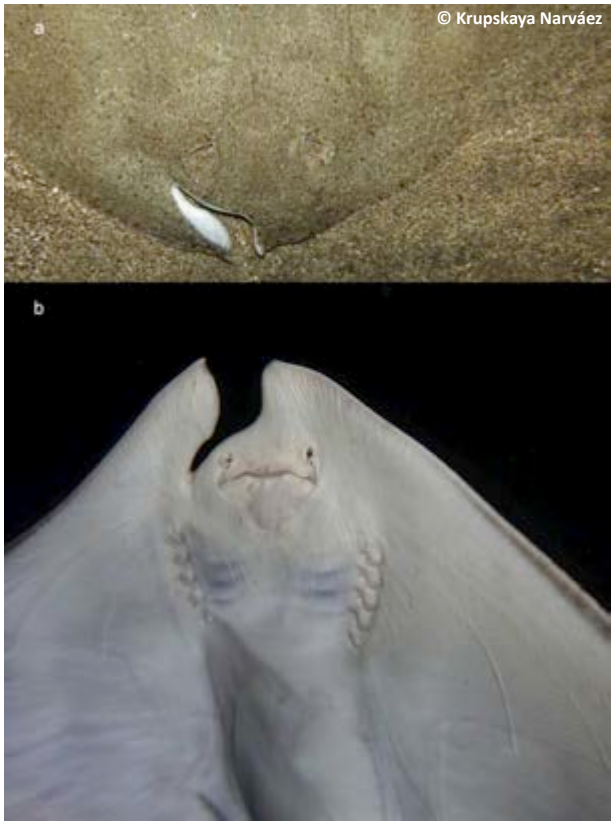

Image 1. Unfused pectoral fin to the braincase in a female, juvenile, Spiny Butterfly Ray *Gymnura altavela* (Linnaeus, 1758) with 41cm disc width observed during a visual census in the Special Area of Conservation 'Playa del Cabrón' (ES7010053, 27.8709^{0}N & 15.3822^{0}W, Gran Canaria, Canary Islands). a - dorsal view; and b - ventral view.

ends in the way the anterior disc margin (pointed versus rounded tips). Both aspects are, however, minimal and might be caused by the size difference of the individuals (41cm versus 137cm disc width).

There is scant information available in the literature of anomaly cases in butterfly rays for individuals above the size of birth. Three instances document an unfused right pectoral fin to the snout (Suresh & Raffi 2012; Narváez & Osaer 2016; the present study) that were similar in sex, shape, location, and texture. Two cases described a dorsal fold on the tail (Nunes & Piorski 2009) and one an absent tip of the snout (Béarez et al. 2008). The low occurrence of reported anomalies in butterfly rays during the last decade in our study region and the survival of the affected individuals could suggest that these instances are not a priority conservation concern at present. More studies, however, are required to better understand the causes for such deformations and to correctly assess this matter.

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A record after 52 years, and additional description of the emesine assassin bug *Emesopsis nubila* (Hemiptera: Reduviidae: Emesinae) from western India

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A small, 5mm long, hairy female bug with long legs, till date not recognized by the authors, was collected near a source of light in Katraj area of Pune City, Maharashtra, the western part of India. Subsequently, a similar male specimen was collected in Shirur, near Pune, in a grassy patch. One dead male was also found trapped in a spider's web at Daund, near Pune. All the three specimens were identified using keys in Wygodzinsky (1966) as *Emesopsis nubila* Uhler, 1893, which is an emesine assassin bug species belonging to the tribe Ploiariolini and is widely distributed in tropical and subtropical zones all around the world. These specimens represent the first record of *E. nubila* from Maharashtra State as well as western part of India. An earlier record of this species (as *Calphurnia reticulata*) was from Calcutta (now Kolkata) (Distant 1910); the checklist of Reduviidae by Ambrose (2006) also states Kolkata as a locality based on Distant's work and not on the basis of any fresh collections. Thus, this finding is a rediscovery of this bug after a prolonged period and also extends the range of its distribution considerably westwards as far as India is concerned. Although widespread, this bug has not been recorded from India in many years, except perhaps the record by Wygodzinsky (1966) of a specimen from Coimbatore, southern India.

In this note, we provide many images of the morphological characters of this species as we strongly support the idea of Ang et al. (2013) who state in the context of taxonomic papers, "We propose that descriptions should become more data-rich by presenting large amounts of images and illustrations to cover as much morphology as possible".

Material and Methods

Material examined: one female from Katraj, Pune (coll. M. Joshi; October 2016); one male from Shirur, Pune (coll. B. Sarode, June 2017); one male from Daund, Pune (coll. P. Pansare, November 2017). Bugs were studied under a Leica stereozoom (MZ6) microscope and also photographed with an attached Canon Powershot S50 camera. Several images were stacked using Combine ZM software and the images were processed with Adobe Photoshop CS5. Measurements were done with Erma stage and ocular micrometer and an accurate scale. The pygophore was dissected after treating the last three

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abdominal segments with hot 10% KOH, the phallic complex was dissected and the parameres and phallus were separated and mounted in polyvinyl lactophenol (PVLP) with lignin pink dye, and photographed. All specimens and slides of genitalia are preserved in Modern College of Arts, Science and Commerce, Shivajinagar, Pune.

Measurements: All measurements (based on one male (MCZH 132, June 2017) and one female (MCZH 131, October 2016) given below are in mm and they are separated as male / female.

Total length 4.5 / 5.125, total length of head 0.625 / 0.625, anteocular length 0.1 / 0.125, postocular length 0.25 / 0.25, head width dorsally at eye 0.5 / 0.5; antenna: length of first segment 1.75 / 1.875, second segment 1 / 1.125, third segment 1 / mutilated, fourth segment 0.375 / mutilated; labium: length of first visible segment 0.3 / 0.275, second visible (globular) segment 0.15 / 0.18, third visible segment 0.2 / 0.18; thorax length 1.125 / 0.8, pronotum length 0.625 / 0.75, width at anterior angles of pronotum 0.45 / 0.375, pronotum widdth at humeral angles 0.675 / 0.625; fore leg: length of coxa 0.625 / 0.75, femur 1.125 / 1.375, tibia 0.8 / 1.05, tarsus with claw 0.25 / 0.25; mid leg: length of coxa 0.2 / 0.2, femur 1.875 / 1.9, tibia 2.45 / 2.5, tarsus with claw 0.125 / 0.15; hind leg: length of coxa 0.25 / 0.25, femur 2.875 / 3, tibia 3.875 / 3.95, tarsus with claw 0.125 / 0.125; length of fore wing: 3.75 / 3.75, maximum width of fore wing 1.125 / 1.125; male pygophore: length measured laterally up to the tip 1.25; length of paramere excluding curved portion 0.625; length of extended phallus 1.65; length of phallobase in extended phallus 0.5; length of articulatory apparatus in extended phallus 0.4.

Heteroptera, Reduviidae, Emesinae, Ploiariolini
***Emesopsis nubila* Uhler, 1893**

Ishikawa & Okajima (2006) have recently given generic diagnosis, synonyms, additional description and illustrations of *E. nubila*. Synonyms are therefore omitted here.

Diagnosis: The diagnostic characters for *E. nubila* are, in brief: head and pronotum yellowish-brown with long erect setae, posterior pronotal lobe about twice as long as anterior pronotal lobe, mid and hind legs with long setae, forewing with typical markings, endosoma of male genitalia with a pair of vesica arms only, and vesica arm thickened in basal half and slender in apical half.

Additional description: Small, delicate, thread-legged bug, with very hairy body. Overall color brown to reddish-brown, ventrally partly dark brown; antennae partly dark brown; membrane of fore wing with a few pale brown spots, veins slightly darker; legs with brown annulations (Image 1A,B). Male darker ventrally than female (at least in the examples before us).

Head small, anteocular part much shorter than sub-globose postocular part; eyes comparatively large; pronotum with short and narrow anterior lobe and long and broad posterior lobe (nearly twice as long as anterior lobe), covered with long colorless wooly setae, these setae densest on posterior lobe of pronotum; female slightly more hairy than male (Image 1C,D). Second visible segment of labium swollen, as seen in lateral view (Image 1E). Pronotum completely covering mesonotum; metanotum with vertical spine (Image 1F).

Fore wing showing typical venation, especially reticulate pattern at base, with brownish spots on membrane (Image 1G).

Fore legs with long coxae; femur with anteroventral and posteroventral series of very small spiniform setae; tibia slightly shorter than femur; tarsus two-segmented; brownish annulation visible on coxa, femur and tibia (Image 1H); mid and hind legs long, slender, with brown annulations; long setae covering on all legs.

Pro-, meso- and metasterna reddish-brown; pleural regions slightly darker (Image 1I,J). Prosternum furrowed in median region; mesosternum with smooth and glabrous patch laterally. Abdomen slender and darker in male (Image 2A), and broad, pale yellow brown but darker at base and apex ventrally in female (Image 2B).

Pygophore elongate, laterally slightly compressed, ventrally convex, setose, moderately sclerotized, with arrow like spiny posterosuperior process projecting above parameres (Image 2C-E). Parameres slightly curved, setose (Image 2F,G). Phallotheca moderately sclerotized; articulatory apparatus short but stout, basal plates fused in apical half; conjunctiva membaranous; vesica with paired processes that are broad at base and narrowed distally (Image 2H–J). Female terminalia (stained with eosin) densely covered with setae (Image 2K).

Discussion

The above-mentioned characters match with those described by earlier workers. To confirm the species further, we compared the images of pygophore and phallus with the figures given by Wygodzinsky (1966), Villiers (1979) and photos given by Ishikawa & Yasunaga (2004), as well as Ishikawa & Okajima (2006).

The checklist of the Indian species of Reduviidae (Ambrose 2006) includes *E. nubila* and another species, namely *Emesopsis bimedia* Ravichandran & Livingstone, 1989 from 'Coimbatore, Tamil Nadu'. This latter species has been never recorded again. Wygodzinsky (1966)

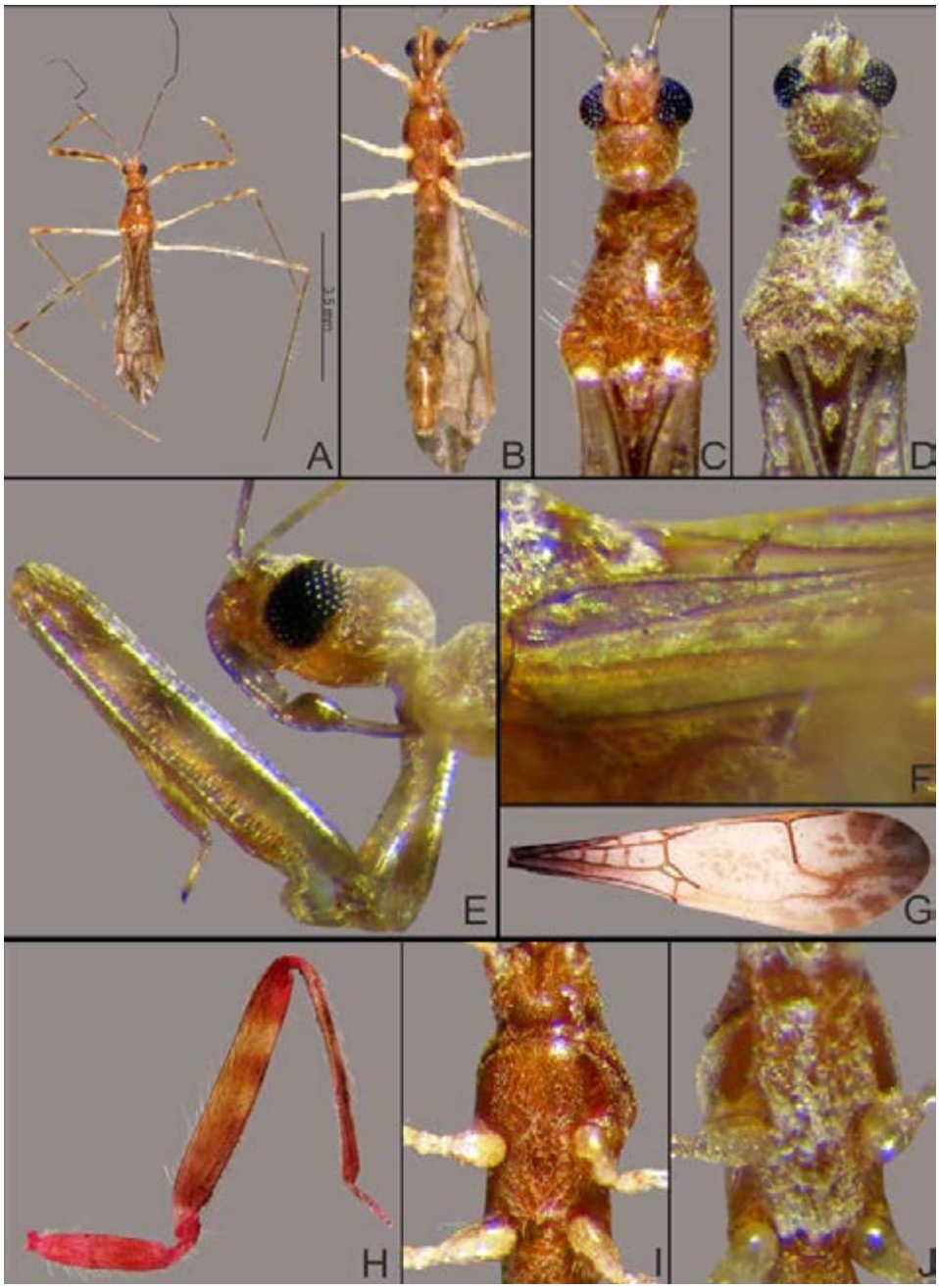

Image 1. A–J. *Emesopsis nubila*. A - Dorsal habitus of male (scale bar = 3.5mm); B - Ventral habitus of male; C - Head and pronotum details of male; D - Head and pronotum details of female; E - Lateral view of head showing second swollen segment of labium; F - Spine on metanotum; G - fore wing; H - Fore leg, stained for contrast; I & J - Sternum of male and female respectively.

studied a specimen of *E. nubila* from Coimbatore and what has been described as *E. bimedia* may also be *E. nubila*. From the description given by the authors (and one line drawing of dorsal habitus in unpublished thesis, Ravichandran 1988), it is difficult to compare *E. bimedia* and *E. nubila*; the authors state the difference to be the absence of setae on mid and hind legs and absence of piceous spot near antennae in *E. bimedia* (Ravichandran & Livingstone 1989). Efforts to collect material in Coimbatore and comparison with actual type (if available) are essential to settle this problem.

We believe this to be the first photographically illustrated documentation and brief description of *Emesopsis nubila* found in India. After Distant's original description of *Calphurnia reticulata* Distant, 1909, currently a junior synonym of *E. nubila*, there is no

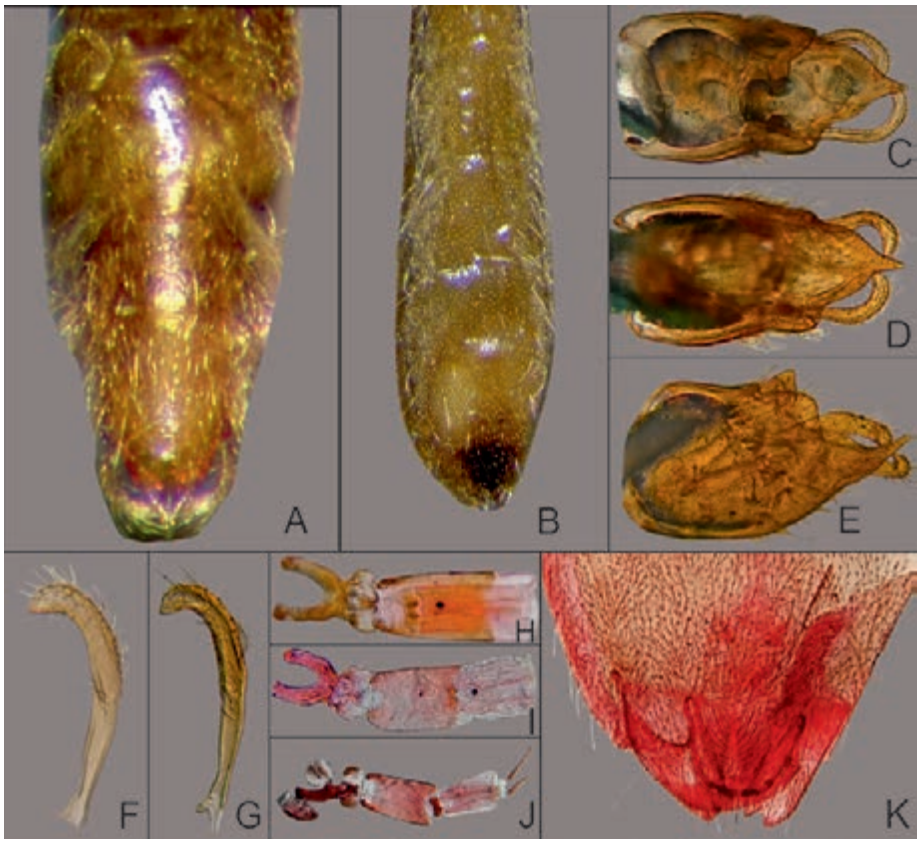

Image 2. A–K. *Emesopsis nubila*. A - Male abdomen in ventral view, B. Female abdomen in ventral view; C–E - Pygophore in dorsal, ventral and lateral view respectively; F & G - Parameres in two views; H - Phallus; I & J - Partially everted phallus; K - Female terminalia.

subsequent record from India. Lack of extensive surveys and lack of expertise in taxonomy of this subfamily in India are probably the main reasons for the poor state of our knowledge about Emesinae of India.

In a brief two-year survey of Emesinae near Pune, Maharashtra State, we have come across several such bugs which will be the subject of separate papers; Kulkarni & Ghate (2016a) have already reported the presence of *Myiophanes greeni* Distant (type locality Sri Lanka) from India for the first time. Subsequently, a new emesine species, namely *Bagauda ernstmyeri* Kulkarni & Ghate, 2016 was also added to the Indian fauna (Kulkarni & Ghate 2016b). This indicates that these small and delicate emesine bugs need more attention as we hardly know about their distribution in India.

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Gentiana aperta (Gentianaceae) - a new record to India from Ladakh Himalaya

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Gentiana L. is the largest and most diverse genus of family Gentianaceae, consisting of c. 362 species (Ho & Liu 2001; Mabberley 2008; Shabir et al. 2017b) and is largely distributed in the meadows of temperate, sub-alpine and alpine regions in Asia, Europe and North America and a few species occur in the Andes of South America, Central America, eastern Australia, and northwestern Africa (Ho & Liu 2001; Struwe & Albert 2002). In India, the genus is represented by 68 species (Gupta et al. 2012; Maity 2014; Shabir et al. 2017a,b) mainly distributed in alpine and sub-alpine meadows of both the eastern and western Himalaya.

During the ongoing revisionary study on the genus *Gentiana* in the Indian Himalaya, some interesting specimens of the genus were collected from alpine slopes of Ldokchan and Spang-rings of Tumail in Kargil District of Jammu & Kashmir, India, at an elevation of 3900–4200 m. After critical examination of the specimens, we identified the species as *Gentiana aperta* Maxim., which has not been recorded in the Indian flora so far. Therefore, a detailed description along with photo plates and other relevant information of the species has been provided to facilitate its easy identification.

Gentiana aperta

Maxim., Bull. Acad. Imp. Sci. Saint-Pétersbourg 3, 27: 500. 1881; T.N. Ho & S. Liu, Worldwide Monogr. *Gentiana*: 386. 2001; T.N. Ho & J.S. Pringle in Z.Y. Wu & P.H. Raven, Fl. China 16: 86. 1995 (Image 1).

Type: China, Qinghai (as W Kansu, Tangut region), to Huangsui river (fl. Rako-gol), 10,000–11,000 ped., in meadows, in 1880, Przewalski *s.n*. (holotype: LE not seen; isotypes: K, P Images)

Annual herbs, 3.0–6.0 cm high. Stem prostrate to ascending, striate, branched from the base. Basal leaves wither on anthesis, leaf blades ovate, 3.0–4.0 × 1.6–2.0 mm, apex obtuse, margin indistinctly membranous, veins distinct; cauline leaves, widely spaced, 3–6 paired, elliptic, spathulate to oblong, 2.5–3.5 × 1.0–1.5 mm, apex acute, mid-vein distinct, margin membranous. Inflorescence terminal, solitary; pedicels 3.0–4.0 mm long. Calyx 4.0–5.0 mm long; tube 2.8–3.4 mm long; lobes more or less equal, ovate, 1.2–1.5 × 0.6–0.8 mm, apex acute. Corolla white, pale blue to blue, 5.0–7.0 mm long, dark spot in the throat, tube 4.5–4.8 mm long; lobes ovate-oblong, 1.0–1.5 × 0.7–0.8, apex obtuse to sub-rounded, margin entire; plicae 0.6–0.9 mm long, 2-cleft, apex acute, margin entire. Stamens 5; filaments

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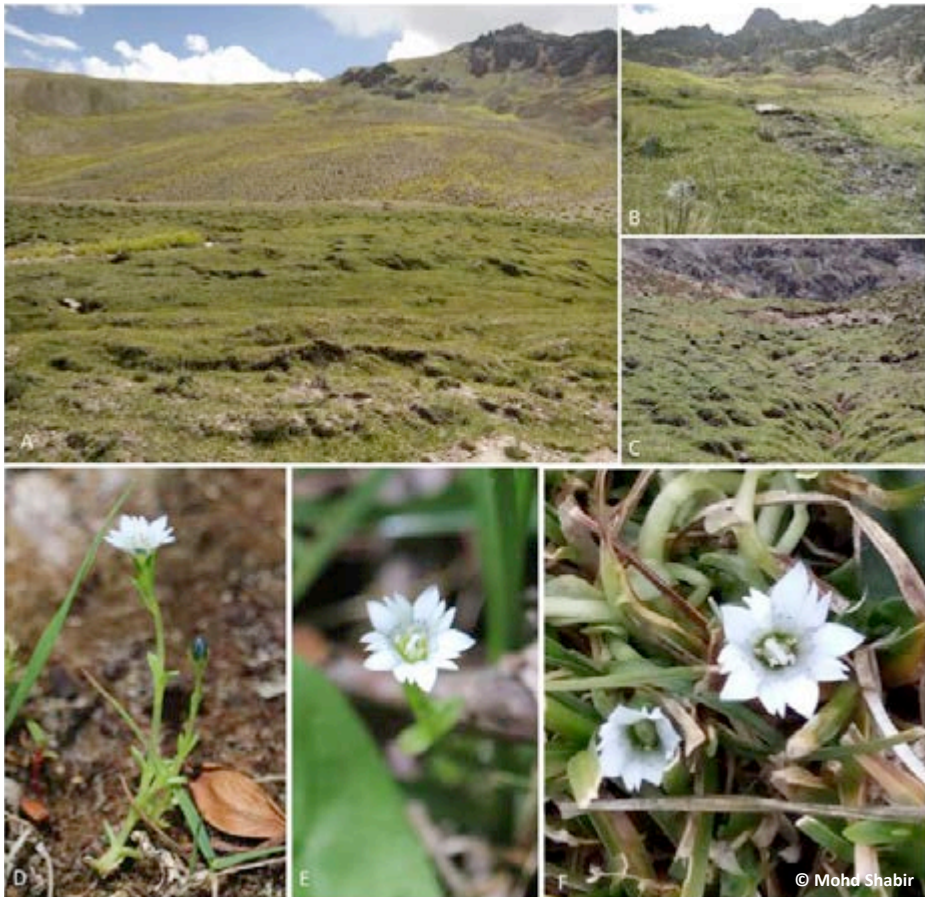

Image 1. *Gentiana aperta* Maxim.: A– C - habitats; D - habit; E–F - flowers.

inserted near the middle of the corolla, 2.0–4.0 mm long; anther ellipsoid to orbicular, 0.35–0.45 × 0.18–0.30 mm. Style short; stigma bifid, recurved, lobes semi-orbicular; ovary 2.5–2.7 × c. 1.8 mm. Capsules 3.6–4.3 mm long; stipe 0.8–1.2 mm long. Seeds ellipsoid, 0.7–0.8 ×0.28–0.33 mm; seed coat reticulate.

Flowering & Fruiting: June–September.

Habitat: The species was found growing on the west facing alpine slopes of Ldokchan and Sprang-rings in Tumail, Kargil of the Ladakh Himalaya, India, associated with *Gentiana leucomelaena* Maxim*, Gentiana aquatica* L., *Gentianopsis detonsa* (Rottb.) Ma, and *Gentianella tumailica* M. Shabir, Agnihotri, Tiwari & Husain.

Distribution: China (Ho & Pringle 1995; Ho & Liu 2001), new to India.

Specimens examined: 309906 (LWG), India, Jammu & Kashmir, Ladakh, Kargil, Tumail, 3,900–4,000 m, 12.viii.2016, coll. Mohd Shabir; 309908 (LWG), India, Jammu and Kashmir, Ladakh, Kargil, Tumail, 4,200m, 12.viii.2016, coll. Mohd Shabir; China: Gansu, Regio Tangut, 30.viii.1980, N.M. Przewalski s.n. (P); Gansu, Regio Tangut, 30.viii.1980, N.M. Przewalski s.n. (K).

Conservation status: Data deficient (DD).

Taxonomic notes: *Gentiana aperta* Maxim., belonging to Section *Chondrophyllae* Bunge, under the genus *Gentiana* was described by Maximowicz (1881) from Gansu, China. In the present state of our knowledge, this species is so far known only from China, and is endemic to the mountains of northeastern Qinghai and northwestern Gansu. The species growing in the Indian Himalaya is characterized by white to bluish-white flowers, apex of corolla lobes acute to sub-acute, dark-blue spot on the corolla throat, spots less dense on the throat and plicae deeply bifurcate, 2-cleft with both segments acute and entire, whereas, the plants growing in China have flowers bluish-white, apex of corolla lobes obtuse, yellowish-white spots on the corolla throat and spots scattered densely up to the base. *Gentiana aperta* is allied to *Gentiana leucomelaena* Maxim. In India, *G. leucomelaena* is distributed in Jammu & Kashmir, Himachal Pradesh, Uttarakhand, and the Sikkim Himalaya, and differs from *G. aperta* in having calyx lobes lanceolate to linear-lanceolate, apex acuminate, mid-vein prominent, plicae oblong, apex obtuse and

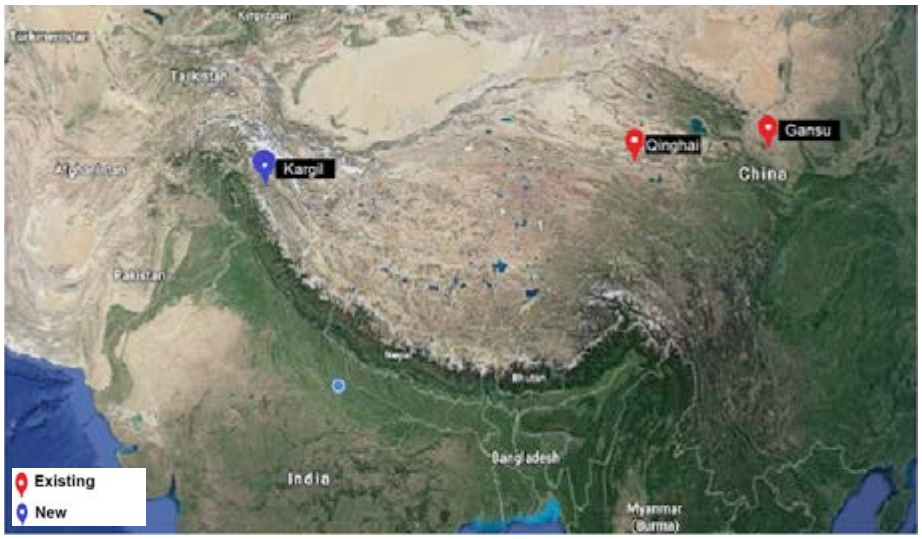

Image 2. Map showing existing and new localities of *Gentiana aperta* Maxim.

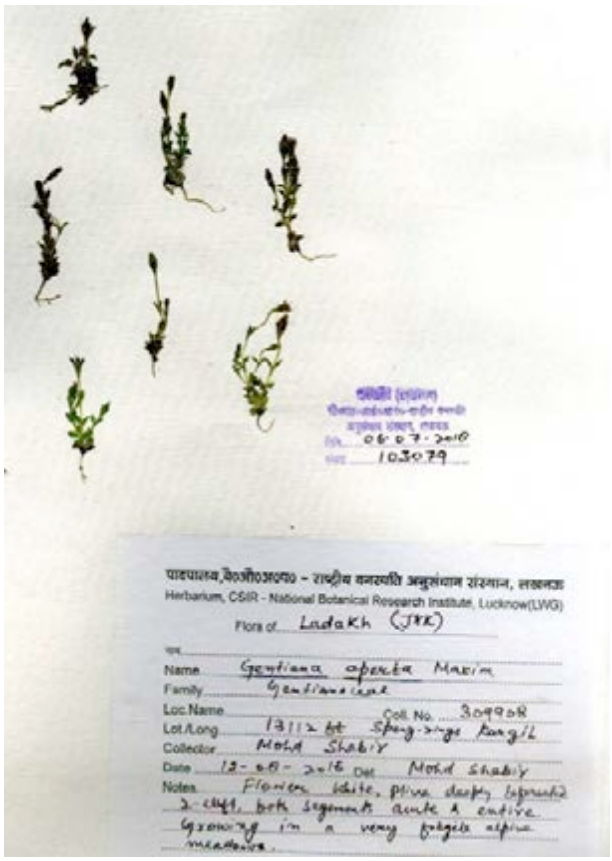

Image 3. Herbarium image of *Gentiana aperta* Maxim., (Mohd Shabir 309908 (LWG)).

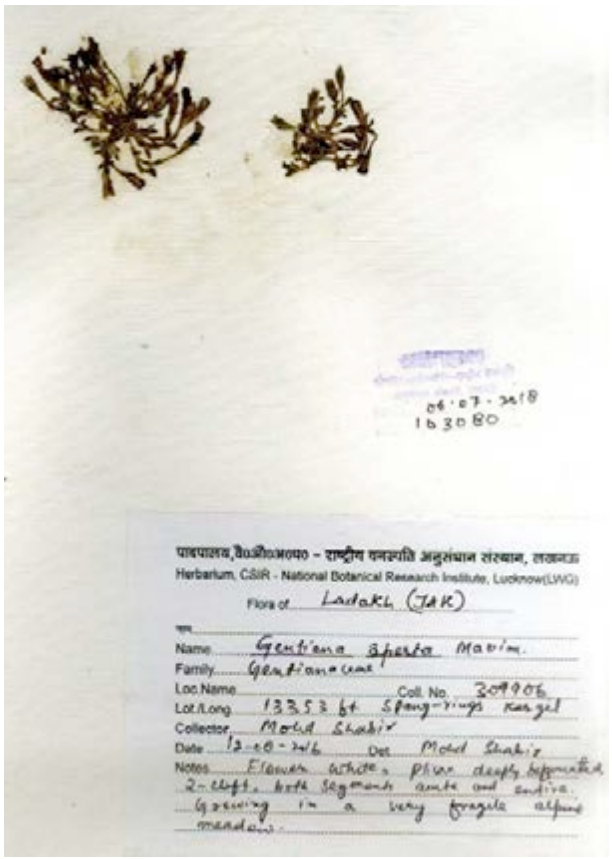

Image 4. Herbarium image of *Gentiana aperta* Maxim., (Mohd Shabir 309906 (LWG)).

margin irregularly laciniate.

Further, *G. aperta* also shows a taxonomic affinity with *Kuepferia pringlei* D. Maity & S.K. Dey, in the nature of habit and floral characters, but plicae well developed, as long as or near to the corolla lobe, apex deeply segmented with both segments acute and entire, not forming auricle, corolla lobes much shorter than the tube differentiate, the former from the latter. The report of *G. aperta* from the Ladakh Himalaya extends its range of distribution further southwestward.

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Notes on *Cinnamomum travancoricum* Gamble (Lauraceae) - a Critically Endangered species from the southern Western Ghats, India

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Cinnamomum Schaeff. belongs to the family Lauraceae, with approximately 350 species distributed from Southeast Asia to Australia and the New World (Rohwer 1993; van der Werff 2009). The species was described by Gamble (1925) based on the specimen collected by T.F. Bourdillon from Chemunji Hills of Agasthyamala Biosphere Reserve, Kerala, India in 1895. Owing to its affinity to *C. sulphuratum* Nees several botanists incorrectly reported this species from different localities (Ramachandran & Nair 1988; Mohanan & Sivadasan 2002; Geethakumary et al. 2013). During recent explorations in 2012 from the Kerala part of the Western Ghats, the present authors collected one unknown *Cinnamomum* species from Pandipath in Agasthyamala Biosphere Reserve, Thiruvananthapuram district of Kerala. Scrutiny of the collected specimens and comparison with the type sheets deposited at L (Nationaal Herbarium Nederland, Leiden), CAL (Central National Herbarium, Howrah, India), TBGT (Tropical Botanic Garden and Research Institute, Trivandrum, India) proved that the collected material was *C. travancoricum* Gamble, a Critically Endangered and endemic plant with a very narrow distribution in Kerala. The misleading report of Geethakumary et al. (2013) from the Anamalai Hill ranges, however, confused us and it led us to the reinvestigation of the literature, type specimens and expert opinions to confirm the correct identity of the species. There are only a few small trees identified from the top edge of the hills. The present effort is a collection of the species after type specimen.

Cinnamomum travancoricum

Gamble in Kew Bull. 1925: 128. 1925 & Fl. Madras 2: 1224. 1925; Bor, Man. Ind. For. Bot. 52. 1953; Kosterm., Bibl. Laur. 358. 1964; Chandras. in A.N. Henry et al. Fl. Tamil Nadu 2: 208. 1987; M. Mohanan & A.N. Henry, Fl. Thiruvanthapuram 392. 1994; Gopalan & A.N. Henry, Endemic Pl. Agasthyamala 81. 2000; N. Mohanan & Sivad., Fl. Agasthyamala 568. 2002; Sasidh., Biodiv. Doc. Kerala - Fl. Pl. 397. 2004 (Images 1 & 2).

Type: India, Kerala, Chemunji, Travancore, ±1200m, 05.iv.1895, Bourdillon 545 (K000778624 (Royal Botanic Gardens, Kew) image! "inadvertently" lectotypified by

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Image 1. *Cinnamomum travancoricum* Gamble
A - habit; B - young leaves; C - leaves-abaxial view; D - leaves-adaxial view; E - inflorescence; F - flowers.

Kostermans in 1983).

Specimens examined: 545 (K000778623 image!), 5.iii.1895, India, Kerala, Travancore, Chemunji, 1,220m, coll. T.F. Bourdillon; 23319 (KFRI!), 24.ii.2012, Thiruvananthapuram District, Pandipath, ±1,600m, coll. A.J. Robi & P. Sujanapal.

Small trees, up to 6m tall; bark greyish; branchlets slender, angular, densely sub-appressed or appressed pilose; terminal buds not perulate, small, sub-appressed pilose. Leaves simple, opposite, estipulate, trinerved; petioles 6–10 mm long, slender, shallowly grooved above, sub-appressed pilose; lamina 3.5–8 × 2–3 cm, elliptic or subovate-elliptic, base cuneate or acute, apex obtusely acuminate or attenuate, thinly coriaceous, glabrous adaxially (young leaves appressed pilose), smooth, glossy adaxially, glaucous, densely appressed sericeous abaxially; midrib slightly raised or impressed adaxially, raised, prominent and slender abaxially; lateral veins 2, paired, opposite, thin, at 2–5 mm above the base and terminate near the tip of lamina, faint and glabrous adaxially, prominent, densely appressed sericeous abaxially; major intercostal veins scalariform, prominent abaxially; minor intercostal veins finely reticulate, prominent abaxially and faint adaxially. Inflorescences pseudo-terminal and axillary reduced cyme (or racemose), 1–4 cm long, slender, few flowered, unbranched, densely brown sub-appressed pubescent, 3–5 flowers per peduncle. Flowers c. 6mm

long, greenish, densely brown-sericeous; pedicels c. 3mm long, thick, greenish, densely appressed sericeous; tepals 6 in 2 whorls of 3 each, equal, ovate, c. 2 × 1 mm long, obtuse at apex, thick, densely sub-appressed light brown pilose, appressed pilose inside (hairs long, coarse) caducous, greenish, margin ciliate; stamens 9 in 3 whorls of 3 each, c. 1.5–2.5 mm long; outer whorl 3, anthers elliptic, 4-locular, fleshy, introrse; filaments densely pilose, thin, eglandular; middle whorl almost the same as the outer; inner whorl 3, latrorse; anthers c. 2mm long, oblong, 4-locular, with obtuse tips; filaments with 2-glands attached near the basal portion; sessile, oblong, obtuse at apex, pilose; staminodes 3, c. 1.5mm long, sagittate, stipitate, densely pilose; ovary c. 1.5mm long, ellipsoid, glabrous; style c. 1mm long, glabrous, stigma large and peltate. Fruits unknown.

Flowering: February–April.

Distribution: Endemic to the southern Western Ghats; Kerala (Thiruvananthapuram District). It is very rare in the high altitude wet evergreen forests, collected from Pandipath of the Agasthyamala Biosphere Reserve (Image 3).

Ecology: This species grows mainly along the wet evergreen forests at an altitude range of 1200–1500 m and the associated species are mainly *Beilschmiedia jacobii* Robi, Udayan & S. George, *Elaeocarpus venustus* Bedd., *Garcinia travancorica* Bedd., and *Litsea gorayana* Udayan & Robi. Only five mature individuals were noted on the hilltop. Natural regeneration of this species is very poor due to the fragmented forest patches.

Notes: In the protologue Gamble mentioned only one specimen, T.F. Bourdillon 545 (K000778624 image!), but there are well-preserved specimens at L, CAL, TBGT. While revising the genus *Cinnamomum* in southern India, Kostermans (1983) typified the name *C. travancoricum* and it should be considered as 'inadvertent' lectotypification according to Art. 7.11 of ICNAFP (Turland et al. 2018). Geethakumary et al. (2013) misidentified *C. sulphuratum* as *C. travancoricum* and reported its occurrence in Munnar sholas, Idukki District of Kerala. Later, Deepu et al. (2017) lectotypified *C. travancoricum*, but it was superfluous. In this paper we report its recollection from Pandipath of Agasthyamalai region.

According to Walter & Gillet (1997), the species was recorded as Vulnerable; however, the number of individuals identified from the locality was five. According to the IUCN Red List category and criteria, the extent of occurrence of *C. travancoricum* is estimated to be less than 50km2 in a single location with a decline in quality of habitat (CR B1ab(iii)). The total number of mature individuals in the known population is less than 5 (D). Based on this evidence the conservation status of *C. travancoricum* is assessed as Critically Endangered (B1ab(iii)+D).

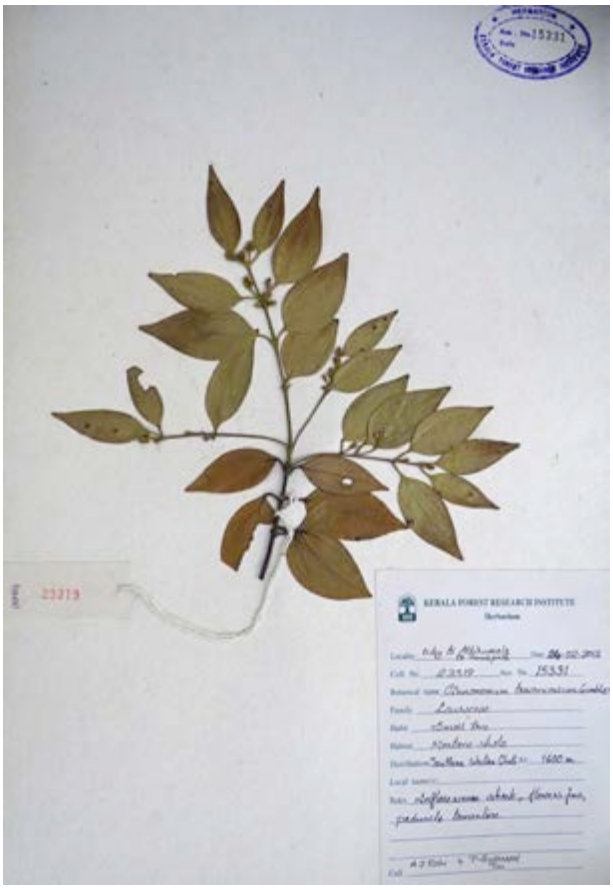

Image 2. Herbarium sheet of *Cinnamomum travancoricum* Gamble (Coll. no 23319 (KFRI!))

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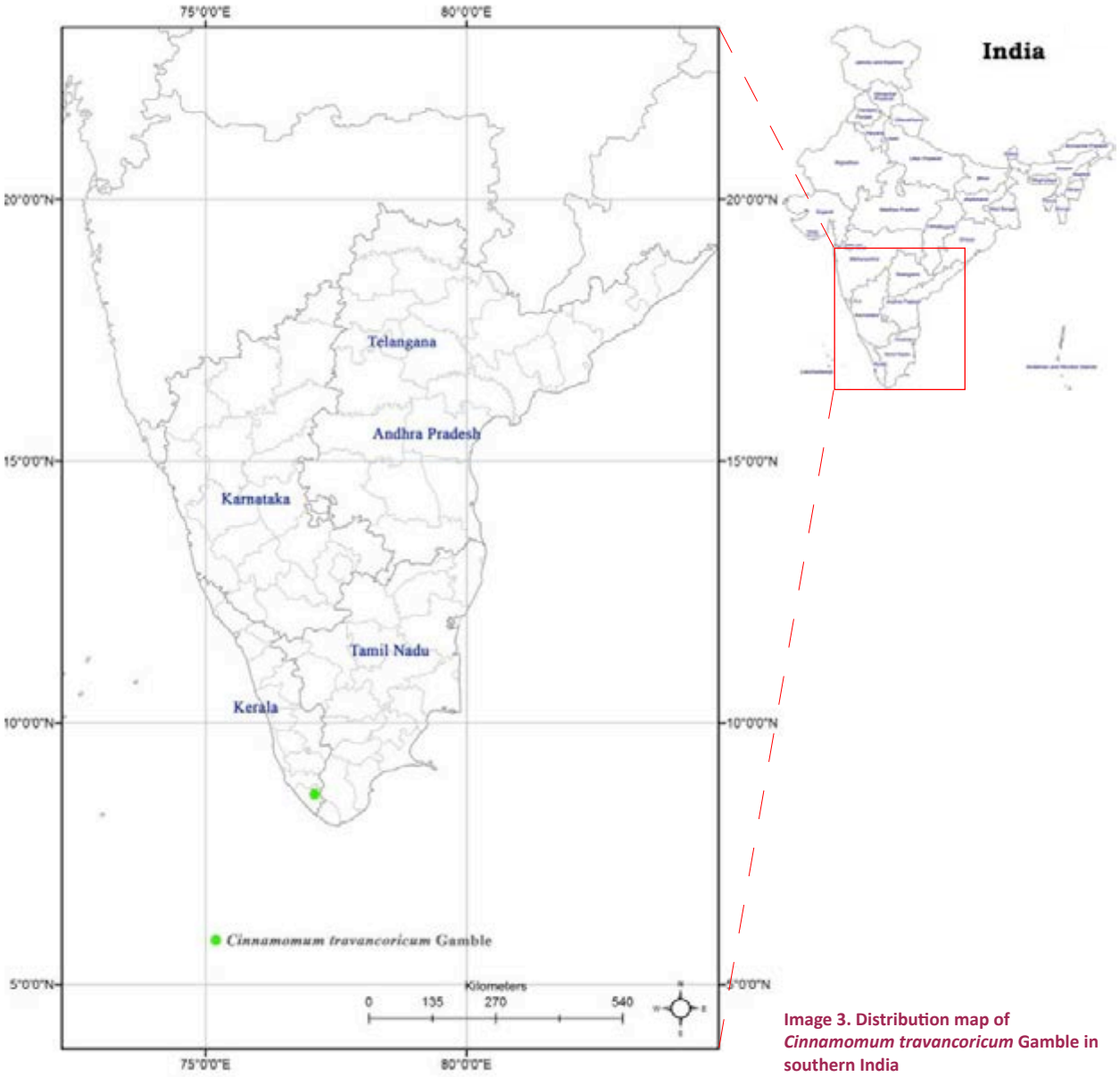

Image 3. Distribution map of *Cinnamomum travancoricum* Gamble in southern India

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Note

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A reassessment and lectotypification of the name *Striga masuria* (Buch.-Ham. ex Benth.) Benth. (Orobanchaceae) and its collection from the Western Ghats of India

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The genus *Striga* Loureiro belongs to the family Orobanchaceae and comprises about 43 species (Omalsree et al. 2015) with the highest diversity in tropical Africa (Mohamed et al. 2001; Fischer et al. 2011). Out of this, nine species have been recorded so far from India, including the recent addition of three new species, viz. *Striga kamalii* Omalsree et al. (2015: 166), *S. indica* Prabhu et al. (in Jayanthi et al. 2013: 284) and *S. scottiana* Jeeva et al. (2012: 79). As a part of the ongoing taxonomic revision on the genus *Striga* in India, the authors collected one unknown species of *Striga* from the Chennai region of Tamil Nadu State in 2015. Further studies based on relevant literature and comparison with type specimens confirmed its identity as *Striga masuria* (Buch.-Ham. ex Benth.) Benth. *Striga masuria* was described by Bentham based on two collections from the Morang Hills of Nepal (Hamilton 1810) and Prome of Myanmar (Wallich 1826). Later, Hooker (1884) reported this species for India based on Shutter's collection in 1880 from the Guindy region of Tamil Nadu. Since then, there have been no reports about this species from any part of India. The present recollection of this taxon from Chennai is the collection of the plant after 135 years (Images 1, 3).

The detailed taxonomic studies based on fresh specimens revealed that the character of the plant shows close similarities with its allied species in the section *Polypleurae*, *S. angustifolia* (D. Don) Saldanha by means of the pubescent nature of the plant, white corolla lobes and 15-ribbed calyx lobes. The only differences observed are the length of the plant, the loosely arranged flowers and closely positioned ribs on calyx lobes. These characters are not strong enough to retain its species status and are reduced as a variety under *S. angustifolia*. During the present study, it was observed that no type has been designated to this taxon and the lectotype are also designated here according to Art. 9.3 of the ICN, Shenzhen code (Turland et al. 2018).

Striga angustifolia (D. Don) Saldanha var. _masuria_ (Buch.-Ham. ex Benth.) Omalsree & V.K. Sreenivas stat. nov. (Image 1)

Striga masuria (Buch.-Ham. ex Benth.) Benth. (1838: 364) syn. nov.

Buchnera masuria Buchanan-Hamilton ex Bentham (1836: 41)

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Image 1. *Striga angustifolia* (D. Don) Saldanha var. *masuria* (Buch.-Ham. ex Benth.) Omalsree & V.K. Sreenivas stat. nov.
A - Natural habitat; B - Habit; C - portion of Stem; D - portion of Leaf; E - Flower; F - Bracteoles; G - Calyx; H - Corolla lobe with tube; I - Single corolla lobe; J - Gynoecium; J - Fruit.

Buchnera wallichi Benth. (in Wallich Cat., 3876)

Type (lectotype, designated here): Nepal, Morang hills, 28.vii.1810, Francis (Buchanan) Hamilton, 1419 (E barcode: E00273651 [digital images!]; isolectotypes, K000899664, K001117506 [digital images!].

Residual Syntypes: Myanmar, Prome, 09.x.1826, N. Wallich, 1161 (K barcode: K001117505, K000899663, E00273649 [digital images!].

Erect annual, chlorophyllous herbs, 32–68 cm tall. Stem densely hispid, quadrangular, green, branched from middle to apex. Leaves opposite at base, alternate towards apex, sessile, 12–40 × 1–4 mm, linear-lanceolate, acute at apex, cuneate at base, hairy on both surfaces especially on mid-rib; margins ciliate with strigose hairs; mid-rib prominent. Inflorescence a raceme, terminal or from axils of upper leaves, 15–45 cm long. Rachis angular, strigose hairy. Flowers zygomorphic, sessile, hypogynous, lax, alternate, 22–34 per inflorescence. Bract 1, 2.6–2.9 mm long, linear-lanceolate, hairy. Bracteoles 2, 1.8–2.1 mm long, linear-lanceolate, hairy. Calyx tubular, 15-ribbed; ribs distantly arranged and ending upto the teeth; lobes 5, 2.4–2.8 mm long, linear-

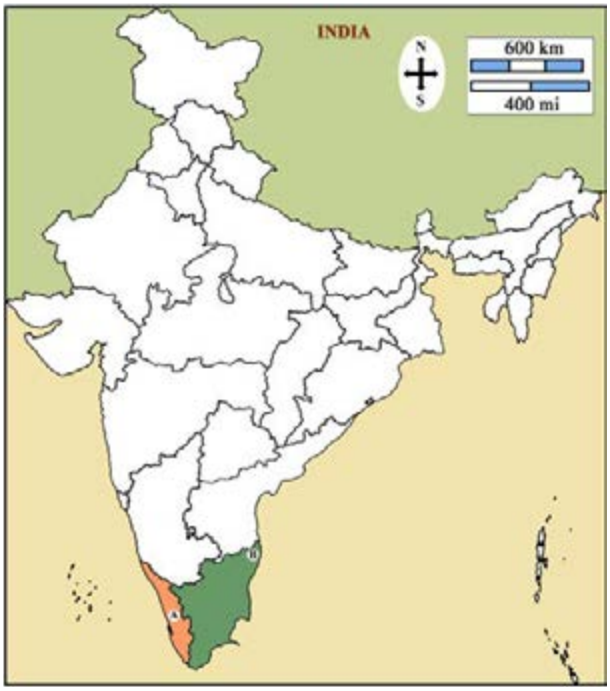

Image 3. Geographical distribution of *S. angustifolia* var. *masuria* in India. A - Kodikuthimala, Malappuram, Kerala; B - Guindy National Park, Chennai, Tamil Nadu.

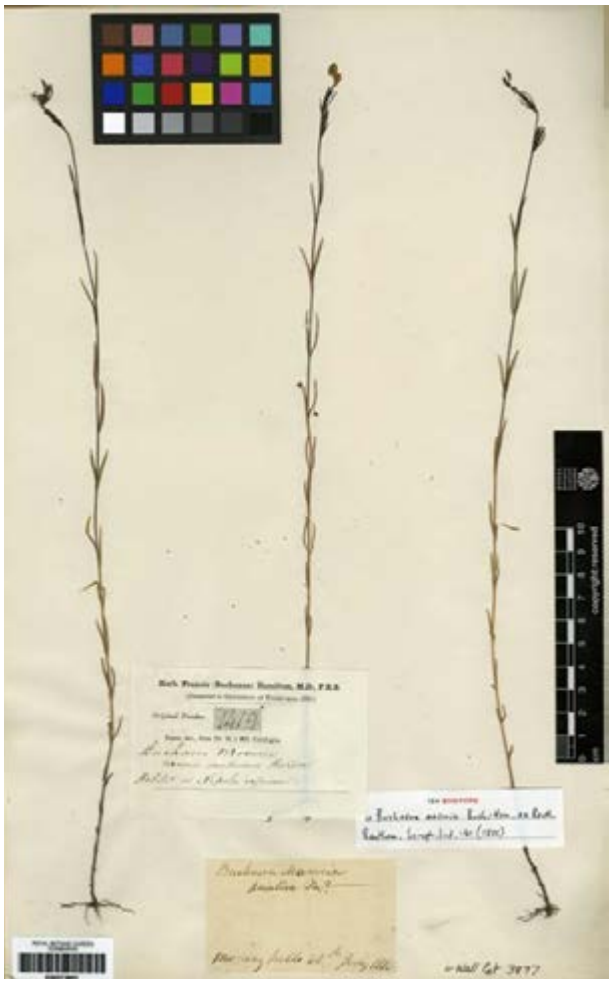

Image 3. Lectotype designated during the study (E barcode E00273651 [digital images]).

lanceolate, hairy, green or with a brownish tinge. Corolla bilabiate; tube 8.8–9.8 mm long, prominently curved above the middle, greenish; lobes creamy-white, 3.8–4.4 mm long, broadly obovate, pubescent without, glabrous within; throat 4–4.2 mm long, hairy. Stamens 4, included, didynamous; filaments 1.5-3.2 mm long, attached to the distal end of the corolla tube; anthers 1-celled. Ovary superior, 2-celled, 2–2.2 mm long, oblong to ellipsoid, glabrous; ovules many, axile; style 4.8mm long, white, brown at apex, glabrous; stigma brown. Fruit 5.5mm long, ellipsoid, beaked. Seeds numerous, 0.3–0.4 mm long, ellipsoid with parallel striations, glabrous.

Phenology: July–November.

Distribution: In India, the plant is narrowly endemic to Kerala and Tamil Nadu states, the southern part of the Western Ghats (Image 2).

Nomenclatural notes: Hamilton proposed the name *Buchnera masuria* based on his own collections from Morang mountains on 28 July 1810. Subsequently, Bentham proposed the name *B. wallichi* based on Wallich's collections from Prome of Myanmar on 09 October 1826. Both names are mentioned only in Wallich's catalogue numbers 3877 and 3876 respectively without giving any additional information such as description of the plant (nomen nudum). Later Bentham (1836) validated the name *Buchnera masuria* Ham. and synonymized the name *B. wallichi* Benth. under *B. masuria*. In that protologue, Bentham mentioned two collections, one by Hamilton for *B. masuria* (mountains of Morang, Nepal) and the latter by Wallich for *B. wallichi* (Prome, Burma). During the study, we have traced six specimens, which represent duplicates from a heterogenous collection, four specimens at K and two specimens at E. All the sheets are well preserved and bear flowers. We found three specimens each from both the localities which were deposited two at K and one at E. According to Art. 9.3 of the ICN, Shenzhen code (Turland et al. 2018), the specimen kept in E (1419, E barcode E00273651 [digital images!]) fits the description, and is preserved very well with collection number, locality and collector name, which is considered as the best choice and designated here as the lectotype (Image 3).

Habitat and biotic association: *Striga masuria* collected from two localities, viz., near Guindy forest

regions of Tamil Nadu and Kodikuthimala Hills of Kerala. We have identified two host species from Guindy region *viz*. *Ischaemum rangacharianum* C.E.C. Fisch. and *Paspalum scrobiculatum* L. and four from Kodikuthimala region *viz*. *Ischaemum rangacharianum* C.E.C. Fisch., *I. tumidum* Stapf ex Bor var. *calicutensis* (Sreek., V.J. Nair & N.C. Nair) R. Kr. Singh & P.S.N. Rao, *Arundinella mesophylla* Nees ex Steud. and *Pennisetum polystachyon* (L.) Schult.

Additional Specimens examined: OM-605 (MH), 12.ix.2015, India: Tamil Nadu: Chennai, Way to Guindy National Park, coll. M. Omalsree; OM-627 (MH), 28.x.2017, Kerala: Malappuram, Kodikuthimala, coll. Omalsree M; OM-629 (MH), 17.xi.2017, Kerala: Malappuram, Kodikuthimala, coll. M. Omalsree.

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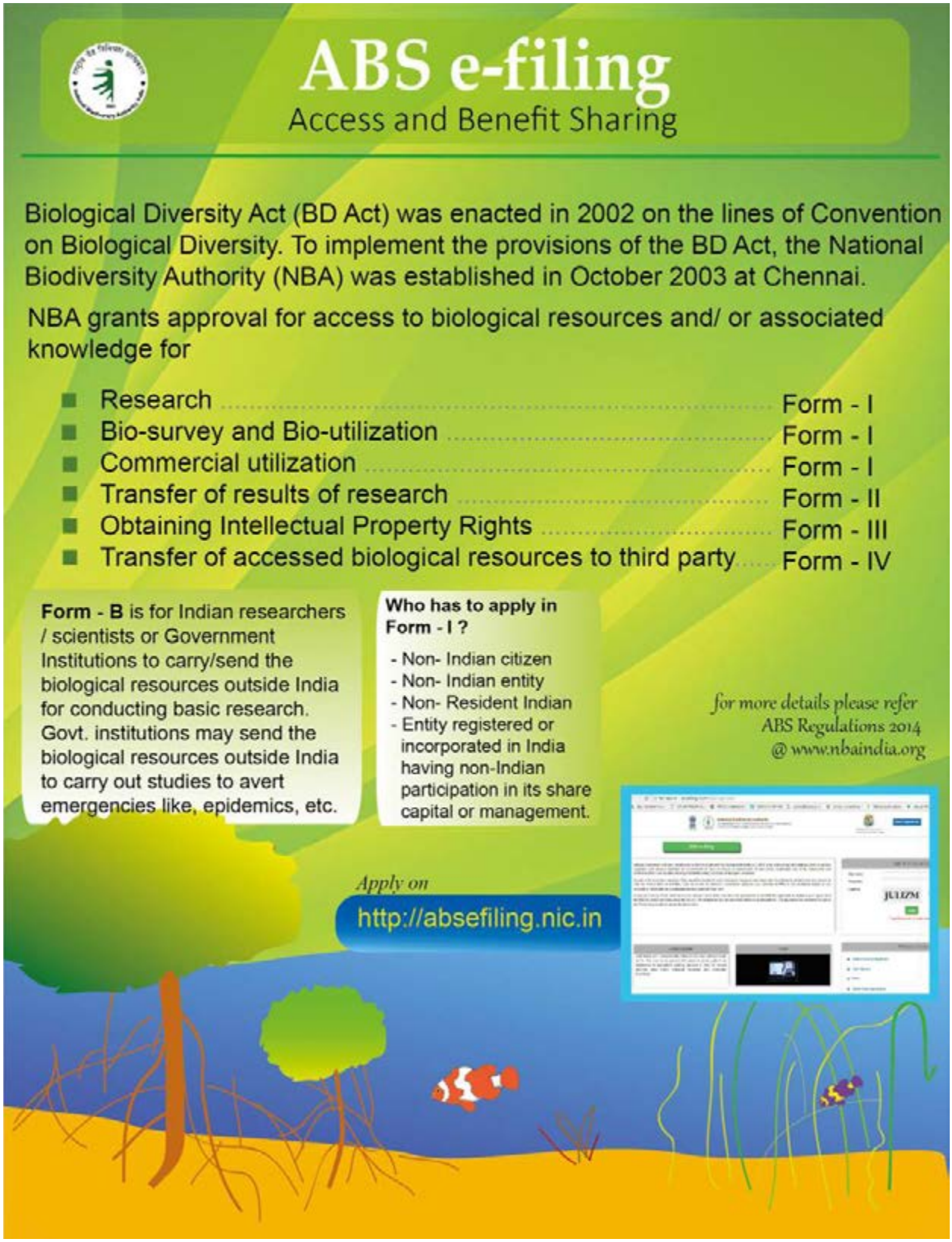

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