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COMMUNICATION

Dusky Langurs *Trachypithecus obscurus* (Reid, 1837) (Primates: Cercopithecidae) in Singapore: potential origin and conflicts with native primate species

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Abstract: The introduction of exotic species can have detrimental effects on local populations via factors such as resource competition and new threats from disease. Singapore has three native species of non-human primates: Sunda Slow Loris *Nycticebus coucang*, Long-tailed Macaque *Macaca fascicularis*, and Raffles' Banded Langur *Presbytis femoralis*. Over the past few months, several non-native Dusky Langurs *Trachypithecus obscurus* were observed in Singapore. We document our observations, compile reports from social media, and attempt to assess the potential impacts on local primates. Whenever Dusky Langurs were encountered, we recorded the date, time, GPS coordinates, group demographics, and behaviour, including interactions with native primates. We also monitored sighting reports of Dusky Langurs posted on local major Facebook groups from 30 December 2019 to 31 January 2020, and privately messaged the person(s) for more information. On 31 August 2019, three Dusky Langurs were seen near a residential area in the northern part of Singapore, and two to three individuals were reported on 14 subsequent occasions. During one encounter on 18 January 2020, an adult male Long-tailed Macaque chased a group of Dusky Langurs from a feeding tree. The next day the same group of Dusky Langurs chased a group of 11 Banded Langurs from another feeding tree. The Dusky Langurs appeared to be healthy and wild, indicating that they may have swum across the Johor Strait and/or traveled on the Johor-Singapore Causeway from Malaysia. Further monitoring of these Dusky Langurs will be required to assess their impact on local primates.

Keywords: Colobine, dispersal, exotic, impacts, macaque.

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INTRODUCTION

Singapore is home to three species of non-human primates—Sunda Slow Loris *Nycticebus coucang*, Long-tailed Macaque *Macaca fascicularis fascicularis*, and Raffles' Banded Langur *Presbytis femoralis*. While the population size of the Sunda Slow Loris in Singapore is unknown, it is considered nationally Critically Endangered (Lim et al. 2008) and globally Vulnerable (Nekaris & Streicher 2008). The Long-tailed Macaque population has an estimated 1,800–2,200 individuals (Riley et al. 2015) and is not facing immediate threats to survival (Ong & Richardson 2008). The Raffles' Banded Langur is nationally Critically Endangered (Lim et al. 2008) and is also considered Critically Endangered globally given its small population size (60 individuals in Singapore and 250–300 individuals in Malaysia), and a recent recommendation to elevate it from subspecies to species (Ang et al. 2020).

In addition to these primate species, sightings of others have been reported in Singapore over the years. Some sightings were attributable to pet abandonment or illegal ownership of primate pets. For example in 2004 an African Vervet Monkey *Chlorocebus pygerythrus* was repatriated to Zambia after being kept as a pet in Singapore (ACRES 2004), and in 2018, five South American marmosets were found abandoned in public areas in Singapore (Channel NewsAsia 2018). Other sightings may have been arrivals from nearby areas. On 19 February 2008, a single adult Dusky Langur *Trachypithecus obscurus obscurus* was observed at Kent Ridge forest in southern part of Singapore, but its origin and subsequent fate were unknown (Yeo & Lim 2013). In 2015, a Southern Pig-tailed Macaque *Macaca nemestrina* was rescued from a car workshop and later rehomed in Malaysia (AsiaOne 2015).

Many primates are able to swim, and there have been instances of other animals reaching Singapore in this way; for example Malayan Tapir likely swam across the straits from Malaysia into Singapore (Chew 2016). To the north of Singapore, the Malaysian state of Johor is home to the non-human primates resident in Singapore, as well as Dusky Langur, Southern Pig-tailed Macaque, and Malaysian White-handed Gibbon *Hylobates lar lar*. To the south of Singapore on the Indonesian islands of Bintan and Batam are found Sunda Slow Loris, Long-tailed Macaque, Bintan Pale-thighed Langur *P. siamensis rhionis*, and Silvered Langur *T. cristatus cristatus*.

Over the past few months several Dusky Langurs have been observed in Singapore. Here we document our observations, compile reports from social media, and attempt to assess the potential impacts of Dusky Langurs on local primates.

MATERIALS AND METHODS

At 10.30h on 31 August 2019, staff of the National Parks Board (NParks) of Singapore were informed by a member of public that a group of Dusky Langurs was seen at 891B Woodlands Drive 50 in the northern part of Singapore. NParks staff, including the last author, went to the location at 12.35h to observe the Dusky Langurs until 19.15h that evening. The next day NParks received further information about the location of what was presumably the same group of langurs from members of the public.

On 30 December 2019, we were alerted to a photograph of Dusky Langurs in Singapore which was posted in a Facebook group (Nature Society Singapore). In order not to alarm the public regarding the presence of a non-native primate species before verifying the sighting, we did not publicly seek for observations on social media platforms. Instead, we monitored sighting reports of Dusky Langurs posted on local major Facebook groups (Birds, Insects and Creatures of Asia; Nature Society Singapore; Wildlife of MacRitchie & Central Catchment) from 30 December 2019 to 31 January 2020, and privately messaged the person(s) for more information.

As part of an ongoing research project on Raffles' Banded Langurs in Singapore, we conducted field observations on weekdays and weekends within the Central Nature Reserve. Whenever Dusky Langurs were encountered, we recorded the date, time, GPS coordinates, group demographics (number of individuals, sex, and age group), and behaviour, including interactions with native primate species.

RESULTS

A total of three Dusky Langurs with at least one male (Image 1) were seen at 891B Woodlands Drive 50. The Dusky Langurs were sighted on trees that were very close to high-rise housing buildings, and spent most of their time between 12.35h and 19.15h on trees. On two occasions, the Dusky Langurs used a building ledge, roof of a covered walkway (Image 2), and/or the ground to get to another tree due to the lack of connectivity between trees. On a separate occasion at 19.10h, one Dusky Langur descended from a tree to drink water from a drain (Image 3). This langur was wary of its surroundings and bolted back up the tree when humans approached, and only came back down to continue drinking when people left. Throughout the entire duration of the observation, the Dusky Langurs stayed within 150m of the location of the initial sighting. On the next day, the same group was sighted by members of the public at 556 Woodlands Drive 53 at 08.52h, 50 Woodlands Drive 16 at 10.20h, and 580 Woodlands Drive 16 at 14.17h (Table 1). It appeared that the langurs were travelling south-east from the initial sighting on 31 August 2019 (Image 4).

Subsequently, there were no records of Dusky Langurs until 30 December 2019, where a photo of a group appeared on social media (Facebook). The sighting happened at Thomson Nature Park in the central part of Singapore within the Central Nature Reserve, but details such as the time and number of langurs could not be obtained. Two days later, another sighting was reported in Thomson Nature Park. Subsequently, we encountered a pair of langurs, an adult male (Image 5a) and a subadult male (Image 5b), five times in January 2020 (Table 1). Based on photographs, both belonged to the group that was initially seen in Woodlands. The absence of a third individual (Image 5c) after 1 September 2019 could mean it died or otherwise left the group.

On 18 January 2020 at 17.20h, a member of the public reported a sighting of two Dusky Langurs at Upper Peirce Reservoir Park, which is adjacent to Thomson Nature Park, feeding on Saga *Adenanthera pavonina* leaves. Sometime later, a group of at least three Long-tailed Macaques approached, and an adult male began chasing the langurs away from the tree (Image 6a). Both species acted aggressively by baring teeth (Image 6b), but no loud calls were heard during the encounter and the langurs moved away. On the next day in Thomson Nature Park we observed a group of 11 Raffles' Banded Langurs feeding on Saga seeds (Image 7). At 16.15h, two Dusky Langurs appeared and chased after the banded langurs. Alarm calls were exchanged and the Banded Langurs scattered out of sight. The Dusky Langurs then took over the Saga tree, although feeding was not observed. The following day at 08.12h, we observed the same pair of two Dusky Langurs (facially identified using photographs) at Thomson Nature Park, 203m (measured on Google Earth) from the site of encounter with the banded langurs a day earlier. As the dusky langurs sighted in both Woodlands and Thomson Nature Park have been identified to be the same group, this would mean that the Dusky Langurs travelled from the northern part to the central part of Singapore in approximately four months between 31 August 2019 and 30 December 2019.

Image 1. Three Dusky Langurs, with at least one male, at 891B Woodlands Drive 50.

Image 2. Two Dusky Langurs jumping to a building ledge from the roof of a covered walkway.

Image 3. A Dusky Langur on the ground, checking out its surroundings in between bouts of drinking from a drain, at 891B Woodlands Drive 50.

Image 4. Initial sightings of Dusky Langurs and a possible route of movement to the latest reported sightings. Image by Max Khoo (edited on Google Earth).

Image 5a. The same adult male Dusky Langur in Woodlands (left) and Thomson Nature Park (right).

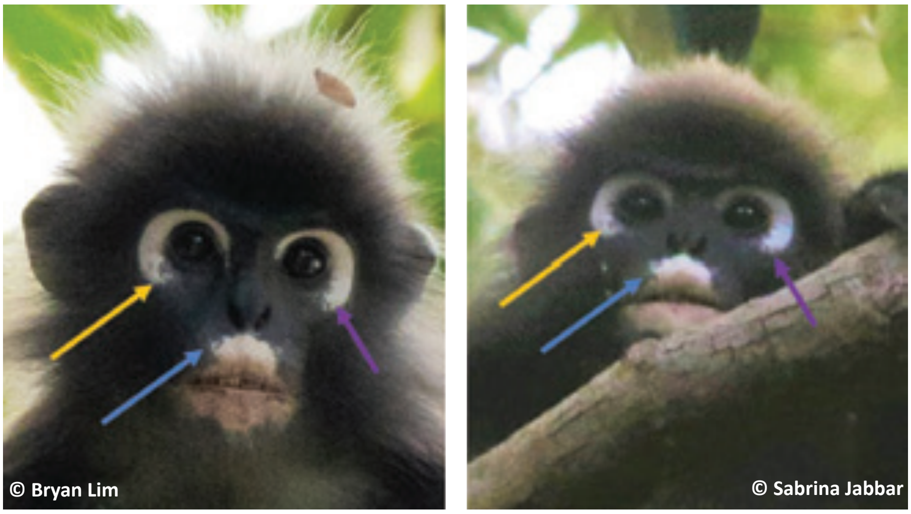

Image 5b. The same subadult male Dusky Langur in Woodlands (left) and Thomson Nature Park (right).

Image 5c. The third Dusky Langur individual that was sighted in Woodlands on 31 August 2019 but was no longer sighted subsequently.

Image 6a. An adult male Long-tailed Macaque chasing two Dusky Langurs.

Image 6b. An adult male Long-tailed Macaque baring teeth at an adult Dusky Langur male.

DISCUSSION

Dusky Langurs, especially the orange-colored infants are a popular pet in the illegal wildlife trade and are often sold within and outside Malaysia (The Straits Times 2019). These individuals often do not survive till adulthood, as they are kept in poor conditions (e.g., cages) and are not fed their natural diet (Mariani Ramli pers. comm. 11 February 2020). The Dusky Langurs sighted at Woodlands and Thomson Nature Park appeared to be healthy, wary of humans, and adapting well to the local wild habitat. The pair who remained in Thomson Nature Park were an adult and subadult. This indicates that these langurs were unlikely pet releases or escapees, and may have entered Singapore by land over the Johor-Singapore Causeway at Woodlands (960m), and/or by water by swimming across the Johor Strait from Malaysia to Singapore (750m). Many primates, including Dusky Langurs are known to be able to swim (Zainol et al. 2019). Silvered Langur *Trachypithecus cristatus*, a closely-related species to the Dusky Langur, have been observed swimming in the sea next to Indonesia's Bintan Island (Supplementary Video). Like most other quadruped mammals, langurs use the dog-paddle style to swim, i.e., with each diagonal pair of limbs moving alternately through the water directly beneath their body (Dagg & Windsor 1972; Gabbatiss 2017). Moreover, Asian colobine primates like Dusky Langurs often exhibit male dispersal when they reach subadult-hood. Given this, along with the initial sighting of the Dusky Langurs at Woodlands being very close to Johor, it is plausible that the Dusky Langurs may have come from neighbouring Malaysia.

Dusky Langurs and Raffles' Banded Langurs are known to be sympatric in a number of forests in Peninsular Malaysia (states of Johor and Pahang) (see Roos et al. 2014; Ang & Baker 2019) but Dusky Langurs are not known to be native in Singapore (Raffles 1821). While the two species have evolved sympatrically and partitioned resources in the same habitat in Peninsular

Table 1. Sightings of Dusky Langurs in Singapore.

Date	Time	No. of individuals	Location	Observer(s)
31.viii.2019	10.30h	3	891B Woodlands Drive 50	Member of public
31.viii.2019	12.35–19.15 h	3	891B Woodlands Drive 50	Bryan Lim, and authors
01.ix.2019	-	3	10 Woodlands Drive 50	Member of public
01.ix.2019	08.52h	3	556 Woodlands Drive 3	Member of public
01.ix.2019	10.20h	3	50 Woodlands Drive 16	Member of public
01.ix.2019	14.17h	3	580 Woodlands Drive 16	Member of public
01.ix.2019	Afternoon	3	576 Woodlands Drive 16	Member of public
30.xii.2019	-	-	Thomson Nature Park	Gerald Lim (Facebook)
01.i.2020	17.45h	2	Thomson Nature Park	Ian Siah, Ethan Siah, Raphael Siah, Cheryl Goh (Facebook)
03.i.2020	08.00h	2	Thomson Nature Park	Authors
07.i.2020	08.36h	2	Thomson Nature Park	Authors
18.i.2020	17.20h	2	Upper Peirce Reservoir Park	Cindy Yeo (Facebook)
19.i.2020	16.15h	2	Thomson Nature Park	Authors, Rahayu Oktaviani, Alice Early, Steve Early, Katherine Kim, Uriana Argeros
20.i.2020	08.12h	2	Thomson Nature Park	Authors
22.i.2020	17.40h	2	Old Upper Thomson Road	Authors

Image 7. Raffles' Banded Langur adult female feeding on Saga *Adenanthera pavonina* seeds on 19 January 2020.

Malaysia during the Pleistocene (Ang et al. 2020), the sympatric occurrence of Dusky Langurs and Raffles' Banded Langurs in Singapore is novel. On one occasion in Thomson Nature Park, although there were only two Dusky Langurs, they displayed aggressive territorial behaviour toward the native and Critically Endangered Raffles' Banded Langurs and displaced them from a food resource. As the Raffles' Banded Langurs are naturally more shy and are smaller in body size than the Dusky Langurs, displacement of Raffles' Banded Langurs from within their home range by Dusky Langurs may occur given that the two langur species share similar food resources as primarily folivores. As such, further monitoring is required to ascertain if the presence of Dusky Langurs is negatively impacting the Raffles' Banded Langur in Singapore in the short term and long term.

The Long-tailed Macaques and Dusky Langurs are also sympatric in forests of Peninsular Malaysia (Bernstein 1967; Johns 1986; Ruslin et al. 2019). The diet of both species overlaps to a lesser extent as compared to the Dusky Langur and Raffles' Banded Langur, with the Long-tailed Macaque being primarily frugivorous, and the Dusky Langur being primarily folivorous but with a large part of their diet being fruits and seeds as well (Johns 1986; Sha & Hanya 2013). It has been hypothesized that Dusky Langurs can switch to feeding on leaves to avoid competition, while Long-tailed Macaques could shift to eating anthropogenic foods (Ruslin et al. 2019). Along with Long-tailed Macaques being comparably more assertive in defending their resources, the impacts of Dusky Langurs on Long-tailed Macaques can be expected to be lower as compared with the impacts on Raffles' Banded Langurs. The observation of the adult Long-tailed Macaque that chased away the two Dusky Langurs at Upper Peirce Reservoir Park on the feeding tree further illustrates the ability of Long-tailed Macaques to defend food resources.

Non-native species can present risks to native biodiversity through the transmission of diseases (Hatcher et al. 2012). The introduction of parasites and pathogens can have serious implications at a population level due to a lack of immunity in the new hosts (Peeler et al. 2011). Islands are also highly vulnerable to the impacts of non-native species as the native biodiversity have often evolved in isolation without diseases that are found on continents (IUCN 2018). Additionally, introduced species can present detrimental effects to local biodiversity if it is able to hybridize with closely-related local species. In primates, hybridization at both the genus and species levels have resulted in speciation at the population level (Zinner et al. 2011) but hybrids may outcompete native species at a local level (see Oliveira & Grelle 2012). In the subfamily Colobinae, to which the Dusky Langur and Raffles' Banded Langur belong, there has been evidence of multiple hybridization events such as with the genera *Trachypithecus* and *Semnopithecus* (Roos et al. 2011). More recently, there have been two separate hybridization events of the Francois' Langur (*T. francoisi*) and White-headed Langur (*T. leucocephalus*) (Liu et al. 2013). As for the Dusky Langur and the Raffles' Banded Langur, there have been no records of hybridization in Peninsular Malaysia where both species are sympatric. As such, hybridization may not be an issue between these two species. It is unlikely for the Dusky Langur and the Long-tailed Macaque to hybridize given that both species belong to different subfamilies.

Non-native species introduced into an existing ecosystem can disrupt local biodiversity and environment in the form of resource competition, disease transmission, hybridization, among others. Even though the two Dusky Langur males will not be able to establish a population in Singapore in the long-term (unless further dispersals happen), it is nonetheless vitally important to continue monitoring efforts on the Dusky Langurs and the native biodiversity so as to assess their impacts and to devise measures to minimize the risks. If it is assessed to be necessary to translocate the Dusky Langurs out of Singapore and back to their native habitat, proper and ethical protocols must be followed (e.g., the IUCN Guidelines for Reintroductions and Other Conservation Translocations; IUCN SSC 2013). Among other requirements, it is important to determine the most likely source of the Dusky Langurs by doing genetic analyses, to ensure that the health and safety of the Dusky Langurs are not compromised during the translocation process, and to select a suitable destination habitat that is under legal protection for the long-term survival of the langurs.

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COMMUNICATION

A new report on mixed species association between Nilgiri Langurs *Semnopithecus johnii* and Tufted Grey Langurs *S. priam* (Primates: Cercopithecidae) in the Nilgiri Biosphere Reserve, Western Ghats, India

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Abstract: Phylogenetic conservatism or rapid anthropogenic habitat modifications could increase the incidences of interspecific associations of Hanuman and Nilgiri langurs (Family: Cercopithecidae, subfamily: Colobinae) in the southern Western Ghats. Opportunistic surveys were conducted at the Silent Valley National Park, Kerala and around Devimalai Ghats, Tamil Nadu for Tufted Grey-Nilgiri Langur association. Based on the observations from Researchers, field assistants, forest staff, and local people, the data in terms of the time of the sighting, number of individuals, phenotypes of individuals, and the time the interaction lasted, were recorded. The study reports data on a troop of Nilgiri Langurs (N=13) around O Valley tea estate at Devimalai Ghat, Gudalur, Tamil Nadu with some hybrid looking individuals and a Tufted female Grey Langur amongst them. A total of six and two uni-male troops of Nilgiri Langurs and grey langurs respectively with Tufted female Grey Langurs, and aberrant coat colored infants observed at the Neelikkal section of Silent Valley National Park are also reported. The study reasonably speculates that there could be more such locations in the southern western ghats and emphasizes the need for more systematic surveys to understand and explore the ecology, behavior, molecular, and other likely factors contributing to the conservation of vulnerable Nilgiri langur (*Semnopithecus johnii*) populations.

Keywords: Colobines, Coromandel Sacred Langur, mixed-species association, southwestern India.

ಎರಡು ಭಿನ್ನ ಪ್ರಬೇಧ ಜೀವಿಗಳ ನೈಸರ್ಗಿಕ ಕಲೆಯುವಿಕೆ /ಬೆರೆಯುವಿಕೆ ವಿಕಾಸವಾದಿ ವಿಜ್ಞಾನಿಗಳಿಗೆ, ಜೀವಿ ವರ್ಗೀಕರಣ ಶಾಸ್ತ್ರಜ್ಞರಿಗೆ ಹಾಗೂ ಪ್ರಾಣಿ ಶಾಸ್ತ್ರಜ್ಞರಿಗೆ ಕುತೂಹಲಕಾರಿ ವಿದ್ಯಮಾನವಾಗಿದೆ. ದಕ್ಷಿಣ ಭಾರತದ ಘಟ್ಟ ಪ್ರದೇಶಗಳಲ್ಲಿ ಇದುವರೆಗೂ ಎರಡು ಭಿನ್ನ ಪ್ರಬೇಧ ಮುಶ್ಯಗಳ ಬೆರೆಯುವಿಕೆಯನ್ನು ಕೇವಲ ಮೂರು ಪ್ರದೇಶಗಳಲ್ಲಿ ಮಾತ್ರ ದಾಖಲಿಸಲಾಗಿದೆ. ಪ್ರಸ್ತುತ ಲೇಖನವು, ತಮಿಳು ನಾಡಿನ ನೀಲಗಿರಿ ಸಂರಕ್ಷಿತ ಕ್ಷೇತ್ರದ ದೇವಿಮಲೆ ಘಾಟ್ ನ (ಗುಡಲೂರು-ಊಟಿ ಮಾರ್ಗ) ಓ ವ್ಯಾಲೀ ಟೀ ಎಸ್ಟೇಟ್ ಸುತ್ತ ಮುತ್ತಲಿನ ಜಾಗದಲ್ಲಿ , ಅವಕಾಶಾವಶಾತ್, ಹದಿಮೂರು ಕರಿ ಮುಶ್ಯಗಳ ಒಂದು ಗುಂಪನ್ನೂ, ಅದರಲ್ಲಿ ಕಂಡು ಬಂದ ಒಂದು ಬಿಳಿ ಹೆಣ್ಣು ಮುಷ್ಯ ಹಾಗೂ ಮೂರ್ನಾಕು ಕರಿ-ಬಿಳಿ ಮಿಶ್ರಿತ ಎಳೆಯ ಮುಶ್ಯಗಳ ವಿವರಣೆಯ ಕುರಿತದ್ದಾಗಿದೆ. ಲೇಖನವು, ಭಿನ್ನ ಪ್ರಬೇಧ ಜೀವಿಗಳ ಬೆರೆಯುವಿಕೆಯ ಕಾರಣಗಳನ್ನು, ಕರಿ ಮುಶ್ಯಗಳ ಸಂತತಿಯ ಸಂರಕ್ಷಣೆಯ ಅಗತ್ಯತೆಯನ್ನು ಹಾಗೂ ಅವುಗಳ ಅತೀ ಸೂಕ್ಷ್ಮ ನೆಲೆಗಳು ಮನುಷ್ಯ ಕಾರಣಗಳಿಂದ ಮಾರ್ಪಾಡು ಆಗುತ್ತಿರುವ ಕಾರಣಗಳೆಡೆಗೆ (ಜೀವಿಗಳ ವಾಸ ಸ್ಥಳಗಳಲ್ಲಿನ ಮಾರ್ಪಾಟುಗಳು ಇಂತಹ ಬೆರೆಯುವಿಕೆಗೆ ಅವಕಾಶ ನೀಡುತಿವೆಯೇ ಎಂಬುದರ ಬಗ್ಗೆ) ಗಮನ ಸೆಳೆಯುತ್ತದೆ. ಈ ಅಧ್ಯಯನವು, ದಕ್ಷಿಣ ಪಶ್ಚಿಮ ಘಟ್ಟಗಳಲ್ಲಿ ಕರಿ-ಬಿಳಿ ಮುಶ್ಯಗಳ ಬೆರೆಯುವಿಕೆಯ ಸ್ಥಳಗಳು ಇನ್ನೂ ಹಲವಾರು ಪ್ರದೇಶಗಳಲ್ಲಿ ಇರಬಹುದು ಎಂದೂ ತೋರಿಸಿಕೊಡುವುದರ ಜೊತೆಗೆ ಇಂತಹ ಇನ್ನೂ ವಿಸ್ತಾರವಾದ ಅಧ್ಯಯನಗಳ ಅನಿವಾರ್ಯತೆಯನ್ನು ಪ್ರತಿಪಾದಿಸುತ್ತದೆ.

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INTRODUCTION

Interspecific short-term associations among animal groups are known to naturally occur in the context of competition for food (Dickman 1992), mutual benefit (Oates & Whitesides 1990), and hybridization (Anderson 1948; Arnold 1997; Alberts & Altmann 2001; Arnold & Meyer 2006). Such associations have generated varied interests among ecologists, behavioral biologists, and geneticists (Evans et al. 2001; Hewitt 2001; Keller et al. 2010; Cortes et al. 2019); however, when two different species live together as a single cohesive unit, interspecific associations are difficult to explain. These associations are difficult to understand when they are seen amongst the species which have well defined social organizations like primates. In other words, biologists are aware of the purpose of the casual encounters of two different species, however, there seems to be a dearth of information in biological literature in the case of two species that exist as a single group going beyond the casual encounters.

Mixed species associations (hereafter referred to as MSAs or interspecific associations) have been usually observed in animals that live in social groups such as birds, ungulates, primates, and cetaceans (Terborgh 1990; Grubb 1999; Krause & Ruxton 2002; Stensland et al. 2003). There have also been a few interesting studies of associations between species from different taxonomic orders (Rodman 1973; Hayashi, 1975; MacKinnon & MacKinnon 1978; Waterman & Roth 2007; Haugaasen & Peres 2008; Grueter et al. 2010). There is a debate that is available on the formation of mixed troops in primates in general and colobines in particular (Phillips-Conroy & Jolly 1986; Gautier 1988; Yeager & Kirkpatrick 1998; Cords 1990; Burton & Chan 1996; Heymann & Buchanann-Smith 2000; Mitani et al. 2000; Stensland et al. 2003; Rehg 2006; Reyer 2008; Werner et al. 2008). Terms like polyspecific associations and mixed-species associations have been applied synonymously to similar phenomena. While some studies have defined polyspecific associations in the context where two or more different species intermix without any physical interactions per se, others define MSAs as species interspersed literally (though for a little time) behaving like members of a single group foraging, grooming with occasional mating as well (Burton & Chan 1996). Such associations are known to vary in duration, frequency, range, and ecological and behavioral relations largely depending on the type of groups/species interacting (Cords 1990; Burton & Chan 1996; Porter 2001; Rehg 2006).

The majority of the available literature related to mixed associations in primates are derived from African primates (Klein & Klein 1973; Struhsaker 1981; Gautier-Hion et al. 1983; Waser 1984; Cords 1990; Oates & Whitesides 1990; Chapman & Chapman 2000; Stensland et al. 2003; Eckardt & Zuberbühler 2004). The reasons for such associations in African primates have been explained and well documented (Schaik & Hörstermann 1994; Freeland 1977; Stensland et al. 2003; Fam & Nijman 2011; Cortes et al. 2019), however, not much literature is available on mixed associations among Asian primates with respect to behavioral, ecological, and evolutionary topics illustrating the range of factors, processes, and mechanisms that affect associations and make similar inferences apart from a few studies (Tables 1, 2).

Taken together, these reviews suggest that MSAs amongst Asian primates seem to be fewer in comparison to African primates. Available data do not indicate whether fewer observations of such MSAs are due to sampling bias or due to lesser proportional existence in Asian colobines. The data available on a few instances of the MSA amongst Asian colobines are predominantly from southern Asia (Table 1). The associations in case of Tufted Grey Langurs and Nilgiri Langurs, colobines of southern India have only been documented in the past by a few studies around the Palghat gap (Chellam 1985; Hohmann 1988, 1991; Ramachandran & Joseph 2001) in the Western Ghats. Until now, associations between these colobines of southern India have only been recorded in Silent Valley, Top Slip, and Kalakkad-Mundanthurai areas in the Western Ghats. Despite these pieces of evidence, the available literature does not show any systematic analysis of MSAs among the colobines of the entire southern Asian region.

Tufted Grey Langurs and Nilgiri Langurs of southern India are well known distinct species, easily distinguishable by pelage color and vocalizations (Brandon-Jones 2004; Hohmann 1988, 1991). The Hanuman Langur also called Grey or Common Langur species are dispersed throughout most of India and Sri Lanka (Ellerman & Morrison-Scott 1966; Oates et al. 1994), and are also found in parts of Pakistan, Nepal (Roonwal 1984; Oates et al. 1994), Bhutan, and Bangladesh (Choudhury 2007). They are known to occur in a wide range of habitats from arid regions on the edge of the desert in Rajasthan to the rainforests of the Western Ghats and at altitudes from sea level (Nag et al. 2011) to 4,270m above mean sea level in the Himalaya (Hrdy 1977; Bishop 1978). The Tufted Grey Langur or Coromandel Sacred Langur or Madras Grey

Table 1. Reported interactions of Asian primates from the literature.

Species	Explanation	Remarks	References
Purple faced Langur-Hanuman Langur	Foraging	*	Hladik (1977)
Lion-tailed Macaque-Bonnet Macaque-Hanuman Langurs	Foraging	*	Singh et al. (2010)
Lion-tailed Macaque-Bonnet Macaque-Nilgiri Langurs	Foraging	*	Sushma & Singh (2006)
Lion-tailed Macaque-Hanuman Langurs	Foraging	*	Singh et al. (2010)
Hanuman Langur-Rhesus Macaque	Antipredatory	*	Mathur & Lobo (1989)
Rhesus Macaque-Crab-eating Macaque-Tibetan Macaque	Foraging	*	Burton & Chan (1996)
Rhesus Macaque-Crab-eating Macaque-Japanese Macaque	Foraging	*	Southwick & Southwick (1983)
Tonkean Macaque-Booted Macaque	Habitat	*	Riley et al. (2007)
Kloss's Gibbon-Mentawai islands Langur	Foraging	*	Tilson & Tenaza (1982)
Kra Macaque-Silvered Leaf Monkey- Javan Grizzled Langur-Proboscis Monkey	Foraging	*	Kurland (1973)
Rhesus Macaque-Pig-tailed Macaque		Hybrid	Malaivijitnond et al. (2007)
Crab-eating Macaque-Pig-tailed Macaque		Hybrid	Bernstein (1967)
Tonkean Macaque-Heck's Macaque		*	Watanabe et al.(1991); Bynum (2002)
Moor Macaque-Tonkean Macaque		Hybrid	Supriatna et al. (1992); Evans et al. (2001)
Sulawesi Crested Macaque-Heck's Macaque		*	Watanabe & Matsumura (1991)
Gorontalo Macaque-Heck's Macaque		*	Watanabe & Matsumura (1991)
Rhesus Macaque-Bonnett Macaque			Fooden (2000); Fooden et al. (1981); Koyama & Shekar (1981); Kumar et al. (2011)
Rhesus Macaque-Crab-eating Macaque		Hybrid	Stevison & Kohn (2009)
Japanese Macaque-Taiwanese Macaque		Hybrid	Kawamoto (2005)

* Lack of empirical evidence to explain the reasons for association

Table 2. Documented hybridizations between Asian colobines (wild and captive).

Hybridising Taxa	Location	Coordinates	Notes	References
S. priam X *S. johnii*	Indira Gandhi Wildlife Sanctuary, Anamalai, Tamil Nadu, India	76.846E & 10.469N	Natural hybrid	Hohmann (1988, 1991)
S. johnii X *S.p. thersites*	Kalakkad-Mundanthurai Tiger Reserve, Tamil Nadu, India	77.311E & 8.689N	Mating photograph	Chellam (1985)
T. obscurus X *S.p. thersites*	Sri Lanka	NA	Captive hybrid	Hill (1939)
S. p. thersites X *S.v. nestor*	Sri Lanka	NA	Captive hybrid	Hill (1936)
S. p. thersites X *S.v. nestor*	Sri Lanka	NA	Captive hybrid	Hill (1936)
S. priam X *S. johnii*	Madura Coats, Ooty, Tamil Nadu, India	NA	Hybrid photograph by Sally Walker	Brandon-Jones (2004)
Pygathrix nemeaus X *T. laotum hatinhensis*	Vietnam	NA	Hybrid captive	Schempp et al. (2008)
T. pileatus X *T. geei*	Bhutan	90.690E & 27.143N	Natural hybrid	Choudhury (2008)

S—Semnopithecus | *T—Trachypithecus* | *v—vetulus* | *p—priam*.

Langur *Semnopithecus priam* groups are organized into uni-male (only one adult male with more of other age and sex classes), multi-male, and all-male groups.

On the other hand, Nilgiri Langur or the Black Leaf Monkey *Semnopithecus johnii* is endemic to the rainforests of the Western Ghats of Tamil Nadu, Kerala, and to the hills of Coorg in Karnataka (Ryley & Shortridge 1913; Tanaka 1965; Sunderraj 2001; Kumara & Singh 2004). The Nilgiri Langurs are usually found in tropical evergreen forests at elevations over 500m, however, in the habitats of the Kalakad-Mundanthurai Tiger Reserve (KMTR) in the Tirunelveli Hills of Tamil Nadu, they are found even at an elevation of 180–200 m (Hohmann 1989; Sunderraj 2001). Nilgiri Langur groups are organized into one or uni-male, multi-male, all-male, and all-female groups, however, multi-male and all-female groups are rare in Nilgiri Langurs (Tanaka 1965; Poirier 1968a; Sunderraj 2001).

In this paper, I briefly describe an opportunistic observation on Nilgiri-Grey Tufted langur associations in the Nilgiri Biosphere Reserve of southwestern India and add some relevant questions to the ongoing debate on interspecific interactions.

STUDY AREA

The study was opportunistically conducted at Nilgiri Biosphere Reserve in the southern Western Ghats of southern India. The first locality was at Neelikkal range, Silent Valley National Park, Kerala and the second locality was around O Valley tea estate, Devimalai Ghats (11.482N & 76.512E), a hilly terrain between Gudalur-Naduvattam-Ooty road interspersed with other tea estates at an elevation of 1,365m with an average rainfall of 3,000mm per annum.

Survey

Opportunistic surveys were conducted at the Silent Valley National Park, Kerala (December 2010), and around Devimalai Ghats (December 2019) for Hanuman Langur and Nilgiri Langur association. The attempts were primarily focused to identify MSAs or hybrid members (only on morphotypic features) in the troops. The survey was primarily conducted in the southwestern part of the park, particularly in the Neelikkal area for a week based on earlier reports (Ramachandran & Joseph 2001) at Silent Valley, and twice around O Valley Devimalai Ghat road based on anecdotal reports and observations. During each visit, an attempt was made to maintain the slow pace in walking (approximately 1km/h) with frequent pauses to look and listen for langurs. Upon encountering monkeys, the data was recorded in terms of the time of the sighting, number of individuals, phenotypes of individuals, and the time the interaction lasted. Generally, the time of sampling was at 06.00–12.00 h and 15.00–18.00 h. Upon detecting troops, they were actively followed, maintaining contact as long as possible. For each of the encounters, the date and time of group detection was recorded along with the total time taken for observation period, number of individuals, phenotypes of individuals, and age-sex class of individuals whenever possible. If the interactions had more than two or more monkeys of two species engaging in affiliation such as foraging or, traveling along the same route of progression, or within 50–100 m of one

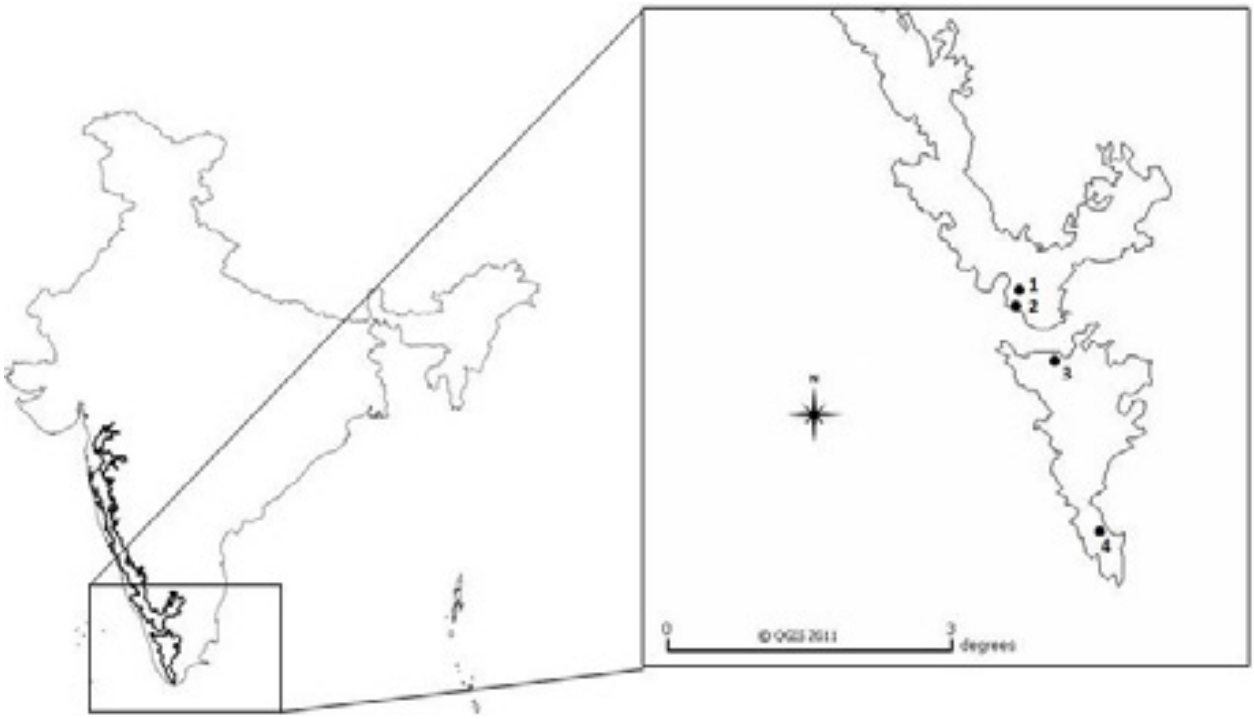

Figure 1. Study area denoting mixed-species associations of Hanuman langurs and Nilgiri Langurs in the Western Ghats of southern India reported from the literature. Numbers 1, 2, 3 & 4 denote Devimalai Ghat , Silent Valley National Park, Indira Gandhi Wildlife Sanctuary, and Kalakkad-Mundanthurai Tiger Reserve, respectively.

another, the study scored them as a group (Glenn 1997). Observations were made using an 8 X 40 Porro prism binoculars. Researchers, field assistants, forest staff, and local people were consulted for information on sightings of MSAs/ hybrids at the sites. A thorough review of the available literature and the recent reports on langurs of this area and MSAs was carried out. Methods described elsewhere (Hrdy 1977) were followed for defining the age-sex compositions in the Tufted Grey Langur troop.

RESULTS

Silent Valley National Park

In total, six and two uni-male troops of Nilgiri Langurs and Tufted Grey Langurs, respectively were observed in the Neelikkal section of Silent Valley National Park. Nilgiri Langurs were recorded between 800–1,121 m and Tufted Grey Langurs at around 913m. A total of 14km in search of Nilgiri Langurs and Tufted Grey Langurs was traveled. Nilgiri Langurs and Hanuman Langurs were observed to co-occur only at the edge of the evergreen forest habitat. Three Nilgiri Langurs were observed foraging with a Tufted Grey Langur troop at a distance of about 50–75 m at Neelikkal for the whole of the study period, however, sexing and photographing these foraging Nilgiri Langur individuals was not possible due to limitations of visibility in the canopy. The nearest troops of Nilgiri Langurs were located >3km away from this Tufted Grey Langur troop. No aggression by the adults of Tufted Grey Langur towards Nilgiri Langurs was observed. During the period of observation, Nilgiri Langurs and Tufted Grey Langurs were either seen moving or feeding together. The same troop also had an adult Tufted Grey Langur female with aberrant coat color. This female, which was carrying a suckling infant at the time of observation, had brownish-black coat color giving an impression of a possible hybrid individual. In addition, I sighted a troop of Nilgiri Langurs close to the Kerala Forest Department camp shed in which an infant with Tufted Grey Langur coat color carried by a Nilgiri Langur adult female was observed twice on 16 December 2010 at 07.30h and 16.00h, respectively. Attempts to photograph them went in vain due to the tree cover and shyness of the Nilgiri Langurs to human proximity. Furthermore, local forest guards and watchers reported another troop of Nilgiri Langurs in and around the camp shed area in which three infants/juveniles with Tufted

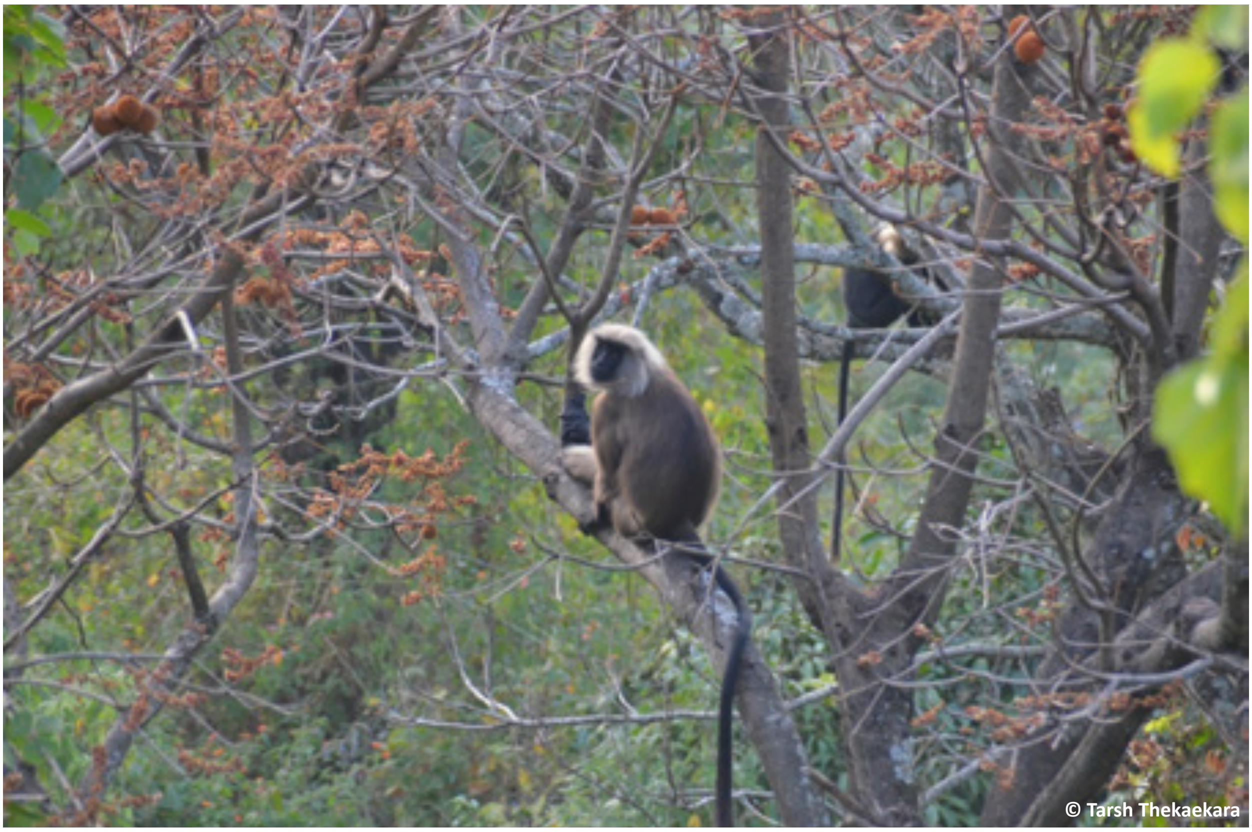

Image 1. A brownish adult female langur foraging with adult female Nilgiri Langur at Devimalai Ghats (Gudalur-Ooty road).

Image 2. Nilgiri Langur troop at Devimalai Ghats (Gudalur-Ooty road) with a brownish (hybrid?) juvenile.

Grey Langur coat color had been observed which could not be confirmed during my study period.

O Valley Tea Estate, Gudalur-Naduvattam Road

A troop of 11–13 individuals of Nilgiri Langurs with brownish individuals was observed near O Valley, Tamil Nadu (11.482N & 76.512E; 1,350m) on 28 December 2019 around 17.00h. I did not encounter adjacent Nilgiri-Tufted Grey Langur troops. The study troop at the time of observation had one adult male, four juveniles, two infants, one sub-adult, four adult females, and one brownish adult female. An adult brownish Tufted Grey Langur female (Image 1) was observed at about 5m foraging with Nilgiri Langur troop. During the period of observation, Nilgiri Langurs and female brownish Tufted Grey Langur were seen moving and feeding together. This troop also had two juveniles with brownish-black coat color (Images 2, 3) giving an impression of a possible hybrid individual. No aggression by the adults of Nilgiri Langur troop towards hybrid looking individual/s was observed. Tarsh Thekaekara (a post-doctoral research associate and tea garden owner where Nilgiri Langurs reside) has personally observed females of this Nilgiri Langur troop mating with a Tufted Grey Langur male from a nearby estate named Silver Springs. This male Tufted Grey Langur has never been observed around this Nilgiri Langur's troop, however, Nilgiri Langur females of this troop often have been observed to initiate the mating with Silver Spring Estate Tufted Grey Langur male (Tarsh Thekaekara pers. comm. March 2020).

Image 3. A brownish (hybrid?) juvenile at Devimalai Ghats (Gudalur-Ooty road).

DISCUSSION

Till date, there were only three confirmed localities (Silent Valley National Park, Top Slip in the Anamalais, and

Kalakkad-Mundanthurai Tiger Reserve) in the southern Western Ghats where associations of Nilgiri and Tufted Grey langurs have been reported. This study provides the fourth location of MSAs in the Nilgiri Hills. Anecdotal observations suggest that the focal troop is a residential one and thus associations and observations could not merely be a chance event, however, the association between Nilgiri and Tufted Grey langurs appears to involve not only hybrids, but langurs who could be coping in a human-disturbed habitat. The effects of such associations due to habitat fragmentation could as well be a possibility to explore and understand these short-term associations at such localities. The formations of interspecific associations are a complex phenomenon to explain. A variety of ecological explanations have been offered. But after a careful examination of interspecific associations in colobines of southern Asia, the available data shows that such mixed associations are formed between closely related species pairs which are recently diverged terminals of a phylogenetic tree. Given the available evidence of higher degree phylogenetic conservatism across the primate phylogenies with respect to the social behavior, it is reasonable to at least propose an ad hoc hypothesis which warrants rigorous analysis. The hypothesis argues that the MSA in colobines of southern Asia happens between a pair of recently diverged taxa that could be due to phylogenetic conservatism (Rendall & De Fiore 1995; Prinzing et al. 2001) in their social behavior. If this hypothesis is true, it would provide a robust framework to reanalyze the MSA in colobines.

Recent molecular phylogenetic analysis of langurs in Asia reveals that Hanuman Langurs are closely related to Nilgiri *Semnopithecus johnii* and Purple-faced langurs *S. vetulus* (Zhang & Ryder 1998; Karanth et al. 2008, 2010; Osterholz et al. 2008), which are distributed in peninsular India and Sri Lanka, respectively. Evidences from molecular data are supported by both ecological and behavioral data wherein Nilgiri Langurs and Hanuman Langurs are similar with respect to size of the troop, troop composition and ranging behavior (Tanaka 1965; Poirier 1968a; Hohmann 1989) and in some behavioral aspects like infant transfer, role of protection of the infants by males, and least protective behaviors of mothers (Tanaka 1965; Poirier 1968b). A review of the literature on such interactions between other similar sister species of Indian colobines revealed that there can exist a close interaction amongst these sister species (Table 1). Both these species are recently diverged taxa and form a close-knit monophyletic clade in a phylogenetic tree. Interestingly, a study by Kavana et al. (2015) while determining the impacts of folivory on social time between Black-footed Grey Langur *Semnopithecus hypoleucos* and Nilgiri Langur in the Western Ghats concluded that phylogenetic inertia was not a constraint determining social behaviour of *S. hypoleucos* and *S. johnii* and that physiological constraint arising from varying degrees of folivory actually appeared to be the important factor. Thus, their study inferred that some traits such as degree of folivory and social time are phylogenetically conserved among Hanuman Langur species and hence, the current study reasonably speculates that the mixed species interactions and associations between Tufted Grey Langurs and Nilgiri Langurs of southern Western Ghats of southern India could be occurring on account of phylogenetic conservatism.

CONCLUSIONS

Taking into consideration the known distribution of Nilgiri Langurs and Hanuman Langurs in southern Western Ghats, it is reasonable to speculate that there could be more such MSAs wherever these two species are co-distributed in this range and elsewhere in the Western Ghats. In this regard, it is imperative to survey MSAs in the entire range of the Western Ghats where both Hanuman Langurs and Nilgiri Langurs co-occur possibly yielding more insights on the biology of these two species groups.

Given the fact that Gudalur-Naduvettam-Ooty road has high human influence and disturbances, the study appeals for more rigorous and systematic surveys on interspecific associations all along the distribution of Nilgiri Langur-Tufted Grey Langur distribution ranges including the entire Nilgiri District. Future studies should determine the ecological or habitat constraints facing both (associated) primate groups. These surveys can aid biologists and park managers to understand the biology of associations and implement appropriate conservation measures. Insights on such associations may have implications for conservation especially if induced by human activities like the introduction of species in areas outside their natural range, decrease in population densities of closely related species due to hunting and habitat fragmentation. A detailed systematic study on ecology, behavior, and molecular aspects of these associations must be the primary goal for future studies.

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A review of the bacular morphology of some Indian bats (Mammalia: Chiroptera)

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Abstract: Bacular studies play a significant role in the case of bats and other mammals since it is considered an important taxon-specific character, thus helping in species discrimination. Structure of the baculum (os penis) also aids in examining and understanding cryptic diversity in bats. The baculum has been used in taxonomic studies of bats but such studies for Indian bats are few and far between. It was felt necessary to put together a comprehensive document depicting the bacular morphology of bats in India so as to be helpful for future bat studies. The penises of the bats were excised, treated with KOH, and then dyed with alizarin red to extract the bacula. The extracted bacula were measured using an oculometer, photographed, and preserved in glycerol. Of the total of 47 species of bats (belonging to nine families) collected and studied during the past decade, we present the bacular morphology of 44 species from peninsular India, Andaman Islands, and Jammu and Kashmir. Bacular morphology of eight taxa, namely, *Eonycteris spelaea*, *Rhinolophus pusillus*, *R. lepidus monticola*, *R. cognatus*, *Hipposideros* cf. *grandis*, *Myotis peytoni*, *M. horsfieldii dryas*, and *M. longipes* are presented here for the first time from India.

Keywords: Andaman Islands, baculum, cryptic species, Jammu & Kashmir, os penis, peninsular India.

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Author contribution: BS and CS planned and wrote the ms. BS and HK did the bacular studies. All the authors contributed equally to the field studies.

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INTRODUCTION

Thomas (1915), for the first time, named the os penis or the penis bone "baculum" (Hill & Harrison 1987), and put to use the study of the baculum in the taxonomy of bats and rodents. The baculum varies between species and is morphologically diverse both in terms of shape and size (Chaine 1925; Hamilton 1946; Eadie 1947; Burt 1960; Patterson & Thaeler 1982; Romer & Parsons 1986; Dixson 1995; Weimann et al. 2014). It was thought to be found only in certain mammalian groups such as Afrosoricida, Carnivora, Chiroptera, Dermoptera, Erinaceomorpha, Primates, Rodentia, and Soricomorpha (Martin 2007; Perrin et al. 2009; Schultz et al. 2016). Recently, the presence of baculum has been discovered in the Lagomorph species *Ochotona princeps* (Weimann et al. 2014), corroborating earlier findings of the baculum in *O. pusilla* by Aksenova & Smirnov (1986) and Erbajeva et al. (2011). These studies show that the baculum might be present in many more taxa than is presently known, however, a baculum is not present in all the species of certain orders, namely Carnivora, Chiroptera, Primates, and Rodentia and is vestigial or absent in felids (Didier 1949; Romer & Parsons 1986; Williams-Ashman 1990; Larivière & Ferguson 2002; Brindle & Ophie 2016).

After Thomas's (1915) pioneering work, many studies described the bacular structure of bats, amongst which some major ones include that of Davis (1947), Hamilton (1949), Krutzsch & Vaughan (1955), Topál (1958), Krutzsch (1959, 1962), Lanza (1959, 1960, 1963, 1970), Didier (1964), Corbet (1964), Brown (1967), Brown et al. (1971), Wassif & Madkour (1972), Wassif et al. (1984), Hill & Harrison (1987), Kitchener & Maharadatunkamsi (1991), Kruskop & Lavrenchenko (2000), Albayrak & Aşan (2001), Benda et al. (2004, 2011), and Rakotondramanana & Goodman (2017).

In India, some of the studies on bacular morphology of bats include those of Bhatnagar (1967), Agrawal & Sinha (1973), Topál (1975), Sinha (1976, 1983), Khajuria (1979, 1980, 1982), Srinivasulu et al. (2010, 2014, 2015, 2018), Kaur et al. (2014, 2017), and Srinivasulu & Srinivasulu (2018).

Bacular morphology is used as a discriminating character for differentiating between different species of bats (Herdina 2014). Studies on the bacular structure of different species of bats have shown the presence of cryptic species among morphologically similar taxa (Krutzsch & Vaughan 1955; Krutzsch 1959; Heller & Volleth 1984; Kitchener et al. 1986; Hill & Harrison 1987; Strelkov 1989; Bates et al. 2006, 2015; Kruskop & Borisenko 2013; Kaur et al. 2014; Goodman et al. 2015; Kruskop 2015; Srinivasulu & Srinivasulu 2018).

India is home to 128 species of bats (Srinivasulu et al. 2020), of which during the last decade we studied 47 species of bats belonging to nine families from peninsular India, Andaman Islands, and Jammu & Kashmir. A comprehensive document on the bacula of bats of India is lacking, hence the present work was planned to fill this lacuna. This work is intended to help as reference material for future bat workers in the region. In this paper, we provide the bacular morphology of 44 species of bats principally found in the Indian subcontinent.

MATERIALS AND METHODS

Male individuals of bats were collected from different parts of Telangana State, Karnataka, Kerala, Tamil Nadu, Maharashtra, Madhya Pradesh, Jammu & Kashmir, Rajasthan and the Andaman Islands after obtaining permissions from the respective forest departments over the last 10 years. Captured bats were handled in strict accordance with good animal practices and according to guidelines of the American Society of Mammalogists (Sikes 2016). Bats were identified following Bates & Harrison (1997) and Srinivasulu et al. (2010). Common names of the species are after Srinivasulu (2018). The voucher specimens were preserved and deposited in the Natural History Museum of Osmania University, Hyderabad, India. From the voucher specimens, the penis was excised and the baculum was extracted following methods outlined by Topál (1958) and Hill & Harrison (1987). The extracted bacula were stained with alizarin red and photographed using a camera mounted on a trinocular microscope. Where possible, photographs of the dorsal, lateral, and ventral aspects of each baculum were taken. The total length of the baculum starting from the basal lobes to the tip of the baculum and breadth of the base of the baculum (where possible) were measured using an oculometer. The stained bacula were then preserved in vials with 100% glycerol.

RESULTS AND DISCUSSION

A total of 47 species of bats belonging to nine families were studied (Table 1). Of these, two species, *Miniopterus fuliginosus* and *M. pusillus,* lack bacula. The bacular structure of *Hipposideros diadema masoni* could not be studied as it is known in India based only on a single female specimen (Srinivasulu et al. 2016).

Table 1. Diversity of bat species studied on mainland India and the Andaman Islands.

Scientific name	Common name
Family Pteropodidae	
Rousettus leschenaultii	Leschenault's Rousette
Pteropus medius	Indian Flying Fox
Pteropus hypomelanus	Variable Flying Fox
Pteropus melanotus	Black-eared Flying Fox
Cynopterus sphinx	Greater Short-nosed Fruit Bat
Cynopterus brachyotis	Lesser Short-nosed Fruit Bat
Eonycteris spelaea	Lesser Dawn Bat
Family Rhinopomatidae	
Rhinopoma hardwickii	Lesser Mouse-tailed Bat
Rhinopoma microphyllum	Greater Mouse-tailed Bat
Family Emballonuridae	
Taphozous longimanus	Long-winged Tomb Bat
Taphozous melanopogon	Black-bearded Tomb Bat
Taphozous nudiventris	Naked-rumped Tomb Bat
Family Megadermatidae	
Lyroderma lyra	Greater False Vampire Bat
Megaderma spasma	Lesser False Vampire Bat
Family Rhinolophidae	
Rhinolophus ferrumequinum	Greater Horseshoe Bat
Rhinolophus andamanensis	Homfray's Horseshoe Bat
Rhinolophus rouxii	Rufous Horseshoe Bat
Rhinolophus pusillus	Least Horseshoe Bat
Rhinolophus lepidus	Blyth's Horseshoe Bat
Rhinolophus lepidus monticola	Montane Horseshoe Bat
Rhinolophus cognatus	Andaman Horseshoe Bat
Rhinolophus beddomei	Lesser Woolly Horseshoe Bat
Family Hipposideridae	
Hipposideros ater	Dusky Roundleaf Bat

Scientific name	Common name
Hipposideros durgadasi	Durga Das's Roundleaf Bat
Hipposideros fulvus	Fulvus Roundleaf Bat
Hipposideros pomona	Pomona Roundleaf Bat
Hipposideros gentilis	Andersen's Roundleaf Bat
Hipposideros hypophyllus	Kolar Roundleaf Bat
Hipposideros galeritus	Cantor's Roundleaf Bat
Hipposideros speoris	Schneider's Roundleaf Bat
Hipposideros cf. *grandis*	Grand Roundleaf Bat
Hipposideros lankadiva	Kelaart's Roundleaf Bat
Hipposideros diadema masoni	Diadem Roundleaf Bat
Family Molossidae	
Tadarida aegyptiaca	Egyptian Free-tailed Bat
Family Vespertilionidae	
Myotis blythii	Lesser Myotis
Myotis peytoni	Peyton's Whiskered Myotis
Myotis longipes	Kashmir Cave Myotis
Myotis horsfieldii dryas	Andaman Myotis
Scotophilus heathii	Asiatic Greater Yellow House Bat
Scotophilus kuhlii	Asiatic Lesser Yellow House Bat
Tylonycteris malayana eremtaga	Andaman Greater Bamboo Bat
Pipistrellus javanicus camortae	Camorta Pipistrelle
Pipistrellus coromandra	Indian Pipistrelle
Pipistrellus tenuis	Least Pipistrelle
Pipistrellus ceylonicus	Kelaart's Pipistrelle
Hesperoptenus tickelli	Tickell's Bat
Family Miniopteridae	
Miniopterus fuliginosus	Eastern Long-fingered Bat
Miniopterus pusillus	Small Long-fingered Bat

Family Pteropodidae Gray, 1821

The bacula of seven out of 12 species of fruit bats in India are reported here.

1. *Rousettus leschenaultii* (Desmarest, 1820) Leschenault's Rousette (Image 1.I)

Material examined: NHM.OU.CHI.65d.2015, male, collected from Golconda fort (17.382N and 78.401E), Hyderabad, Telangana State, by C. Srinivasulu and Tariq A. Shah on 27.ix.2015.

The baculum is medium-sized (2.7mm long; 1.1mm broad), flat, and more or less dumb-bell shaped. The proximal end is round and broad. The apical end has two swellings and is equally as broad as the proximal end. Both the apical and the proximal regions of the baculum look raised in the lateral view. The shaft of the baculum is broad and parallel-sided.

Variations: The shape of the baculum reported here from a specimen from the Golconda fort, Telangana State, differs from that described by Agrawal & Sinha (1973) from Satara, Maharashtra. The baculum of the Telangana specimen is broad with both the apical and proximal ends being equally broad. The baculum from Maharashtra (Agrawal & Sinha 1973; Sinha 1976) has an oval-shaped larger base and the shaft narrows toward the distal end, which is smaller than the base.

2. *Pteropus medius* Temminck, 1825 Indian Flying Fox (Image 1.II)

Material examined: NHM.OU.CHI.21.2012, male, collected from Osmania University (17.422N and 78.530E), Hyderabad, Telangana State by M. Seetharamaraju on 15.ii.2012.

The baculum is medium-sized (2.7mm long, 2.7mm wide), flat, and rectangular. No difference in the dorsal or the ventral surface was observed. The distal end is broad and has a median projection, while the proximal ends are situated apart from each other. Laterally, the baculum has a straight profile.

Variations: The structure of this baculum reported here from a specimen from Osmania University, Hyderabad, Telangana State, differs slightly from that of specimens from Lucknow, Uttar Pradesh and Imphal, Manipur as described by Agrawal & Sinha (1973) and from specimens from Nasirabad and Jodhpur, Rajasthan (Sinha 1976). The baculum in adults is semicircular, and the proximal ends are situated close to each other giving a more rounded appearance with a heart-shaped concavity in the middle. The shape of the baculum in sexually immature individuals has an inverted U-shape with the proximal ends situated far apart from each other (Agrawal & Sinha 1973). The shape of the baculum that was observed by us in our specimen from Telangana with proximal ends situated far apart shows that this is probably a sexually immature specimen.

3. *Pteropus hypomelanus* Temminck, 1853 Variable Flying Fox (Image 1.III)

Material examined: NHM.OU.CHI.133.2014, male, collected from Bahadur Nala (12.071N and 92.741E), near Baratang Island, North & Middle Andaman District, Andaman & Nicobar Islands, by Bhargavi Srinivasulu and C. Srinivasulu on 21.xi.2014.

The baculum is very large (10.0mm long) with a wide, apical portion tapering to a narrower proximal portion. Dorsally, the proximal ends touch each other and have slight swellings resulting in a small concavity at the point of contact. The arms enclose a space that is broad apically and narrowly rounded off proximally. Ventrally, at the base, a concavity is seen.

Variations: The general shape of the baculum reported here from a specimen from Bahadur Nala, South Andaman, Andaman Islands is similar to that described by Lanza (1970) of the nominate form from Ternate Island, Indonesia, although in his description, the proximal ends are almost but not completely touching.

4. *Pteropus melanotus* Blyth, 1863 Black-eared Flying Fox (Image 1.IV)

Material examined: NHM.OU.CHI.192.2015, male, collected from Rutland Island (11.395N and 92.561E), South Andaman District, Andaman & Nicobar Islands, by Asad Gopi and Tauseef Hamid Dar, on 16.xii.2015.

The baculum is very large (9.0mm long), robust, and roughly rectangular with a broad base (6.0mm). The apical portion is broader than the proximal portion with a cavity in the centre which is broad at the apical portion and narrows down to a pointed tip toward the proximal portion. The baculum is concave on the ventral surface.

Remarks: The structure of the baculum of a specimen from Rutland Island, South Andaman, matches the description by Lanza (1970) of that of *Pteropus melanotus tytleri* from the Andaman Islands.

5. *Cynopterus sphinx* (Vahl, 1797) Greater Short-nosed Fruit Bat (Image 1.V)

Material examined: NHM.OU.CHI.10.2012, male, collected from Osmania University (17.422N and 78.530E), Hyderabad, Telangana State, by P. Venkateswarlu, on 02.ii.2012.

The baculum is short (2.0mm long, 1.3mm wide). The base of the baculum is high and broad (1.3mm) and has well-developed shoulders that join medially, into a tall and narrow shaft ending with a narrowly rounded tip. The proximal border of the baculum has uneven edges. The ventral surface of the baculum is concave in appearance.

Remarks: The structure of the baculum of a specimen from Osmania University, Hyderabad, Telangana State, matches the description provided by Bates & Harrison (1997) of the specimen from Haldwani, Uttarakhand, India. It slightly differs from that described by Agrawal & Sinha (1973) from Kolkata, West Bengal, in which the shaft is short and distal end is bulbous.

6. *Cynopterus brachyotis* (Müller, 1838) Lesser Short-nosed Fruit Bat (Image 1.VI)

Material examined: NHM.OU.CHI.121.2015, male, collected from Devpur (12.862N and 92.867E), near Mayabunder, North & Middle Andaman District, Andaman & Nicobar Islands, by C. Srinivasulu and Aditya Srinivasulu, on 19.x.2015.

Only the Andaman population of this species was studied. The baculum is small (1.1mm long). The base is broad with high shoulders. The base then joins medially to continue to a broad shaft, which ends with a broadly rounded tip. The baculum is concave in its ventral aspect.

Variations: In the Andaman populations, we have observed variations; in some, the shaft is much shorter and stouter, and no development of shoulders was observed. A much more detailed study is needed to

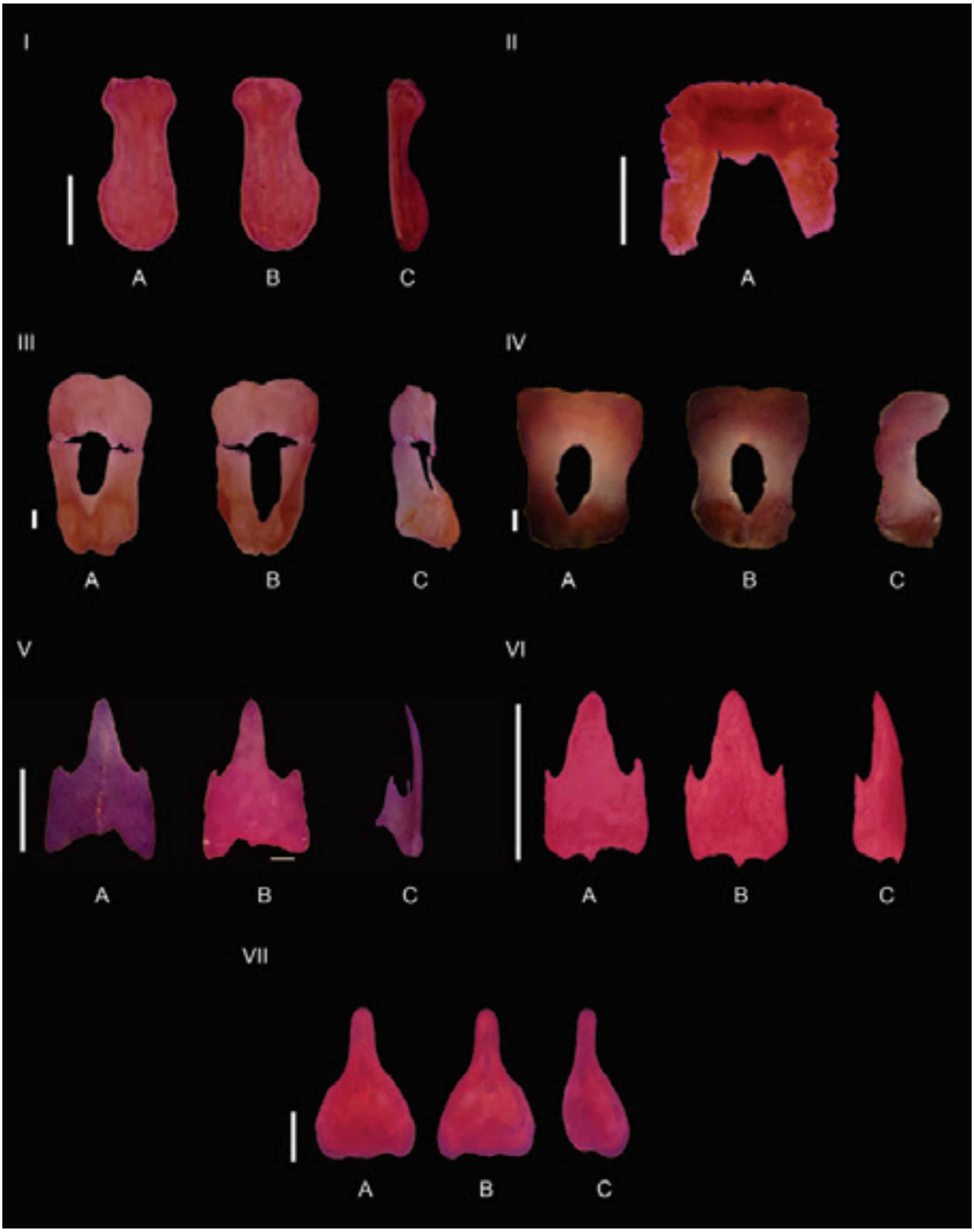

Image 1. Bacula of selected species belonging to the family Pteropodidae in India: I—*Rousettus leschenaultii* | II—*Pteropus medius* | III—*Pteropus hypomelanus* | IV—*Pteropus melanotus* | V—*Cynopterus sphinx* | VI—*Cynopterus brachyotis* | VII—*Eonycteris spelaea*. (Scale: 1mm). A—Dorsal view | B—Ventral view | C—Lateral view.

ascertain the presence of any cryptic species/subspecies among the island forms.

Remarks: The structure of the baculum of a specimen from Devpur, near Mayabunder, Middle Andaman, Andaman Islands, differs in lacking the two projections on either side of the base as described by Bates & Harrison (1997) of specimens from Tamil Nadu, India and Agrawal & Sinha (1973) from Goa, India. We also observed that the shaft of the baculum of this species is broad, and not narrow and tall as in *C. sphinx*.

7. *Eonycteris spelaea* (Dobson, 1871) Lesser Dawn Bat (Image 1.VII)

Material examined: NHM.OU.CHI.41.2012, male, collected from Baratang Island (12.095N and 92.749E), North & Middle Andaman District, Andaman & Nicobar Islands, by Bhargavi Srinivasulu and G. Chethan Kumar, on 04.vii.2012.

The baculum of *Eonycteris spelaea* is being reported for the first time. The baculum of the specimen from the Baratang Island, Andaman Islands, is medium-sized (3.1mm long), with a broad base (2.0mm). The base is slightly notched in the centre on the proximal border. The distal portion has a short shaft ending with a rounded-off tip.

Remarks: The baculum structure of *Eonycteris spelaea* described in the present work differs greatly from that described by Krutzsch (1959 & 2005) from Soka, Bali, Indonesia and from Batu caves, near Kuala Lumpur, West Malaysia respectively. It is for the first time that the baculum of this species is described from India.

Family Rhinopomatidae E. Geoffroy, 1818

The bacula of both species of mouse-tailed bats in India are reported here.

8. *Rhinopoma hardwickii* (Gray, 1831) Lesser Mouse-tailed Bat (Image 2.I)

Material examined: NHM.OU.CHI.16.2015, male, collected from Mukta Bhai (20.583N and 79.506E), Doma, Chimur, Chandrapur District, Maharashtra, by Tariq A. Shah and G. Devender, on 27.ii.2015.

The baculum is very small (1.0mm long), with a unique shape. The proximal portion (0.3mm wide) has two arms which are placed widely from each other. In between the two arms of the proximal portion, a small process extends downward, which sometimes gets easily broken leaving behind a tiny projection that can be seen on the lateral aspect. The arms of the proximal portion are broadly rounded off. The shaft of the baculum is thick and parallel-sided. The shaft starts from the mid-portion of the base of the baculum and ends with a broadly rounded tip.

Remarks: The structure of the baculum of the specimen from Chimur, near Chandrapur, Maharashtra is slightly similar to that of specimens from Solayan, Nagaur District, Rajasthan (Sinha 1976). The baculum of the present specimen differs in having a broad base with arms extending outward and a shorter parallel-sided shaft.

9. *Rhinopoma microphyllum* (Brünnich, 1792) Greater Mouse-tailed Bat (Image 2.II)

Material examined: NHM.OU.CHI.138h.2015, male, collected from Juna Mahal (23.826N and 73.714E), Dungarpur District, Rajasthan, by Tariq A. Shah, on 29.x.2015.

The baculum is very small (0.7mm long) and triangular. It is concave on the ventral aspect. Two projections are observed on either side of the base (0.3mm wide) leading to the formation of a concavity in the mid-portion of the base of the baculum. The base extends into a parallel-sided shaft, which narrows in a rounded-off tip toward the apex. In the lateral aspect, the baculum shows a straight profile.

Remarks: The baculum of the specimen from Juna Mahal, Dungarpur, Rajasthan resembles that described by Sinha (1976) from Jodhpur, Rajasthan. The structure of the baculum of the specimen from Delhi (Agrawal & Sinha 1973) differs in structure from that of the Rajasthan specimens examined during the present study and also by Sinha (1976). Further studies are needed to ascertain any cryptic diversity among populations of *R. microphyllum* in India.

Family Emballonuridae Gervais, 1855

The bacula of three out of six species of tomb bats in India are reported here.

10. *Taphozous longimanus* (Hardwicke, 1825) Long-winged Tomb Bat (Image 3.I)

Material examined: NHM.OU.CHI.5.2015, male, collected from Old High Court (21.153N and 79.071E), Civil Lines, Nagpur, Nagpur District, Maharashtra, by G. Devender and Tariq A. Shah, on 24.ii.2015.

The baculum is very small (0.4mm long), flat, blunt, and irregular in shape. The proximal end is broad and the distal end is somewhat broadly pointed. The distal end shows a slight concavity on the ventral surface.

Remarks: The baculum structure of the specimen from Nagpur, Maharashtra, is similar in structure with

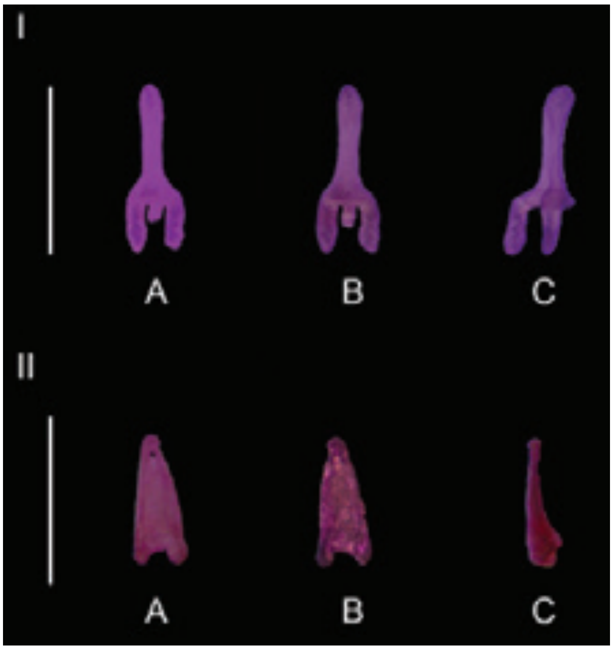

Image 2. Bacula of species belonging to the family Rhinopomatidae in India: I—*Rhinopoma hardwickii* | II—*Rhinopoma microphyllum* (Scale: 1mm). A—Dorsal view | B—Ventral view | C—Lateral view.

that described by Sinha (1976) from Kota, Rajasthan.

11. *Taphozous melanopogon* Temminck, 1841 Black-bearded Tomb Bat (Image 3.II)

Material examined: NHM.OU.CHI.18.2015, male, collected from Ambai-Nimbai (19.783N and 79.577E), Chimur, Chandrapur District, Maharashtra, by G. Devender and Tariq A. Shah, on 27.ii.2015.

The baculum is very small (1.0mm long), with a slightly broad base and a knob-like tip. No noticeable difference between the proximal and apical portions is observed. Additionally, there is no demarcation between the ventral and dorsal surfaces, as it is cylindrical.

Remarks: The baculum structure of the specimen from Chimur, Chandrapur, Maharashtra, is similar to that described by Sinha (1983) from Patna, Bihar. Another baculum of this species was described from Tennaserim, Myanmar (=Burma) (Agrawal & Sinha 1973), where the baculum was also cylindrical and knob-like, similar to that described by Sinha (1983) and that observed in the present specimen. The Tennaserim baculum had a swollen distal end with a crescent-shaped notch at the tip.

12. *Taphozous nudiventris* (Cretzschmar, 1830-31) Naked-rumped Tomb Bat (Image 3.III)

Material examined: NHM.OU.CHI.65f.2015, male, collected from Golconda Fort (17.382N and 78.401 E), Hyderabad, Telangana State, by C. Srinivasulu and Aditya Srinivasulu, on 27.ix.2015.

The baculum is very small (0.5mm long) and resembles the shape of a shoe. The base of the baculum is broader than the apex and continues into a parallel-sided straight shaft which becomes narrower and pointed near the apex. In the lateral aspect, a slight concavity is seen just above the base rendering the dorsal aspect of the baculum near the base to be slightly curved to the outside.

Remarks: The baculum structure of the specimen from the Golconda Fort, Telangana State, differs from that described by Sinha (1976) from Kota, Rajasthan, in which the baculum was described to be lingulate in structure with a narrow and concave base.

Family Megadermatidae H. Allen, 1864

The bacula of both the species of false vampire bats in India are reported here.

13. *Lyroderma lyra* E. (Geoffroy, 1810) Greater False Vampire Bat (Image 4.I)

Material examined: NHM.OU.CHI.12.2014, male, collected from Naramvarigudem (17.250N and 81.068E), Bhadradri Kothagudem district, Telangana State, by G. Devender and K. Krishna Prasad, on 25.i.2014.

The baculum is very small (0.5mm long), with two semi-curved, concave, small, simple, thin bones that are arranged beside one another without any medial attachment inside the penis. One bone has a very slightly expanded base and narrowly pointed apex, while the other has a wavy lateral border and has the proximal and apical portions narrowly rounded off.

Remarks: The bacular structure of the specimen from Naramvarigudem, Khammam, Telangana State matches that described by Sinha (1976) from Ranthambore, Sawai Madhopur, Rajasthan.

14. *Megaderma spasma* (Linnaeus, 1758) Lesser False Vampire Bat (Image 4.II)

Material examined: NHM.OU.CHI.49.2016, male, collected from 10th Block (11.933N and 75.795E), Forest Quarters, Aralam Wildlife Sanctuary, Kannur district, Kerala, by Bhargavi Srinivasulu and G. Devender, on 13.x.2016.

The baculum is small (1.3mm long), and resembles a tuning fork. The thick base has a bone extending down from it in the form of a stalk. The shaft is made of two arms which extend toward the distal end and have narrowly rounded off tips. The arms converge as

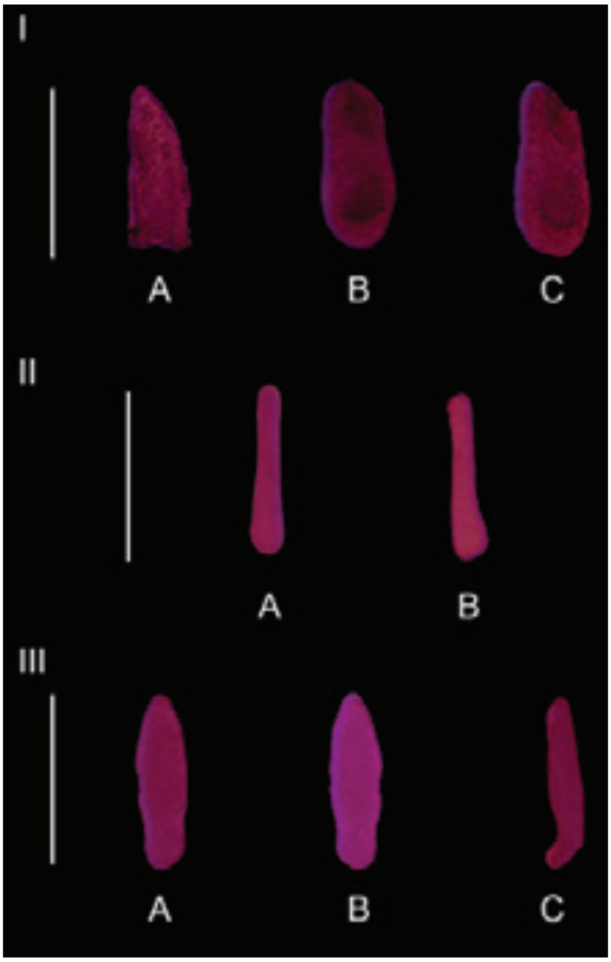

Image 3. Bacula of selected species belonging to the family Emballonuridae in India: I—*Taphozous longimanus* | II—*Taphozous melanopogon* | III—*Taphozous nudiventris* (Scale: I & III 0.5mm; II 1mm). A—Dorsal view | B—Ventral view | C—Lateral view.

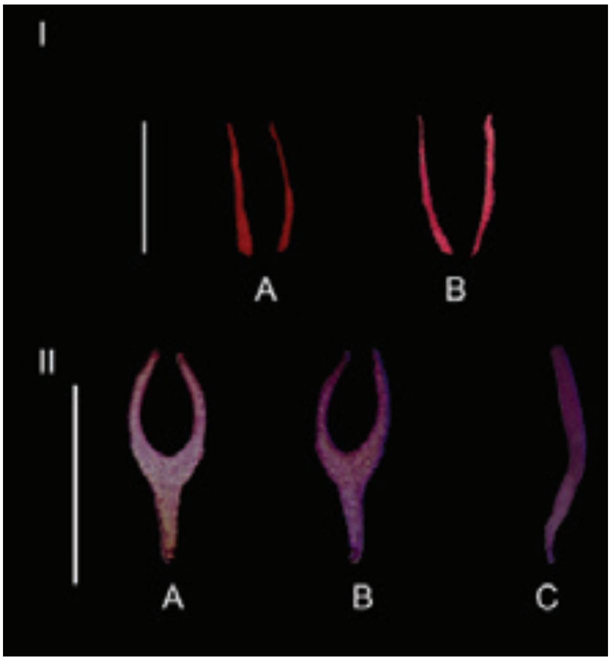

Image 4. Bacula of species belonging to the family Megadermatidae in India: I—*Lyroderma lyra* | II—*Megaderma spasma* (Scale: I 0.5mm; II 1mm). A—Dorsal view | B—Ventral view | C—Lateral view.

they reach the apical portion to form a 'U' shape. When observed in the lateral aspect, the baculum shows concavity on the ventral side.

Remarks: The baculum structure of the specimen from Aralam Wildlife Sanctuary, Kerala matches that described by Bates & Harrison (1997) from Pilikutthuwa, Sri Lanka and Sinha (1983) from India (exact locality not known).

Family Rhinolophidae Lacépède, 1799

The bacula of seven out of 19 species of horseshoe bats in India are reported here.

15. *Rhinolophus ferrumequinum* (Schreber, 1774) Greater Horseshoe Bat (Image 5.I)

Material examined: NHM.OU.CHI.27a.2016, male, collected from Bumzov Cave (33.769N and 75.213E), Martand, Anantnag District, Jammu and Kashmir, by Tariq A. Shah, on 30.iv.2016.

The baculum is large (4.7mm long), and spindle-shaped. The base is broad (1.5mm) and has a deep concavity on the ventral surface. The shaft is thick, initially near the base it is parallel-sided, a bit further up it expands into a spindle shape, and later converges into a narrowly pointed tip.

Remarks: The baculum structure of the specimen from Bumzov cave, Jammu & Kashmir matches that described by Topál (1975) from Bumzov cave, Jammu & Kashmir, and Bates & Harrison (1997) from Abbottabad, Pakistan.

16. *Rhinolophus andamanensis* (Dobson, 1872) Homfray's Horseshoe Bat (Image 5.II, 5.III)

Materials examined: NHM.OU.CHI.72.2014, male, collected from Baratang Island (12.095N and 92.749E), North & Middle Andaman District, Andaman & Nicobar Islands, by Chelmala Srinivasulu and Asad Gopi, on 15.x.2014; NHM.OU.CHI.31.2012, male, collected from Baratang Island (12.095N and 92.749E), North & Middle Andaman District, Andaman & Nicobar Islands, by Bhargavi Srinivasulu and G. Chethan Kumar, on 04.vii.2012.

The baculum (typical form, Image 5.II) is medium-sized (3.1mm long). The base is broad (1.0mm), four-pronged and has a V-shaped fissure that appears deep on the ventral aspect and shallow on the dorsal aspect. The broad base extends to about 25% of the length of the baculum and then narrows into a thin parallel-sided long shaft, which curves slightly near the apical region.

Variation: The second type of baculum (Image 5.III) has also been observed among individuals of the same population of this species. The baculum is medium-sized (2.2mm). The base is small and three-pronged with a small concavity on the ventral aspect. The base extends into a thin, long, parallel-sided shaft which ends in a narrowly rounded off tip. In the lateral aspect, the shaft shows slight curvature toward the apical region (Srinivasulu et al. 2019).

Remarks: The structure of the baculum of the specimen from Baratang Island, Andaman Islands, shows slight similarity to that described by Sinha (1983) from North Andaman, Andaman Islands.

17. *Rhinolophus rouxii* (Temminck, 1835) Rufous Horseshoe Bat (Image 5.IV)

Material examined: NHM.OU.CHI.15.2017, male, collected from Karagal Village (14.1897N and 74.8138E), Shivamogga District, Karnataka, by Bhargavi Srinivasulu and G. Devender, on 15.v.2017; NHM.OU.CHI.66.2016, male, collected from Kerala Agriculture University – Periyar Hostel (10.5502N and 76.27837E), Vellanikkara, Thrissur District, Kerala, by Bhargavi Srinivasulu and Tariq A Shah, on 31.x.2016.

The baculum is medium-sized (2.3mm long), with a long, thin shaft and expanded base. The expanded base has a deep sulcus on the ventral aspect. The middle portion of the base has an uneven border and the sides are slightly longer than the middle portion. Apically the shaft is narrowly rounded-off. Laterally it has a slight curvature starting from the distal end to the base. The base of the baculum shows a more rounded appearance laterally. Ventral basal emarginations are deeper than the dorsal ones. The ventral surface shows a wide median depression. The tip is acutely pointed when seen laterally.

Remarks: The structure of the baculum of the specimen from Kargal, Shivamogga, Karnataka matches that described by Topál (1975) from Udaygiri, Odisha, and Mahabaleshwar, Maharashtra, and Bates & Harrison (1997) from Talewadi, Karnataka. The baculum of the present specimen differs slightly in having a slight curvature of the shaft toward the apical region visible in the lateral aspect. The taxon *R. indorouxii* Chattopadhyay et al. (2012) was described as separate from *R. rouxii* based on echolocation calls and cytb sequences, however, the *nomen* is treated as invalid by Hutson et al. (2019). The baculum structure of the populations described as *R. indorouxii* (Image 5.V; here treated as *R.* cf. *rouxii*) is roughly similar to that of *R. rouxii* and differs slightly in having a small, not so rounded base. The shaft shows slight curvature and the tip of the shaft is slanting and flat.

18. *Rhinolophus pusillus* (Temminck, 1834) Least Horseshoe Bat (Image 5.VI)

Material examined: NHM.OU.CHI.14.2017, male, collected from Karagal Village (14.1897N and 74.8138E), Shivamogga District, Karnataka, by Bhargavi Srinivasulu and G. Devender, on 15.v.2017.

The baculum of the specimen from Kargal, Shivamogga, Karnataka, is medium-sized (3.5mm long), with a deeply forked broad base (1.0mm). The shaft is long, thin, and cylindrical, ending in a narrowly rounded-off tip. The tip of the baculum shows a slight flattening at an angle. On the lateral aspect, a pronounced curvature is observed in the middle region of the shaft.

Remarks: This is the first time that the baculum of this species from India is described.

19. *Rhinolophus lepidus* (Blyth, 1844) Blyth's Horseshoe Bat (Image 5.VII)

Material examined: NHM.OU.CHI.28.2015, male, collected from Kandri Mine Cave (21.412N and 79.268E), Nagpur, Nagpur district, Maharashtra, by G. Devender and Tariq A. Shah, on 03.iii.2015.

The baculum is medium-sized (3.5mm long), with a slightly forked broad base. The base (0.8mm) shows the presence of a thin sulcus on the ventral surface. The shaft is narrow, long, cylindrical, ending in narrowly pointed tip. The lateral profile of the baculum is straight.

Remarks: The structure of the baculum of the specimen from Nagpur, Maharashtra, matches that described by Sinha (1976) from Ranthambore, Sawai Madhopur, Rajasthan.

19a. *Rhinolophus lepidus monticola* Andersen, 1905 Montane Horseshoe Bat (Image 5.VIII)

Material examined: NHM.OU.CHI.19.2016, male, collected from Bumzov Cave (33.769N and 75.213E), Martand, Anantnag District, Jammu and Kashmir, by Tariq A. Shah, on 30.iv.2016.

The baculum of the specimen from Anantnag, Jammu & Kashmir is large (4.5mm long), longer than the nominate subspecies. It has a broad base (1.0mm) with a shallow proximal emargination. The emargination is shallower than that of *R. lepidus*. The base has a thin sulcus on the ventral surface, which extends into a

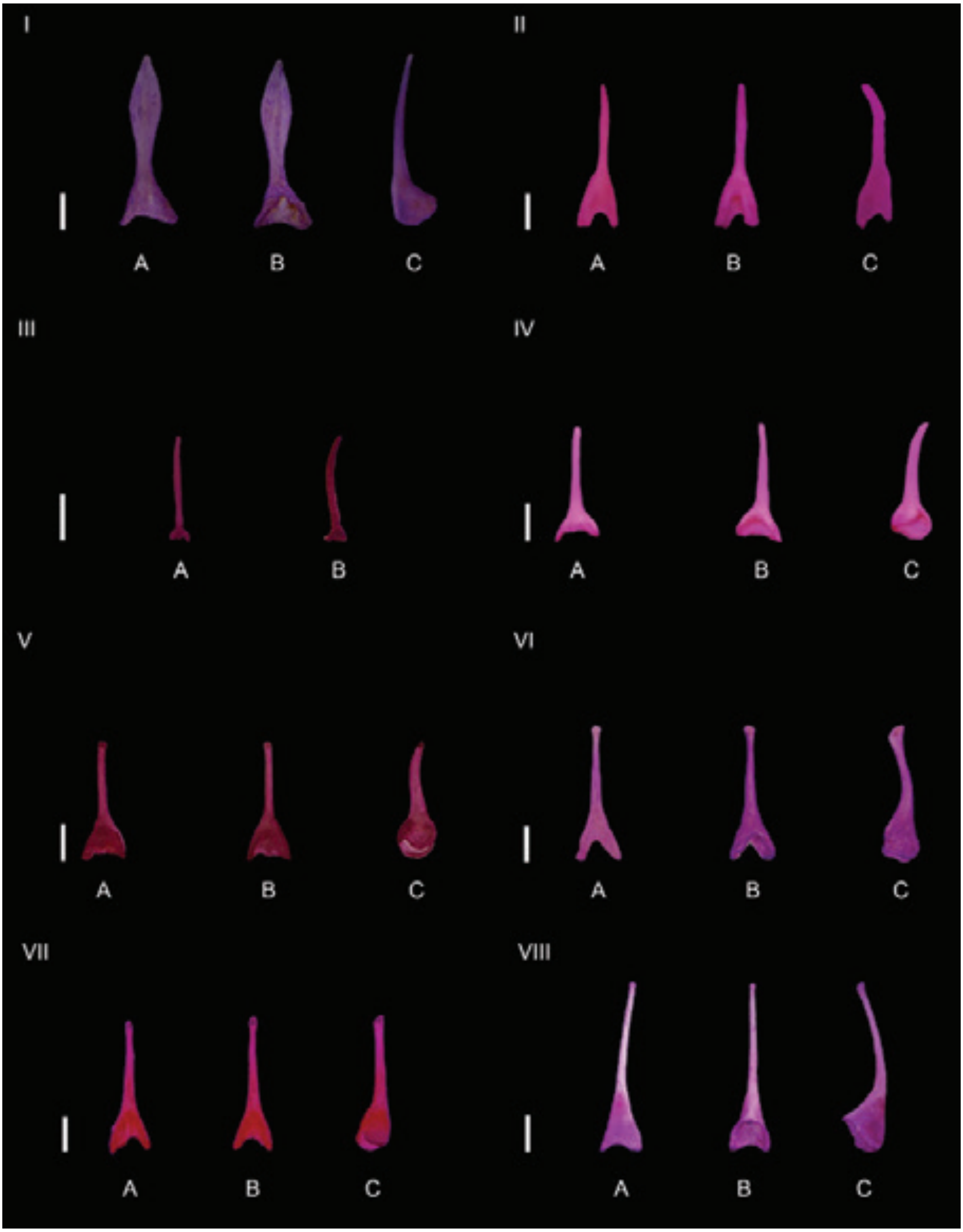

Image 5. Bacula of selected species belonging to the family Rhinolophidae (in part) in India: I—*Rhinolophus ferrumequinum* | II—*Rhinolophus andamanensis* (from Baratang Island) | III—*Rhinolophus andamanensis* (from Baratang Island) | IV—*Rhinolophus rouxii* | V—*Rhinolophus* cf. *rouxii* | VI—*Rhinolophus pusillus* | VII—*Rhinolophus lepidus* | VIII—*Rhinolophus lepidus monticola* (Scale: 1mm). A—Dorsal view | B—Ventral view | C—Lateral view.

concavity. The shaft is thin, long, and cylindrical ending in a tapered and pointed tip. In the lateral profile, a pronounced curvature starting from just above the broad base to the tip is observed.

Remarks: This is the first time that the baculum of this subspecies is described.

20. *Rhinolophus cognatus* (Andersen, 1906) Andaman Horseshoe Bat (Image 6.I, 6.II)

Materials examined: NHM.OU.CHI.94.2015 male, collected from Baratang Island (12.095N and 92.749E), North & Middle Andaman District, Andaman & Nicobar Islands, by C. Srinivasulu and Aditya Srinivasulu, on 14.x.2015; NHM.OU.CHI.127.2014, male, collected from Interview Island (12.888N and 92.687E), North & Middle Andaman District, Andaman & Nicobar Islands, by Asad Gopi and Tauseef Hamid Dar, on 12.xi.2014.

The baculum of the specimen from Baratang Island is medium-sized (3.0mm long), with a long, thin shaft, and thick and bulbous tip. The base is wide (0.7mm) with a distinct deep concavity very clearly visible in the ventral aspect. In the dorsal aspect, a slight sulcus is seen on the base. The shaft shows a distinct curvature in the lateral aspect, just above the base.

Variation: In a population of this species on Interview Island, the baculum structure, although quite similar, shows slight variations. The baculum is medium-sized (2.0mm long), has a deep sulcus at the base and a long shaft ending with a bulbous tip. The baculum is straight in lateral profile.

Remarks: This is the first time that the baculum of this Indian endemic species is described.

21. *Rhinolophus beddomei* (Andersen, 1905) Lesser Woolly Horseshoe Bat (Image 6.III)

Material examined: NHM.OU.CHI.10.2013, male, collected from Shivagange (13.169N and 77.222E), Bengaluru Rural District, Karnataka, by Bhargavi Srinivasulu and Harpreet Kaur, on 13.xi.2013.

The baculum of the specimen from Shivagange, Karnataka, is large (5.8mm long) and is comprised of a thick and triangular base and a narrow distal shaft. The margin of the broad base (2.2mm) has a deep sulcus dorsally and a deep groove ventrally. The shaft is long and ends with a rounded tip. The basal processes are shorter than the shaft and are well separated by the deep groove on the base.

Remarks: The structure of the baculum of the specimen from Shivagange, Bengaluru rural, Karnataka, matches that described by Srinivasulu et al. (2015) from Sandur, Bellary district, Karnataka.

Family Hipposideridae Lydekker, 1891

The bacula of 10 out of 16 species of roundleaf bats in India are reported here.

22. *Hipposideros ater* Templeton, 1848 Dusky Roundleaf Bat (Image 7.I)

Material examined: NHM.OU.CHI.9.2018, male, collected from Navarkulam (11.9614N and 79.8059E), Pondicherry, Tamil Nadu, by Tariq A. Shah, on 01.vii.2018.

The baculum is small (1.6mm long). The base is small, with a slight concavity in the middle. The shaft is long and cylindrical and tapers into a narrowly pointed tip. A slight curvature starting from about one quarter the length of the shaft to the tip is observed in the lateral aspect.

Remarks: The structure of the baculum of the specimen from Navarkulam, Pondicherry, matches that described by Topál (1975) from Konark, Odisha.

23. *Hipposideros durgadasi* (Khajuria, 1970) Durga Das's Roundleaf Bat (Image 7.II)

Material examined: NHM.OU.CHI.28.2014, male, collected from Therahalli (13.133N and 78.095E), Kolar district, Karnataka, by Harpreet Kaur and Bhargavi Srinivasulu, on 13.v.2014.

The baculum is small (1.5mm long), with a distinct 'C' shape in the lateral aspect. The base of the baculum is squarish, simple, and the shaft gradually tapers towards the pointed tip. On the dorsal aspect, a conspicuous constriction is seen just above the base.

Remarks: The structure of the baculum of the specimen from Hanumanahalli, Kolar district, Karnataka, matches that described by Topál (1975) from Gwarighat, Madhya Pradesh.

24. *Hipposideros fulvus* (Gray, 1838) Fulvus Roundleaf Bat (Image 7.III)

Material examined: NHM.OU.CHI.9.2014, male, collected from Naramvarigudem (17.250N and 81.068E), Bhadradri Kothagudem District, Telangana State, by G. Devender and K. Krishna Prasad, on 25.i.2014.

The baculum is small (1.8mm long), with a thick base and a long slender shaft. The base is small and has no appearance of any concavity. The shaft is long, slender, showing slight curvature along the length and tapers to a pointed tip. In the lateral view, a slight curvature of the shaft is clearly visible.

Remarks: The structure of the baculum of the specimen from Naramvarigudem, Bhadradri Kothagudem district, Telangana State matches that described by Topál (1975) from Bhaja, Maharashtra; from Jodhpur,

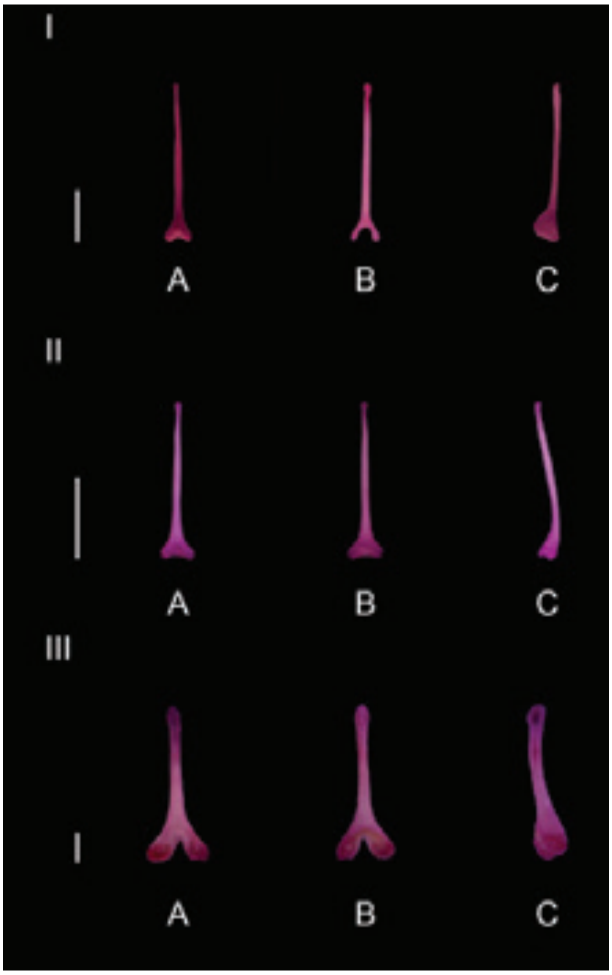

Image 6. Bacula of selected species belonging to the family Rhinolophidae (in part) in India: I—*Rhinolophus cognatus* (from Interview Island) | II—*Rhinolophus cognatus* (from Baratang Island) | III—*Rhinolophus beddomei* (Scale: 1mm). A—Dorsal view | B—Ventral view | C—Lateral view.

Rajasthan described by Sinha (1976) and that described by Bates & Harrison (1997) from Sri Lanka.

25. *Hipposideros pomona* Andersen, 1918 Pomona Roundleaf Bat (Image 7.IV)

Material examined: NHM.OU.CHI.2.2018, male, collected from Ranipuram (12.4262N and 75.3623E), Kasaragod District, Kerala, by Sreehari Raman, on 25.xi.2017.

The baculum of the specimen from Ranipuram, Kasaragod district, Kerala, is small (1.7mm long), with a thick base and a bifid tip. The base is thick with a small concavity in the middle. The shaft of the baculum is long, slender, straight-sided, and ends with a bifid apical portion.

Remarks: The strucutre of the baculum of the specimen from Ranipuram, Kerala matches that described by Srinivasulu & Srinivasulu (2018) based on a historic specimen collected from Travancore, southern India.

26. *Hipposideros gentilis* Andersen, 1918 Andersen's Roundleaf Bat (Image 7.V)

Material examined: NHM.OU.CHI.135.2014, male, collected from Baratang Island (12.095N and 92.749E), North & Middle Andaman District, Andaman & Nicobar Islands, by Tauseef Hamid Dar and Asad Gopi, on 22.xi.2014.

The baculum is very small (0.6mm long), simple, tapering gradually to a tip.

Remarks: The structure of the baculum of the specimen from Baratang Island, Andaman Islands, matches that of *H. pomona* described by Douangboubpha et al. (2010) from Thailand and Zubaid & Davison (1987) from Peninsular Malaysia. A slight variation in the baculum structure was observed in some populations, in which the baculum (0.5mm) shows a rounded base with a slight concavity near the apical region, and ends with a squarish tip.

27. *Hipposideros hypophyllus* Kock & Bhat, 1994 Kolar Roundleaf Bat (Image 7.VI)

Material examined: NHM.OU.CHI.19.2014, male, collected from Hanumanahalli (13.158N and 78.291E), Kolar District, Karnataka, by C. Srinivasulu and Aditya Srinivasulu, on 12.v.2014.

The baculum is medium-sized (2.5mm long), straight-sided, and a slightly round and broad base. There is a prominent concavity present at the base ventrally. The shaft of the baculum is long and gradually tapers into a bifid distal end. When viewed laterally, the tip appears bulb-like and the base is sharply angulated.

28. *Hipposideros galeritus* (Cantor, 1846) Cantor's Roundleaf Bat (Image 8.I)

Material examined: NHM.OU.CHI.35.2014, male, collected from Shivagange (13.169N and 77.222E), Bengaluru Rural District, Karnataka, by Bhargavi Srinivasulu and Harpreet Kaur, on 16.v.2014.

The baculum is very small (0.7mm long), with a broad base, gradually tapering shaft and a blunt tip. There is a faint concavity present near the base on the ventral aspect. In the lateral view, the shaft is faintly curved.

Remarks: The structure of the baculum of the specimen from Shivagange, Karnataka matches that described by Topál (1975) from Ajanta, Maharashtra.

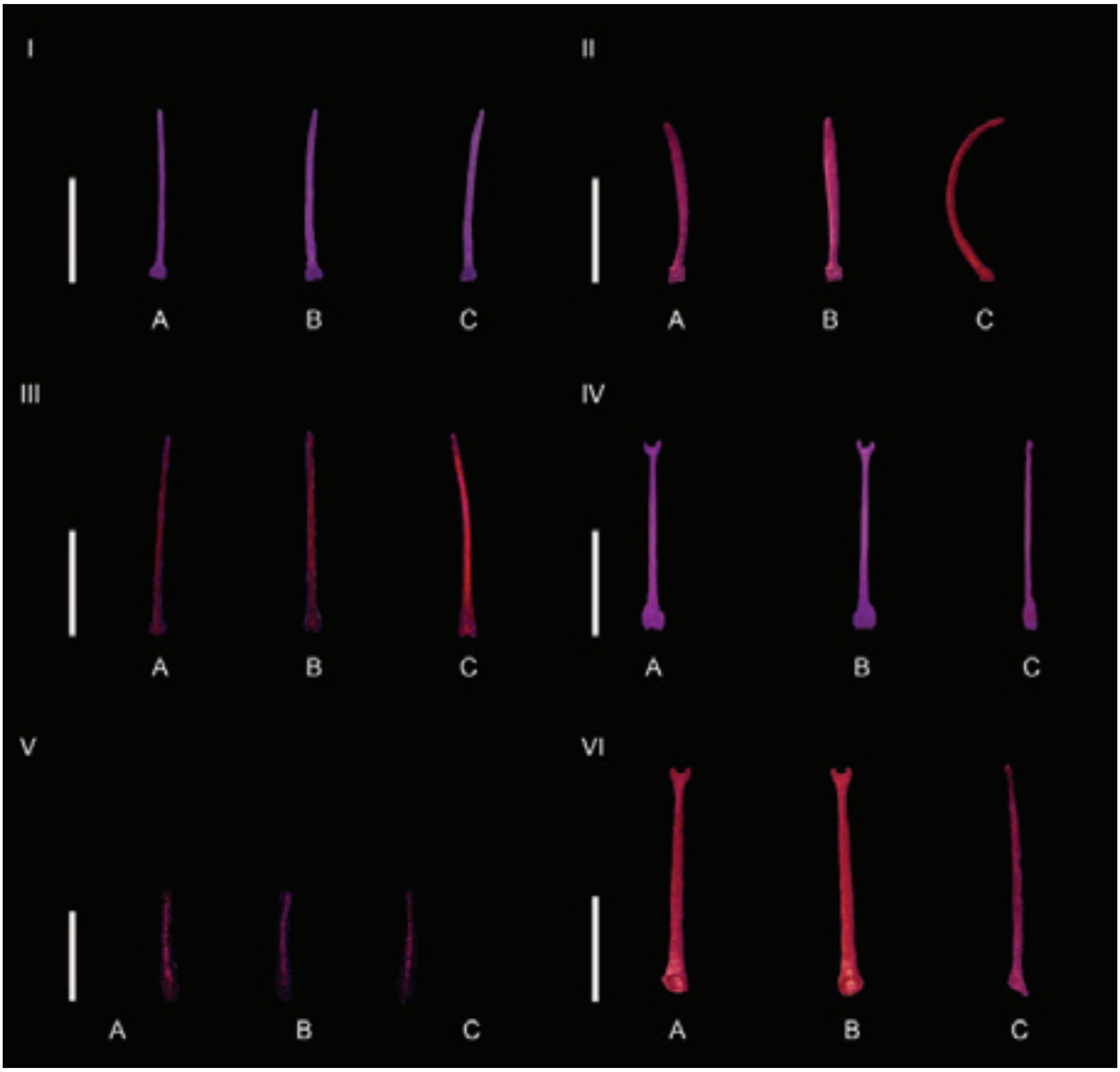

Image 7. Bacula of selected species belonging to the family Hipposideridae (in part) in India: I—*Hipposideros ater* | II—*Hipposideros durgadasi* | III—*Hipposideros fulvus* | IV—*Hipposideros pomona* | V—*Hipposideros gentilis* | VI—*Hipposideros hypophyllus* (Scale: V 0.5mm; Scale: I–IV & VI 1mm). A—Dorsal view | B—Ventral view | C—Lateral view.

29. *Hipposideros speoris* (Schneider, 1800) Schneider's Roundleaf Bat (Image 8.II)

Material examined: NHM.OU.CHI.32.2013, male, collected from Hanumanahalli (13.158N and 78.291E), Kolar District, Karnataka, by G. Devender and Tariq A. Shah, on 14.xii.2013.

The baculum is very small (0.5mm long), with a slightly expanded base, a straight shaft, and a notched, broad tip. Laterally, it shows the presence of a slight curvature of the shaft from the base to the apical region.

Remarks: The structure of the baculum of the specimen from Hanumanahalli, Karnataka matches that described by Topál (1975) from Elephanta, Maharashtra.

30. *Hipposideros* cf. *grandis* (G.M. Allen, 1934) Grand Roundleaf Bat (Image 8.III)

Material examined: NHM.OU.CHI.177.2015, male, collected from V.K. Pur (10.726N and 92.576E), Little Andaman, Andaman & Nicobar Islands, by Asad Gopi and Tauseef Hamid Dar, on 05.xii.2015.

The baculum is small (1.2mm long), with a roughly U-shaped structure. The apical processes are long with lateral thickenings and converge toward the apex. The tips are not in contact with each other. The outer margins

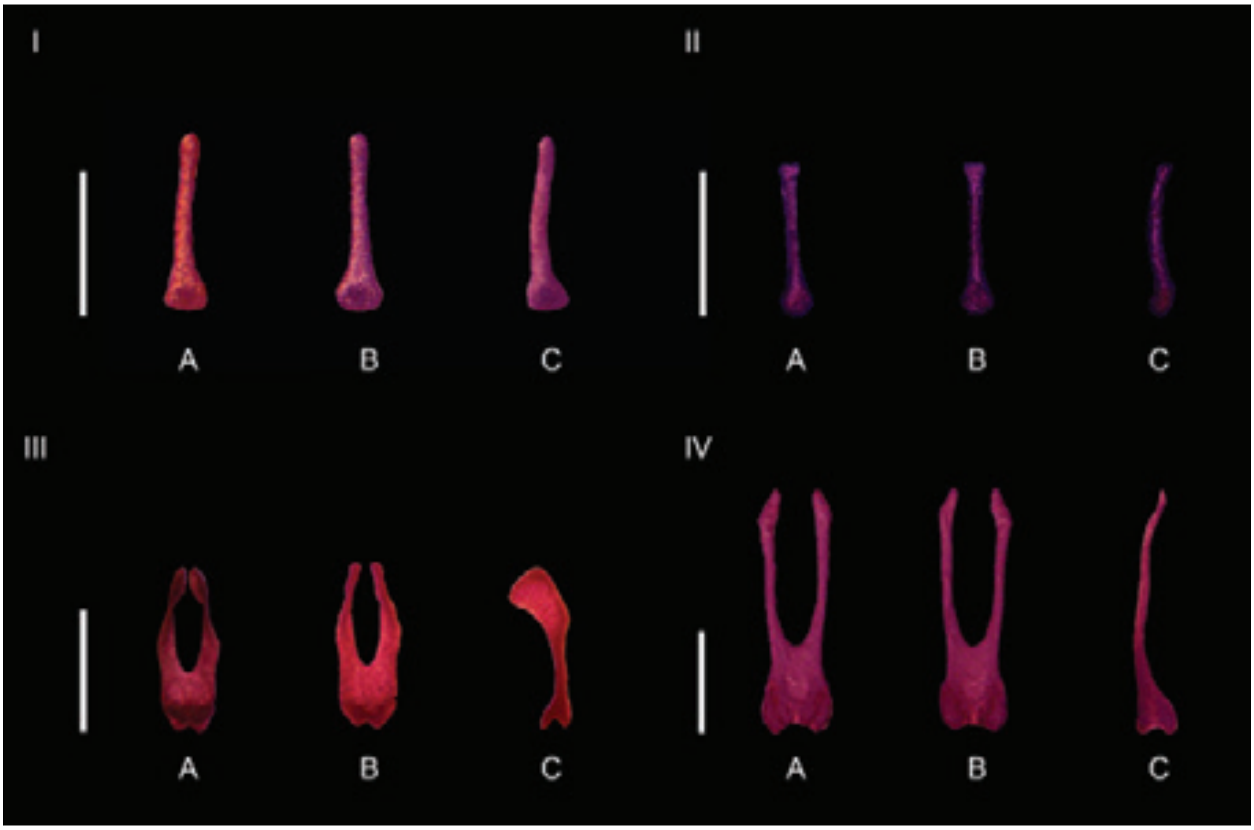

Image 8. Bacula of selected species belonging to the family Hipposideridae (in part) in India: I—*Hipposideros galeritus* | II—*Hipposideros speoris* | III—*Hipposideros* cf. *grandis* | IV—*Hipposideros lankadiva* (Scale: I & II 0.5mm; III & IV 1mm). A—Dorsal view | B—Ventral view | C—Lateral view.

of the apical process are projecting. The proximal end is grooved in the middle, and a concavity is present at the base of the proximal end.

Remarks: The baculum of the specimen from Little Andaman, Andaman Islands matches that described by Agrawal & Sinha (1973), as *Hipposideros larvatus grandis*, from Prome, Myanmar (=Burma); however, a slight difference is observed. Agrawal & Sinha (1973) mention that the arms are narrower in the middle than at the apex, however in the baculum of the present specimen the arms narrow toward the apex. This is the first time that the baculum of this species from India is described.

31. *Hipposideros lankadiva* (Kelaart, 1850) Kelaart's Roundleaf Bat (Image 8.IV)

Material examined: NHM.OU.CHI.59.2015, male, collected from Chikatimori (19.11N and 79.09E), Maliyal, Jannaram, Mancherial District, Telangana State, by G. Devender and G. Chethan Kumar, on 25.ix.2015.

The baculum is medium-sized (2.4mm long), with two apical processes extending from the base. The baculum is longer than broad and slender in appearance. The basal portion of the baculum is broad, with a small concavity in the middle. From the base, the broad shaft extends to 1/3rd the length of the baculum after which two apical processes arise from the broad shaft. These are thin and tall and run parallel to each other. Toward the apical portion, they slightly bend toward each other. The tips of the apical processes are narrowly rounded off. Laterally, the apical processes exhibit uneven borders and a pointed tip and a gentle bend toward the forked base.

Remarks: The structure of the baculum of the specimen from Jannaram, Mancherial district, Telangana State matches that described by Agrawal & Sinha (1973) from Garo Hills, Meghalaya.

Family Molossidae Gervais, 1856

The baculum of one out of three species of free-tailed bats in India is reported here.

32. *Tadarida aegyptiaca* (E. Geoffroy, 1818) Egyptian Free-tailed Bat (Image 9)

Material examined: NHM.OU.CHI.45.2014, male, collected from Shiva Temple (15.317N and 76.464E),

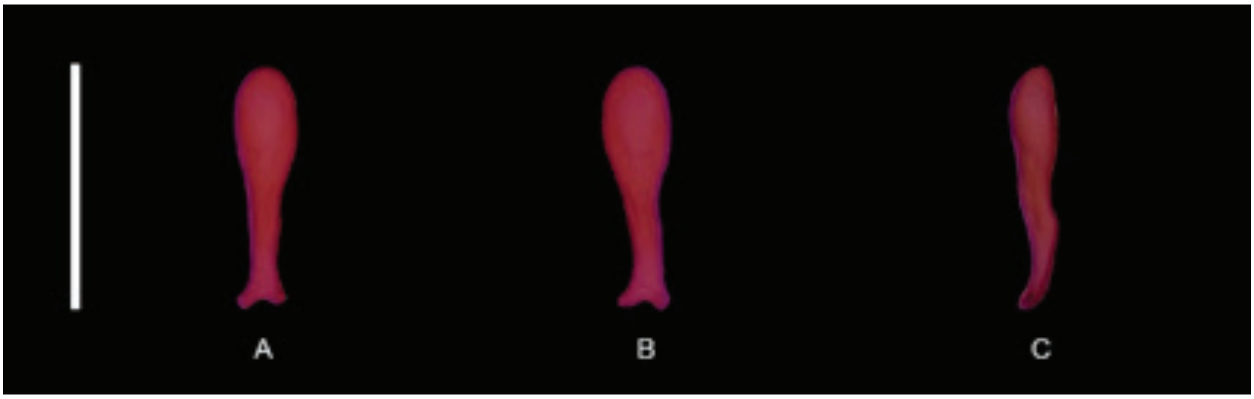

Image 9. Bacula of selected species belonging to the family Molossidae (*Tadarida aegyptiaca*) in India (Scale: 0.5mm). A—Dorsal view | B—Ventral view | C—Lateral view.

Hampi, Bellary District, Karnataka, by Tariq A. Shah and C. Srinivasulu, on 19.v.2014.

The baculum is very small (0.5mm long). The base is small and has a concavity in the middle. It continues into a parallel-sided thick shaft, which expands into a bulbous apical region.

Remarks: The structure of the baculum of the specimen from Hampi, Karnataka, differed from that described by Agrawal & Sinha (1973) from Alwar, Rajasthan, in having a distinct shaft ending with a bulbous apical region, however, it matches that described by Sinha (1976) from Kota, Rajasthan.

Family Vespertilionidae Gray, 1821

The bacula of 12 out of 65 species of evening bats in India are reported here.

33. *Myotis blythii* Tomes, 1857 Lesser Myotis (Image 10.I)

Material examined: NHM.OU.CHI.20.2016, male, collected from Bumzov Cave (33.769N and 75.213E), Martand, Anantnag District, Jammu and Kashmir, by Tariq A. Shah, on 30.iv.2016.

The baculum is very small (0.9mm long), broad (0.6mm) and triangular. On the dorsal surface, a small knob-like projection is seen medially on the base of the baculum. The baculum is concave on the ventral surface. The shaft is broad and parallel-sided, narrowing slightly toward the apical region and ends with a broadly rounded tip. A faint ridge is seen connecting the knob-like projection on the base to the tip of the baculum.

Remarks: The structure of the baculum of the specimen from Bumzov cave, Jammu & Kashmir matches that described by Albayrak & Aşan (2001) from Turkey.

34. *Myotis peytoni* Wroughton & Ryley, 1913 Peyton's Whiskered Myotis (Image 10.II)

Material examined: NHM.OU.CHI.06.2017, male, collected from Makuta (12.077N and 75.725E), Kodagu district, Karnataka, by Bhargavi Srinivasulu and G. Devender, on 07.v.2017.

The baculum of the specimen from southern Karnataka is very small (0.8mm long), broad (0.5mm) and triangular. The ventral surface is concave and the dorsal surface is uneven in texture. The mid-point of the base is slightly raised on the dorsal surface. The base extends in the form of a broad, parallel-sided shaft which joins roughly in a triangular shape at the apical region and ends in a rounded tip. The proximal border is uneven in nature. Laterally, a concavity is observed on the ventral surface to give an appearance of a boat shape to the baculum.

Remarks: This is the first time that the baculum of this Indian endemic species is described.

35. *Myotis longipes* Dobson, 1873 Kashmir Cave Myotis (Image 10.III)

Material examined: NHM.OU.CHI.24.2016, male, collected from Bumzov Cave (33.769N and 75.213E), Martand, Anantnag District, Jammu and Kashmir, by Tariq A. Shah, on 30.iv.2016.

The baculum of the specimen from Bumzov Cave, Jammu & Kashmir is very small (0.4mm long) and flat. It is distinctly shaped not being typically 'triangular' as in other species of *Myotis* studied during the present study. The base is wide and has a slight concavity in the middle. The base extends onto a parallel-sided tall shaft, which ends in a narrowly pointed tip.

Remarks: The bacular structure of the specimen from Jammu and Kashmir roughly matches with that provided by Hanak and Gaisler (1969) from Afghanistan.

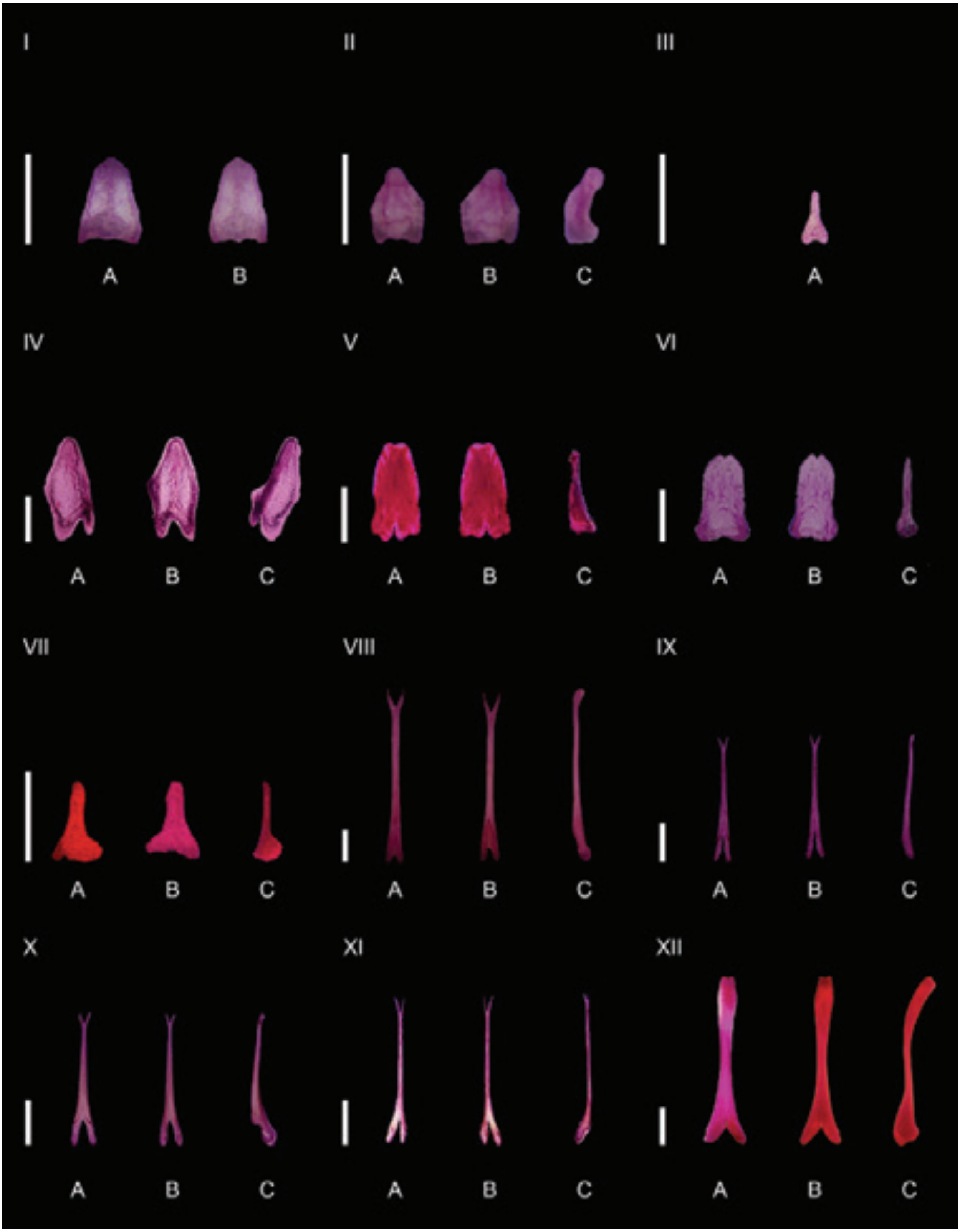

Image 10. Bacula of selected species belonging to the family Vespertilionidae in India: I—*Myotis blythii* | II—*Myotis peytoni* | III—*Myotis longipes* | IV—*Myotis horsfieldii dryas* | V—*Scotophilus heathii* | VI—*Scotophilus kuhlii* | VII—*Tylonycteris malayana eremtaga* | VIII—*Pipistrellus javanicus camortae* | IX—*Pipistrellus coromandra* | X—*Pipistrellus tenuis* | XI—*Pipistrellus ceylonicus* | XII—*Hesperoptenus tickelli* (Scale: I to VI, VIII to XII 1mm; VII 0.5mm). A—Dorsal view | B—Ventral view | C—Lateral view.

However, it differs from that depicted in Hanak and Gaisler (1969) in having a parallel-sided tall shaft, and a flat appearance.

36. *Myotis horsfieldii dryas* (Andersen, 1907) Andaman Myotis (Image 10.IV)

Material examined: NHM.OU.CHI.125.2015, male, collected from Bamboo Nullah (12.856N and 92.875E), near Mayabunder, North & Middle Andaman district, Andaman & Nicobar Islands, by C. Srinivasulu and Aditya Srinivasulu, on 19.x.2015.

The baculum is very small (2.3mm long), saddle-shaped, with a deep median emargination on the base (1.5mm wide). On the dorsal surface, a projection is seen on the basal margin of the baculum. The baculum becomes slightly narrower toward the apical portion and ends in a narrowly rounded off tip. The tip and the bony projection are connected by means of a ridge on the dorsal surface of the baculum. Ventrally, the baculum shows a concavity. The distal end of the baculum is blunt, without any abrupt constrictions.

Remarks: The structure of the baculum of the specimen from Mayabunder, Andaman Islands roughly matches the general structure of that described by Bates & Harrison (1997) from Venniar Estate, Tamil Nadu, however, the baculum of the present specimen differs from that described by Bates & Harrison (1997) in being triangular with a deep emargination on the basal margin and a well-defined ridge on the dorsal surface. This is the first time that the baculum of this subspecies endemic to Andaman Islands is described.

37. *Scotophilus heathii* (Horsfield, 1831) Asiatic Greater Yellow House Bat (Image 10.V)

Material examined: NHM.OU.CHI.27.2015, male, collected from Nagardan Qila (21.337N and 79.315E), Ramtek, near Kandheri Moil, Nagpur District, Maharashtra, by Tariq A. Shah and G. Devender, on 03.iii.2015.

The baculum is small (1.8mm long). The base is broader (1.0mm) than the apex and shows the presence of a deep median emargination, with a shaft being as thick as the base. The broad base extends in the form of a parallel-sided shaft, which is as broad as the base. The broad shaft narrows slightly toward the apex and ends in a broadly rounded apex. At the apex, a slight concavity is observed. In the lateral profile, the baculum is thick at the base and shows a slight curvature as it extends toward the apex.

Remarks: The structure of the baculum of the specimen from Nagardan Qila, Maharashtra matches roughly with that described by Hill & Harrison (1987) from Tori, Pakistan. The baculum, however, differs from that depicted in Hill and Harrison (1987) in having a single deep emargination in the base, a concavity at the tip on the dorsal and ventral aspects and being broad and stout in the lateral aspect.

38. *Scotophilus kuhlii* (Leach, 1821) Asiatic Lesser Yellow House Bat (Image 10.VI)

Material examined: NHM.OU.CHI.67.2015, male, collected from Singaraipet Beat, Thallapet (19.07N and 79.09E), Mancherial District, Telangana State, by G. Devender and K. Krishna Prasad, on 30.ix.2015.

The baculum is small (1.6mm long). The base is broad, with a slight concavity in the centre. The shaft is parallel-sided, as broad as the base and narrows toward the apical region where it shows the presence of a deep notch at the tip. The tip seems pointed due to the presence of the deep notch. Laterally the baculum is straight and thin with a rounded base.

Remarks: The structure of the baculum of the specimen from Thallapet, Mancherial District, Telangana State roughly matches that described by Hill & Harrison (1987) from Chiang Mai, Thailand. However, the baculum differs from that depicted in Hill and Harrison (1987) in having a single shallow emargination at the base and a deep notch at the tip.

39. *Tylonycteris malayana eremtaga* Srinivasulu et al. 2018 Andaman Greater Bamboo Bat (Image 10.VII)

Material examined: NHM.OU.CHI.151.2015, male, collected from Chipo (13.527N and 93.013E), North & Middle Andaman District, Andaman & Nicobar Islands, by Asad Gopi and Tauseef Hamid Dar, on 06.xi.2015.

The baculum is very small (0.4mm long), with a broad concave base. The shaft of the baculum is long, straight, with a slight concavity just beneath the rounded tip. In lateral aspect, the shaft of the baculum is long and straight, and the base is much flared.

Remarks: The structure of the baculum of the specimen from Chipo, North Andaman, Andaman Islands roughly matches that described by Hill & Harrison (1987) from Bukit Lagong Forest Reserve, Kepong, Selangor, Malaya. However, it differs in having a much flared base, a long and straight shaft.

40. *Pipistrellus javanicus camortae* (Miller, 1902) Camorta Pipistrelle (Image 10.VIII)

Material examined: NHM.OU.CHI.158.2015, male, collected from Devpur (12.862N and 92.867E), near Mayabunder, North & Middle Andaman District, Andaman & Nicobar Islands, by Tauseef Hamid Dar and Asad Gopi, on 18.xi.2015.

The baculum is large (5.3mm long), long, and slender. The base is narrow, and the proximal portion shows the presence of a shallow V-shaped fissure. The apical portion is wider than the basal portion. The shaft of the baculum is long, parallel-sided and at the apical portion, the shaft bifurcates into two arms. The tips of the arms show a slight inward curvature. In lateral view, the baculum has a slightly curved profile. The apical portion shows the presence of a concavity just beneath the bifid tip on the ventral surface giving the appearance of slight curvature of the baculum near the tip. The proximal portion extends slightly and is in line with the apical curvature of the baculum.

Remarks: The structure of the baculum of the specimen from Mayabunder, Middle Andaman, Andaman Islands matches that described by Soota & Chaturvedi (1980) from Tee Top, Car Nicobar, Andaman & Nicobar Islands, and Hill & Harrison (1987) from Car nicobar. However, the baculum does not show as much curvature of the shaft in the lateral profile as is depicted in Hill and Harrison (1987).

41. *Pipistrellus coromandra* (Gray, 1838) Coromandel Pipistrelle (Image 10.IX)

Material examined: NHM.OU.CHI.53.2016, male, collected from Chembanoda (11.6384N and 75.865E), Perivanamuzhi, Kozhikode District, Kerala, by Bhargavi Srinivasulu and G. Devender, on 19.x.2016.

The baculum is medium-sized (3.1mm long). The proximal lobes of the base of the baculum are narrow and have a deep emargination. The shaft is long, ending with a bifid tip. The apical lobes are thick, short and deflected slightly outward. Toward the apical region, the shaft shows a slight curvature on the dorsal surface observed in the lateral profile. The tip also shows a slight downward curvature.

Remarks: The structure of the baculum of the specimen from Kozhikode, Kerala, matches that described by Hill & Harrison (1987) from near Mirzapur, Uttar Pradesh, India.

42. *Pipistrellus tenuis* (Temminck, 1840) Least Pipistrelle (Image 10.X)

Material examined: NHM.OU.CHI.1.2013, male, collected from Gachibowli (17.440N and 78.352E), Hyderabad District, Telangana State, by Harpreet Kaur, on 24.i.2013.

The baculum is medium-sized (3.3mm long). The proximal lobes of the narrow base are well developed and have a deep emargination. The lobes have processes on them and are deflected outward. The shaft is long, slightly thick, ending in a bifid tip. The apical lobes are short. In the lateral aspect, a concavity is seen just above the base, followed by the presence of a distinct process immediately above it. The apical region does not show any curvature on the lateral aspect.

Remarks: The structure of the baculum of the specimen from Hyderabad, Telangana State matches that described by Hill & Harrison (1987) from the Coast of Sabah, Borneo. In the baculum of the present specimen, the shaft has a straight profile, and shows the presence of processes on the proximal lobes unlike that depicted by Hill & Harrison (1987).

43. *Pipistrellus ceylonicus* (Kelaart, 1852) Kelaart's Pipistrelle (Image 10.XI)

Material examined: NHM.OU.CHI.8.2012, male, collected from Osmania University Campus (17.417N and 78.531E), Hyderabad, Telangana State, by Bhargavi Srinivasulu and C. Srinivasulu, on 23.i.2012.

The baculum is medium-sized (3.8mm long). The basal lobes are well-developed and are deflected outward. The shaft is slender and tall. The tip is bifid, and the apical lobes are thin with a deep emargination separating them. In the lateral aspect, the shaft exhibits a straight profile.

Remarks: The structure of the baculum of the specimen from Osmania University, Telangana State matches that described by Hill & Harrison (1987) from Astoli, Belgaum, Karnataka, although in their depiction, the shaft of the baculum is shown to have a slight curvature on the lateral aspect.

44. *Hesperoptenus tickelli* (Blyth, 1851) Tickell's Bat (Image 10.XII)

Material examined: NHM.OU.CHI.155.2015, male, collected from Devpur (12.862N and 92.867E), near Mayabunder, North and Middle Andaman District, Andaman & Nicobar Islands, by Tauseef Hamid Dar and Asad Gopi, on 16.xi.2015.

The baculum is large (4.5mm long). The base of the baculum expands to form paired basal lobes separated both dorsally and ventrally by median V-shaped fissure. The shaft of the baculum is long, parallel-sided and expands as it approaches the tip. The tip shows a slight concavity in the middle. When viewed laterally, the shaft shows curvature starting at the midpoint gradually to the tip.

Remarks: The structure of the baculum of the specimen from Devpur, Middle Andaman, Andaman

Islands roughly matches to that described by Hill (1976) and Hill & Harrison (1987) both from Sri Lanka. The present baculum differs from that earlier described in having the apical region expanded and a gradual curvature from the midpoint of the shaft to the tip. It also differs in having a concavity at the tip.

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COMMUNICATION

Status of the Critically Endangered Bengal Florican *Houbaropsis bengalensis* (Gmelin, 1789) in Koshi Tappu Wildlife Reserve, Nepal

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Abstract: The Bengal Florican is one of the rarest bustard species and is listed 'Critically Endangered' by the IUCN. The species is restricted to the lowland grasslands of India, Nepal, and Cambodia with fewer than 1,000 mature individuals. To assess the species status in Koshi Tappu Wildlife Reserve, Nepal, we repeated our first comprehensive survey conducted during the 2012 breeding season. In spite of a larger area coverage we recorded only 41 adult Bengal Floricans in 2017 compared to 47 individuals in 2012. Detectability of this rare species is low in its *Imperata-Saccharum* grasslands. We, therefore, used a long pole with black and white clothing to mimic Bengal Florican's display flight to stimulate male Bengal Florican. The number of adult males recorded was the same as in the 2012 survey and the adult male density remains one of the highest in the Indian subcontinent. Management recommendations for the long-term conservation of the species in Koshi Tappu include maintenance of *Imperata-Saccharum* grasslands in the reserve favoured by the Bengal Florican and working with farmers and communities adjacent to the reserve where the birds breed in order to maintain some agricultural lands with vegetation height suitable for the species especially during the species' breeding season.

Keywords: Otidiformes, Otididae, bustard, abundance, terai grasslands, bird, flagship species, threats.

Abbreviations: CITES—Convention on International Trade in Endangered Species of Wild Fauna and Flora | GPS—Global Positioning System IUCN—International Union for Conservation of Nature | NGOs—Non-Governmental Organisations.

खरमुजुर विश्वमै अति संकटापन्न अवस्थामा रहेको लोपोन्मुख बस्टर्ड जातिको चरा हो । यो प्रजाति नेपाल, भारत र दक्षिणी इन्डोचाइनाको कम उचाईमा भएका घाँसेमैदानहरूमा सीमित छ । हाल भारतीय उपमहाद्विप र कम्बोडियाको टोन्ले साप तालका घाँसेमैदान क्षेत्रहरूमा १००० भन्दा कम वयस्क खरमुजुर रहेको अनुमान गरिएको छ । सन् २०१२ मा कोशी टप्पु क्षेत्रमा यस प्रजातिको वृहत सर्वेक्षण गरिएको थियो । सोही विधि अपनाएर यो सर्वेक्षण सम्पन्न गरिएको हो । यस सर्वेक्षणमा पहिलेको भन्दा बढी क्षेत्र ओगटिएको भए पनि पहिले (४७ वटा) भन्दा अहिले (४१ वटा) कम वयस्क खरमुजुरहरू भेटियो । अग्ला घाँस प्रजाति र यिनको लजालु स्वभावले गर्दा सर्वेक्षणका बेला यो प्रजाति सजिलै देखियोस भन्ने हेतुले लुकेका ठाउँबाट बाहिर निकाल्न लामो लट्ठीको टुप्पामा प्रणयका बेला नाच्ने खरमुजुरझैं भान हुने कालोसेतो ध्वजाको मद्दत लिइयो । कुल संख्या घटेता पनि यो सर्वेक्षणमा पनि पहिलेको सर्वेक्षणमा जतिनै वयस्क भाले खरमुजुरहरू देखिए । कोशी टप्पु क्षेत्रमा भेटिएको वयस्क भाले खरमुजुरको घनत्व भारतीय उपमहाद्विपकै उच्च मध्येको हो । बासस्थानका रुपमा रहेका घाँसेमैदानहरू विनाश हुदै जानु र बाँकी रहेका घाँसेमैदानहरूमा पनि व्यवस्थापनका अनुपयुक्त तरिका अपनाइनुका कारण वासस्थानको गुणस्तरमा ह्रास हुनु खरमुजुरका लागि प्रमुख चुनौतीका रुपमा रहेका छन् । खरमुजुरको दिगो संरक्षणका लागि संरक्षित क्षेत्रहरूमा यस प्रजातिलाई उपयुक्त घाँसेमैदान व्यवस्थापन गर्नुका साथसाथै संरक्षित क्षेत्र आसपासका स्थानीय समुदाय र कृषकहरूसँग सहकार्य गरी यस प्रजातिको बासस्थानको उचित संरक्षण, विशेषत बच्चाकोरल्ने समयमा, गर्नु पर्ने कुरा यस वैज्ञानिक पत्रमा उल्लेख गरिएको छ ।

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INTRODUCTION

Bengal Florican *Houbaropsis bengalensis* (Gmelin, 1789) is the only member of its genus, and is the rarest member of the bustard order, Otidiformes. The species is classified as Critically Endangered on the IUCN Red List due to the widespread and on-going modification of its grassland habitat (BirdLife International 2018). It is also included on Appendix I of CITES (BirdLife International 2018).

Resident populations of Bengal Florican (Image 1) occur in the floodplain grasslands in Cambodia, India, and Nepal (BirdLife International 2018). The Cambodia population is estimated to be 432 individuals (Packman et al. 2014). The overall population estimate for India is not available, but it is certain to hold a significant population considering the large areas of suitable habitat especially within its northern protected areas. Recent surveys have recorded 72 adult males in Manas Tiger Reserve, Kaziranga and Orang National Parks in Assam and 60–70 territorial male Bengal Floricans are estimated to be present in D'Ering Wildlife Sanctuary in Arunachal Pradesh (BirdLife International 2018).

In Nepal, the species occurs in Shuklaphanta National Park, Bardia National Park, Chitwan National Park, Koshi Tappu Wildlife Reserve, and Koshi Barrage area with a combined population of less than 100 individuals (DNPWC 2016, Figure 1). In Koshi Tappu Wildlife Reserve, the species was occasionally seen in the 1970s (Dahmer 1976) and there were several records from the Koshi Barrage in the early 1980s (Baker 1981; Turton & Speight 1982), but none were sighted after 1986 (Inskipp & Inskipp 1991).

However, in 2011 the Bengal Florican made a come-back to the wildlife reserve. A 2011 survey estimated as many as 12 pairs in Koshi area at nine sites along a 39km north-south stretch of the Koshi River. Out of the total of 17 birds recorded during the survey only five birds were recorded outside the Koshi Tappu Wildlife Reserve. A comprehensive follow-up survey in April and May 2012 counted 47 birds. This represented the largest known population in Nepal, with perhaps the highest density in the Indian subcontinent (Baral et al. 2013).

The main threat to the Bengal Florican in the protected areas in Nepal is improper habitat management by ploughing, intensive burning and grass harvesting leading to a loss of suitable habitat (Poudyal et al. 2008; Baral et al. 2013; DNPWC 2016). The Bengal Florican is a 'flagship' species in the Terai grasslands. There is a need to develop a sustainable recovery strategy for the critically threatened Bengal Florican that

Image 1. Bengal Florican *Houbaropsis bengalensis*

provides long-term biodiversity benefits not only for the florican but also for other species that rely on the fragile and threatened grassland habitats. An effective strategy needs to establish an improved scientific evidence-base on the dynamics of Bengal Florican population decline, increase regional conservation capacity-building and cooperation, raise awareness, and build legislation for habitat protection, and appropriate management aiming to support optimum population size. Despite years of conservation focus on this species, the population continues to decline elevating the species' status recently to Critically Endangered from Endangered. A global scenario for the Bengal Florican and other bustard species is adequately presented in a recent publication (Collar et al. 2017).

Following recommendations by Baral et al. (2013), the objective of this study was to assess the change in status of the population of the Bengal Florican in Koshi Tappu Wildlife Reserve and its adjacent areas after a period of five years.

METHODS

Study area

Koshi Tappu Wildlife Reserve (26.65°N & 87.00°E) lies in the floodplain of the Sapta Koshi River in southeastern lowland Nepal (Figure 2). The reserve was officially established in 1976 and extended in 1980 covering an area of 175km^2. The habitat within Koshi Tappu Wildlife Reserve and its adjacent areas, referred henceforth as Koshi Tappu, is broadly classified as mixed deciduous riverine forest (5.4%), grassland (17.1%), swamp (18.1%),

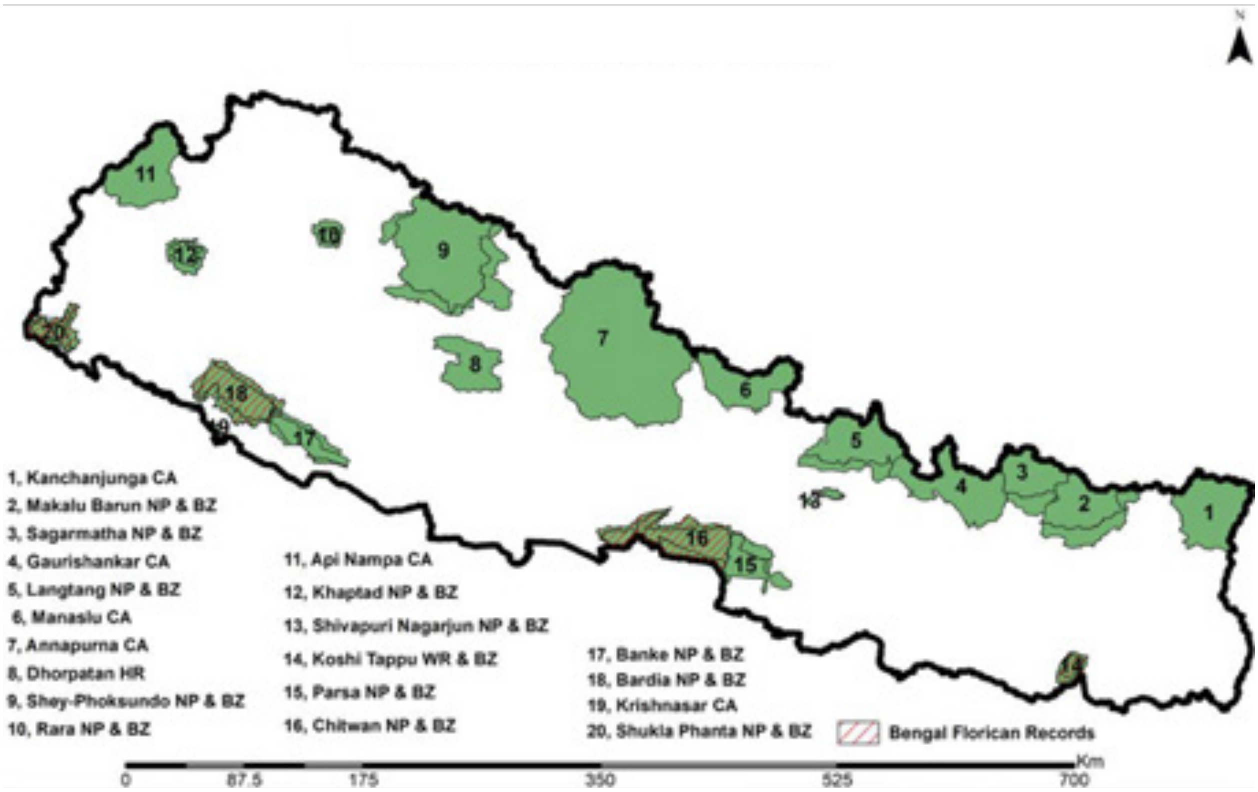

Figure 1. Distribution of Bengal Florican in Nepal.

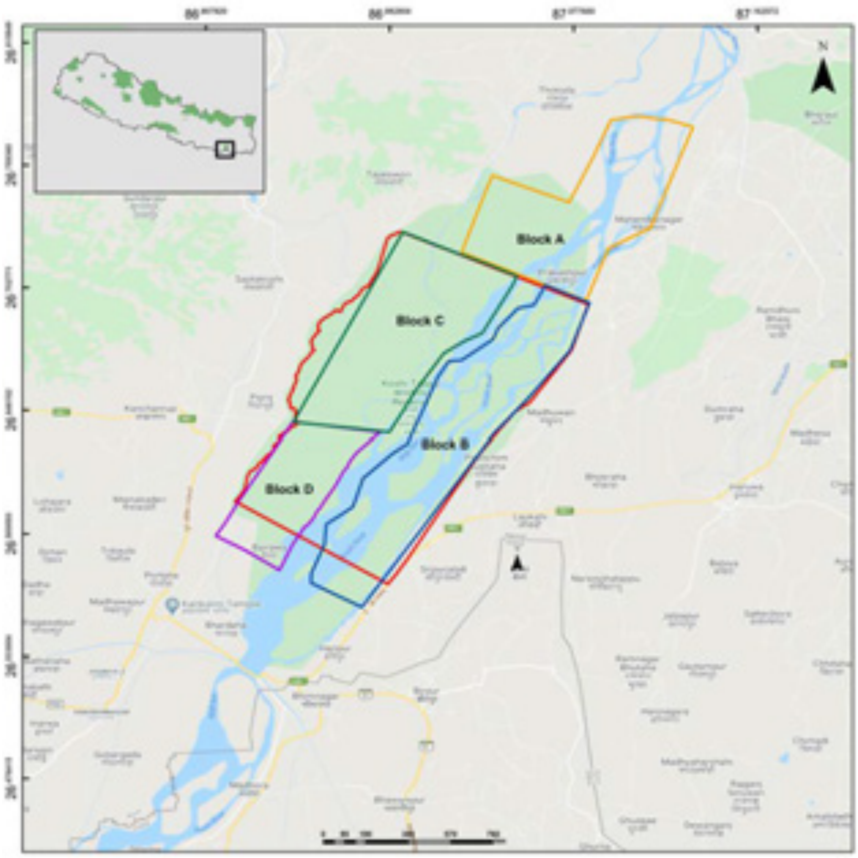

Figure 2 . Koshi Tappu showing the survey area with four blocks.

Table 1. Description of survey blocks in Koshi Tappu Wildlife Reserve and its adjacent areas.

Block	Sites	Location	Area (km²)	Habitat characteristics	Disturbance level
A	Site 1	26.77N 87.10E	4	*Saccharum spontaneum* with smaller patches of Imperata grasses; within Koshi Tappu Wildlife Reserve and buffer zone	High
	Site 2	26.74N 87.12E	14	*S. spontaneum* with fewer patches of Imperata grasses than site 1; outside Koshi Tappu Wildlife Reserve and buffer zone	High
	Site 3	26.77N 87.07E	30.2	Cultivation land with some thatched houses. Few patches of *Typha elephantine* and short grasses mainly *Imperata*.	High
B	Site 1	26.69N 87.09E	30.5	*S. spontaneum* with a sward height of about 50cm; within Koshi Tappu Wildlife Reserve and buffer zone	Medium
	Site 2	26.66N 87.09E	6	*S. spontaneum* with a sward height of about 50cm; within Koshi Tappu Wildlife Reserve and buffer zone	Medium
	Site 3	26.56N 87.01E	9	*S. spontaneum* with a sward height of about 50cm; within Koshi Tappu Wildlife Reserve and buffer zone	Medium
C	Site 1	26.66N 87.04E	12.9	*Saccharum* and *Imperata* grasslands with patches of young *Dalbergia sissoo* and *Acacia catechu*: within Koshi Tappu Wildlife Reserve and buffer zone	Medium
	Site 2	26.66N 87.04E	37.3		Medium
D	Site 1	26.63N 87.02E	25	Saccharum and *Imperata* species: within Koshi Tappu Wildlife- Reserve and buffer zone	High

Disturbance was measured in three categorical levels—low, medium, and high.

river (52.4%), and agricultural land (7.0%) (Dahal et al. 2009). The southern part of the reserve is a large expanse of open water, marshes and reed-beds created by the construction of Koshi barrage between 1958 and 1964 (Limbu & Subba 2011). The reserve is bounded by two parallel embankments, a shorter one to the west and longer one to the east of the Sapta Koshi River and is subject to annual flooding (Baral et al. 2012). Koshi Tappu Wildlife Reserve was Nepal's first Ramsar site in 1987 (Sah 1997) and is an Important Bird Area (Baral & Inskipp 2005). A total of 526 bird species has been recorded in the area (Baral 2016; Koshi Tappu Wildlife Reserve 2018).

Field method

Prior to the field survey, we identified suitable Bengal Florican habitats in and around Koshi Tappu Wildlife Reserve using Google Earth Image (2016) and reconnaissance survey. We followed the previous 2012 survey design and established four survey blocks (Table 1, Figure 2). Survey blocks A and B were considerably larger, by 30.2km^2 and 30.4km^2, respectively, compared to 2012 survey due to the dynamic nature of the floodplain.

The survey was conducted between 23–29 April 2017. The survey blocks were reached either by boat or by a four-wheel vehicle and the surveys were conducted on foot between 05.00–10.00 hr and 15.00–18.00 hr. Bengal Floricans are most active during the early morning and late afternoon and human disturbance is also minimal during these times.

In total 12 experienced surveyors took part in the survey. Each surveyor had a pair of binoculars and forms to record data on sighted birds along with location and habitat information. Additionally, each survey team carried a mobile phone, digital camera and a GPS receiver. Watches were synchronised among team members to record accurate time of Bengal Florican sightings. Each survey team also carried a long pole with black and white clothing to mimic male Bengal Florican display flight. The aim of this was to stimulate male Bengal Floricans to display thus increasing detectability. Sightings of flying birds were communicated to other teams via mobile phones to minimize double counts. The survey covered 168.9km^2 of the 193km^2 identified as suitable Bengal Florican habitat in Koshi Tappu.

Enumerating number of Bengal Floricans

Bengal Florican sighting records were checked for double counts using sex, location and time. The species nesting season is from May to August (Oates 1898). We, therefore, assumed that the adult birds had already established territories during the survey and were faithful to their sites. The total number of birds was obtained by adding the total number of birds recorded in each survey block.

Several factors were recognized to be potential biases in counting the Bengal Florican population. Since only adult males displayed, counts were likely to be biased towards males. Grass height varied considerably across the survey area, and we did not correct for detection bias due to variation in visibility. Bias due to different observers, timing of count, and varying levels of human disturbance were also recognized. Potential variability introduced using Bengal Florican dummies was not estimated. The number of Bengal Floricans that had not yet established territories during the survey was unknown. The possibility of birds moving between blocks during the survey period was recognized.

RESULTS

Bengal Florican was recorded in all four surveyed blocks. In total, 41 adult birds were recorded of which 29 birds were male and 12 birds were female. Five birds were recorded outside the Koshi Tappu Wildlife Reserve and its buffer zone, four birds in the buffer zone, and 32 birds in the reserve (Table 2).

The highest number (15 birds) and density (0.33 birds/km^2) of Bengal Floricans were recorded in Block B. Only four Bengal Floricans at a density of 0.16 birds/km^2 were counted in Block D. In Block A nine adult Bengal Floricans at a density of 0.19/km^2 were counted. The survey blocks A and D were the most grazed and disturbed areas, evident by the large number of cattle present and on average, the shortest grass sward height. All the blocks except Block A were within the reserve and buffer zone. Seventy percent of Block A was outside the reserve and buffer zone.

The overall density of the species in the surveyed area was 0.24 birds/km^2. Assuming that the un-surveyed area had a density of Bengal Floricans similar to the area covered, we estimated a total population of 46 Bengal Floricans within suitable habitat in Koshi Tappu. Bengal Floricans were only recorded in grasslands predominantly consisting of *Imperata cylindrica* and *Saccharum spontaneum* with a sward height greater than 50cm.

Correction of the Bengal Florican 2012 survey estimate (Baral et al. 2013)

We found that the area of Block C reported by Baral et al. (2013) was much larger than its actual size. Based on area calculated using QGIS 2.18 (QGIS Development Team 2004), we revised this to 50km^2 (105km^2 was reported in Baral et al. 2013). The revised estimated density of Bengal Floricans in Koshi Tappu for 2012 was 0.43 bird/km^2 (Table 3).

DISCUSSION

We counted fewer adult Bengal Floricans (41 birds) in Koshi Tappu over a larger area (168.9km^2) compared to the previous survey in 2012 (Baral et al. 2013, 47 birds in 108.1km^2). This indicates a 13% decline over five years.

The survey found a 2.42 male to female sex ratio. It is not unusual to find a higher number of males compared to females in populations of globally threatened bird

Table 2. The number of adult Bengal Floricans counted within the surveyed blocks in Koshi Tappu Wildlife Reserve and its adjacent areas.

Sampling block	Area (km^2)	Number of adult male Bengal Floricans counted	Number of adult female Bengal Floricans counted	Total number of adult Bengal Floricans counted	Estimated adult density (birds / km^2)
Block A	48.2	6	3	9	0.19
Block B	45.5	10	5	15	0.33
Block C	50.2	10	3	13	0.26
Block D	25	3	1	4	0.16
Total	168.9	29	12	41	0.24

Table 3. Revised 2012 survey density estimate of Bengal Florican in Koshi Tappu Wildlife Reserve and its adjacent areas (data source Baral et al. 2013).

Sampling block	Area (km^2)	Number of male Bengal Floricans counted	Number of female Bengal Floricans counted	Total number of Bengal Floricans counted	Estimated density (birds / km^2)
Block A	18	9	5	14	0.78
Block B	15.1	5	3	8	0.53
Block C	50	14	9	23	0.46
Block D	25	1	1	2	0.08
Total	108.1	29	18	47	Average total density 0.43

Table 4. Density of adult male Bengal Florican populations in southern and southeastern Asia.

Site	Number of adult male Bengal Floricans	Area (km^2)	Density (individuals /km^2)	Data source
Manas Tiger Reserve, India	33	319	0.1	BirdLife International (2017)
Kaziranga National Park, India	32	378	0.08	BirdLife International (2017)
D'Ering Wildlife Sanctuary, India	60–70 (mean 65)	190	0.34	BirdLife International (2017)
All Bengal Florican habitat, Cambodia	216	307	0.7	Packman et al. (2014)
Koshi Tappu, Nepal	29	163.65	0.18	Bengal Florican Survey (2017)

species (Donald 2007). Further studies are required to understand reasons for the higher percentage of male Bengal Florican sightings. Comparing the density of adult male Bengal Floricans as a proxy of Bengal Florican population density across the various sites in southern and southeastern Asia, Koshi Tappu continues to remain one of the strongholds for the species (Table 4).

Previous studies have reported species dependence on *Saccharum-Imperata* assemblage during the breeding season (Inskipp & Inskipp 1983; Baral 2001; Poudyal et al. 2008). This study also found higher density of Bengal Floricans in *Saccharum-Imperata* grassland assemblage with sward height of about 50cm. Detailed studies on grassland ecology combined with studies on the ecology of the Bengal Florican are necessary to understand their habitat preferences which can guide management intervention to maintain viable populations (Baral et al. 2013).

The species faces a number of threats in Nepal. Very small areas of suitable habitat remain, and these are mainly within protected areas. At present, the grasslands of Koshi Tappu Wildlife Reserve and Shuklaphanta National Park provide the best habitats for this species. In Chitwan and Bardia National Parks, single habitat patches suitable for Bengal Florican have been reduced to less than 50ha. Even in protected areas, the species is threatened by improper habitat management by ploughing, grass harvesting and intensive burning, leading to a loss of suitable habitat (Poudyal et al. 2008). Other significant threats are disturbance (overgrazing), susceptibility to predation and hunting (Poudyal et al. 2008). In addition, the invasive alien plant species *Mikania micrantha* which can smother grasslands, has had serious impact on Chitwan National Park and Koshi Tappu Wildlife Reserve habitats (Siwakoti 2007; Baral & Adhikari 2017). At Koshi, feral dogs, fern and wood collectors and an unnatural increase in native predators, Asiatic Golden Jackal *Canis aureus* and Indian Grey Mongoose *Herpestes edwardsi*, are additional threats (Baral et al. 2013). Both native predators have increased and are possibly still increasing in Koshi as they are more adaptable to the widespread disturbance that Koshi faces and are known to flourish in such conditions. Pressure on lowland grasslands is increasing. Bengal Floricans are especially at risk during the monsoon when some move outside the protected areas where they might breed into unprotected riverine areas with adjacent agricultural fields.

Based on our studies and experience, we recommend that the local communities should be trained and supported in managing grasslands that fulfil their needs for cattle fodder and thatch grasses and provide suitable habitat for Bengal Floricans and other grassland species. Farmers should be encouraged to leave some of the grassland habitats within farmlands especially during Bengal Florican's breeding season. This is already happening in Chitwan National Park buffer zone in East Nawalparasi District, where a community-managed grassland is working along similar lines to that of community forestry (Chitwan National Park 2016). Relevant national and local NGOs should buy and manage fallow-land and grassland areas along the Koshi River (and other major river courses in Nepal). Similar initiatives should be promoted in adjoining parts of India and establish transboundary cooperation to restore river habitat corridors facilitating bird movements. The Nepal Government should create and expand protected zones along river corridors.

The feral cattle and to some extent Wild Water Buffalo *Bubalus arnee* in Koshi Tappu have helped to keep the *Saccharum* and *Imperata* grasses short and suitable for Bengal Florican. This grazing needs to be monitored and regulated especially during the breeding season of birds, viz., April to August. Use of heavy machinery by Koshi Project, Government of Bihar, India should be avoided in Koshi Tappu especially during breeding season of April–August. Similarly, urgent action is needed to control the spread of invasive alien plant species, especially *Mikania micrantha* and *Parthenium hysterophorus*. Management with the aim to restore and/ or maintain areas of intact grasslands should be implemented, based on improved understanding of floodplain grassland dynamics in Koshi Tappu Wildlife Reserve. Nationwide awareness programme should be conducted through audio-visual media such as documentaries on Bengal Florican as public support is crucial for the conservation of threatened species at the grass-root level.

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COMMUNICATION

Observations on breeding behaviour of a pair of endangered Egyptian Vultures *Neophron percnopterus* (Linnaeus, 1758) over three breeding seasons in the plains of Punjab, India

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Abstract: The present study has been conducted to document information on breeding behaviour of Egyptian Vultures *Neophrons percnopterus* from Punjab. This study is based on 688 hours of video records documenting breeding behaviour of a pair of endangered Egyptian Vultures *Neophrons percnopterus* occupying the same nesting site over three consecutive breeding seasons from 2015 to 2017. The site is located in the hollow of a ventilation window of the Space Observatory in Punjabi University, Patiala, Punjab. During the third breeding period (February to August 2017), the nest activity has been extensively video-recorded in egg laying and incubation period, and chick rearing period using a Dome CCTV Camera. Both parents participated in nest building, and of the total recorded incubation time of 339.39h over 23 days the nest was attended for 199.35 and 139.46h by the female and male respectively, and unattended for 0.58h. The incubation period was 42 to 43 days, and the egg laying/hatching intervals between eggs/chicks was five days. A total of six young ones hatched and fledged from three broods of two eggs each. All chicks survived to fledging and no mortality or siblicide of younger chick occurred due to aggression/starvation by elder chick. The high fledging success rate indicates a healthy habitat and food source in the nesting area.

Keywords: Ecological role, feeding, habitat, incubation, nest, scavengers.

Punjabi abstract: ਖੇਤਰੀ ਅਧਾਰ ਪੱਖੋਂ, ਹਾਲੇ ਤਕ ਅਣਫਰੋਲੇ ਪ੍ਰਜਨਣ ਵਤੀਰੇ ਦੇ ਵੱਖ-ਵੱਖ ਪਹਿਲੂਆਂ ਸਬੰਧੀ ਜਾਣਕਾਰੀ, ਗਿੱਧਾਂ ਦੇ ਜੀਵਨ ਨਾਲ ਜੁੜੇ ਗਿਆਨ ਵਿੱਚ ਹੋਰ ਵਾਧਾ ਕਰਨ ਅਤੇ ਉਹਨਾਂ ਦੇ ਸੁਰੱਖਿਅਣ ਲਈ ਢੁੱਕਵੇਂ ਕਦਮ ਵਿਉਂਤਣ ਲਈ ਅਤਿ ਜ਼ਰੂਰੀ ਹੈ। ਇਹ ਖੋਜ-ਕਾਰਜ ਪੰਜਾਬ ਵਿੱਚ ਚਿੱਟੀ ਗਿੱਧ ਨੀਓਫ੍ਰਾਨਸ ਪ੍ਰਕਨੋਪਟੈਰਸ ਦੇ ਪ੍ਰਜਨਣ ਵਤੀਰੇ ਸਬੰਧੀ ਜਾਣਕਾਰੀ ਇਕੱਠੀ ਕਰਨ ਲਈ ਕੀਤਾ ਗਿਆ ਹੈ। ਇਹ ਖੋਜ-ਕਾਰਜ ਇੱਕ ਹੀ ਆਲ੍ਹਣਾ-ਸਥਾਨ ਮੱਲਣ ਵਾਲੇ ਇੱਕ ਚਿੱਟੀ ਗਿੱਧ ਜੋੜੇ ਦੇ 2015 ਤੋਂ 2017 ਤੱਕ ਤਿੰਨ ਲਗਾਤਾਰ ਪ੍ਰਜਨਣ ਸਮਿਆਂ ਦੇ 688 ਘੰਟਿਆਂ ਦੇ ਵੀਡਿਓ ਰਿਕਾਰਡਾਂ ਉੱਪਰ ਅਧਾਰਿਤ ਹੈ। ਇਹ ਆਲ੍ਹਣਾ-ਸਥਾਨ, ਪੰਜਾਬੀ ਯੂਨੀਵਰਸਿਟੀ, ਪਟਿਆਲਾ, ਪੰਜਾਬ ਸਥਿਤ ਸਪੇਸ-ਆਬਜ਼ਰਵੇਟ੍ਰੀ ਦੀ ਇੱਕ ਰੋਸ਼ਨਦਾਨ-ਖਿੜਕੀ ਵਿੱਚ ਹੈ। ਤੀਸਰੇ ਪ੍ਰਜਨਣ ਕਾਲ (ਫਰਵਰੀ ਤੋਂ ਅਗਸਤ 2017) ਦੌਰਾਨ ਆਲ੍ਹਣੇ ਵਿੱਚ ਅੰਡੇ ਦੇਣ, ਅੰਡਿਆਂ ਉੱਪਰ ਬੈਠਣ ਅਤੇ ਚੂਚਿਆਂ ਦੇ ਪੋਸ਼ਣ ਆਦਿ ਨਾਲ ਸਬੰਧਿਤ ਵਤੀਰੇ ਨੂੰ ਸੀ.ਸੀ.ਟੀ.ਵੀ ਡੋਮ ਕੈਮਰੇ ਦੁਆਰਾ ਵਿਸਥਾਰ ਨਾਲ ਵੀਡਿਓ ਰਿਕਾਰਡ ਕੀਤਾ ਗਿਆ।. ਦੋਵੇਂ ਮਾਂ-ਬਾਪ ਆਲ੍ਹਣਾ ਬਨਾਉਣ ਵਿੱਚ ਭਾਗ ਲੈਂਦੇ ਹਨ। ਅੰਡਾ-ਪ੍ਰਫੁਲਣ ਕਾਲ ਦੇ 23 ਦਿਨਾਂ ਦੌਰਾਨ 339.39 ਨਿਰੀਖਣ-ਘੰਟਿਆਂ ਵਿੱਚੋਂ ਮਾਦਾ ਅਤੇ ਨਰ ਗਿੱਧ ਨੇ ਕ੍ਰਮਵਾਰ 199.35 ਅਤੇ 139.46 ਆਲ੍ਹਣੇ ਵਿੱਚ ਹਾਜ਼ਰੀ ਭਰੀ, ਜਦਕਿ 0.58 ਘੰਟੇ ਲਈ ਆਲ੍ਹਣਾ ਸੱਖਣਾ ਰਿਹਾ। ਅੰਡਾ-ਪ੍ਰਫੁਲਣ ਕਾਲ 42 ਤੋਂ 43 ਦਿਨ ਸੀ ਅਤੇ ਅੰਡੇ-ਦੇਣ/ਬੱਚੇ-ਨਿਕਲਣ ਸਮੇਂ ਅੰਡਿਆਂ/ਚੂਚਿਆਂ ਵਿਚਕਾਰਲਾ ਅੰਤਰਾਲ ਪੰਜ ਦਿਨ ਸੀ। ਦੋ ਦੋ ਅੰਡਿਆਂ ਦੇ ਤਿੰਨ ਪੂਰਾਂ ਵਿੱਚੋਂ ਕੁੱਲ ਛੇ ਚੂਚੇ ਨਿੱਕਲੇ।. ਸਾਰੇ ਹੀ ਚੂਚੇ ਆਲ੍ਹਣੇ 'ਚੋਂ ਉਡਾਰੀ ਮਾਰਨ ਤੱਕ ਜਿਉਂਦੇ ਰਹੇ ਅਤੇ ਕਿਸੇ ਵੀ ਛੋਟੇ ਚੂਚੇ ਦੀ ਵੱਡੇ ਚੂਚੇ ਦੇ ਮਾਰਖੋਰੀ-ਵਤੀਰੇ/ ਭੁੱਖਮਰੀ ਕਾਰਨ ਮੌਤ ਜਾਂ ਭਰਾ-ਹੱਤਿਆ ਨਹੀਂ ਹੋਈ। ਚੂਚਿਆਂ ਦੇ ਸਫਲਤਾ ਨਾਲ ਉਡਾਰੀ ਮਾਰਨ ਦੀ ਉੱਚ ਦਰ ਇਹ ਦਰਸਾਉਂਦੀ ਹੈ ਕਿ ਇਸ ਆਲ੍ਹਣਾ-ਖੇਤਰ ਵਿੱਚ ਚਿੱਟੀ ਗਿੱਧ ਲਈ ਇੱਕ ਸਿਹਤਮੰਦ ਰਹਿਣ-ਬਸੇਰਾ ਮੌਜੂਦ ਹੈ।

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INTRODUCTION

Punjab is primarily an agrarian state, with 84 percent of its area under agriculture and 6.5 percent under forest (Singh et al. 2014). Since independence many local environments have been impacted by deforestation, industrialization, increased transportation networks, modern agricultural practices, urbanization, and other anthropogenic factors. As a result, Punjab has lost much of its forest and dominant wildlife. Vultures are important to human beings and the environment because they feed upon the carcasses of dead animals and act as scavengers. On the basis of road transect surveys conducted from 1991 to 2003 in and around 18 national parks and wildlife sanctuaries spread across the northern, western, and eastern parts of India, Cuthbert et al. (2006) recorded an 80% decline in the population of Egyptian Vulture (EV) *Neophrons percnopterus*, due to poisoning by the veterinary drug diclofenac and other factors. The rapid decline in populations in India (Cuthbert et al. 2006), combined with severe long-term declines in Europe, western Africa and the rest of its African range, has led this species to be classified as Endangered in the IUCN Red List of Threatened Species since 2007 (BirdLife International 2017).

As per Grimmett & Inskipp (2010), there are seven species of vultures in Punjab and the EV is an not-common resident. Nevertheless, Punjab is not an exception to the global population decline of vultures, and Kler & Kumar (2014) while monitoring 18 animal flaying/disposal sites located in nine districts of Punjab under an All India Network Project on Agricultural Ornithology, reported occurrence of only EV from only two sites located in districts of Ropar and Kapurthala. Presently, this species is sighted at only a few animal carcass dumping sites located nearer to Shivalik foothills in Punjab and there exists no study documenting the breeding aspects of any vulture species from the agricultural plains of Punjab. Vultures provide a variety of economic, ecological, and cultural services (Ogada et al. 2012), and studies on habitat requirements of endangered species are crucial for conservation purposes (Manly et al. 1993; Noss et al. 1997).

The present study documents aspects of the breeding biology of EV that include breeding time, nesting site, clutch size, incubation, nestling period, feeding and nestling growth pattern, reproductive success, and parental care.

Background

Perusal of available sources reveals that barring a few studies documenting EV sightings at animal carcass disposal sites, by Malhi & Kaur (1999), Kler (2004), and Kler & Kumar (2014), no attempt has been made to study the breeding biology, habitat ecology, distribution, and impact of human disturbances of vultures living in the plains of Punjab. Naoroji (2006) gave definitive account of status, distribution, feeding, and breeding aspects of EV from the Indian subcontinent. Although the EV was well known to ornithologists of the 19th and 20th centuries, detailed accounts of nesting are few (Ramirez et al. 2016). Cuthbert et al. (2006) and Galligan et al. (2014) documented population declines of EV from India. Other studies exploring aspects like distribution, dispersal, effect of human activities, and conservation of EV from different regions include: Donázar & Ceballos (1989), Liberatori & Penteriani (2001), Margalida & Boudet (2003), Sara & Vittorio (2003), Carrete et al. (2007), Zuberogoitia et al. (2008), Hernández & Margalida (2009), Elorriaga et al. (2009), Angelov et al. (2013), Zuberogoitia et al. (2014), and Tauler-Ametller et al. (2017).

Study Area

The study area is located within a radius of 3km from the Space Observatory located at geographical coordinates 30.359^{0}N & 76.445^{0}E in Punjabi University, Patiala (Punjab). The university campus of over 323 acres is situated in the outskirts of Patiala City, surrounded by adjoining semi-urban and cropland areas. This territory is characterized by the presence of urban patches, open croplands, an old drain 'Badi Nadi', small forest patches, slaughter houses and rubbish dumps/animal carcass disposal sites. The climate is typical of the Punjab plains in being hot in summer and cool in winter. Habitat components around the nesting site provide a mixture of feeding sites, natural vegetation, agricultural lands, and human settlements suitable for EV breeding.

MATERIALS AND METHODS

During the course of weekly field surveys (2015–2017) undertaken to document the avifauna dwelling in the agricultural plains of district Patiala, a pair of EV was first sighted at a rubbish dump/animal carcass dumping site located at 30.361^{0}N & 76.441^{0}E near the village Saifdipur at the time of pre-laying period in February 2015. Municipal waste and animal carcasses are dumped at this site. Following the direction of flight over the fields and examining likely sites, a nesting site was located about 1km away from rubbish dump/animal carcass dumping sites in the Space Observatory of Punjabi University. Repeated site visits were undertaken from 2015 to 2017, and video data was recorded in 2017. During the first and second breeding periods (February–August, 2015 & 2016) observations on incubation, feeding, breeding success, and activities of chicks were made from a secure distance using Olympus 10x50 DPS binoculars, and also via direct nest visits. During the third breeding period (February–August 2017) the nest was monitored during egg laying, incubation, and chick rearing period using a Dome CCTV camera with inbuilt-SD Card (32GB) recording. The camera (9.3 x 7 x 9.3 cm) was mounted in the window corner opposite to the nest, and data were extracted every third/fourth day by replacing the SD card without disturbing incubating birds or chicks. The nest was built on the ventilation window platform of the observatory store, allowing observation to be performed discretely from inside the store through a partly-opened frosted glass window. A 3.5m long wooden ladder was placed against the wall in the store to reach the window. The incubating parent did not directly notice the presence of the observer except for observer's hand extending in the window corner to remove the camera. The parent never left the nest during the first week, and at times tried to attack the observer's hand. Before the start of incubation, the nest site was inspected twice a day to document egg laying. Still photography was done using a Sony A-57 DSLR camera fitted with Tamron 18-200mm telephoto lens. Nest activities were also monitored from a secure distance using binoculars. Location measurements were obtained using a Bosch GLM 40 laser distance meter. Video records spanned 23 days and 688 hours, supplemented by photographs and direct observations.

OBSERVATIONS AND RESULTS

Nest Site and Nest Construction

During January and February (the pre-laying period), both members of the pair were first sighted visiting the nest site (Space observatory and nearby academic block) in the early morning and evening hours, carrying nest material to the cuboid hollow (1.9m x 0.66m x 0.5m) of the ventilation window of the space observatory (Image 1), 25.9m above ground level. The aspect of the hollow was towards the south. The addition of nest material continued during the incubation period. The nest material haphazardly placed over the entire platform (1.9m X 0.66m) included branched/unbranched dried twigs, dried bark and leaves of *Eucalyptus*, pieces of cardboard packing boxes, towel and soiled cloth pieces, thick strips of sawdust board, polythene sheet pieces, empty poly milk pouches, coconut coir, wool, cotton pulled from disposed beddings, jute rug pieces, dried human faeces, pieces of writing paper, sanitary napkins, animal fur, pieces of polypropylene cement bags, pieces of sink hose, rotten pumpkin, and other debris. At the time of laying the first egg (03 March 2017), these contents of the nest were seen scattered all over the nest platform, however, after laying of the second egg (08 March 2017), contents including cotton, woolen fragments and jute rug pieces were arranged to form a scrape (inner width 10" & outer width 14") around the eggs (Image 2). Most of this nest material was from waste items, and about four days before the hatching of first chick (10 April 2017) both the parents piled dry twigs along the open side of the platform, as if to form a barricade to prevent chicks from falling. During the chick rearing period, remains of food items including

Image 1: Nesting site: Space Observatory, Punjabi University, Patiala. © Charn Kumar.

the bones of pigeons, rats, snakes and dogs, and bird feathers appeared in the nest. During the subsequent 42 days of incubation till hatching of the second egg (19 April 2017), the incubating parents maintained the scrape edges by repeatedly arranging the lining material (cotton, soiled cloth pieces, jute rug pieces, sanitary napkins) using their hooked beaks.

Egg Laying and Incubation

The interval between the laying of the first (03 March 2017) and second eggs (08 March 2017) was five days. Eggs are oval, non-glossy, dull-white, partly smeared, and streaked with reddish-brown. Egg shell was 0.66mm in thickness and rough with small protrusions. The extent of reddish-brown streaking was variable between eggs. During the three consecutive successful breeding seasons (2015, 2016, 2017), the clutch size was two eggs/per year. No change in egg coloration happened during the course of incubation.

The breeding adults were sexed on basis of difference in face colour (Newton & Olsen 1990; Clark & Schmitt 1998), presence or absence of black smudge below eyes (Levy 1990) and the size and appearance of brood patches. In consonance with these, the female had a yellow face colour and no black smudge below the eyes, whereas the male had an orange-yellow face colour and a black smudge below the eyes. A yellow coloured, well-marked, larger brood patch was visible since the first week of incubation in the female. In case of the male a small sized brood patch was seen during the sixth week of incubation. Coupled with these characters, the presence of a dark patch on forehead of male proved as a distinct marker in all the video records.

Both the parents incubated the eggs (Images 3 & 4). Partial incubation was observed during the egg laying period and hatching period. Wang & Beissinger (2011) also observed such incubation. In partial incubation, the adult/s attended the nest but were observed sitting on the egg less regularly in a non-rhythmic manner as compared to the intensity of incubation after completion of the clutch. A review of 131 video clips spanning 64.99 hours of observation time (OT) spread over five days and four nights of hatching period (Table 1) revealed that the nest platform remained unoccupied by the parents only for two short diurnal absences of 0.07% (0.05 hour) OT and the parent/s were in the nest for 99.93% (64.94 hours) OT. During their stay in the nest, the parents were engaged in partial incubation of the egg for 53.96% (35.07 hours) OT, male incubating for 15.94% (10.36 hours) OT and female incubating 38.02% (24.71 hours) OT. They alternatively changed the incubation shifts 20

Image 2. Eggs in nest scrape.

Image 3. Incubation by Egyptian Vulture - male.

Image 4. Incubation by Egyptian Vulture - female.

Table 1. Time budget of partial incubation in Egyptian Vulture during hatching period (14–19 April 2017) On basis of video records: total observation time (OT) of 64.99 hours.

Incubating parent	Total stay in nest	Stay with partial incubation	Stay without partial incubation	Nest unattended
Male	49.94% OT (32.45 hours)	15.94% OT (10.36 hours)	34% OT (22.09 hours)	0.07% OT (0.05 hours)
Female	49.99 % OT (32.49 hours)	38.02% OT (24.71 hours)	11.97% OT (7.78 hours)	
Total	99.93% OT (64.94 hours)	53.96% OT (35.07 hours)	45.97% OT (29.87 hours)	

Table 2. Time budget of full incubation in Egyptian Vulture (09 March–10 April 2017). On basis of video records: total observation time (OT) of 339.39 hours.

Incubating parent	Total stay in nest	Stay with full incubation	Stay without incubation	Nest unattended
Male	41.09% OT (139.46 hours)	40.90% OT (138.81 hours)	0.19% OT (0.65 hours)	0.17% OT (0.58 hours)
Female	58.74 % OT (199.35 hours)	58.52% OT (198.61 hours)	0.22% OT (0.74 hours)	
Total	99.83% OT (338.81 hours)	99.42% OT (337.42 hours)	0.41% OT (1.39 hours)	

times, and male and female stayed two nights each in the nest. While sitting on the eggs in partial incubation, the incubating parent adopted a posture different than that in the full incubation by keeping the neck raised above the edge of the nest scrape.

The parents, however, were observed investing much time in full incubation after completion of clutch till the hatching of elder chick. A review of 688 video clips spanning 339.39 hours OT referable to 23 days and 17 nights of full incubation (Table 2) revealed that the nest platform remained unattended by the parents only for 16 short diurnal absences of 0.17% (0.58 hour) OT and the parents stayed in the nest for 99.83% (338.81 hours) OT, male incubating for 40.90% (138.81 hours) OT and female incubating 58.52% (198.61 hours) OT. There occurred 32 incubation shift changes during 339.39 hours full incubation OT.

During full incubation period, the eggs were kept below the body one behind the other and the incubating parent used to maintain a firm body contact with the eggs by exerting a grip over the nest rim with its hooked beak. In avian incubation, egg turning behavior plays an important role in ensuring proper embryonic development (Taylor et al. (2018). Both the incubating parents regularly turned the eggs using beak or feet for a total of 983 times, male and female 416 and 567 times, respectively.

The incubating male was very sensitive to disturbances near the nest and produced hoarse warning hisses to the Black Kites flying near the nest. During the course of incubation, both the parents maintained sanitation of the nest scrape and never defecated inside or over the rim of the nest scrape. An incubating parent left the nest scrape and moved away to other side of the nest platform to defecate. While sitting on the eggs, they also maintained the scrape rim by resetting the nest material. The male and female parent contributed 181 and 177 nest resetting attempts, respectively. The floor material of the nest scrape below the eggs was made soft and fluffy from time to time by the incubating parent using its curved beak. The male and female made 278 and 693 nest softening actions, respectively.

Hatching, Feeding and Fledging of nestlings

During the 2017 breeding season, an incubation period of 42 days and asynchronous hatching period of five days were recorded as the two eggs laid on 03 March and 08 March 2017 hatched on 14 and 19 April respectively. After hatching of the elder chick, both the egg and chick were incubated by the parents till hatching of the younger chick. Newly hatched chicks had naked faces, open eyes and bodies with fluffy, creamish down (Image 5). Both the parents brought food (dead pigeons, rats, snakes, human faeces, etc.) for the nestlings at regular intervals, and food was also kept in reserve scattered on the nest platform. Parents held food items in their claws and broke small pieces provided to the chicks. The body plumage markedly changed after four weeks with emergence and growth of new feathers (Image 6–9). During third week after hatching, the nestlings left the nest crater and were confined to one corner of the nest platform till completion of fifth

Image 5. Elder chick 3 days old

Image 8. Elder chick 54 days old

Image 6. Elder chick 24 days old

Image 9. Elder chick 94 days old

Image 7. Elder chick 33 days old

week, and then they started moving around the window platform. During this phase the parents were seen sitting on the observatory dome nearer to the nest window. The fledglings were observed out of nest platform exploring adjacent windows 94 days after hatching, and on the dome of the space observatory 98 days after hatching. They left the nesting site 112 days (16 weeks) after hatching. At the time of fledging they had a darker body, grayish face and short feathers on neck and crown.

DISCUSSION

Food availability is an important determinant of nest site quality and productivity of breeding pairs (Newton 1979; Levy & Segev 1996; Liberatori & Penteriani 2001). As opportunistic scavengers (Ali & Ripley 1983; Naoroji 2006), vultures feed on the remains of small animals, debris or rubbish dump, insects in dung, human and ungulate faeces, and vegetable matter (Prakash & Nanjappa 1988; Naoroji 2006; Angelov et al. 2013; Jha 2015). Active nesting sites are present near rubbish dumps (Liberatori & Penteriani 2001). During the present study, the vicinity of the observed nesting site contained urban patches, open croplands, an old drain, rubbish dumps, patches of trees and slaughter houses. Adults were often seen feeding at rubbish/carcass dumps, which served as a source of consistently available food for their young, and also primary sources of nest material.

It has been reported that an EV clutch generally contains two eggs (Brown & Amadon 1968; Cramp & Simmons 1980; Naoroji 2006), of which one usually hatches (Naoroji 2006), although Angelov et al. (2013) reported an EV clutch of four eggs from Masirah Island. In the present study the clutch size was two eggs per year, and all eggs (n=6) hatched and nestlings fledged successfully over three consecutive years (2015–2017). According to Mendelssohn & Leshem (1983), hatching interval in EV varies from three to eight days, and when the age difference between siblings is large the younger chick generally dies due to competition with the elder chick. In the present study the hatching interval was five days, nestlings faced no shortage of food supply by the parents and sibling aggression was not observed (Morandini & Ferrer 2015). Margalida et al. (2004) have reported siblicide of the younger chick due to sibling aggression during feeding bouts in the Bearded Vulture *Gypaetus barbatus*. In the 2017 breeding season the EV nestlings fledged 94–98 days after hatching, whereas fledging periods of 70 days (Donazar & Ceballos 1989), 75–80 days (Naoroji 2006), and 70–90 days (Bilgecan 2012) have been reported. The complete breeding season stretched from February to July in the years 2015, 2016, and 2017. As per Dharmakumarsinhji (1955) the breeding season of EV extends from end February/March to June, mainly February to May and some birds may initiate as early as December.

EV shows recognizable philopatry and long-term nest occupancy year after year (Newton 1979; Donázar et al. 1996; Sara & Vittorio 2003; Carrete et al. 2007). Ramirez et al. (2016) reported long-term occupancy (1900–2015) of an EV nest and suggested that some high-quality breeding sites provide important resources for long term nest occupancy. The authors have monitored this nesting site since 2015, but it may have been under long-term occupancy prior to this study. In view of sharp decline in EV populations throughout Punjab, the present observations on breeding biology have important implications for future management and conservation initiatives for breeding sites at the regional level.

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COMMUNICATION

Additions to the cicada (Insecta: Hemiptera: Cicadidae) fauna of India: first report and range extension of four species with notes on their natural history from Meghalaya

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Abstract: In order to broaden our understanding about cicada diversity of northeastern India, a comprehensive survey was conducted in the year 2017, in Garo, Khasi, and Jaintia hills of Meghalaya and an occasional opportunistic survey was carried out in northern West Bengal and Arunachal Pradesh. During these surveys, we came across four species of cicadas, viz., *Meimuna duffelsi*, *Dundubia annandalei, Balinta tenebricosa*, and *Orientopsaltria fangrayae*, which were not reported from India earlier and among them the genus *Orientopsaltria* is being reported for the first time from the country. This work provides an account of the taxonomy, natural history, distribution, and acoustics of these four species of cicadas along with their attribute to the culture and customs of the indigenous tribes of the landscape.

Keywords: Acoustics, Garo Hills, Jaintia Hills, Khasi Hills, new distribution report, natural history, northeastern India, northern Bengal, *Orientopsaltria*, taxonomy.

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Competing interests: The authors declare no competing interests.

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Author contribution: VS—conceived the project, collected samples, recorded acoustics and other field data, inspected collected specimens, compiled data, verified records, and wrote the manuscript. CM—assisted in manuscript writing and verified records. PPM—assisted in manuscript writing and verified records. MVN—collected samples and related field data for Dundubia annandalei and Balinta tenebricosa in 2019, assisted in manuscript writing and verified records.

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INTRODUCTION

Considering the crucial biogeographic role that the Indian subcontinent plays and the fact that the generic diversity of cicadas in India ranks highest in the world, it is unfortunate that very little research has been conducted on them since the early part of the 20th century (Price et al. 2016). In order to aid in the understanding on the cicada diversity of India, we conducted rapid surveys from February to December 2017, in different localities of Garo Hills, Khasi Hills, and Jaintia Hills of the Indian state of Meghalaya which falls under the Indo-Burma biodiversity hotspot. We also conducted an opportunistic survey in the northern parts of West Bengal from the year March 2014 to May 2019 and in Assam in the year 2017 and 2018 where the cicadas were only recorded and observed but not collected. A more focused survey was conducted in Arunachal Pradesh in October 2018 where cicadas were extensively sampled. The primary objective of these surveys was to prepare an inventory of cicadas of the region, along with their natural history and acoustic profiling. During the study period, we came across many known and lesser-known species of cicadas along with some interesting species. After a proper taxonomic diagnosis and call analysis of those, four of them, viz., *Meimuna duffelsi* Boulard, 2005, *Dundubia annandalei* Boulard, 2007, *Balinta tenebricosa* (Distant, 1888), and *Orientopsaltria fangrayae* Boulard, 2001 turned out to be new reports for India.

MATERIAL AND METHODS

Most of the cicadas in the field were spotted by their calls. Individual cicadas were observed through a Canon EOS-600D Rebel T3i Digital SLR with Sigma 70–300mm APO-Digimacro lens, and the observed behavior was noted down. All the cicadas were collected by a sweeping hand net. A few of the specimens of *Dundubia* were collected using a light trap. After collection, two legs and part of the thoracic tissues were extracted in order to preserve the DNA for future molecular work. Each insect was fixed with a pin through the mesonotum with wings outstretched after the extraction of tissue. After fixing the insect it was kept in a hot air oven for 48 hours at 56^{o} C. Panasonic Lumix DMC FZ-35 and Canon EOS-600D Rebel T3i DSLR with Sigma 70–300mm APO-Digimacro lens was used to photograph the live cicadas in the field where the same camera along with a Canon 100mm Macro lens was used to photograph the specimen for morpho-taxonomic work. Live cicadas were photographed as instructed in Sarkar (2015). A Canon 18–55mm lens with reverse mount ring was used to take images of the male genitalia. After taking images of different parts of the male genitalia, multiple images were stacked in Adobe Photoshop 7.0 for proper representation of the male genitalia. Image plates were prepared in Adobe Photoshop as well. The terminology used for the description of the adult cicada is adopted from Moulds (2005). Morphometric measurements of the adult cicadas were taken from images using ImageJ (64-bit Java 1.6.0) software. The measurements presented here are adopted from Sarkar (2019) (Figure 1). The male tymbalization was recorded using Telinga unidirectional microphone with parabola connected to Zoom H6 digital sound recorder. The sound was recorded in .WAVE format at a sampling rate of 48Khz in 24 bit dynamic range. The recorded sound files were transferred to HP Notebook laptop powered by Intel core i5, 7th generation for further analysis. For viewing, analysing song signals, and preparation of 'Cards for Identification by Acoustics' (here onward mentioned as CIA), Raven pro 1.5 (Cornell Lab of Ornithology) was used, and Microsoft Excel was used for statistical evaluation.

RESULT AND DISCUSSION

Meimuna duffelsi Boulard, 2005
(Figure 2; Table 1; Images 1, 2, 3)

The species belonging to the genus *Meimuna* Distant, 1905 has clear wings; the males have tymbal covers as wide as their length with external edges close to the opercula, but not attached; male abdomen significantly longer than the forebody; head broader than the mesonotum; pronotal margin has one tooth almost at the middle (Distant 1905; Boulard 2013). This genus is represented by seven species in India (including Bangladesh), viz.: *M. cassandra, M. gamameda, M. microdon, M. pallida, M. silhetana, M. tripurasura*, and *M. velitaris* (Sanborn 2014; Price et al. 2016). *Meimuna duffelsi* stands out from rest of the species by its stocky opercula and large rich brown abdomen and, in addition, the series of spots on the dorsal side are considerably underdeveloped compared to its closely related species (Boulard 2005; Boulard 2013). The male genitalia of the collected specimen are as same as the one represented in 'Cicadas of Thailand, Vol. I' (Boulard 2007a).

Collected specimen

Specimen Code: VS-AA219, 01.v.2017, 1 adult male; VS-AA220, 01.v.2017, 01.v.2017, 1 adult male; VS-

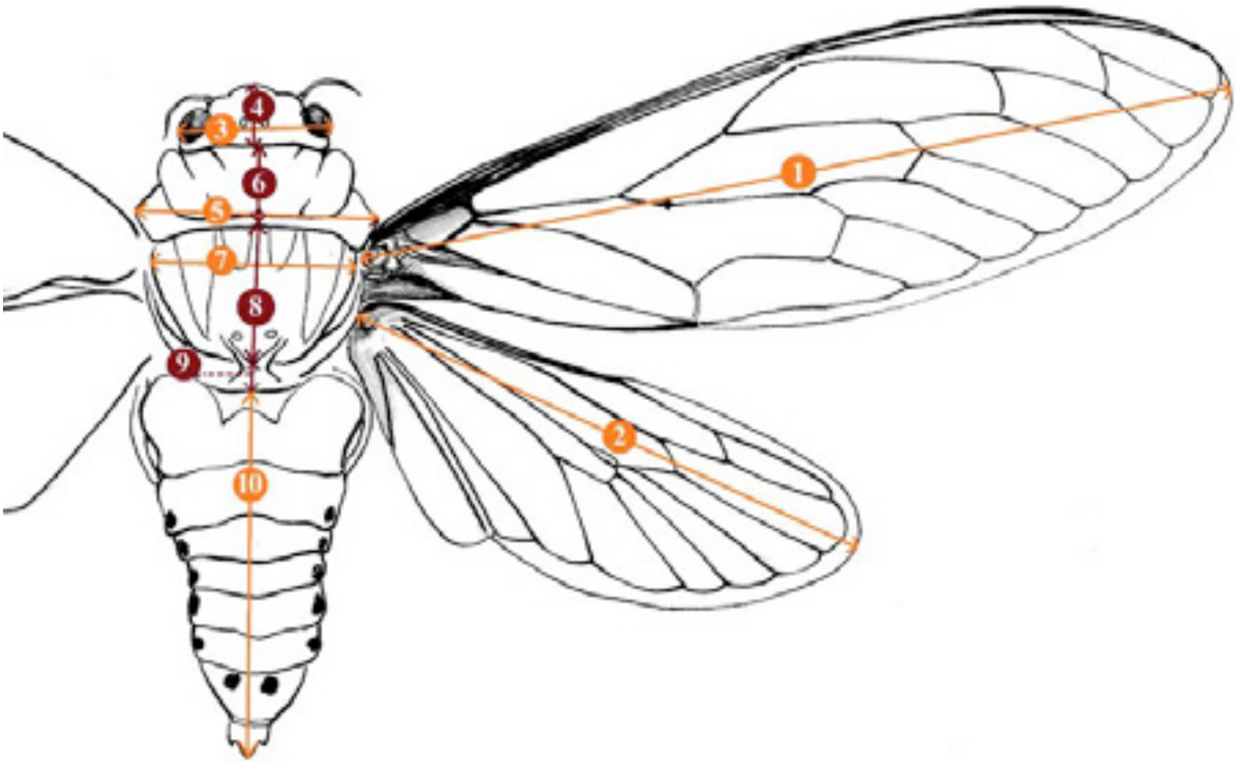

Figure 1. Cicada showing the area measured (Sarkar 2019).

Table 1. Measurement of specimen.

	Name of the body part	*Meimuna duffelsi* VS-AA222	*Dundubia annandalei* VS-AA532	*Balinta tenebricosa* VS-AA268	*Orientopsaltria fangrayae* VS-AA438
1.	Forewing	39.24mm	38.15mm	26.95mm	52.00mm
2.	Hindwing	20.91mm	20.92mm.	14.51mm	28.66mm
3.	Width of the head	9.82mm	10.17mm	7.80mm	14.46mm
4.	Length of the head	2.53mm	3.10mm	1.94mm	2.36mm
5.	Width of pronotum	10.24mm	11.07mm	8.00mm	15.13mm
6.	Length of pronotum	3.59mm	4.30mm	2.92mm	6.16 mm
7.	Width of mesonotum	9.13mm	9.26mm	7.46mm	12.97mm
8.	Length of mesonotum	5.98mm	5.49mm	4.18mm	8.06mm
9.	Length of metanotum	1.31mm	1.00mm	1.33mm	2.75mm
10.	Length of abdomen	17.88mm	14.55mm	15.29mm	21.29mm
11.	Length of Proboscis (length of rostrum including labrum and mentum)	6.61mm	5.23mm	4.99mm	12.17mm

AA221, 01.v.2017, 1 adult male; VS-AA222, 01.v.2017, 1 adult male; NCBS-PZ562, 11.v.2014, 1 adult male. Four specimens were collected in 2017, from one of the streams in the outskirts of Mawlynnong Village of East Khasi Hills District and out of these four, only one (VS-AA222) is presented in the paper. Apart from that a single specimen was collected in 2014 from Ribhoi District.

Description

Head: The head is dark from above, almost the entire epicranium is black except the thin area adjacent to the eyes and the ocular tubercle towards the pronotum which appears as an imperfect squarish pale olive green patches with a black dot in the centre in the live insect. Postclypeus is dark throughout the median region which spreads toward the frontoclypeal suture and anteclypeus. Spaces between the pale transverse grooves of postclypeus are dark. The front of postclypeus has a pale olive green streak at the middle in the live insect which turns rich brown in the pinned specimen. The eyes are dark brown, almost appearing black in the live insect. The ocelli are white in the live insect which turns pale sanguine in the pinned specimen. The median ridge of dark anteclypeus is pale brown with olive green which broadens towards the postclypeus. The mentum and labium is pale brown in colour even in the live specimen with 1/5th darker region at the tip of the labium. The frontal and dorsal part of the specimen is smooth but the ventral part of the head is covered with a fine white hair like structure gena and mandibular plate onward which turns brown in the pinned specimen.

Thorax: Entire thorax is different shades of dark green from top in live insect which turns pale brown in the pinned specimen (Image 1.A, 1.F). Pronotum has dark green base colour. The median part of the pronotum has a black bordered, inverted Christmas tree shaped patch with oval apex (Image 1A). The black border of this oval-apex inverted Christmas tree has a broad base towards pronotal collar and even broader base toward the head. The paramedian fissure is dark, broken almost at the centre and approaching the black border of the median patch but not adjoining. A faint trail of black line goes down toward the pronotal collar from the middle of the paramedian fissure. The ambient fissure is dark which is in contiguity with the dark lateral fissure, giving an impression of a Trapezium. The dark edge of pronotal collar extends below lateral angle, towards mesonotum. Mesonotum is green with a tinge of pale yellowish brown towards the upper side with paler upper lateral sides. Mesonotum has a median dark arrow mark pointing towards the scutellum. Submedian sigilla have a club like black patch towards the outer side in such a way that parapsidal suture is at the outer edge of this club-shaped patch. There is a small triangular spot at the inner side of lateral sigilla, towards the base of the club-shaped patch of submedian sigilla. The outer edge of lateral sigilla have a dark elongated patch which somewhat resembles the blade of an imperfect bowie knife. The scutal depression is covered by a comma-shaped spot which extends to the upper arms of cruciform elevation. Metanotum is brownish green in the live insect and uniform pale brown in the pinned specimen. Thorax below is green and yellow, covered with fine white coloured hair like structure. Coxa is entirely green in fore leg, yellowish green with a triangular yellow patch in mid leg and yellow with green in meracanthus in hind leg. The trochanter is yellowish green in fore leg, predominantly yellow with traces of green in mid leg and entirely yellow in hind leg. Femur is green to yellowish green in all legs, most greenish in fore leg and most yellowish in hind leg. Primary and secondary spine of the for femur is entirely greenish yellow with darker tips. The tibia of fore and mid legs are distinctly green to turquoise towards the outside and brown towards the inner side without any diffusion in the middle. In hind leg, the green is prominent towards the outer side and they start turning yellowish from the starting of the tibial spur and turns entirely yellow towards the tibial comb. The tibial comb and the tibial spurs are dark rich brown. The triangular orange operculum has green at the base and partially covered with white hair like structure. Operculum have prominent orange ridge at the edges. Operculum can reach till 6th abdominal sternite in the live males as the abdominal segments contract in, however, the tip of the operculum can be between 5th to 6th sternites in the pinned specimen depending on the stretching of the abdomen. Both wings are entirely transparent without even any apical infuscations in the fore wings. The basal veins are green including the basal part of the costa whereas the other veins are black in the fore wing. The basal membrane of the forewing is greyish brown. The costal vein till radius anterior, the entire cubitus anterior veins and the 1st anal vein except the marginal area is green in colour where rest of the veins in hindwing are black.

Abdomen: Whole abdomen is rich brown, overlaid with golden hair-like structures at the dorsal side and paler at the ventral side with overlaying of fine white hair-like structures. All the sternites are light rich orange coloured and covered with fine white scales towards the hypopleurite. Epipleurites have a rich chestnut base colour which appears darker than the base colour of sternites and entirely covered with fine white scales. The first tergite is entirely black with the traces of rich brown at the part adjoining to the scutellum. The second tergite has thin black area adjacent to the 1st tergite which looks like a continuity of it. The mid dorsal area has an imperfect triangle or rather a trapezium shaped black patch which also appear as a continuity of the black 1st tergite. This spot does not adjoin the lower part of the 2nd tergite. 3rd Tergite has the imperfect 'T' shaped spot where the upper area of the 'T' is nearly as broad as the space between the tymbal covers. Similar but thinner median T-shaped spot also occurs in the 4th tergite. 5th and 6th tergites has traces of these median black spots on them. 3rd, 4th and 5th tergites have deficiently triangular lateral black spots and 6th tergite has more of an oblong spot.

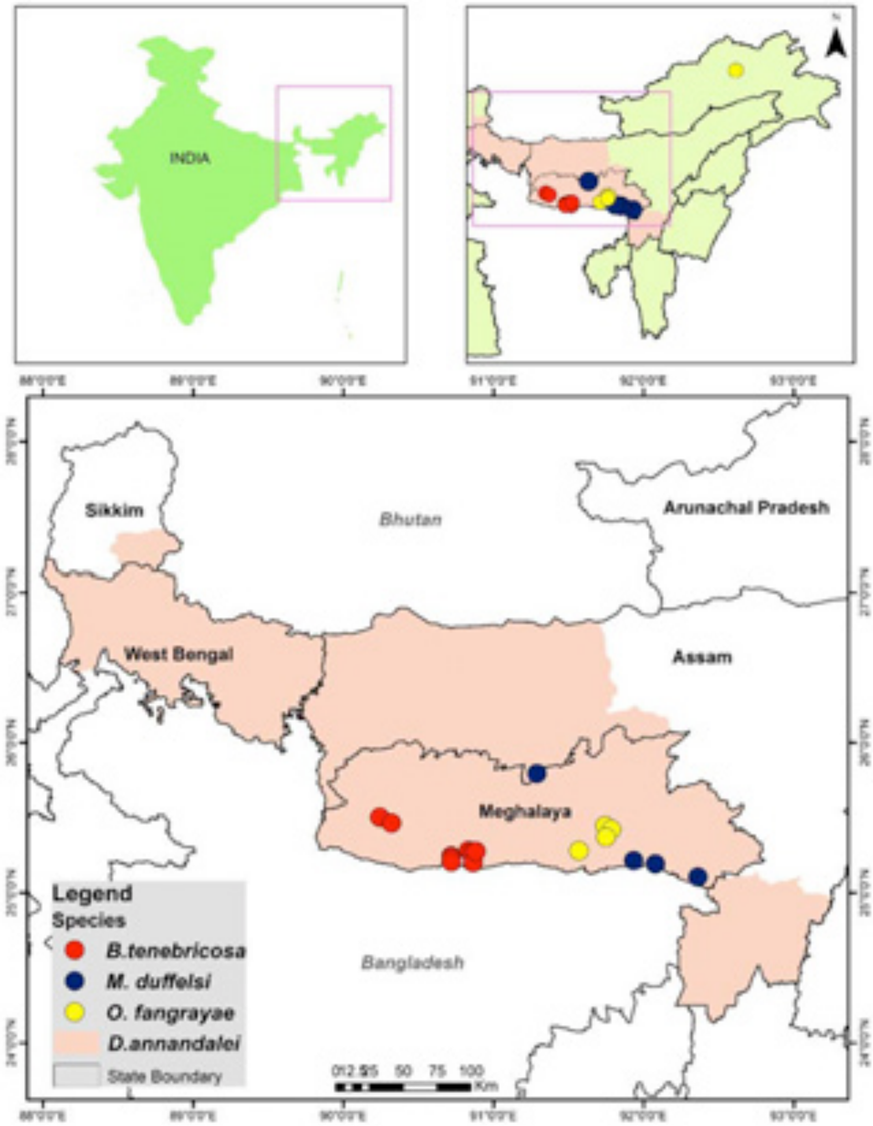

Figure 2. Location of four newly reported cicadas from India.

Male Genitalia: The pygofer is pale brown, cup shaped, with an oval opening from where the bifurcated, dark claspers come out. One of the two arms of the bifurcated claspers is long, tapered and curved and the other arm is small, undeveloped and situated towards the outer side. Median lobe of the uncus rudimentarily pointed. The upper lobe of pygofer is in a continuum with joint basal lobe providing a contiguous edge of the cup shaped pygofer.

Distribution

The only known distribution of this species was from Thailand until now (Boulard 2005a,b, 2008a,b, 2014) and this will be its first record outside Thailand. We recorded the species from Norpu Wildlife Sanctuary and Dawki of Jaintia Hills and Mawlynnong, Shella, Saiden, and Nongpoh of Khasi Hills and apart from these localities, the species was also seen and heard in Rani Reserve Forest of Assam (Figure 2). This species is likely to occur in areas that are south of Bramhaputra River, including parts of southwestern Assam, Manipur, and Mizoram having its preferred habitat.

Bionomics

Habitat type: The species predominantly prefers the riparian forests of hilly torrential streams.

Annual appearance period of adults: The first individual was spotted in second week of April during the field work of 2017 and they were active till the end of May. In the second week of May 2014. We spotted one individual mud-puddling in community reserve of Iewsier, Saiden Village of Nongpoh, and was caught by

Image 1. ***Meimuna duffelsi*****: A—Dorsal side of the pinned specimen | B—Ventral side of the pinned specimen | C—Front view of the male genitalia | D—Side view of the male genitalia | E—Lateral image of the live cicada | F—Dorsal image of the live cicada | G—Lateral close up of the live cicada | H—Ventral image of the live cicada. (© Vivek Sarkar)**

Image 2. *Meimuna duffelsi*: A—Preferred habitat | B—Bushes and shrubs surrounding the stream where this drinking cicada take shelter once disturbed | C—Resting individual in the bushes adjacent to stream | D—Mud-puddling of male Cicada from the seepage. (© Vivek Sarkar)

Dr. Krushnamegh Kunte.

Behaviour: Sun-loving and dendrophilous in nature. In sunny morning, the males usually call from the higher perches of tall trees and as the day progress they come down to the under growth and often emit sound signals from the small bushes adjacent to the stream. By the latter part of the morning when the day turns hotter, the males emit sound from the seepage and riverbed while drinking water. *Meimuna duffelsi* is one of the very few well studied cicadas due to their unique behaviour. This is one of the very few cicadas that exhibits the phenomenon which is popularly known as 'mud-puddling' in case of lepidopterans. The males of this species settle down in the wet patches, often adjacent to small streams and river banks and suck water from the seepage or wet soil or smaller water pool on large rocks and consistently excrete water like a jet spray from the tip of the abdomen. We have seen multiple males group together in such puddling and even producing a synchronized sound. Michel Boulard, who discovered this cicada from north of Chiang Mai Province, Thailand in 2004, named such puddling site "duffelsi pub" in his cicadas of Thailand book (Boulard 2013). Boulard described this phenomenon in great details on multiple occasions (Boulard 2005, 2006, 2013). If disturbed, the males fly straight up and settle on higher parts of the adjacent tree trunk or the high branches. Usually one alarmed cicada starts a series of chain reaction that makes all the cicadas fly within a few seconds. The males of this cicada were also seen drinking from wet forest floors of Saiden and Lewsier community forest, Ribhoi District, Meghalaya. We observed large congregation of this cicada on the stony riverbed of the torrential streams of Mawlynnong and Shela of East Khasi Hill District. In the first week of May 2017, a few individuals were also spotted in a seepage situated at the edge of Ramakrishna Ashram boundary at Shela. The species was never reported from the upper part of Meghalaya and they occur at a maximum height of 880m at one of the hill streams of the Jaintia Hills.

Acoustic: Image 3.A showing two complete sequences of calling tymbalization. Each begins with preliminary sizzling phase (G) which consist of gradually increasing groans and alternate short bursts of whistle like crackling (g). Although the overall call and the spectrum matches the description given by Boulard (2013) but, unlike his finding, we found the average spectrum centred at 2660Hz. Image 3.B showing the temporal spectrogram of two different frequency zone G and mgs/MS phase which alternate with exact repetitiveness. Image 3.C magnifies the selected area in Image 3.B and showing the alternate crackles and whistling (g) of the group of modules (mgs) becoming shorter as the call progresses till they get completely replaced by only the whistle phase which is a much condensed module (MS). According to Boulard (2013), every MS module ends with the very fleeting but powerful emission of sound which goes up to 18000 Hz.

Proposed common name

Based on the unique behaviour the common name proposed for this cicada is Duffels' Drinking Cicada.

Justification

Originally Boulard, the authority on this species, termed this cicada as 'Sand Cicada' as he saw the mass aggregation of males of this species for mud-puddling in the sandy banks of torrential Huai Mae Kam Pong River in the month of April–May (Boulard 2013). The males often tymbalize while sucking water from these sandy banks. The substrate of the river banks chosen by this cicada is not necessarily always sandy. It has been observed in our study area that this cicada drinks from the seepage of mud banks next to the village roads, wet humus soil of the forest floor, as well as the stony river banks. Drinking is a unique trait in this cicada that makes it stand out

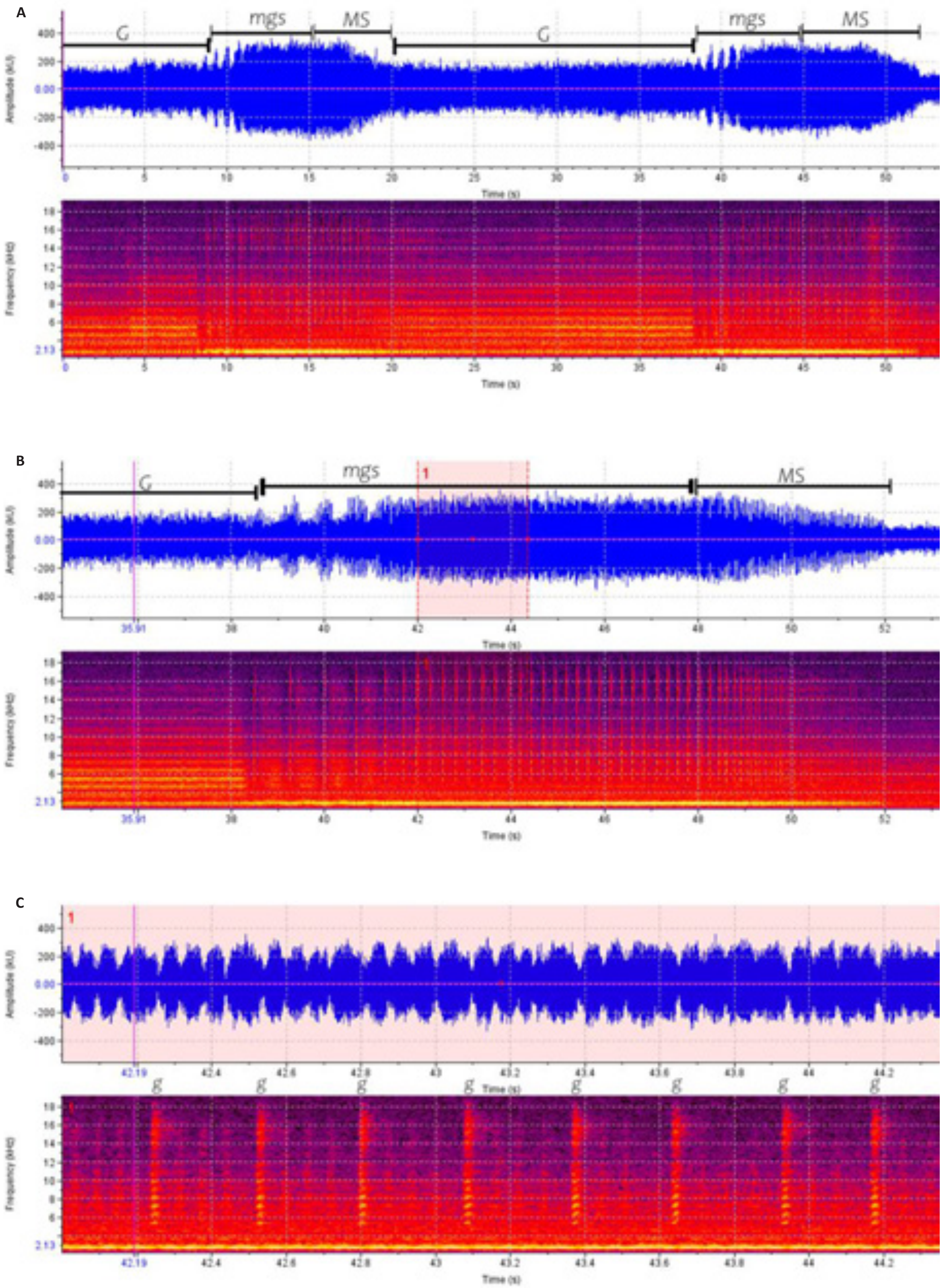

Image 3. ***Meimuna duffelsi*****: A, B & C—Cards for Identification by Acoustics (CIA).**

from most of the cicada of its preferred habitat and only seen in a very limited group of cicadas.

***Dundubia annandalei* Boulard, 2007**
(Figure 2; Table 1; Images 4, 5)

The species belonging to the genus *Dundubia* Amyot & Audinet-Serville, 1843, have a head wider than mesonotum, postclypeus fairly prominent; rostrum scarcely or not reaching the posterior coxae; thorax with pronotal collar laterally amplified and rounded, then towards the front marked with one or several denticles, sometime faint; male opercula monochromatic, hyper-devoloped, well separated at the base and more than two third of the abdomen length; male abdomen equal or mostly longer than the forebody; tymbal covers dorsally closing the dorsal acoustic chambers, but not adjoining the opercula laterally, revealing the tymbals at the side (Distant 1906; Boulard 2013). This genus is represented by nine species in India, viz.: *D. emanatura* Distant, 1889, *D. ensifera* Bloem & Duffels, 1976, *D. hastata* (Moulton, 1923), *D. laterocurvata* Beuk, 1996, *D. nagarasingna* Distant, 1881, *D. oopaga* (Distant, 1881), *D. rufivena* Walker, 1850, *D. terpsichore* (Walker, 1850), and *D. vaginata* (Fabricius, 1787) (Sanborn 2014; Price et al. 2016). *Dundubia annandalei* stands out from all other species due to its uniform grass-green colour and the comma-shaped male opercula. This cicada, however, has confused many workers due to its morphological similarities with *Dundubia terpsichore* as pinned specimens of both the species are brown and both of them have similar shaped opercula. These twin species were initially thought to be distinguished only based on the male tymbalization, however after studying both the cicadas in nature, Boulard found out that *Dundubia annandalei* is teneral-looking, uniform green when live and turn brown in the pinned specimen unlike *Dundubia terpsichore* which is brown, alive or dead (Boulard 2013).

Collected Specimen

Specimen Code: VS-AA532, 14.v.2017, 1 adult male; VS-AA533, 14.v.2017, 1 adult male; NCBS-AK278, 10.v.2015 1 adult male; NCBS-AK279, 10.iii.2015, 1 adult male.

Two specimens were collected in 2017, from Karwani Village of Baghmara, South Garo Hills District, Meghalaya and out of these two, only one (VS-AA532) is presented in the paper. Apart from them, two male specimens were collected in 2015 from Koler par Village, Coochbehar District, West Bengal.

Description

Head: The entire head is leaf green with orange to golden eyes and pale sanguine ocelli. The anteclypeus and mentum is also leaf green but the labium of the rostrum is brown which turn darker towards the piercing end. The pedicel of antenna is usually green with brownish second flagellomere but in relatively freshly enclosed individuals the entire antenna appear green after developing colour.

Thorax: Thorax is also leaf green in colour. The younger individuals have minute silvery hairs on the body making the body appear as greyish green which later turn leaf green with yellow patches towards the end of their lifecycle. The base of the legs, viz., coxa and trochanter, however, are always yellow, irrespective of the age and so is the tip of the leg, viz., tarsus and claw, which is yellowish-brown. The opercula are elongated comma shaped with prominent ridge. Wing is completely transparent. The basal veins are that of the body colour which turn darker towards the marginal area. In older specimen, the basal vein of the forewing can turn greenish-yellow or completely yellow. The radius and subcostal vein is dark roseate brown to black in appearance.

Abdomen: The abdomen is mostly in same green colour like rest of the body except the median part of all the eight sternites which varies from yellowish-green to rich yellow.

Male genitalia: Upper lobe of pygofer reduced, exposing the base of the clasper. The clasper has two pointed lobes split vertically, make it appear as inverted ‘Y’ from the side, giving an impression of the claw of a crab. Each of these lobes are further bifurcated in two outwardly curved pointed projections, forming a structure of inverted ‘V’ toward the distal end. Median lobe is attached to the upper part of the clasper leaving an opening for the head of the aedeagus. Anal tube and anal style are prominent.

Distribution

This cicada was first observed by Annandale in Phatthalung region and later described by Boulard from Thailand and the occurrence of this species has been reported from Thailand, Malacca and peninsular Malaysia (Boulard 2003, 2007a,b, 2008b). Boulard found this cicada in the surroundings of Lampang, surroundings of Ban Mae Kam Pong and in the King’s orchard of Chiang Mai Province and Wiang Papao, near Wang Nua and Ban Pha Kang of northern Thailand whereas it has been recorded in Tungka Forest of Ranong Province and Khao Sok rainforest of Surat Thani Province in southern

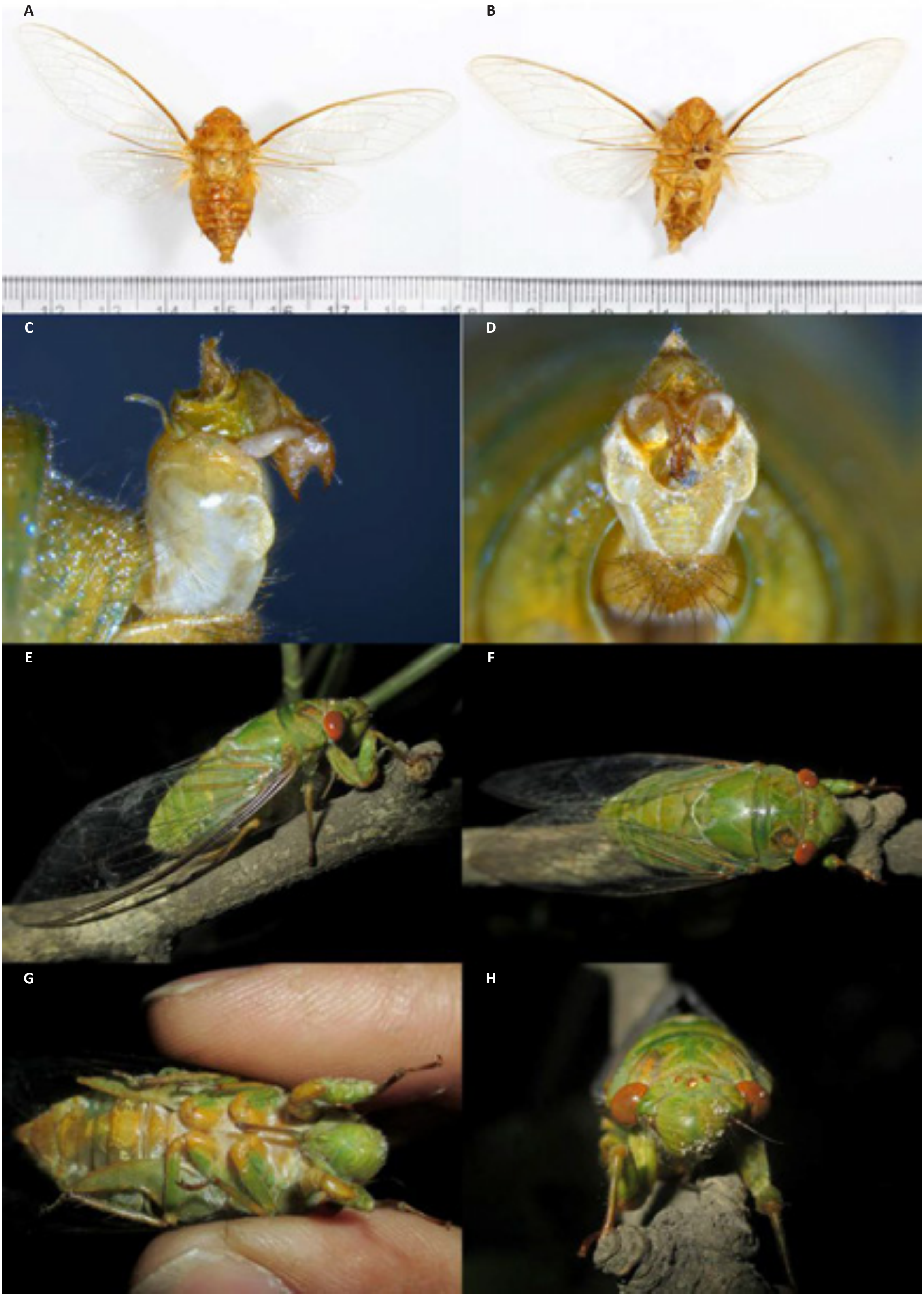

Image 4. *Dundubia annandalei*: A—Dorsal side of the pinned specimen | B—Ventral side of the pinned specimen | C—Male genitalia from the front | D—Male genitalia from the side | E—Lateral image of the live cicada | F—Dorsal image of the live cicada | G—Ventral image of the live cicada | H—Close up of the head. (© Vivek Sarkar)

Thailand (Boulard 2007a). This cicada is widespread in Meghalaya, Assam, and West Bengal. We have recorded this cicada in the lower to mid elevations of Meghalaya such as almost the entire Ri-bhoi District; Norpu Wildlife Sanctuary, Dawki, Umsyiem, Burhill and adjacent areas of Riwai-Dawki Road of Jaintia Hills; Mawlynnong, Shella and the lower part of Mawlong-Tyrna road and all other low elevation areas from Khasi Hills; and the entire Garo Hills except the peak of the Nokrek National Park and a few parts of the Balpakram National Park plateau. The species has also been recorded in the plains of Assam such as Karimganj, Silchar, Haflong, Guwahati, Boko, Dudhnoi, Goalpara, Joghigopa, Nalbari, Bongaigaon, Barapeta, Manas National Park, Kokrajhar ,and Dhubri. In northern part of West Bengal, the species is distributed similarly in the foothills and the plains of Coochbehar, Alipur, Jalpaiguri, Siliguri, foothills of Darjeeling, and all the way to the lower elevations of Sikkim (Figure 2) making it a desideratum for the foothills of eastern Nepal.

Bionomics

Habitat type: This cicada is an epitome of generalists, recorded in the secondary hill forests, primary riparian forests, disturbed and degraded forests in the hill slope of Jhum plantation, fragments of kitchen gardens in the vast paddy fields of Assam and Bengal, avenue plantations of the state highways and national highways, children's park, almost omnipresent through its range. This cicada can often be heard in the middle of heavily urbanised locations as well such as in the middle of Guwahati, Siliguri or Cooch Behar.

Annual appearance period of adults: As Boulard recorded in Thailand, this cicada is mostly active between February to April (Boulard 2007). We have recorded this cicada between March to May between 2013 to 2018. Most likely the emergence of this cicada is rain driven. They show irregularities in their emergence timing. For example, in 2015 the cicada emerged in great numbers in the first week of March, whereas in 2017 the species emerged in the third week of April and stayed till the first week of June. In 2019, the species emerged in the last week of January in a few places in southeastern Meghalaya and northern West Bengal and stayed on until April. Their annual emergence pattern and the driving factors of the emergence event are yet to be explored and subjected to long term monitoring.

Behaviour: The male of the species calls rigorously right before the sunrise in the morning along with *Pomponia* sp. during April–May. It is followed by a prolonged pause from 06.00h to almost 11.00h after which they again start calling. Initial calls have irregular intervals inbetween which gradually decrease as the day progresses and the calls become more rigorous in the late afternoon with almost no intervals in between. Locally this cicada is known as 'Phegol' in most part of the South and West Garo Hills whereas in parts of Assam such as Boko Village, it is known as 'Phodaning' or 'Phodaring'. Both the names having no particular meaning and mostly refer to pale-coloured cicadas, even soft bodied teneral cicadas. But it has been recorded in Daribokgre Village of East Garo Hills that this cicada is known as 'Phegol' and *Euterpnosia madhava* is known as 'Phodaning' or 'Phodaring. In Ri-Bhoi District of Khasi Hills it is called 'Jamalang', comprising two words, 'Jah' and 'Malung' meaning 'food' and 'soft body', respectively. In this region, collection of teneral *Chremistica ribhoi* as a source of food is a common practice in the mass emergence year (Hajong & Yaakop 2013). The coloration of matured and hardened *Dundubia annandalei* is very similar to the newly emerged teneral cicada which makes it a preferred food for local communities hence this species along with *Euterpnosia madhava* is a popular source of nutrition in the region. Both the sexes are attracted to light. The locals light up torches and beat two dry sticks to attract this cicada, a technique used for collection of the adult *Chremistica ribhoi* as well. Though it is a known practice yet not documented by Hajong (Hajong 2013), as only the matured and hardened adult cicadas get attracted by this technique and not the soft-bodied teneral cicadas which are preferred as a local delicacy. Although *D. annandalei* is attracted to light, the beating of sticks bring more individuals to light which we documented in April 2017 in Baghmara. The male cicadas perhaps perceive the sound of this stick beating as the female wing flicking response signals. Male calls by lifting their bodies up (Image 5A).

Acoustic: Image 5B representing temporal oscillogram of 128 seconds of tymbalization of this species. The call consists of two parts, repeating for alternately for long time, sometime more than 30min. The relatively longer and melodious comb scrapping that lasts for about 6.8 to 8.8 seconds, consists of 18 to 21 number of equidistant pulses. In between these comb scraping, there is crackling sequence which lasts for around 2–4 seconds. Image-5.C magnifies the selected part of temporal oscillogram of Image 5B, representing the 18 pulses of the longer and melodious comb scrapping sequence.

Proposed common name

Based on the male tymbalization, the name 'Comb Scraper' seems appropriate for this species.

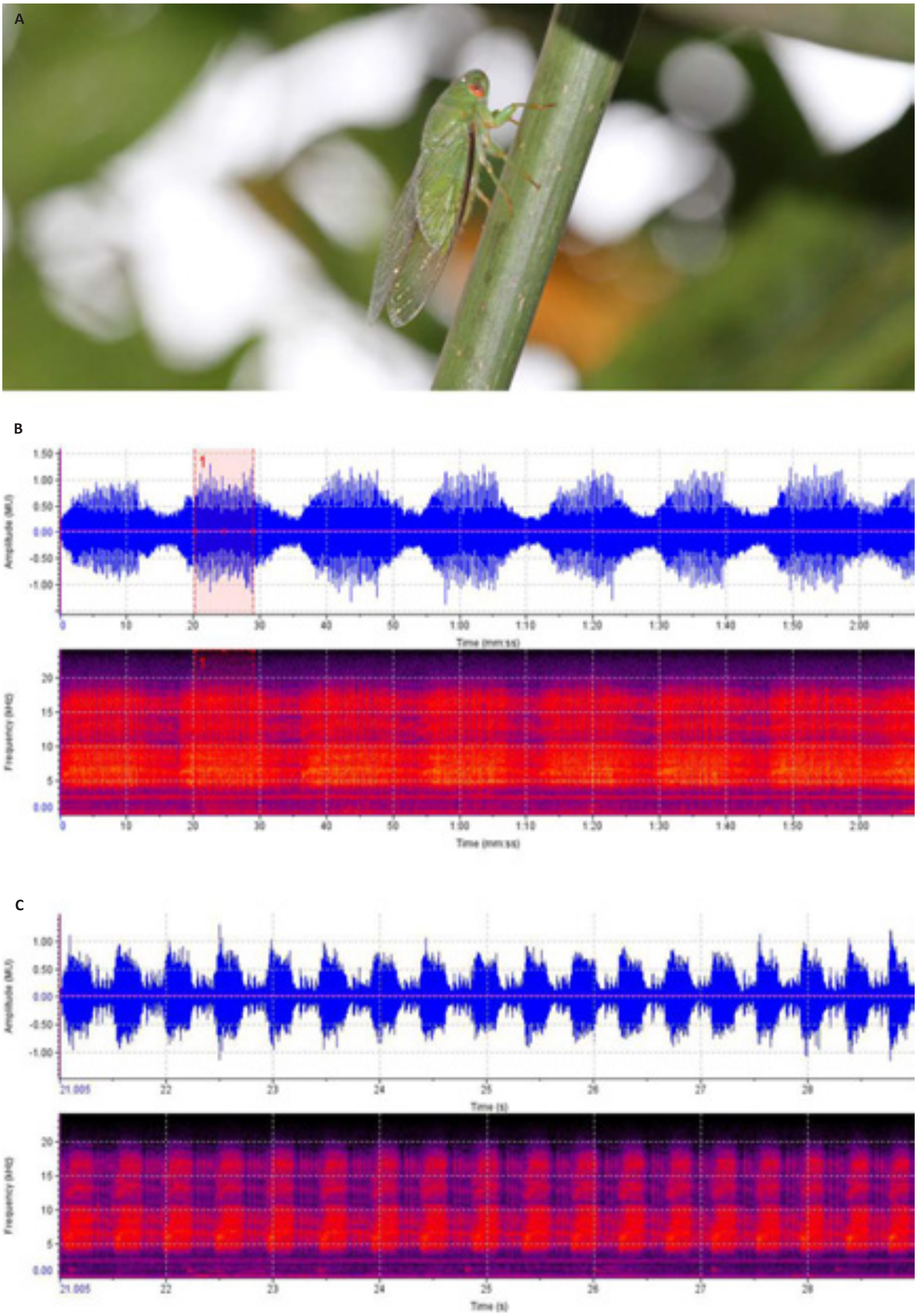

Image 5. ***Dundubia annandalei*****: A—Tymbalizing male | B & C—Cards for Identification by Acoustics (CIA). (© A—Pushpal Goswami; B&C—Vivek Sarkar).**

Justification

The tymbalization of the males of this species resembles the comb scraping sound.

***Balinta tenebricosa* (Distant, 1888)**
(Figure 2; Table 1; Images 6, 7, 8)

Balinta tenebricosa was described from the 'Teinzo on the Moolay River' originally as *Gaeana tenebricosa* (Distant, 1888). The genus *Balinta*, however, differs from *Gaeana* by having its head obliquely depressed in front of eyes, not longer than pronotum and having the widest part of tegumina only about one-third of the length of the tegumina (Distant 1905). There are three species of *Balinta* that are known from India (including Bangladesh), viz., *Balinta delinenda* (Distant, 1888), *Balinta octonotata* (Westwood, 1842), and *Balinta sanguiniventris* Ollenbach, 1929 (Price et al. 2016); among them *B. tenebricosa* resembles closely *B. octonotata*. But, as the name suggests, *B. octonotata* has four distinct white spots in each tegumina which gave them an impression of a black cicada with eight prominent white spots from above and the colour of the abdomen is rich sanguine with dorsal black spots whereas *B. tenebricosa*, as the name suggests, have completely black abdomen and have three small spots on the wing. Apart from Burma or present-day Myanmar (Distant 1888, 1905; Metcalf 1963; Boulard 2013; Sanborn 2014; Price et al. 2016), *B. tenebricosa* has been collected from Tonkin in Vietnam by R.V. de Salvaza (Price et al. 2016), Laos (Metcalf 1963), Guangxi in China (Sanborn 2014), and Thailand (Boulard 2007a, 2013; Sanborn 2014).

Collected specimen

Specimen Code: VS-AA276, 17.v.2017, 1 adult male; VS-AA268, 15.v.2017, 1 adult male. Two specimen were collected in 2017, one from the Chimitap Village and another from Hatisia Village of South Garo Hill District and out of these two, only one (VS-AA268) is presented in the paper.

Description

Head: Head is creamy white to yellow from the top with black frons, ocular tubercle and supra-antennal plate. Eyes dark brown with prominent pseudopupil in the live specimen. Ventral part of the head is mostly black, anteclypeus, lorum, and vertex black. Postclypeus broadly black at the centre with yellowish-orange at the adjacent edge of anteclypeus and lorum and turns paler towards the epistomal suture. The transverse grooves of postclypeus entirely black which appear as series of black lines towards the yellow edge.

Thorax: Pronotum dorsally black with pale patches at the edge joining the head and pronotal collar. A pale median longitudinal fascia continues from the pale area adjacent to the head and narrows down the most at right before the imaginary confluence point of two paramedian fissure, from where it widens and form a club like shape which joins the pale pronotal collar. The base of paramedian fissure is pale and broad which narrow down and appear as a traces of pale line along the fissure as it moves towards the pronotal collar. The pronotal collar is entirely yellowish-beige with a very thin dark edge towards the mesonotum and dark lateral angle. Mesonotum entirely black below with all the legs entirely black. Dorsally the submedian sigillas, lateral sigillas and the area adjacent to scutal depressions are entirely black. Area between submedian sigilla and lateral sigilla pale which runs towards the pale scutellum, constituting dorsolateral pale fasciae which are narrow and more yellowish towards the end adjacent to submedian sigilla and broadens at the posterior end. Metanotum rich orange till wing groove. Scutellum prominently pale creamy white which looks like the extension of pale elongated dorsolateral fascia of mesonotum. The borders of scutellum have traces of dark colouration which continue with the dark area adjacent to scutal depressions anteriorly and of uniformly dark first tergite posteriorly. Forewing dark brownish-black with three pale yellowish spot. Hindwing bright red with very broad dark outer border, making the red restricted to almost one third basal area of the wing. However, the anal lobe is only about one third black at the outer edge.

Abdomen: Entire abdomen is black. The overlaying brown hairs may give the appearance of the abdomen bronze-brown.

Male genitalia: The male genitalia identical to the one represented in the Cicadas of Thailand (Boulard 2013). The pygofer is dark towards the upper side with a thin pale band and paler on the side and base but the colour varies from individual to individual. There are males recorded with entirely dark pygofer as well. The upper and basal lobe of pygofer is fused and appear as a ridge. Pygofer very similar to that of the *B. octonotata* as illustrated by Hayashi (1978a & b) but unlike it the distal shoulder of pygofer is not protruded and pointed dorsally and in addition the pygofer is broader at the base toward the basal lobe and narrows down towards the apex where as in *B. octonotata* the entire pygofer appear as oblong rectangle. Median lobe of uncus is prolonged and bifurcated from where the aedeagus comes out. Aedeagus tapered ridge like structure which often appear as a hook at the opening. The claspers appear as globous

Image 6. *Balinta tenebricosa*: A—Dorsal side of the pinned specimen | B—Ventral side of the pinned specimen | C—Male genitalia from the front | D—Male genitalia from the side | E—Lateral image of the live cicada | F—Dorsal image of the live cicada | G—Ventral image of the live cicada | H—Lateral close up of the live cicada. (© Vivek Sarkar)

structure at the base of the median lobe of uncus.

Distribution

This species was only seen in the southern areas of Garo Hills whereas in Ribhoi, Khasi Hills and Jaintia Hills of Meghalaya, parts of Assam, northern West Bangal and Chhattisgarh the species gets replaced by *Balinta octonotata*. The species was seen in different forested areas between Baghmara Reserve to Balpakhram National Park not in continuity but in fragments. We have recorded this species in Karwani, Baghmara Reserve Forest, Gongrot, Hatisia, Chimitap, Rongcheng, Tura Peak, Nokrek National Park, and Balpakhram National Park (Figure 2).

Bionomics

Habitat type: The insect was seen both in primary and secondary forests of the hill slopes and foot hills in Garo Hills. An association of species' presence with the forest patches with lot of soft bodied climbers as well as lianas was noticed.

Annual appearance period of adults: In the year 2017, this cicada was first recorded in the third week of April and the last individual was recorded in the second week of June. The peak of activity was recorded between the second and third week of May.

Behaviour: The cicada is dendrophilous and shade loving. They remain silently settled in the thick vegetation, mostly at the shaded areas of lianas which makes them very difficult to spot due to their dark appearance. They feed on the liana and other climbers throughout the day, as one can see them excreting the excess water with regular jet spray. As the direction of sun changes from east to west, the cicada also changes its resting position, however, there are areas where the sunlight hardly reaches and often more than one individual settle closely in these types of areas. The males start tymbalizing from late-afternoon, starting from around 14.30h and continues till about 18.00h. Initially the males call from one spot, after repeating few set of calls they walk slowly and change the position in the time between the calls. After repeating this a few times on the same plant or tree, they fly and change the tree or liana and repeat the process. They call almost in a sub-gregarious manner as the afternoon progresses and call rigorously and desperately as dusk approaches. Usually the males call from a little higher parts of the vegetation whereas the females prefer to settle 1.21–1.82 m from the ground on the climbers and lianas. Sometime, towards the evening, the males come down and settle close to the ground or even fall on the ground close to the plant where female is resting and announce their acoustic signals desperately. While calling, the raised abdomen of the males, which is otherwise covered comes out in between two tegumina (Image 7E).

Acoustics: Image 7A representing temporal oscillogram of 68 seconds of tymbalized calling re-transcribed in real time, showing two complete calling sequence of this species. Each sequence consist of two uneven phases, The initial short phase is designated as ph-1 and prolonged phase designated as ph-2, as shown in Image 7A. Second phase consist of highly condensed signals as shown in Image 7B, which shows the partial oscillogram of 10/100^{ths} of a second of the ph-2. Towards the end of the prolonged second phase (as shown in Image 6) of the double motif at the rate of three per hundredth of a second as shown in the Image 7B get a regular interval (sandwiched between seven to eight crackling signals as shown in Image 7C) which is crescendo until the crackling signals reduced to four to five (Image 7D). Image 6 showing partial oscillogram stretching out in an arbitrary space-time unit showing the initial first phase (ph-1) and prolong second phase (ph-2) along with the ending of entire second phase. Sometime there is a minor variation in first phase that occur in different tymbalized calling, often of the same individual as shown in the Image 7F&G.

Proposed common name

Based on its appearance, this cicada can be called 'Variable Dark Balinta'.

Justification

In Latin, 'tenibracosa' means dark. This cicada is darker than closely related species *Balinta octonotata* in its general appearance by having three reduced pale spots on dark tegumina and black abdomen. Colour variations have been reported as well for the females of this species from Thailand such as some individuals having yellow abdomen instead of complete black with only dorsal black spots along with individual colour variations of hindwings (Boulard 2013). Hence, it is justified to add 'variable' in common name to represent the species better.

Orientopsaltria fangrayae Boulard, 2001
(Figure 2; Table 1; Images 9, 10, 11)

Genus *Orientopsaltria* Kato, 1944 consists of 33 species distributed across the Philippines Borneo, Sumatra, Malayan Peninsula, and Thailand (Duffels & Zaidi 2000; Boulard 2013; Sanborn 2014), with a recent record from Vietnam (Pham et al. 2019). The species

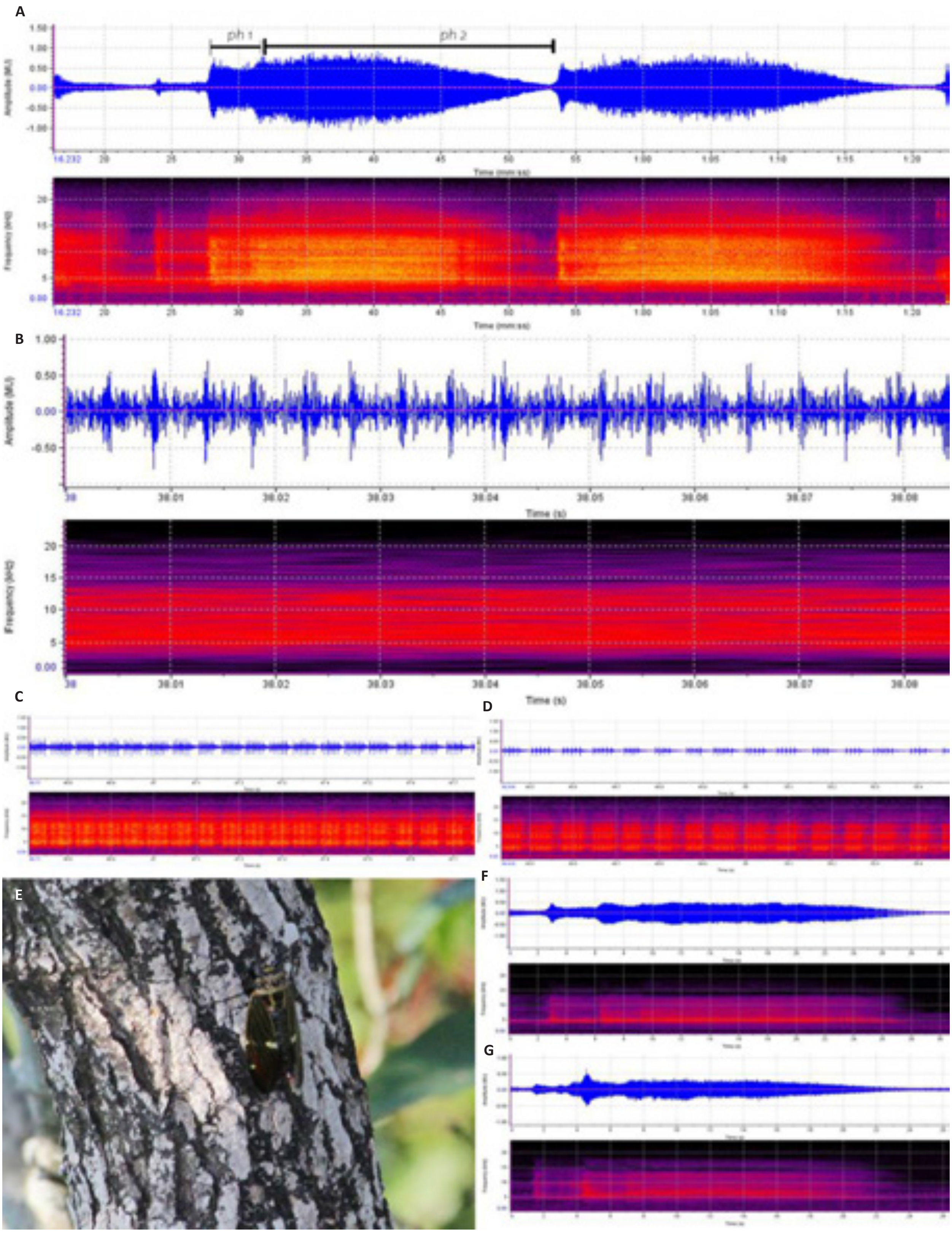

Image 7. *Balinta tenebricosa*: A, B, C, D, F, G & H—Cards for Identification by Acoustics (CIA); E—Tymbalizing male. (© Vivek Sarkar)

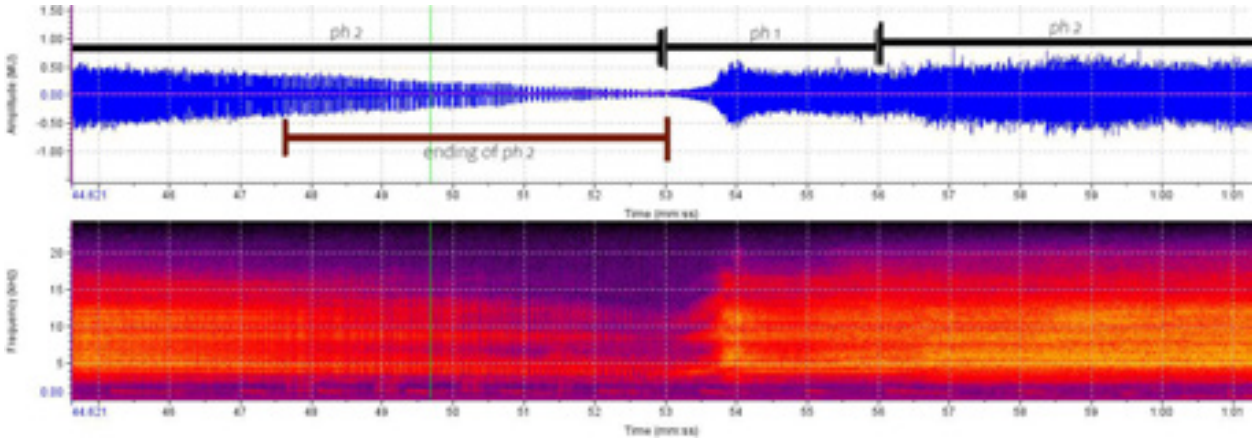

Image 8. *Balinta tenebricosa*: Oscillogram showing the magnified structure of both the phases of tymbalized call.

under the genus *Orientopsaltria* are medium to fairly large in size and very similar to the genus *Cosmopsaltria* Stål, 1866 or *Dundubia* Amyot & Audinet-Serville, 1843; however, unlike *Cosmopsaltria*, the genus *Orientopsaltria* have rounded pygoferal lobes and unlike unicolour male opercula and globous head of *Dundubia* they have bi or multi-coloured male opercula and head globous but not as much as *Dundubia*, postclypeus fairly strongly produced (Duffels & Zaidi 2000; Boulard 2013). The latero-posterior ocelli significantly closer to each other than from the corresponding eye; pronotum marked with two black parasagittal lines and possibly two black sub marginal bands; mesonotum, in most cases, heavily decorated with long black sagittal stripe with four black fasciae, as well as two maculae in front of scutellum; hyaline wing with only apical nervules highlighted or with transverse nervulation lined with bistre or without any infuscations; subapical and brownish spots often on the longitudinal nervules; hindwing with six apical cells; male opercula elongated, wide with either single green ochre tint or broadly greenish with black or bistre along internal margin and on apex (Kato 1944; Boulard 2013). *Orientopsaltria fangrayae* was first discovered from Chiang Mai Province (Boulard 2001, 2013). The species from India was first identified based on the CIA provided in Cicadas of Thailand (Boulard 2013) and later confirmed with acoustics, general morphology and the male genitalia which is identical to the description given in the book (Boulard 2013).

Collected specimen

Specimen Code: VS-AA438, 10.ix.2017, 1 adult male. Only one specimen was collected in 2017 from the upper hill slopes of Mawsinram Village of Khasi Hills and the same specimen is presented in the paper.

Description

Head: Eyes rich chestnut brown in live specimen which appear reddish from distance (Image 11) and turns dark brown in pinned specimen. Head green with heavy decoration. Supra-antennal plates black below and green on the top which sometime looks darker in live insect. Both side of epicranium have rectangular black spots and two traces of tiny spot posteriorly. Ocular tubercle including frons and epicranial suture black which sometime continues as parasagittal lines of pronotum in some individuals. Postclypeus not protruded, base colour light sea green with green coloured transverse grooves. A median black line at the front of postclypeus narrow at the adjacent area of anteclypeus and broadens as it goes towards the dorsal side and bifurcate which dorsally forms two big spots at the dorsal part of the postclypeus. Dorsally, the area adjacent to pronotum, behind the eyes have black elongated spot parallel to the border of the head. The part of lorum adjacent to anteclypeus have traces of black. Rostrum pale coloured with dark tip.

Thorax: Pronotum has a central greenish brown oblong spot, somewhat like the shape of a squid, bordered by dark parasagittal lines which originate from the back of the head and ends just above the pronotal collar. There is an Inverted “L” shape spot attached to parasagittal lines diagonally. Dark paramedian fissure join this L-shaped spot at the angle. Lateral fissure dark. The pronotum collar has the thin black margin in the inner part of the lateral margin which goes beyond lateral fissure. Pronotum collar green with thin black outer margin which crosses the pronotal collar just above the lateral angle. Submedian sigilla black which is incomplete at the median area but barely crosses parapsidal suture posteriorly and enters at the central part of mesonotum. The base of the lateral sigilla which is adjacent to pronotal collar black. The lateral fasciae run below this basal dark area posteriorly along and within lateral sigilla. Scutal depression and surrounding area black, giving an impression of oval spots to some extent. A pointed, spear-head shaped, oblong median fascia runs from the posterior area between two submedian sigillas till above the cruciform elevation. Cruciform elevation uniformly brownish green. Femur of foreleg sea green coloured, similar to that of the postclypeus, with black joints and black edge with dark primary and secondary spines. The joint between femur and tibia in second and third pair of legs are prominently yellow with black spots. Opercula long, reaches till seventh sternite. The spoon shaped operculum is hyper-developed and as mentioned by Boulard and shown in Image 8G & H, strengthened laterally with a strong brilliant bistre helm, broadly separated from base, occurring initially in a short patch and then in large ventro-lateral spoon shapes (Boulard 2013). Less than two third of the opercula from the base are green and smoky dark with white overlaid scales towards the tip in live specimen. Wings entirely hyaline. Forewing have traces of pale brown infuscation at radial and radiomedial crossvein. Veins at the base of the forewing are green in live insect (Image 8E) which turns pale brown in pinned specimen (Image 8A).

Abdomen: Abdomen darker than the forebody. Sternites greenish-brown with darker margin posteriorly and overlaid with pollinosity which appear as in continuity with the tip of the opercula (Image 8G). First tergite reduced. All tergites are dark brown except second and third tergites which have prominent median green patch and traces of median green patch on them, respectively. Timbal cover is brown and covers the timbal completely from top and only opens laterally. Third tergite has two dorsolateral silver spot, one at each side. This is due to heavy pollinosity caused by silver overlaid hair like structure.

Male genitalia: The lateral lobe of the pygofer apically rounded without protrusion. Basal pygofer lobes appear as a distinct ridge with pointed apical protrusion. Uncus lobes look square like, with angular, robust lateral spine with internal median groove. The apical part of lateral margin straight and tapered.

Distribution

The species was first discovered in the wet mountain forest of Fang of Chiang Mai Province and later reported from Wiang Papao, Khun Lao Mountain and Doi Ang Kang in Thailand (Boulard 2001, 2003, 2005b, 2006b, 2007b, 2008, 2013; Sanborn et al. 2007). We had first recorded the species in East Khasi Hills in 2017, in the hilly surroundings of Mawsinram Village and later in Mawphlang adjacent area. It has been recorded till Ladmawphlang but not beyond Mawkdok Valley. In 2018, we recorded the species only from the mid-elevation wet forests (up to 2000m) of Moulin National Park in Upper Siang District, Arunachal Pradesh. In this case the species was observed and recorded but could not be collected as they were settled high up in the trees.

Bionomics

Habitat type: The species was encountered between 890–1,400 m, mostly in the thick forests of the hill slopes consisting predominantly of *Prunus* sp., *Rhododendron* sp., and *Castanopsis* sp. trees. The presented specimen was collected at 1,161m. As rightly mentioned by Boulard (2013), they are ambrophilous, mostly prefer the wetter forests of the mid to higher elevation. Towards the end of their activity period a few desperate males wander off and can be found outside their preferred habitat.

Annual appearance period of adults: The first Individual was encountered on 28 August 2017 and the last individual was encountered in the second week of November 2017. Their activity is at peak from mid-September to third week of October. Boulard recorded the species in September in the year 2000, 2004 and 2006 and in November in the year 2004 (Boulard 2013). They are active mostly in the day time.

Behaviour: The males settle at the ventral side of the upper branches of tall trees of thick forest of the hill slopes, making them very difficult to spot due to their decorative forebody matching with the thick mosses of tree trunk. Usually they have been spotted using headlight and binoculars as they prefer forests where light barely penetrates but their red eyes give their position away in green mossy branches (Image 10). The males emit the acoustic signal randomly without any particular gap in between. Although Boulard (2013) described the species as heliophilous, in our observation, we find them certainly dendrophilous. Boulard mentioned that males often exhibit 'synchronous orchestra' (Boulard 2013), however, we noticed this behaviour in mostly prolonged rainy and extremely foggy days and occasionally during sunny days. Gregarious by nature, males settle in nearby trees and display this synchronous orchestra. They also often show this behaviour if a pre-recorded call is played in a portable speaker but not necessarily always. The males settle at one place and tymbalize, often they do not change the place for several days, moving only insignificantly from the settled area.

Acoustics: Calling tymbalization sounds like a scream which appear as extremely dense signal of spindle in

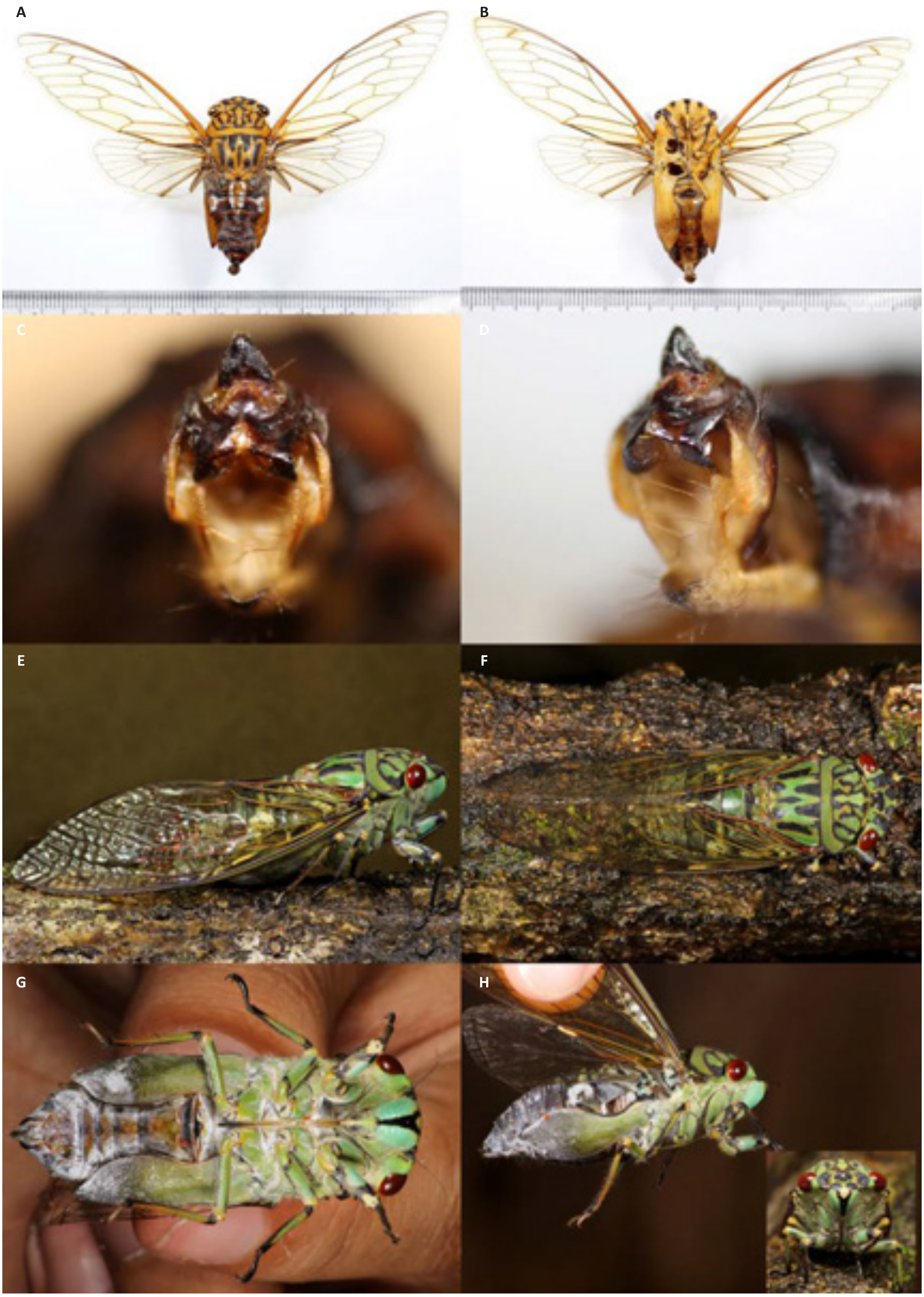

Image 9. *Orientopsaltria fangrayae*: A—Dorsal side of the pinned specimen | B—Ventral side of the pinned specimen | C—Male genitalia from the front | D—Male genitalia from the side | E—Lateral image of the live cicada | F—Dorsal image of the live cicada | G—Ventral image of the live cicada | H—Lateral close up of the live cicada, head from front in inset. (© Vivek Sarkar)

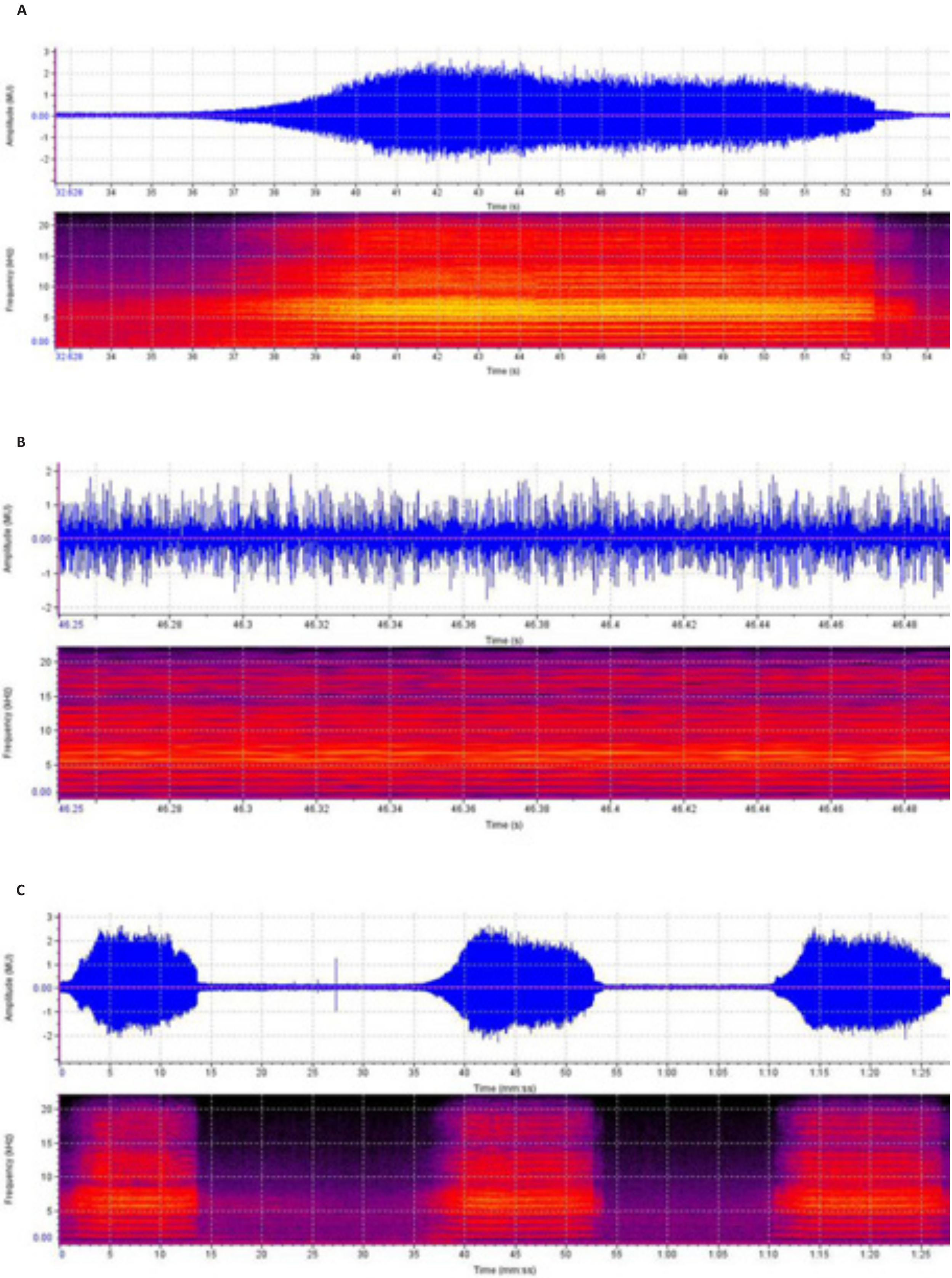

Image 10. *Orientopsaltria fangrayae*: A, B & C—Cards for Identification by Acoustics (CIA).

Image 11. *Orientopsaltria fangrayae* in natural habitat.

oscillogram without any detectable structures (Image 10A). Image 10B showing the sonogram stretching 25/100ths of a second representing an arbitrary space-time unit to represent a magnified structural Image. Image 10C showing the synchronous orchestra where every spindle is of +/-18seconds and the distance varies from 16.2 to 21.8 seconds.

Proposed common name

Based on its appearance and behaviour, the name proposed is 'Red-eyed Hill Screamer'.

Justification

The call of this species is spindle-shaped with thick signals that gives an impression of screaming and this cicada prefers wet forests of the Hills throughout its range hence the 'Hill Screamer'. The first striking feature that anyone would observe in this cicada when they are alive is their red eyes (Image 11).

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PLATINUM OPEN ACCESS

COMMUNICATION

The perceptions of high school students on the habitat of the crab *Ucides cordatus* (Linnaeus, 1763) (Crustacea: Decapoda: Ucididae) in northern Rio de Janeiro State, southeastern Brazil

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Abstract: The study evaluated the perceptions of high school students (15 to 22 years old) on the value and ecosystem services (ES) provided by mangroves in the Paraíba do Sul River estuary, which is the habitat of the crab *Ucides cordatus* in northern Rio de Janeiro State, southeastern Brazil. One of the schools, Colégio Estadual Ercilia Muylaert de Menezes (CEEMM), is located in a rural area close to the mangroves, while the other school, Colégio Estadual Benta Pereira (CEBP), is located in an urban area 50km from the mangroves. The CEEMM students (n= 62) mainly attributed economic value to the ecosystem, while the CEBP students (n= 67) attributed ecological value. Students of both schools recognize the provision of services relating to commercial fishing of the crab *U. cordatus* as the main ES provided by the mangroves. The value of direct use (crab fishing) can encourage ecosystem conservation, however, it should not be the only resource considered for this purpose. We recommend that both schools implement environmental education activities to consolidate student knowledge about mangrove dynamics and its importance as an environment that supports and regulates coastal areas.

Keywords: Crab, ecosystem services, education, environmental value, mangrove.

Portuguese: O estudo avaliou a percepção de estudantes do Ensino Médio (15 a 22 anos) sobre o valor e os serviços ecossistêmicos (SE) prestados pelo manguezal do estuário do Rio Paraíba do Sul, o habitat do caranguejo *Ucides cordatus* na costa norte do estado do Rio de Janeiro, SE, Brasil. O Colégio Estadual Ercilia Muylaert de Menezes (CEEMM) está localizado em área rural, próximo do manguezal, e o Colégio Estadual Benta Pereira (CEBP) se localiza em área urbana, a 50 km do manguezal. Os estudantes do CEEMM (n= 62) atribuem principalmente valor econômico ao ecossistema, enquanto os estudantes do CEBP (n= 67) atribuem valor ecológico. Os estudantes de ambas as escolas reconhecem a provisão como principal SE proporcionado pelo manguezal, relacionado com a pesca comercial do caranguejo *U. cordatus*. O valor de uso direto (caranguejo) pode incentivar a conservação do ecossistema, porém não deve ser o único recurso considerado para essa finalidade. Nós recomendamos atividades de educação ambiental nas duas escolas para consolidar o conhecimento dos estudantes sobre a dinâmica do manguezal e sua importância como ambiente de suporte e regulação de áreas costeiras.

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Author contribution: Study design: LHOC and APMDB; field work, data analysis and writing the first draft: LFQR; APMDB: writing the final version.

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INTRODUCTION

Mangrove forests are coastal ecosystems located in the transition areas between terrestrial and marine environments, and in Brazil, they occupy approximately 14,000km² of the coastline between 02°N & 25°S. These ecosystems have high productivity and provide natural resources for humans (e.g., fish, mollusks, crustaceans, wood, medicinal plants) (Côrtes et al. 2014, 2018; ICMBio 2018). One of the resources is the crab *Ucides cordatus* (Linnaeus, 1763). This crustacean occurs in the mangroves along the western Atlantic Ocean from 24°N to 28°S, and it is the most exploited species within the Brazilian mangroves (Neto & Baptista-Metri 2011; Côrtes et al. 2014; Nascimento et al. 2017).

Ecosystem services (ES) are benefits provided by nature that have economic, social and cultural importance, and they are grouped into four categories: provision, regulation, support and culture (MEA 2005; Kaltenborn et al. 2017). In mangrove areas, the provision services are responsible for providing natural resources for utilization or commercial purposes, such as crabs, mollusks and fish. Regulation services are responsible for regulating environmental conditions, such as by maintaining climate and water quality and controlling coastal erosion. The support services, such as photosynthesis and soil formation, maintain other types of ES. Cultural services provides populations with recreational, spiritual and aesthetic benefits. Currently, many natural ecosystems are affected by pollution, fragmentation and loss of habitat, threatening the well-being of humans and other species through ES loss (Barbier et al. 2011; Kaltenborn et al. 2017).

The mangroves of the Paraíba do Sul River estuary (21°23'S) are located in northern Rio de Janeiro State, southeastern Brazil. These mangroves cover approximately 725ha, and local communities have carried out commercial fishing of the crab *U. cordatus* for decades (Filho & Filho 1995; Passos & Di Beneditto 2005; Côrtes et al. 2014, 2019). This study evaluated the student perceptions of the value and ES provided by this ecosystem. The assumption was that the recognition of the value and ES would be greater among students of the rural school, who live close to the mangroves and whose relatives use their natural resources, compared to students of the urban school, who live further from this ecosystem. We expect that the daily experiences of the students living near this ecosystem would increase their knowledge about it and would not be limited to the information transmitted formally by the school.

MATERIAL AND METHODS

At first, we contacted the school administrations to deliver the 'Letter of Consent' (*Carta de Anuência*). This document described the aims of the study and asked for permission to carry it out with the students (Brasil 2015). The *Colégio Estadual Ercília Muylaert de Menezes* (herein named CEEMM) is a school located in a rural area close to the mangroves of the Paraíba do Sul River estuary (Figure 1). The *Colégio Estadual Benta Pereira* (herein named CEBP) is an urban school situated 50km from mangroves (Figure 1). The students were interviewed in May and August 2018, and at that time, CEEMM had 95 students at the high school level (62 participated in the study), and CEBP had 367 students (67 participated in the study). The age of the students ranged from 15 to 22 years. Previous studies that have applied questionnaires to obtain data on the knowledge of a homogeneous population, such as high school students (present study), have considered 15–20 questionnaires sufficient for representative results (Crouch & McKenzie 2006; Guest et al. 2006).

The questionnaire had one open question: 'Describe what the mangrove represents to you'. It was applied in the classroom after the study aim was explained to the students and everyone had agreed to participate. The same questionnaire was applied to all students individually and simultaneously, according to the assumptions of the repeated information technique in a synchronous situation (Goldenberg 1999). The authors classified all information resulting from the open question as the values and ES provided by the mangroves.

The categories to assess the value of the mangroves were based on Henkel (2017). The economic value was assigned to reports that attributed financial or food values to the mangrove resources. The ecological value was assigned to the recognition of the importance of mangroves for maintaining environmental quality. The cultural value was defined as the utilization of mangrove areas and their resources for leisure and tourism. Reports that did not provide context or that did not attach any importance to the mangrove were classified as 'null', and reports that demonstrated recognition of the mangrove as an ecosystem, without specifying any value, were considered as 'other' (Table 1).

The ES provided by the mangroves were classified according to MEA (2005) and Steger et al. (2018). Provision services were referenced by reports on direct supplies, such as food and raw materials. Regulation services were described by reports on the importance of mangroves in the regulation of ecosystem processes, such as biological, climatic, disease and water purification

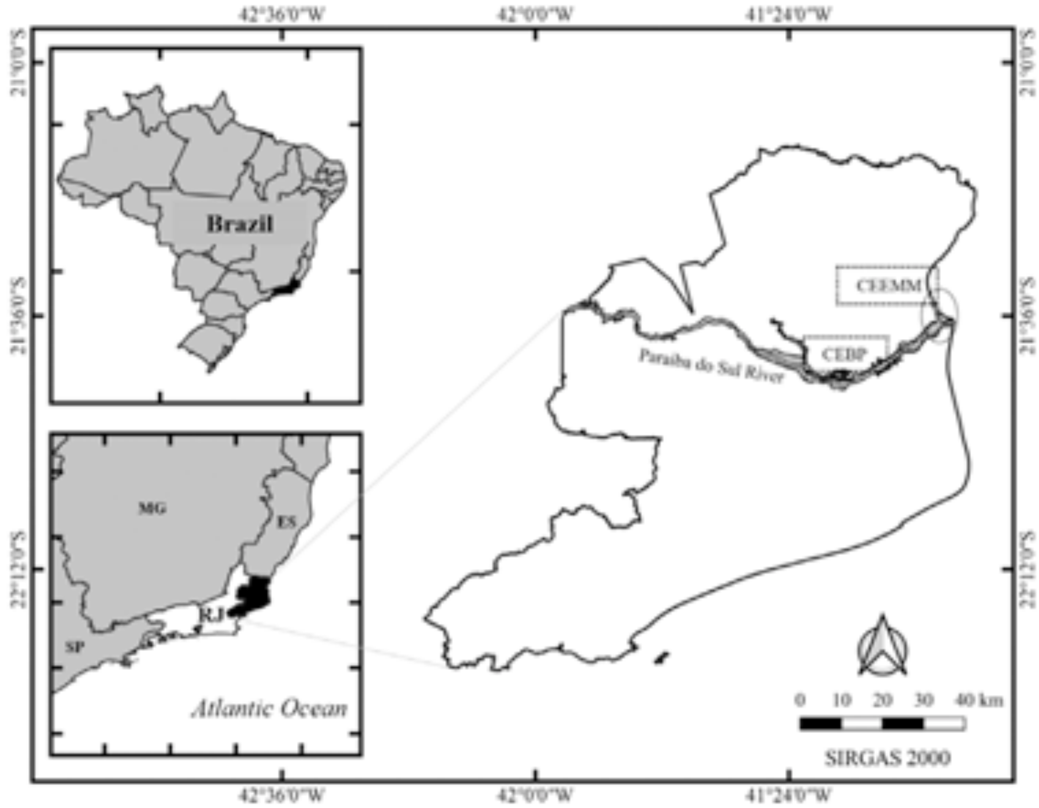

Figure 1. Location of the schools in northern Rio de Janeiro State, southeastern Brazil (CEEMM: Colégio Estadual Ercília Muylaert de Menezes, CEBP: Colégio Estadual Benta Pereira). The black circle is the mangroves in the Paraíba do Sul River estuary.

regulation. Support services included the conditions for the existence of other ES, such as oxygen production, nutrient cycling and primary production. Cultural services were described by reports on the utilization of mangrove areas for recreational, aesthetic, educational and spiritual purposes. Reports that did not show any recognition of the ES provided by the mangroves were classified as 'do not recognize' (Table 1).

The results were analyzed by frequency (%), and each student could mention one or more values and/or ES. The difference between schools was tested with a normal chi-square test ($p < 0.05$) in Statistica for Windows 12.

RESULTS

According to the response classification, 46% of the CEEMM students considered the mangrove as a source of economic value, mentioning its importance for the livelihoods of local families. In CEBP, this percentage was lower (15%) in reference to the use of the ecosystem for the commercialization of the crab *U. cordatus* (Table 1). Meanwhile, most CEBP students (51%) recognize the resources provided by the mangrove as having ecological value, while at CEEMM, this proportion was lower (16%) (Table 1). The students highlighted the importance of the main ecological roles of the ecosystem in the maintenance of native species, nursery area and air purification ('filter') as the main ecological roles. The cultural values were also different between the two schools (CEEMM: 16%; CEBP: 4%; Table 1) and were related to leisure and tourism. Decontextualized reports or those that did not attribute any value to the mangroves (null responses) were present for 16% and 29% of respondents from CEEMM and CEBP, respectively.

The main ES recognized by CEEMM (49%) and CEBP (46%) students were provision services, which were related to the commercial fishing of the crab *U. cordatus*. The importance of ES regulation for the balance of other ecosystems was reported by 17% of respondants at CEBP and only 6% at CEEMM, however, CEEMM students recognized cultural ES more than the CEBP students did (18% vs. 4%) (Table 1). The support services were poorly recognized in both schools (4%), and more than 20% of respondents in the schools did not recognize any ES provided by the mangroves (Table 1).

Table 1. Comparisons between the high school students from CEEMM (Colégio Estadual Ercilia Muylaert de Menezes) and those from CEBP (Colégio Estadual Benta Pereira) regarding the values and ecosystem services (ES) provided by the mangroves in the Paraíba do Sul River estuary (*p < 0.05).

Ecosystem values/services	% Positive		*p*-values
	CEEMM	CEBP	
Values			
Economic	46	15	<0.001*
Ecological	16	51	<0.001*
Cultural	16	4	0.014*
Null/No response	16	29	0.050
Others	6	1	0.962
Ecosystem services			
Provision	49	46	0.709
Support	4	4	1.000
Regulation	6	17	0.031*
Cultural	18	4	0.006*
No response/do not recognize	23	29	0.394

DISCUSSION

The assumption that the value attributed to the mangroves from the Paraíba do Sul River estuary and ES recognition would be higher among CEEMM students because of their proximity to the mangrove area, their daily experiences and the economic dependence of local families on the mangroves was not confirmed. In fact, due to the Brazilian educational model, students from both schools were expected to demonstrate a greater understanding of what the mangrove ecosystem represents and to recognize the value and the provided ES.

In Brazil, the guidelines for educational practices in basic education (elementary and high school) are established by the National Curriculum Parameters (*Parâmetros Curriculares Nacionais* - PCNs), which are documents from the Ministry of Education. In these documents, 'environment' is one of the transversal themes that must be addressed by Brazilian schools in a continuous, systematic and comprehensive way (Brasil 1997; Chaves & Barbosa 2015). Thus, it is expected that all Brazilian students, regardless of their regional origin, proximity or distance from natural ecosystems, would have comparable knowledge about the environment. Bomfim et al. (2013) evaluated 'environment' and 'health' as transversal themes in Brazilian schools and concluded that they were recognized but not covered comprehensively. In general, these themes are included in events on the annual school calendar and addressed in a fragmented way.

Most CEEMM students attributed economic value to the mangroves, emphasizing provision services and frequently mentioning the crab *U. cordatus*. This corroborates the results of Côrtes et al. (2019), who analyzed the sustainability of this crab fishery in the same region from interviews with local fishers, many of who were relatives of CEEMM students (A.P.M. Di Beneditto, personal observation). The fishers attributed high economic value to the ecosystem, with a direct use value because of their economic dependence (crab fishing). In contrast, the CEBP students live in urban areas and have no direct economic relationship with mangroves. Thus, the low perception of the economic value of the ecosystem was already expected, however, these students recognized provision as the main ES provided by the mangroves. This might be related to crab marketing and consumption. In northern Rio de Janeiro State, the production of *U. cordatus* is mainly destined for Campos dos Goytacazes city, where CEBP is located, with sales in natura of live animals in markets and even on the city streets (Côrtes et al. 2014).

The difference between students regarding mangrove ecological value (CEEMM: 16% vs. CEBP: 51%) was unexpected since the educational guidelines are the same for both schools (Brazil 1997). One possible explanation would be the differences in the way that each school addresses the 'environment' (and ecosystems) as a transversal theme, but this different was not verified for further conclusions. The ecological value attributed to the mangrove would presuppose the recognition of both support and regulation ES, however, these were the least commonly recognized ES in both schools (Table 1). These values are more critical for CEEMM, which is located close to mangroves and educates students who are related to fishers. Because of their daily contact with this ecosystem, the local inhabitants can affect it more directly (e.g., cutting trees, dumping domestic waste and solid waste, illegal hunting) and, therefore, should act as partners in its conservation.

The students differed in their perceptions of the cultural value (and cultural ES) provided by the mangroves. At CEEMM, the greater value/recognition can be attributed to their utilization of mangroves for daily leisure, as previously described in Côrtes et al. (2019). The cultural ES provide several benefits for human beings, such as recreation, religious practices and cognitive development (Andrade & Romeiro 2009). The geographical distance of the CEBP students from the mangroves explained the low value/recognition the cultural purposes of this ecosystem.

More than 20% of students (in each school) did not recognize any ES provided by the mangroves, which is a cause for concern. Limited knowledge of mangrove-related values indicates that the education about environmental issues in schools is insufficient. The difficulty in recognizing ecosystem functions may be related to fragmented teaching, which does not encourage students to assimilate and integrate information (Vairo & Filho 2010; Bomfim et al. 2013). When perceiving themselves as agents of change for the environment, students can positively assist in conservation.

In conclusion, the importance of the mangroves was mainly related to their economic role (economic value and provision ES) and not to their ecological role. The importance of the ecosystem was attributed mainly to the value of direct use (economic), such as crab fishing, which can encourage the conservation of its resources as a whole, however, this value cannot be the only parameter considered for the conservation of the ecosystem. Thus, we suggest that environmental education activities should be performed regularly at CEEMM and CEBP, including lectures and guided visits to the mangroves and the distribution of alternative material, such as booklets and brochures that detail what mangroves represent to the balance of coastal areas. These activities will consolidate student knowledge about the ecosystem and highlight its importance in providing support and regulation for coastal areas and as a hotspot for tropical biodiversity conservation that goes beyond the habitat of the crab *U. cordatus*.

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COMMUNICATION

Woody species diversity from proposed ecologically sensitive area of northern Western Ghats: implications for biodiversity management

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Abstract: The Western Ghats of India support an array of tropical forests ranging from wet evergreen to scrub formations. Several endemic and threatened plant species are located in areas other than protected areas (PAs). There is an urgent need to understand species diversity in areas other than PAs, for effective management of tropical forests. In this context, reserve forests and informal PAs of Amboli from northern Western Ghats have been investigated. Woody species composition, diversity, and stand structure were assessed by laying quadrats and transects (n=46, area=2.575ha) in closed and open canopy forest patches covering habitat heterogeneity and environmental gradient of the area. A total of 2,224 individuals (of 87 species, 68 genera, and 35 families) was enumerated. *Memecylon umbellatum*, *Syzygium cumini*, and *Diospyros nigrescens* were found to be the most dominant species as per importance value index. Melastomataceae was the most dominant family as per family importance value, whereas Euphorbiaceae and Rutaceae were the most speciose. Fourteen IUCN Red List assessed species and 18 species endemic to the Western Ghats were encountered. Endemic species accounted for nearly 20% of the total number of individuals sampled. Demographic profile exhibited reverse 'J' pattern. Average basal area was 27.02m^2 per hectare. Woody species diversity of Amboli forests was found comparable with other PAs from northern Western Ghats. Amboli and the adjoining area have been proposed as ecologically sensitive and in the wake of anthropogenic and developmental pressures they experience, it calls for urgent conservation attention.

Keywords: Endemicity, protected area comparison, species composition, stand structure

Abbreviations: BMC—Biodiversity Management Committee | DPL—Dry period length | E—Evergreen | ESA—Ecologically sensitive area | FIV—Family importance value | GBH—Girth at breast height | GPS—Global positioning system | IUCN—International Union for Conservation of Nature | IVI—Importance value index | MSL—Mean sea level | NP—National park | NWG—Northern Western Ghats | PA—Protected area | RF—Reserve forest | SWG—Southern Western Ghats | VU—Vulnerable | WG—Western Ghats | WS—Wildlife sanctuary.

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INTRODUCTION

Woody species form an important component of the forest landscape both because of their diversity and biomass. They play a vital role in shaping overall structural dynamics of the forest stands and offer various kinds of 'ecosystem services'. Of the 36 global hotspots of biodiversity, Western Ghats, extending along the western coast of India, along with Sri Lanka comprise the Western Ghats-Sri Lanka hotspot (Conservation International 2019; Myers et al. 2000). Western Ghats of India occupy the fifth position in the world in terms of economic potential of their biological resources (Ganeshaiah & Shaanker 2007). It is globally, an area of high endemism with 1,500 endemic species of which 352 are woody plant species and also houses over 4,000 medicinal plants species. WGs support an array of tropical forest types ranging from wet evergreen to scrub formations covering an area of about 1,64,284km^2 (Kasturirangan et al. 2013). Although nearly 10 percent of the Western Ghats hotspot is under formal protection, it has been pointed out that PAs in this region have historically been established on an ad-hoc basis with little attention to diversity distribution (Bhagwat et al. 2005). There is indeed a growing recognition that PAs cannot be conceived and managed as "islands" isolated from other PAs and from the rest of the landscape context (Laurance et al. 2012). Hence, there is a need to recognize high potential of informal protected areas such as sacred groves for effective conservation management (Bhagwat & Rutte 2006) that can supplement the PA diversity. The conservation management in the region needs to address the following questions: (1) do existing PAs adequately represent the biodiversity? (2) do excluded forest patches sustain more species than PAs? and (3) how many PAs are required to cover the entire gamut of biodiversity? Considering the high endemism, it is necessary and urgent to evaluate conservation potential andecosystem services of the buffer areas surrounding the PAs or other areas not included in formal PA network.

CEPF (2007) report showed that NWG have presence of more fragmented forests patches than the southern Western Ghats (SWG) and are under the pressures of selective logging, excessive grazing, fire, and road construction. Though sporadic records of quantitative inventorization of forest stands from PAs of NWG area available (Kanade et al. 2008; Joglekar et al. 2015), lack of focused studies on diversity that exists outside PAs in fragmented forests is a major challenge in understanding changes in forest community under anthropogenic impacts. Understanding the spatial distribution of these forests, their conservation significance and knowledge of vegetation types thus, becomes essential for outlining effective management strategies.

The forests of Amboli area act as a transition zone between NWG and SWG. CEPF (2007) report identified Amboli region as an irreplaceable site for certain globally threatened species that lack formal protection. Four new faunal species were described from Amboli region in a span of less than five years (Satose et al. 2018). The forests of Amboli experience high developmental pressures owing to growing tourism enterprises, necessitating conservation planning, for which exploration of the region's diversity is necessary. In this paper, we have characterized the woody species diversity, composition and stand structure of Amboli forests from relatively less explored area of NWG.

MATERIAL AND METHODS

Study area

NWGs in Maharashtra range from 15.5°–20.5°N & 73°–74°E. Popularly known as Sahyadri, the forests in this region are highly seasonal (annual rainfall range: 50–7000 mm, dry period length (DPL): 8–9 months, temperature: 10–40 ^{0}C). Amboli (MSL=700m) is located in Sawantwadi Taluka of Sindhudurg District of Maharashtra (Figure 1) in NWG. Although the area lies outside the formal PA network, it includes private forests, reserved forests and community owned forests spread across 659.88ha (Bharmal et al. 2011). Fragmented forests of Amboli form a mosaic of different vegetation and habitat types. Primary vegetation type is evergreen (closed canopy: >60% and height 15–20m), with stunted vegetation around lateritic outcrops (open canopy: 20–40%, height 5–8m) (Image 1). These together harbor endemic and threatened plant species and unique ephemeral flush vegetation that characterize lateritic plateaus. The area is proposed as ecologically sensitive (Maharashtra Government Resolution) and also forms a part of geographically and ecologically important Sahyadri-Konkan Ecological corridor (CEPF 2007).

It is the type locality of species like a Caecilian *Gegeneophis danieli* (Giri et al. 2003), Amboli Tiger Toad *Xanthophryne tigerina* (Biju et al. 2009), leaping frog *Indirana chiravasi* (Padhye et al. 2014) and water snake *Rhabdops aquaticus* (Giri et al. 2017). Biologists who studied the diversity of avifauna and Lepidoptera (Bharmal et al. 2011; Satose et al. 2018) concluded that the area is rich in biological diversity. Though the area has been explored in details for faunal diversity,

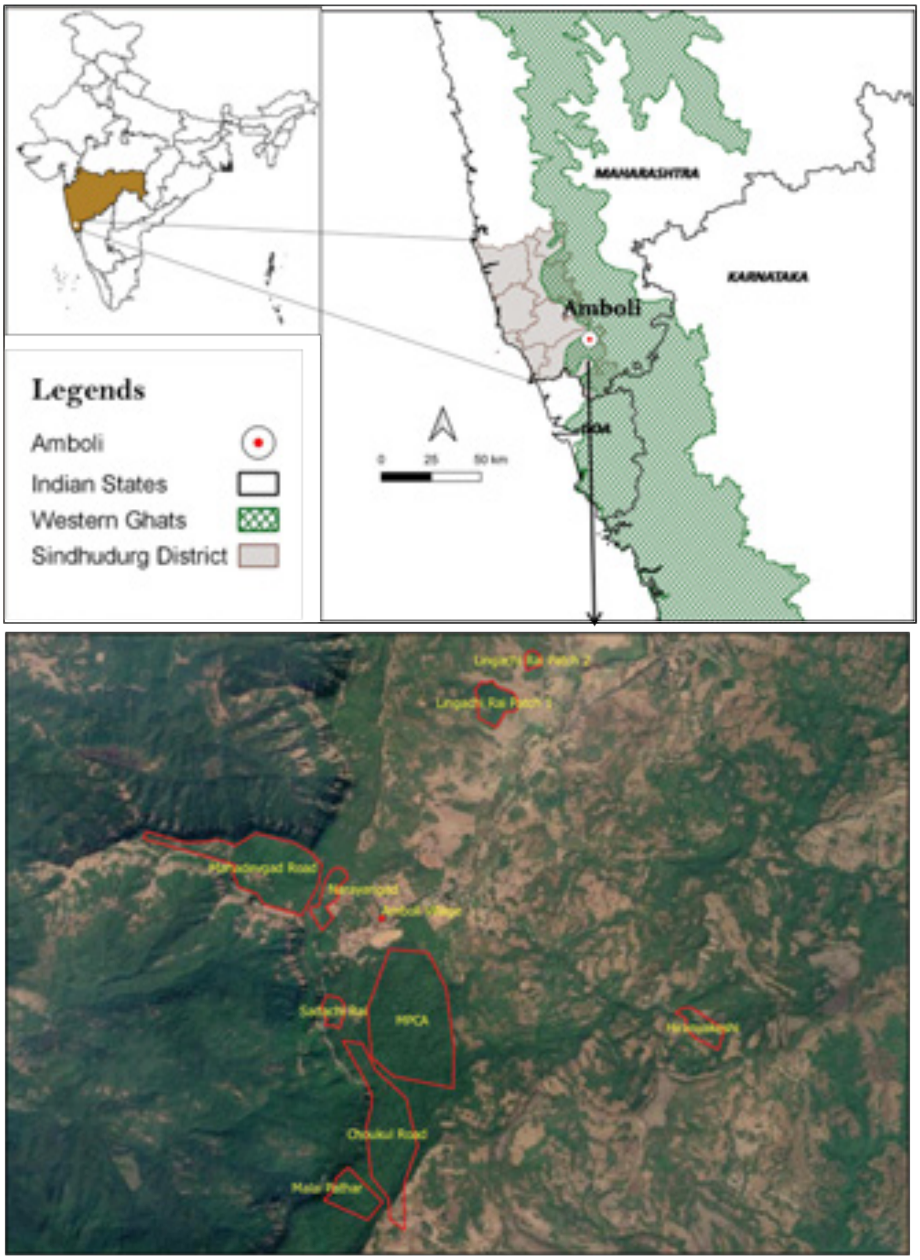

Figure 1. Study area. Source: QGIS Development Team (2019)

comprehensive taxonomic floristic studies are rare (Kulkarni 1988; Almeida 1990). There is dearth of quantitative ecological studies.

Amboli is a famous destination for tourists and naturalists alike due to picturesque landscapes, waterfalls and faunal sightings. But owing to the unplanned and unregulated tourism, the area witnesses encroachment into the forested landscapes, logging, and poorly planned construction.

Sampling design

Standard methods of woody vegetation analysis were followed (Ganesh et al. 1996; Sutherland 2006). Species composition and diversity were assessed by laying quadrats (n=40, size 20 x 20 m) and transects (n=6) in closed and open canopy forest patches covering habitat heterogeneity. It was ensured that the sampling plots cover significant environmental gradient of the area. Transect length varied from 500 x 5 m or 250 x 5 m or 200 X 5m depending on the patch size. Each quadrat and transect was marked by GPS. The total area sampled was 2.575ha and intensity of sampling amounts to 0.39% of sampling, which is more than a standard requirement of 0.01% for such enumerations (Shivraj et al. 2000).

Image 1. Habitat and disturbance in the study area: A—Evergreen forests | B—Lateritic plateaus | C—Open scrub along forest edge | D—Sacred grove | E—Expanding habitation in natural areas | F—Construction debris and littering | G—Tree cutting | H—Roadkill - snake. © Ankur Patwardhan, Medhavi Tadwalkar & Amruta Joglekar.

Vegetation composition, stand structure and diversity assessment

All woody species were enumerated for individual height and girth (≥15cm at 1.3m height above ground) measurements. Species level identification was done using regional flora (Almeida 1990; Singh et al. 2001). Endemicity and IUCN Red List status of the species were assignedby referring to standard literature (Pascal 1988; BIOTIK 2008; Singh et al. 2015; https://www.iucnredlist.org/). Data collected from quadrat and transect sampling were used to understand woody species composition and diversity. For stand structure and basal area estimates data from quadrats was used. Importance value index (IVI) and family importance value (FIV) were calculated as per Ganesh et al. (1996). For the diversity estimates, data from quadrats and transects was pooled. Diversity was estimated using Shannon's index (H') as per Magurran (2004). Compositional similarity between sampled plots was assessed by Bray Curtis similarity index calculated using PAST (version 3). Correlation analysis was performed using the R software (version 3.5.1).

RESULTS

(A) Woody species composition and diversity

A total of 2,224 individuals were sampled during the study representing 87 species spanning across 68 genera and 35 families. Genus *Diospyros* was found to be the most diverse genus with four species followed by *Ixora* and *Ficus* (represented by three species each). Fifty-six genera (82%) were represented by only one species in the sampled area. Figure 2 represents 10 most abundant genera in the sampled area with corresponding abundance.

Out of 87 species that were encountered during the study, *Memecylon umbellatum* was found to be the most abundant species in the area (N=501, 22.53%) followed by *Mallotus phillipensis*, *Syzygium cumini*, *Diospyros candolleana*, *Symplocos racemosa*, and *Diospyros nigrescens*. These six species together contributed to 56.11% of the total abundance. A long tail of singleton species was seen where, singleton species and doubleton species contributed to 24.1% (n=21) and 12.6% (n=11), respectively, to the stand structure. *Persea macrantha*, *Homalium ceylanicum*, and *Mitragyna praviflora* were among a few species represented by only one individual and *Euonymus indicus*, *Lagerstroemia microcarpa*, and *Litsea deccanensis* were represented by two individuals. Table 1 depicts various phyto-sociological attributes from the sampled plotsin the study area. The abundance in the sampled plots varied greatly from one individual (OLR2, OMD2) to 384 individuals (CCR3); whereas number of species ranged from 1 (OLR2, OMD2) to 32 (CCR3). Maximum number of woody endemic species (9) was reported from Malai Pathar (CMP4), whereas Mahadevgad road (CMD1) showed highest number of endemic individuals (59). Presence of WG endemic species, *Diospyros candolleana* was a notable feature in this area. Shannon index varied from 0 to 2.86 within sampled plots, '0' being recorded for two open forest plots which were represented by single individual. In order to get insights into the contribution of singleton and doubleton species in overall woody species diversity of the area, Shannon index value was plotted against the proportion of singleton and doubleton species in the sampled plots, depicted in Figure 3 (r=0.798, p<0.001).

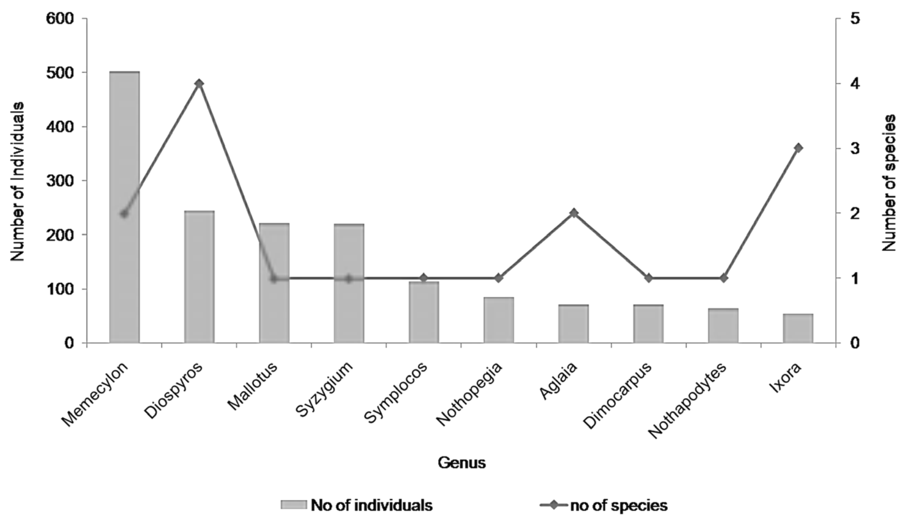

Figure 2. Ten most abundant genera with number of species.

Table 1. Diversity parameters in the sampled plots.

Area	Plot code	No. of species	No. of families	Stem density per sampling unit	Endemic species*	IUCN assessed species	Shannon index
Choukul Road	CCR1	16	13	68	2 (5)	3 (7)	1.97
	OCR1	5	5	8	1 (3)	0	1.39
	CCR4#	17	13	76	4 (23)	4 (15)	2.19
	CCR5	9	9	60	3 (29)	0	1.54
	CCR2	18	14	79	4 (10)	3 (9)	2.39
	CCR3##	32	22	384	6 (35)	3 (32)	2.59
Hiranyakeshi	CHR1	9	7	28	3 (5)	2 (3)	1.53
	OHR2	4	4	5	1 (1)	0	1.33
	CHR3	19	14	50	2 (7)	0	2.14
	OHR4	5	5	8	1 (6)	0	1.49
Lingachi Rai	CLR1	11	9	35	2 (8)	4 (12)	2.04
	OLR2	1	1	1	0	1 (1)	0
	OLR3	11	8	33	7 (16)	5 (15)	2.18
	CLR2	16	11	30	5 (7)	5 (13)	2.54
	CLR3	13	10	42	4 (9)	6 (20)	2.32
	CLR4	13	9	28	5 (11)	4 (14)	2.33
	CLR5	5	4	16	1 (1)	2 (7)	1.13
	CLR6	12	10	28	3 (10)	4 (9)	2.29
	CLR7	13	10	31	5 (11)	4 (14)	2.36
	CLR8	9	7	33	2 (5)	4 (16)	1.87
	OLR1	4	3	5	0	0	1.33
Mahadevgad Road	CMD1	16	11	67	5 (59)	2 (11)	2.41
	OMD1	5	5	16	0	0	1.23
	CMD2	11	9	35	2 (10)	2 (2)	1.67
Malai Pathar	CMP1#	19	15	119	4 (29)	2 (21)	2.44
	CMP2	12	9	39	3 (6)	2 (6)	2.21
	CMP3	15	13	43	6 (8)	2 (2)	2.33
	CMP4##	29	19	209	9 (45)	3 (47)	2.86
MPCA	CCR6###	27	17	124	7 (14)	2 (2)	2.71
	CMC1	12	11	39	3 (5)	1 (2)	2.01
	CMC2	12	10	43	2 (10)	2 (11)	1.98
	CMC3	16	13	47	7 (17)	3 (4)	2.33
	CMC4	6	5	43	3 (13)	1 (5)	1.21
	CMC5#	17	15	99	4 (15)	2 (10)	2.3
Narayangad	OMD2	1	1	1	1 (1)	0	0
	OMD3	4	4	9	2 (5)	0	1.22
Sadachi Rai	CSR1	12	10	24	4 (17)	2 (11)	2.31
	OSR5	8	8	14	3 (6)	0	1.95
	CSR2	15	12	26	3 (9)	3 (10)	2.56
	CSR3	18	13	52	5 (21)	2 (15)	2.49
	CSR4	12	9	29	6 (27)	3 (9)	2.29
	CSR5	14	10	34	6 (9)	2 (13)	2.30
	OSR1	7	6	17	3 (15)	0	1.79
	OSR2	6	6	11	1 (7)	0	1.59
	OSR3	5	5	15	1 (7)	0	1.23
	OSR4	7	7	21	2 (10)	0	1.61

*Values in the parentheses depict the number of individuals encountered
All sampling units are primarily quadrats (20 x 20m, n=40) except # Transects: 250 x 5m (n=3); ##Transects: 500 x 5m (n=2) & ###Transects: 200 x 5m (n=1)

Table 2. Species encountered in the sampled plots and their attributes.

	Species	Family	Number of Individuals	Dispersal Mode#	E/D Habit$	Forest strata*	Endemicity	IUCN Red List category##
1	*Aglaia lawii*	Meliaceae	54	Z	E	C		LC
2	*Aglaia* sp.	Meliaceae	17	Z	E	C		
3	*Allophylus cobbe*	Sapindaceae	2	Z	E	Liana		
4	*Alstonia scholaris*	Apocynaceae	1	An	E	C		LC
5	*Ardisia solanacea*	Myrsinaceae	3	Z	E	U		
6	*Artocarpus hirsutus*	Moraceae	2	Z	E	C		LC
7	*Atalantia racemosa*	Rutaceae	28	Z	E	M		
8	*Beilschmiedia dalzellii*	Lauraceae	23	Z	E	C	WG	
9	*Blachia denudata*	Euphorbiaceae	10	At	E	U	WG	
10	*Bridelia retusa*	Euphorbiaceae	3	Z	D	M		
11	*Callicarpa tomentosa*	Verbenaceae	3	Z	E	U		
12	*Canthium anguistifolium*	Rubiaceae	1	Z	E	Liana		
13	*Canthium dicoccum*	Rubiaceae	1	Z	E	M		VU
14	*Canthium rheedei*	Rubiaceae	1	Z	E	U		
15	*Carallia brachiata*	Rhizophoraceae	3	Z	E	C		
16	*Careya arborea*	Lecythidaceae	6	Z	D	M		
17	*Carissa congesta*	Apocynaceae	1	Z	E	U		
18	*Carissa inermis*	Apocynaceae	9	Z	E	Liana		
19	*Caryota urens*	Arecaceae	10	Z	E	C		LC
20	*Casearia graveolens*	Flacourtiaceae	1	Z	E	U		
21	*Casearia* sp.	Flacourtiaceae	5	Z	E	U		
22	*Catunaregam spinosa*	Rubiaceae	28	Z	D	C		
23	*Celtis timorensis*	Ulmaceae	3	Z	E	C		
24	*Cinnamomum verum*	Lauraceae	6	Z	E	C		
25	*Clausena anisata*	Rutaceae	2	Z	E	C		
26	*Clausena indica*	Rutaceae	9	Z	E	U		
27	*Combretum extensum*	Combretaceae	1	An	D	Liana		
28	*Combretum ovalifolium*	Combretaceae	1	An	D	Liana		
29	*Connarus wightii*	Connaraceae	1	At	E	Liana		
30	*Dichapetalum gelonioides*	Dichapetalaceae	10	Z	E	U		
31	*Dimocarpus longan*	Sapindaceae	71	Z	E	C		NT
32	*Dimorphocalyx lawianus*	Euphorbiaceae	18	At	E	U	WG	
33	*Diospyros candolleana*	Ebenaceae	115	Z	E	C	WG	VU
34	*Diospyros montana*	Ebenaceae	16	Z	D	C		
35	*Diospyros nigrescens*	Ebenaceae	112	Z	E	M	WG	
36	*Diospyros* sp.	Ebenaceae	1	Z	E	M		
37	*Drypetes venusta*	Euphorbiaceae	10	Z	E	M	WG	
38	*Dysoxylum binectariferum*	Meliaceae	11	Z	E	C		
39	*Euonymus indicus*	Celastraceae	2	Z	E	C	WG	
40	*Ficus exasperata*	Moraceae	1	Z	D	U		LC
41	*Ficus racemosa*	Moraceae	7	Z	D	C		
42	*Ficus* sp.	Moraceae	1	Z	E	C		
43	*Flacourtia indica*	Flacourtiaceae	2	Z	D	U		
44	*Garcinia indica*	Clusiaceae	4	Z	D	M	WG	VU
45	*Garcinia talbotii*	Clusiaceae	20	Z	E	M	WG	

	Species	Family	Number of Individuals	Dispersal Mode#	E/D Habit$	Forest strata*	Endemicity	IUCN Red List category##
46	*Glochidion ellipticum*	Euphorbiaceae	17	At	E	C	WG	
47	*Glycosmis pentaphylla*	Rutaceae	5	Z	E	U		
48	*Heterophragma quadriloculare*	Bignoniaceae	11	An	D	C		
49	*Holigarna grahamii*	Anacardiaceae	29	Z	D	C	WG	
50	*Homalium ceylanicum*	Flacourtiaceae	1	Z	E	C		
51	*Hymenodyction obovatum*	Rubiaceae	1	Z	D	M		
52	*Ixora brachiata*	Rubiaceae	37	Z	E	M	WG	
53	*Ixora nigricans*	Rubiaceae	4	Z	E	U		
54	*Ixora* sp.	Rubiaceae	13	Z	E	U		
55	*Knema attenuata*	Myristicaceae	1	Z	E	C	WG	LC
56	*Lagerstroemia microcarpa*	Lythraceae	2	An	D	C	WG	
57	*Leeaindica*	Leeaceae	29	Z	E	U		
58	*Lepisanthes tetraphylla*	Sapindaceae	18	At	E	M		
59	*Ligustrum perrottetii*	Oleaceae	18	Z	D	M	WG	
60	*Litsea deccanensis*	Lauraceae	2	Z	E	U		
61	*Litsea stocksii*	Lauraceae	4	Z	E	M	WG	
62	*Mallotus philippensis*	Euphorbiaceae	221	Z	E	C		
63	*Mangifera indica*	Anacardiaceae	24	Z	E	C		DD
64	*Meiogyne pannosa*	Annonaceae	3	Z	E	U	WG	
65	*Memecylon umbellatum*	Melastomataceae	501	Z	E	C		
66	*Memecylon wightii*	Melastomataceae	1	Z	E	U		
67	*Mimusops elengi*	Sapotaceae	9	Z	E	C		LC
68	*Mitragyna parviflora*	Rubiaceae	1	At	D	C		
69	*Moullava spicata*	Caesalpineaceae	2	At	E	Liana		
70	*Murraya koenigii*	Rutaceae	2	Z	E	U		
71	*Murraya paniculata*	Rutaceae	1	Z	E	U		
72	*Myristica dactyloides*	Myristicaceae	31	Z	E	U		VU
73	*Neolitsea cassia*	Lauraceae	1	Z	E	U		
74	*Nothapodytes nimmoniana*	Icacinaceae	64	Z	D	M		
75	*Nothopegia castaneifolia*	Anacardiaceae	84	Z	E	M		
76	*Olea dioica*	Oleaceae	31	Z	E	C		
77	*Oxyceros rugulosus*	Rubiaceae	1	Z	E	Liana		
78	*Persea macrantha*	Lauraceae	1	Z	E	C		
79	*Salacia chinensis*	Celastraceae	2	Z	E	U		
80	*Scutia myrtina*	Rhamnaceae	12	Z	E	Liana		
81	*Symplocos racemosa*	Symplocaceae	114	Z	E	C		
82	*Syzygium cumini*	Myrtaceae	185	Z	E	C		
83	*Syzygium hemisphericum*	Myrtaceae	35	Z	E	C		
84	*Tabernaemontana alternifolia*	Apocynaceae	14	Z	D	U	WG	NT
85	*Terminalia chebula*	Combretaceae	8	Z	D	C		
86	*Xantolisto mentosa*	Sapotaceae	46	Z	E	C		
87	*Ziziphus rugosa*	Rhamnaceae	2	Z	E	U		

Dispersal mode category: Z—Zoochory | At—Autochory | An—Anemochory |$ E/D habit: E—Evergreen | D—Deciduous | *Forest Strata: C—Canopy species | M—Middle Storey Species | U—Under storey |## IUCN category: DD—Data Deficient | NT—Near Threatened | LC—Least Concern | VU—Vulnerable.

Table 3. Importance Value Index of the species from the study area.

	Species	Frequency	Relative frequency	Density	Relative density	Basal area (m^2)	Relative dominance	IVI
1	*Memecylon umbellatum*	32	7.862	334	27.512	447.083	26.221	61.596
2	*Syzygium cumini*	22	5.405	75	6.178	264.011	15.484	27.067
3	*Diospyros nigrescens*	23	5.651	72	5.931	31.495	1.847	13.429
4	*Aglaia lawii*	16	3.931	54	4.448	85.247	5.000	13.379
5	*Dimocarpus longan*	14	3.440	45	3.707	81.107	4.757	11.903
6	*Holigarna grahamii*	12	2.948	26	2.142	101.144	5.932	11.022
7	*Diospyros candolleana*	18	4.423	48	3.954	38.110	2.235	10.612
8	*Mangifera indica*	9	2.211	24	1.977	107.012	6.276	10.464
9	*Nothopegia castaneifolia*	21	5.160	47	3.871	13.787	0.809	9.840
10	*Mallotus philippensis*	10	2.457	42	3.460	28.339	1.662	7.579
11	*Beilschmiedia dalzellii*	9	2.211	22	1.812	57.208	3.355	7.379
12	*Ixora brachiata*	13	3.194	34	2.801	14.830	0.870	6.865
13	*Symplocos racemosa*	9	2.211	35	2.883	22.388	1.313	6.407
14	*Catunaregam spinosa*	11	2.703	23	1.895	29.089	1.706	6.303
15	*Syzygium hemisphericum*	7	1.720	13	1.071	42.462	2.490	5.281
16	*Garcinia talbotii*	9	2.211	19	1.565	22.757	1.335	5.111
17	*Xantolisto mentosa*	9	2.211	20	1.647	18.739	1.099	4.958
18	*Atalantia racemosa*	11	2.703	17	1.400	5.826	0.342	4.445
19	*Nothapodytes nimmoniana*	6	1.474	28	2.306	11.032	0.647	4.428
20	*Caryota urens*	7	1.720	10	0.824	20.474	1.201	3.744
21	*Ligustrum perrottetii*	6	1.474	18	1.483	7.783	0.456	3.413
22	*Terminalia chebula*	7	1.720	8	0.659	16.206	0.950	3.329
23	*Ficus* sp.	1	0.246	1	0.082	47.130	2.764	3.092
24	*Glochidion ellipticum*	7	1.720	10	0.824	7.979	0.468	3.012
25	*Heterophragma quadriloculare*	7	1.720	11	0.906	6.233	0.366	2.992
26	*Dysoxylum binectariferum*	6	1.474	8	0.659	14.603	0.856	2.990
27	*Olea dioica*	6	1.474	9	0.741	7.341	0.431	2.646
28	*Drypetes venusta*	4	0.983	10	0.824	14.087	0.826	2.633
29	*Diospyros montana*	4	0.983	8	0.659	14.816	0.869	2.511
30	*Mimusops elengi*	5	1.229	9	0.741	7.271	0.426	2.396
31	*Ficus racemosa*	5	1.229	5	0.412	12.846	0.753	2.394
32	*Myristica dactyloides*	2	0.491	6	0.494	22.084	1.295	2.281
33	*Tabernaemontana alternifolia*	5	1.229	9	0.741	3.461	0.203	2.173
34	*Careya arborea*	5	1.229	6	0.494	5.774	0.339	2.061
35	*Lepisanthes tetraphylla*	5	1.229	6	0.494	2.792	0.164	1.886
36	*Scutia myrtina*	4	0.983	9	0.741	2.222	0.130	1.854
37	*Carissa inermis*	4	0.983	8	0.659	1.414	0.083	1.725
38	*Dimorphocalyx lawianus*	2	0.491	5	0.412	8.572	0.503	1.406
39	*Blachia denudata*	2	0.491	8	0.659	2.318	0.136	1.286
40	*Cinnamomum verum*	2	0.491	3	0.247	8.343	0.489	1.228
41	*Clausena indica*	1	0.246	9	0.741	2.175	0.128	1.115
42	*Carallia brachiata*	3	0.737	3	0.247	1.481	0.087	1.071
43	*Persea macrantha*	1	0.246	1	0.082	12.560	0.737	1.065

	Species	Frequency	Relative frequency	Density	Relative density	Basal area (m^2)	Relative dominance	IVI
44	*Dichapetalum gelonioides*	3	0.737	3	0.247	0.358	0.021	1.005
45	*Callicarpa tomentosa*	2	0.491	2	0.165	5.160	0.303	0.959
46	*Clausena anisata*	2	0.491	2	0.165	2.835	0.166	0.822
47	*Meiogyne pannosa*	2	0.491	3	0.247	1.005	0.059	0.797
48	*Bridelia retusa*	2	0.491	2	0.165	1.130	0.066	0.722
49	*Euonymus indicus*	2	0.491	2	0.165	0.674	0.040	0.696
50	*Neolitsea cassia*	1	0.246	1	0.082	6.243	0.366	0.694
51	*Leea indica*	1	0.246	5	0.412	0.574	0.034	0.691
52	*Ardisia solanacea*	2	0.491	2	0.165	0.184	0.011	0.667
53	*Glycosmis pentaphylla*	2	0.491	2	0.165	0.181	0.011	0.667
54	*Salacia chinensis*	2	0.491	2	0.165	0.167	0.010	0.666
55	*Artocarpus hirsutus*	1	0.246	2	0.165	2.033	0.119	0.530
56	*Lagerstroemia microcarpa*	1	0.246	1	0.082	3.267	0.192	0.520
57	*Celtis timorensis*	1	0.246	1	0.082	2.377	0.139	0.467
58	*Ziziphus rugosa*	1	0.246	2	0.165	0.537	0.031	0.442
59	*Moullava spicata*	1	0.246	2	0.165	0.411	0.024	0.435
60	*Flacourtia indica*	1	0.246	2	0.165	0.362	0.021	0.432
61	*Allophylus cobbe*	1	0.246	2	0.165	0.182	0.011	0.421
62	*Murraya koenigii*	1	0.246	1	0.082	1.583	0.093	0.421
63	*Casearia* sp.	1	0.246	2	0.165	0.171	0.010	0.420
64	*Alstonia scholaris*	1	0.246	1	0.082	1.016	0.060	0.388
65	*Garcinia indica*	1	0.246	1	0.082	0.723	0.042	0.371
66	*Murraya paniculata*	1	0.246	1	0.082	0.430	0.025	0.353
67	*Knema attenuata*	1	0.246	1	0.082	0.407	0.024	0.352
68	*Mitragyna parviflora*	1	0.246	1	0.082	0.246	0.014	0.343
69	*Combretum extensum*	1	0.246	1	0.082	0.152	0.009	0.337
70	*Diospyros* sp.	1	0.246	1	0.082	0.152	0.009	0.337
71	*Memecylon wightii*	1	0.246	1	0.082	0.152	0.009	0.337
72	*Canthium anguistifolium*	1	0.246	1	0.082	0.138	0.008	0.336
73	*Connarus wightii*	1	0.246	1	0.082	0.126	0.007	0.335
74	*Carissa congesta*	1	0.246	1	0.082	0.091	0.005	0.333
75	*Casearia graveolens*	1	0.246	1	0.082	0.091	0.005	0.333
76	*Combretum ovalifolium*	1	0.246	1	0.082	0.091	0.005	0.333
77	*Oxyceros rugulosus*	1	0.246	1	0.082	0.085	0.005	0.333
78	*Litsea deccanensis*	1	0.246	1	0.082	0.080	0.005	0.333

The results showed highly significant relation indicating contribution of rare speciesin the overall diversity of the study area.

Table 2 gives various species attributes of the study area. Fourteen IUCN assessed species together accounted for 15% of the total number of individuals encountered. *Diospyros candolleana*, listed in the Vulnerable (VU) category, was found to be one of the dominant species in the study area. Evergreen (E) is the dominant habit represented by 78% of species which are mainly distributed in closed forest patches. Eighty-six percent of species showed zoochory as a dispersal mode. An attempt has also been made to assign species status (canopy / middle storey / understorey) as per the vegetation strata observed in the study area.

Cluster analysis (Figure 4) revealed that maximum species similarity of the plots was observed to be ca. 74%. Quadrats laid in Lingachi rai sacred grove area (a community owned forest), formed a cluster. This cluster exhibits low similarity with the other quadrats taken in reserve forests, private forests and Sadachi rai (a sacred grove situated in the reserved forests). It is interesting to note here that these quadrats despite being laid in the closed forests exhibit different patterns. Open forest patches showed lowest (2% to 20%) species compositional similarity with closed forest patches.

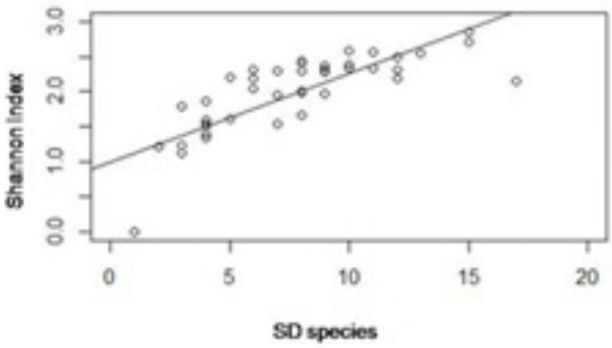

Figure 3. Relation of singleton and doubleton species (SD species) with the Shannon diversity index.

(B) Importance Value Index (IVI) and Family Importance Value (FIV)

Data collected through quadrat sampling (S=78, N=1213) was used for the estimation of IVI and FIV. *Memecylon umbellatum* was found to be the most dominant species as per IVI (Table 3). Though represented by only 6% of individuals, *Syzygium cumini* was found to be second most important species due to its high basal area followed by *Diospyros nigrescens, Aglaia lawii*, and *Dimocarpus longan*. Family Melastomataceae represented by the genus *Memecylon* in the study area, showed the highest FIV (56.38) due to its abundance as well as the basal area. Families Myrtaceae, Anacardiaceae, Ebenaceae, and Euphorbiaceae were found to be the other most important families as per FIV (Figure 5). Euphorbiaceae and Rutaceae were the most speciose families with six species each followed by Lauraceae and Rubiaceae (5 species each).

(C) Stand structure

The girth class distribution showed typical reverse 'J' shaped curve (Figure 6). First three GBH classes, i.e., 15–30cm, 30–45cm, and 45–60 cm contributed to 73% of the individuals (no. of species=70) (Figure 7). Less than 1% individuals were represented in GBH class > 210cm. They were comprised by species such as *Holigarna grahamii, Persea macrantha, Syzygium cumini*, *Mangifera indica*, and *Memecylon umbellatum*. Total basal area recorded was 43.23m^2. GBH classes (45–120 cm) contributed to highest basal area (40.99%), however, it should be noted that maximum number of individuals was found among lower GBH classes with subsequent GBH classes showing steady decrease in number of individuals (Figure 7). Basal area decreased with increasing GBH which was depicted by very low abundance. Stand basal area of *Memecylon umbellatum* and *Syzygium cumini* was around 41% of the total basal area.

(D) Endemic species diversity and abundance

Of the total number of species recorded, 18 species were Western Ghats endemics and accounted for nearly 20% of the total number of individuals sampled. Genus *Diospyros* (represented by two endemic species – *D. candolleana* and *D. nigrescens*) comprised of 51.8% of the endemic individuals. *D. candolleana* (VU) was also found to be one of the dominant species in the study area as revealed from IVI. *Drypetes venusta, Knema attenuata*, and *Meiogyne pannosa* were encountered only in the sacred groves. Sacred groves also showed presence of *H. grahamii* (>195cm) and *Beilschmiedia dalzellii* (>180cm). Such hefty individuals of these species were seldom seen elsewhere highlighting the significance of protection of sacred groves in biodiversity conservation. Endemic species richness also exhibited highly significant relation with Shannon diversity (r=0.766, p<0.001) (Figure 8).

(E) Woody species diversity across various PAs vis-a-vis vegetation at Amboli

Table 4 represents various ecological attributes from

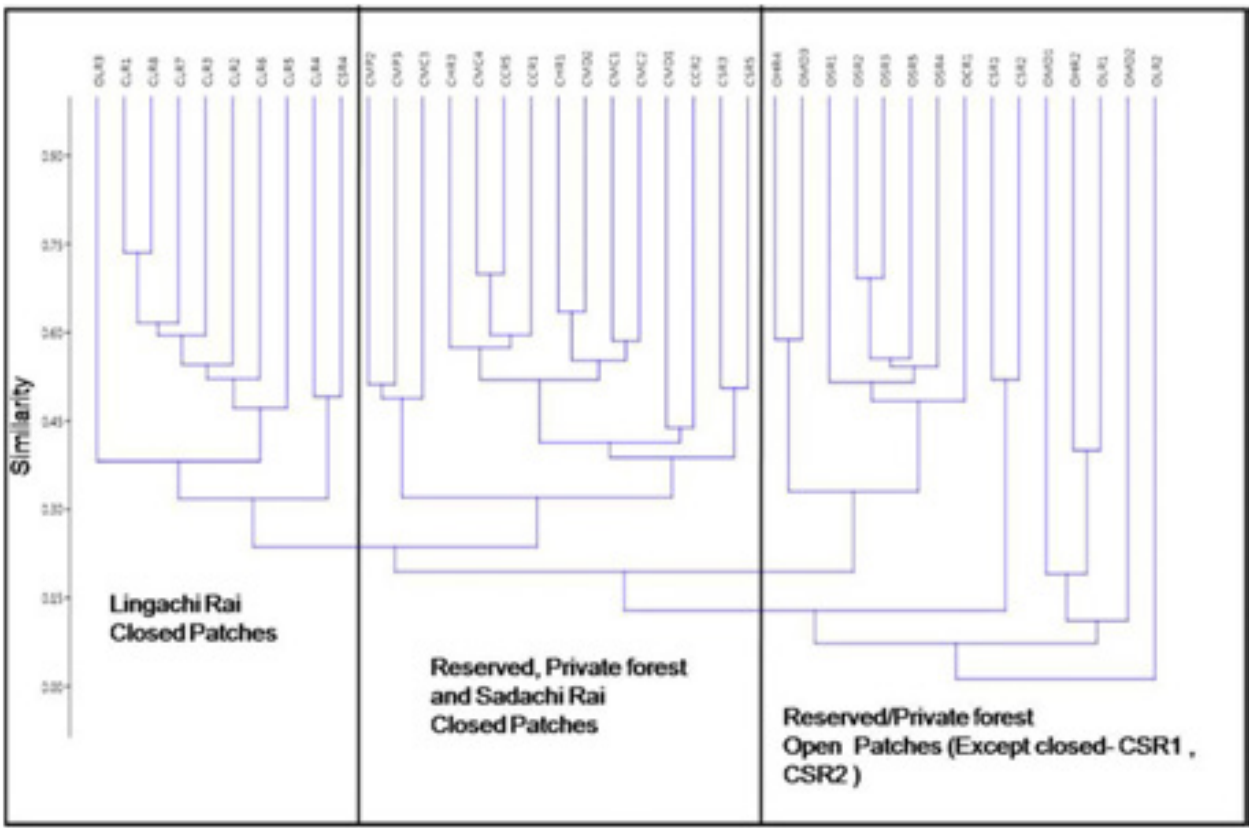

Figure 4. Bray-Curtis similarity plot based on species composition.

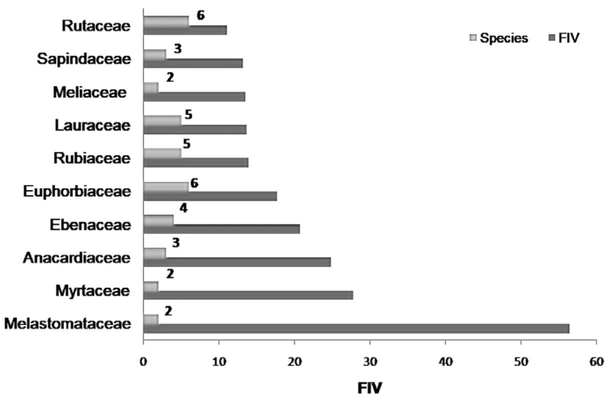

Figure 5. Family dominance based on FIV.

study area and compares it with similar such studies conducted elsewhere inside PAs and reserve forests of NWG.

DISCUSSION

Present study provides systematic account of woody species composition of Amboli forests. In comparison with studies from protected areas from NWG, the sampled area showed high species richness and abundance (Table 4). Out of 35 families, Euphorbiaceae and Rutaceae were found to be diverse families of Amboli forest followed by Lauraceae and Rubiaceae. Though highly diverse, Lauraceae and Rubiaceae showed lower FIV values due to its lower density and lower basal area as similar to studies conducted in Kalakad-Mundanthurai forests of SWGs by Ganesh et al. (1996). As per FIV, Melastomataceae was found to be the most dominant family which is very similar to family dominance in Chandoli NP (Kanade et al. 2008) and Koyna WS (Joglekar et al. 2015). Puri et al. (1983) and Pascal (1988) assigned *Memecylon-Syzygium-Actinodaphne* (M-S-A) floristic series to evergreen forests of NWG based on the criteria of dominance–abundance–fidelity. Current study revealed *Memecylon-Syzygium–Diospyros* type which is found to be different from *Memcylon-Syzygium-Olea* type found in protected areas of NWG (Table 4). *M. umbellatum,* the most dominant species

Table 4. Woody plant species diversity in Amboli vis-à-vis PAs and RF from northern Western Ghats.

Study area	Present study Amboli forest	Mulshi forest (Watve et al. 2003)	Chandoli NP (Kanade et al. 2008)	Koyna WS (Joglekar et al. 2015)	Radhanagari WS (Unpublished data)	Fragmented forest of Mulshi Taluka (Kasodekar et al. 2019)
Location	15.95⁰N & 74⁰E	18.43⁰N & 73.42⁰E	17.12⁰N & 73.85⁰E	17.42⁰N & 73.77⁰E	16.40⁰N & 73.98⁰E	18.53⁰N & 73.42⁰E
Annual Rainfall (mm)	7000	6500	6200	5000	5000	6500
Altitude (m)	600–700	500–1000	589–1044	740–1005	579–853	700–1000
Dry period length	7 months	8–9 months	8–9 months	8–9 months	8 months	8–9 months
Forest type	Evergreen	Semi evergreen	Evergreen, semi evergreen	Evergreen, semi evergreen, moist deciduous	Evergreen, semi evergreen, moist deciduous	Semi evergreen forest
Area sampled (ha)	2.575	0.635	5	6	6.5	0.3
Species encountered	87	52	107	108	165 (Includes unidentified species)	49
Girth class measured	≥15cm	≥10cm	≥15cm	≥15cm	≥15cm	>10cm
Total no. of individuals	2224	-	4200	4296	4754	444
Density	1213 individuals/1.6ha	633–1720 individuals/ha	149–657 individuals /0.5ha	84–544 individuals /0.5ha	140–648 individuals /0.5ha	-
No. of endemic species	18	-	13	21	17	4
IUCN assessed species	14	-	-	13	-	-
Basal area	27.02m²/ha	14.5–72.9 m²/ha	10.22–57.16 m²/ha	6.76–58.23 m²/ha	20.33m²/ha	-
Floristic series	Memecylon-Syzygium-Diospyros	Dimocarpus-Aglaia-Ficus nervosa	Memecylon-Syzygium-Olea	Memecylon-Syzygium-Olea	Memecylon-Syzigium-Olea	-
Shannon index	0–2.86	2.1–3.83	2.0–3.2	1.5–3.03	2.52–3.47	2.97–3.26

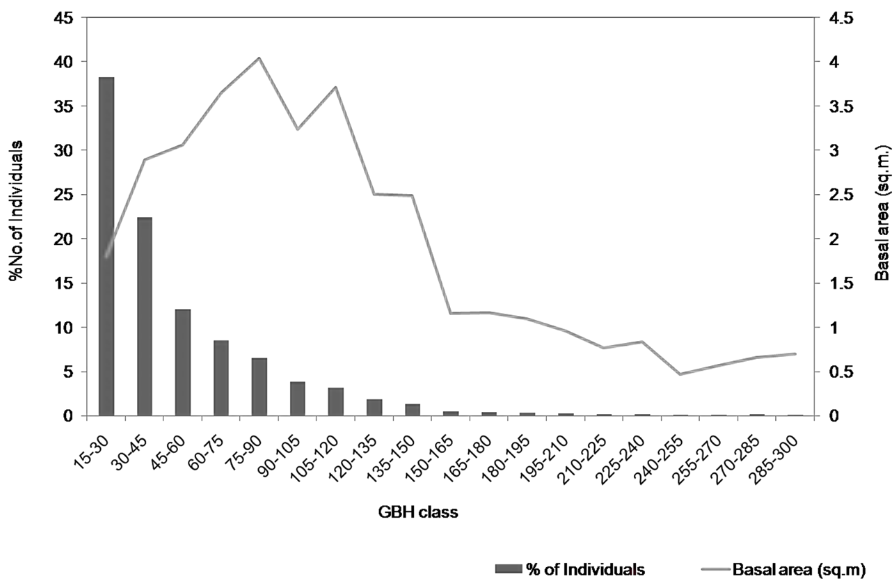

Figure 6. Number of individuals and corresponding basal area across GBH.

in the study area was represented by >20% of the total number of individuals. Similar trend was found in studies conducted in Chandoli NP and Koyna WS where *M. umbellatum* was represented by 27% and 34% individuals, respectively. The study area harbored 18 species endemic to the WG that accounted for around 20% of the individuals sampled. It is interesting to note that some endemic species represented in the study

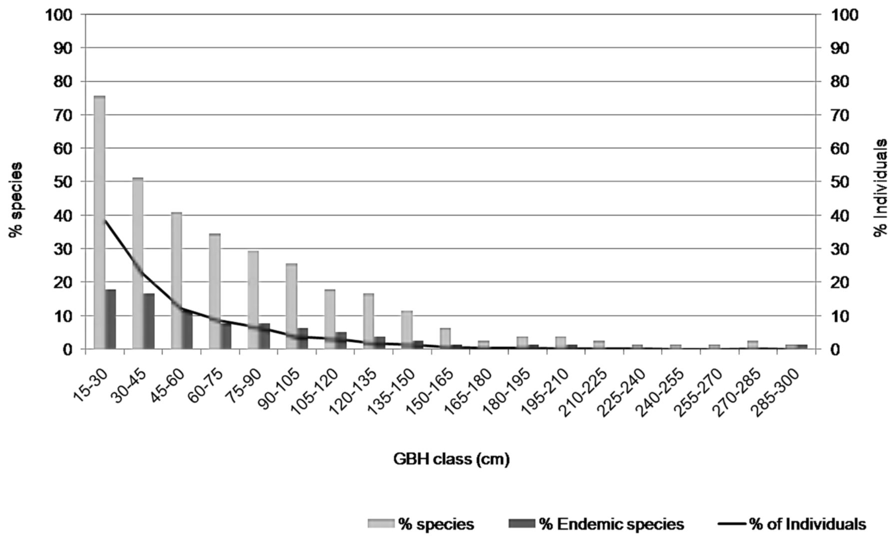

Figure 7. Number of species and individuals across GBH classes.

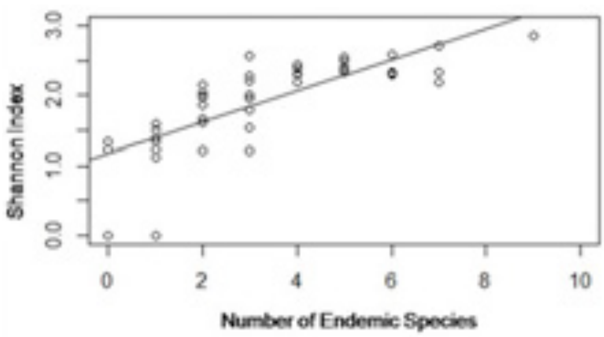

Figure 8. Relation between endemic species richness and Shannon diversity.

area are among the most important species according to IVI. These include *D. nigrescens* (IVI 13.43), *Holigarna grahamii* (IVI 11.02) and *D. candolleana* (IVI 10.61). This underlines the importance of the study area in sustaining the population of endemic woody species. High proportion of endemic species was also reported by Kanade et al. (2008) from undisturbed evergreen forest patches of Chandoli NP. Similar findings were reported from Koyna WS which showed presence of 23 endemic species represented by 656 individuals (15.27%). The dominance of typical evergreen forest species such as *Holigarna grahamii* and *Aglaia lawii*, both endemic species, suggest an origin from a community differing in composition from the typical M-S-A types (Watve et al. 2003). Amboli forests showed presence of 14 IUCN assessed species (six species being VU or NT) with 15% of total individuals sampled which is comparable to Koyna WS that recorded 13 IUCN assessed species and 9% of total number of individuals (Joglekar et al. 2015).

Since the area under consideration is relatively small, we may expect high similarity among the species in the sampled plots, however, clustering with Bray-Curtis similarity plot reveals that there are unique species conferring unique composition to the plots. Closed forest patches of Lingachi rai form a separate cluster as against other closed reserved forest patches and Sadachi rai. Species like *Artocarpus hirsutus*, *Blachia denudata*, *Beilschmiedia dalzellii*, and *Caryota urens* were present in Lingachi rai with low/no occurrence in other closed forest patches. Average stand basal area of Amboli forests was 27.02m^2/ha which was found to be comparable with other studies conducted in protected areas of NWG (Table4). Present study also showed reverse 'J' pattern of the stand structure with highest number of species and individuals in lowest GBH class (15–30 cm) (Kanade et al. 2008; Joglekar et al. 2015) while higher basal area was found to be between 45–120 cm. Typical evergreen endemic forest species like *Aglaia lawii*, *Beischmedia dalzellii*, *Holigarna grahamii* and ecologically important species like *Ficus* sp., *Dimocarpus longan* were present in higher GBH classes (above 180cm) indicating healthy nature of vegetation.

CONCLUSION

Studies on the vegetation analysis and biodiversity pattern are of utmost importance especially in the forest areas outside the PA network. Such areas in tropics are actively managed and modified by humans. Unplanned and uncontrolled tourism especially during monsoon, poorly planned construction and logging are some of the disturbance drivers affecting floral and faunal diversity of Amboli (Image1). Floristic surveys form the primary step for carrying out ecological restoration of a particular area (Mota et al. 2017) and provide the inputs which feed large scale databases.

In this context, present study forms an important step in establishing the baseline data about woody plant diversity of the region. Closed forest patches with dominance of endemic and rare species emphasized the importance of conservation of Amboli forests in patchily distributed forests of NWG. It also revealed that the woody plant diversity in Amboli forest is comparable to other PAs from NWG. The information thus generated can be used effectively by BMC formed under the provisions of Biological Diversity Act (2002). Conserving this unique landscape rich in flora and fauna involving BMC and other stakeholders such as local community and forest department will reveal new facets of participatory conservation model that can be replicated elsewhere in the adjoining areas.

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Author contribution: MT—concept design, data collection, data analysis; AJ—concept design, data collection, data analysis; MM—data collection; AP—concept design finalization, data collection, data analysis.

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COMMUNICATION

Resolving taxonomic problems in the genus *Ceropegia* L. (Apocynaceae: Asclepiadoideae) with vegetative micromorphology

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Abstract: The genus *Ceropegia* L. of Family Apocynaceae, subfamily Asclepiadoideae comprises 213 accepted taxa distributed in tropical and sub-tropical regions of Africa, India, Australia and neighbouring regions. The taxa are mainly identified on the basis of flower morphology. A study was undertaken to reveal micromorphology of 26 taxa distributed in Western Ghats of India to solve the identity problems. The micromorphology is studied with standard microscopic methods in five replicates of each character and taxa to reveal the parameters, distribution of stomata, stomatal index, stomatal density, epidermal cell wall pattern and stomatal measurements. The data obtained was subjected to ANOVA to find out the experimental mean, standard deviation and standard error. A consensus phylogeny tree is constructed using the PAST on the basis of Jaccard similarity coefficient. Results of study revealed that, micro morphological characters, viz., type of stomata, number and characters of subsidiaries, anticlinal cell wall pattern, and stomatal index are very significant in delimitation of closely allied taxa. Beside 'paracytic' stomata, 'tetracytic', 'isotricytic', & 'anomocytic' stomatal types, and amphistomatic distribution are recorded for first time in *Ceropegia*. The taxa are separated easily from each other using vegetative micromorphology and can be identified even in absence of flowers. An identification key and phylogenetic tree is derived on the basis of vegetative micro-morphology and gross morphological characters.

Keywords: Epidermal cell wall pattern, identification key, phylogeny, stomata, stomatal index, subsidiaries.

Abbreviations: SD—Stomatal density | SI—Stomatal index | WG—Western Ghats.

हिंदी सारांशः अपोसायनेसी परिवार के उपपरिवार अस्क्लेपीडोयडी के सिरोपेजिया लिन॰ प्रजाती में अफ्रीका, भारत, ऑस्ट्रेलिया और पडोसी क्षेत्रों के उष्णकटिबंधीय और उप-उष्णकटिबंधीय क्षेत्रों में वितरित २१३ पादप प्रजाती शामिल हैं | यह प्रजातीयां मुख्य रूप से फूलों के आकृती के आधार पर पहचाने जाते हैं | पहचान की समस्याओं को हल करने के लिए भारत के पश्चिमी घाटों में वितरित २६ प्रजातीयों के शाकिय सुक्ष्माकृती को प्रकट करने के लिए एक अध्ययन किया गया | इस शाकिय सूक्ष्मदर्शी अध्ययन के लिए प्रत्येक वर्ण के पांच प्रतिकृतियों को समावेशित किया गया | इनमें निम्न मापदंडों को जैसे की, पर्णरंध्रों के वितरण, पर्णरंध्रों का इंडेक्स, पर्णरंध्रों की घनता, उपत्वक कोशिकाओं के दिवार की रचना, और पर्णरंध्रों के माप शामिल है | प्राप्त जाणकारी के प्रयोगात्मक माध्य, मानक विचलन, और मानक त्रुटि का पता लगाने के लिए एनोवा लागू किया गया | फ़ायलोजेनेटिक वृक्ष साकारणे के लिए पास्ट कार्यप्रणाली का उपयोग किया गया | अध्ययन के परिणामों से पता चलता है कि, सूक्ष्म रूपात्मक वर्ण, अर्थात, पर्णरंध्र प्रकार, संख्या, और पर्णरंध्र सहायक कोशिकाओं के चरित्र, उपत्वक कोशिकाओं के दिवार की रचना, और पर्णरंध्रों का इंडेक्स बारीकी से संबध्द प्रजातीयों के परिसीमन में बहुत महत्वपूर्ण हैं | पैरासाइटिक पर्णरंध्रों के अलावा टेट्रासाइटिक, आइसोट्राइसाइटिक, और एनेमोसाइटिक, प्रकार के साथ एम्फिस्टोमेटिक वितरण पहली बार सिरोपेजिया में दर्ज किये गये हैं | शाकिय सूक्ष्मदर्शी अध्ययन का उपयोग करके प्रजातीयों को एक दूसरे से आसानी से अलग किया एवं फूलों की अनुपस्थिति में भी पहचाना जा सकता हैं | शाकिय सुक्ष्माकृती और सकल आकारिकीय वर्णों के आधार पर एक पहचान कुंजी और फ़ाइलोजेनेटिक वृक्ष की उत्पत्ति की गयी हैं |

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INTRODUCTION

The genus *Ceropegia* L. of family Apocynaceae, subfamily Asclepiadoideae comprises many narrow endemic and threatened species distributed only in tropical and sub-tropical regions especially, Africa, India, Australia, and neighbouring region. The genus comprises of 213 accepted species, eight unplaced, and 36 un-assessed taxa of species and infra-specific ranks (Plant list 2019; Plant of the World Online 2020). Most of the taxa are endemic to the regions or locations from where they are described. In India, it is represented by about 68 taxa comprising of 61 species, two subspecies and five varieties with recent descriptions by Diwakar & Singh (2011), Rahangdale & Rahangdale (2012), Kamble et al. (2012), Sujanapal et al. (2013), and Kumar et al. (2018). Of these taxa, 40 species and six varieties are endemic to India, while 34 species and two varieties are endemic to Western Ghats (Jagtap & Singh 1999; Singh et al. 2015).

The taxa under this genus are mainly described on the basis of floral characters, while many vegetative characteristics are similar in many taxa. The taxonomists in the world have tried to resolve systematic crises among these species or taxa below rank of species. Since last decade many new taxa at specific and infra-specific rank are described (Singh et al. 2015). Still, many of the Indian taxa are kept under unresolved categories by international databases (such as The Plant List (2019) as well as POWO (2020)) due to insufficient data related to allied species and varieties. In India, there are two major regions of distribution of this genus, viz., Himalaya and peninsular India. Most species found in Western Ghats or peninsular India possess tubers, while those found in the Himalayan region do not have tubers and are non-succulent. In general, all these taxa are described on the basis of morphological characters; especially on floral morphology as the allied taxa do have many similarities in vegetative characters. The vegetative micro-morphology was neglected in most of the cases, may be because of morpho-similarities among the taxa in vegetative condition. There is negligible literature available on microscopic characters of vegetative organs; and *Ceropegia* species are generally identified on the basis of habit and flower characters. Therefore, it is a difficult task to identify the species without flowers. So, there is need of micro-morphological as well as anatomical characters that would be helpful in identification of taxa at species and infra-specific level in vegetative state. Considering these facts and lacunae in the literature a study was undertaken to reveal micro-morphological characters of taxa of this genus and provide identification key on the basis of vegetative and micro-morphological characters.

MATERIALS AND METHODS

Plant Materials

Materials for the present study comprise a total 26 taxa of the genus *Ceropegia* L. from Western Ghats. Fresh materials were collected from wild plants as well as plants maintained in the nursery for study. The locations of taxa included in the study range from Nashik in Maharashtra to Coimbatore in Tamil Nadu through Wayanad in Kerala. A list of taxa under study with their status, distribution, and locations of collection for the present study is given in the Table 1.

In the present study, *C. attenuata* Hook. var. *attenuata, C. attenuata* Hook. var. *mookambikae* Diwakar & Singh, *C. mahabalei* Hemadri & Ansari var. *hemalatae* Rahangdale & Rahangdale, *C. mahabalei* Hemadri & Ansari var. *mahabalei, C. maharashtrensis* Punekar et al. are retained because these taxa are merged without any solid reasons and without comparing the characters said in original protologues of above mentioned taxa. As the present study is aimed to find out more stable characters for correct distinction between the taxa, the above mentioned taxa are accepted.

Methods

Vegetative morphology

Total 14 vegetative morphological characters of each taxon are recorded by observation of living materials. They are mentioned in the Table 4 to avoid repetition. Only newly observed characters are mentioned in detail.

Micro-morphology

For epidermal study, five leaves per sample were picked at 4–6th nodes from base. Epidermal peelings of suitable size were made from both upper and lower surfaces of each leaf. Peelings were treated with 5% Sodium Hypochlorite for clearing. Then epidermal debris was brushed off under observation using Lawrence and Mayo stereo-zoom microscope NSZ-606 and the peel was finally mounted in 50% Glycerine. Thereafter, slides were observed under research microscope (Lawrence & Mayo Model No. XSZ-N107T) for epidermal details. For this, five leaves were taken and from each leaf five different fields were observed and data was recorded, making total observation size of 25 sample areas. The observed parameters are, type of stomata, distribution of stomata on leaf surface (hypostomatic/amphistomatic), stomatal density/mm^2, stomatal Length (μ), Width (μ), pore length

Table 1. Plant materials (taxa) used in the present study.

	Taxa name	Status*	Distribution*	Locality of collection	Specimen number
1	*Ceropegia anantii* Yadav et al.	EN	Endemic; MS	Konkan, Ratnagiri, MS	1122
2	*C. anjanerica* Malpure et al.	CR	Endemic; MS	Anjaneri, Nashik, MS	23926
3	*C. attenuata* Hook. var. *attenuata*	EN	Endemic; MS, Goa, KA, Raj.	Junnar, Pune, MS	907, 1116, 21441 (AHMA)
4	*C. attenuata* Hook. var. *mookambikae* Diwakar & Singh	EN	Endemic; MS, KA	Konkan, Ratnagiri, MS	1112
5	*C. bulbosa* Roxb. var. *bulbosa*	Common	Asia & Africa	Junnar, Pune, MS	18544, 18545 (AHMA)
6	*C. bulbosa* Roxb. var. *lushii* (Grah.) Hook. f.	Common	India, Pakistan	Junnar, Pune, MS	21685, 24312 (AHMA)
7	*C. candelabrum* L.	VU	India, Sri Lanka	Waynad, KL	23924
8	*C. concanensis* Kamble et al.	EN	Endemic; MS	Konkan, Ratnagiri, MS	1120, 1121
9	*C. elegans* Wall.	Occasional	India, Sri Lanka	Coimbatore, TN	23923
10	*C. evansii* McCann	EN	Endemic; MS	Ambegaon, Pune, MS	139, 1117, 1118
11	*C. fantastica* Sedgwick	CR	Endemic; MS, KA, Goa	Amboli, Sindhudurg, MS	23920
12	*C. hirsuta* Wight & Arn.	Common	India, Thailand	Junnar, Pune, MS	0466, 23908, 23909, 23910, 23911,
13	*C. jainii* Ansari & Kulkarni	EN	Endemic; MS	Kas, Satara, MS	23927
14	*C. juncea* Roxb.	Occasional	India, Sri Lanka	Coimbatore, TN	23925
15	*C. lawii* Hook. f.	EN	Endemic; MS	Junnar, Pune, MS	0316
16	*C. maccannii* Ansari	EN	Endemic; MS	Simhagarh, Pune, MS	0832
17	*C. mahabalei* Hemadri & Ansari var. *hemalatae* Rahangdale & Rahangdale	CR	Endemic; MS	Junnar, Pune, MS	0136, 0137 (Types), 1114
18	*C. mahabalei* Hemadri & Ansari var. *mahabalei*	CR	Endemic; MS	Junnar, Pune, MS	0138, 0908, 23915, 23916, 23918
19	*C. maharashtrensis* Punekar et al.	CR	Endemic; MS	Junnar, Pune, MS	23222
20	*C. media* (Huber) Ansari	EN	Endemic; MS	Junnar, Pune, MS	0774, 1119, 22735X, 23917
21	*C. oculata* Hook.	VU	Endemic; MS, KL, TN	Junnar, Pune, MS	23902, 23903, 23904, 23914
22	*C. odorata* Nimmo ex. Hook f.	CR	Endemic; MS, Raj, Guj.	Junnar, Pune, MS	22922
23	*C. panchganiensis* Blatt. & McCann	CR	Endemic; MS	Junnar, Pune, MS	18549 (AHMA)
24	*C. rollae* Hemadri	CR	Endemic; MS	Junnar, Pune, MS	1123, 23209, 23334, 23912, 23913
25	*C. sahyadrica* Ansari & Kulkarni	CR	Endemic; MS	Ambegaon, Pune, MS	0188, 23907
26	*C. vincifolia* Hook.	VU	Endemic; MS	Junnar, Pune, MS	0313

CR—Critically Endangered | EN—Endangered | VU—Vulnerable | Guj—Gujarat | KA—Karnataka | KL—Kerala | MS—Maharashtra | Raj—Rajastha | TN—Tamil Nadu | *—as per Singh et al. (2015). Specimens are deposited at AHMA—Agharkar Research Institute, Pune and Herbarium of Hon. Balasaheb Jadhav College, Ale.

(µ), characters and number of subsidiaries and epidermal cell wall characters as per the techniques described by Dilcher (1974) and Kotresha & Seetharam (2000). The classification of stomatal types given by Prabhakar (2004) was followed to recognize stomatal complex, with number and characteristics of subsidiaries.

Parameters studied

1. Stomatal index (SI):

Stomatal index = [S ÷ (E+S)] × 100

where, E = no. of epidermal cells, S = no. of stomata in an unit (mm^2) area taken for observation ($0.022mm^2$ under 400X magnification).

2. Stomatal Density (SD):

Stomatal Density = No. of stomata per unit area ($1mm^2$)

For this, number of stomata in a unit area is recorded for total sample size as that for stomatal index observations.

3. Stomatal length (µ):

The length of stomata is measured as the longitudinal end to end distance of guard cells, using ocular meter scale standardized for each magnification with the stage micrometer.

4. Stomatal width (µ):

This is the maximum length in the middle transect of stoma with the ocular meter scale.

5. Stomatal pore length (µ):

This is length of stomatal opening observed with the help of ocular meter scale.

Statistical analysis comprising of mean, variance, standard deviation, and standard error are applied for each parameter as per method given by Singh & Chaudhary (1985).

Phylogenetic analysis

Phylogenetic analysis was done on the basis of 42 vegetative morphological and micro-morphological characters (Table 4). For phylogenetic analysis PAST ver.03 was used as per Harper (1999), Hammer et al. (2001), Hammer & Harper (2006). In this, the characters were represented in the binary format (Table 5), which was used to generate a phylogenetic tree by Jaccard similarity coefficient model and data replication method - bootstrap method at 1,000 replications on the basis of a matrix of characters.

RESULTS

The observations regarding stomatal distribution, type, subsidiaries character & number, and the anticlinal wall characters of epidermal cells are presented in the Table 2 and Image 1. The results are described under the subheads as mentioned below.

Distribution and type of stomata

The stomata are distributed only on lower surface of the leaf (hypostomatic) in all the taxa studied except in *C. bulbosa*. In both varieties, *C. bulbosa* var. *bulbosa* and *C. bulbosa* var. *lushii*, the leaves are amphistomatic, i.e., stomata are present on both surfaces of the leaves. Four types of stomata, i.e., paracytic, anomocytic, tetracytic, and isotricytic are recorded in the taxa under study. Among these types, the paracytic stomata are most common and found in 16 taxa, the anomocytic are less common and recorded in four taxa; while the tetracytic stomata are observed in only *C. elegans*. Five taxa have mixed stomata; of which, four taxa viz., *C. anantii, C. attenuata* var. *attenuata, C. maharashtrensis*, and *C. sahyadrica* have isotricytic and tetracytic intermixed with each other, while in *C. rollae* paracytic stomata were found along with anomocytic stomata.

Characters and number of subsidiaries

The subsidiaries in studied taxa are either distinct (different than epidermal cells) or indistinct (same as epidermal cells). The stomatal complexes in 12 taxa have distinct subsidiaries while 13 taxa have indistinct ones. Among the 16 taxa having paracytic stomata, 12 taxa have distinct subsidiaries while remaining four have indistinct ones. In *C. rollae,* where stomata are of mixed type, i.e., paracytic and anomocytic, the subsidiaries were distinct along the paracytic stomata while with anomocytic stomata there were indistinct subsidiaries. The number of subsidiaries is also variable from two to five, but generally showed a fixed number or a range in all the specimens of same taxon. The number is fixed to two subsidiaries in nine taxa and four subsidiaries in two taxa. In other 15 taxa, the number of subsidiaries ranges 2–3 in three taxa, 2–4 in three taxa, 3–4 in seven taxa, and 4–5 subsidiaries in two taxa with anomocytic stomata. The taxa having mixed stomata with isotricytic and tetracytic types have indistinct subsidiaries.

Anticlinal wall pattern

The patterns of anticlinal walls of epidermal cells are observed and recorded in all the taxa under study. There are three patterns, 'straight', 'rounded (curved)', and 'undulate (wavy)'. Out of all 26 taxa, 10 have undulate anticlinal walls, eight taxa have rounded walls, and remaining eight have straight anticlinal walls. The results showed that, anticlinal wall pattern is not found to be associated with the other characters studied. This character is independent of stomatal type, size or number and type of subsidiaries. But, it is important for the differentiation between different taxa.

Stomatal characteristics

The experimental results about stomatal measurements are presented in Table 3 and described below.

Stomatal Index (SI)

The results revealed that, mean value of SI for the taxa under study (experimental mean) is 14.75±0.35. The highest SI is found in *C. attenuata* var. *attenuata* (21.80) followed by *C. mahabalei* var. *hemalatae* (20.32), and *C. sahyadrica* (19.94); while the lowest value of SI is recorded in *C. juncea* (8.18) along with *C. panchganiensis* (11.24), *C. vincifolia* (11.81), and *C. hirsuta* (11.88).

Stomatal Density (SD)

The mean value for stomatal density/mm^2 of leaf area is 252.31±8.50 with the highest value of 403.64±10.60 in *C. maharashtrensis* followed by *C. anantii* (390.91), and *C. jainii* (370.91), while the lowest SD 98.18±3.40 in *C. juncea* subtended by *C. bulbosa* var. *lushii* (105.45), *C. bulbosa* var. *bulbosa* (127.27), and *C. hirsuta* (152.73). *C. juncea* is a succulent taxon with highly reduced leaves

Table 2. Epidermal and stomatal characters observed in the taxa under study.

	Name of taxon	Stomatal distribution	Type of Stomata #	Subsidiary cells		Anticlinal cell wall pattern (Epidermal Cell outline) $
				Number	Character	
1	*Ceropegia anantii*	Hypostomatic	Isotricytic & Tetracytic	3–4	Indistinct	Rounded
2	*C. anjanerica*	Hypostomatic	Paracytic	2–3	Distinct	Undulate
3	*C. attenuata* var. *attenuata*	Hypostomatic	Isotricytic & Tetracytic	3–4	Indistinct	Undulate
4	*C. attenuata* var. *mookambikae*	Hypostomatic	Paracytic	2	Distinct	Undulate
5	*C. bulbosa* var. *bulbosa*	Amphistomatic	Anomocytic	3–4	Indistinct	Straight
6	*C. bulbosa* var. *lushii*	Amphistomatic	Anomocytic	3–4	Indistinct	Straight
7	*C. candelabrum*	Hypostomatic	Paracytic	2	Distinct	Undulate
8	*C. concanensis*	Hypostomatic	Paracytic	4	Indistinct	Undulate
9	*C. elegans*	Hypostomatic	Tetracytic	4	Indistinct	Rounded
10	*C. evansii*	Hypostomatic	Paracytic	2	Distinct	Undulate
11	*C. fantastica*	Hypostomatic	Paracytic	2	Distinct	Straight
12	*C. hirsuta*	Hypostomatic	Paracytic	3–4	Distinct	Rounded
13	*C. jainii*	Hypostomatic	Paracytic	2–3	Distinct	Rounded
14	*C. juncea*	Hypostomatic	Paracytic	2–4	Distinct	Straight
15	*C. lawii*	Hypostomatic	Paracytic	2	Distinct	Undulate
16	*C. maccannii*	Hypostomatic	Anomocytic	4–5	Indistinct	Straight
17	*C. mahabalei* var. *hemalatae*	Hypostomatic	Paracytic	2–4	Indistinct	Rounded
18	*C. mahabalei* var. *mahabalei*	Hypostomatic	Paracytic	2	Distinct	Undulate
19	*C. maharashtrensis*	Hypostomatic	Isotricytic & Tetracytic	3–4	Indistinct	Straight
20	*C. media*	Hypostomatic	Paracytic	2	Distinct	Straight
21	*C. oculata*	Hypostomatic	Paracytic	2	Distinct	Undulate
22	*C. odorata*	Hypostomatic	Paracytic	2	Indistinct	Rounded
23	*C. panchganiensis*	Hypostomatic	Anomocytic	4–5	Indistinct	Rounded
24	*C. rollae*	Hypostomatic	Paracytic & Anomocytic	2–4	Distinct & Indistinct	Straight
25	*C. sahyadrica*	Hypostomatic	Isotricytic & Tetracytic	3–4	Indistinct	Rounded
26	*C. vincifolia*	Hypostomatic	Paracytic	2–3	Indistinct	Undulate

#—as per Prabhakar (2004) | $—as per Dilcher (1974) | Curved—Rounded | Wavy—Undulate.

and also have lowest value of SI.

Stomatal Size

Regarding the stomatal dimensions, the largest stomata are recorded in *Ceropegia juncea,* while the smallest stomata in the *C. attenuata* var. *mookambikae*. The experimental mean for stomatal length is 29.54±0.73µ, stomatal width 19.68±0.67µ and the pore length 19.68±0.64 microns. The stomatal length is highest in *C. juncea* (39.0µ), followed by *C. vincifolia* (32.5µ), *C. bulbosa* (32.25µ), *C. oculata* (32.0µ), and *C. candelabrum* (31.5µ). The succulent species *C. juncea* have largest stomata with respect to length 39.0±1.5µ, width 26.5±1.7µ, and pore length 27.0±0.97µ; while those values for *C. attenuata* var. *mookambikae* are 23.0±0.5µ, 15.0±0.79µ, and 12.0±0.5µ, respectively having the smallest stomata. As per the ratio of length x width, the stomatal size is ranging from the smallest one of 345μ^2 in *C. attenuata* var. *mookambikae* to 1033.5μ^2 in *C. juncea* has largest stomata with the experimental mean value of 587.3μ^2.

Phylogeny

A consensus phylogenetic tree based on 42 morphological and micro-morphological characters obtained after 1,000 replications revealed that the dendrogram is divided into three clusters (Figure 1). Cluster I comprises seven taxa: *C. maccannii*, *C. panchganiensis*, *C. rollae*, *C. attenuata* var. *attenuata*, *C. sahyadrica, C. maharashtrensis*, and *C. anantii*. All these taxa are clustered with unit distance of 0.2–0.8.

Cluster II comprises total 15 taxa with unit distance of

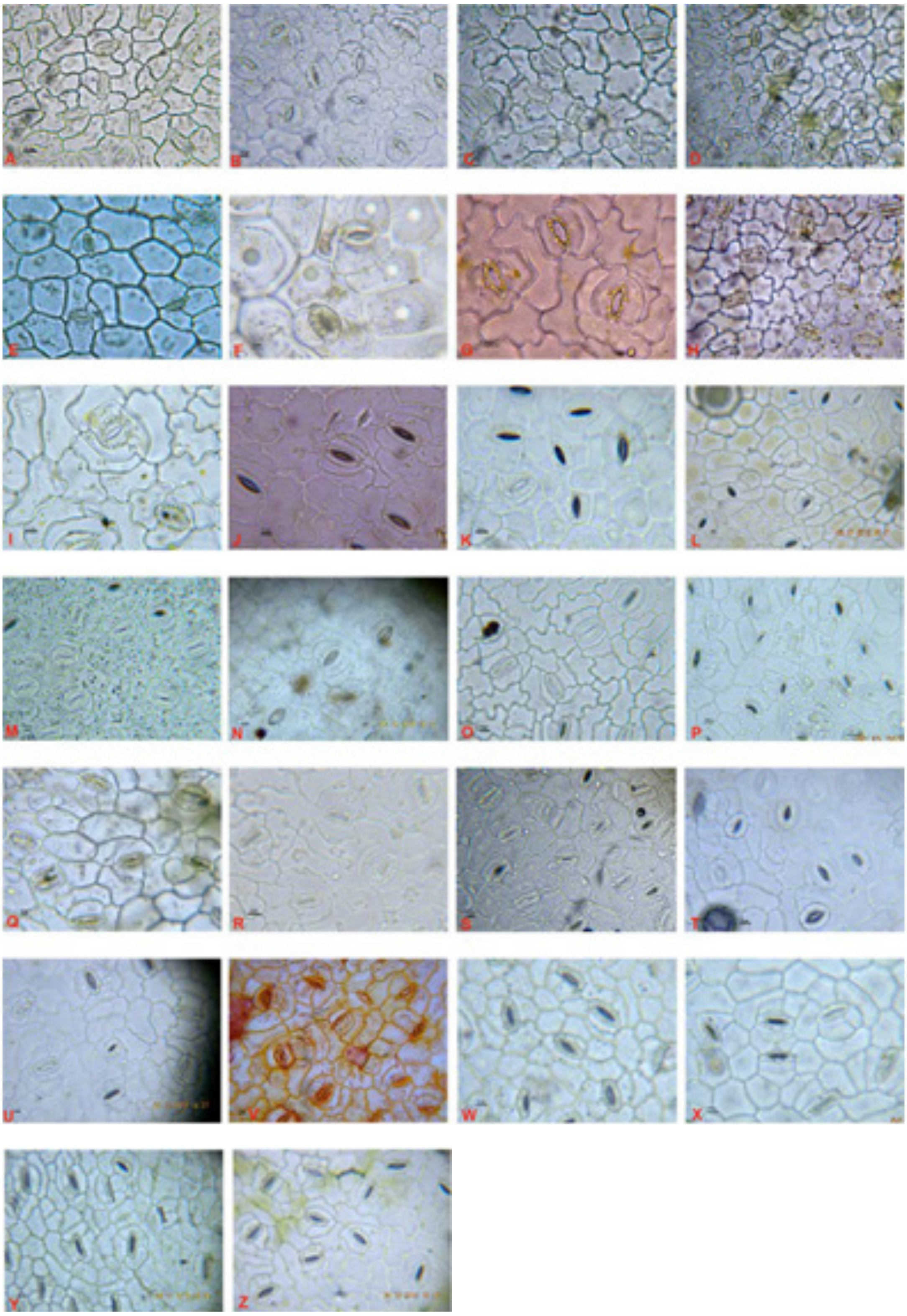

Image 1. Type of stomata and epidermal cell wall pattern in *Ceropegia* L. | A—*Ceropegia anantii* | B—*Ceropegia anjanerica* | C—*Ceropegia attenuata* var. *attenuata* | D—*Ceropegia attenuata* var. *mookambikae* | E—*Ceropegia bulbosa* var. *bulbosa* | F—*Ceropegia bulbosa* var. *lushii* | G—*Ceropegia candelabrum* | H—*Ceropegia concanensis* | I—*Ceropegia elegans* | J—*Ceropegia evansii* | K—*Ceropegia fantastica* | L—*Ceropegia hirsuta* | M—*Ceropegia jainii* | N—*Ceropegia juncea* | O—*Ceropegia lawii* | P—*Ceropegia maccannii* | Q—*Ceropegia mahabalei* var. *hemalatae* | R—*Ceropegia mahabalei* var. *mahabalei* | S—*Ceropegia maharashtrensis* | T—*Ceropegia media* | U—*Ceropegia oculata* | V—*Ceropegia odorata* | W—*Ceropegia panchganiensis* | X—*Ceropegia rollae* | Y— *Ceropegia sahyadrica* | Z—*Ceropegia vincifolia*. Scale bar in each picture = 10µm. © Sanjaykumar R. Rahangdale.

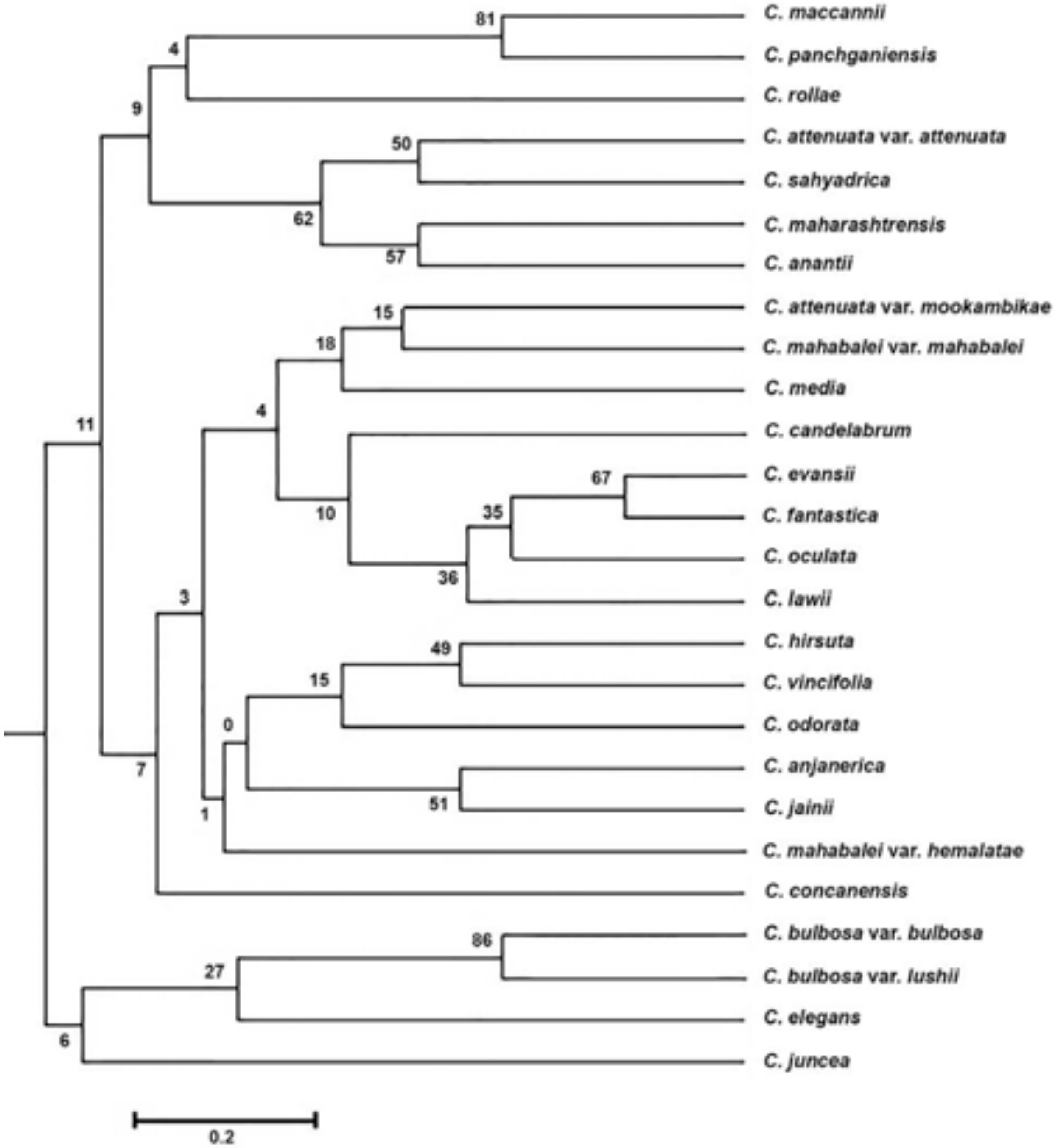

Figure 1. A consensus phylogenetic tree of 26 taxa of the genus *Ceropegia* L. (The numbers near branches represent the % of replications).

0.2–0.7. All the taxa of this cluster have paracytic stomata. This cluster further has two sub-clusters. The sub-cluster IIa comprises eight taxa: *C. attenuata* var. *mookambikae*, *C. mahabalei* var. *mahabalei*, *C. media, C. candelabrum, C. evansii, C. fantastica, C. oculata*, and *C. lawii*. Taxa in this sub-cluster have two distinct subsidiaries in all the taxa. From the dendrogram it is observed that the taxa, *C. evansii, C. fantastica, C. oculata*, and *C. lawii* are closely related having unit distance of 0.2–0.4. Another sub-cluster IIb comprises seven taxa having indistinct and variable subsidiaries: *C. hirsuta, C. vincifolia, C. odorata, C. anjanerica, C. jainii, C. mahabalei* var. *hemalatae*, and *C. concanensis*.

The Cluster III is an externally linked group having four taxa with unit distance of 0.2–0.8. It comprised two varieties of *C. bulbosa, C. elegans*, and *C. juncea.*

Table 3. The stomatal measurements recorded in the taxa.

	Name of taxon	Stomatal index		Stomatal density/ mm²		Stomatal length (µ)		Stomatal width (µ)		Stomatal pore length (µ)		Size of stomata (µ²)
		Mean	SE ±	Mean	SE ±	Mean	SE ±	Mean	SE ±	Mean	SE ±	
1	*C. anantii*	16.71	0.28	390.91	10.50	26.00	0.61	18.50	0.61	17.50	1.12	481.0
2	*C. anjanerica*	14.69	0.16	338.18	9.85	31.00	0.61	21.00	1.00	22.00	0.94	651.0
3	*C. attenuata* var. *attenuata*	21.80	0.47	300.00	12.03	28.50	1.00	20.50	0.50	16.50	0.61	584.3
4	*C. attenuata* var. *mookambikae*	15.05	0.16	329.09	7.99	23.00	0.50	15.00	0.79	12.00	0.50	345.0
5	*C. bulbosa* var. *bulbosa* ^	14.04	1.64	101.82	2.40	33.5	1.7	21.5	1.00	23.5	0.61	
	C. bulbosa var. *bulbosa* ˅	17.15	1.05	152.73	2.68	31.0	1.0	18.5	1.27	19.0	1.27	
	C. bulbosa var. *bulbosa* *	15.60	0.60	127.27	7.41	32.25	1.35	20.00	1.13	21.25	0.94	645.0
6	*C. bulbosa* var. *lushii* ^	13.80	1.04	96.36	1.70	31.5	0.61	20.0	0.0	20.5	0.5	
	C. bulbosa var. *lushii* ˅	12.41	1.13	114.55	2.19	29.5	0.50	19.5	0.5	19.5	0.5	
	C. bulbosa var. *lushii* *	13.10	0.48	105.45	4.17	30.50	0.55	19.75	0.25	20.00	0.50	602.4
7	*C. candelabrum*	14.39	0.28	145.45	3.71	31.50	0.61	20.50	0.50	20.00	0.00	645.8
8	*C. concanensis*	12.11	0.30	258.18	9.36	26.00	0.61	15.50	0.50	13.00	0.50	403.0
9	*C. elegans*	12.39	0.23	198.18	5.80	30.00	0.79	21.00	0.61	20.50	0.50	630.0
10	*C. evansii*	15.04	0.52	209.09	12.03	33.00	0.50	19.50	0.50	19.50	0.50	643.5
11	*C. fantastica*	16.94	0.46	269.09	7.84	28.50	1.27	23.00	1.22	16.00	0.61	655.5
12	*C. hirsuta*	11.88	0.40	152.73	5.17	30.00	0.00	22.00	1.46	19.50	0.50	660.0
13	*C. jainii*	12.26	0.30	370.91	8.58	31.50	1.00	20.00	0.00	20.50	0.50	630.0
14	*C. juncea*	8.18	0.37	98.18	3.40	39.00	1.50	26.50	1.70	27.00	0.94	1033.5
15	*C. lawii*	14.49	0.46	263.64	11.13	29.00	1.00	15.50	0.94	18.50	0.61	449.5
16	*C. maccannii*	17.36	0.41	254.55	8.30	28.00	0.50	23.00	0.50	18.50	0.61	644.0
17	*C. mahabalei* var. *hemalatae*	20.32	0.33	341.82	10.54	30.50	0.50	20.00	0.00	24.00	1.00	610.0
18	*C. mahabalei* var. *mahabalei*	16.50	0.12	325.45	10.05	29.50	0.50	19.50	0.50	24.50	0.94	575.3
19	*C. maharashtrensis*	15.48	0.18	403.64	10.60	28.00	1.46	21.00	0.61	15.50	0.50	588.0
20	*C. media*	14.85	0.46	314.55	17.39	28.00	1.66	16.25	1.12	16.25	1.12	455.0
21	*C. oculata*	14.76	0.52	230.91	8.27	32.00	0.94	16.75	0.50	20.00	1.37	536.0
22	*C. odorata*	13.51	0.43	250.91	8.35	28.00	0.94	21.50	0.61	21.00	0.61	602.0
23	*C. panchganiensis*	11.24	0.28	205.45	5.33	29.50	0.50	21.00	0.61	19.50	0.50	619.5
24	*C. rollae*	12.99	0.22	201.82	4.61	30.00	0.00	18.50	0.61	19.00	0.61	555.0
25	*C. sahyadrica*	19.94	0.60	285.45	15.19	30.00	0.00	16.00	0.61	20.00	0.00	480.0
26	*C. vincifolia*	11.81	0.20	189.09	3.40	32.50	0.00	20.00	0.00	22.50	0.00	650.0
	Experimental mean @ 25*df*	**14.75**	**0.35**	**252.31**	**8.50**	**29.84**	**0.73**	**19.68**	**0.67**	**19.40**	**0.64**	**587.3**

*—the data of amphistomatic taxa are taken from mean of both the surfaces and then the experimental mean is calculated | ^—upper surface of leaf | ˅—lower surface of leaf.

DISCUSSION

As the genus *Ceropegia* is considered to be xerophytic because of its escape mechanism against the hot period by perennial tubers. It should be preferably hypostomatic and the results are in corroboration with the concept, but the exceptions are both the varieties of *C. bulbosa* as they have amphistomatic leaves. Both the varieties of this taxon are usually distributed in dry rain-shadowed area of the Western Ghats, even though they are amphistomatic; this may be due to more succulent leaves than other taxa. Metcalfe & Chalk (1950) reported isobilateral leaves in the species of *Ceropegia* and *Hoya* R.Br. having fleshy leaves. Therefore, present results also confirm the amphistomatic nature of some taxa in *Ceropegia* which have fleshy leaves. The presence of stomata only on

Key for identification of species on the basis of vegetative and micro-morphological characters

1. Plants erect 2
1. Plants twiner 3
2. Leaves broadly ovate 4
2. Leaves lanceolate/linear 5
4. Stomata paracytic or anomocytic 6
4. Stomata mixed 7
6. Stomata paracytic, subsidiaries 2 distinct, epidermal cell wall undulate .... *C. lawii*
6. Stomata anomocytic, subsidiaries 4–5 indistinct, epidermal cell wall straight / rounded 8
7. Stomata para & anomocytic, subsidiaries 2–4, epidermal cell wall straight .... *C. rollae*
7. Stomata isotricytic & tetracytic, subsidiaries 3–4 indistinct 9
8. Epidermal cell wall straight, SI 17.36 .... *C. maccannii*
8. Epidermal cell wall rounded, SI 11.24 .... *C. panchganiensis*
9. Epidermal cell wall rounded, SI 19.94, SD 285.45 .... *C. sahyadrica*
9. Epidermal cell wall straight, SI 15.48, SD 403.64 .... *C. maharashtrensis*
5. Plants robust up to 1m tall, stomata paracytic 10
5. Plants small / delicate, shorter than 0.5m tall, stomata paracytic / other types 11
10. Stem stout, leaf margin straight, subsidiary 2, distinct, epidermal cell wall undulate .... *C. mahabalei* var. *mahabalei*
10. Stem scandant, leaf margin undulate, subsidiary 2–4, indistinct, epidermal cell wall rounded .... *C. mahabalei* var. *hemalatae*
11. Stomata paracytic, subsidiaries distinct 12
11. Stomata isotricytic & tetractytic, subsidiaries 3–4 indistinct 13
12. Subsidiaries 2 or 4, epidermal cell wall undulate 14
12. Subsidiaries 2–3, epidermal cell wall rounded / undulate 15
14. Subsidiaries 2, SI 15.05, SD 329.09 .... *C. attenuata* var. *mookambikae*
14. Subsidiaries 4, SI 12.11, SD 258.18 .... *C. concanensis*
15. Leaves hirsute, epidermal cell wall undulate, SI 14.69, SD 338.18 .... *C. anjanerica*
15. Leaves sparsely hairy, epidermal cell wall rounded, SI 12.26, SD 370.91 .... *C. jainii*
13. Epidermal cell wall undulate, SI 21.80, SD 300.0 .... *C. attenuata* var. *attenuata*
13. Epidermal cell wall rounded, SI 16.71, SD 390.91 .... *C. anantii*
3. Plants succulent, leaves ovate/lanceolate/linear/minute, epidermal cell wall straight 16
3. Plants non succulent, leaves ovate/ lanceolate, epidermal cell wall otherwise 17
16. Leaves minute, hypo-stomatic, stomata paracytic, subsidiaries 2–4 distinct .... *C. juncea*
16. Leaves conspicuous, amphi-stomatic, stomata anomocytic, subsidiaries 3–4 indistinct 18
18. Leaves ovate-lanceolate, SI 15.60, SD 127.27 .... *C. bulbosa var. bulbosa*
18. Leaves linear, SI 13.10, SD 105.45 .... *C. bulbosa var. lushii*
17. Leaves lanceolate, stomata paracytic 19
17. Leaves broadly ovate, stomata otherwise 20
19. Leaves minutely hairy, veins winged below, epidermal cell wall straight, SI 14.85, SD 314.55 .... *C. media*
19. Leaves glabrous, veins not winged, epidermal cell wall rounded, SI 13.51, SD 250.91 .... *C. odorata*
20. Plants almost glabrous, stomata para or tetracytic 21
20. Plants hairy, stomata paracytic 22
21. Stomata paracytic, subsidiaries 2 distinct, epidermal cell wall undulate .... *C. candelabrum*
21. Stomata tetracytic, subsidiaries 4 indistinct, epidermal cell wall rounded .... *C. elegans*
22. Epidermal cell wall rounded / straight, subsidiaries distinct 23
22. Epidermal cell wall undulate, subsidiaries distinct / indistinct 24
23. Subsidiaries 2, epidermal cell wall straight .... *C. fantastica*
23. Subsidiaries 2–4, epidermal cell wall rounded 25
25. Plants densely hirsute, SI 11.88, SD 152.73 .... *C. hirsuta*
25. Plants sparsely hirsute, especially on leaves, SI 14.76, SD 230.91 .... *C. oculata*
24. Subsidiaries 2 distinct .... *C. evansii*
24. Subsidiaries 2–3 indistinct .... *C. vincifolia*

lower surface of leaf is an adaptation to reduce the rate of transpiration. It is interesting to note that except *C. candelabrum, C. elegans*, and *C. juncea*, all the taxa have tubers and their vegetative growth is confined to the rainy season only, but still they have hypostomatic leaves. This is an interesting fact and raises further curiosities towards the taxa. The taxa *C. candelabrum, C. elegans*, and *C. juncea* generally remain in their active growth during summer season also and therefore their hypostomatic nature is justified, but for other taxa which grow in high rainfall area and escape the dry spell, especially about 8–9 months of year except rainy season and still have the hypostomatic leaves. This fact is interesting and the hypostomatic leaves must be a qualitative character governed by genes only; because in the present study beside *C. bulbosa* three more taxa, viz., *C. candelabrum, C. elegans* and *C. juncea*, have succulent leaves but have only hypostomatic nature unlike *C. bulbosa*.

Table 4. List of characters and character state used for phylogenetic analysis.

	Character with character state
1	Tuber: Absent (0), Present (1)
2	Stem erect: Absent (0), Present (1)
3	Stem twining: Absent (0), Present (1)
4	Stem scandant: Absent (0), Present (1)
5	Stem: Non succulent (0), Succulent(1)
6	Leaves: Large (0), Minute (1)
7	Plant habit: Small (0), Robust (1)
8	Leaves ovate: Absent (0), Present (1)
9	Leaves lanceolate: Absent (0), Present (1)
10	Leaves linear: Absent (0), Present (1)
11	Leaves: Non succulent (0), Succulent (1)
12	Leaves: Non hairy (0), Hairy (1)
13	Leaf margin: Straight (0), Undulate (1)
14	Leaf veins winged on lower surface: Not winged (0), Winged (1)
15	Leaf: Amphi-stomatic (0), Hypo-stomatic (1)
16	Epidermal cell anticlinal wall, Straight: Absent (0), Present (1)
17	Epidermal cell anticlinal wall, Rounded: Absent (0), Present (1)
18	Epidermal cell anticlinal wall, Undulate: Absent (0), Present (1)
19	Stoma: Mixed types (0), Single type (1)
20	Stoma paracytic: Absent (0), Present (1)
21	Stoma anomocytic: Absent (0), Present (1)
22	Stoma tetracytic: Absent (0), Present (1)
23	Stoma isotricytic & tetracytic: Absent (0), Present (1)
24	Stoma paracytic & anomocytic: Absent (0), Present (1)
25	Subsidiary cells: Indistinct (0), Distinct (1)
26	Subsidiary cell number two: Absent (0), Present (1)
27	Subsidiary cell number four: Absent (0), Present (1)
28	Subsidiary cell number 2–3: Absent (0), Present (1)
29	Subsidiary cell number 3–4: Absent (0), Present (1)
30	Subsidiary cell number 4–5: Absent (0), Present (1)
31	Size of stoma 300–450 μ: Out of range (0), Within range (1)
32	Size of stoma 450–600 μ: Out of range (0), Within range (1)
33	Size of stoma 600–750 μ: Out of range (0), Within range (1)
34	Size of stoma 750–1100 μ: Out of range (0), Within range (1)
35	Stomatal index (SI) range value 8–11 : Out of range (0), Within range (1)
36	Stomatal index (SI) range value 11–14: Out of range (0), Within range (1)
37	Stomatal index (SI) range value 14–17: Out of range (0), Within range (1)
38	Stomatal index (SI) range value 17–22: Out of range (0), Within range (1)
39	Stomatal density (SD) range value <100: Out of range (0), Within range (1)
40	Stomatal density (SD) range value 100-200: Out of range (0), Within range (1)
41	Stomatal density (SD) range value 200-300: Out of range (0), Within range (1)
42	Stomatal density (SD) range value 300-400: Out of range (0), Within range (1)

The type of stomata is paracytic in most of the taxa (16 out of 26) under study. Rubiaceous type (paracytic) stomata are reported to be common feature of many genera of Asclepiadaceae (present Asclepiadoideae of Apocynaceae) (Metcalfe & Chalk 1950; Paliwal et al. 1980). The results of present study showed similar observations about the type of stomata in *Ceropegia*, but besides paracytic stomata, tetracytic, anomocytic and mixed stomata of isotricytic + tetracytic, & paracytic + anomocytic are also found. Thus, the variations of type of stomata occur in the genus.

The results revealed that, mean value of stomatal index for the taxa under study, i.e., experimental mean is 14.75±0.35. The highest SI is found in *C. attenuata* var. *attenuata* while the lowest value for SI is observed in *C. juncea* (8.18±0.37). The mean value for stomatal density/ mm^2 of leaf area is 252.31±8.50 with the highest value of 403.64±10.60 in *C. maharashtrensis* and the lowest 98.18±3.40 in *C. juncea.* There is no correlation observed among the taxa with respect to SI values, but for SD the taxa occurring in the dry climates and with succulent habits have relatively lower values for the parameter. The SI remain unchanged even in different seasons in soybean cultivars (Rahangdale 2003) suggesting true genetic nature of this parameter. The SD is the lowest in *C. juncea* a succulent taxon with highly reduced leaves and increasing to some extent in *C. bulbosa* var. *lushii*, *C. bulbosa* var. *bulbosa*, and *C. hirsuta*. Low SD helps these taxa to retain more water in plant body and survive during dry spell of the year. On the other hand, taxa growing under high rainfall conditions, viz., *C. attenuata, C. anantii, C. jainii, C. media, C. mahabalei, C. anjanerica*, and *C. maharashtrensis*, have high stomatal density ranging from 325 to 403 stomata/mm^2, thereby adapting to the high annual rainfall of about 2,000–4,000 mm. It is interesting to note that, *C. concanensis* found in the Konkan region, on lateritic rock plateaux with very negligible soil have intermediate value of stomatal density. This is in accordance with it's relatively broader leaves and habitat because the rain water never remain on the sloppy plateaux. Such plateaux show relatively dry conditions as compared to the little more soil rich habitats where *C. anantii* and *C. attenuata* occur.

Present study revealed that on the basis of micro-morphological characters, the taxa with overlapping vegetative characters can be easily identified. The type of stomata, number and nature of subsidiary cells and anticlinal wall pattern are important characters to differentiate between very closely allied taxa at species as well as infraspecific ranks. This has been shown in an artificial key as well as the morphological phylogeny

Table 5. Character state of taxa under study (Character no. as per Table 4).

Sno	Character No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
	Taxa																																										
1	*C. anantii*	1	1	0	0	0	0	0	0	0	1	0	1	0	0	1	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	1
2	*C. anjanerica*	1	1	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	1	1	1	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	0	1	0	0	0	0	1
3	*C. attenuata* var. *attenuata*	1	1	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	0	1	0
4	*C. attenuata* var. *mookambikae*	1	1	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	1	1	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1
5	*C. bulbosa* var. *bulbosa*	1	0	1	0	1	0	1	1	0	0	1	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	1	0	0
6	*C. bulbosa* var. *lushii*	1	0	1	0	1	0	1	0	0	1	1	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	1	0	0
7	*C. candelabrum*	0	0	1	0	1	0	1	1	0	0	1	0	0	0	1	0	0	1	1	1	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0
8	*C. concanensis*	1	1	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	1	1	1	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0
9	*C. elegans*	0	0	1	0	1	0	1	1	0	0	1	0	0	0	1	0	1	0	1	0	0	1	0	0	0	0	1	0	0	0	0	0	1	0	0	1	0	0	0	1	0	0
10	*C. evansii*	1	0	1	0	0	0	1	1	0	0	0	1	0	0	1	0	0	1	1	1	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0
11	*C. fantastica*	1	0	1	0	0	0	1	1	0	0	0	1	0	0	1	1	0	0	1	1	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0
12	*C. hirsuta*	1	0	1	0	0	0	1	1	0	0	0	1	0	0	1	0	1	0	1	1	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	1	0	0	0	1	0	0
13	*C. jainii*	1	1	0	0	0	0	0	0	1	0	0	1	0	0	1	0	1	0	1	1	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	1	0	0	0	0	0	1
14	*C. juncea*	0	0	1	0	1	1	1	0	1	0	1	0	0	0	1	1	0	0	1	1	0	0	0	0	1	0	0	1	0	0	0	0	0	1	1	0	0	0	1	0	0	0
15	*C. lawii*	1	1	0	0	0	0	1	1	0	0	0	1	0	0	1	0	0	1	1	1	0	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0
16	*C. maccannii*	1	1	0	0	0	0	1	1	0	0	0	1	0	0	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	1	0
17	*C. mahabalei* var. *hemalatae*	1	0	0	1	0	0	1	0	0	1	0	1	1	0	1	0	1	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	1
18	*C. mahabalei* var. *mahabalei*	1	1	0	0	0	0	1	0	0	1	0	1	0	0	1	0	0	1	1	1	0	0	0	0	1	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1
19	*C. maharashtrensis*	1	1	0	0	0	0	1	1	0	0	0	1	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	1
20	*C. media*	1	0	1	0	0	0	1	0	1	0	0	1	0	1	1	1	0	0	1	1	0	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1
21	*C. oculata*	1	0	1	0	0	0	1	1	0	0	0	0	0	0	1	0	0	1	1	1	0	0	0	0	1	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1	0
22	*C. odorata*	1	0	1	0	0	0	1	0	1	0	0	1	0	0	1	0	1	0	1	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	1	0	0	0	0	1	0
23	*C. panchganiensis*	1	1	0	0	0	0	1	1	0	0	0	1	0	0	1	0	1	0	1	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0	0	1	0
24	*C. rollae*	1	1	0	0	0	0	1	1	0	0	0	1	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0
25	*C. sahyadrica*	1	1	0	0	0	0	1	1	0	0	0	1	0	0	1	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	0	1	0
26	*C. vincifolia*	1	0	1	0	0	0	1	1	0	0	0	1	0	0	1	0	0	1	1	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1	0	0	0	1	0	0

tree derived in the present study. These results are in corroboration of the previous studies in different angiosperm taxa. Metcalfe & Chalk (1988) reported that stomatal index is independent of the changes in epidermal cell size brought by the environmental factors, and therefore, the SI is generally considered as a taxonomic character along with the others. Many of the works have considered SI as a strong taxonomic character to delimit the allied taxa of family Vitaceae (Patil & Patil 1983, 1984), in *Bauhinia* L. (Kotresha & Seetharam 1995), and *Cassia* L. species (Kotresha & Seetharam 2000). The leaf micromorphological characters are very significant to compare the fossil taxa with the allied species of extant taxa (Dilcher 1974). Doyle & Endress (2000) observed that, the morphological evidences overcome the weak molecular evidences while assigning the phylogeny of angiosperms. Kotresha & Seetharam (2000) studied epidermal micromorphology of *Cassia* L. species and delimited the species within the genus on the basis of stomatal index, size, and epidermal cell wall structure (especially the anticlinal wall pattern) and the type of stomata. Thus, stomatal characters and micromorphology can play a very significant role in resolving the taxonomic ambiguities. Present study is also showing similar outcomes giving significant information in delimitation of *Ceropegia* species and varieties on the basis of micromorphological characters. For example, two varieties of *C. mahabalei*, viz., var. *mahabalei* and var. *hemalatae*, are different with respect to many characters including stem scandant, undulate leaf margins, 2–4 indistinct subsidiaries and rounded anticlinal walls of epidermal cells in latter, whereas var. *mahabalei* have erect stout stem, straight leaf margins, two distinct subsidiaries, and undulate epidermal anticlinal walls. These characters are other than the characters which are provided in original protologue. Variety *hemalatae* does not match in any characters with *C. oculata*. Similar is the case of varieties of *C. attenuata*, viz., var. *attenuata* and var. *mookambikae*. The later variety has paracytic stomata with two distinct subsidiaries and SI 15.05, while the variety *attenuata* has mixed stomata of isotricytic and tetracytic types with 3–4 indistinct subsidiaries stomatal index 21.80. As per the key provided in the present study variety *mookambikae* is more allied to *C. concanensis* than with *C. attenuata* var. *attenuata*.

The consensus phylogenetic tree has three clusters. The type of stomata is defining character for these three clusters and supported by the number & nature of subsidiary cells. Cluster I is having anomocytic and mixed type of stomata with indistinct variable number of (two/three/four/five) subsidiary cells. All the taxa in this cluster are erect ones. Cluster II comprises total 15 taxa having paracytic stomata. This cluster further has two sub-clusters. Sub-cluster IIa comprises eight taxa having two distinct subsidiaries in all. From the dendrogram it is observed that the taxa, *C. evansii, C. fantastica, C. oculata*, and *C. lawii* are closely related having unit distance of 0.2–0.4. Along these *C. candelabrum* is separated from others on the basis of having fascicled roots and undulate anticlinal epidermal walls. Sub-cluster IIb comprises seven taxa having indistinct and variable subsidiaries. *C. mahabalei* var. *hemalatae* is separated from others on the basis of scandant habit, undulate leaf margins and high SI value. The cluster III is an externally linked group has four taxa clustered with unit distance of 0.2–0.8. It comprised two varieties of *C. bulbosa*, *C. elegans*, and *C. juncea*. This is the group of taxa having succulent stems and leaves. Among them *C. juncea* is placed as distinct taxon as it has highly reduced leaves. Among these *C. elegans* has tetracytic stomata while others have paracytic ones and therefore, it is placed little distantly. The dendrogram depicts clear differences among related taxa on the basis of micromorphology, especially the type of stomata, anticlinal wall pattern, SI and supported by gross morphology. In the present study, the grouping of *C. maccannii*, *C. panchganiensis*, *C. sahyadrica*, and *C. rollae* in first cluster, as well as *C. anjanerica*, *C. mahabalei*, *C. jainii*, *C. media*, and *C. odorata* in second cluster is in corroboration with the molecular phylogeny done by Surveswaran et al. (2009) where these taxa were placed in two separate clusters.

It is necessary to discuss here the delimitation of some of the taxa in present study. *C. mahabalei* var. *mahabalei* and *C. mahabalei* var. *hemalatae* are distinct in gross morphology of stem, leaves, inflorescence and the corolla beak, in a similar way they also differ in having indistinct 2–4 subsidiaries, rounded anticlinal walls and higher SI in the later variety. In the dendrogram they are also placed apart from each other on the basis of above characters. Similarly, two varieties of *C. attenuata*, viz., var. *attenuata* and var. *mookambikae*, are also placed distantly in the dendrogram in two different clusters. This is because of the type of stomata, number & characters of subsidiaries, size of stomata and SI. The most confusing taxa in terms of vegetative and floral morphology are *C. rollae* and *C. lawii*, as they are morphologically very similar to each other. Results of the present study separated them in the dendrogram as well as in the identification key on the basis of type of stomata, number and feature of subsidiaries, anticlinal wall pattern, and size of stomata. Thus, their identity can be confirmed on the basis of micro-morphology even in vegetative state. Similarly, all the above mentioned taxa are separated on the basis of micro-morphological characters in the artificial key also. Thus, micro-morphological characters when combined with the gross morphological characters give better opportunity for correct identification of the taxa. The inter-specific variations in the stomatal characters such as stomatal index and stomatal frequency in *Vitis* L., *Cissus* L., and *Leea* D. Royen ex L. were studied by Patil & Patil (1984) and the taxa within these three genera were delimited on the basis of the stomatal characters and relationship among them was also established. Stomatal size and frequency was used to delimit between 56 species of genera of family Vitaceae by Patil & Patil (1983) and opined that, the stomatal data is supporting other characters to delimit the species and also to establish phylogenetic relationship to some extent. The results of present study show a similar trend in the genus *Ceropegia*.

Therefore, on the basis of studied micromorphological characters combined with other vegetative characters 26 taxa of *Ceropegia* at species and infraspecific level are delimited and an identification key is being provided for easy identification. These characters provide a very easy way of identification even in absence of flowers of these taxa.

CONCLUSION

The micro-morphology of taxa in the genus *Ceropegia* L. is revealed and is determinative for the identification of taxa even in a vegetative state in combination with the other general morphological characters. The type of stomata, number and nature of subsidiary cells, anticlinal epidermal wall pattern and stomatal index are key characters for differentiation of the taxa. Besides paracytic stomata, anomocytic, tetracytic and mixed, isotricytic + tetracytic and paracytic + anomocytic stomata are found in the genus *Ceropegia*. These characters are crucial in correct identification of the taxa at species and infraspecific level. Occurrence of tetracytic and mixed stomata is a first report in the genus by this study. It is also confirmed that, *C. mahabalei* var. *hemalatae* and *C. attenuata* var. *mookambikae* are distinct taxa from their allied taxa, respectively.

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PLATINUM OPEN ACCESS

Phytodiversity of chasmophytic habitats at Olichuchattam Waterfalls, Kerala, India

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Abstract: The present study was conducted to analyse the Phytodiversity of Chasmophytic habitats at Olichuchattam waterfalls, Kerala, India. The studies on the plants in such special type of habitats are very less. Hence the present study will help to know more about them. Field exploration and observations were made, plants were collected, identified and herbarium was prepared. Analysis of plants and soil samples from different regions of the study area based on altitudinal variations was also done. As a result of the study, a total of 120 plant species that belonging to 49 families and 93 genera were documented. Of these 5 species are bryophyte, 10 species are pteridophytes and 105 species are angiosperms. The ornamental potentiality of the plants in the study area was also analysed and it shows that a total of 47 species have ornamental potentialities. The present study also highlighted some threatening factors can affect the distribution of plants in the present study area. The present study highlights that, the rocky cliffs and crevices serves as an excellent habitat for many interesting plant groups. The plants in these habitats are very unique and are attractive.The rocky cliffs and crevices represents a good indicator of rich biodiversity within small areas.

Keywords: Floristic diversity, chasmophytes, Olichuchattam, invasive species, threats.

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Author contribution: AC—conducted the field trip, collection, Identification and compilation of various datas on chasmophytic plants in the study area. BT—planned the outline of this research work and provided necessary guidelines for the research.

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INTRODUCTION

Floristic diversity refers to the variety and variability of plants in a given region. It refers to the number of types or taxa in a given region or group. India is one of the 12 mega diversity centres of the world where the Western Ghats and the Himalayan region constitute two of the 34 biodiversity hotspots representing a storehouse of several promising economically important plants (Myers 1990). Species richness and endemism are, however, not uniformly distributed along the Western Ghats. The southernmost regions which have the most favourable climatic conditions with high, but not excessive rainfall and short dry season are the ones with the highest biodiversity and contain the highest number of endemic species (Pascal et al. 2004). Southern Western Ghats is one of the two mega endemic centres in Western Ghats (Nair & Daniel 1986; Nayar 1996). Kerala forms a major species-rich part of southern Western Ghats harbouring a total of 4,679 flowering plants (Sasidharan 2004).

The vegetation on the surface of rocks or stones are lithophytes, while the vegetation in the crevices of rocks are chasmophytes (Schimper 1898). Rock crevices form a major habitat for many plants and host rich biodiversity within a small area. The rocky habitat provides an extremely harsh physical environment for plants that leads to the development of specialized plant communities with endemic and habitat specific species. Microhabitats like rock crevices possess diverse forms of plants, which are mainly seasonal herbs. These habitats differ from each other due to changes in geographical terrain and soil cover (Porembski 2000).

Chasmophytes are plants rooted in clefts of rocks that are filled with detritus. In these clefts, particles of earth conveyed by wind and water accumulate. The amount and rate of accumulation depends upon the width and situation of the clefts (Davis 1982). The soil thus constituted facilitates plants to establish and their dead fragments further add to the supply of the nutritive material in the clefts (Bashan et al. 2002). Rocky cliffs are microhabitats which are slightly mineral rich and can support the growth and survival of many chasmophytic species. The occurrence of such habitats ultimately depends on a number of factors such as geographical location, levels of exposure, high evaporation rates, nature of soil geology, and water runoff during the rainy season (Danin et al. 1982). The chasmophytic species growing on rock crevices and cliffs have to deal with an extremely inhospitable environment. Therefore, they have developed several adjustments such as strong roots and reduced life form structure. This root system supports them on the cliffs and allows for maximum exploitation of the little water and nutrients contained in minimal soil. This habitat is also susceptible to strong winds and full sunlight, as there is no tall vegetation to protect it from these climatic factors (Binu & Rajendran 2012).

The growth of chasmophytic plants mainly depends on the availability of water and depth of soil with nutrients. The number of plants is more during the wet season than during the dry season. The rocky cliffs and crevices represent a good indicator of rich biodiversity within small areas (Binu et al. 2012). The pioneering plants such as lichens, mosses, ferns & fern allies, small herbs, and grasses grow in the weathered soil in the rock crevices and loosen the weathered particles of rocks and add an organic material to the developing soil. These plants trap water and wind-blown soil and can add soil content in the crevices. Finally, dead organic matter of such a pioneer community can add more suitable substrata for the growth of the next community (Roy et al. 1983).

The objectives of the present study were: (i) to document the chasmophytic diversity of the study area, (ii) to study the various factors affecting the growth and survival of chasmophytes in the study area, and (iii) to characterize the chasmophytic plants in the study area.

MATERIALS AND METHODS

Study Area

The study area Olichuchattam is situated in Thiruvambady Panchayath of Kozhikode District of Kerala State, India (11.435°N & 76.079°E; Figure 1, Image 1). Olichuchattam area comes under the jurisdiction of Vellarimala Forest Range which is a part of the Western Ghats. Most of the hill range falls in the Meppadi Forest Range of South Wayanad Division, with some parts falling in the Thamarassery Range of Kozhikode Division (Image 2–5). Olichuchattam is a waterfall of Iruvanji River situated in evergreen forests on the way to Vellarimala Hills. The hill ranges are accessible on foot from Muthappanpuzha, a small town which is about 50km from Kozhikode. By trekking for about 4–5 km (approximately three hours) one can explore the Olichuchattam Waterfalls. By trekking from Olichuchattam to the upper foothills one can explore different places like Vellarimala, Vavulmala, and Masthakappara. From the top of Olichuchattam itself one can clearly notice the changes in vegetation and the changes in the landscape because of the altitudinal

Figure 1. Map of India and Kerala State (Source: GIS)

Image 1. Satellite image of the study area (Souce: Google Map)

variations. The entire waterfall area and adjacent areas are full of wet and moist rocky patches especially in the monsoons and become dry during the summer. This characteristic habitat enables different plants to survive and adapt in a special way based on the different seasons.

Data collection and analysis

The current study was based on extensive exploration and field observations during the period September 2017–February 2018. In the present study an attempt was made to document and analyse the chasmophytic vegetation of Olichuchattam Waterfall areas of Kozhikode District, Kerala. The documentation was mainly based on field observations, discussions with local people as well as scrutinizing the literature. For effective and accurate study, the area was visited and analysed in different climatic conditions in different periods such as rainy season, winter season, and summer season. The study was mainly based on the rock crevices in nearby areas of the upper regions of the waterfalls (1,400m), near the waterfalls (1,250m), and the lower foothills of the waterfalls (700m) which showed considerable variations in their altitudes ranging 700–1,400 m.

During the field visits, the plant specimens were collected to prepare herbariums. The collected specimens were identified taxonomically with the help of available floras and literature (Gamble 1915–1936; Sasidharan 2004). The specimens were processed for the preparation of the herbarium by standard methods. The voucher specimens are deposited in the Herbaria of PG & Research Department of Botany, St. Joseph's College, Kozhikode (DEV) for future reference. Photographs of the study area in different seasons as well as the images of plants were taken. In addition to these, suitable maps, tables, figures, and images are given in appropriate places.

RESULTS AND DISCUSSIONS

Chasmophytic diversity

Results of the present study reveal 120 species (106 native species and 14 non-native species) belonging to 49 families and 93 genera documented in general (Table 1). Of these, five species are bryophytes of five families and five genera. Similarly, in pteridophytes, a total of 10 species belonging to nine families and nine genera are recorded. Angiosperms are dominant among these groups, which include 105 species that belong to 35 families and 79 genera (Table 2, Figure 2).

The dominant native chasmophytic plant families of the study area are analysed. The dominant native families are as follows, Poaceae with 15 species followed by Balsaminaceae with seven species, Asteraceae and Commelinaceae with six species each, Malvaceae and Melastomataceae with five species each, and Scrophulariaceae represented by three species (Figure 3).

Similarly, the analysis of the dominant native genera reveals that the genus *Impatiens* dominates with seven species followed by *Blumea, Cyanotis, Eriocaulon*, and *Arundinella* each with three species, respectively (Figure 4).

The analysis of the overall plant habits/growth form reveals that herbs are the dominant with 100 species,

Image 2–5. Different views of the study area. © Arun Christy.

followed by 16 species of shrubs and four species of climbers.

Distribution pattern of chasmophytic plants

The diversity and distribution of the recorded 120 chasmophytic plants in the study area reveals that there are only about 25 species which are commonly distributed. Fifty-eight species are uncommon or sporadically distributed and 37 of them are very rarely occurring in the study area. The high number of uncommon and rare plants in the study area indicates that they need very specific ecological conditions.

It was observed the distribution of the plants greatly vary with respect to the different seasons. In the monsoon season, the diversity of water loving chasmophytic plants are seen more. The taxa like *Impatiens, Sonerila, Eriocaulon, Utricularia* are dominant vegetation cover during this period. While in the summer period, fewer species survive in the area but grasses and some weedy

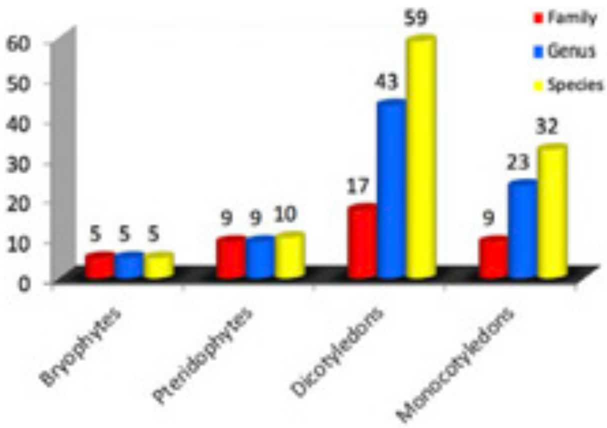

Figure 2. Floristic analysis of native chasmophytes in the study area.

species are seen thriving well. Also with the variations in the altitudes, the vegetation changes. Plants like *Pellaea falcata, Bolbitis appendiculata, Impatiens* sp., *Sonerila* sp., *Osbeckia* sp., *Arundinella* sp., *Pouzolzia*

Table 1. Total plant checklist of the study area.

	Botanical name	Family	Native/ Non-native
Bryophytes			
1	*Bryum argenteum* Hedw.	Bryaceae	Native
2	*Campylopus flexuosus* (Hedw.) Brid.	Dicranaceae	Native
3	*Cyathodium cavernarum* Kunze	Targioniaceae	Native
4	*Pogonatum aloides* (Hedw.) P. Beauv.	Polytrichaceae	Native
5	*Riccia crystallina* L.	Ricciaceae	Native
Pteridophytes			
1	*Adiantum raddianum* C. Presl	Adiantaceae	Native
2	*Bolbitis appendiculata* (Willd.) K. Iwats.	Dryopteridaceae	Native
3	*Drynaria quercifolia* (L) J. Sm.	Drynariaceae	Native
4	*Lepisorus nudus* (Hook.) Ching	Polypodiaceae	Native
5	*Lygodium flexuosum* (L.) Sw.	Lygodiaceae	Native
6	*Parahemionitis cordata* (Roxb. *ex* Hook. & Grev.) Fras.	Hemionitidaceae	Native
7	*Pellaea falcata* (R.Br.) Fee	Pteridaceae	Native
8	*Pteridium aquilinum* (L.) Kuhn.	Dennstaedtiaceae	Native
9	*Selaginella involvens* (Sw.) Spring	Selaginellaceae	Native
10	*Selaginella tenera* (Hook. & Grev.) Spring	Selaginellaceae	Native
Angiosperms			
1	*Abelmoschus angulosus* Wall. ex Wight & Arn.	Malvaceae	Native
2	*Aeschynomene americana* L.	Fabaceae	Non-native
3	*Apluda mutica* L.	Poaceae	Native
4	*Arundina graminifolia* (D. Don) Hochr.	Orchidaceae	Native
5	*Arundinella leptochloa* (Nees *ex* Steud.) Hook. F.	Poaceae	Native
6	*Arundinella metzii*Hochst. *ex* Miq.	Poaceae	Native
7	*Arundinella pumila* (Hochst. *ex* A. Rich.) Steud.	Poaceae	Native
8	*Barleria courtallica* Nees	Acanthaceae	Native
9	*Blumea barbata* DC.	Asteraceae	Native
10	*Blumea belangeriana* DC.	Asteraceae	Native
11	*Blumea membranacea* Wall. *ex* DC.	Asteraceae	Native
12	*Bulbophyllum sterile* (Lam.) Suresh	Orchidaceae	Native
13	*Burmannia coelestis* D. Don	Burmanniaceae	Native
14	*Canscora diffusa* (Vahl) R. Br. *ex* Roem. & Schult.	Gentianaceae	Native
15	*Canscora perfoliata* Lam.	Gentianaceae	Native
16	*Christisonia tubulosa* (Wight) Benth. *ex* Hook. f.	Orobanchaceae	Native
17	*Chromolaena odorata* (L.) King & Robins.	Asteraceae	Non-native

	Botanical name	Family	Native/ Non-native
18	*Chrysopogon hackelii* (Hook.f.) C.E.C. Fisch	Poaceae	Native
19	*Cleome burmannii* Wight & Arn.	Capparaceae	Native
20	*Cleome viscosa* L.	Capparaceae	Native
21	*Commelina benghalensis* L.	Commelinaceae	Native
22	*Commelina clavata* Clarke	Commelinaceae	Native
23	*Costus speciosus* (Koenig) J.E. Smith	Zingiberaceae	Native
24	*Crassocephalum crepidioides* (Benth.) S. Moore	Asteraceae	Native
25	*Cyanotis arachnoidea* Clarke	Commelinaceae	Native
26	*Cyanotis cristata* (L.) D. Don.	Commelinaceae	Native
27	*Cyanotis papilionacea* (Burm. f.) Schult. f.	Commelinaceae	Native
28	*Cymbopogon flexuosus* (Nees *ex* Steud.) Wats.	Poaceae	Native
29	*Cyperus tenuispica* Steud.	Cyperaceae	Native
30	*Drymaria cordata* (L.) Willd.	Caryophyllaceae	Native
31	*Emilia sonchifolia* (L.) DC.	Asteraceae	Native
32	*Eriocaulon quinquangulare* L.	Eriocaulaceae	Native
33	*Eriocaulon rhodae*Fyson	Eriocaulaceae	Native
34	*Eriocaulon xeranthemum* Mart.	Eriocaulaceae	Native
35	*Euphorbia vajraveluii*Binoj. & Balakr.	Euphorbiaceae	Native
36	*Geissaspis cristata* Wight & Arn.	Fabaceae	Native
37	*Glinus oppositifolius* (L.) A. DC.	Aizoaceae	Native
38	*Hemidesmus indicus* (L.) R. Br.	Apocynaceae	Native
39	*Heteropogon contortus* (L.) P. Beauv. ex Roem. &Schult.	Poaceae	Native
40	*Hibiscus hispidissimus* Griff.	Malvaceae	Native
41	*Homonoia riparia* Lour.	Euphorbiaceae	Native
42	*Hyptis suaveolens* (L.) Poit.	Lamiaceae	Non-native
43	*Impatiens cordata* Wight	Balsaminaceae	Native
44	*Impatiens diversifolia* Wall. *ex* Wight & Arn	Balsaminaceae	Native
45	*Impatiens gardneriana* Wight	Balsaminaceae	Native
46	*Impatiens herbicola* Hook. f.	Balsaminaceae	Native
47	*Impatiens modesta* Wight	Balsaminaceae	Native
48	*Impatiens scapiflora* Heyne *ex* Roxb.	Balsaminaceae	Native
49	*Impatiens viscosa* Bedd.	Balsaminaceae	Native
50	*Ipomoea deccana* Austin	Convolvulaceae	Native
51	*Isachne bourneorum* C.E.C. Fisch.	Poaceae	Native
52	*Isachneglobosa* (Thunb.) O. Ktze.	Poaceae	Native
53	*Ischaemum dalzelii* Stapf *ex* Bor	Poaceae	Native

	Botanical name	Family	Native/ Non-native
54	*Isodon lophanthoides* (Buch.-Ham. *ex* D.Don) H.Hara	Lamiaceae	Native
55	*Jansenella griffithiana* (C. Muell.) Bor	Poaceae	Native
56	*Justicia japonica* Thunb	Acanthaceae	Native
57	*Knoxia sumatrensis* (Retz.) DC.	Rubiaceae	Native
58	*Lantana camara* L.	Verbenaceae	Non-native
59	*Leucas ciliata* Benth. *ex* Wall.	Lamiaceae	Native
60	*Lindernia ciliata* (Colsm.) Pennell	Scrophulariaceae	Native
61	*Lindernia crustacea* (L.) F.v. Muell.	Scrophulariaceae	Native
62	*Melastoma malabathricum* L.	Melastomataceae	Native
63	*Melochia corchorifolia* L.	Sterculiaceae	Native
64	*Merremia umbellata* (L.) Hall.	Convolvulaceae	Native
65	*Microstachys chamaelea* (L.) Muell.-Arg.	Euphorbiaceae	Native
66	*Mimosa diplotricha* C. Wight ex Sauvalle	Mimosaceae	Non-native
67	*Mimosa pudica* L.	Mimosaceae	Non-native
68	*Mitracarpus hirtus* (L.) DC.	Rubiaceae	Non-native
69	*Mollugo pentaphylla* L.	Aizoaceae	Native
70	*Murdannia semiteres* (Dalz.) Sant.	Commelinaceae	Native
71	*Naregamia alata* Wight & Arn.	Meliaceae	Native
72	*Oldenlandia corymbosa* L.	Rubiaceae	Native
73	*Osbeckia aspera* (L.) Blume	Melastomataceae	Native
74	*Osbeckia virgata* D. Don *ex* Wight & Arn.	Melastomataceae	Native
75	*Peliosanthes teta* Andr. ssp. *humilis*	Haemodaraceae	Native
76	*Pennisetum polystachyon* (L.) Schult.	Poaceae	Native
77	*Peperomia pellucida* (L.) Kunth	Piperaceae	Non-native
78	*Pilea microphylla* (L.) Liebm.	Urticaceae	Non-native
79	*Pogonatherum crinitum* (Thunb.) Kunth	Poaceae	Native
80	*Pouzolzia wightii* Bennett,	Urticaceae	Native
81	*Rotala malampuzhensis* Nair *ex* Cook	Lythraceae	Native
82	*Rungia pectinata* (L.) Nees	Acanthaceae	Native
83	*Scoparia dulcis* L.	Scrophulariaceae	Non-native
84	*Sida alnifolia* L.	Malvaceae	Native
85	*Smithia gracilis* Benth.	Fabaceae	Native
86	*Sonerila rheedei* Wight & Arn.	Melastomataceae	Native
87	*Sonerila versicolor* Wight var. axillaris	Melastomataceae	Native
88	*Spermacoce latifolia* Aubl.	Rubiaceae	Non-native
89	*Spilanthes radicans* Jacq.	Asteraceae	Non-native
90	*Stemodia verticillata* (Mill.) Sprague	Scrophulariaceae	Non-native
91	*Strobilanthes lanatus* Nees	Acanthaceae	Native
92	*Themeda sabarimalayana* Sreek. & V.J. Nair	Poaceae	Native
93	*Themeda triandra* Forssk.	Poaceae	Native
94	*Torenia bicolor* Dalz.	Scrophulariaceae	Native
95	*Tridax procumbens* L.	Asteraceae	Non-native
96	*Triumfetta annua* L.	Tiliaceae	Native
97	*Triumfetta rhomboidea* Jacq.	Tiliaceae	Native
98	*Urena lobata* L ssp. *lobata*	Malvaceae	Native
99	*Urena lobata* L. ssp. *sinuata*	Malvaceae	Native
100	*Utricularia graminifolia* Vahl.	Lentibulariaceae	Native
101	*Utricularia striatula* Smith	Lentibulariaceae	Native
102	*Vernonia cinerea* (L.) Less.	Asteraceae	Native
103	*Xenostegia tridentata* (L.) Austin & Staples	Convolvulaceae	Native
104	*Xyris indica* L.	Xyridaceae	Native
105	*Zeuxine longilabris* (Lindl.) Benth. *ex* Hook. f.	Orchidaceae	Native

Table 2. Analysis of chasmophytic diversity in the study area.

<table>
<tr><th colspan="2">Analysis of plant diversity</th><th colspan="2">Families</th><th colspan="2">Genera</th><th colspan="2">Species</th></tr>
<tr><td colspan="2">Bryophyta</td><td colspan="2">5</td><td colspan="2">5</td><td colspan="2">5</td></tr>
<tr><td colspan="2">Pteridophyta</td><td colspan="2">9</td><td colspan="2">9</td><td colspan="2">10</td></tr>
<tr><td rowspan="3">Dicotyledons</td><td>Polypetalae</td><td>12</td><td rowspan="3">26</td><td>20</td><td rowspan="3">56</td><td>*29(3)</td><td rowspan="3">73</td></tr>
<tr><td>Gamopetalae</td><td>11</td><td>30</td><td>*26(9)</td></tr>
<tr><td>Monochlamydae</td><td>3</td><td>6</td><td>*4(2)</td></tr>
<tr><td colspan="2">Monocotyledons</td><td colspan="2">9</td><td colspan="2">23</td><td colspan="2">32</td></tr>
<tr><td colspan="2">Total</td><td colspan="2">49</td><td colspan="2">93</td><td colspan="2">120</td></tr>
</table>

*—native species | ()—Non-native species

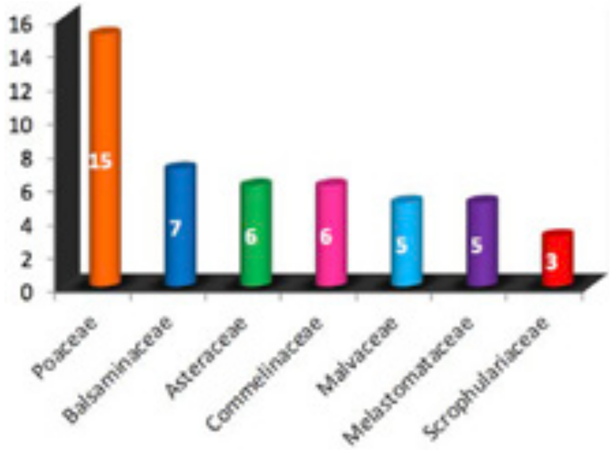

Figure 3. Analysis of dominant native families of angiosperms.

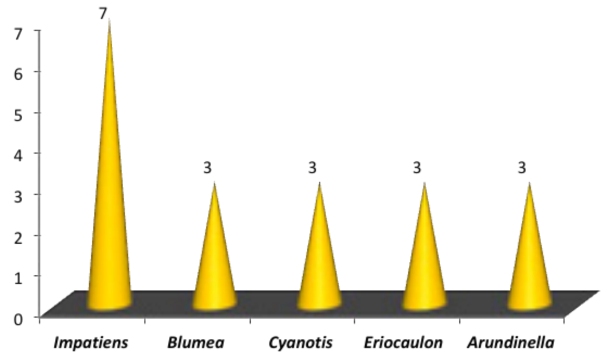

Figure 4. Analysis of dominant native genera.

wightii, Strobilanthes lanatus, Arundina graminifolia, and *Themeda* sp. are distributed in high altitude areas (1,200–1,400m).

Ornamental chasmophytes

The present study analysed that 47 species of plants have ornamental potential. Among the 47 species, four of them are pteridophytes and the rest of the 43 species are angiosperms. Of the 47 species distributed in the area, family Balsaminaceae is dominant with seven species followed by Melastomataceae and Commelinaceae with five species each, Scrophulariaceae and Convolvulaceae with three species each. Considering the ornamental potential of the plants of documented chasmophytes, 32 species have a good looking habit, seven species have attractive foliage and about 37 species have good looking flowers (Table 3). The colour of the flowers along with good looking habit of many chasmophytic plants is an aspect of ornamental potentiality, therefore, such taxa has also been identified for possible cultivation in rock gardens or rockeries for ornamental purposes (Binu et al. 2012).

Impatiens for rockery/rock gardening

Balsams or *Impatiens* are often called 'Jewel Weeds' or 'Orchid Balsams'. They are handsome plants bearing curious and variously coloured flowers. Southern Indian species of *Impatiens* have a wealth of new and ornamentally desirable flower colours like red, pink, orange, scarlet, yellow and may have different combinations of these colours. This beautiful wild flower can be seen on wet perpendicular rocks or old walls in the hills of high elevations. The balsam thrives best during monsoon months (June–September) and the best collections can only be acquired in the monsoon. Developing a normal garden for balsams will not be effective because many balsams (especially scapigerous species) cannot survive in normal greenhouses. So there is a need for a special type of gardening for balsams. Bhaskar (2012) developed special gardening methods for balsams by providing splash watering, water drippings, and shady conditions which are essential for developing the *Impatiens'* microclimate inside greenhouses (Image 6).

Invasive chasmophytes

The present study also observed that, there are 14 plant species, which are introduced from various countries as well as different regions of the world and now they are naturalized in chasmophytic habitats of the present study area. The nativity of these species includes central America, South America, tropical America, and tropical Africa (Sasidharan 2004). These species are invasive in our country and have established themselves, thereby a threat to other native flora (Table 4).

Soil analysis

Soil samples from different regions of the study area (three samples were collected based on altitudinal variations such as lower, middle, higher altitudes) were used for the soil analysis. Soil samples were analysed with the help of Indian Institute of Spices Research, Kozhikode as per the methods adopted by Jackson (1971). The parameters analysed are pH value, percentage of organic Carbon, amount of Nitrogen, Phosphorous, and Potassium and the results are presented in Table 5 (Furley 1968).

The soil analysis indicates that the rocky crevices of the lower foothills (700m) is more nutrient rich than the middle and high altitude soils. This may be due to the washing of the soil and nutrients from the high altitude areas to low altitude areas and the subsequent

Table 3. List of ornamental chasmophytes from the Olichuchattam area of Kozhikode District, Kerala.

	Botanical name	Family	Ornamental characters
Pteridophytes			
1.	*Adiantum raddianum* C. Presl	Adiantaceae	Good looking habit and attractive foliage.
2.	*Bolbitis appendiculata* (Willd.) K.Iwats.	Dryopteridaceae	Good looking habit and attractive foliage.
3.	*Pellaea falcata* (R.Br.)	Pteridaceae	Good looking habit and attractive foliage.
4.	*Selaginellainvolvens* (Sw.) Spring	Selaginellaceae	Good looking habit and attractive foliage.
Angiosperms			
1.	*Abelmoschus angulosus* Wall. ex Wight & Arn.	Malvaceae	Attractive large pink coloured flowers
2.	*Arundina graminifolia* (D.Don) Hochr.	Orchidaceae	Good looking pink/purple coloured flowers also have a good looking habit
3.	*Barleria courtallica* Nees	Acanthaceae	Attractive light blue coloured flowers.
4.	*Burmannia coelestis* D.Don.	Burmanniaceae	Attractive light pink coloured flowers.
5.	*Canscora diffusa* (Vahl) R.Br. ex Roem. & Schult.	Gentianaceae	Good looking habit
6.	*Canscora perfoliata* Lam.	Gentianaceae	Beautiful cream coloured flowers
7.	*Christisonia tubulosa* (Wight) Benth. ex Hook.f.	Orobanchaceae	Attractive purple-white tinged-yellow coloured flowers
8.	*Commelina benghalensis* L.	Commelinaceae	Beautiful blue flowers with good looking habit.
9.	*Commelina clavata* Clarke	Commelinaceae	Good looking blue coloured flowers with attractive creeping plant habit.
10.	*Crassocephalum crepidioides* (Benth.) S.Moore	Asteraceae	Good looking yellow-orange coloured flowers and also have attractive pappus hairs.
11.	*Cyanotis arachnoidea* Clarke	Commelinaceae	Attractive blue coloured flowers and also have attractive habit
12.	*Cyanotis papilionacea* (Burm.f.) Schult.	Commelinaceae	Attractive blue coloured flowers and nice habit.
13.	*Eriocaulon quinquangulare* L.	Eriocaulaceae	Attractive plant habit with good looking white headed flowers.
14.	*Eriocaulon xeranthemum* Mart.	Eriocaulaceae	Attractive plant habit with good looking white headed flowers.
15.	*Euphorbia vajravelui* Binoj. & Balakr.	Euphorbiaceae	Good looking plant habit.
16.	*Geissaspis cristata* Wight & Arn.	Fabaceae	Good looking habit, with delicate flowers and persistent fimbriate bracts
17.	*Impatiens cordata* Wight	Balsaminaceae	A good habit and pink coloured flowers.
18.	*Impatiens diversifolia* Wall. ex Wight	Balsaminaceae	Attractive pink coloured flowers.
19.	*Impatiens gardneriana* Wight	Balsaminaceae	Attractive plants with a good habit and pink coloured flowers.
20.	*Impatiens herbicola* Hook. f.	Balsaminaceae	Small attractive white coloured flowers
21.	*Impatiens modesta* Wight	Balsaminaceae	Attractive plants with rose coloured flowers.
22.	*Impatiens scapiflora* Heyne ex Roxb.	Balsaminaceae	Attractive habit and light rose coloured flowers.
23.	*Impatiens viscosa* Bedd.	Balsaminaceae	Attractive small pink flowers and an attractive habit.
24.	*Ipomoea deccana* Austin	Convolvulaceae	Good looking purple coloured flowers and attractive habit.
25.	*Leucas ciliata* Benth. ex Wall.	Lamiaceae	Good looking white flowers.
26.	*Lindernia ciliata* (Colsm.) Pennell var. *ciliata*	Scrophulariaceae	Good looking purple flowers with attractive habit.
27.	*Lindernia crustacea* (L.) Muell.	Scrophulariaceae	Good looking purple flowers.
28.	*Melastoma malabathricum* L.	Melastomataceae	Attractive large rose coloured flowers.
29.	*Merremia umbellata* (L.) Hall. f.	Convolvulaceae	Attractive white coloured flowers.
30.	*Murdannia semiteres* (Dalz.) Sant.	Commelinaceae	Attractive plant habit
31.	*Naregamia alata* Wight & Arn.	Meliaceae	Good looking white coloured flowers.
32.	*Osbeckia aspera* (L.) Blume var. *aspera*	Melastomataceae	Attractive large pink coloured flowers and a good looking habit.
33.	*Osbeckia virgata* D. Don ex Wight & Arn.	Melastomataceae	Attractive large pink coloured flowers with good looking habit.
34.	*Pogonatherum crinitum* (Thunb.) Kunth	Poaceae	Attractive plant habit and nice foliage
35.	*Rotala malampuzhensis* Nair ex Cook	Lythraceae	Attractive plant habit with good looking foliage.
36.	*Smithia gracilis* Benth.	Fabaceae	Attractive yellow flowers and a good looking habit.
37.	*Sonerila rheedei* Wight & Arn.	Melastomataceae	Attractive pink coloured flowers
38.	*Sonerila versicolor* Wight var. *axillaris* (Wight) Gamble	Melastomataceae	Attractive pink coloured flowers with good looking habit which have leaves with white dots on it.
39.	*Torenia bicolor* Dalz.	Scrophulariaceae	Attractive dark purple-yellow coloured flowers.
40.	*Utricularia graminifolia* Vahl.	Lentibulariaceae	Attractive plants with a good habit and blue coloured flowers.
41.	*Utricularia striatula* Smith	Lentibulariaceae	Attractive plants with pink-yellow coloured flowers.
42.	*Xenostegia tridentata* (L.) Austin & Staples	Convolvulaceae	Attractive cream to yellow coloured flowers.
43.	*Xyris indica* L.	Xyridaceae	Good looking plants with beautiful yellow flowers.

Table 4. List of invasive chasmophytes of study area.

	Botanical names	Family	Nativity
1.	*Aeschynomene americana* L.	Fabaceae	Central America
2.	*Chromolaena odorata* (L.) King	Asteraceae	Central America
3.	*Hyptis suaveolens* (L.) Poit.	Lamiaceae	Central America
4.	*Lantana camara* L.	Verbenaceae	Tropical America
5.	*Mimosa diplotricha* Wight ex Sanv.	Mimosaceae	Tropical America
6.	*Mimosa pudica* L.	Mimosaceae	South America
7.	*Mitracarpus hirtus* (L.) DC.	Rubiaceae	Tropical Africa
8.	*Peperomia pellucida* (L.) Kunth.	Piperaceae	Tropical America
9.	*Pilea microphylla* (L.) Liebm.	Urticaceae	South America
10.	*Scoparia dulcis* L.	Scrophulariaceae	Tropical America
11.	*Spermacoce latifolia* Aubl.	Rubiaceae	Tropical Africa
12.	*Spilanthes radicans* Jacq.	Asteraceae	Tropical America
13.	*Stemodia verticillata* Mill.	Scrophulariaceae	Tropical America
14.	*Tridax procumbens* L.	Asteraceae	Tropical America

Table 5. Analysis of soil samples from chasmophytic habitats.

Altitudes	pH	Organic carbon (%)	Nitrogen (mg/kg)	Phosphorous (mg/kg)	Potassium (mg/kg)
Lower altitude (700m)	5.00	5.95%	390	5.1	172
Middle altitude (1,250m)	4.71	5.90%	380	4.1	145
Higher altitude (1,400m)	4.52	5.85%	370	3.8	138

deposition. The soil samples of rock crevices are rich in organic carbon and nitrogen due to the weathering of rocks and the deposition of them into the crevices. The present study also highlights that the growth pattern of chasmophytes in the rock crevices mainly depends on the amount of essential elements in the soil of such micro habitats.

Threats to the chasmophytic habitats

Generally, habitat loss is due to the anthropogenic activities. It was noticed that compared to anthropogenic activities, the present study area was also affected by over grazing as well as unsustainable utilization of natural resources by natives. It may enhance the depth of threat

Image 6. Different species of *Impatiens* from the study area: a—*Impatiens cordata* Wight | b—*Impatiens gardneriana* Wight | c—*Impatiens scapiflora* Heyne ex Roxb | d—*Impatiens diversifolia* Wall. ex Wight | e—*Impatiens modesta* Wight. | f—*Impatiens viscosa* Bedd. © Arun Christy

Image 7. Selected images of chasophytes in the study area: a—*Cyathodium cavernarum* Kunze | b—*Adiantum raddianum* C.Presl. | c—*Osbeckia aspera* (L.) Blume | d—*Sonerila rheedei* Wight & Arn. | e—*Sonerila versicolor* Wight var. *axillaris* (Wight) Gamble |f—*Christisonia tubulosa* (Wight) Benth. ex Hook.f. | g—*Utricularia graminifolia* Vahl | h—*Utricularia striatula* Smith | i—*Euphorbia vajravelui* Binoj. & Balakr. | j—*Pilea microphylla* (L.) Liebm. |k—*Cyanotis arachnoidea* Clarke | l—*Murdannia semiteres* (Dalz.) Sant. © Arun Christy.

to the study especially during peak monsoon period by land slides and flooding of rivers. Invasive species are the biggest threat to many native chasmophytes in the study area. Tourists trekking the Vellarimala cause destruction to the existing ecosystem to some extent. There are also many study reports showing that the plants which were distributed earlier in the foothills of Olichuchattam area are disappearing due to the frequent land slides during the monsoon (Manudev et al. 2012).

CONCLUSION

Chasmophytes to some extent determine the vegetation of the valley. The rocky cliffs and crevices represent a good indicator of rich biodiversity within small areas. The chasmophytic vegetation hasn't gained much attention because of the lack of research carried out in this field and the lack of knowledge about this particular vegetation.

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COMMUNICATION

A checklist of angiosperm flora of low elevation lateritic hills of northern Kerala, India

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Abstract: An inventory to prepare the checklist of angiosperm species in the lateritic hillocks of northern Kerala was conducted in five sampling sites during April 2013–March 2015. In total, we recorded 364 genera with 535 species, of which 334 are native and 201 are non-native. Native species were represented in 102 families, namely, Poaceae (28), Fabaceae (25), Acanthaceae (22), Rubiaceae (17) Euphorbiaceae (14), Commelinaceae (11), Phyllanthaceae (7), etc., whereas, non-native species were represented in 99 families. Among the native species herbs are the predominant habit with 147 species (44%). Out of the 72 endemic species, three taxa namely, *Syzygium travancoricum*, *Santalum album* and *Hopea ponga* are red listed species documented from the study area. Twenty-seven invasive species were also recorded and major threats to the laterite ecosystems are by *Lantana camara*, *Mikania micrantha, Pennisetum polystachyon*, *Ipomoea* spp., and *Senna* spp. Most part of the laterite has been converted to plantations, building sites and mining sites. The indiscriminate mining for laterite, soil and demolishing the hillocks have severely threatened the very existence of the flora.

Keywords: Endemism, floristic inventory, lateritic plateau, microhabitats.

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Author contribution: KAS—contributed to field survey, identification and paper writing; VBS—contributed to field survey, identification and paper writing; PP—contributed to field survey and identification; NS—contributed to paper writing; MPP—contributed to field survey; MSS—contributed for preparation of herbarium and paper writing.

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INTRODUCTION

Francis Hamilton-Buchanan from Angadipuram in Kerala, India in the 1800s, while on a journey through the regions of Mysore, Canara, and Malabar (Buchanan 1807; Narayanaswamy 1992) came across a type of weathered substance. This substance used in building material, consisted of indurated clay, full of cavities and pores. It had large quantities of iron in the form of red and yellow ochre. Soft when fresh, this could be cut with any iron instrument; but if exposed, it hardened and resisted air and water. This came to be known as laterite. This unique geological formation is reported to occur from Karnataka, Kerala, Maharashtra, Madhya Pradesh in central India, the Eastern Ghats regions of Odisha, from parts of Assam, and more (Raychaudhuri 1981).

Floristic studies in lateritic plateaus have reported occurrence of many endemic species and habitat-specific flora (Bachulkar 1983; Yadav & Sardesai 2002; Watve 2013; Rahangdale & Rahangdale 2014) throughout the Western Ghats, India.

Some of the new species discovered from laterite ecosystems in India include *Rotala malabarica* Pradeep, Joseph & Sivar. (Pradeep et al. 1990), *Nymphoides krishnakesara* Joseph & Sivar. (Joseph & Sivarajan 1990), *Justicia ekakusuma* Pradeep & Sivar. (Pradeep & Sivarajan 1991), *Lepidagathis keralensis* Madhu. & Singh (Madhusoodanan & Singh 1992), *Eriocaulon sivarajanii* R. Ansari & N.P. Balakr. (Ansari & Balakrishnan 2009), and *Eriocaulon madayiparnese* Swapna, Rajesh, Manju & Prakashkumar (Swapna et al. 2012). There are so many new discoveries from the plateau ecosystems from the Western Ghats and especially from lateritic ones. Therefore, the basaltic as well as lateritic plateaus are inhabited by a great diversity of flora. The plateaus are very species rich, for example the Durgawadi Plateau in Maharashtra of three square kilometer area has more than 600 angiospermic taxa of which 150 are endemic and also 105 faunal members (Rahangdale & Rahangdale 2018), which indicates the extent of species richness on the isolated hillocks or plateaus in the Western Ghats.

Some other taxa also described from laterite habitats, especially from the Western Ghats and adjoining areas are: *Ceropegia attenuata* Hook. var. *mukambikae* (Diwakar & Singh 2011) from Mookambika Hills, Karnataka, *Ceropegia anantii* (Yadav et al. 2004), *Dipcadi concanense* (Dalzell) Baker (Prabhugaonkar et al. 2009), both from low elevation laterites of the Konkan region in Maharashtra, and *Ceropegia mahabalei* Hemadri & Ansari var. *hemalatae* (Rahangdale & Rahangdale 2012) from basaltic plateaus of high elevation from the Western Ghats, Maharashtra.

Recent reports of new angiosperm species like *Lindernia madayiparense* Ratheesh, Sunil & Nandakumar, *Eriocaulon madayiparense* Swapna, Rajesh, Manju & Prakashkumar, *Eriocaulon kannurense* Sunil, Ratheesh & Nandakumar, and *Rotala khaleeliana* Sunil, Ratheesh & Nandakumar from the lateritic hills in northern Kerala highlights the importance of these ecosystems in terms of floral diversity and species richness. Though many endemic and new species have been reported from the lateritic hills of northern Kerala, floral inventory of these ecosystem are limited (Jayarajan 2004; Balakrishnan et al. 2010). Hence, this study was undertaken to document floristic composition and to highlight the significance of these ecosystem in the laterite hills of low elevations of northern Kerala.

MATERIALS AND METHODS

Study Site

The lateritic regions are a unique feature of northern Kerala and are found from Malappuram District in the south and extend upwards to southern Karnataka towards the north. For the present study, intensive surveys were conducted in three lateritic hillocks of Cherupara, IT park, and Kookanam of the Kavvayi Basin (12.087–12.262 ^{0}N & 75.179–75.236 ^{0}E), spread across Kannur and Kasargod districts. Additionally, lateritic hills of Ariyittapara and Madayipara were also selected. Madayipara (12.031 ^{0}N & 75.258 ^{0}E) is a popular and typical lateritic plateau in Kannur District and lies on the north bank of Kuppam River, located in Madayi Village. Ariyittapara (12.248^{0}N & 75.280^{0}E) is a lesser known hillock in Cheemeni, Kasargod (Figure 1). The altitude gradient of the selected sites ranges from 23m to about 140m. The vegetation in these midland hillocks support scrub jungles, cashew plantations, grasslands, and aquatic & semiaquatic plants.

Data Collection

Field surveys were conducted in the five selected sampling sites from April 2013 to March 2015. Survey frequency was thrice a month during the months of June to September for extensive representation of monsoon ephemeral plants that are characteristic of lateritic hillocks and monthly for the remaining months of the year. The collected plant specimens were processed using standard herbarium techniques, identified with the aid of regional floras (Hooker 1872–1897; Gamble

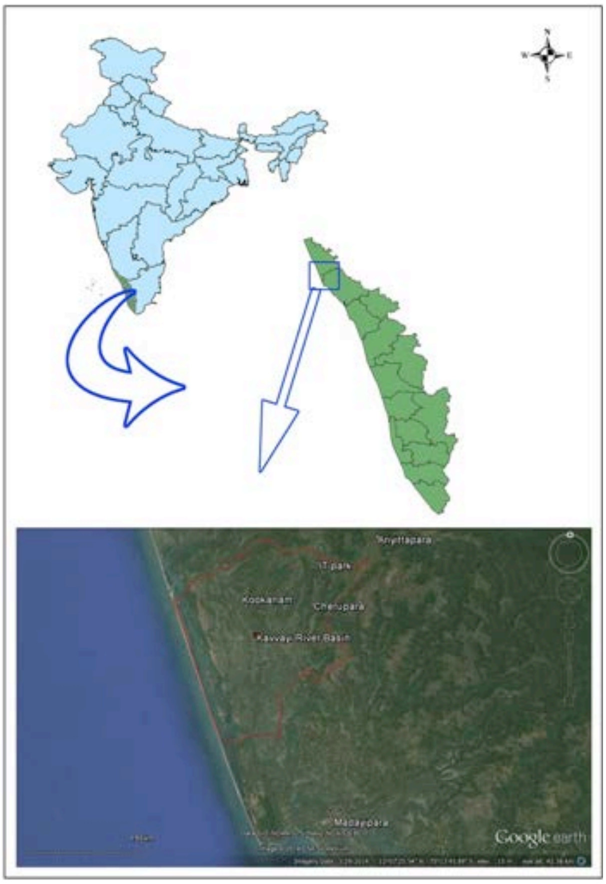

Figure 1. Study Sites: Kavvayi River Basin (boundary marked in red), Madayipara, and Ariyittapara.

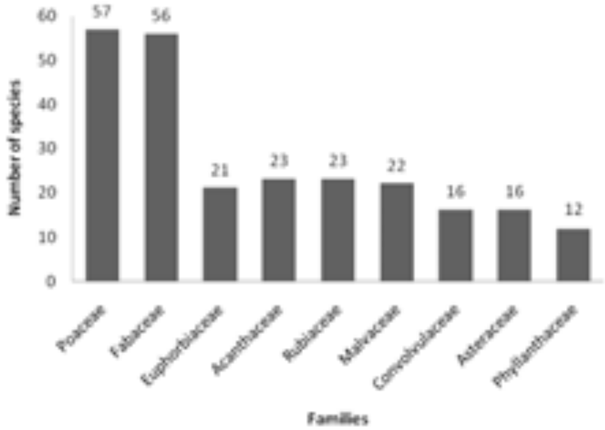

Figure 2. Plant families with higher native species richness in the study area.

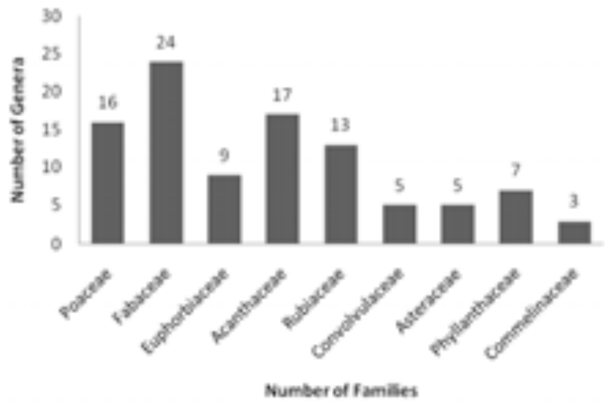

Figure 3. Plant families with highest number of genera native in the study area.

1915–1935; Ramachandran & Nair 1988; Sasidharan 2004, 2007) and deposited at the Kerala Forest Research Institute Herbarium (KFRI). A checklist was prepared based on the APG IV system of classification and the families and species are arranged alphabetically. Information such as habit, endemism, Red List category if any of each taxon is also provided.

RESULTS

During the present study a total of 535 species belonging to 364 genera of 102 families were recorded from the study area (Table 1). Eight predominant families (i.e., with number of species ≥ 15 in each family), namely Poaceae (57 species), Fabaceae (56 species), Acanthaceae (23 species), Rubiaceae (23 species), Malvaceae (22), Euphorbiaceae (21 species), Asteraceae (16) and Convolvulaceae (16 species) were listed. Families with the greatest number of genera included Fabaceae (39 genera), Poaceae (35 genera), Euphorbiaceae (12 genera), Acanthaceae (17 genera), Rubiaceae (16 genera) and Asteraceae (15 genera).

Of the flora documented 2.25% were magnoliids, 21.75% were monocots and the remaining 76% were eudicots comprising rosids (39.8%) and asterids (36.2%). Among the native species of lateritic hills of northern Kerala, herbaceous species were the predominant habit (147 species: 44% of the total) followed by trees (87 species, 26% of the total), climbers (55 species, 16%), and shrubs (45 species, 14%) (Figure 4). Out of the 535 species, 334 are native and 201 are non-native species. Native species were represented in 102 families, namely Poaceae (28), Fabaceae (25), Acanthaceae (22), Rubiaceae (17), Euphorbiaceae (14), etc. (Figure 2). Families with the greatest number of genera in the native species are Fabaceae (27), Poaceae (16), Acanthaceae (17), Rubiaceae (13), Euphorbiaceae (9), etc. (Figure 3). Whereas, non-native species were represented in 99 family and dominated by Poaceae (32), Fabaceae (27), Malvaceae (17), Convolvuvaceae (11), etc. Twenty-

Table 1. Angiosperm plant species from lateritic hills of northern Kerala, India.

	Taxon	Life form	Phyto-geographic distribution	Voucher number
	Family: Piperaceae			
1	*Peperomia pellucida* (L.) Kunth	Herb [Ex]	Native of Tropical America; now Pantropica	KFRI 28939
2	*Piper longum* L.	Shrub	Indo-Malaysia	#
3	*Piper nigrum* L.	Climber	Peninsular India and Sri Lanka, cultivated elsewhere	#
	Family: Aristolochiaceae			
4	*Aristolochia indica* L.	Climber	Indo-Malaysia	KFRI 28967
5	*Thottea siliquosa* (Lam.) Ding Hou	Shrub	Peninsular India and Sri Lanka	#
	Family: Myristicaceae			
6	*Knema attenuata* Warb.	Tree [W]	Western Ghats	KFRI 28993
	Family: Annonaceae			
7	*Polyalthia korinti* (Dunal) Thwaites	Shrub	Southern India and Sri Lanka	KFRI 22366
8	*Uvaria narum* Wall.	Climber	Southern India and Sri Lanka	KFRI 22361
	Family: Lauraceae			
9	*Alseodaphne semecarpifolia* Nees	Tree	Peninsular India and Sri Lanka	KFRI 28920
10	*Cinnamomum malabatrum* (Burm. f.) J.Presl	Tree [W]	Western Ghats	KFRI 28625
11	*Cinnamomum verum* Presl	Tree	Southwestern India and Sri Lanka	#
12	*Litsea glutinosa* (Lour.) C.B.Rob.	Tree	Indo-Malaya and China	#
	Family: Araceae			
13	*Amorphophallus paeoniifolius* (Dennst.) Nicolson	Herb	India, Sri Lanka, and Pacific Islands	KFRI 22345
14	*Ariopsis peltata* Nimmo	Herb	India and western Malaysia	KFRI 22330
15	*Cryptocoryne spiralis* (Retz.) Fisch. ex Wydler	Herb	India extending to Bangladesh	KFRI 22312
16	*Pothos scandens* L.	Climber	India to Malaysia and Madagascar	KFRI 28966
17	*Typhonium flagelliforme* (Lodd.) Blume	Herb	Indo-Malaysia	KFRI22386
18	*Typhonium roxburghii* Schott	Herb	Southern Asia from India through New Guinea	KFRI 22378
	Family: Hydrocharitaceae			
19	*Blyxa octandra* (Roxb.) Planch. ex Thwaites	Herb	Indo-Malesia to Australia	#
20	*Ottelia alismoides* (L.) Pers.	Herb	Indo-Malesia to Pacific Islands and East Asia	KFRI 28919
	Family: Burmanniaceae			
21	*Burmannia coelestis* D.Don	Herb	Indo-Malesia	#
	Family: Dioscoreaceae			
22	*Dioscorea alata* L.	Climber [I]	India	KFRI 28974
23	*Dioscorea bulbifera* L.	Climber	Paleotropics	KFRI 28947
24	*Dioscorea hispida* Dennst.	Climber	Southern and southeastern Asia	KFRI 22380
25	*Dioscorea oppositifolia* L.	Climber	Indo-Malesia and China	#
26	*Dioscorea pentaphylla* L.	Climber	Indo-Malesia and China	KFRI 28975
27	*Dioscorea wallichii* Hook. f.	Climber	India, Myanmar and Thailand	#
	Family: Pandanaceae			
28	*Pandanus amaryllifolius* Roxb.	Shrub [Ex]	Native of Indonesia	KFRI 28629
	Family: Colchicaceae			
29	*Gloriosa superba* L.	Climber	Paleotropics	KFRI 28682
30	*Iphigenia indica* (L.) A. Gray ex Kunth	Herb	Indo-Malesia to Australia	#
	Family: Smilacaceae			
31	*Smilax zeylanica* L.	Climber	Indo-Malesia	KFRI 22324
	Family: Orchidaceae			
32	*Acampe praemorsa* (Roxb.) Blatt. & McCann	Herb	India, Sri Lanka and Seychelles	#
33	*Bulbophyllum sterile* (Lam.) Suresh	Herb	Peninsular India, Nepal, Bangladesh, and Myanmar	KFRI 28647
34	*Dendrobium ovatum* (L.) Kranz.	Herb [W]	Western Ghats	#
35	*Rhynchostylis retusa* (L.) Blume	Herb	Indo-Malesia	#
36	*Zeuxine longilabris* (Lindl.) Trimen	Herb	Indo-Malesia	#

	Taxon	Life form	Phyto-geographic distribution	Voucher number
	Family: Hypoxidaceae			
37	*Curculigo orchioides* Gaertn.	Herb	Indo-Malesia	#
	Family: Asparagaceae			
38	*Dracaena terniflora* Roxb.	Shrub	India and southeastern Asia	KFRI 28945
39	*Furcraea foetida* (L.) Haw.	Shrub [Ex]	Native to central America; introduced in other parts of Tropics	KFRI 22391
	Family: Arecaceae			
40	*Areca catechu* L.	Tree	Cultivated from India to the Solomon Islands and less commonly in Africa and Tropical America	#
41	*Caryota urens* L.	Tree	Indo-Malesia	#
42	*Cocos nucifera* L.	Tree	Cultivated throughout the tropics	#
	Family: Commelinaceae			
43	*Commelina benghalensis* L.	Herb	Africa, India, China, Japan, and Malaysia	KFRI 28968
44	*Commelina diffusa* Burm. f.	Herb	Pantropical	KFRI 22370
45	*Commelina erecta* L.	Herb	India, Africa, and Australia	#
46	*Commelina wightii* Raiz.	Herb [W]	Western Ghats	#
47	*Cyanotis axillaris* (L.) D. Don ex Sweet	Herb	Indo-Malaya	KFRI 28940
48	*Cyanotis burmanniana* Wight	Herb [W,VU]	Western Ghats	#
49	*Cyanotis cristata* (L.) D. Don	Herb	Paleotropics	KFRI 28959
50	*Cyanotis fasciculata* (B.Heyne ex Roth) Schult. & Schult.f.	Herb	Peninsular India and Sri Lanka	KFRI 28969
51	*Cyanotis papilionacea* (Burm. f.) Schult. & Schult. f.	Herb [PI]	Peninsular India	#
52	*Murdannia crocea* (Griff.) Faden	Herb [PI,VU]	Peninsular India	KFRI 28970
53	*Murdannia lanuginosa* (Wall. ex Clarke) Brueckn.	Herb [PI,VU]	Peninsular India	KFRI 22371
54	*Murdannia nudiflora* (L.) Brenan	Herb	Indo-Malaya and Africa	KFRI 28929
55	*Murdannia semiteres* (Dalz.) Sant.	Herb [PI]	Peninsular India	KFRI 28939
	Family: Pontederiaceae			
56	*Monochoria vaginalis* (Burm. f.) C. Presl	Herb	India to China, Malaysia, and Japan	#
	Family: Marantaceae			
57	*Stachyphrynium spicatum* (Roxb.) Schum.	Herb [W]	Southern Western Ghats	KFRI 28643
	Family: Costaceae			
58	*Cheilocostus speciosus* (J.Koenig) C.D.Specht	Herb	Indo-Malaya	#
	Family: Zingiberaceae			
59	*Curcuma oligantha* Trimen	Herb	Southern India, Sri Lanka, and Myanmar	KFRI 22316
60	*Curcuma zanthorrhiza* Roxb.	Herb	Cultivated and naturalised in Indo-Malaya	KFRI 22311
61	*Globba sessiliflora* Sims	Herb	India to Thailand	#
62	*Zingiber zerumbet* (L.) Roscoe ex Sm.	Herb	India, Sri Lanka, and Malaysia	KFRI 22306
	Family: Eriocaulaceae			
63	*Eriocaulon cuspidatum* Dalz.	Herb [W,EN]	Western Ghats	#
64	*Eriocaulon heterolepis* Steud.	Herb [W]	Western Ghats	KFRI 28949
65	*Eriocaulon lanceolatum* Miq. ex Koernicke	Herb [SI]	Southern India	#
66	*Eriocaulon madayiparense* Swapna, Rajesh, Manju & Prakashkumar	Herb [W]	Southern Western Ghats (Kerala)	#
67	*Eriocaulon parviflorum* (Fyson) R. Ansari & N.P. Balakr.	Herb [PI]	Peninsular India	KFRI 28950
68	*Eriocaulon xeranthemum* Mart.	Herb	Tropical Africa and India	KFRI 28948
	Family: Cyperaceae			
69	*Cyperus castaneus* Willd.	Herb	Indo-Malaya to Northern Australia	KFRI 28946
70	*Cyperus compressus* L.	Herb	Pantropical	KFRI 28973
71	*Cyperus distans* L. f.	Herb	Pantropical	KFRI 22381
72	*Kyllinga brevifolia* Rottb.	Herb	Pantropical	#
73	*Kyllinga nemoralis* (J. R & G. Forst.) Dandy ex Hutch. & Dalz.	Herb	Pantropical	#

	Taxon	Life form	Phyto-geographic distribution	Voucher number
	Family: Poaceae			
74	*Alloteropsis cimicina* (L.) Stapf	Herb	Paleotropics	KFRI 28695
75	*Apluda mutica* L.	Herb	Tropical Asia and Australia	KFRI 28637
76	*Apocopis mangalorensis* (Hochst. Ex steud.) Henrard	Herb	Peninsular India	KFRI 28639
77	*Arundinella cannanorica* V.J.Nair, Sreek. & N.C.Nair	Herb W	Western Ghats	#
78	*Arundinella leptochloa* (Steud.) Hook. f.	Herb	Peninsular India and Sri Lanka	#
79	*Arundinella metzii* Hochst. Ex Miq.	Herb W	Western Ghats	#
80	*Axonopus compressus* (Sw.) P.Beauv.	Herb	Tropics and subtropics	#
81	*Bhidea fischeri* Sreek. & B.V.Shetty	Herb SI	Southern India	
82	*Brachiaria ramosa* (L.) Stapf	Herb	Africa and Tropical Asia	#
83	*Brachiaria reptans* (L.) C.A.Gardner & C.E.Hubb.	Herb	Tropical Asia; now introduced throughout the tropics	#
84	*Brachiaria subquadripara* (Trin.) Hitchc.	Herb	Indo-Malaya	KFRI 28990
85	*Centotheca lappacea* (L.) Desv.	Herb	Asia and Africa	KFRI 28649
86	*Chloris barbata* Sw.	Herb Ex	Native of tropical Africa	#
87	*Chrysopogon aciculatus* (Retz.) Trin.	Herb	Tropical Asia and Australia	#
88	*Chrysopogon hackelii* (Hook.f.) C.E.C. Fisch.	Herb PI	Peninsular India	KFRI 28638
89	*Cymbopogon flexuosus* (Nees ex Steud.) Wats.	Herb	India and southeastern Asia	#
90	*Cynodon dactylon* (L.) Pers.	Herb	Tropical and warm temperate regions of the world	#
91	*Cyrtococcum trigonum* (Retz.) A. Camus	Herb	Southeastern Asia, Sri Lanka, and peninsular India	KFRI 28661
92	*Dactyloctenium aegypticum* (L.) Willd.	Herb Ex	Native of South America	#
93	*Digitaria bicornis* (Lam.) Roem. & Schult.	Herb	Pantropical	#
94	*Digitaria ciliaris* (Retz.) Koeler	Herb	Paleotropics	#
95	*Dimeria bialata* C.E.C. Fisch.	Herb SI	Southern India	KFRI 28637
96	*Dimeria hohenackeri* Hochst. ex Miq.	Herb PI	Peninsular India	#
97	*Echinochloa colona* (L.) Link	Herb	Tropical Asia and Africa	KFRI 28938
98	*Eleusine indica* (L.) Gaertn.	Herb	Pantropical	#
99	*Eragrostis patula* (Kunth) Steud.	Herb	Tropical Africa and southern India	KFRI 28636
100	*Eragrostis unioloides (*Retz.) Nees ex Steud.	Herb	Southeastern Asia, India, and Africa	#
101	*Eragrostis viscosa* (Retz.) Trin.	Herb	Pantropical	#
102	*Eragrostis amabilis* (L.) Wight & Arn.	Herb	Paleotropics; introduced in America	#
103	*Heteropogon contortus* (L.) P. Beauv. ex Roem. & Schult.	Herb	Cosmopolitan	#
104	*Isachne globosa* (Thunb.) Ktze.	Herb	Tropical Asia	KFRI 28631
105	*Ischaemum burmanicum* Bor.	Herb VU	Myanmar and India	#
106	*Ischaemum commutatum* Hack.	Herb	Peninsular India and Sri Lanka	KFRI 28658
107	*Ischaemum indicum* (Houtt.) Merr.	Herb	America, Australia, southeastern Asia, and India	#
108	*Ischaemum molle* Hook.f.	Herb	India and Pakistan	#
109	*Ischaemum muticum* L.	Herb	Australia, China, southeastern Asia to Polynesia, Sri Lanka, and India	KFRI 28635
110	*Ischaemum pappinisseriensis* Ravi N. Mohanan & R. Rajesh	Herb SI	South India	#
111	*Ischaemum timorense* Kunth	HerbEx	America, Java, Malaysia, Myanmar, Pakistan, Sri Lanka, Sumatra, Thailand, and Taiwan	#
112	*Ischaemum tumidum* Stapf ex Bor	Herb PI	Peninsular India	#
113	*Microchloa indica* (L.f.) P. Beauv.	Herb	Pantropical	#
114	*Oplismenus burmanni* (Retz.) P.Beauv.	Herb	Pantropical	KFRI 28698
115	*Oplismenus compositus* (L.) P. Beauv.	Herb	Pantropical	#
116	*Oryza rufipogon* Griff.	Herb	India, Sri Lanka, and tropical Australia	#
117	*Oryza sativa* L.	Herb	Widely cultivated	#
118	*Panicum brevifolium* L.	Herb	Paleotropics	#
119	*Panicum notatum* Retz.	Herb	Southern and southeastern Asia	#
120	*Panicum repens* L.	Herb	Tropics and subtropics of both hemispheres	#

	Taxon	Life form	Phyto-geographic distribution	Voucher number
121	*Paspalum scrobiculatum* L.	Herb	India and Pakistan	#
122	*Pennisetum polystachyon* Schult.	Herb [Ex]	Paleotropics	KFRI 28937
123	*Perotis indica* (L.) Ktze.	Herb	Indo-Malaya	#
124	*Pseudanthistiria umbellata* (Hack.) Hook. f.	Herb	Peninsular India and Sri Lanka	#
125	*Rottboellia cochinchinensis* (Lour.) Clayton	Herb	Paleotropics	#
126	*Sacciolepis interrupta* (Willd.) Stapf	Herb	Tropics of southeastern Asia, and Africa	KFRI 28622
127	*Setaria pumila* (Poir.) Roem. & Schult.	Herb	Paleotropics	#
128	*Spodiopogon rhizophorus* (Steud.) Pilg.	Herb	Southwestern India	#
129	*Sporobolus diandrus* (Retz.) P.Beauv.	Herb	Indo-Malaya to Australia	#
130	*Themeda triandra* Forssk.	Herb	Paleotropics	#
	Family: Menispermaceae			
131	*Anamirta cocculus* (L.) Wight & Arn.	Climber	Indo-Malaya	#
132	*Cyclea peltata* (Lam.) Hook. f. & Thoms.	Climber	India and Sri Lanka	KFRI 28627
133	*Diploclisia glaucascens* (Blume) Diels	Climber	Indo-Malaya and China	#
134	*Tinospora sinensis* (Lour.) Merr.	Climber	Sri Lanka, India, Bangladesh, and Myanmar	#
	Family: Ranunculaceae			
135	*Naravelia zeylanica* (L.) DC.	Climber	Southeastern Asia	KFRI 28621
	Family: Crassulaceae			
136	*Bryophyllum pinnatum* (Lam.) Oken	Herb [Ex]	Originally from tropical Africa; now pantropical	KFRI 28934
	Family: Vitaceae			
137	*Ampelocissus latifolia* (Roxb.) Planch.	Climber	Southern Asia	KFRI 28663
138	*Cayratia trifolia* (L.) Domin	Climber	Indo-Malaya, China, and Australia	KFRI 28653
139	*Cissus latifolia* Lam.	Climber	Peninsular India and Sri Lanka	KFRI 23321
140	*Cissus javana* DC.	Climber	Indo-Malaya	#
141	*Leea indica* (Burm. f.) Merr.	Shrub	Indo-Malaya, China, and Australia	KFRI 28685
142	*Leea macrophylla* Roxb. ex Hornem.	Shrub	Southern and southeastern Asia	#
	Family: Fabaceae			
	Sub Family: Caesalpinioideae			
143	*Cassia fistula* L.	Tree	Indo-Malaya	#
144	*Chamaecrista mimosoides* (L.) Greene	Herb	Paleotropics	KFRI 28925
145	*Chamaecrista nictitans* subsp. *patellaria* (Collad.) Irwin & Barneby	Herb	Pantropical	#
146	*Delonix regia* (Hook.) Raf.	Tree[Ex]	Native of Madagascar; now cultivated throughout the tropics	#
147	*Peltophorum pterocarpum* (DC.) K.Heyne	Tree [Ex]	Native of Sri Lanka, Andamans, Malaya peninsula and northern Australia	#
148	*Senna alata* (L.) Roxb.	Shrub [Ex]	Pantropical	#
149	*Senna hirsuta* (L.) Irwin & Barneby	Shrub [Ex]	Native of tropical America	#
150	*Senna occidentalis* (L.) Link	Shrub [Ex]	Native of South America; naturalised in Asia	#
151	*Senna siamea* (Lam.) Irwin & Barneby	Tree [Ex]	Native of southeastern Asia; now widely cultivated	#
152	*Senna tora* (L.) Roxb.	Herb [Ex]	Native of South America	KFRI 28921
153	*Tamarindus indica* L.	Tree[Ex]	Native of tropical Africa; introduced and widely grown in India and other parts of tropics	KFRI 28679
	Sub Family: Mimosoideae			
154	*Acacia caesia* (L.) Willd.	Climber	Indo-Malaysia	#
155	*Acacia pennata* (L.) Willd.	Climber	Paleotropics	#
156	*Acacia auriculiformis* Benth.	Tree [Ex]	Native of Tropical Australia	KFRI 28910
157	*Adenanthera pavonina* L.	Tree [Ex]	Sri Lanka, Himalaya, Myanmar, Thailand, Malaysia, and China	KFRI 28675
158	*Albizia odoratissima* (L.f.) Benth.	Tree	Indo-Malaya	#
159	*Albizia saman* (Jacq.) Merr.	Tree [Ex]	Native of central and South America; widely planted in the tropics as avenue tree	#
160	*Dichrostachys cinerea* (L.) Wight & Arn.	Tree	India and Sri Lanka	#

	Taxon	Life form	Phyto-geographic distribution	Voucher number
161	*Mimosa pudica* L.	Herb [Ex]	Native of South America; now pantropical	#
162	*Xylia xylocarpa* (Roxb.) Taub.	Tree	Indo-Malaya	KFRI 28925
	Sub Family: Papilionoideae			
163	*Abrus precatorius* L.	Climber	Pantropical	KFRI 22389
164	*Aeschynomene americana* L.	Herb [Ex]	Central America; now introduced and naturalised in some parts of Peninsular India	#
165	*Aeschynomene aspera* L.	Shrub	Indo-Malaya	#
166	*Alysicarpus bupleurifolius* (L.) DC.	Herb	Indo-Malaya to Polynesia	KFRI 28927
167	*Butea monosperma* (Lam.) Taub.	Tree	Tropical Asia	KFRI 28915
168	*Cajanus scarabaeoides* (L.) Thouars	Herb	Tropical Asia; introduced in Africa	#
169	*Calopogonium mucunoides* Desv.	Climber [Ex]	Introduced form tropical Asia; now wild in southern India	KFRI 28903
170	*Canavalia gladiata* (Jacq.) DC.	Climber [Ex]	Pantropical	#
171	*Centrosema molle* Benth.	Climber [Ex]	Native of America; introduced in India	KFRI 28909
172	*Clitoria ternatea* var. *pleniflora* Fantz	Climber [Ex]	Pantropical	KFRI 28907
173	*Clitoria ternatea* L.	Climber [Ex]	Widely cultivated in the tropics, probably native of South America	#
174	*Crotalaria pallida* Aiton	Shrub	Pantropical	KFRI 22393
175	*Crotalaria quinquefolia* L.	Herb	Tropical Asia; introduced in Jamaica and West Indies	KFRI 28676
176	*Dalbergia horrida* (Dennst.) Mabb.	Climber [W]	Western Ghats	KFRI 28962
177	*Derris scandens* (Roxb.) Benth.	Climber	Indo-Malaya	KFRI 22395
178	*Derris trifoliata* Lour.	Climber	Paleotropics	#
179	*Desmodium gangeticum* (L.) DC.	Herb	Paleotropics	KFRI 28913
180	*Desmodium heterocarpon* (L.) DC.	Shrub	Indo-Malaya, China, and Japan	#
181	*Desmodium heterophyllum* (Willd.) DC.	Herb	Indo-Malaya and China	KFRI 28914
182	*Desmodium scorpiurus* (Sw.) Desv.	Herb [Ex]	Native of America; introduced and naturalised in the pacific regions of Asia	KFRI 28908
183	*Desmodium triflorum* (L.) DC.	Herb	Indo-Malaya and Australia	KFRI 28902
184	*Erythrina variegata* L.	Tree	Indo-Malaya, China, and Africa	KFRI 28677
185	*Geissaspis cristata* Wight & Arn.	Herb	Southwestern India to Indo-China, Sri Lanka, and China	#
186	*Gliricidia sepium* (Jacq.) Walp.	Tree [Ex]	Native of South America; Introduced and now widely grown in India	#
187	*Indigofera trifoliata* L.	Herb	Indo-Malaya, China and Australia	KFRI 28916
188	*Mucuna pruriens* (L.) DC.	Climber	India, Myanmar, and Sri Lanka	KFRI 28917
189	*Pongamia pinnata* (L.) Pierre	Tree	Indo-Malaya	KFRI 28911
190	*Pseudarthria viscida* (L.) Wight & Arn.	Shrub	Peninsular India and Sri Lanka	KFRI 28623
191	*Smithia conferta* Smith	Herb	Indo-Malaya to Australia	#
192	*Spatholobus parviflorus* (DC.) Kuntze	Climber	Indo-Malaya	KFRI 28678
193	*Stylosanthes fruticosa* (Retz.) Alston	Shrub	Sri Lanka, India, Africa, and Madagascar	#
194	*Tadehagi triquetrum* (L.) H.Ohashi	Shrub	Indo-Malaya to Pacific Islands, and China	#
195	*Tephrosia purpurea* (L.) Pers.	Herb	Indo-Malaya	KFRI 28680
196	*Vigna trilobata* (L.) Verdc.	Climber	Indo-Malaya	KFRI 28912
197	*Zornia gibbosa* Span.	Herb	Indo-Malaya to Australia and China	#
	Family: Polygalaceae			
198	*Polygala elongata* Klein ex Willd.	Herb	India and Sri Lanka	#
199	*Salomonia ciliata* (L.) DC.	Herb	Indo-Malaya and Australia	#
200	*Xanthophyllum arnottianum* Wight	Tree [W]	Western Ghats	KFRI 22359
	Family: Rhamnaceae			
201	*Ziziphus oenoplia* (L.) Mill.	Climber	Tropical Asia and Australia. Throughout the hotter parts of India	#
202	*Ziziphus rugosa* Lam.	Shrub	India, Sri Lanka, Bangladesh, and Myanmar	#
203	*Ziziphus jujuba* Mill.	Tree [Ex]	Paleotropics	#

	Taxon	Life form	Phyto-geographic distribution	Voucher number
	Family: Ulmaceae			
204	*Holoptelea integrifolia* Planch.	Tree	Indo-Malaya	KFRI 28667
	Family:Cannabaceae			
205	*Celtis philippensis* Blanco	Tree	Indo-Malaya to Australia and Tropical Africa	KFRI 22322
206	*Trema orientalis* (L.) Blume	Tree	Tropical Africa, Asia, and Australia	KFRI 28666
	Family: Moraceae			
207	*Antiaris toxicaria* Lesch.	Tree	Paleotropics	KFRI 28645
208	*Ficus arnottiana* (Miq.) Miq.	Tree	India and Sri Lanka	KFRI 28691
209	*Ficus benghalensis* L.	Tree	Indian subcontinent; widely grown as avenue tree	#
210	*Ficus callosa* Willd.	Tree	Indo-Malaya	#
211	*Ficus exasperata* Vahl	Tree	Eastern Africa, Arabia, India, and Sri Lanka	#
212	*Ficus heterophylla* L.f.	Tree	Indo-Malaya and China	KFRI 28692
213	*Ficus hispida* L.f.	Tree	Indo-Malaya to Australia	KFRI 28992
214	*Ficus racemosa* L.	Tree	Indo-Malaya to Australia	#
215	*Ficus religiosa* L.	Tree[Ex]	Eastern Himalaya; naturalised in India	#
216	*Ficus tinctoria* G. Forst. ssp. *gibbosa* (Blume) Corner	Tree	Indo-Malaya	#
	Family: Urticaceae			
217	*Elatostema cuneatum* Wight	Herb	Indo-Malaya	KFRI 28634
218	*Laportea interrupta* (L.) Chew	Herb	Paleotropics	#
219	*Pilea microphylla* (L.) Liebm.	Herb [Ex]	South America; now introduced into other tropical regions	#
220	*Pouzolzia zeylanica* (L.) Bennett	Herb	Tropical Asia	#
	Family: Cucurbitaceae			
221	*Diplocyclos palmatus* (L.) C.Jeffrey	Climber	Indo-Malaya, China, and Africa	#
222	*Momordica dioica* Roxb. ex Willd.	Climber	Indo-Malaya and China	KFRI 28928
223	*Mukia maderaspatana* (L.) Roem.	Climber	Paleotropics	#
224	*Solena amplexicaulis* (Lam.) Gandhi	Climber	Indo-Malaya to Australia	#
225	*Trichosanthes nervifolia* L.	Climber	Southwestern India and Sri Lanka	KFRI 22373
226	*Trichosanthes tricuspidata* Lour.	Climber	Indo-Malaya to Australia and eastern Asia	KFRI 28933
	Family: Celastraceae			
227	*Loeseneriella arnottiana* (Wight) A.C.Sm.	Climber	Southern India and Sri Lanka	#
228	*Lophopetalum wightianum* Arn.	Tree	Indo-Malaya	KFRI 28958
229	*Salacia chinensis* L.	Climber	Indo-Malaya	KFRI 28923
230	*Salacia fruticosa* Wall.	Climber [W]	Western Ghats	#
	Family: Connaraceae			
231	*Connarus monocarpus* L.	Climber	Peninsular India and Sri Lanka	KFRI 28931
232	*Connarus wightii* Hook.f.	Shrub [W]	Western Ghats	KFRI 28943
233	*Rourea minor* (Gaertn.) Alston	Climber	India, Sri Lanka, Bangladesh, and Malaysia	KFRI 22372
	Family: Oxalidaceae			
234	*Biophytum reinwardtii* (Zucc.) Klotzsch.	Herb	Indo-Malaya and China	#
235	*Oxalis corniculata* L.	Herb	Cosmopolitan	KFRI 28648
	Family: Rhizophoraceae			
236	*Carallia brachiata* (Lour.) Merr.	Tree	Indo-Malaya and Australia	KFRI 28935
237	*Rhizophora mucronata* Lam	Tree	Paleotropics	#
	Family: Ochnaceae			
238	*Gomphia serrata* (Gaertn.) Kanis	Shrub	Indo-Malaya	KFRI 28646
	Family: Achariaceae			
239	*Hydnocarpus pentandrus* (Buch.-Ham.) Oken	Tree [W]	Western Ghats	KFRI 28922
	Family: Violaceae			
240	*Hybanthus ennaespermus* (L.) F.Muell.	Herb	Sri Lanka, India, China, Madagascar, Africa, and tropical Australia	KFRI 28980

	Taxon	Life form	Phyto-geographic distribution	Voucher number
	Family: Passifloraceae			
241	*Passiflora foetida* L.	Climber Ex	Native of tropical America; now naturalised in India, China, and Africa	KFRI 28659
242	*Turnera subulata* Smith	Shrub Ex	Native of Tropical Americ	KFRI 28670
	Family: Salicaceae			
243	*Flacourtia indica* (Burm. f.) Merr.	Shrub	Paleotropics	#
	Family: Euphorbiaceae			
244	*Acalypha indica* L.	Herb	Indo-Malaya and tropical Africa	#
245	*Acalypha paniculata* Miq.	Herb	Indo-Malaya and tropical Africa	KFRI 28951
246	*Agrostistachys borneensis* Becc.	Tree	Indo-Malaya	#
247	*Croton caudatus* Geisel.	Climber	Indo-Malaya	KFRI 28905
248	*Croton persimilis* Muell.-Arg.	Tree	India to China	#
249	*Euphorbia deccanensis* V.S.Raju	Herb SI	Southern India	KFRI 28953
250	*Euphorbia heterophylla* L.	Herb Ex	Native of central America; now a pantropical weed	KFRI 22385
251	*Euphorbia hirta* L.	Herb Ex	Native of tropical America; now pantropical	#
252	*Euphorbia nivulia* Buch.-Ham.	Herb	India and Myanmar	KFRI 28904
253	*Euphorbia thymifolia* L.	Herb	Tropical Asia	#
254	*Falconeria insignis* Royle	Tree	Indo-Malaya	#
255	*Jatropha curcas* L.	Shrub Ex	Native of tropical America; now widespread in paleotropics	KFRI 28960
256	*Jatropha gossypifolia* L.	Shrub Ex	Native of South America, planted elsewhere in the tropics	#
257	*Macaranga peltata* (Roxb.) Muell.-Arg.	Tree	India, Sri Lanka, and Andamans	#
258	*Mallotus philippensis* (Lam.) Muell.Arg.	Tree	Indo-Malaya and Australia	#
259	*Mallotus repandus* (Willd.) Muell.Arg.	Shrub	India, China, and Malaysia	KFRI 22387
260	*Micrococca mercurialis* (L.) Benth.	Herb	Tropical Africa, Arabia, India, Sri Lanka, and Myanmar	#
261	*Microstachys chamaelea* (L.) Muell. Arg.	Herb	Indo-Malaya to Australia	KFRI 28906
262	*Microstachys chamaelea* (L.) Muell.Arg.	Herb	Indo-Malaya to Australia	#
263	*Ricinus communis* L.	Shrub Ex	Native of tropical Africa; now cultivated throughout tropics	#
264	*Tragia involucrata* L.	Herb	India and Sri Lanka	KFRI 28674
	Family:Linaceae			
265	*Hugonia mystax* Cav.	Climber	India and Sri Lanka	#
	Family: Phyllanthaceae			
266	*Antidesma acidum* Retz.	Shrub	Indo-Malaya and southern China	KFRI 28979
267	*Antidesma bunius* (L.) Spreng.	Tree	Indo-Malaya to Australia and southern China	KFRI 22383
268	*Aporosa cardiosperma* (Gaertn.) Merr.	Tree	Peninsular India and Sri Lanka	KFRI 28672
269	*Breynia vitis-idaea* (Burm.f.) C.E.C.Fisch.	Shrub	Indo-Malaya	KFRI 28961
270	*Bridelia retusa* (L.) A.Juss.	Tree	Indo-Malaya	#
271	*Bridelia stipularis* (L.) Blume	Shrub PI	Peninsular India	KFRI 28952
272	*Flueggea virosa* (Roxb. ex Willd.) Royle	Shrub	Tropical Africa, Asia, and Australia	#
273	*Glochidion zeylanicum* (Gaertn.) A. Juss.	Tree	Indo-Malaya	#
274	*Phyllanthus amarus* Schum. & Thonn.	Herb	Tropics	#
275	*Phyllanthus emblica* L.	Tree	Throughout the tropics	#
276	*Phyllanthus reticulatus* Poir.	Shrub	Paleotropics	#
277	*Phyllanthus urinaria* L.	HerbEx	Native of tropical eastern Asia; now a circumtropical weed	KFRI 28673
	Family: Combretaceae			
278	*Combretum latifolium* Blume	Climber	Indo-Malaya	#
279	*Terminalia bellirica* (Gaertn.) Roxb.	Tree	Indo-Malaya	#
280	*Terminalia catappa* L.	Tree	Indo-Malaya to northern Australia and Polynesia, commonly planted in the tropics	#
281	*Terminalia paniculata* Roth	Tree PI	Peninsular India	KFRI 28931

	Taxon	Life form	Phyto-geographic distribution	Voucher number
	Family: Lythraceae			
282	*Rotala malabarica* Pradeep, Joseph & Sivar.	Herb SI	Southern India	#
283	*Rotala malampuzhensis* R.V. Nair	Herb W	Western Ghats	#
	Family: Onagraceae			
284	*Ludwigia hyssopifolia* (G. Don) Exell	Herb	Pantropical	#
285	*Ludwigia octovalvis*subsp. sessiliflora (Michx.) P.H. Raven	Herb	Pantropical	#
	Family: Myrtaceae			
286	*Syzygium caryophyllatum* (L.) Alston	Tree	Western Ghats and Sri Lanka	KFRI 28991
287	*Syzygium cumini* (L.) Skeels	Tree W	Western Ghats	KFRI 28995
288	*Syzygium grande* (Wight) Walp.	Tree	Indo-Malaya	#
289	*Syzygium travancoricum* Gamble	Tree W, EN	Southern Western Ghats	KFRI 28994
290	*Syzygium zeylanicum* (L.) DC.	Tree	Indo-Malaya	#
	Family: Melastomataceae			
291	*Melastoma malabathricum* L.	Shrub Ex	Southeastern Asia	#
292	*Memecylon randerianum* S.M. Almeida & M.R. Almeida	Shrub W	Western Ghats	#
293	*Memecylon umbellatum* Burm.f.	Shrub	Peninsular India and Sri Lanka	#
294	*Osbeckia muralis* Naud.	Herb W	Western Ghats	KFRI 28998
	Family: Burseraceae			
295	*Garuga pinnata* Roxb.	Tree	Indo-Malaya	KFRI 22360
	Family: Anacardiaceae			
296	*Anacardium occidentale* L.	Tree Ex	Native of South America; now widely cultivated in Asia and Africa	#
297	*Holigarna arnottiana* Hook. f.	Tree W	Western Ghats	#
298	*Lannea coromandelica* (Houtt.) Merr.	Tree	Indo-Malaya and China	KFRI 22317
299	*Mangifera indica* L.	Tree	Indo-Malaya	#
	Family: Sapindaceae			
300	*Allophylus cobbe* (L.) Raeusch.	Shrub	Southern India, Sri Lanka, and southeastern Asia	KFRI 28632
301	*Cardiospermum halicacabum* L.	Climber	Pantropical	#
302	*Sapindus trifoliatus* L.	Tree	Southern Asia	#
303	*Schleichera oleosa* (Lour.) Merr.	Tree	Indo-Malaya	#
	Family: Rutaceae			
304	*Aegle marmelos* (L.) Correa	Tree	India and Sri Lanka; widely cultivated in southeastern Asia, Malaysia, tropical Africa and the United States	KFRI 28934
305	*Citrus medica* L.	Shrub Ex	Probably indigenous in India; not exactly known	#
306	*Glycosmis mauritiana* (Lam.) Tanaka	Shrub	Indo-Malaya	#
307	*Glycosmis pentaphylla* (Retz.) DC.	Shrub	Indo-Malaya	KFRI 28620
308	*Melicope lunu-ankenda* (Gaertn.) Hartley	Tree	Indo-Malaya	#
309	*Naringi crenulata* (Roxb.) Nicolson	Tree	Indo-Malaya	#
310	*Zanthoxylum rhetsa* DC.	Tree	Indo-Malaya	KFRI 22342
	Family: Meliaceae			
311	*Aglaia elaeagnoidea* (A.Juss.) Benth.	Tree	Indo-Malaya to Pacific Islands	#
312	*Azadirachta indica* A.Juss.	Tree	Indo-Malaya	KFRI 28628
313	*Naregamia alata* Wight & Arn.	Herb PI	Peninsular India	#
	Family: Malvaceae			
314	*Abutilon indicum*(L.) Sweet	Shrub	Tropics and subtropics	#
315	*Bombax ceiba* L.	Tree	Tropical Asia and New Guinea	#
316	*Corchorus aestuans* L.	Herb	Pantropical	KFRI 28671
317	*Corchorus capsularis* L.	Herb Ex	Cultivated in most tropical countries	#
318	*Grewia nervosa* (Lour.) Panigrahi	Shrub	Tropical Asia	#
319	*Grewia tiliifolia* Vahl	Tree	Tropical Africa, India to Indo-China	#

	Taxon	Life form	Phyto-geographic distribution	Voucher number
320	*Helicteres isora* L.	Shrub	Indo-Malaya, China and Australia	#
321	*Hibiscus hispidissimus* Griff.	Shrub	Palaeotropics	KFRI 28639
322	*Hibiscus surattensis* L.	Shrub	Pantropical	#
323	*Melochia corchorifolia* L.	Herb	Pantropical	KFRI 28618
324	*Pterospermum diversifolium* Blume	Tree	Indo-Malaya	#
325	*Pterospermum rubiginosum* Heyne ex Wall.	Tree [W]	Western Ghats	#
326	*Pterygota alata* (Roxb.) R. Br.	Tree	Southern Asia and Myanmar	KFRI 28619
327	*Sida acuta* Burm. f.	Shrub	Pantropical	KFRI 28626
328	*Sida cordata* (Burm. f.) Borss. Waalk.	Herb	Pantropical	#
329	*Sida cordifolia* L.	Shrub	Pantropical	KFRI 28690
330	*Sida rhombifolia* L.	Shrub	Pantropical	#
331	*Sterculia guttata* Roxb. ex G. Don	Tree	Indo-Malaya	#
332	*Triumfetta rhomboidea* Jacq.	Shrub	Pantropical	KFRI 28650
333	*Urena lobata* L.	Shrub	Pantropical	KFRI 28996
334	*Urena sinuata* L.	Shrub	Pantropical	#
335	*Waltheria indica* L.	Shrub	Pantropical	#
	Family: Dipterocarpaceae			
336	*Hopea ponga* (Dennst.) Mabb.	Tree [W, VU]	Western Ghats	KFRI 28976
337	*Vateria indica* L.	Tree [W]	Western Ghats	KFRI 28932
	Family: Capparaceae			
338	*Capparis baducca* **L.**	Shrub [W,VU]	Western Ghats	KFRI 28957
339	*Capparis sepiaria* L.	Shrub	Pantropical	#
340	*Capparis zeylanica* L.	Shrub	Indo-Malaya and China	#
	Family: Cleomaceae			
341	*Cleome rutidosperma* DC.	Herb	Pantropical	KFRI 22362
342	*Cleome viscosa* L.	Herb	Pantropical	#
	Family: Opiliaceae			
343	*Cansjera rheedei* J.F. Gmel.	Climber	India through Malaya to Hong Kong and northern Australia	#
	Family: Santalaceae			
344	*Santalum album* L.	Tree [VU]	Peninsular India and Malaysia	#
	Family: Loranthaceae			
345	*Dendrophthoe falcata* (L.f.) Etting.	Shrub	Peninsular India	#
346	*Helicanthes elastica* (Desr.) Danser	Shrub [W]	Western Ghats	#
347	*Macrosolen parasiticus* (L.) Danser	Shrub	Southwestern India and Sri Lanka	KFRI 28637
348	*Scurrula parasitica* L.	Shrub	Southern and southeastern Asia	#
	Family: Plumbaginaceae			
349	*Plumbago zeylanica* L.	Shrub	Pantropical	KFRI 28660
	Family: Droseraceae			
350	*Drosera indica* L.	Herb	Paleotropics	KFRI 28977
	Family: Ancistrocladaceae			
351	*Ancistrocladus heyneanus* Wall. ex J.Graham	Climber	Southern India and Sri Lanka	KFRI 22302
	Family: Caryophyllaceae			
352	*Polycarpaea corymbosa* (L.) Lam.	Herb	Pantropical	#
	Family: Amaranthaceae			
353	*Achyranthes aspera* L.	Herb	Pantropical	KFRI 22301
354	*Achyranthes bidentata* Blume	Herb	Indo-Malaya to Australia and eastern Asia	KFRI 22392
355	*Aerva lanata* (L.) Juss.	Herb	Widespread in the tropics and subtropics	KFRI 22375
356	*Alternanthera bettzickiana* (Regel) G. Nicholson	Herb [Ex]	Native of tropical America; getting naturalised in Asia	KFRI 22353
357	*Alternanthera brasiliana* (L.) Kuntze	Herb [Ex]	Native of tropical America	KFRI 22399
358	*Alternanthera sessilis* (L.) R. Br. ex. DC.	Herb	Pantropical	KFRI 22376

	Taxon	Life form	Phyto-geographic distribution	Voucher number
359	*Amaranthus spinosus* L.	Herb [Ex]	Originally from America; now found in warmer regions of the world	KFRI 22397
360	*Amaranthus viridis* L.	Herb	Pantropical	KFRI 22343
361	*Celosia argentea* L.	Herb	Cosmopolitan	KFRI 22331
362	*Cyathula prostrata* (L.) Blume	Herb	Pantropical	KFRI 28964
363	*Gomphrena celosioides* Mart.	Herb [Ex]	Originally from South America; now widespread in the tropics	KFRI 22352
	Family: Aizoaceae			
364	*Trianthema portulacastrum* L.	Herb	Tropics of the world	KFRI 22363
	Family: Nyctaginaceae			
365	*Boerhavia diffusa* L.	Herb	Pantropical	#
	Family: Molluginaceae			
366	*Glinus oppositifolius* (L.) A. DC.	Herb	Pantropical	#
367	*Mollugo pentaphylla* L.	Herb	Pantropical	#
368	*Mollugo stricta* L.	Herb	Pantropical	#
	Family: Portulacaceae			
369	*Portulaca oleracea* L.	Herb	Pantropical	KFRI 28699
	Family: Cactaceae			
370	*Cereus pterogonus* Lem.	Shrub[Ex]	Pantropical	KFRI 28936
	Family: Cornaceae			
371	*Alangium salviifolium* subsp. *hexapetalum* (Lam.) Wang.	Climber	Indo-Malaya	KFRI22314
	Family: Balsaminaceae			
372	*Impatiens balsamina* L.	Herb	Indo-Malaya; introduced into many countries	KFRI 22318
373	*Impatiens chinensis* L.	Herb	India and China	KFRI 22303
374	*Impatiens flaccida* Arn.	Herb	Southern India and Sri Lanka	KFRI 22315
375	*Impatiens minor* (DC.) Bennet	Herb [PI]	Peninsular India	KFRI 22320
	Family: Lecythidaceae			
376	*Careya arborea* Roxb.	Tree	Tropical Asia	KFRI 28636
	Family: Sapotaceae			
377	*Madhuca neriifolia* (Moon) H. J. Lam	Tree	India and Sri Lanka	KFRI 22339
378	*Mimusops elengi* L.	Tree	Indo-Malaya	#
	Family: Ebenaceae			
379	*Diospyros buxifolia* (Blume) Hiern	Tree	Indo-Malaya	KFRI 29000
380	*Diospyros candolleana* Wight	Tree [PI]	Peninsular India	KFRI 28978
	Family: Rubiaceae			
381	*Benkara malabarica* (Lam.) Tirveng.	Shrub	Peninsular India and Sri Lanka	KFRI 28700
382	*Canthium coromandelicum* (Burm.f.) Alston	Shrub	Indo-Malaya	KFRI 28657
383	*Catunaregam spinosa* (Thunb.) Tirveng.	Shrub	Tropical Asia and Africa	#
384	*Chassalia curviflora* var. *ophioxyloides* (Wall.) Deb & Krishna	Shrub	Indo-Malaya	#
385	*Hedyotis cyanantha* Kurz	Shrub	Peninsular India and Sri Lanka	#
386	*Ixora brachiata* Roxb.	Shrub [W]	Western Ghats	#
387	*Ixora coccinea* L.	Shrub	Peninsular India and Sri Lanka	KFRI 22357
388	*Mitracarpus hirtus* (L.) DC.	Herb [Ex]	Tropical Africa and America; now common in southern India	#
389	*Morinda citrifolia* L.	Tree	Indo-Malaya to Australia	#
390	*Mussaenda frondosa* L.	Shrub [PI]	Peninsular India	#
391	*Neanotis hohenackeri* Daniel & Vajr.	Herb [I]	India	#
392	*Neanotis rheedei* (Wall. & Arn.) W.H. Lewis	Herb [W, En]	Western Ghats	KFRI 28936
393	*Neanotis tubulosa* (G. Don) Mabb.	Herb	Peninsular India and Sri Lanka	#
394	*Oldenlandia corymbosa* L.	Herb	Pantropical	
395	*Oldenlandia herbacea* (L.) Roxb.	Herb	Tropical Africa and Asia	#

	Taxon	Life form	Phyto-geographic distribution	Voucher number
396	*Ophiorrhiza mongus* L.	Herb	India, Myanmar, and Sri Lanka	#
397	*Pavetta indica L.*	Shrub	India and Sri Lanka	#
398	*Psychotria flavida* Talbot	Shrub [W]	Southern Western Ghats	#
399	*Psydrax umbellata* (Wight) Bridson	Tree	Indo-Malaysia and China	#
400	*Spermacoce alata* Aubl.	Herb [Ex]	Native of Tropical America; now established in Tropical Africa and Asia	#
401	*Spermacoce articularis* L. f.	Herb	Tropical Asia and Africa	KFRI 22346
402	*Spermacoce ocymoides* Burm.f.	Herb	Indo-Malaysia and Tropical Africa	#
403	*Spermacoce pusilla* Wall.	Herb	India and Myanmar	#
	Family: Gentianaceae			
404	*Canscora diffusa* (Vahl) R.Br. ex Roem. & Schult.	Herb	Tropical Africa, Asia, and Australia	KFRI 28923
405	*Hoppea fastigiata* (Griseb.) Clarke	Herb	Peninsular India, Sri Lanka, and Myanmar	#
	Family: Loganiaceae			
406	*Mitrasacme indica* Wight	Herb	Indo-Malaya to Australia and eastern Asia	KFRI 28641
407	*Strychnos nux-vomica* L.	Tree	Indo-Malaya	KFRI 28638
408	*Strychnos vanprukii* Craib	Climber [W]	Western Ghats	KFRI 28999
	Family: Apocynaceae			
409	*Aganosma cymosa* (Roxb.) G.Don	Climber	Peninsular India and Sri Lanka	KFRI 22349
410	*Allamanda cathartica* L.	Climber [Ex]	Native of Tropical America; now naturalised in the tropics of the world	KFRI 22332
411	*Alstonia scholaris* (L.) R. Br.	Tree	Southern and southeastern Asia to Australia	#
412	*Catharanthus pusillus* (Murr.) G. Don	Herb	India and Sri Lanka	#
413	*Cryptolepis dubia (Burm.f.) M.R.Almeida*	Climber	Peninsular India and Sri Lanka	#
414	*Holarrhena pubescens* Wall. ex G. Don	Tree	Indo-Malaya	KFRI 28956
415	*Ichnocarpus frutescens* (L.) W.T.Aiton	Climber	Indo-Malaya and Australia	KFRI 28935
416	*Kamettia caryophyllata* (Roxb.) Nicolson & Suresh	Climber [W]	Western Ghats	KFRI 22326
417	*Plumeria rubra* L.	Tree[Ex]	Native of tropical America; widely naturalised elsewhere in the tropics	#
418	*Rauvolfia serpentina* (L.) Benth. ex Kurz	Herb	Southern and southeastern Asia	KFRI 28965
419	*Tabernaemontana alternifolia* L.	Tree [W]	Western Ghats	KFRI22384
420	*Tabernaemontana divaricata* (L.) R. Br. ex Roem. & Schult.	Shrub [Ex]	Native of southern Himalaya	#
421	*Wrightia tinctoria* R. Br.	Tree	India, Myanmar, and Timor	KFRI 28955
	Family: Boraginaceae			
422	*Cordia dichotoma* G. Forst.	Tree	Pakistan, India, Sri Lanka, and northern Africa	KFRI 22356
423	*Heliotropium indicum* L.	Herb	Pantropical	#
424	*Heliotropium keralense* Sivar. & Manilal	Herb [W]	Western Ghats	KFRI 22354
425	*Heliotropium marifolium* J.Koenig ex Retz.	Herb	Peninsular India and Sri Lanka	KFRI 22305
	Family: Convolvulaceae			
426	*Argyreia nervosa* (Burm.f.) Bojer	Climber	Indo-Malaya, China, and Mauritius	KFRI 28954
427	*Cuscuta reflexa* Roxb.	Climber	Indo-Malaysia and China	KFRI 22374
428	*Erycibe paniculata* Roxb.	Climber	India, Himalaya, and Andaman Islands	KFRI 22369
429	*Evolvulus alsinoides* (L.) L.	Herb	Pantropical	KFRI 28938
430	*Evolvulus nummularius* (L.) L.	Herb[Ex]	Native of tropical America; naturalised in Africa and Indo-Malaya	KFRI 28971
431	*Hewittia malabarica* (L.) Suresh	Climber	Asia, Africa, and South America	KFRI 28941
432	*Ipomoea cairica* (L.) Sweet	Climber [Ex]	Paleotropics	#
433	*Ipomoea hederifolia* L.	Climber [Ex]	Native of tropical America; now naturalised in tropical Asia	#
434	*Ipomoea mauritiana* Jacq.	Climber	Pantropical	KFRI 28930
435	*Ipomoea nil* (L.) Roth	Climber [Ex]	Native of South America; now naturalised in tropics	#
436	*Ipomoea pes-tigridis* L.	Climber	Pantropical	#
437	*Ipomoea pileata* Roxb.	Climber	Tropical Africa and Indo-Malaya	KFRI 28942

	Taxon	Life form	Phyto-geographic distribution	Voucher number
438	*Merremia tridentata* (L.) Hall.f.	Herb	Paleotropics	#
439	*Merremia umbellata* (L.) Hall.f.	Climber	Pantropical	#
440	*Merremia vitifolia* (Burm. f.) Hall.f.	Climber	Indo-China and China	KFRI 28944
441	*Neuropeltis malabarica* Ooststr.	Climber [W]	Western Ghats	KFRI 28972
	Family: Solanaceae			
442	*Capsicum annuum* L.	Shrub [Ex]	Native to West Indies; widely cultivated all over the world	#
443	*Datura stramonium* L.	Shrub [Ex]	Widely distributed in most parts of the temperate regions of the world	#
444	*Physalis angulata* L.	Herb [Ex]	Tropical Asia, Africa, and Australia	KFRI 28981
445	*Solanum americanum* Mill.	Herb [Ex]	Cosmopolitan	#
446	*Solanum torvum* Sw.	Shrub	Throughout the tropics	KFRI 28655
	Family: Oleaceae			
447	*Chionanthus mala-elengi* (Dennst.) P.S.Green	Tree [PI]	Peninsular India	#
448	*Jasminum azoricum* L.	Climber[Ex]	Native to the Azores Islands	#
449	*Jasminum malabaricum* Wight	Climber [W]	Western Ghats	#
450	*Olea dioica* Roxb.	Tree [I]	India	KFRI 28662
	Family: Gesneriaceae			
451	*Rhynchoglossum notonianum* (Wall.) Burtt	Herb	Southwestern India and Sri Lanka	#
	Family: Plantaginaceae			
452	*Dopatrium junceum*(Roxb.) Buch.-Ham. ex Benth.	Herb	Eastern tropics	#
453	*Limnophila repens* (Benth.) Benth.	Herb	Tropical Asia	KFRI 22337
454	*Mecardonia procumbens* (Mill.) Small	Herb[Ex]	Native of tropical America; naturalised in India	KFRI 22328
455	*Microcarpaea minima* (Koenig ex Retz.) Merr.	Herb	Paleotropics	#
456	*Scoparia dulcis* L.	Herb [Ex]	Native of tropical America; now pantropical	#
	Family:Linderniaceae			
457	*Lindernia ciliata* (Colsm.) Pennell	Herb	Indo-Malaya	#
458	*Lindernia crustacea* (L.) F.Muell.	Herb	Africa, America, and tropical &subtropical Asia	#
459	*Lindernia hyssopioides* (L.) Haines	Herb	Southeastern Asia, Malaysia and China	#
460	*Lindernia viscosa* (Hornem.) Merr.	Herb	Indo-Malaya and China	#
	Family: Martyniaceae			
461	*Martynia annua* L.	Shrub [Ex]	Tropical and subtropical America; naturalised in Indian subcontinent	#
	Family: Pedaliaceae			
462	*Pedalium murex* L.	Herb	Tropical Africa, Sri Lanka, India, and Pakistan	KFRI 28698
463	*Sesamum indicum* L.	Herb	Tropical Africa and Asia	KFRI 28630
464	*Sesamum radiatum* Schum. & Thonn.	Herb [Ex]	Native of tropical western Africa; now widely spread	#
	Family: Acanthaceae			
465	*Acanthus ilicifolius* L.	Shrub	Indo-Malaya and Australia	KFRI 22229
466	*Andrographis paniculata* (Burm. f.) Wall.	Herb	Peninsular India and Sri Lanka	KFRI 22301
467	*Asystasia dalzelliana* Sant.	Herb	Tropical Asia and Africa	KFRI 22341
468	*Asystasia gangetica* (L.) Anders.	Herb	Peninsular India, Sri Lanka, Arabia, and Africa	KFRI 22329
469	*Barleria cristata* L.	Shrub[Ex]	Indo-Malaya and southern China	KFRI 22351
470	*Barleria prionitis* L.	Shrub	Tropical Africa and Asia	KFRI 22355
471	*Dicliptera paniculata* (Forssk.) I. Darbysh.	Herb	India, Myanmar, and tropical Africa	KFRI 22350
472	*Dipteracanthus prostratus*(Poir.) Nees	Herb [I]	India	KFRI 22338
473	*Eranthemum capense* L. var. *capense* Hook. f.	Herb	Peninsular India and Sri Lanka	KFRI 22336
474	*Gymnostachyum febrifugum* Benth.	Herb [W]	Southern Western Ghats	#
475	*Haplanthodes neilgherryensis* (Wight) Majumdar	Herb [W]	Western Ghats	KFRI 22394
476	*Justicia adhatoda* L.	Shrub	Indo-Malaya	KFRI 22390
477	*Justicia ekakusuma* Pradeep & Sivar.	Herb [SI]	Southern India	KFRI 22382
478	*Justicia japonica* Thunb.	Herb	Indo-Malaya and eastern Africa	KFRI 22313

	Taxon	Life form	Phyto-geographic distribution	Voucher number
479	*Lepidagathis incurva* Buch.-Ham. ex D.Don	Herb	India, Myanmar, and China	KFRI 22353
480	*Lepidagathis keralensis* Madhu. & Singh	Herb [SI]	Southern India	KFRI 22340
481	*Phaulopsis imbricata* (Forssk.) Sweet	Herb	Indo-Malaysia, China, and Africa	KFRI 22400
482	*Pseuderanthemum malabaricum* Gamble	Herb	Peninsular India and Sri Lanka	KFRI 22396
483	*Rhinacanthus nasutus* (L.) Kurz	Herb	India, Sri Lanka, Java, and Madagascar	KFRI 22358
484	*Rungia pectinata* (L.) Nees	Herb	India, Sri Lanka, and Myanmar	KFRI 22329
485	*Staurogyne glutinosa* Kuntze	Herb	India and Bangladesh	KFRI 22341
486	*Strobilanthes heyneanus* Nees	Shrub	India and Sri Lanka	KFRI 22334
487	*Strobilanthes perfoliata* Anders.	Shrub [W]	Western Ghats	KFRI 22367
	Family: Bignoniaceae			
488	*Millingtonia hortensis* L.f.	Tree	Southeastern Asia and Malaysia	KFRI 22358
489	*Pajanelia longifolia* (Willd.) K.Schum.	Tree	India and Myanmar	KFRI 22304
490	*Stereospermumtetragonum* DC.	Tree	Indo-China and Malaysia	KFRI 28937
	Family: Lentibulariaceae			
491	*Utricularia cecilii* P.Taylor	Herb [W]	Western Ghats	KFRI 28918
492	*Utricularia graminifolia* Vahl	Herb	India and Sri Lanka	#
493	*Utricularia lazulina* P.Taylor	Herb [W]	Western Ghats	KFRI 28683
494	*Utricularia malabarica* Janarth. & A.N Henry	Herb [SI]	South India	#
495	*Utricularia reticulata* Smith	Herb	India and Sri Lanka	#
496	*Utricularia striatula* Smith	Herb	Paleotropics	KFRI 28640
497	*Utricularia uliginosa* Vahl	Herb	Indo-Malaya, China, and Australia	#
	Family: Verbenaceae			
498	*Lantana camara* L.	Shrub [Ex]	Native of tropical America, widely naturalised in the tropics and subtropics	#
499	*Phyla nodiflora* (L.) Greene	Herb	Tropics and subtropics	KFRI 28664
500	*Stachytarpheta jamaicensis* (L.) Vahl	Shrub	Pantropical	KFRI 28665
	Family: Lamiaceae			
501	*Anisochilus carnosus* (L. f.) Wall.	Herb	Southern India, Sri Lanka and Myanmar	#
502	*Anisomeles indica* (L.) Kuntze	Herb	Indo-Malaya and China	KFRI 28644
503	*Hyptis suaveolens* (L.) Poit.	Shrub [Ex]	Originally from America now pantropical	
504	*Leucas aspera* (Willd.) Link	Herb	Indo-Malaya	#
505	*Leucas biflora* (Vahl) Sm.	Herb	Peninsular India and Sri Lanka	KFRI 28681
506	*Ocimum americanum* L.	Herb [Ex]	Paleotropics	#
507	*Platostoma hispidum* (L.) A.J.Paton	Herb	Indo-Malaya	#
508	*Pogostemon deccanensis* (Panigrahi) Press	Herb [SI]	Southern India	KFRI 28642
509	*Pogostemon purpurascens* Dalz.	Herb [SWI]	Southwestern India	#
510	*Pogostemon quadrifolius* (Benth.) F.Muell.	Herb [I]	India	#
511	*Symphorema involucratum* Roxb.	Climber	Indo-Malaya	KFRI 22323
	Family: Orobanchaceae			
512	*Centranthera indica* (L.) Gamble	Herb	Indo-Malaya, China, and Australia	#
513	*Rhamphicarpa fistulosa* (Hochst.) Benth.	Herb [I]	India	#
514	*Sopubia trifida* Buch.-Ham. ex D. Don	Herb	Indo-Malaya and China	#
515	*Striga angustifolia* (D. Don) Saldanha	Herb	Indo-Malaya	KFRI 28933
516	*Striga asiatica* (L.) Ktze.	Herb[Ex]	Southeastern Asia and Africa	#
517	*Striga gesnerioides* (Willd.) Vatke	Herb	From tropical and southern Africa through Arabia to India and Sri Lanka	#
	Family: Menyanthaceae			
518	*Nymphoides krishnakesara* Joseph & Sivar.	Herb [W]	Southern Western Ghats	KFRI 28997
	Family: Asteraceae			
519	*Acanthospermum hispidum* DC.	Herb [Ex]	Pantropical	KFRI 22309
520	*Ageratum conyzoides* (L.) L.	Herb [Ex]	Pantropical	KFRI 22325

	Taxon	Life form	Phyto-geographic distribution	Voucher number
521	*Bidens pilosa* L.	Herb Ex	Pantropical	KFRI 22310
522	*Blumea membranacea* DC.	Herb	Indo-Malaya	KFRI 22365
523	*Blumea oxyodonta* DC.	Herb	Indo-Malaya and southern China	KFRI 22308
524	*Cosmos caudatus* Kunth	Herb Ex	West Indies and central America; introduced in India	KFRI 22307
525	*Eclipta prostrata* (L.) L.	Herb	Pantropical	#
526	*Elephantopus scaber* L.	Herb	Pantropical	#
527	*Emilia sonchifolia* (L.) DC. ex DC.	Herb	Tropical and subtropical Africa and Asia	KFRI 22347
528	*Grangea maderaspatana* (L.) Poir.	Herb	Indo-Malaya and Africa	KFRI 22335
529	*Mikania micrantha* Kunth	Climber Ex	Pantropical	#
530	*Phyllocephalum phyllolaenum* (DC.) Narayana	Herb I	India	KFRI 22344
531	*Sphagneticola trilobata* (L.) Pruski	Herb Ex	Native of tropical America	KFRI 22368
532	*Synedrella nodiflora* (L.) Gaertn.	Herb Ex	Native of West Indies; naturalised in India, China, Malaysia, and Polynesia	KFRI 22319
533	*Tridax procumbens* (L.) L.	Herb Ex	Native of tropical America; now widespread throughout tropics and subtropics	#
534	*Vernonia cinerea* (L.) Less.	Herb	Pantropics	#
	Family: Apiaceae			
535	*Centella asiatica* (L.) Urb.	Herb	Tropical Asia and Africa	#

#—not accessed due to restriction in collection | EN—Endangered | Ex—exotic | I—endemic to India | PI—endemic to peninsular India | SI—endemic to southern India | SWI—endemic to southwestern India | VU—Vulnerable | W—endemic to Western Ghats.

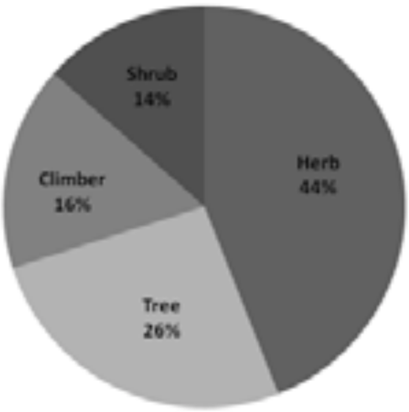

Figure 4. Percentage distribution of native plant habits of the documented species.

seven invasive species were recorded and major threats to the laterite ecosystems are by *Lantana camara* L., *Mikania micrantha* Kunth, *Pennisetum polystachyon* Schult., *Ipomoea* spp., and *Senna* spp.

Of the 334 native species reported, *Asparagus fysonii* Macbr., *Eriocaulon cuspidatum* Dalz., *Neanotis rheedei* (Wall. ex Wight & Arn.) Lewis are listed as Endangered; *Capparis baducca* L., *Cyanotis burmanniana* Wight, *Ischaemum burmanicum* Bor., and *Murdannia lanuginosa* (Wall. ex Clarke) Bruckn. as Vulernable (Sasidharan 2007); whereas *Syzygium travancoricum* Gamble is listed as Critically Endangered (CAMP Workshops on Medicinal Plants, India 1998), *Hopea ponga* (Dennst.) Mabb. as Endangered (Ashton 1998) and *Santalum album* L. are listed as Vulnerable (Arunkumar et al. 2019). Important plant species images are also provided (Image 1–4).

DISCUSSION

The alteration in wet and dry spells creates unique microhabitats that support the varied biota in it. The microhabitats and larger area could be the reasons for accommodating more angiosperms (Rahangdale & Rahangdale 2014). Most of the lateritic flora is adapted to the various microhabitats and each microhabitat is unique in its edaphic properties, water availability, and species composition. This makes such floristic studies ecologically significant. Floral inventories as provided here contribute to understanding and highlighting the ecological significance of the landscape. The current inventory adds to the floristic knowledge of lateritic hills in these areas. The floristic composition may differ from site to site, but in general these (Table 1) were the frequent families recorded during the study in the lateritic hills in northern Kerala.

Also, of the seven new species recorded from lateritic hills of northern Kerala over the years, only two species were observed during the current study. These are *Justicia ekakusuma* Pradeep & Sivar. and *Rotala malabarica* Pradeep et al. Most of the lateritic

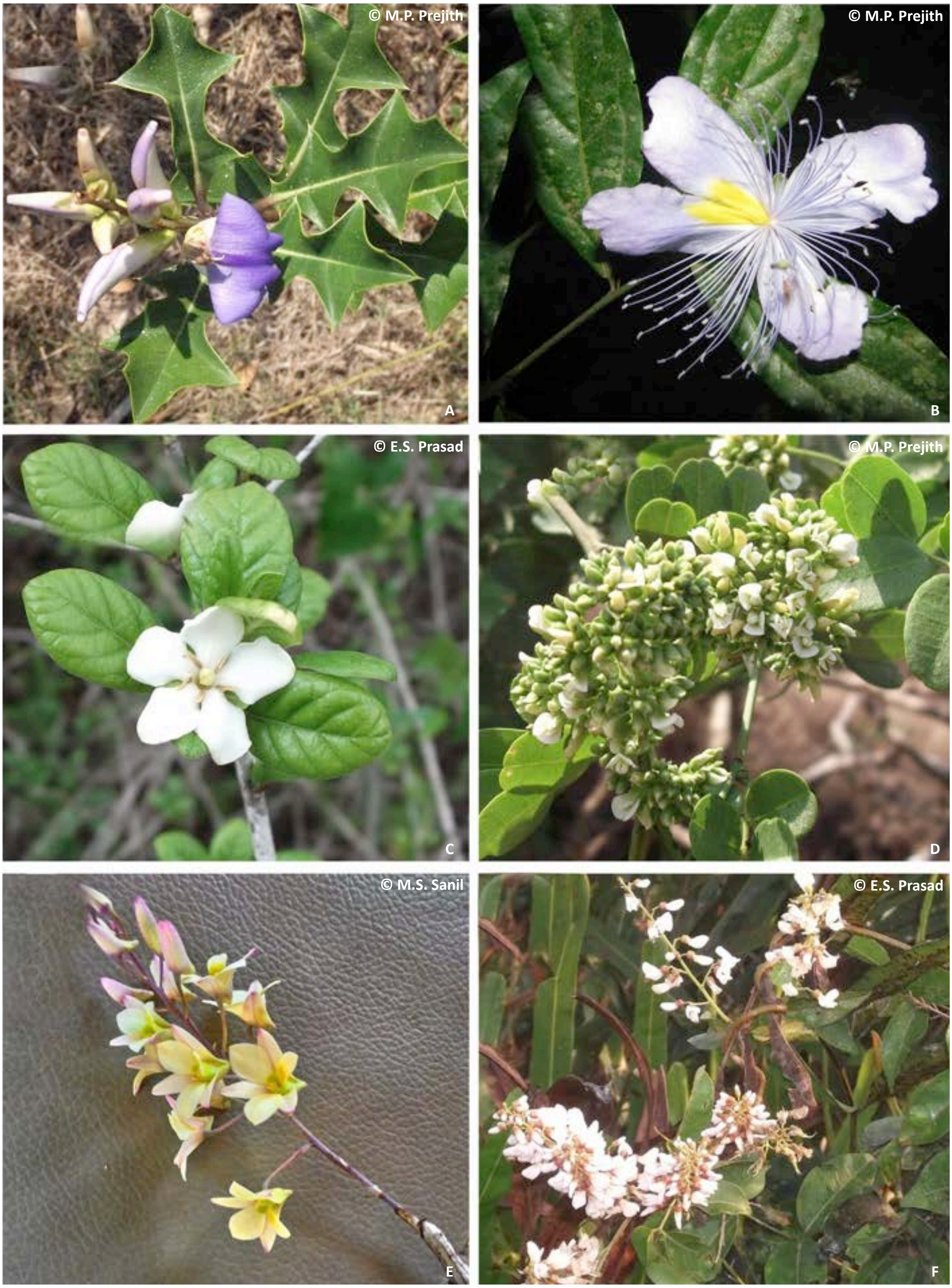

Image 1. A—*Acanthus ilicifolius* | B—*Capparis baducca* | C—*Catunaregam spinosa* | D—*Dalbergia horrida* | E—*Dendrobium ovatum* | F—*Derris trifoliata.*

Image 2. A—*Eriocaulon madayiparense* | B—*Erythrina variegata* | C—*Globba sessiliflora* | D—*Grewia tiliifolia* | E—*Gymnostachyum febrifugum* | F—*Hopea ponga*

Image 3. A—*Ixora brachiata* | B—*Melastoma malabathricum* | C—*Neanotis hohenackeri* | D—*Psychotria flavida* | E—*Rhizophora mucronata* | F—*Rhynchostylis retusa*

Image 4. A—*Rotheca serrata* | B—*Sesamum radiatum* | C—*Strobilanthes perfoliata* | D—*Syzygium zeylanicum* | E—*Terminalia paniculata* | F—*Utricularia cecilii*

exposed areas have been converted into industrial and residential areas. Infrastructure developments lead to mining and extraction of more lateritic hills and the soil from the mining are used to fill wetland and paddy field which again utilized for building and infrastructure development. This series of events in turn seriously affected the natural environment of the lateritic biotopes in northern Kerala (Sreejith et al. 2016). The indiscriminate mining for laterite & soil and demolishing the hillocks have severely threatened the very existence of the biota, culture, and the water availability in most areas (Balakrishnan et al. 2010). Currently, these systems in the lateritic hills are undergoing severe degradation, destruction, alteration through various activities such as mining, shifting to monoculture plantation, rapid infrastsructure development, and from alien invasive species. Since only a small portion of this landscape remains undisturbed, an urgent intervention from concerned authorities to formulate and implement strict guidelines & policies to conserve the species-rich lateritic biotope, to evolve & implement site-specific restoration, and conservation programmes are to be initiated & implemented to protect the floristically rich lateritic hillocks of northern Kerala.

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COMMUNICATION

Contribution to the macromycetes of West Bengal, India: 51–56

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Abstract: The West Bengal is a treasure house for macro-fungal diversity due to its varied geo-climatic conditions. Detailed macroscopic and microscopic characterization was made to identify the collected specimens. Altogether six species belonging to the family Xylariaceae (three species), Hypoxylaceae (one species), Ascobolaceae (one species) and Pyronemataceae (one species) were collected from different corners of the state. Literature survey revealed that all of the collected taxa represent their first detailed description and distributional record from the state. A comprehensive macro-morphological description, field photographs along with microscopic observations are provided. The outcome of the present study will enrich data related to the diversity of macrofungi from the state West Bengal.

Keywords: Ascomycota, fungi, morphology, taxonomy.

সংক্ষিপ্তসার: পশ্চিমবঙ্গ তার ভূ-প্রকৃতি ও জলবায়ুর বিভিন্নতার জন্য বৃহৎ ছত্রাক বৈচিত্র্যের এক উৎকৃষ্ট ভান্ডার। সংগৃহীত ছত্রাক সমূহের নমুনাগুলি সনাক্তকরনের জন্য বৃহৎ ও আণুবীক্ষণিক চারিত্রাবলির পর্যবেক্ষণ করা হয়েছে। রাজ্যের বিভিন্ন প্রান্ত থেকে সংগৃহীত মোট ছয়টি প্রজাতির উপস্থাপনা বর্তমান গবেষণা পত্রে রয়েছে। এই প্রজাতিসমূহের গোত্রগুলি হল- জাইলারিয়াসি (তিনটি প্রজাতি), হাইপোক্সিলেসি (একটি প্রজাতি), অ্যাসকোবোলেসি (একটি প্রজাতি) এবং পাইরোনিমাটেসি (একটি প্রজাতি) । উপযোগী প্রকাশিত গ্রন্থ ও গবেষণাপত্র অধ্যয়নের মাধ্যমে জানা যায় বর্তমানে আলোচিত ছয়টি প্রজাতির ব্যাপ্তি এই রাজ্য থেকে সর্বপ্রথম নথিভুক্ত ও বিস্তারিত ভাবে বর্ণিত হল। অণুবীক্ষনিক পর্যবেক্ষণের সাথে সাথে দৃষ্টিগোচর বৃহৎ অঙ্গ সংস্থানিক চারিত্রাবলির বিস্তারিত বর্ণনা এবং সংশ্লিষ্ট প্রজাতির বাসস্থানসহ আলোকচিত্র বর্তমান গবেষণাপত্রে পরিবেশিত হয়েছে। এই গবেষণার ফলাফল পশ্চিমবঙ্গের বৃহৎ ছত্রাক বৈচিত্র্যের তথ্যভান্ডার কে সমৃদ্ধ করবে।

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Author contribution: Specimen collected by DD, ET, MB, AR and KA. Field Photographed by ET, AR and KA. Microscopy photographed by DD and MB. Macro and microscopy described by DD and MB. Data analysis and compiled by KA, AR and ET.

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WBBB

INTRODUCTION

West Bengal possesses diverse phytogeographical realms, spreading through its coastal to subalpine regions, due to its varied ecological conditions like altitude, temperature, edaphic factors, etc. Thus, vegetation of this state is greatly diversified from its east to west and north to south. These wide arrays of geomorphology, climatic variations and vegetation structure make conducive for the luxuriant growth of macrofungi (Acharya et al. 2017a; Tarafder et al. 2017).

The genus *Xylaria* under the family Xylariaceae can easily be identified by their cardial anatomical features including the perithecial ascomata embedded in the dark coloured stromata, cylindrical asci with an amyloid apical ring, ascospores with dark coloured complex multi-layered walls with a germ slit and asexual morph during maturation (Rogers 2000). The most of the species are growing on several substrates like fallen leaves, petioles, herbaceous stems, dung, grasses, seeds, fruits, wood and soil, preferably grow on rotten wood (Rogers et al. 1986; Hashemi et al. 2014). Recent studies revealed that the family Xylariaceae is one of the largest and most diverse family among Ascomycota, which comprised 85 genera and more than 1350 species (Daranagama et al. 2017). Both the genera *Daldinia* and *Hypoxylon*, belonging to the family Hypoxylaceae have some common characters like presence of nodulisporium-like asexual morph and geniculosporium-like asexual morph respectively (Daranagama et al. 2017). But *Daldinia* can easily be distinguished from the genus *Hypoxylon* by having distinctly zonate inner entostroma. The genera *Ascobolus* and *Scutellinia* belonging two different families Ascobolaceae and Pyronemataceae respectively are differentiated by bright coloured apothecia with marginal septate hairs and ellipsoid ascospores with irregular ornamentation and less bright apothecia without any marginal hairs and dark purplish brown ascospores with reticulate fissure. Moreover, *Ascobolus* are coprophilous where *Scutellinia* are lignicolous.

The present work is the continuation of series of papers dealing with the macro-fungal diversity of West Bengal (Acharya et al. 2017a, b, c; Tarafder et al. 2017; Bera et al. 2018; Saha et al. 2018). In this communication, six species belonging to the Ascomycetes group viz. *Xylaria arbuscular* Sacc., *Xylaria multiplex* (Kunze) Fr., *Xylaria nigripes* (Klotzsch) Cooke, *Daldinia childiae* J.D. Rogers & Y.M. Ju, *Ascobolus scatigenus* (Berk. & M.A. Curtis) Brumm., and *Scutellinia jungneri* (Henn.) Clem., collected from the state, are reported herein with their detailed macro-morphological characters.

MATERIAL AND METHODS

Macrofungal specimens were collected during monsoon and post monsoon period (June–October) from different forest and forest fringe areas of West Bengal. During fieldwork, digital photographs of the samples were taken in their habitat and their macro-morphological and habitat features were noted. The standard identifying protocol, colour photographs, and macro-morphological features of each specimen were taken in the field. Collected specimens were wrapped with tissue paper and kept in separate boxes for avoiding mixing of spores. Finally, the collected specimens were carefully withered in a hot air drier until the moisture was minimal. Microscopic features were observed with Carl Zeiss AX10 Imager A1 phase contrast microscope from thin handmade sections of the dried ascocarps by staining with Congo red, and Melzer's reagent. Microscopic features were photographed with microscope mounted digital camera. Thirty measurements of ascospores were taken from each sample for calculating dimensions of ascospores. Length/breadth ratio denotes the Q value. Mean Q value (Q_m) was measured by dividing sum of Q value by total number of spores observed. Specimens were identified by using standard taxonomic keys and literatures (Seaver et al. 1961; Brummelen 1967; Schumacher 1990; Stadler et al. 2014; Daranagama et al. 2017). Methuen Handbook of Colour (Kornerup & Wanscher 1978) was followed for colours terms and codes. The voucher specimens were preserved (Pradhan et al. 2015) and deposited at the Calcutta University Herbarium (CUH).

RESULTS

During the exploration of macro-fungal diversity of West Bengal, numerous specimens were collected of which six species of Phylum Ascomycota had been identified, among them three species belonging to the genus *Xylaria*, one species under *Daldinia*, one belongs to *Ascobolus* and the remaining one is from *Scutellinia*.

TAXONOMY

***Xylaria arbuscula* Sacc.,** Michelia 1(2): 249 (1878) (Image 1)

Specimen examined: CUH AM612, 14.vii.2017, 58.047^{0}N & 133.240^{0}E, elevation 46m, Tufanganj-I, Cooch Behar District, West Bengal, India, coll. D. Das, E. Tarafder, K. Acharya & A. Roy.

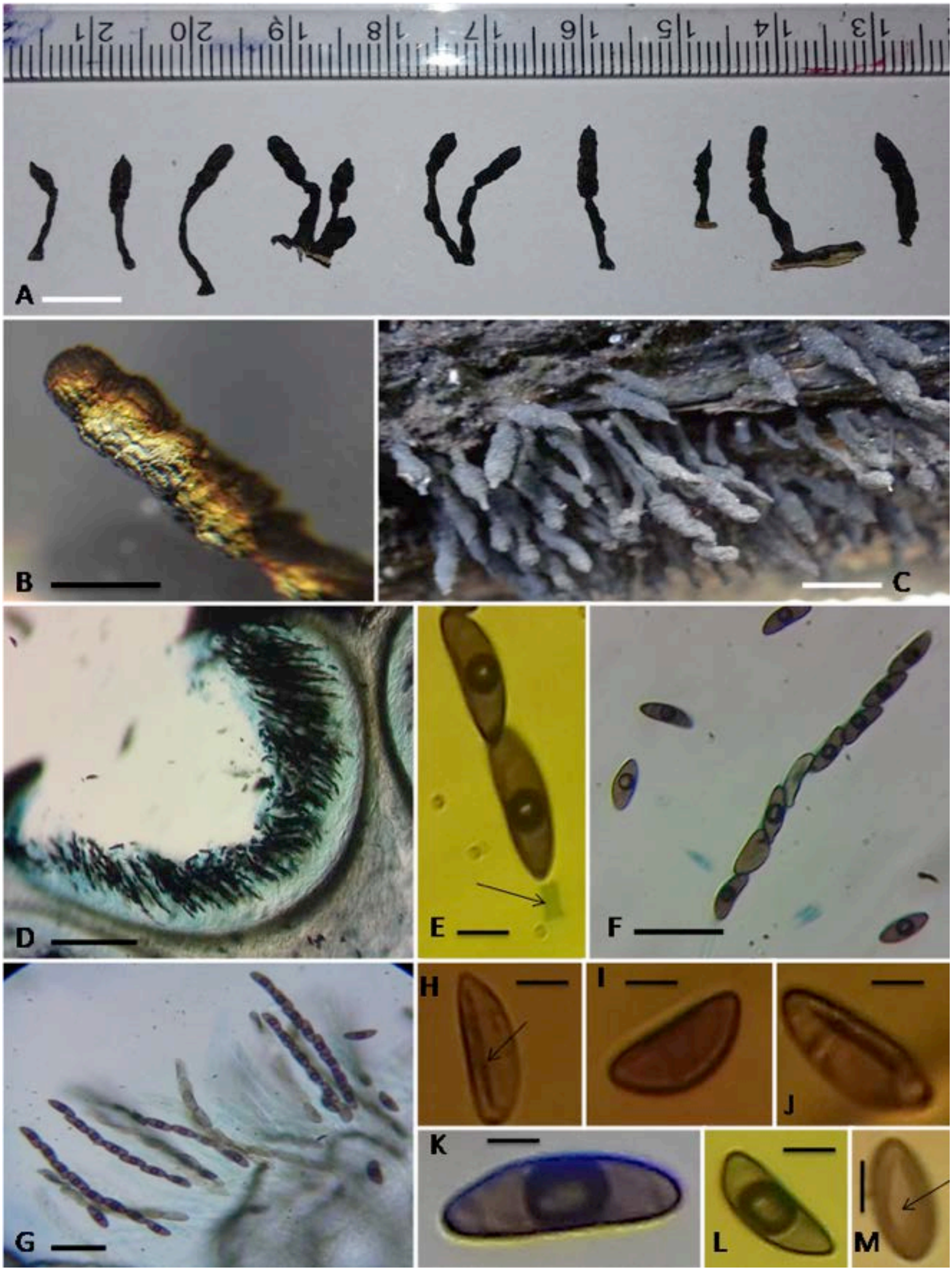

Image 1. ***Xylaria arbuscula*** **Sacc.: A—Specimen picture, scale 10mm | B—Surface of ascomata, scale 5mm | C—Habitat, scale 10mm | D—Perithecium, scale 100µm | E—Ascus apical ring blueing in Melzer's reagent (black arrow), scale 5µm | F—Ascus containing eight ascospores, scale 25µm | G—Several asci arise from perithecium, scale 25µm | H–M—Ascospores (black arrows show the germ slit), scale 5µm.**

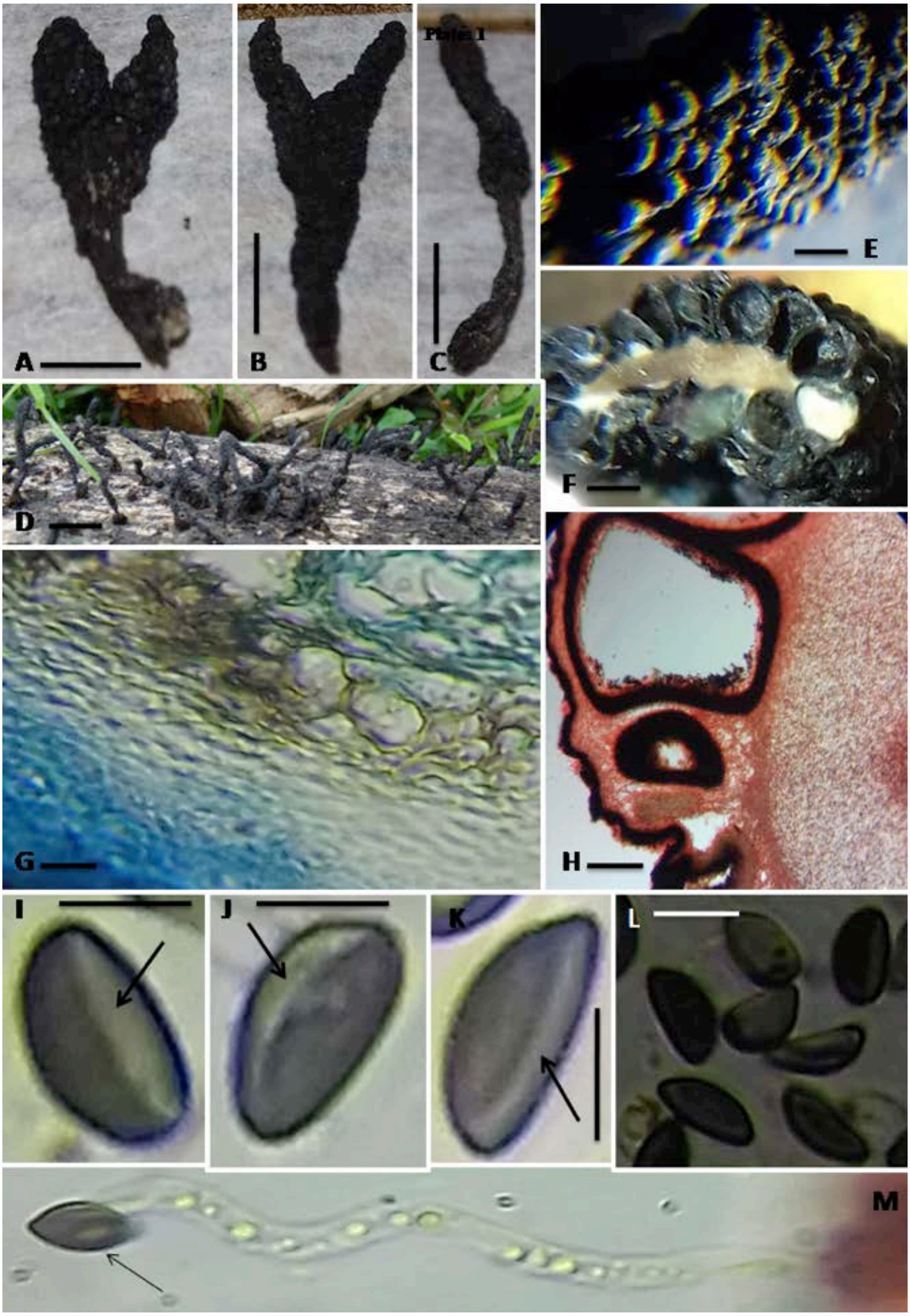

Image 2. *Xylaria multiplex* (Kunze) Fr.: A–C—Teleomorph of *X. multiplex* (Kunze) Fr. Nova Acta R., scale 5mm | D–Habitat, scale 5mm | E—Enlarged stromatal surface, scale 5mm | F—Perithecia in transverse section, scale 5mm | G—Outer entostroma, scale 50µm | H—Perithecia under microscope, scale 100µm | I–L—Ascospores with germ slits (black arrows), scale 5µm | M—Dehiscing ascus (black arrow shows an ascospore coming out from ascus).

Teleomorph Stromata erect, 8–20 mm total height, stipitate. Stipe 4–15 mm long × 2–3 mm width, unbranched dark grey (1F1). Fertile part 4–12 mm high × 2–3 mm width, cylindrico-clavate with rounded to mucronate sterile apices, surface with several longitudinal cracks, dark grey (1F1). Outer entostroma tough, carbonaceous, interior solid. Perithecia globose to sub-globose 249–333 × 226–306 µm without or with slightly exposed outlines, Ostioles without papillae.

Ascospores (10.9–)13.3–14.5–16.6(–19.6) × (3.6–)3.9–4.6–5.3(–5.9) µm, (n=30 spores), Q_m=3.15, uniseriate ellipsoid-inequilateral with narrowly to broadly rounded ends, with no hyaline cellular appendage, dark brown (6F8), smooth, uni-guttulate, guttule central, conspicuous straight germ slit slightly less than the spore-length on the less convex side. Abnormal, pyriform ascospores with beaked ends also frequently found, these were not taken for measurements. Asci 72–111 µm long × 6–9 µm broad, cylindrical, 8-spored; stalk 36–71 µm long, with apical apparatus, tubular to urn-shaped, apical ring positive in Melzer's reagent. Outer entostroma textura prismatica type and inner entostroma textura angularis.

Habit and habitat: Ascomata grown gregariously on rotten wood having no host specificity. Saprotroph, lignicolous.

Notes: *Xylaria arbuscula* Sacc. is well characterized morphologically by its 8–20 mm erect ascomata, 4–5 mm long unbranched stipe, mucronate sterile apices and microscopically by having (11–)13.5–16.5(–19.6) × (3.6–)3.9–5.3(–5.9) µm sized, uniseriate, ellipsoid in-equilateral ascospores and straight germ slit. It has been described first from a green house in Italy and distribution is cosmopolitan having no such host specificity. The present taxon is satisfyingly harmonized with the species reported from New Zealand in spore size [(11–)13.5–165(–19.6) × (3.6–)3.9–5.3(–5.9) µm vs (11–)13–16(–19) × (4.0–)5.0–6.0(–7.5) µm], J+ apical ring of ascus, straight germ slit and wrinkled teleomorph in dry condition (Rogers et al. 2012). The same species reported from Iran shows slight mismatch in spore size with the present taxon [(10.9–)13.3–16.6(–19.6) × (3.6–)3.9–5.3(–5.9) µm vs 12–16(–17) × 5–6 µm] (Hashemi et al. 2014) *Xylaria arbuscula* Sacc., differs from its closely related species *Xylaria multiplex* (Kunze) Fr. in having 10–13(–14) × (4–)5(–6) µm sized ascospores and germ slit equal to the length of ascospore (Hashemi et al. 2014).

***Xylaria multiplex* (Kunze) Fr.** Nova Acta R. Soc. Scient. Upsal., Ser. 3, 1(1): 127(1851) (Image 2)

Specimen examined: CUH AM611, 16.vii.2017, 73.674^{0}N & 141.510^{0}E, 49m, Buxa Tiger Reserve Forest, Alipurduar District, West Bengal, India, coll. K. Acharya, A. Roy, D. Das & E. Tarafder.

Teleomorph Stromata erect, mostly unbranched but sometimes branched towards the apex, 8–27 mm total height, stipitate; stipe very short to short, 3–11 mm long × 1–2 mm width, unbranched, dark grey(1F1). Fertile parts 4–25 mm high × 1–2.5 mm width, cylindrico-clavate with rounded to slightly fusoid fertile apices, surface roughened with several ostiolar ridges, dark grey(1F1); outer entostroma tough, highly carbonaceous, interior solid. Perithecia sub-globose, 239–530 × 138–340 µm, with slightly exposed outlines, ostioles with conspicuous papillae.

Ascospores (8.3–)8.6–9.2–9.9(–10.6) × (3.3–)3.3–3.3–3.3–3.6) µm, (n=30 spores) Q_m=2.7 uniseriate ellipsoid-inequilateral with narrowly to broadly rounded ends, without hyaline cellular appendage, dark brown (6F8), smooth, multi-guttulate, conspicuous straight germ slit equal to the spore-length on the less convex side. Abnormal, ascospores with beaked ends also found frequently. Asci cylindrical, 8-spored, difficult to measure. Outer entostroma textura prismatica type 38–76 µm wide and inner entostroma textura angularis.

Habit and habitat: Ascomata grown gregariously on rotten wood. Having no host specificity. Saprotroph.

Notes: *Xylaria multiplex* (Kunze) Fr. is characterized morphologically by its dark grey (1F1) coloured erect, unbranched to branched, stipitate stromata with a fusoid apices and anatomically in its spore size (5.9–)6.6–10.6(–12.6) × (3.3–3.6) µm and germ slit equals to spore length. The species is a tropical species distributed throughout the tropical region of world. The present taxon nicely matches with the previously reported Indian taxon from Western Ghats, Karnataka in spore size (8.3–)8.6–9.2–9.9(–10.6) × (3.3–)3.3–3.3–3.3–3.6) µm vs 8.9–10.8 × 3.9–4.7 µm] (Karun et al. 2015). *Xylaria multiplex* (Kunze) Fr. differs from its closely related species *X. longipes* Nitschke, in having cylindrical, dull black coloured fruit-body with elevated, grooved stromal surface and having a short stipe and sigmoid germ slit (Karun et al. 2015).

***Xylaria nigripes* (Klotzsch) Cooke,** Grevillea 11(59): 89 (1883) (Image 3)

Specimen examined CUH AM297, 21.viii.2012, 77.947^{0}N & 125.076^{0}E, 10m, Rajbhavan, Kolkata, West Bengal, India, coll. K. Acharya.

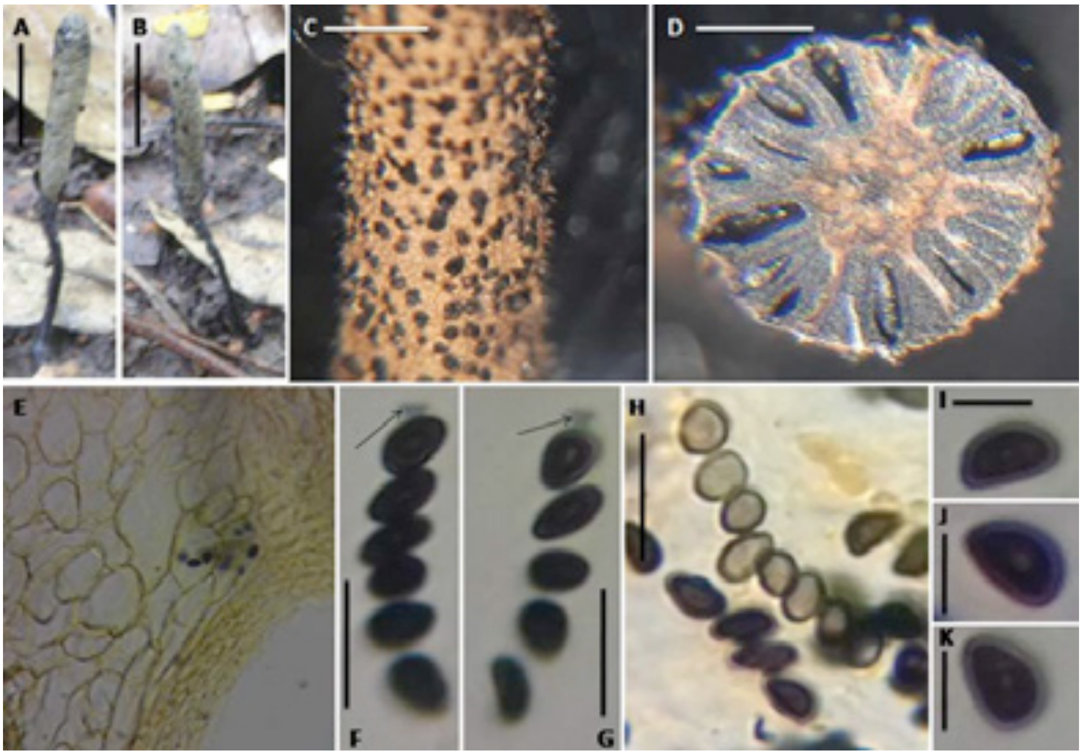

Image 3. ***Xylaria nigripes*** **(Klotzsch) Cooke: A–B—Habitat, scale 15mm | C—Papillate ostioles on the stromatal surface, scale 1mm | D—Stromata in Transverse section, scale 1mm | E—Outer entostroma | F–G—Asci apical disc bluing in Melzer's reagent (black arrows point the apical disc), scale 15µm | H—Ascus containing eight ascospores, scale 15µm | I–K—Ascospores, scale 5µm.**

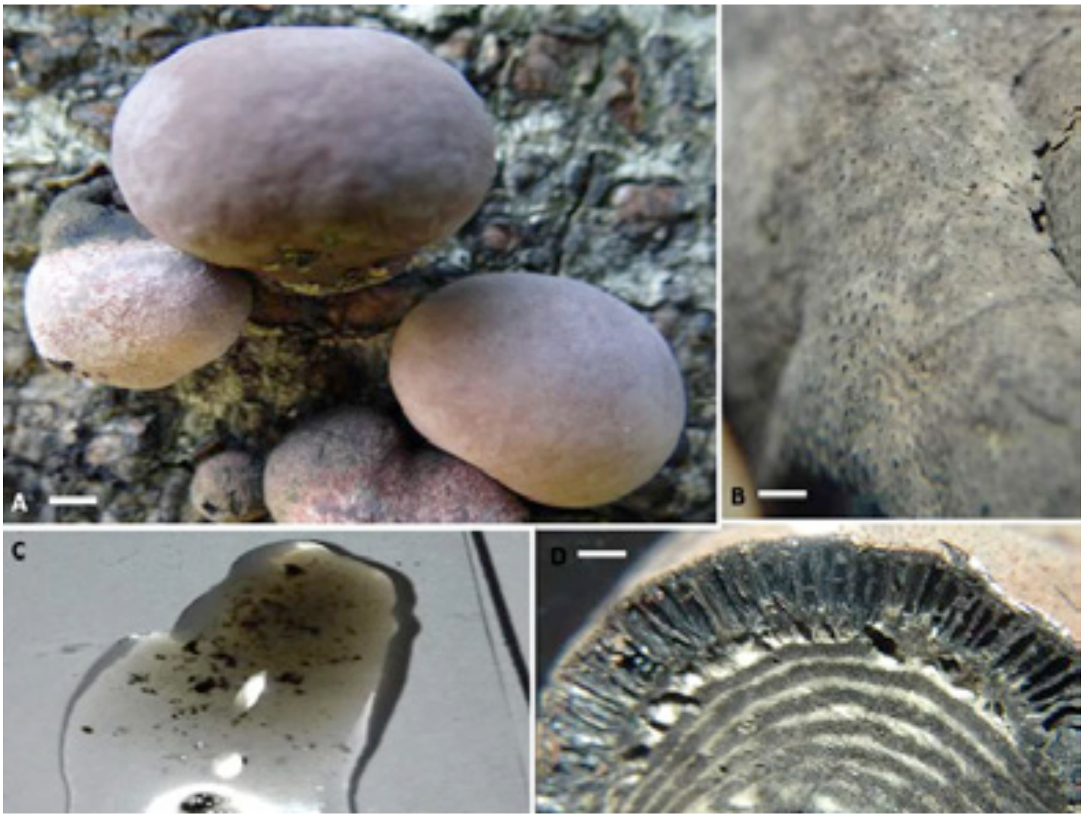

Image 4a. ***Daldinia childiae*** **J.D. Rogers & Y.M. Ju: A—Habitat, scale 5mm | B—surface of the stromata, scale 5mm | C—KOH extractable pigment | D—Longitudinal section of the stromata showing perithecia along with darker and lighter zones of inner entostroma, scale 5mm.**

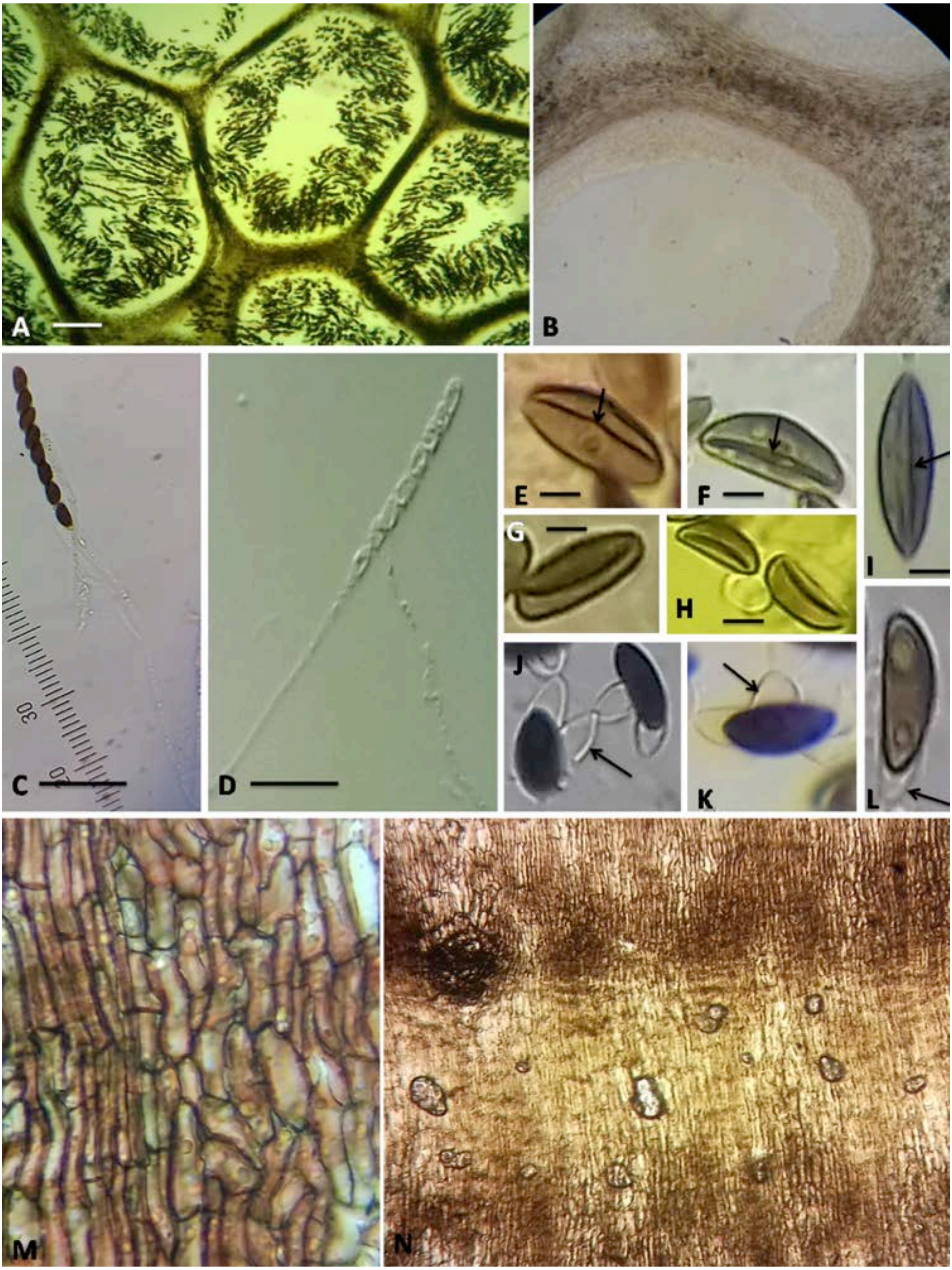

Image 4b. ***Daldinia childiae*** **J.D. Rogers & Y.M. Ju: A—perithecia in transverse section, scale 300µm | B—Outer entostroma | C–D—Asci containing eight ascospores, scale 50µm | E–I—Ascospores (black arrows point the germ slits), scale 5µm | J–L—Perispore dehiscet in 10% KOH | M—Inner entostroma | N—Dark and lighter zones of inner entostroma.**

Teleomorph stromata erect, acute apex, 50–75 mm total height, stipitate; stipe moderately long, 20–30 mm long × 1–3 mm broad, unbranched, dark grey (1F1). Fertile part 30–55 mm high × 3–6 mm width, cylindrico-clavate, with papillate ostioles, surface roughened, greyish yellow (3D3). Outer ectostroma tough, carbonaceous, interior solid. Perithecia narrow ellipsoid 300–680 × 114–243 µm.

Ascospores (5.4–)5.7–6.3–7.1(–7.8) × (2.6–)2.8–2.9–3.1(–3.4) µm, (n=30 spores), Q_m=2.1, uniseriate ellipsoid-inequilateral, without hyaline cellular appendage, dark brown, smooth, with a centre guttule, inconspicuous germ slit. Asci 63–78 × 3.4–3.7 µm, narrow cylindrical, 8-spored. Outer entostroma textura angularis and inner entostroma inconspicuous.

Habit and habitat: Terrestrial in habitat and were associated with termite nest.

Notes: *Xylaria nigripes* (Klotzsch) Cooke is well characterized morphologically by 50–75 mm long ascomata having greyish-yellow (3D3) coloured fertile portion surrounded by distinctly papillate ostioles causing a spiny stromatal surface and anatomically by its (5.4–)5.7–6.3–7.1(–7.8) × (2.6–)2.8–2.9–3.1(–3.4) µm sized ascospores. The present taxon has been reported several times from different corners of tropical regions. The present taxon is very well harmonized with the previously reported species from Karnataka (India) in its spore size [(5.4–)5.7–6.3–7.1(–7.8) × (2.6–)2.8–2.9–3.1(–3.4) µm vs 5.3–7.9 × 2.6–3.3 µm] (Karun et al, 2015). The present taxon differs from closely related species *X. escharoidea* in having cylindric to fusoid, black ascomata with obtuse apex and smaller sized ascospores (3.7–5.2 × 2.5–3 µm).

Daldinia childiae **J.D. Rogers & Y.M. Ju,** in Rogers, Ju, Watling & Whalley, Mycotaxon 72: 512 (1999) (Image 4a,b)

Specimen examined: CUH AM615, 14.vii.2017, 58.047^0N & 133.240^0E, 46m, Tufanganj-II, Rashik Bill, Cooch Behar District, West Bengal, India, coll. K. Acharya, D. Das, E. Tarafder & A. Roy; CUH AM613, 14.vii.2017, 58.047^0N & 133.240^0E, 46m, Check Post, Cooch Behar District, West Bengal, India, coll. K. Acharya, D. Das, E. Tarafder & A. Roy; CUH AM614, 14.vii.2017, 58.047^0N & 133.240^0E, 46m, Check Post, Cooch Behar District, West Bengal, India, coll. K. Acharya, D. Das, E. Tarafder & A. Roy; CUH AM616, 15.vii.2017, 77.856^0N & 144.291^0E, 50m, Damanpur, Alipurduar District, West Bengal, India, coll. K. Acharya, D. Das, E. Tarafder & A. Roy; CUH AM617, 16.vii.2017, 73.674^0N & 141.510^0E, 49m, Buxa Tiger Reserve Forest, Alipurduar District, West Bengal, India, coll. K. Acharya, D. Das, E. Tarafder & A. Roy.

Stromata shows spherical to turbinate geometry in structure, pulvinate, 15−46 × 11−36 × 9−35 mm, attached with a small stipe, coalescent, surface smooth with inconspicuous perithecial moulds, smooth but slightly undulating, dull red to reddish-brown (9C4−9D4). KOH extractable pigments Cinnamon brown (6D6−6E6). Outer entostroma textura prismatica type, dark brown (6F6), pithy to woody; inner entostroma consists of alternately placed darker and lighter zones, the ratio of darker with lighter zone is 1: 1.5−2, pithy to woody; dark

Image 5a. ***Ascobolus scatigenus*** **(Berk. & M.A. Curtis) Brumm.: A—Habitat | B—Apothecia, scale 5mm.**

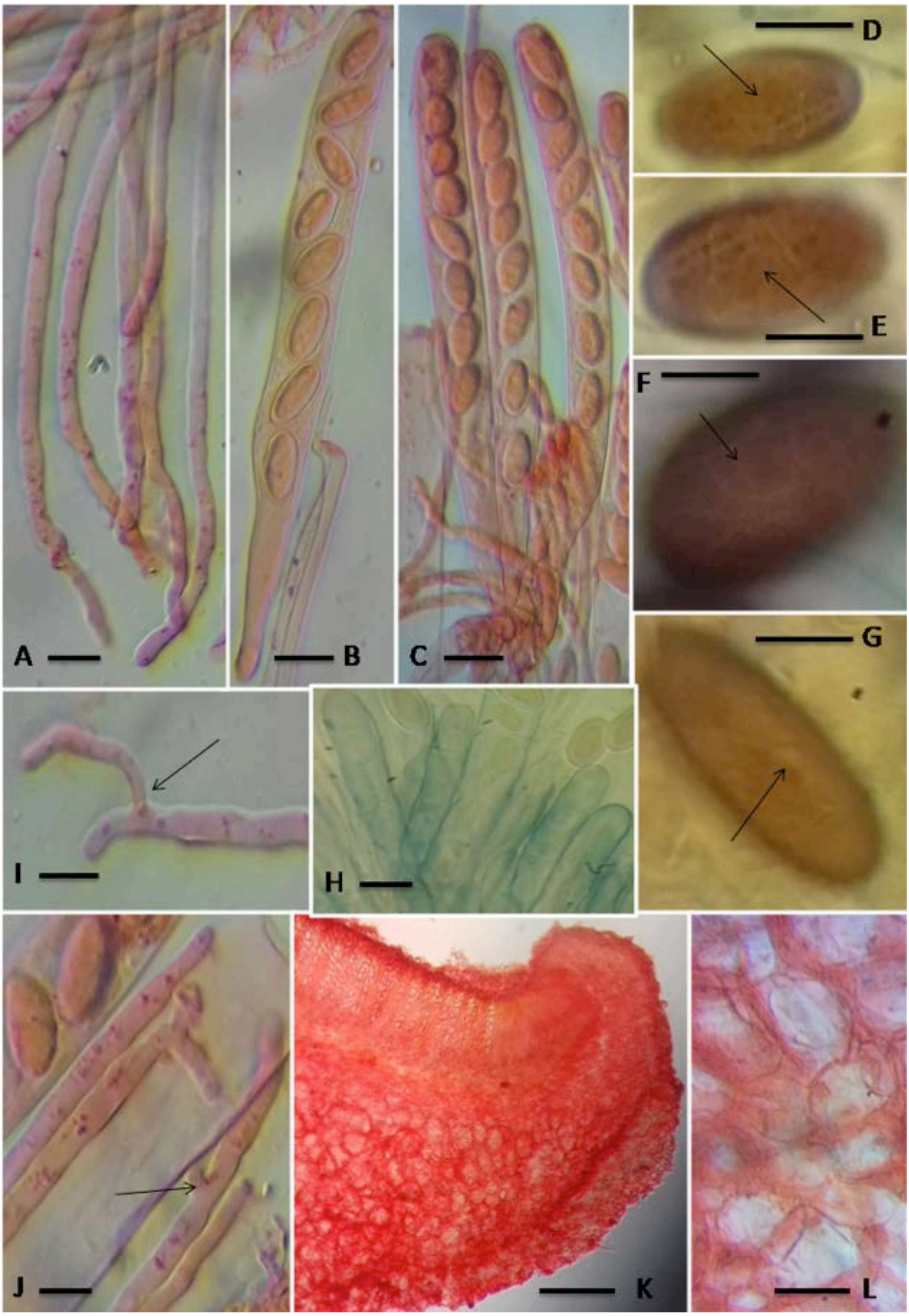

Image 5b. ***Ascobolus scatigenus*** **(Berk. & M.A. Curtis) Brumm.: A—Paraphyses with narrow cylindric tips, scale 10µm | B–C—Asci with eight ascospores, scale 20µm | D–G—Ascospores with reticulate fissures (black arrows show the fissures), scale 10 µm | H—Asci wall blueing in Melzer's reagent, scale 15µm | I–J—branched paraphyses (Black arrow points the branched portion), scale 10µm | K—a cross section of an ascoma shows hymenium and excipulum, scale 250µm | L—Excipulum with textura globulosa, scale 5µm.**

zone textura porrecta to textura angularis with hyphae or cells, dark brown (6F6) pigmented, thick walled; lighter zone textura porrecta with broad thick walled hyphae, less pigmented to hyaline, agglutinated. Perithecial layer loculate on drying. Perithecia obovoid to lanceolate, 2–3.2 × 1–2.3 mm. Ostioles slightly papillate.

Ascospores (11.6–)11.9–14–16.6(–16.9) × (5.3–)5.6–6.4–6.9(–7.3) µm, (n=30 spores), Q_m=2.2, ellipsoid-inequilateral, germ slit equal to spore length in convex side, brown (6E8) to dark brown (6F6), epispore smooth. Asci 183–216 × 7.3–11.6 µm, with amyloid, discoid apical apparatus. Perispore dehiscent in 10% KOH. Perithecial diameter 600–1,500 µm.

Habit and habitat: Ascoma appear in solitary or aggregated together on a dead decayed trunk of a sal tree. Saprophytic, late decomposer, having no host specificity.

Notes: *Daldinia childiae* J.D. Rogers & Y.M. Ju, is well characterized by stipitate ascomata, cinnamon brown coloured KOH extractable pigment, dehiscent perispore and (11.6–)11.9–14–16.6(–16.9) × (5.3–)5.6–6.4–6.9(–7.3) µm sized, inequilateral, dark brown ascospores. Distribution of *Daldinia childiae* J.D. Rogers & Y.M. Ju, is cosmopolitan throughout the tropical region of the world. The present taxon is satisfyingly harmonized with the Stadler's described specimen in spore size (11.6–)11.9–14–16.6(–16.9) × (5.3–)5.6–6.4–6.9(–7.3) µm vs. 12–16(–17) × 5.5–7.5 µm, ascus size 183–216 × 7.3–11.6 µm vs. 180–220 × 8–12 µm and cinnamon brown coloured KOH extractable pigment (Stadler et al. 2014). This specimen also very nicely matches with the described species from Gujrat (Koyani et al. 2016) in spore size [(11.6–)11.9–14–16.6(–16.9) × (5.3–)5.6–6.4–6.9(–7.3) µm vs. 11–16 × 5–8 µm] and also shows some tiny difference with the previously described species of Vadodora, India in spore size [(11.6)–11.9–14–16.6–(16.9) × (5.3–)5.6–6.4–6.9(–7.3) µm vs.10–16 × 4–8 µm] (Koyani et al. 2016; Nagadesi et al. 2017). *Daldinia childiae* J.D. Rogers & Y.M. Ju, differs from closely related species *Daldinia pyrenaica* M. Stadler & Wollw, in spore size [(11.6)–11.9–14–16.6–(16.9) × (5.3)–5.6–6.4–6.9(–7.3) µm vs. 13–17 × 6.5–8 µm] and *Daldinia* cf. *childiae* in having germ slit length less than spore length and smooth stromal surface (Stadler et al. 2014).

***Ascobolus scatigenus* (Berk. & M.A. Curtis) Brumm.**, Persoonia, Suppl. 1: 159 (1967) (Image 5a,b)

Specimen examined: CUH AM292, 17.vii.2017, 58.331^{0}N & 137.670^{0}E, 50m, Bara Debi Bari, Cooch Behar District, West Bengal, India, coll. D. Das, E. Tarafder, K. Acharya & A. Roy; CUH AM295, 18.vii.2017, 58.047^{0}N & 133.240^{0}E, 46m, Kaljani, Cooch Behar District, West Bengal, India, coll. D. Das, E. Tarafder, K. Acharya & A. Roy.

Image 6a. *Scutellinia jungneri* (Henn.) Clem.: A—Habitat | B—Ascomata, scale 1mm.

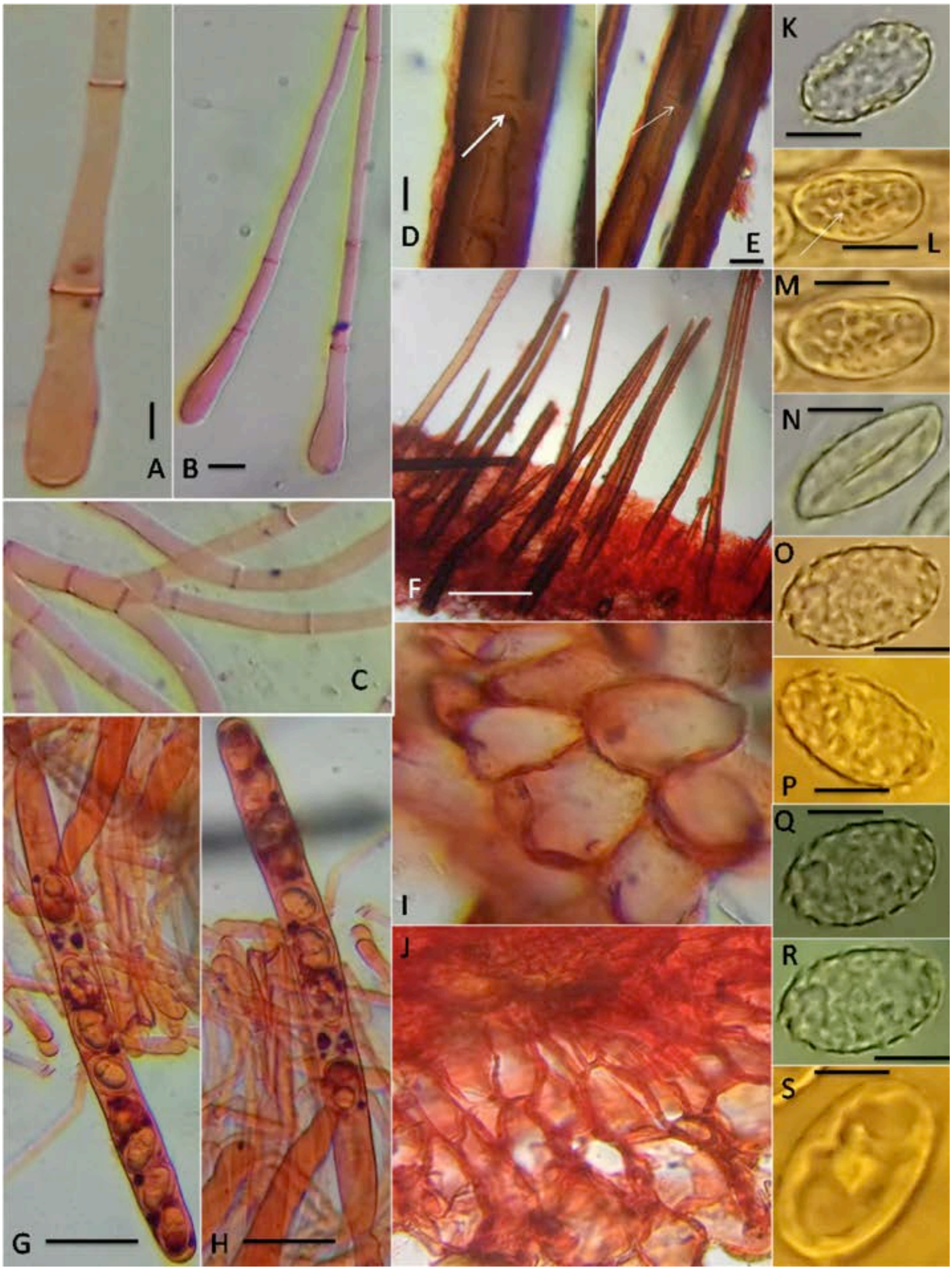

Image 6b. ***Scutellinia jungneri*** **(Henn.) Clem.: A–B—Paraphyses, scale 5µm | C—Branched portion of paraphyses | D–E—Marginal hairs with prominent septa, scale 20µm | F—Hairs, scale 150µm | G–H—Asci containing eight ascospores, scale 25µm | I–J—Ectal excipulum cells | K–S—Ascospores (white arrows point the ornamentation), scale 10µm.**

Ascomata 8–25 mm in diam., 2–4 mm high, sessile, deep concave when young becoming flat at maturity, hymenophore covered with white (1A1) granular margin, disk always darker than excipulum, greyish-green (1D5–1D6–1D7).

Ascospores (19.8–)20–22.3–24.3(–24.9) × (10–)10.3–11.6–12.6(–13.2) µm, (n=30 spores), Q_m=1.9, ellipsoid, uniseriate or irregular biseriate, smooth, with sigmoid or longitudinal two or more fissures, finely reticulate, pigments precipitate in uniform patches. Asci 146–253 × 16–22 µm, 8-spored, cylindrico-clavate, wall turning blue in Melzer's reagent; stalk very narrow, short 11.5–21 µm in length. Hymenium 172–204 µm, uniform; hypothecium distinct, composed of 5–11 mm diam., globose cells, textura globulosa. Paraphyses 2.8–3.4 µm, simple septate, sometimes branched; tapered towards apex, narrow cylindrical, hyaline in 5% KOH. Excipulum 45–62 µm thick, made up of globose to sub-globose cells, textura globulosa.

Habit and habitat: Grows gregariously on cow or buffalo dung, coprophilous.

Notes: *Ascobolus scatigenus* (Berk. & M.A. Curtis) Brumm, is very well characterized microscopically by its ellipsoid, reticulated, (19.8–)20–22.3–24.3(–24.9) × 10–11.6–12.6(–13) µm sized ascospores and morphologically by its coprophilous habitat, greyish green (1D5–1D6–1D7) coloured hymeneal disc, granular white margin and sessile flat concave ascomata. *Ascobolus scatigenus* (Berk. & M.A. Curtis) Brumm, distributed throughout the tropic region of the world. The present taxon satisfyingly harmonized with the previously reported taxon from northern Rhodesia by J. Van Brummelen (1967) in his world monograph of *Ascobolus* and *Saccobolus* and with the Brazilian species (Melo et. al. 2014) in its spore size [19.8–24.9 × 10–13 µm vs. 20–26 × 11–14 µm], shape and reticulate fissures on the spore wall. *Ascobolus scatigenus* (Berk. & M.A. Curtis) Brumm., differs from its closely related species *A. castaneus* Teng, in having 15–19.5 × 7.5–9 µm sized ascospores and perfectly smooth episporium.

***Scutellinia jungneri* (Henn.) Clem.,** Bull. Torrey bot. Club 30: 90 (1903) (Image 6a,b)

Specimen examined: CUH AM298, 19.ix.2017, 78.163^{0}N & 160.517^{0}E, 84m, Targhera, Jalpaiguri District, West Bengal, India, coll. D. Das, E. Tarafder, K. Acharya & A. Roy.

Apothecia 2–6 mm in diam., 2–4 mm high, sessile, disk flat, yellowish golden yellow to orange (5B7–5B8); margin along with receptacle covered with brown erect hairs with various length, dark brown (7F7–7F8).

Ascospores (15.8–) 17–18–19.5 (–20) × (9.2–) 10.4–11.3–11.4 (–11.8) µm, (n=30 spores), Q_m=1.6, ellipsoid, with two or more guttule, ornamentation consisting of angular or rounded warts, inamyloid. Ascus 149–220 × 12–18 µm, 8-spored, cylindrico-clavate, inamyloid; stalk very short, 5.7–11.8 µm in length. Hymenium 250–400 µm, uniform; sub-hymenium distinct, composed of narrow cells. Paraphyses 3.5–8.6 µm broad, simple septate, straight, branched at the middle or basal portion, cylindrico-clavate apex, hyaline in 5% KOH. Ectal-excipulum made up with 23–71.7 µm diam., globose cell, textura globulosa. Hair 229–574 × 31–40 µm straight, multi septate, no furcation at the base, thick walled; wall 3.7–8.6 µm thick.

Habit and habitat: Ascomata grown solitary to gregariously on a rotten wood, saprotroph.

Notes: *Scutellinia jungneri* (Henn.) Clem. is very well characterized by 2–6 × 2–4 mm, yellow to orange (5B7–5B8) ascomata surrounded by 229–574 × 31–40 µm dark brown (7F7–7F8) hair, (15.8–)17.2–18.1–19.5(–20) × (9.2–)10.4–11.3–11.4(–11.8) µm, ellipsoid ascospores having angular or rounded warts, 149–220 × 11.5–17.2 µm ascus with short narrow base. The present taxon is distributed throughout the tropical region of the world. It was reported previously from India in the year of 1968 as *Scutellinia jungneri* (Henn.) Clem, by Kar & Pal (Schumacher 1990). The present taxon is satisfyingly harmonized with the Trond Schumacher's description in spore size [15.8–17.2–18.1–19.5–20 × 9.2–10.4–11.3–11.4–11.8 µm vs. 16.8–19.4 × 8.8–12.2], shape, ascus size [149–220 × 11.5–17.2 µm vs 160–250 × 11–15 µm] and the size of the dark brown coloured marginal hair [155–574 × 31–40 µm vs 150–400 µm] with no furcation at the base (Schumacher 1990). *Scutellinia jungneri* (Henn.) Clem., differs from its closely related species *Scutellinia jungneri* (Henn.) Clem, in having 17.4–22.8 × 11–13 µm sized ascospores, 360–1600 × 22–47 µm marginal hairs with multibranched base (Schumacher 1990).

DISCUSSION

The genus *Xylaria* under the family Xylariaceae can easily be identified by their cardial anatomical features including the perithecial ascomata embedded in the dark coloured stromata, cylindrical asci with an amyloid apical ring, ascospores with dark coloured complex multi-layered walls with a germ slit and asexual morph during maturation (Rogers 2000). Most of the species grow on several substrates like fallen leaves, petioles, herbaceous stems, dung, grasses, seeds, fruits, wood, soil, and rotten wood (Rogers & Samuels 1986; Hashemi et al. 2014). Recent studies revealed that the family Xylariaceae is one of the largest and most diverse family among Ascomycota, which comprised 85 genera and more than 1,350 species (Daranagama et al. 2017). Both the genera *Daldinia* and *Hypoxylon*, belonging to the family Hypoxylaceae have some common characters like presence of nodulisporium-like asexual morph and geniculosporium-like asexual morph respectively (Daranagama et al. 2017). But *Daldinia* can easily be distinguished from the genus *Hypoxylon* by having distinctly zonate inner entostroma. The genera *Ascobolus* and *Scutellinia* belonging two different families Ascobolaceae and Pyronemataceae respectively are differentiated by bright coloured apothecia with marginal septate hairs and ellipsoid ascospores with irregular ornamentation and less bright apothecia without any marginal hairs and dark purplish brown ascospores with reticulate fissure. Moreover, *Ascobolus* are coprophilous where *Scutellinia* are lignicolous.

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PLATINUM OPEN ACCESS

SHORT COMMUNICATION

Catalogue of herpetological specimens from peninsular India at the Sálim Ali Centre for Ornithology & Natural History (SACON), India

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Abstract: We list the herpetological voucher specimens in the holdings of the Sálim Ali Centre for Ornithology & Natural History (SACON), a wildlife research institute in India. Most of the collections are the fruition of fieldwork by SACON's herpetologist and a coauthor of this work—late Dr. Subramanian Bhupathy (1963–2014). Taxonomically, the collection represents 125 species, comprising 29 amphibian species belonging to eight families and 96 reptilian species belonging to 17 families. Geographically, the material in this collection originates from the Western Ghats, the Eastern Ghats, the Deccan Plateau, and the Coromandel Coast, comprehensively covering all ecoregions of peninsular India. A total of 15 taxa (three amphibians, 12 reptiles) remain to be fully identified and are provisionally referred to most-resembling taxa, with cf. prefix. All the specimens in this collection are non-types as on date.

Keywords: Amphibians, biological museum, distribution, reptiles, taxonomy.

Natural history collections are professional holdings of scientifically named and classified voucher specimens of organisms or their biological samples thereof, for research and public education purposes (Melber & Abraham 2002). Of late, their value as an enormous source of data on the diversity and distribution of plants and animals have been increasingly realized and acknowledged (Winker 2004). So much so that even species extirpation patterns and population declines can be traced and deduced from such collections (Shaffer et al. 1998; Lister 2011). Faunal catalogues from under-researched tropical countries have served as immense source of information on regional biodiversity (e.g., Mahony et al. 2009 for Bangladesh's herpetofauna).

In Indian herpetology, most of the historical information on species were based on specimens lodged in the British Museum (now the Natural History Museum London, UK) that were worked out by Boulenger (1882, 1885a,b, 1887, 1889, 1893, 1894, 1896) in a series of technical monographs. Two other important regional museums were the Indian Museum Calcutta (now Zoological Survey of India, ZSI, Kolkata) and the Bombay Natural History Society Museum (BNHS), Mumbai. The herpetological holdings of ZSI were worked out by Theobald (1876) and Sclater (1891, 1892), while that of the snakes of BNHS were enumerated by Phipson (1888).

Later, post-Independence, Satyamurti (1967) enlisted the amphibians of the Madras Government Museum, another old regional museum at Chennai, India (also see

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Thurston 1888). Bauer (1998) published a catalogue of important South Asian herpetological specimens in the Zoological Museum Berlin, Germany. With regards to the type specimens, Das & Chaturvedi (1998) prepared the herpetological type catalogue for the BNHS museum. Das et al. (1998) published the reptilian type catalogue of the Zoological Survey of India (also see Das & Gayen 2004). Chanda et al. (2000) provided the type catalogue of amphibians in the same institution. Lastly, on general holdings, Ganesh & Asokan (2010) published the catalogue of Indian herpetofauna in the Madras Government Museum.

The Sálim Ali Centre for Ornithology & Natural History (SACON), is one of the India's leading institutes dedicated for wildlife research. The institute was inspired by and named in honour of Sálim Ali (1896–1987), the leading pioneer of ornithology in India. Located in the outskirts of Coimbatore City (Tamil Nadu, India), abutting the Western Ghats, this institute has been functioning since 1990. Being a Centre of Excellence, under the auspices of the Ministry of Environment, Forest and Climate Change, Government of India (MoEFCC, GoI), SACON has teams of wildlife biologists and experts conducting research and teaching.

One such scientist of SACON, Dr. Subramanian Bhupathy (1963–2014) headed the Conservation Ecology Division at this institute and with the help of his numerous students, amassed a good collection of amphibian and reptilian specimens as a part of their research work. His publications on herpetology date back to 1986 and he has been conducting field surveys and research throughout the country, on herpetofauna, among other animal taxa. The material enumerated below is from three decades of his fieldwork across Tamil Nadu, Pondicherry, Kerala, Karnataka, Andhra Pradesh, Telangana, Maharashtra, and Odisha states of India. Though old, the material still continues to bear immense academic value. We have already initiated taxonomic studies on several species complexes based on this collection. This holding is now in an initial research collection phase and will subsequently be made available later on for external researchers.

Materials and Methods

In the catalogue below, we list entire, formalin-preserved, and identifiable specimens of amphibians and reptiles. As far as possible, all legible hand-written information from the specimen jar labels have been furnished below to maximize the biological importance of specimens mentioned. This includes the scientific name of varying taxonomic resolutions, specimen collection locality and the number of examples in most cases. Date or year of collections was not to be found in most if not all jars and hence stands unknown. But judging by his track records, it is deduced to be between 1986 and 2014, spanning three decades. We have maintained the Institution acronym SACON for denoting this museum abbreviation as well, accompanied by other suffixes V- for vertebrates, A- for amphibians, R- for Reptiles. This is followed by the museum registration number that continues sequentially, species after species. Where more than a single specimen is in the same jar, alphabets are added onto their registration numbers to differentiate them. Where appropriate, we also furnish comments on taxonomy, nomenclature, and distribution of the species dealt with. Scientific names and taxonomic classifications were updated after recent systematic revisions for species whose labels furnished obsolete names originally. Throughout the catalogue below, we only use the currently-valid scientific names and concepts of taxa (after Frost 2020 for amphibians; Pyron et al. 2016, Uetz et al. 2020 for reptiles).

Catalogue of Specimens

Amphibia
Gymnophiona
Ichthyophiidae

1. Sharp-tailed Caecilian ***Uraeotyphlus* cf. *oxyurus*** (Duméril & Bibron, 1841)
Material: SACON/VA-1 one from Anamalai.
Comments: Nominotypical species is endemic to the Western Ghats (Thurston 1888).

Anura
Bufonidae

2. Common Toad ***Duttaphrynus melanostictus*** (Schneider, 1799)
Material: SACON/VA-2a–c three from Nilgiris, SACON/VA-2d one from Topslip, SACON/VA-2e one from Meghamalai, SACON/VA-2f–h three from unknown locality
Comments: Frost et al. (2006) erected the genus *Duttaphrynus* for this species (type species). Wogan et al. (2016) reported distinct phylogenetic structures in multiple distant populations of this species, after sampling in the eastern parts of its range.

3. Dwarf Toad ***Duttaphrynus scaber*** (Schneider, 1799)
Material: SACON/VA-3a–b two from Tirunelveli, SACON/VA-3c one from Coimbatore, SACON/VA-3d–j seven from Madurai, SACON/VA-3k–l two from

Srivilliputhur

Comments: Frost et al. (2006) did not include this species in the genus *Bufo* and its generic allocation stood unresolved until Bocxlaer et al. (2009) worked on its taxonomy and gave the current name combination.

4. Marbled Toad ***Duttaphrynus stomaticus*** (Lütken, 1864)

Material: SACON/VA-4a–c three from Tuticorin, SACON/VA-4d one from Coimbatore, SACON/VA-4e–g three from Srivilliputhur

Comments: For remarks on generic allocation, see comments for the above species.

Microhylidae

5. Triangle-spotted Frog ***Uperodon triangularis*** (Günther, 1876)

Material: SACON/VA-5 one from Srivilliputhur

Comments: This species was previously classified in the genus *Ramanella*, now synonymized under *Uperodon* by Peloso et al. (2016). Endemic to Western Ghats (Garg et al. 2018a).

6. Marbled Balloon Frog ***Uperodon systoma*** (Schneider, 1799)

Material: SACON/VA-6a one from Anaikatti, SACON/VA-6b one from Chinnamanur, SACON/VA-6c, one from Gadag

Comments: Garg et al. (2018a) redescribed this species based on the syntypes.

7. Painted Frog ***Uperodon taprobanicus*** (Parker, 1934)

Material: SACON/VA-7 one from Anaikatti

Comments: Peloso et al. (2016) worked on the generic taxonomy and allocated this species to the strictly southern Asian genus *Uperodon*.

8. Red Small-mouthed Frog ***Microhyla rubra*** (Jerdon, 1853)

Material: SACON/VA-8a–b two from Anaikatti, SACON/VA-8c one from Gadag

Comments: Wijayathilaka et al. (2016) redescribed this species and restricted it to populations from India, whilst recognizing the Sri Lankan population as a new species *Microhyla mihintalei*.

9. Ornate Small-mouthed Frog ***Microhyla ornata*** (Duméril & Bibron, 1841)

Material: SACON/VA-9 one from Anaikatti

Comments: This species complex was recently revised by Garg et al. (2018b) and populations from parts of India was recognized as a different species (see below).

10. Nilphamari Small-mouthed Frog ***Microhyla nilphamariensis*** Howlader, Nair, Gopalan & Merilä, 2015

Material: SACON/VA-10a–b two from Gadag

Comments: Though originally described from Bangladesh, recent genetic studies revealed populations from parts of Indian peninsula to be conspecific to this species (Garg et al. 2019).

Ranidae

11. Bi-coloured Frog ***Clinotarsus curtipes*** (Jerdon, 1853)

Material: SACON/VA-11 one from Meghamalai

Comments: This species has not been recorded from Meghamalai so far (Chandramouli & Ganesh 2010; Srinivas & Bhupathy 2013; Chaitanya et al. 2019).

Ranixalidae

12. Short-handed Leaping Frog ***Indirana brachytarsus*** (Günther, 1876)

Material: SACON/VA-12 one from Srivilliputhur

Comment: Inger et al. (1984) resurrected it from the synonymy of *I. beddomei*, as a valid species endemic to southern Western Ghats.

13. Beddome's Leaping Frog ***Indirana beddomii*** (Günther, 1876)

Material: SACON/VA-13 one from Ooty

Comment: Dahanukar et al. (2016) redescribed this taxon and restricted the species to populations in the Nilgiri-Wayanad.

Micrixalidae

14. Beautiful Dancing Frog ***Micrixalus adonis*** Biju, Garg, Gururaja, Shouche & Walujkar, 2014

Material: SACON/VA-14a–b two from Meghamalai

Comment: Biju et al. (2014) revised *M. fuscus* (Boulenger, 1882), restricted it to populations south of Shencottah Gap and described northerly populations from Cardamom hills as a distinct species *Micrixalus adonis*.

Dicroglossidae

15. Paddy Field Frog ***Minervarya agricola*** (Jerdon, 1853)

Material: SACON/VA-15a one from Anaikatti, SACON/VA-15b one from Gadag

Comment: Ganesh et al. (2017) designated a neotype to this nomen and resurrected this species from the synonymy of the catch-all taxon *Fejervarya limnocharis* (Gravenhorst, 1829). Chandramouli et al. (2019) synonymised *Minervarya granosa* (Kuramoto, Joshy, Kurabayashi & Sumida, 2008) with *Minervarya* *agricola* based on genetic studies.

16. Nilgiri Cricket Frog ***Minervarya nilagirica*** (Jerdon, 1853)
Material: SACON/VA-16a–c three from Nilgiris
Comment: Dubois (1984) resurrected this species from the synonymy of "*Rana limnocharis*" and designated a neotype from Ooty, where it is endemic to upper Nilgiris, Tamil Nadu.

17. Kalinga Cricket Frog ***Minervarya* cf. *kalinga*** (Raj, Dinesh, Das, Dutta, Kar & Mohapatra, 2018)
Material: SACON/VA-17 one from Araku Hills
Comments: Raj et al. (2018) described this new species from northern Eastern Ghats, from Odisha State. Populations from further south of these ranges, in Andhra Pradesh state requires further confirmation.

18. Kerala Cricket Frog ***Minervarya keralensis*** (Dubois, 1981)
Material: SACON/VA-18a one from Anamalai, SACON/VA-18b–c two from Topslip, SACON/VA-18d–k eight from Meghamalai
Comments: Generic allocation follows Sanchez et al. (2018). Endemic to Western Ghats.

19. Western Pond Frog ***Euphlyctis* cf. *mudigere*** Joshy, Alam, Kurabayashi, Sumida& Kuramoto, 2009
Material: SACON/VA-19a–b two from Meghamalai
Comments: Khajeh et al. (2014) reported the undocumented presence of many candidate species within the nominal taxon *E. cyanophlyctis* from many southern Asian countries and suggested that populations from parts of southern India and Sri Lanka are not *E. cyanophlyctis*, but referable to *E. mudigere*. We, however, opine that at least one sample from Adyar in Mangalore, was misrepresented as Adyar in Madras, on the eastern coast.

20. Jerdon's Burrowing Frog ***Sphaerotheca pluvialis*** (Jerdon, 1853)
Material: SACON/VA-20 one from Araku Hills
Comments: Dutta (1986) provided precise records of *S. dobsonii* group taxa from eastern peninsular India that have later come to be called as *S. pluvialis* (see Dahanukar et al. 2017).

21. Indian Burrowing Frog ***Sphaerotheca breviceps*** (Schneider, 1799)
Material: SACON/VA-21a–b two from Anaikatti
Comments: Dahanukar et al. (2017) provided a refined definition of the taxon *S. breviceps*, restricting it to parts of eastern peninsular India, in the lowlands.

22. Western Burrowing Frog ***Sphaerotheca pashchima*** Padhye, Dahanukar, Sulakhe, Dandekar, Limaye & Jamdade, 2017
Material: SACON/VA-22a–c three from Gadag
Comments: Padhye et al. (2017) recognized the western peninsular or the Deccan Plateau upland populations as a new species, *S. pashchima*.

Rhacophoridae

23. Malabar Flying Frog ***Rhacophorus malabaricus*** Jerdon, 1870
Material: SACON/VA-23a one from Anamalai, SACON/VA-23b one from Srivilliputhur
Comments: Biju et al. (2013) redescribed and clarified its name-bearing type and provided a summary of previous literature sightings / reports of this species.

24. Variable Ghat Tree Frog ***Ghatixalus variabilis*** (Jerdon, 1853)
Material: SACON/VA-24 one from Ooty
Comments: Biju et al. (2008) erected the genus *Ghatixalus*, for this species (as *Polypedates variabilis* Jerdon, 1853) and restricted its concept to populations inhabiting Nilgiri Hills.

25. Tinkling Bush Frog ***Raorchestes tinniens*** (Jerdon, 1853)
Material: SACON/VA-25a–l 12 from Ooty
Comments: Vijayakumar et al. (2014) refined the definition of *R. tinniens*, after describing a related new species, *R. primarrumpffi*, also from upper Nilgiris.

26. Nilgiri Bush Frog ***Raorchestes signatus*** (Boulenger, 1882)
Material: SACON/VA-26a–e five from Ooty
Comments: Zachariah et al. (2011) described a new species *R. thodai*, from the upper Nilgiris, and it is reported to be closely resembling *R. signatus* and a proper clarification of its status is yet awaited (see Vijayakumar et al. 2014).

27. Sacred Grove Bush Frog ***Raorchestes sanctisilvaticus*** (Das & Chanda, 1997)
Material: SACON/VA-27 one from Araku Hills
Comments: Mirza et al. (2019) redefined this species (previously considered to be endemic to Jabalpur Hills) as his molecular revision proved the conspecificity of two nominate taxa *Philautus terebrans* and *P. simlipalensis* from parts of northern Eastern Ghats.

28. Beddome's Bush Frog ***Raorchestes beddomii*** (Günther, 1876)
Material: SACON/VA-28 one from Meghamalai

29. Waynad Bush Frog ***Pseudophilautus wynaadensis*** (Jerdon, 1853)
Material: SACON/VA-29a one from Topslip, SACON/

VA-29b one from Coonoor, SACON/VA-29c one from Anaimalai
Comments: Gopalan et al. (2016) reported cryptic genetic diversity in populations south of Palghat Gap, by examining populations from Waynad, Idukki, and Ponmudi clusters.

Reptilia
Sauria
Gekkonidae

30. Nilgiri Day Gecko ***Cnemaspis indica*** Gray, 1846
Material: SACON/VR-1a–d four from Ooty
Comments: Manamendra-Arachchi et al. (2007) redescribed its name-bearing type and clarified its taxonomy as a species endemic to upper Nilgiris and ranges just northwards.

31. Slender Day Gecko ***Cnemaspis* cf. *gracilis*** (Beddome, 1870)
Material: SACON/VR-2a–c three from Anaikatti, SACON/VR-2d–e two from Srivilliputhur, SACON/VR-2f one from Agasthyamalai
Comments: Manamendra-Arachchi et al. (2007) redescribed the name-bearing type and clarified the systematics of this species, an inhabitant of Palghat-Anamalai region.

32. Araku Slender Gecko ***Hemiphyllodactylus arakuensis*** Agarwal, Khandekar, Giri, Ramakrishnan & Karanth, 2019
Material: SACON/VR-3 one from Araku Hills
Comments: Agarwal et al. (2019) described the Araku Hills endemic population in parts of northern Eastern Ghats, as this new species.

33. Clouded Ground Gecko ***Cyrtodactylus* cf. *nebulosus*** (Beddome, 1870)
Material: SACON/VR-4 one from Araku Hills
Comments: Agarwal & Karanth (2014) showed through their molecular studies that this taxon and its congeners of '*Geckeolla*' are in fact nested within the genus *Cyrtodactylus*.

34. Erode Ground Gecko ***Cyrtodactylus speciosus*** (Beddome, 1870)
Material: SACON/VR-5a–b two from Anaikatti
Comments: This species was recently redescribed and its taxonomy was clarified after elevating it to a species status whilst describing a related, new species from western India (Agarwal et al. 2016).

35. Bark Gecko ***Hemidactylus leschenaultii*** Duméril & Bibron, 1836
Material: SACON/VR-6a–b two from Anaikatti, SACON/VR-6c one from Srivilliputhur, SACON/VR-6d one from Top Slip

36. House Gecko ***Hemidactylus frenatus*** Duméril & Bibron, 1836
Material: SACON/VR-7 one from Araku hills

37. Vanam Rock Gecko ***Hemidactylus vanam*** Chaitanya, Lajmi & Giri 2018
Material: SACON/VR-8a–c three from Srivilliputhur
Comments: This population closely matches with the topotypic specimens from High Wavy Mountains that was described as a new species (Chaitanya et al. 2018).

38. Murray's Gecko ***Hemidactylus murrayi*** Gleadow, 1887
Material: SACON/VR-9a–d four from Gadag
Comments: This species was resurrected recently, for a predominantly wet zone populations of southern and southeastern Asia (Lajmi et al. 2016).

39. Gleadow's Gecko ***Hemidactylus* cf. *gleadowi*** Murray, 1884
Material: SACON/VR-10a–c three from Gadag
Comments: Mahony (2011) resurrected this nominate taxon after a taxonomic revision of *Hemidactylus brookii* complex.

40. Spotted House Gecko ***Hemidactylus parvimaculatus*** Deraniyagala, 1953
Material: SACON/VR-11a–b two from Pondicherry
Comments: This species, once thought to be found only in Sri Lanka and Kerala, was later proved to be widespread throughout much of southeastern India, till Bengal (Lajmi et al. 2016).

41. Whitaker's Gecko ***Hemidactylus whitakeri*** Mirza, Gowande, Patil, Ambekar & Patel, 2018
Material: SACON/VR-12a–b two from Gadag
Comments: This recently described cryptic species inhabiting the uplands of Mysore Plateau, was long misunderstood to belong to *H. triedrus* (see Mirza et al. 2018).

Agamidae

42. Western Ghats Flying Lizard ***Draco dussumierii*** Duméril & Bibron, 1837
Material: SACON/VR-12a–c three from Agathyamalai, SACON/VR-12d one from Meghamalai, SACON/VR-12e–f two from Anamalai, SACON/VR-12g one from Top Slip

43. Visiri Fan-throated Lizard ***Sitana visiri*** Deepak, 2016
Material: SACON/VR-13 one from Srivilliputhur
Comments: The southerly populations of fan-throated lizard were found to belong to a different species after a recent study (Deepak et al. 2016).

44. Pondicheri Fan-throated Lizard ***Sitana***

ponticeriana Cuvier, 1829
Material: SACON/VR-14 two from Sriharikota
45. Unidentified Fan-throated Lizard ***Sitana*** sp.
Material: SACON/VR-16a–e five from Gadag
Comments: This population was discerned, characterized, and is undergoing a taxonomic treatment (Deepak & Karanth 2018).
46. Green Forest Lizard ***Calotes calotes*** (Linnaeus, 1758)
Material: SACON/VR-17a one from Srivilliputhur, SACON/VR-17b one from Meghamalai, SACON/VR-17c–d two from Anaikatti
47. Indian Garden Lizard ***Calotes versicolor*** (Daudin, 1802)
Material: SACON/VR-18a-b two from Anaikatti, SACON/VR-18c–d two from Maharashtra, SACON/VR-18e–g three from Araku Hills
48. Large-scaled Forest Lizard ***Calotes grandisquamis*** Günther, 1875
Material: SACON/VR-19a one from Meghamalai, SACON/VR-19b one from Srivilliputhur
Comments: An uncommon endemic species of agamid from the Western Ghats.
49. Nilgiri Forest Lizard ***Calotes nemoricola*** Jerdon, 1853
Material: SACON/VR-20 one from Agasthyamalai
Comments: An uncommon endemic species of agamid from the Western Ghats.
50. Spiny-headed Lizard ***Monilesaurus acanthocephalus*** Pal, Vijayakumar, Shankar, Jayraj & Deepak, 2018
Material: SACON/VR-21a–b two from Meghamalai
Comments: This species was recently described as a distinct species, a point-endemic, found only in Meghamalai Hills (Pal et al. 2018).
51. Elliot's Forest Lizard ***Monilesaurus ellioti*** (Günther, 1864)
Material: SACON/VR-22a–b two from Agasthyamalai, SACON/VR-22c one from Top Slip
Comments: This species was recently reallocated to a newly described endemic genus inhabiting lower elevation forest of the Western Ghats (Pal et al. 2018).
52. Roux's Forest Lizard ***Monilesaurus rouxii*** (Duméril & Bibron, 1837)
Material: SACON/VR-23a–c three from Nilgiris
Comments: This species was recently reallocated to a newly described endemic genus inhabiting parts of Western and Eastern Ghats and hills in the Deccan (Pal et al. 2018).
53. Anamalai Spiny Lizard ***Salea anamallayana*** (Beddome, 1878)
Material: SACON/VR-24a–b two from Anamalai, SACON/VR-24c one from Meghamalai.
Comment: A range-restricted species endemic to Anamalai, Palnis and Meghamalai hills (Srinivas et al. 2008).
54. Nilgiri Spiny Lizard ***Salea horsfieldii*** Gray, 1845
Material: SACON/VR-25 one from Ooty, Nilgiris
Comment: An endemic species found only in upper Nilgiris (Bhupathy & Nixon 2011).
55. Blandford's Rock Agama ***Psammophilus* cf. *blanfordanus*** (Stoliczka, 1871)
Material: SACON/VR-26a–h eight from Araku, SACON/VR-26i–q nine from Vizag Ghats
Comments: This species is most likely restricted to central and eastern peninsular India, as postulated by Pal et al. (2018).
56. Southern Rock Agama ***Psammophilus dorsalis*** (Gray in Griffith & Pidgeon, 1831)
Material: SACON/VR-27a–e five from Srivilliputhur, SACON/VR-27f–k six from Kolli hills, SACON/VR-27l–r seven from Nagercoil
Comments: This is a species complex pending revision (Pal et al. 2018).

Chamelionidae

57. Southern Asian Chameleon ***Chamaeleo zeylanicus*** Laurenti, 1768
Material: SACON/VR-28a–d four from Anaikatti.

Varanidae

58. Indian Monitor Lizard ***Varanus bengalensis*** (Daudin, 1802)
Material: SACON/VR-30 one from Anaikatti.

Mabuyidae

59. Keeled Skink ***Eutropis carinata*** (Schneider, 1801)
Material: SACON/VR-31a–f six from Anaikatti, SACON/VR-31g one from Araku, SACON/VR-31h–i two from Meghamalai, SACON/VR-31j one from Gadag.
60. Bronze Skink ***Eutropis* cf. *macularia*** (Blyth, 1853)
Material: SACON/VR-32a–b two from Anaikatti, SACON/VR-32c–d two from Meghamalai, SACON/VR-32e–f two from Agasthyamalai, SACON/VR-32g one from Gadag.
Comments: This is a species complex pending revision (Datta-Roy et al. 2012).
61. Beddome's Skink ***Eutropis beddomei*** (Jerdon,

1870)

Material: SACON/VR-33a-d four from Araku hills, SACON/VR-33e one from Anaikatti.

Comments: This species has recently been redescribed (Amarasinghe et al. 2016a).

62. Ponmudi Skink ***Eutropis clivicola*** (Inger, Shaffer, Koshy & Bakde, 1984)

Material: SACON/VR-34 one from Agasthyamalai.

63. Bibron's Sand Skink ***Eutropis bibronii*** (Gray, 1839)

Material: SACON/VR-35a one from Sriharikota, SACON/VR-35b–d three from Tuticorin, SACON/VR-35e–h four from Pondicherry.

Comments: This species has recently been redescribed (Amarasinghe et al. 2016b). Chandramouli et al. (2012) reported an inland record from Eastern Ghats and its status is under investigation.

Lygosomidae

64. Spotted Snake Skink ***Riopa punctata*** (Linnaeus, 1758)

Material: SACON/VR-36a–b two from Araku hills, SACON/VR-36c one from Gadag

Comments: Bauer (2003) clarified some long-standing problems with the identity and authorship of this nomen. Generic assignment follows Freitas et al. (2019).

65. White-spotted Skink ***Riopa albopunctata*** (Gray, 1846)

Material: SACON/VR-37a–b two from Anaikatti, SACON/VR-37c one from Sriharikota, SACON/VR-37d one from Pondicherry.

Comments: Ganesh (2017) clarified its taxonomy and redescribed topotypical specimens from Madras. Generic assignment and taxonomy follows Freitas et al. (2019).

66. Günther's Supple Skink ***Riopa guentheri*** (Peters, 1879)

Material: SACON/VR-38 one from Gadag.

Comments: Javed et al. (2010) provided a distribution summary of this species, with a new record from Nallamalai Hills, Eastern Ghats.

Sphenomorphidae

67. Dussumier's Skink ***Sphenomorphus dussumierii*** (Duméril & Bibron, 1839)

Material: SACON/VR-39 one from Agasthyamalai.

Comment: A species endemic to the Western Ghats (Das, 2002).

68. Side-spotted Skink ***Kaestlea laterimaculata*** (Boulenger, 1887)

Material: SACON/VR-40a–b two from Meghamalai.

Comments: This species was recorded from High Wavy Mountains by Chandramouli & Ganesh (2010); but see Chaitanya et al. (2019).

69. Twin-striped Skink ***Kaestlea bilineata*** (Gray, 1846)

Material: SACON/VR-41 one from Ooty.

Comments: This is a fairly common species in this region (Bhupathy & Nixon 2011).

Lacertidae

70. Blinking Lacertid *Ophisops nictans* Arnold, 1989

Material: SACON/VR-42a–c three from Gadag, SACON/VR-42d–f three from Chitradurga.

Serpentes

Typhlopidae

71. Unidentified worm snake ***Indotyphlops*** sp.

Material: SACON/VR-43a–g seven from unknown localities.

Comments: Hedges et al. (2014) erected the genus *Indotyphlops* for a group of primarily southern Asian worm snakes.

Uropeltidae

72. Spotted Shieldtail ***Melanophidium punctatum*** Beddome, 1871

Material: SACON/VR-44 one from Anamalai.

Comments: Gower et al. (2016) redefined this species after recognizing the northerly population as a new species – *M. khairei* Gower, Giri, Captain & Wilkinson, 2016.

73. Perrotet's Shieldtail ***Plectrurus perroteti*** Duméril & Bibron in Duméril & Duméril, 1851

Material: SACON/VR-45a–e five from Ooty

Comments: This species is known only from upper Nilgiris and other records from elsewhere have been doubted (Pyron et al. 2016).

74. Bloody Shieldtail ***Teretrurus sanguineus*** (Beddome, 1867)

Material: SACON/VR-46 one from Anamalai

Comments: This is a species complex pending taxonomic revision (Pyron et al. 2016).

75. Shortt's Shieldtail ***Uropeltis* cf. *shorttii*** (Beddome, 1863)

Material: SACON/VR-47 one from Anamalai.

Comments: This is currently under taxonomic investigation (in prep).

76. Bhupathy's Shieldtail ***Uropeltis bhupathyi*** Jins, Sampaio & Gower, 2018

Material: SACON/VR-48a–o 15 from Anaikatti

Comments: This new species is apparently known only from this single location (Jins et al. 2018).

77. Kerala Shieldtail ***Uropeltis* cf. *ceylanica*** Cuvier, 1829
Material: SACON/VR-49 one from Anamalai.
Comments: This is a species complex pending taxonomic revision (Pyron et al. 2016)

78. Elliot's Shieldtail ***Uropeltis ellioti*** (Gray, 1858)
Material: SACON/VR-50 one from Shevaroys.
Comments: This is a species complex pending taxonomic revision (Whitaker & Captain 2004; Pyron et al. 2016).

79. Ocellated Shieldtail ***Uropeltis* cf. *ocellata*** (Beddome, 1863)
Material: SACON/VR-51 one from Anamalai.
Comments: This species complex is currently under taxonomic investigation (Pyron et al. 2016).

80. Palni Shieldtail ***Uropeltis pulneyensis*** (Beddome, 1863)
Material: SACON/VR-52 one from Parambikulam Tiger Reserve.
Comments: This species is endemic to hills between Palghat and Shencottah gaps (Pyron et al. 2016).

Pythonidae

81. Indian python ***Python molurus*** (Linnaeus, 1758)
Material: SACON/VR-53 one from Anaikatti (roadkill, juvenile).

Erycidae

82. Common Sand Boa ***Eryx conicus*** (Schneider, 1801)
Material: SACON/VR-54 one from Anaikatti.
Comments: Pyron et al. (2014) revised the taxonomy of this and related species.

83. Red Sand Boa ***Eryx johnii*** (Russell, 1801)
Material: SACON/VR-55 one from Anaikatti.

Viperidae

84. Russell's Viper ***Daboia russelii*** (Shaw & Nodder, 1797)
Material: SACON/VR-56a–d four from Anaikatti.

85. Saw-scaled Viper ***Echis carinatus*** (Schneider, 1801)
Material: SACON/VR-57a–c three from Anaikatti, SACON/VR-57d one from Srivilliputhur, SACON/VR-57e one from Chinnamanur.

86. Hump-nosed Pitviper ***Hypnale hypnale*** (Merrem, 1820)
Material: SACON/VR-58a–c three from Meghamalai, SACON/VR-58d one from Anamalai, SACON/VR-58e one from Nilgiris.

87. Horse-shoe Pitviper ***Trimeresurus strigatus*** Gray, 1842
Material: SACON/VR-59 one from Ooty (damaged).
Comment: This endemic species occurs in upper Nilgiris (Bhupathy & Nixon 2011).

88. Bamboo Pitviper ***Trimeresurus gramineus*** (Shaw, 1802)
Material: SACON/VR-60a–b two from Anaikatti, SACON/VR-60c one from Meghamalai.

89. Large-scaled Pitviper ***Trimeresurus macrolepis*** Beddome, 1862
Material: SACON/VR-61a–b two from Meghamalai, SACON/VR-61c–d two from Anamalai.
Comment: This species is endemic to southern Western Ghats (Chandramouli & Ganesh 2010).

Elapidae

90. Indian Krait ***Bungarus caeruleus*** (Schneider, 1801)
Material: SACON/VR-62a–b two from Anaikatti, SACON/VR-62c one from Chinnamanur.

91. Spectacled Cobra *Naja naja* (Linnaeus, 1758)
Material: SACON/VR-63a–b two from Anaikatti.

92. Five-striped Coral Snake ***Calliophis nigrescens pentalineatus*** Beddome, 1871
Material: SACON/VR-64a one from Anamalai, SACON/VR-64b one from Meghamalai, SACON/VR-64c one from Agasthyamalai.
Comments: This taxon is endemic to parts of southern Western Ghats (Chandramouli & Ganesh 2010).

Pareidae

93. Perrotet's Wood Snake ***Xylophis perroteti*** (Duméril, Bibron & Duméril, 1854)
Material: SACON/VR-65a–c three from Ooty.
Comments: This endemic species is found to upper Nilgiris (Bhupathy & Nixon 2011).

Natricinae

94. Checkered Keelback ***Fowlea piscator*** (Schneider, 1799)
Material: SACON/VR-66a–b two from Anamalai, SACON/VR-66c one from unknown locality, SACON/VR-66d from Agasthyamalai (with a complete collar mark).
Comments: Generic allocation follows Purkayashta et al. (2018).

95. Olive Keelback ***Atretium schistosum*** (Daudin, 1803)
Material: SACON/VR-67a–b two from Anaikatti

96. Green Keelback ***Rhabdophis plumbicolor*** (Cantor, 1839)
Material: SACON/VR-68a–c three from Anaikatti, SACON/VR-68d–e two from Ooty, SACON/VR-68f one from Meghamalai.
Comments: Takeuchi et al. (2018) reconstructed a phylogeny of Asian keelbacks and effected this genus transfer.
97. Striped Keelback ***Amphiesma stolatum*** (Linnaeus, 1758)
Material: SACON/VR-69a–b two from Meghamalai.
Comments: Guo et al. (2014) split the genus *Amphiesma* into many genera, and this genus is now retained solely for *A. stolatum*.
98. Beddome's Keelback ***Hebius beddomei*** (Günther, 1864)
Material: SACON/VR-70a–c three from Nilgiris, SACON/VR-70d–e two from Top Slip, SACON/VR-70f–h three from Meghamalai, SACON/VR-70i one from Agasthyamalai.
Comments: Guo et al. (2014) effected this provisional genus transfer to *Hebius*. This Western Ghats-endemic species has not yet been represented in molecular phylogeny.
99. Hill Keelback ***Hebius monticola*** (Jerdon, 1853)
Material: SACON/VR-71a one from Top Slip, SACON/VR-71b–c two from Meghamalai.
Comments: Guo et al. (2014) effected this provisional genus transfer to *Hebius*. This Western Ghats-endemic species has not yet been represented in molecular phylogeny.

Colubridae

100. Indian Cat Snake ***Boiga trigonata*** (Schneider, 1802)
Material: SACON/VR-72a one from Anaikatti, SACON/VR-72b one from Srivilliputhur
101. Collared Cat Snake ***Boiga nuchalis*** (Günther, 1875)
Material: SACON/VR-73a–b two from Meghamalai, SACON/VR-73c one from Anamalai, SACON/VR-73b one from Ooty.
Comments: This species is endemic to hills of southwestern India and is absent in the northern ranges including the Himalaya (Ganesh et al. 2020a).
102. Yellow-green Cat Snake ***Boiga flaviviridis*** Vogel & Ganesh, 2013
Material: SACON/VR-74a–b two from Anaikatti, SACON/VR-74c one from Tirunelveli, SACON/VR-74d–e two from Chinnamanur.
Comments: Chaitanya et al. (2019) referred this population from Meghamalai as '*B. beddomei*' but they belong to *B. flaviviridis* (see Vogel & Ganesh 2013).
103. Thakeray's Cat Snake ***Boiga* cf. *thackerayi*** Giri, Deepak, Captain, Pawar & Tillak, 2019
Material: SACON/VR-75a one from Meghamalai, SACON/VR-75b one from Anamalai.
Comments: Recently, a new species was described from northern Western Ghats (Giri et al. 2019). This and nearby population is under taxonomic revision (Ganesh et al. 2020a).
104. Common Vine Snake ***Ahaetulla* cf. *nasuta*** (Lacepede, 1789)
Material: SACON/VR-76a one from Top Slip, SACON/VR-76b one from Meghamalai.
Comments: This species is in need of a taxonomic revision (Mallik et al. 2019).
105. Brown Vine Snake ***Ahaetulla* cf. *pulverulenta*** (Duméril, Bibron & Duméril, 1854)
Material: SACON/VR-77 one from Meghamalai.
Comments: This species is in need of a taxonomic revision (Mallik et al. 2019).
106. Variable Vine Snake ***Ahaetulla* cf. *anomala*** (Annandale, 1906)
Material: SACON/VR-78a–b two from Anaikatti.
Comments: Many Indian congeners are undergoing a revision (Mallik et al. 2019). This taxon was recently revived and redescribed (Mohapatra et al. 2017).
107. Günther's Vine Snake ***Ahaetulla dispar*** (Günther, 1864)
Material: SACON/VR-79a one from Meghamalai, SACON/VR-79b one from Anamalai.
Comments: Endemic to Southern Western Ghats (Chandramouli & Ganesh 2010).
108. Perrotet's Vine Snake ***Aahetulla perrotetii*** (Duméril, Bibron & Duméril, 1854)
Material: SACON/VR-80 one from Ooty.
Comments: Endemic to upper Nilgiris. Detailed information on biology and taxonomy of this species was recently presented by Ganesh & Chandramouli (2011).
109. Giri's Bronzeback ***Dendrelaphis girii*** Vogel & van Rooijen, 2011
Material: SACON/VR-81 one from Meghamalai.
Comments: This Western Ghats-endemic species was recently described as a vicar of *D. bifrenalis* from Sri Lanka (Vogel & Van Rooijen 2011).
110. Indian Bronzeback ***Dendrelaphis tristis*** (Daudin, 1803)
Material: SACON/VR-82a–b two from Anaikatti, SACON/VR-82c one from Chinnamanur.

111. Rat Snake ***Ptyas mucosa*** (Linnaeus, 1758)
Material: SACON/VR-83 one from Meghamalai.
112. Indian Trinket Snake ***Coelognathus helena*** *helena* (Daudin, 1803)
Material: SACON/VR-84a–b two from Anaikatti
113. Montane Trinket Snake ***Coelognathus helena*** *monticollaris* (Schulz, 1992)
Material: SACON/VR-85a–c three from Anaikatti, SACON/VR-85d one from Anamalai, SACON/VR-85e–g three from Meghamalai.
Comments: These populations resemble the southern Western Ghats morphotype as postulated by Mohapatra et al. (2016).
114. Banded Racer ***Argyrogena fasciolata*** (Shaw, 1802)
Material: SACON/VR-86a–c three from Anaikatti.
Comments: The distribution of this species in southern India was recently clarified (Janani et al. 2019) and there is a need to further assess the status of this taxon.
115. Indian Reed Snake ***Liopeltis calamaria*** (Günther, 1858)
Material: SACON/VR-87a–b two from Araku hills, SACON/VR-87c–e three from Anaikatti, SACON/VR-87f–g two from Anamalai, SACON/VR-87h one from Agasthyamalai.
Comments: This species was recently redescribed, including its constituent subspecies (Amarasinghe et al. 2020). The status of the Western Ghats populations are again being worked upon (in prep.).
116. Banded Kukri ***Oligodon arnensis*** (Shaw, 1802)
Material: SACON/VR-88a–b two from Anaikatti.
117. Black-spotted Kukri ***Oligodon* cf. *venustus*** (Jerdon, 1853)
Material: SACON/VR-89 one from Meghamalai
118. Streaked Kukri Snake ***Oligodon taeniolatus*** (Jerdon, 1853)
Material: SACON/VR-90a–d four from Anaikatti, SACON/VR-90e–g three from Srivilliputhur, SACON/VR-90h-i two from Araku Hills, SACON/VR-90j–k two from Anamalai, SACON/VR-90l one from Ooty.
119. Black-headed Snake ***Sibynophis subpunctatus*** (Duméril, Bibron & Duméril, 1854)
Material: SACON/VR-91a–c three from Anaikatti, SACON/VR-91d–e two from Srivilliputhur, SACON/VR-91f–g two from Chinnamanur.
120. Indian Bridal Snake ***Dryocalamus nympha*** (Daudin, 1803)
Material: SACON/VR-92a–b two from Anaikatti, SACON/VR-92a one from Tirunelveli
121. Unidentified Wolf Snake ***Lycodon*** sp.
Material: SACON/VR-93 from Anaikatti, damaged specimen.
Comments: The taxonomic status of this population is currently under study (in prep.).
122. Common Wolf Snake ***Lycodon aulicus*** (Linnaeus, 1758)
Material: SACON/VR-94a–c three from Anaikatti, SACON/VR-94d one from Anamalai.
Comments: This species was recently re-characterized by Ganesh & Vogel (2018).
123. Slender Wolf Snake ***Lycodon anamallensis*** Günther, 1864
Material: SACON/VR-95a–b two from Anaikatti, SACON/VR-95c one from Chinnamanur.
Comments: Ganesh & Vogel (2018) clarified the taxonomy and nomenclature of this taxon and synonymized the Sri Lankan taxon *L. osmanhilli* under this nomen.
124. Barred Wolf Snake ***Lycodon striatus*** (Shaw, 1802)
Material: SACON/VR-96 one from Chinnamanur
125. Travancore Wolf Snake ***Lycodon travancoricus*** (Beddome, 1870)
Material: SACON/VR-97 one from Meghamalai.
Comments: This species has sometimes been confused with other sympatric congeners and was recently redescribed to clarify the status (Ganesh et al. 2020b).

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SHORT COMMUNICATION

Osteological description of Indian Skipper Frog *Euphlyctis cyanophlyctis* (Anura: Dicroglossidae) from the Western Ghats of India

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Abstract: The present study provides description of the osteology of Skipper Frog *Euphlyctis cyanophlyctis*. Seven adult specimens of *E. cyanophlyctis* from northern Western Ghats of India were cleared and double stained for studying osteological characteristics. The baseline description of osteological characters of cranial and post-cranial elements (paired nasals, tubular sphenethmoid, well-developed vomerine teeth, arciferal pectoral girdle, fan-shaped omosternum, cartilaginous W-shaped xiphisternum, hind limb with longest cylindrical humerus, V-shaped pectoral girdle and phalangeal appendages) provided in present study will help in further taxonomic investigations of the genus *Euphlyctis*. Further, the baseline information on osteology of Skipper frog will serve as a reference material for investigations related to malformations, either in this or related species. We also provide first observation on sacro-pelvic malformation in one of the studied specimens.

Keywords: Skeletal morphology, amphibian decline, anthropogenic stressors, malformation, conservation.

Amphibians are declining globally with highest number of species at risk of extinction than any other vertebrate group (Stuart et al. 2004). Limited information on the basic biology, population status, distribution, life-history and potential threats to the anurans is one of the major hurdles in amphibian conservation (Dinesh & Radhakrishnan 2011; Dahanukar et al. 2013). In addition to population declines, amphibian malformations has become a major conservation concern and studies reporting and analyzing amphibian deformities have gained momentum (Johnson et al. 1999; Schoff et al. 2003; Peloso 2016). Investigations into the basic biology, including the osteology of a species, will not only help in understanding its taxonomy, but also form a baseline for comparative osteology of malformed individuals. Therefore, the fundamental objective of the present

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study was to describe detailed osteology of the Indian Skipper Frog *Euphlyctis cyanophlyctis* (Schneider, 1799) to serve as a baseline data for further investigations.

Adult specimens (n = 7; SVL= 25.50–55.67 mm) of *E. cyanophlyctis* consists of both male and female individuals were collected from temporary pool situated at Sangrun (18.404°N & 73.687°E) Haveli, Pune and Nere (18.619°N & 73.702°E) Mulshi, Pune, Maharashtra, India on 23 July 2017 and 2 August 2017, respectively. The specimens were cleared and double stained differentially for bone and cartilage as per Potthoff (1984). The osteological terminology follows Trueb (1973), Duellman & Trueb (1986) and Pugener & Maglia (1997). Cleared and double stained specimens are deposited in the museum collection of Bombay Natural History Society (BNHS) under the accession numbers BNHS 6031–BNHS 6037.

Irrespective of the sex, no significant differences were observed in the osteology of seven specimens. The osteological representation of *E. cyanophlyctis* is shown in Figure 1. The detailed description of the osteology is provided below.

Cranium (Figure 1A & B)

It is well-developed, triangular and dorso-ventrally flat structure. The frontoparietals are paired, fully ossified and flat structure forming the roof of the skull. They are separated throughout their length, cover the sphenethmoid anteriorly and extend till the exoccipitals posteriorly. They fail to articulate with nasals anteriorly but firmly attached with the prootic and exoccipitals posteriorly. Sphenethmoid is located anterior to the cranial cavity and forms the posterior boundary of the olfactory chambers. It is a tubular-shaped bone formed by a combination of anterior ethmoidal and posterior sphenoidal regions separated from each other by a transverse partition. Ethmoidal region separates into the right and left halves by longitudinal partition, which further encloses the olfactory sac. A small portion of the bone is visible particularly at the posterior boundary (sphenoidal region), as it is covered ventrally by parasphenoid and dorsally by nasals and frontoparietals bones. Parasphenoid is single, elongated, large dagger-like or inverted 'T' shaped bone forming the cranial floor. It shows a pointed long shaft directed anteriorly and its cross piece handle lies across the auditory capsule. The occipitals form posterior-most boundary of the cranium. Presence of a large hole, foramen magnum is noticeable, which serves as the entry point for the spinal cord. Postero-laterally, the foramen is surrounded by two roughly oval-shaped exoccipitals. The exoccipitals posteriorly have cartilaginous occipital condyles, which further articulates with the first vertebra (atlas) anteriorly. The outer margin of each exoccipital is firmly attached to the cartilaginous auditory capsule. The anterior wall and partly the roof and floor of each capsule are formed by a fully ossified, roughly rectangular prootic. It is partly covered by squamosal on its dorsal side. The occipital region is enclosed by frontoparietals, while the floor is occupied by a dagger-shaped parasphenoid. Supraoccipital and basioccipital are absent.

Sense capsule, consisting of an auditory capsule, an olfactory capsule and an optical capsule, encloses the organs of the hearing, the organs of the smell and the eye, respectively. The auditory and olfactory capsules are firmly attached to the cranium, while the eyes are not fused with the skull. Nasals are paired, fully ossified bones that form the roof of the olfactory capsule covering the anterior dorsal region of the skull and are not medially fused. Their anterior ends extend to the dorsal processes of the premaxillae and thus partially form the boundary of external nares. Septomaxillaries are small, irregular-shaped bones present close to the anterior part of each nasal bone. Vomers are paired, completely ossified, roughly triangular bones, located ventrally to the nasal capsule floor. The presence of a row of vomerine teeth on the posterolateral margin is noticeable. Anterolateral and lateral margin bears pointed projections.

Upper jaw (Figure 1A & B)

Premaxillae are paired bones, fuse medially, well-ossified and form the anterior boundary of the maxillary arch. Each premaxilla has two rows (16 + 14) of teeth. On the outer side, each premaxilla articulates a maxilla of its respective side. Maxillae are quite long, sharply curved bone and bears numerous, sharply pointed teeth arranged in two rows (34 + 51). At the middle of its length, it is articulated with the palatine and pterygoid. The maxilla is connected to the quadratojugal posteriorly. Quadratojugals are paired, short rod-like bones, completely ossified. The posterior portion of the quadratojugal underlies the margin of the squamosal. Squamosals are irregular shaped-bones located just above the pterygoid. Anteriorly it remains free, whereas posteriorly it forms a connection to the auditory and prootic capsules. Pterygoids are paired, fully ossified, 'Y'-shaped bone with three limbs, laterally positioned on either side of cranium and ventrally positioned to the squamosal. The anterior limb is linked to the maxilla. The inner limb is connected to the pterygoid and the

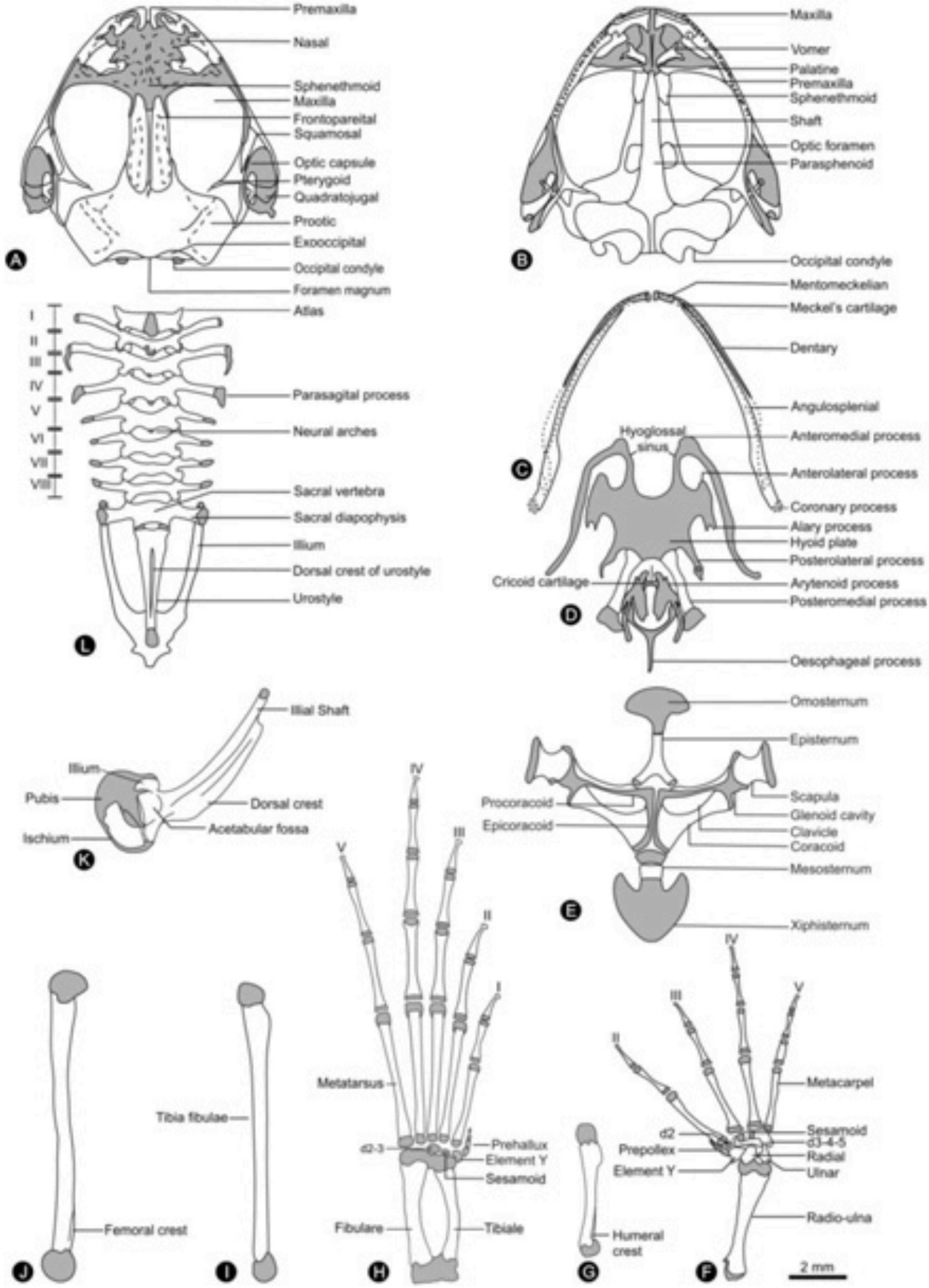

Figure 1. Osteology of *Euphlyctis cyanophlyctis*, BNHS 6032: A—cranium, dorsal view | B—cranium, ventral view | C—lower jaw | D—hyoid skeleton | E—pectoral girdle | F—forelimb | G—humerus | H—hindlimb | I—tibia and fibula | J—femur | K—pelvic girdle, lateral view | L—pelvic girdle, front view and axial skeleton.

auditory capsule, whereas the posterior limb joins with the quadratojugal. Pterygoids also contribute for the formation of the posteroventral margin of the orbit of respective side. Palatines are paired, elongated, rod-shaped bones that are located ventrally and form the anterior side of each orbit. They serve as a transverse link between the anterior side of the cranium and the maxilla.

Lower jaw or mandible (Figure 1C)

It is semi-circular and consists of two halves or rami which are connected to each other by a ligament at the anterior end. Teeth are absent. Each ramus consists of a core of Meckel's cartilage, surrounded by mento-meckelian, angulosplenial and dentary. Mento-meckelian is small, entirely cartilaginous and located at the extreme anterior end of the Meckel's cartilage, where both rami unite together. Angulosplenial is a long, strongly curved prominent bone forming most of the inner and posterior portion of each ramus of the mandible. Its anterior end is tapering, whereas the posterior end has articulating process/condyle for the quadrate cartilage of the skull. Just close to the articulating condyle, it also has a small knob-like coronary process. Dentary is an elongated rod-like bone covering almost 50% of the outer surface of the anterior portion of Meckel's cartilage. Anteriorly, it extends up to the Mento-meckelian, whereas posteriorly up to the outer side of the coronary process.

Hyoid skeleton (Figure 1D)

It consists of thin cartilaginous shield-shaped hyoid plate (=corpus), U-shaped hyoglossal sinus, anterolateral (cartilaginous), anteromedial (longest), posterolateral processes (cartilaginous and almost the same size as anterolateral), posteromedial (fully ossified) processes and cartilaginous, thin, long, curved hyales allowing the hyoid apparatus to be attached to the cranium. A small, thin, rounded medial element is present on the anterior process of the hyale. Stalk of anterolateral processes is comparatively thicker than its distal portion, which bears the alary process. Hyoglossal sinus is deeply grooved. Posterolateral processes are long and nearly 50% of the total length of the posteromedial process.

Vertebral column (Figure 1L)

The presacral region consists of eight vertebrae, a sacral region with one sacral vertebra and a caudal region with the urostyle. The atlas (1^{st} vertebra) anteriorly articulates with the posterior-most regions of exoccipitals. Centrum of the atlas is comparatively larger than other presacral vertebrae (visible from the ventral view). The presacral II–VII are procoelous, while the presacral VIII is amphicoelous. All vertebrae connected to each other through post-zygapophyses of one vertebra with the pre-zygapophyses of the next vertebra. The neural arches of each vertebra have a well-developed dorsal ridge and a pair of transverse processes extending laterally with terminal parasagital processes. The first four pairs of transverse processes (presacrals II–IV) are relatively more robust than those of last four pairs (presacrals V–VIII). The neural arches of I–V vertebrae are imbricate. The relative lengths of transverse processes are as follows: III > IV > V > VI=VII=VIII < II. The transverse process of vertebrae IV, V and VI are directed posteriorly, the VIII vertebra is directed anteriorly, whereas III and VII are approximately perpendicular to the notochordal axis. Sacral diapophyses are laterally oriented, positioned perpendicular to the notochordal axis and are of similar size to transverse processes of VI, VII, VIII vertebrae. Urostyle is slender, shorter than the presacral length and articulates the sacrum through a bicondylar articulation. It has a prominent dorsal crest most of its length.

Pectoral girdle (Figure 1E)

It is arciferal in structure. Suprascapulae are paired, completly ossified, with the larger partion forming the distal edge of the pectoral girdle and articulates with scapula medially. Cleithrum is cartilaginous and covers most of the suprascapula. Scapula is rectangular and articulates with the clavicle anterolaterally and coracoid medially at the glenoid cavity. Laterally it joins with supra scapula and the cleithrum. Clavicle is slender, completely ossified, slightly curled, with a shape of bow that forms the anterior part of the pectoral girdle. Procoracoids are present, separated medially, extend along the dorsal posterior of clavicles, and articulate with the scapula at the distal end. The coracoids are rectangular shaped, fully ossified and distally expanded extremities which articulate with the epicoracoid medially and scapula ventrolaterally. Epicorocoids is cartilaginous, separated throughout their length and forms arciferal arrangement. Omosternum is cartilaginous, fan-shaped expanded distal end and comparatively smaller than 'W' like shaped cartilaginous xiphisternum. Episternum is fully ossified, inverted 'Y' shaped structure, articulates with omosternum anteriorly and procoracoids posteriorly. Mesosternum is ossified with the anterior cartilaginous end and comparatively wider than the episternum.

Forelimbs (Figure 1F and 1G)

Humerus is the longest bone of forelimb with well-defined humeral crest, cylindrical in appearance, articulates into glenoid cavity proximally and radio-ulna distally. Six carpel elements (ulnare, distal carpel 3–4–5, distal carpel 2, element 'Y', radial, and prepollex) are present, representing 'Type-C' morphology of Fabrezi (1992). The sesamoid is cartilaginous, rounded and positioned above the radial. The relative length of metacarpals is as follows: II=IV>III>V. The phalangeal formula is 2–2–3–3.

Pelvic girdle (Figure 1K and 1L)

It is 'V' shaped and consists of pair of ilia, ischia and pubis. The ilial shafts are round in cross-section and articulate with the sacral diapophysis. Ischia and pubis are fused together, forming the acetabulum.

Hind limbs (Figure 1H, 1I, 1J)

Femur is the longest bone (slightly larger than tibia-fibulae) of the body, articulates with the acetabulum proximally and with tibia-fibula distally. Tibia-fibulae distally articulate with tibiale and fibulare, which are separated throughout their length, except for proximal and distal ends. Tibiale and fibulare are about half of the length of tibia-fibula. A sesamoid is positioned proximally to tibiale. Pes consists of fused distal tarsals 2–3, element 'Y' prehallical elements (cartilaginous elements; I, II, III and IV), metatarsals and phalanges. The relative length of the metatarsals is as follows: V=IV=III>II>I. The phalangeal formula is 2–2–3–4–3.

Sacro-pelvic malformation

In one of the specimens collected from Sangrun, we observed two sacral vertebrae with transverse processes (Image 1A; malformed individual) in contrast to the one sacral vertebra (Image 1B; normal individual).

Knowledge of the basic osteology of anurans is critically important in taxonomic investigations (Lynch 1971). At present, the genus *Euphlyctis* is represented by eight extant species (Priti et al. 2016). For the first time, using skeletal characters, Deckert (1938) provided brief generic description for *Dicroglossus* Günther (1860) and placed *cyanophlyctis* under *Dicroglossus* (= *Euphlyctis* Fitzinger 1843 according to Dubois 1980) other than *Rana*. However, detailed osteological characters for any species of the genus *Euphlyctis* is not available, which limits comparative analysis. Therefore, the osteology of *E. cyanophlyctis* was compared with the *Quasipaa robertingeri* (= *Quasipaa boulengeri*) and *Nannophrys marmorata* which belongs to the family Dicroglossidae (Senevirathne & Meegaskumbura 2015; Zhang et al. 2016). The comparative descriptions of the prominent and distinctive osteological characters between *E. cyanophlyctis*, *Q. robertingeri* and *N. marmorata* are given in Table 1. Although the characters presented in this study are generic rather than species-specific, they could be used as a reference data for more thorough species-specific osteological investigations of the genus *Euphlyctis*.

Several stressors (environmental pollution, greater exposure to the UV–B radiation, and parasitic overload) contribute to the development of abnormal or bizarre morphological features, especially affecting the limbs and vertebrae of amphibians, which are referred to as 'malformation' (Silva et al. 2019). The incidence of occurrence of malformed anurans is increasing (Blaustein & Johnson 2003; Pelaso 2016). Therefore, the osteological description provided in present study will also serve as a baseline data of normal form which

Table 1. Comparative analysis of osteological characters of three species belongs to the family Dicroglossidae representing three different genera.

Characters	*Euphlyctis cyanophlyctis*	*Quasipaa robertingeri*	*Nannophrys marmorata*
Frontoparietal	Thin and long	Rigid and broad	Rigid and broad
Episternum	Y-shaped	Funnel shaped	Cylindrical
Xiphisternum	W-shaped	W-shaped	Fan-shaped
Omosternum	Fan-shaped expanded distally	Fan-shaped expanded distally	Tube like fused with the cartilaginous epicoracoids
Metacarpal length	II=IV>III>V	IV>V> II>III	IV>III>V>II
Phalanges (Palm)	2–2–3–3	2–2–3–3	3–3–4–4
Metatarsal length	V=IV=III>II>I	V>III >V >II >I	IV>V>III>II>I
Phalanges (Toes)	2–2–3–4–3	2–2–3–4–3	3–3–4–5–4
Reference	Present study	Zhang et al. (2016)	Senevirathne & Meegaskumbura (2015)

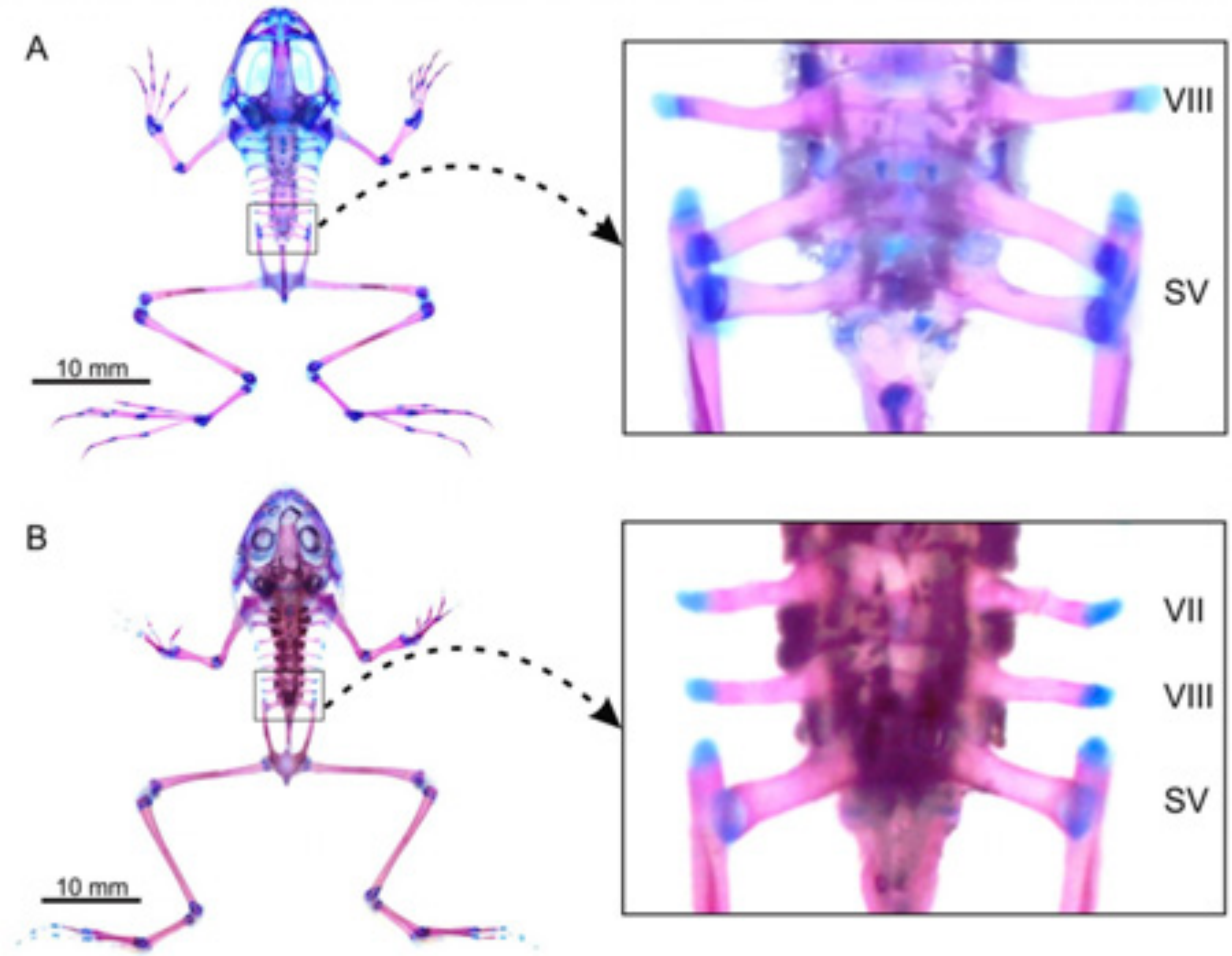

Image 1. Cleared and double stained specimens of *Euphlyctis cyanophlyctis*, A—malformed individual and its enlarged view with VIII[th] pre-sacral vertebra followed by double sacral vetebrae and | B—normal individual and its enlarged view with VII[th], VIII[th] pre-sacral vertebrae followed by single sacral vertebra. SV—sacral vertebra. © Chandani Verma.

could be effectively use to differentiate malformed individuals from normal onces. At present it is difficult to pinpoint the exact cause/s of observed malformation in *E. cyanophlyctis*, however, the malformed individuals are often easy target for the predators, failed to reproduce and thereby compromise with their survival and fitness (Sower et al. 2000; Blaustein & Johnson 2003; Bowerman et al. 2010). Owing to the global amphibian decline and ongoing controversy over the types of amphibian malformations caused by various factors, the information presented in this study not only have implications for the continued investigation of amphibian malformations but also has a conservation implication.

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SHORT COMMUNICATION

DNA barcode reveals the occurrence of Palearctic *Olepa schleini* Witt et al., 2005 (Lepidoptera: Erebidae: Arctiinae) from peninsular India with morphological variations and a new subspecies

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Abstract: The present study was taken up to report a new record of the tiger moth genus, *Olepa* Watson, 1980 from India along with the discovery of a new subspecies. Earlier the genus was thought to have restricted distribution range in South and South-East Asia until the report of *O. schleini* Witt, Müller, Kravchenko, Miller, Hausmann & Speidel from the Mediterranean Coastal Plain of Israel in 2005. The species identification and the new subspecies is proposed based on the combination of morphological studies, available literature comparisons, geographical distribution, DNA barcoding and its phylogeny. Morphological character crypticity and genital structure variations are well documented in the genus with 'bio-species' groups. DNA Barcoding data of mt COI has provided some resolution in sorting the problems of 'bio-species' groups of the genus in the past studies. In the present study, with the available mt DNA COI barcodes and newly generated barcodes genetic identity is confirmed for the species *O. ricini*, *O. schleini*, *O. toulgoeti* and *Olepa schleini chandrai* ssp. nov., with their phylogenetic relationships. Morphological variations within the *O. schleini* species complex are discussed with a new record of the species for India and a new subspecies description. With the first mt COI barcode phylogeny for the genus, comments are made on the taxonomic identity of the mt COI DNA barcodes available in the GenBank for the *Olepa* species from India.

Keywords: mt COI gene, Maharashtra, new record, *Olepa schleini chandrai* ssp. nov., Oriental region, tiger moth, Western Ghats.

Abbreviations: tl—total length | mw—maximum width | vl—length of vinculum | vw—maximum width of vinculum | jl—length of juxta | jw—maximum width of juxta | al—length of aedagus (excluding vesica) | aw—maximum width of aedagus.

The genus *Olepa* Watson, 1980 was previously considered monotypic, with a single species, *O. ricini* (Fabricius, 1775). In 1986, Orhant revised the taxonomy and systematics of the genus into two morphological species-groups of *O. ocellifera* (Walker, 1855) and *O. clavatus* (Swinhoe, 1885) and he described four new species, namely, *O. duboisi* Orhant, 1986, *O. anomi* Orhant, 1986, *O. koslandana* Orhant, 1986, and *O. toulgoeti* Orhant, 1986 from southern India and Sri Lanka. Subsequently, four more species were added to the genus, thereby making the total 11 from the World (see Orhant 2000, 2012; Witt et al. 2005; Dubatolov 2011). The caterpillars of this genus feed on various

ZooBank: urn:lsid:zoobank.org:pub:DC0B6F86-AE6F-4115-A71E-5266AC5842A5

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crops such as cotton, castor, sunflower, sesame, maize, ivy gourd, brinjal, sweet potato, and banana (ICAR-NBAIR 2019).

Orhant (2000) divided *Olepa* into two morphological species group based on the shape of uncus and valvae, viz.: the *ricini* group (uncus and valvae narrow, pointed at tip mostly) and *ocellifera* group (uncus broad, triangular; valvae digitiform, apex rounded). He added *O. ricini*, *O. clavatus*, and *O. koslandana* to the *ricini* species group and *O. ocellifera*, *O. duboisi*, *O. anomi*, and *O. kakatii* Orhant, 2000 to the *ocellifera* group. This was further modified by Witt et al. (2005) who added *O. toulgoeti* to the *ricini* species group. The first set of DNA barcodes for the genus *Olepa* was provided for the species *O. ricini*, *O. toulgoeti*, and *O. schleini* by Witt et al. (2005) during the new species description of *O. schleini* from Israel.

During our studies in the peninsular India, we found some of our *Olepa* specimens were matching the morphological descriptions and male genital characters with the species of *O. schleini* from Israel. Due to the contrasting zoogeographical collection localities from Oriental and Palearctic regions and their geographical isolation, we subjected our samples of *Olepa* for DNA Barcode studies. The outcome of the studies is presented here as a new report of *O. schleini* from peninsular India with the proposal of a new subspecies of *Olepa*.

In the past studies, the intraspecies variability among the species of *Olepa* is well documented by Witt et al. (2005); in his words "Within the two groups, the species are slightly variable in habitus and genitalia so that some species are doubtful, especially in the *ocellifera* group". Also, *O*. *toulgoeti* which was synonymised by Singh & Singh (2013) under *O*. *clavatus* is reinstated herein based on distinct features of their genitalia and DNA study (Witt et al. 2005).

Material and Methods

The moth specimens were collected by using a light trap during night, and were euthanized by ethyl acetate vapors and dry preserved in fumigated entomological boxes for further study. The specimens were studied under Leica EZ4E stereomicroscope. The series of images obtained from the stereomicroscope was stacked using the CombineZP software (Hadley 2010). The geographic coordinates and altitude were obtained, possibly by a Garmin GPS. The maps of the collection locality were

Figure 1. Collection sites of *O. schleini*: Indian *O. schleini* new record to India (star), *O. schleini chandrai* ssp. nov. (oval).

prepared using QGIS software. The details of collection locality are given under material examined and also shown in Figure 1. The identification of the specimen was done with the help of Orhant (1986) and Witt et al. (2005) terminology followed herein is after Orhant (1986, 2012). The genitalia of male and female were studied following Robinson (1976), and terminology is after Klots (1970), Orhant (1986, 2012), and Pekarsky (2012). The material examined is deposited in the Zoological Survey of India, Western Regional Centre, Pune, Maharashtra, India (ZSI-WRC).

DNA extraction, amplification, and sequencing

Whole genomic DNA was extracted from the dried leg and abdomen part of pinned preserved adults by modified Phenol-Chloroform method (Sambrook & Russell 2001) and the resultant pellet was eluted in 50µL of TE buffer pH 8.0, followed by DNA quantitation using Qubit 2.0 fluorometer by highly sensitive dsDNA assay kit. Approximately 578bp nucleotide portion of the mitochondrial COI gene was amplified using the primer pair LepCOI F, 5'-ATTCAACCAATCATAAAGATAT-3' and LepCOI R, 5'-TAAACTTCTGGATGTCCAAAAA-3' (Hebert et al. 2004). PCR reaction was performed in 25µL reaction volume comprising 12.5µL 2X Master Mix (Promega) DNAPolymerase, Reaction Buffer (pH 8.5), 400µM of each dNTPand 4mM MgCl2; 10µM of each forward and reverse primers, 1-5µL DNA (20-100ng) and nuclease free water to Q.S. Thermo cycling profile was as described by Hebert et al. (2003), with modifications, one cycle of 1min at 94°C; 10 cycles of 0.5min at 94°C, 1.5min at 45°C and 1.5min at 72°C; 30 cycles of 0.5min at 94°C, 1.5min at 51°C and 1min at 72°C and a final cycle of 1min at 72°C. PCR products were subjected to electrophoresis in 1% TAE gel stained with ethidium bromide (EtBr) and visualized under UV light via Gelstain Gel Documentation system. The amplified PCR product was purified using Invitrogen's Pure Link PCR Purification Kit. Purified PCR product was sequenced by Sanger's method on ABI 377 (Applied Biosciences) sequencer outsourced through M/S GeneMatrix, LLP, Pune.

Phylogenetic analysis

Generated sequences were initially aligned manually using MEGA version X (Tamura et al. 2011). With our sequences, mt COI DNA sequences for the species for the genus *Olepa* (21 sequences) were downloaded from the GenBank and aligned. Uncorrected pair-wise genetic distances (p-distances) were computed in MEGA version X (Tamura et al. 2011) to delineate our COI sequences from the rest of the *Olepa* sequences from GenBank. Final maximum likelihood (ML) tree was generated using raxmlGUI v1.3 (Silvestro & Michalak 2012). The ML tree (Figure 2) was obtained with 1,000 thorough bootstrap replicates under GTR+I model of nucleotide substitution using Akaike Information Criterion (-lnL = 1874.65; AIC = 3935.30) in jModel test (Posada 2008) and the consensus-generated tree was viewed using Fig. Tree v1.4.0, treating species of *Pygospila* as out-group (Table 1).

Result and Discussions

Our mt COI DNA studies confirmed two genetically distinct populations within the *O. schleini* species complex with morphological variations. Since the mt COI DNA sequences for our collections of *O. schleini* populations from Nandurbar were matching 100% with the mt COI DNA sequences of *O. schleini* from Israel we are treating the *Olepa* specimens from Nandurbar as the new report of *O. schleini* from peninsular India. Another population of *O. schleini* from Palghar which is 0.6% divergent for mt COI DNA with the *O. schleini* from Israel is described here as a new subspecies under *O. schleini*. The morphological character variations across the *O. schleini* populations from Israel (Palaearctic regions) and peninsular India (Oriental region) are discussed below (see taxonomic details).

Geographically, the type locality of *O. schleini* from Israel and the present record of the species from peninsular India are separated by a minimum aerial distance of 4,000km. This forms the first report for an *Olepa* species having its distribution range in both the Oriental and Palearctic regions

In the taxonomic account the comparisons were made on the basis of morphological characters, male genitalia, aedagus, position and number of cornuti as these characters were considered for comparison by Orhant (1986, 2000, 2012), Witt et al. (2005), and Dubatolov (2011). The VIIIth abdominal sternite is also considered for comparison as per Orhant (1986, 2000, 2012) and Dubatolov (2011).

Taxonomic account

Family Erebidae Leach, [1815]

Subfamily Arctiinae Leach, [1815]

Tribe Arctiini Leach, [1815]

Genus *Olepa* Watson, 1980

Olepa Watson, 1980, *The Generic Names of Moths of the World* 2: 133.

Type species: *Alope ocellifera* (Walker, 1855) [=*Olepa ocellifera* (Walker, 1855)]

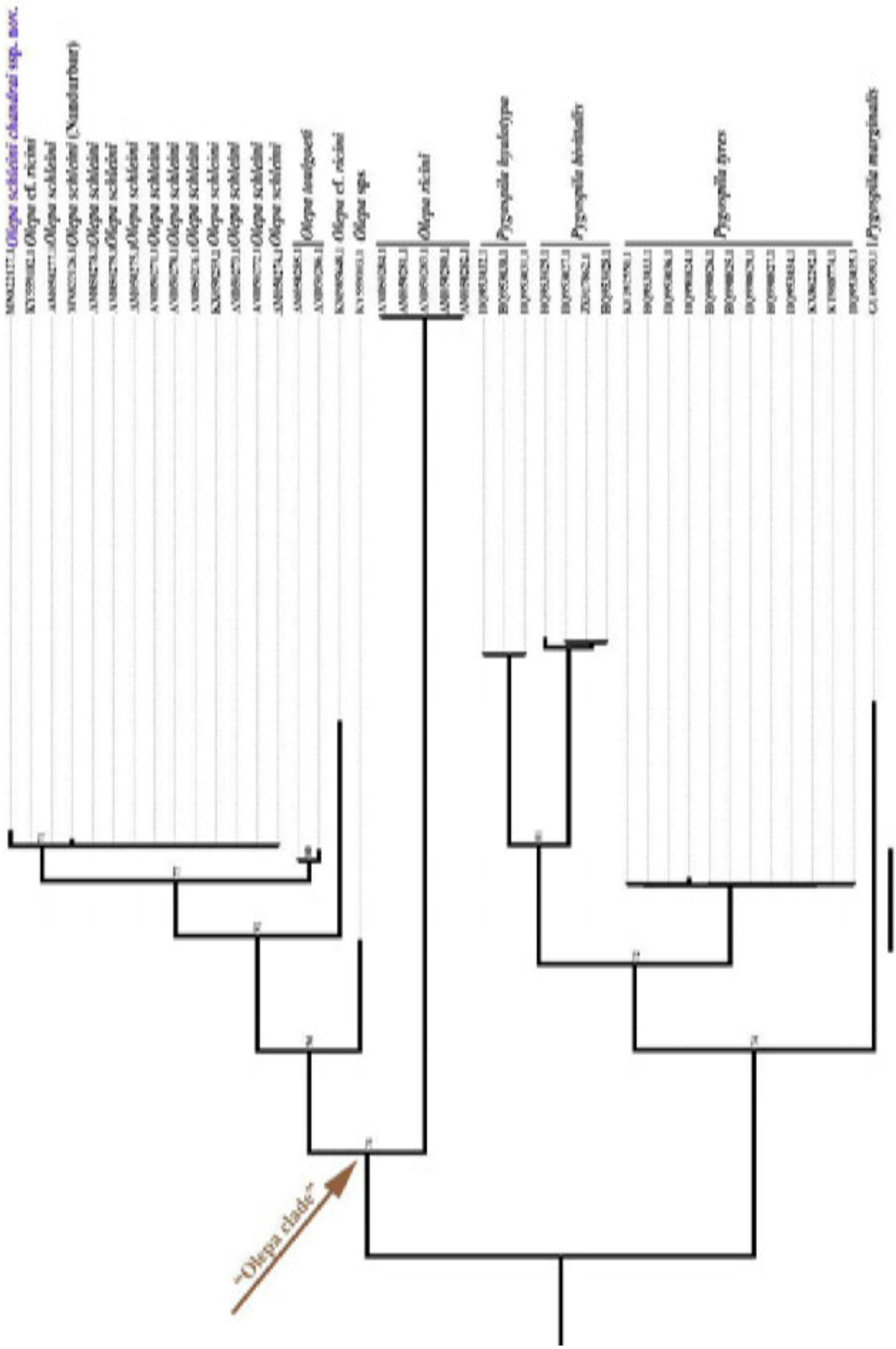

Figure 2. Maximum Likelihood (ML) tree for the species of *Olepa* based on the 578 bp of mitochondrial COI DNA gene sequences

Olepa schleini **Witt, Müller, Kravchenko, Miller, Hausmann & Speidel, 2005**
(Image 1A–G)

Material examined: ZSI-WRC L-2028, 04.vii.2019, 01 male, Nandurbar (21.363N & 74.241E; 216m), Maharashtra, India, coll. Shital Pawara.

Molecular diagnosis: mt COI DNA sequences of ZSI/ENT/311 (GenBank accession number MN822126.1) were homologous with the sequences of *O. schleini* by Witt et al. (2005) without any nucleotide base pair differences.

Description: (Image 1A–B). Forewing length 46mm. Antennae brown and bipectinate, branches very small. Head and thorax dark grey-brown; collar bordered with yellow band, with two yellow ringed black spots; patagia with two pairs of big, same sized, yellow ringed black spots; one same bigger spot on middle of thorax. Abdomen coral, with eight dorsal and lateral black spots or bands; extremity of abdomen yellow; underside of abdomen yellowish. Legs fuscous brown, except extremity of femura and joints of tarsus yellowish. Forewing brown, with pale ringed dark spots, incomplete basal line; subbasal line very broad, curved, complete; median, subterminal and terminal lines macular, with variable spots; cilia greyish in between yellowish; underside same pattern. Hindwing light coral, somewhat yellowish near the coastal area, with three brown lines or bands; antemedial band thick, complete; median band incomplete; postmedial band with five blotches, interrupted in middle; underside same pattern as dorsal; cilia greyish in between yellowish.

Male Genitalia (Image 1 C–E). Total length of genitalia 5.82mm, maximum width 4.64mm. Genitalia heavily sclerotized. Uncus oblong, narrow than the other members, parallel sided (unlike Israelian *O. schleini*, where the base of uncus very narrow); apex tapering, blunt, surrounded by elongated thick setae. Valvae simple, very broad comparatively, curved in its half portion, long, central portion more broad, less narrowed and tapering in its distal portion ending in blunt apex; in an inflection directed against the uncus; the inner margin very broadly serrated at the tip, very distinctly patterned; the outer margin strongly serrated; the tip of the valvae not smooth, directed outward, convex. Juxta (length: 1.89mm, width: 1.56mm) longer, surai shaped. Vinculum (length: 0.772mm, width: 1.94mm) broad U-shaped, very shorter than tegumen, more than twice wider, uniformly sclerotized, with small outgrowth on its proximal end. Tegumen longer than uncus; broad inverted U-shaped, strongly sclerotised, comparatively smaller.

Aedagus (Image 1F). The length of aedagus: 4.34mm, width: 0.597mm. Short, thin, moderately sclerotized, minutely concave in the middle portion; with single, small, apical spine, apex acute; two-third portion of aedagus near apical spine highly sclerotized, remaining area opposite to it is membranous. Vesica membranous near base; subbasal diverticulum moderately scobinated, with two small patches of five, sclerotised cornuti; medial diverticulum heavily scobinated, with two short patches of eight to nine small, diverse cornuti, situated at posterior and anterior portion of diverticulum; the distal diverticulum, very heavily scobinated, with two patches of cornuti, situated medially and terminally, the medial patch consists of very minute 5–6 cornuti and the terminal, consists of comparatively big patch of small cornuti; a unique feature seen, is small patch of moderate sclerotisation present on the portion between the basal and the medial diverticulum on the ventral side.

VIIIth Abdominal sternite: the central plate of VIIIthAbdominal sternite is tridentate, with a very distinct pattern (Image 1G).

Measurement (in mm). tl: 5.82, mw: 4.64; vl: 0.772, vw: 1.94; jl: 1.89, jw: 1.56; al: 4.34, aw: 0.597.

Morphological variations within *O. schleini*: The forewing of adult of Indian *O. schleini* is with pale ringed macular bands (vs. without pale ringed spots on forewing of Israelian *O. schleini*). The subbasal band of forewing is broadest among all members of the group (it is normal, not very broad in Israelian *O. schleini*). The uncus of Indian *O. schleini* is narrow and parallel sided (which is very narrow at the base in Israelian *O. schleini*). The vinculum is broad U-shaped in Indian *O. schleini* which is of various shapes in Israelian *O. schleini* (see Witt et al. 2005) but not broad U-shaped. Juxta also differs significantly and is very broad in Indian *O. schleini*. The intraspecies variability is well supported and is in consistent with the study of Witt et al. (2005), wherein he stated the occurrence of intraspecies variability in this species and related taxa. The morphometric data conforms that the genitalial components of *O. schleini* is comparatively smaller than its subspecies.

Distribution: Israel; India (Nandurbar in Maharashtra).

Olepa schleini chandrai **Kalawate, ssp. nov.**
(Image 1H–N)

urn:lsid:zoobank.org:act:5118E0A1-8041-41DB-9A83-551DD964022E

Holotype: ZSI-WRC L-2029, 07.x.2017, 1 male, Suryamal, (19.758N & 73.347E; 518m), Palghar District, Maharashtra, India, coll. V.D. Hegde and team, GenBank

Table 1. GenBank accession numbers for the species of *Olepa* and *Pygospila* used in the construction of Maximum likelihood tree.

	GenBank accession number	Species	Samples from	Source
1	MN822127.1	*Olepa schleini chandrai*	Palghar, Maharashtra, India	Current studies
2	KY559102.1	*Olepa* cf. *ricini*	India	Unpublished
3	AM050277.1	*Olepa schleini*	Israel	Unpublished
4	MN822126.1	*Olepa schleini*	Nandurbar, Maharashtra, India	Current studies
5	AM050278.1	*Olepa schleini*	Israel	Unpublished
6	AM050279.1	*Olepa schleini*	Israel	Unpublished
7	AM050275.1	*Olepa schleini*	Israel	Unpublished
8	AM050271.1	*Olepa schleini*	Israel	Unpublished
9	AM050270.1	*Olepa schleini*	Israel	Unpublished
10	AM050276.1	*Olepa schleini*	Israel	Unpublished
11	KX050259.1	*Olepa schleini*	NA	Ronka et al. (2016)
12	AM050273.1	*Olepa schleini*	Israel	Unpublished
13	AM050272.1	*Olepa schleini*	Israel	Unpublished
14	AM050274.1	*Olepa schleini*	Israel	Unpublished
15	AM050285.1	*Olepa toulgoeti*	India	Unpublished
16	AM050286.1	*Olepa toulgoeti*	India	Unpublished
17	KM985648.1	*Olepa* cf. *ricini*	Malappuram, Kerala, India	Unpublished
18	KY559103.1	*Olepa* sp.	India	Unpublished
19	AM050284.1	*Olepa ricini*	India	Unpublished
20	AM050281.1	*Olepa ricini*	India	Unpublished
21	AM050283.1	*Olepa ricini*	India	Unpublished
22	AM050280.1	*Olepa ricini*	India	Unpublished
23	AM050282.1	*Olepa ricini*	India	Unpublished
24	HQ953032.1	*Pygospila hyalotypa*	Australia	Unpublished
25	HQ953030.1	*Pygospila hyalotypa*	Australia	Unpublished
26	HQ953031.1	*Pygospila hyalotypa*	Australia	Unpublished
27	HQ953029.1	*Pygospila bivittalis*	Australia	Unpublished
28	HQ953027.1	*Pygospila bivittalis*	Australia	Unpublished
29	JX017862.1	*Pygospila bivittalis*	Australia	Haines & Rubinoff (2012)
30	HQ953028.1	*Pygospila bivittalis*	Australia	Unpublished
31	KF392550.1	*Pygospila tyres*	Australia	Hebert et al. (2013)
32	HQ953033.1	*Pygospila tyres*	Australia	Unpublished
33	HQ953036.1	*Pygospila tyres*	Australia	Unpublished
34	HQ990824.1	*Pygospila tyres*	Pakistan	Unpublished
35	HQ990826.1	*Pygospila tyres*	Pakistan	Unpublished
36	HQ990825.1	*Pygospila tyres*	Pakistan	Unpublished
37	HQ990828.1	*Pygospila bivittalis*	Pakistan	Unpublished
38	HQ990827.1	*Pygospila tyres*	Pakistan	Unpublished
39	HQ953034.1	*Pygospila tyres*	Australia	Unpublished
40	KX862292.1	*Pygospila tyres*	Pakistan	Ashfaq et al. (2017)
41	KT988774.1	*Pygospila tyres*	NA	Unpublished
42	HQ953035.1	*Pygospila tyres*	Australia	Unpublished
43	GU695393.1	*Pygospila marginalis*	Papua New Guinea	Unpublished

accession number MN822127.1.

Differential diagnosis: This subspecies could be distinguished from the other taxa in the genus by a combination of the following characters: thick median line of hindwing cojoined to antemedial line in some places; uncus long with blunt apex; valvae with slender apex, more recurved, the inflection directed against the uncus; juxta broader in its basal part and bigger; the central plate of VIIIth Abdominal sternite distinctly tridentate resembling a frill. The position of cornuti in the new subspecies is almost similar to *O. neumuthi* Orhant, 2012, except cornuti in the new subspecies is stronger, longer, denser, and present only in the subbasal region of vesica.

Molecular diagnosis: Pair wise genetic distance was 0.6% for the mt COI DNA sequences of *O. schleini chandrai* ssp. nov. from peninsular India and *O. schleini* from Israel; 1.8% to 2.% from *O. toulgoeti* and 25.4% from *O. ricini*. Due to limitations with mt COI DNA sequences further genetic studies are warranted to elevate the taxa to the species rank.

Description: (Image 1 H–I). Forewing length 48mm. Head and thorax dark grey-brown with admixture of olive-green scales; palpi brown; collar bordered with a yellow band and two black spots surrounded with whitish-yellow ring; patagia with two pairs of whitish-yellow ringed black spots, the front spot smaller; one same spot, bigger, on middle of thorax. Abdomen coral, with black bands, the first two are shorter, not reaching the lateral side, others reaching the lateral side of abdomen, lateral spots present, extreimity of abdomen black; underside of abdomen yellowish. Legs fuscous brown, except extremity of femura and joints of tarsus yellowish. Forewing moderately broad, apex rounded, fuscous brown, with several black spots surrounded by whitish-yellow ring, these spots sometimes fused to form band or line; basal and subbasal bands are not complete; antemedial band thick; median and subterminal bands complete; terminal line as a row of blackish dots between the veins; cilia brownish, in between patches of off-white. Hindwing light coral, costal area yellowish, with dark brown spots or blotches, these spots sometimes unites to form band or line; antemedial band thick, curved; thick median band cojoined to antemedial band in some places; postmedial band interrupted in the middle; thin marginal band; underside pattern of both the wings are exactly same as the dorsal; cilia brownish, in between patches of off-white.

Male Genitalia (Image 1J–L). The total length of genitalia 6.00mm, width 5.44mm. Genitalia less sclerotised comparatively. Uncus fused with tegumen, oblong, narrow, tapering towards apex, with blunt apex, long, surrounded by elongated, thin, minute setae. Tegumen shouldered, longer than uncus, broad inverted U-shaped, moderately sclerotised. Valvae curved, long, central portion broad, cucullus narrowing and ending in a blunt apex, in an inflection directed against uncus, costa plough-like; the inner margins broadly serrated in the upper region, the outer margin minutely serrated, tip of valvae not smooth, directed outward, convex. Juxta (length: 1.72mm, width: 1.66mm) broader in its basal part and bigger. Vinculum (length: 0.797mm, width: 1.84mm) truncated U-shaped, very shorter than tegumen, uniformly sclerotized, two times wider, with moderate outgrowth on its proximal end.

Aedagus (Image 1M). Length: 5.10mm, width: 0.687mm; is closer to *O. neumuthi*. It is long, thick, crooked, with single large, stout, apical spine, the tip of spine rounded; two-third portion of the aedagus near apical spine more sclerotised than the rest of the aedagus, the ramianing area opposite to it, is membranous, not sclerotised, the whole aedagus except the portion mentioned, is minutely sclerotised; vesica membranous, with patches of scobination, armed with stout, very long cornuti in three patches present on the subbasal region, comparatively dense cornuti.

VIIIth Abdominal sternite: the central plate of it is distinctly tridentate, resembles a frill, present in double layer (Image 1N).

Measurement of genitalia (in mm). tl: 6.00, mw: 5.44; vl: 0.797, vw: 1.84; jl: 1.72, jw: 1.66; al: 5.10, aw: 0.687.

Etymology: The subspecies is named after Dr. Kailash Chandra, an eminent Entomologist and the Director of the Zoological Survey of India, Kolkata.

Remarks: The new subspecies is externally similar to *O. neumuthi* and belongs to the *ricini-schleini-neumuthi* complex. It differs from all congeners by the distinct cucullus, which is narrowing and ending in a blunt apex, (vs. cucullus of *O. ricini* and *O. neumuthi* always ending in a point or less rounded apex; in *O. schleini*, it is rounded). The inflection of valvae is directed towards the uncus in *O. ricini*, *O. neumuthi*, and *O. schleini*. Whereas, it is directed against the uncus in the new subspecies. The vinculum is truncated U-shaped, very shorter than the tegumen, with moderate outgrowth on its proximal end (vs. U-shaped in *O. ricini*, and *O. schleini* with comparatively large and moderate outgrowth, respectively; in *O. neumuthi* it is V-shaped, with small outgrowth).

The aedagus of the new subspecies is similar to the *O. neumuthi*. Aedagus of *O. schleini chandrai* ssp. nov. is thick, crooked and strong, with three patches of strong,

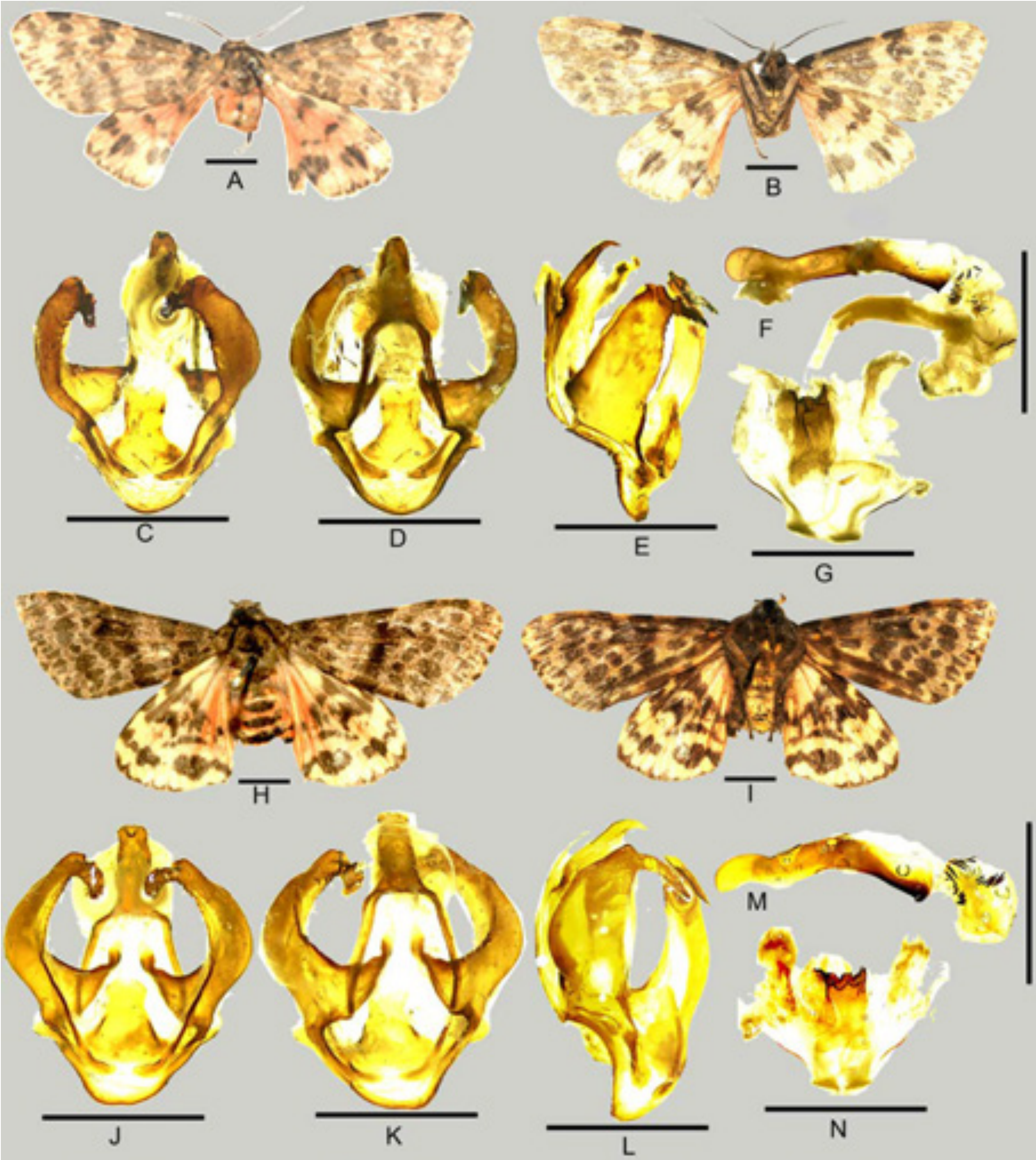

Image 1. A–G, *Olepa schleini* from India (A—habitus, dorsal | B—habitus, ventral | C—male genitalia in ventral view | D—male genitalia in dorsal view | E—male genitalia in lateral view | F—aedagus | G—VIII^th^ Abdominal sternite) | H–N—*Olepa schleini chandrai* ssp. nov. (holotype) (H—habitus, dorsal | I—habitus, ventral | J—male genitalia in ventral view | K—male genitalia in dorsal view | L—male genitalia in lateral view | M—aedagus | N—VIII^th^ Abdominal sternite). Scale bars = 1mm (C–G, J–N); 5mm (A–B, H–I).

longer and dense cornuti in the subbasal region of vesica (vs. almost straight aedagus, presence of three patches of modest cornuti in the basal region in *O*. *neumuthi*; in *O. schleini* and *O. ricini* there are 5–6 patches of cornuti).

Distribution: Known only from the type locality: Suryamal, Palghar District (Western Ghats), Maharashtra, India.

The present study is indicative of the species richness of this genus which was underestimated due to its complex cryptic nature and wide range of distribution. A

Table 2. Genetic distance (in percentage) matrix for the mt COI DNA among the DNA Barcode available species of *Olepa*.

	Olepa schleini	*Olepa schleini chandrai*	*Olepa toulgoeti*	*Olepa ricini*
Olepa schleini				
Olepa schleini chandrai	0.60			
Olepa toulgoeti	1.60	2.30		
Olepa ricini	25.90	25.90	25.40	

total of 21 mt COI sequences of *Olepa* were downloaded from the GenBank, with our two mt COI sequences on the phylogenetic tree five clear sub-clades could be discerned within the larger 'Olepa clade'. Our sequences of *Olepa* species formed a monophyletic clade with the species of *O. schleini*, over all genetic distance within the '*Olepa schleini* species clade' was up to 0.6%. Since our sequence for *O. schleini* (Nandurbar) was matching 100% with the 11 *Olepa schleini* sequences of Witt et al. (2005) we have treated our sample of *O. schleini* from Nandurbar, Maharashtra as the first record of *O. schleini* to Indian sub-continent extending its range of distribution from Israel in spite of slight morphological differences (see taxonomic discussion above).

Our *Olepa* species collected from Palghar, Maharashtra is showing a very shallow genetic divergence of 0.6% from *O. schleini* populations of India and Israel with high morphological divergence. Hence, *O. schleini* collections from Palghar has been proposed as a subspecies (*O. schleini chandrai* ssp. nov.) of *O. schleini* due to high morphological divergence (i.e., hindwing pattern, distinct cucullus and the position of cornuti in the new subspecies) and shallow genetic distance (Table 2) warranting further molecular studies. Spatially *O. schleini* from Nandurbar and *O. schleini chandrai* ssp. nov. from Palghar are 180km apart. Shallow genetic divergence of 1.8% was earlier reported between the species *O. ricini* and O. *toulgoeti* by Witt et al. (2005).

Interestingly, sequence of *O. ricini* (KY559102.1) from India matches 100% with the sequences *O. schleini* (Figure 2), where voucher specimen studies are warranted to understand the morphological divergence. Also, the sequence of *O. ricini* (KM985648.1) from Malappuram, Kerala do not match either of the sequences of *O. ricini* or *O. schleini*, where morphological studies of voucher samples are warranted for the exact identity of the species. Likewise, the voucher specimen of the sequence of *Olepa* sp. (KY559103.1) from India needs examination to justify the species name for the sequence. As of now among the 11 species of *Olepa* available globally mt COI DNA gene data are available specifically only for *O. toulgoeti*, *O. ricini, O. schleini*, and *O. schleini chandrai* ssp. nov. Voucher specimen studies on the two lineages of *O.* cf. *ricini* (KM985648.1) and *Olepa* sp. (KY559103.1) could provide information on the mt COI DNA barcode data for the known species of *Olepa* or it may be a potential new species awaiting formal description. As stated earlier, the new subspecies is proposed on the basis of the following set of characters: it possesses a thick median line of hindwing cojoined to antemedial line in some places; uncus long and valvae with slender apex, more recurved, the inflection directed against the uncus; the central plate of VIIIth abdominal sternite distinctly tridentate resembling a frill. The position of cornuti in the new subspecies is almost similar to *O. neumuthi*, except cornuti in the new subspecies is stronger, longer and denser and present only in the subbasal region of vesica.

This study forms the first report for the *O. schleini* described from Palearctic region having its distribution in Oriental region which is around 4,000km apart invoking many zoogeographic question of species distribution spatially. Understanding the genetic heterogeneity and morphological divergences within the species of *Olepa* from the studies of Witt et al. (2005) and the current study, there could be many more new species awaiting formal description which can be justified through spatial sampling and DNA studies.

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SHORT COMMUNICATION

Present status of the genus *Sphrageidus* Maes, 1984 (Lepidoptera: Erebidae: Lymantriinae) from India

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Abstract: The surveys to different localities of Himachal Pradesh, Jammu & Kashmir and Uttarakhand yielded three species of genus *Sphrageidus* Maes, namely *S. similis* (Fuessly), *S. simlensis* (Gupta) and *S. xanthorrhoea* (Kollar) of subfamily Lymantriinae. The external morphological characters particularly wing maculation and venation along with genitalia characteristics have been studied and illustrated in detail. The male genitalic features like distinct saccus, ring-like juxta, simple valva, aedeagus with a hook or reversed spine at the apex and distinct wing venation, i.e., absence of vein M2 in hindwing completely conform the characterization of the genus. In the present studies, the species *simlensis* has been placed under genus *Sphrageidus* Maes making a new combination as *Sphrageidus simlensis* (Gupta) for its proper placement. The genus diagnosis has also been updated. The external morphological characters including wing maculation, venation and particularly the genitalic features proved significant from taxonomic point of view in all the three species.

Keywords: African, Palaearctic, similis, simlensis, xanthorrhoea.

Abbreviations: 1A—First anal vein | 2A—Second anal vein | 3A—Third anal vein | AED—Aedeagus; | AP.S—Apical spur | ANT.APO—Anterior apophyses | CRN—Cornuti | CRP.BU—Corpus bursae | CU$_1$—First cubital vein | CU$_2$—Second cubital vein | DU.BU—Ductus bursae | JX—Juxta | M$_1$—First median vein | M$_3$—Third median vein | PAP.A—Papilla analis | PO.APO—Posterior apophyses | R$_1$—First radial vein | R$_2$—Second radial vein | R$_3$—Third radial vein | R$_4$—Fourth radial vein | R$_5$—Fifth radial vein | SA—Saccus | Sc—Subcosta | Sc+R$_1$—Subcosta+First radial vein | TG—Tegumen | UN—Uncus | VIN—Vinculum | VLV—Valva.

For the proper placement of a group of Palaearctic, African, and Madagascan species with white or yellowish forewings and a yellow anal tuft, genus *Sphrageidus* by Maes (1984) with *similis* Fuessly, 1775 as its type species from Europe was proposed. Holloway (1999) updated the status of *virguncula* Walker, 1855 and *xanthorrhoea* Kollar, 1848; he placed them under the genus *Sphrageidus*. He further remarked that the genus is related to two other genera namely *Toxoproctis* Holloway, 1999 and *Urocoma* Herrich-Schaffer, 1858 on the basis of long saccus in male genitalia. The genus is closely allied to genus *Euproctis* Hübner, 1819, but it is distinct in terms of wing venation, i.e., absence of vein M$_2$ in hindwing and male genitalic features such as ring-shaped juxta and presence of hook or reversed spine at apex of aedeagus. It also resembles with other allied genera namely *Somena* Walker, 1856 and *Orvasca* Walker, 1865 due to the absence of vein M$_2$ in hindwing (Holloway 1999). It is widely distributed in India, Africa, Myanmar, Sundaland, and Thailand. Gupta (1986) described a new species i.e., *simlensis* under genus *Porthesia* Stephens, 1829 from Shimla (Himachal Pradesh) but the male genitalia completely conforms the characterization of genus *Sphrageidus*. A new combination as *Sphrageidus simlensis* (Gupta, 1986) is

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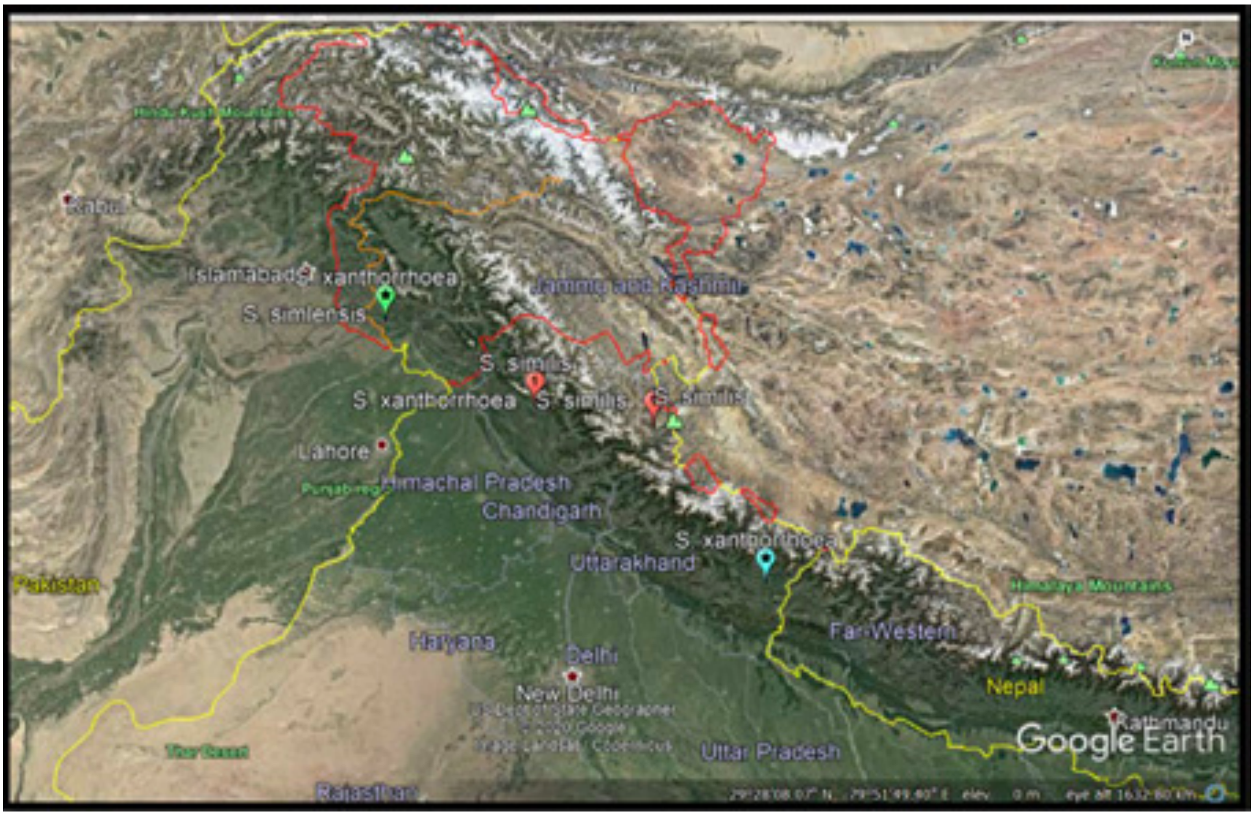

Image 1. Distribution of the genus *Sphrageidus* Maes in India.

proposed for the proper placement of the species.

Material and Methods

Different localities of Himachal Pradesh (32.084^{0}N & 77.571^{0}E), Jammu & Kashmir (34.083^{0}N & 74.797^{0}E), and Uttarakhand (30.316^{0}N & 78.032^{0}E) were surveyed for the collection of adult moths. The distribution map of the species studied was also drawn (Fig.1). The light traps equipped with a 160w mercury bulb and vertical white sheet were used for collection. To study of wing venation, the methodology proposed by Zimmermann (1978) was followed. The male and female moths were dissected to examine the external genital features (Robinson 1976) and the terminology for naming various genital parts given by Klots (1970) was followed in the present communication.

Results and Discussion

The external morphological characters like ornamentation of antennae, legs and abdomen, wing maculation, wing venation, and significantly the external genitalic features contributed towards the authentic identification and characterization of examined taxa. The taxonomic status of the genus *Sphrageidus* has been updated along with the upgradation of the distribution range.

Genus *Sphrageidus* Maes, 1984

Maes, 1984, *Nota. Lepid.*, 7(1): 55–58; Holloway, 1999, *Moths Borneo*, 5: 59.

Type species: *Phalaena similis* Fuessly, 1775

Distribution: Africa, Europe, Pakistan, India, China, Nepal, Myanmar, Thailand, South Korea, Sundaland.

Diagnosis: Small sized moths, usually white in colouration. Labial palpi porrect, hairy. Antennae bipectinate in both sexes. Forewing with ground colour whitish or yellowish; discal cell half the length of wing, closed; 1A+2A from base of wing, reaching apex; 3A absent; R_5-R_2 stalked, R_5 branching off more basally from Rs system than R_2; Sc from base of wing not reaching the apex. Hindwing with ground colour white; discal cell half the length of wing, closed; 1A+2A from base of wing, reaching apex; 3A absent; Cu_1 and M_3 stalked or arising independently from lower angle of cell; M_2 absent; M_1 and Rs stalked from upper angle of cell; Sc+R_1 from base of wing anastomosing with discal cell. Legs dressed with scales; fore-tibia with an epiphysis; mid-tibia with one pair of tibial spurs of unequal length; hind-tibia with two

Key to the studied species of the genus *Sphrageidus*

1. Head with orangish-yellow line; forewing with marginal area without yellow scales. Male genitalia with saccus having emarginate apex; juxta without any projection .... *similis* (Fuessly)
- Head without orangish-yellow line; forewing with marginal area irrorated with yellow scales. Male genitalia having saccus without emarginate apex; juxta with backwardly directed projection 2

2. Hindwing with ground colour white, costal area irrorated with grey scales, underside dressed with grey scales; forewing with M_1 shortly stalked with common stalk of R_5-R_2. Male genitalia with saccus long, having rounded tip; juxta dome-shaped; valva with distal end reaching the level of uncus .... *simlensis* (Gupta) comb. nov.
- Hindwing with ground colour black, basal area irrorated with white scales, underside dressed with black scales; forewing with vein M_1 from upper angle of cell. Male genitalia with juxta ring-like having backwardly directed projection; valva reaching above the level of uncus .... *xanthorrhoea* (Kollar)

pair of tibial spurs of equal length. Abdomen slender, clothed with scales; distinct yellow anal tuft in females. Male genitalia with uncus robust; saccus long; juxta ring-like; valva simple, slightly upcurved; aedeagus with a hook or reversed spine at the apex. Female genitalia with papilla analis relatively short, extending ventrally in a quadrate manner like the head of manta-ray; corpus bursae may be with bicornute signum.

Sphrageidus similis (Fuessly, 1775)
(Image 1–10)

Phalaena similis Fuessly, 1775, *Verz. Schweiz. Ins.*, 1775: 35.

Sphrageidus similis: Maes, 1984, *Nota. Lepid.,*7(1): 55–58; Holloway, 1999, *Moths Borneo*, 5: 59.

Euproctis similis: Inoue et al., 1957, *Journ. Med. Sci and Biol*., 10: 198.

Porthesia similis: Chao, 2003, *Fauna Sinica*, 30: 321.

Type locality: Europe

Diagnosis: Head with vertex and frons clothed with white scales, an orangish-yellow line behind the head. Labial palpi fringed with white scales. Antennae with scape and flagellum studded with white scales. Thorax with collar and tegula covered with white scales. Legs dressed with white scales. Abdomen furnished with white scales; anal segment fringed with orangish-yellow scales.

Wing maculation: Forewing with ground colour white, a small black or brown tornal mark, absent in females; fringe white; underside with costal area irrorated with greyish scales. Hindwing white.

Wing venation: Forewing with Cu_2 from middle of cell; Cu_1 from well before lower angle of cell; M_3 from lower angle of cell; M_2 from above lower angle of cell; M_1 from upper angle of cell; R_5-R_2 highly stalked from before upper angle of cell; R_1 from well before upper angle of cell. Hindwing with Cu_2 from beyond middle of cell; Cu_1 just before lower angle of cell; M_3 from lower angle of cell; M_2 absent; M_1 and Rs stalked from upper angle of cell; Sc+R_1 from base of wing anastomosing with discal cell beyond middle.

Wingspan: Male: 50–52 mm; female: 26–40 mm.

Body length: Male: 12–14 mm; female: 4–12 mm.

Male genitalia: Uncus well developed, moderately sclerotized, basal half triangular, distal half laterally compressed, narrow with blunt apex; tegumen broad, U-shaped, narrow towards vinculum; vinculum moderately sclerotized, narrow ending into long, narrow saccus with blunt apex which is slightly emarginate giving minute knob-like appearance on lateral side, appears slightly bifid in lateral view; juxta ring-like, well sclerotized, without any backwardly directed projection. Valva simple; narrow, without any demarcation; semi-sclerotized; setosed; gradually narrowing towards distal end, having a slight protrusion on saccular side near one-third of valva, valva ending well above the level of uncus. Aedeagus of moderate size; proximal end flap-like; moderately sclerotized; distal end armed with backwardly directed spine, distal end circumferenced with fine denticles.

Female genitalia: Corpus bursae wedge-shaped, membranous without any distinct signum; ductus bursae from one side of the corpus bursae, narrow, almost half the length of corpus bursae, membranous; ductus seminalis originating from the junction of ductus bursae and corpus bursae; apophysis well-sclerotized, posterior apophysis narrower than anterior ones having tapering apices; papilla analis relatively short; rectangular, produced on one side, setosed with small setae; pseudo-papillae small, triangular, setosed with small setae.

Material examined: India: Himachal Pradesh: PUP-LYM-30i-ii, 09.x.2013, 2 females, Baijnath (32.052^{0}N & 76.648^{0}E, 998m), coll. Gagan Bali; PUP-LYM-30iii, 07.ix.2013, 1 male, Chamunda Devi (32.051°N & 76.643°E, 996m), coll. Gagan Bali; PUP-LYM-30iv, 14.v.2015, 1 female, Janitri (31.834°N & 76.777°E, 760m), coll. Gagan Bali; PUP-LYM-30v-vi, 14.ix.2014, 1 male, 1 female, Ropa (31.795°N & 78.421°E, 2086m), coll. Gagan Bali; PUP-LYM-30vii, 11.ix.2013, 1 male, Lamberi (33.077°N & 74.324°E, 336m), Jammu & Kashmir, coll. Gagan Bali.

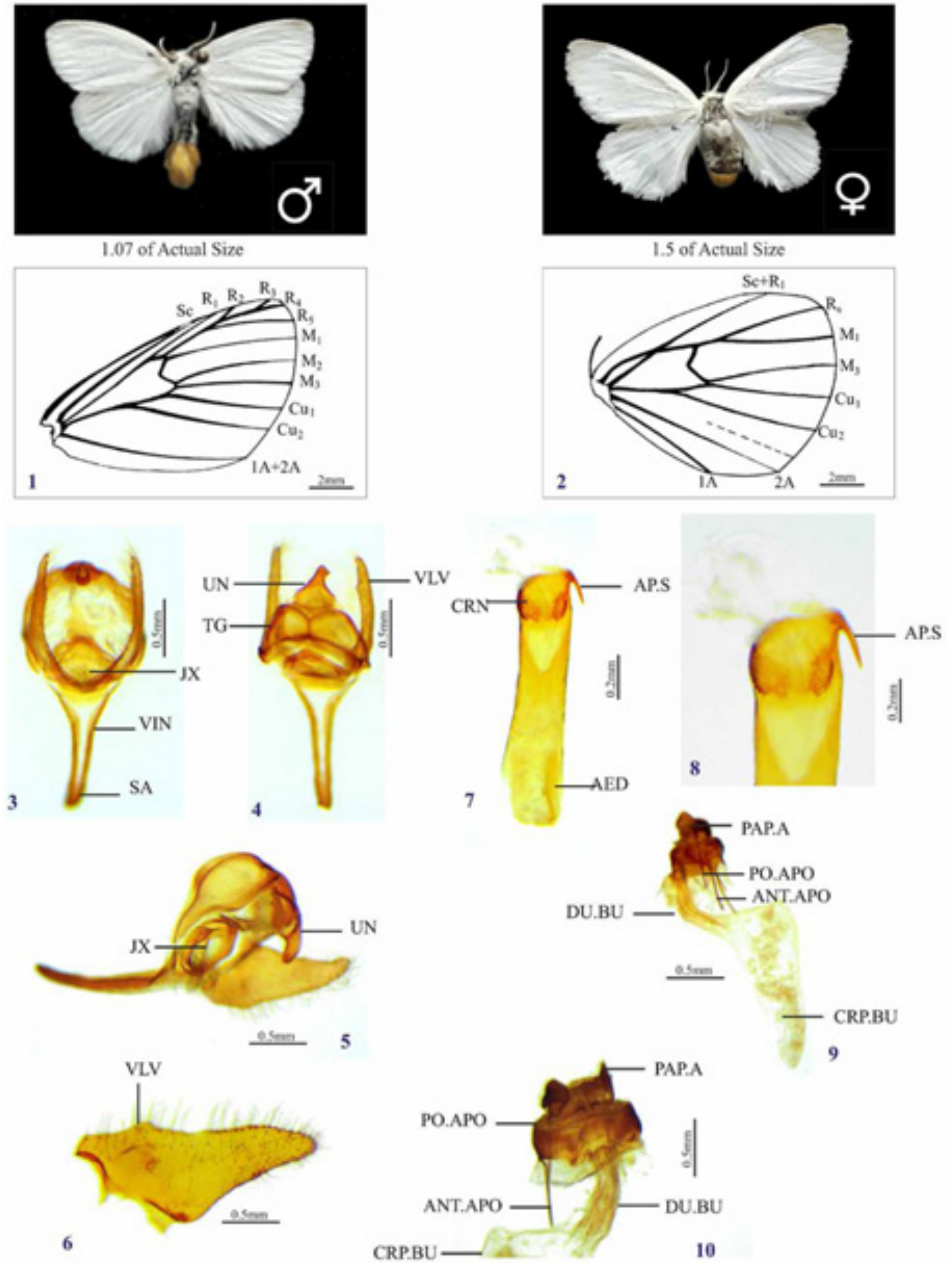

Image 1–10. ***Sphrageidus similis*** **(Fuessly): 1—Forewing | 2—Hindwing | 3—Male genitalia - ventral view | 4—Dorsal view | 5—Lateral view | 6—Valva | 7–8—Aedeagus | 9–10—Female genitalia.**

Distribution: Europe; India (Jammu & Kashmir, Himachal Pradesh); China; Sri Lanka; Korea; Siberia; Japan.

Remarks: Fussely (1775) originally described this species under genus *Phalaena* Linnaeus, 1758 from Europe. Inoue et al. (1957) transferred it to genus *Euproctis* Hübner, 1819. Maes (1984) proposed a new genus, *Sphrageidus* for its proper placement. Holloway (1999) followed the same nomenclature. Chao (2003) included it under another genus, *Porthesia* Stephens, 1829. In the present studies, the male and female genitalia of the present species have been studied in detail and it has been concluded that it completely conforms the characterization of *Sphrageidus* and the nomenclature proposed by Maes (1984) has been adopted.

Sphrageidus simlensis (Gupta) comb. nov. (Image 11–20)

Porthesia simlensis Gupta, 1986, *Reichenbachia*, 24: 107–108.

Type Locality: India (Shimla)

Diagnosis: Head with vertex and frons clothed with white scales. Labial palpi fringed with white scales. Antennae with scape and flagellum studded with white scales. Thorax, collar and tegula dressed with white scales. Legs covered with white scales. Abdomen furnished with white scales; distal segment fringed with orangish-yellow scales.

Wing maculation: Forewing with ground colour white; marginal area irrorated with yellow scales; underside white, costal half fuscous-grey. Hindwing white, costal area smoky; fringe white; underside fuscous-grey.

Wing venation: Forewing with Cu_2 from middle of cell; Cu_1 from beyond three-fourth of cell; M_3 from lower angle of cell; M_2 from above lower angle of cell; M_1 shortly stalked with common stalk of R_5–R_2; R_5–R_2 well stalked from upper angle of cell; R_1 from well before upper angle of cell. Hindwing with Cu_2 from beyond middle of cell; Cu_1 before lower angle of cell; M_3 from lower angle of cell; M_2 absent; M_1 and Rs highly stalked from upper angle of cell; $Sc+R_1$ from base of wing anastomosing with discal cell beyond its middle.

Wing expanse: Male: 26–44 mm; female: not examined.

Body Length: Male: 11–21 mm; female: not examined.

Male genitalia: Uncus of moderate size, well sclerotized, broad at base, dorsally setosed with small setae, gradually narrowing towards blunt apex; tegumen broad, U-shaped, medially dilated, narrow, quite narrow towards vinculum; vinculum semi-sclerotized, narrow, ending into long saccus with rounded end; juxta well sclerotized forming a circular ring and having a long backwardly projected projection. Valva simple; semi-sclerotized; setosed; without any demarcation; distal end narrow, rounded, reaching upto the level of uncus. Aedeagus of moderate size, moderately sclerotized; proximal end flap-like; ductus ejaculatorius entering directly under this flap; distal end armed with backwardly directed long spine and circumference with two patches of fine denticles.

Material examined: India: PUP-LYM-29A i-iii, 11.ix.2013, 3 males,Lamberi (33.077°N & 74.324°E, 336m), Jammu & Kashmir, coll. Gagan Bali.

Distribution: India (Jammu & Kashmir, Himachal Pradesh).

Remarks: Gupta (1986) described the present species as a new species under genus *Porthesia* from Shimla (Himachal Pradesh). During the present studies, the external morphological structures including the wing venation and genitalia have been studied in detail. On the basis of characters such as absence of vein M_2 in hindwing and robust uncus; long saccus; simple, slightly upcurved valva; ring-like juxta and reversed spine at the apex of aedeagus in male genitalia, it has been concluded that it completely conforms to the characterization of the present genus. Thus, it has been placed under the present genus *Sphrageidus* making a new combination as *Sphrageidus simlensis* (Gupta, 1986). Its collection from Lamberi is its first record from Jammu & Kashmir.

Sphrageidus xanthorrhoea (Kollar) (Image 21–29)

Liparis xanthorrhoea Kollar, 1848, *in Hugel, Kaschmir und das Reich derSiek,* 4(2): 470.

Sphrageidus xanthorrhoea: Holloway, 1999, *Moths Borneo*, 5: 59; Shah et al. 2018, *Bionotes* 20(1): 28.

Porthesia xanthorrhoea: Hampson, 1892, *Moths India:* 1: 485; Chao 2003, *Fauna Sinica* 30: 318.

Arctornis xanthorrhoea: Swinhoe, 1922, *Ann. Mag. Nat. Hist*. (9) 10 (58): 479.

Euproctis xanthorrhoea: Kishida, 1993, *in Haruta, Moths Nepal*, Part 2, 13(3): 88.

Type locality: Sri Lanka

Diagnosis: Head with vertex and frons clothed with white scales. Labial palpi fringed with white scales. Antennae with scape and flagellum studded with white scales. Thorax, collar and tegula dressed with white scales. Legs furnished with white scales. Abdomen covered with white scales; distal segment fringed with orangish-yellow scales.

Wing maculation: Forewing with ground colour white, marginal area irrorated with yellow scales;

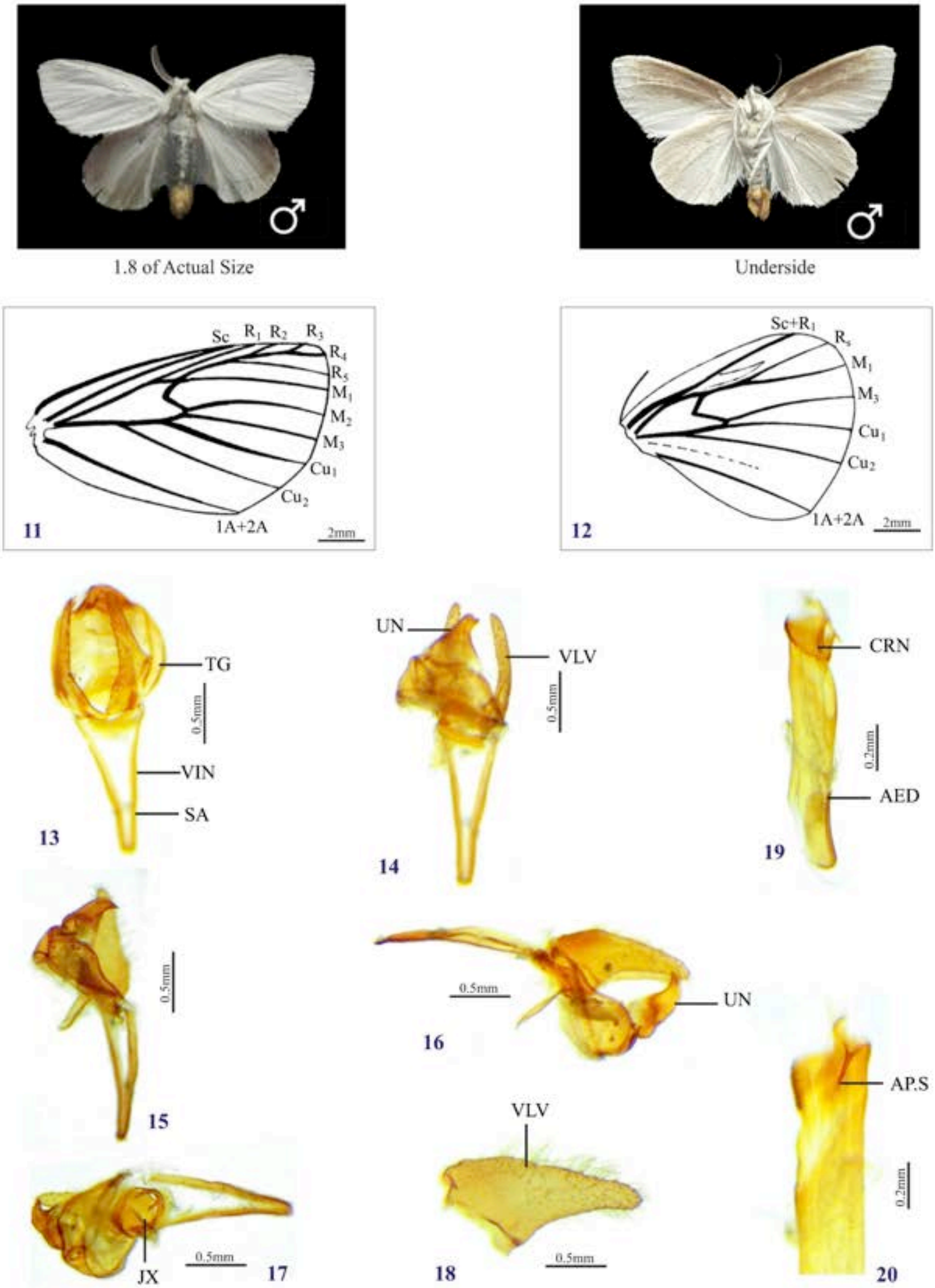

Image 11–20. *Sphrageidus simlensis* (Gupta) comb. nov.: 11—Forewing | 12—Hindwing | 13—Male genitalia - ventral view | 14—Dorsal view | 15–17—Lateral view | 18—Valva | 19–20—Aedeagus.

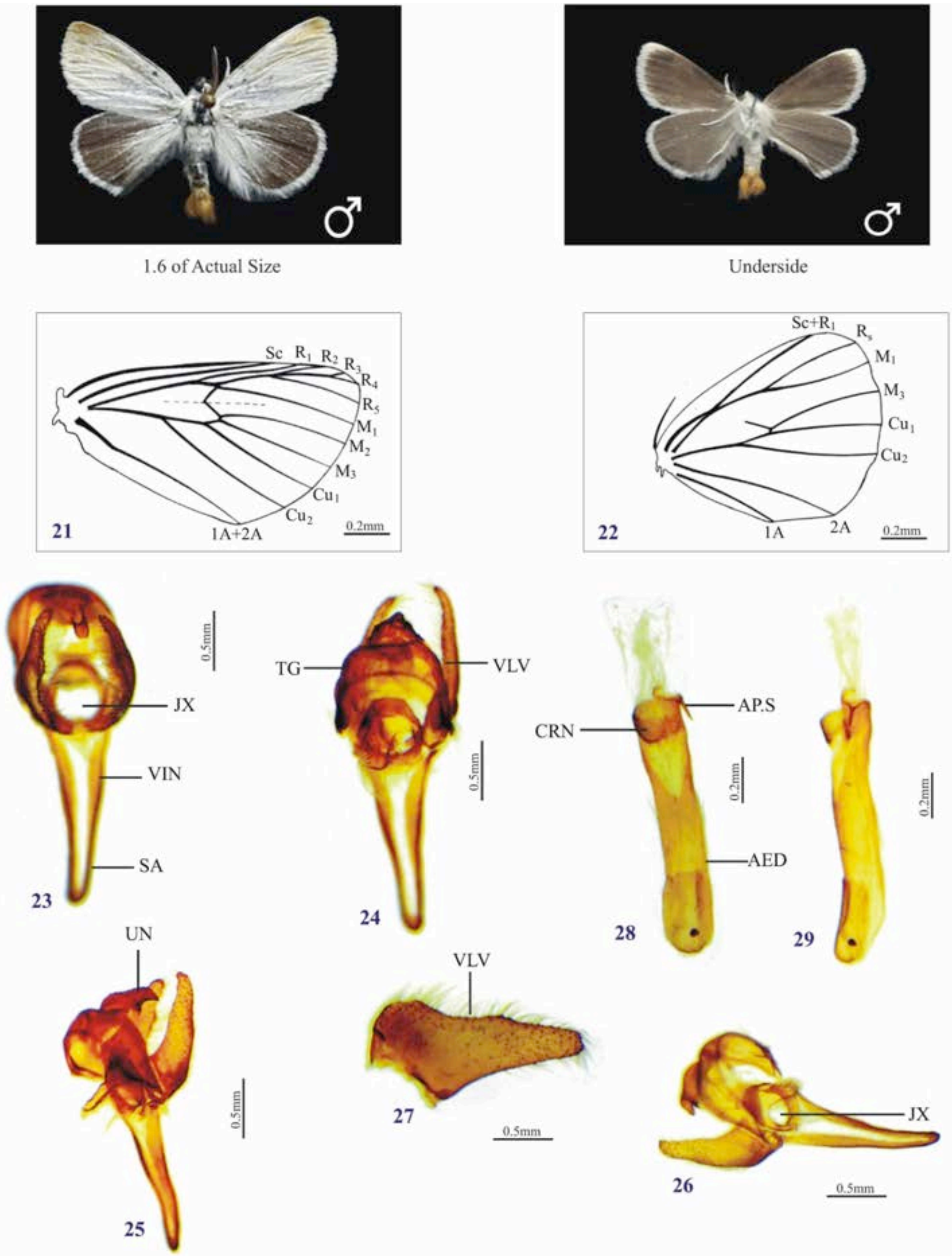

Image 21–29. *Sphrageidus xanthorrhoea* (Kollar): 21—Forewing | 22—Hindwing | 23—Male genitalia - ventral view | 24—Dorsal view | 25–26—Lateral view | 27—Valva | 28–29—Aedeagus.

underside blackish-grey, outlined with pure white; fringe white. Hindwing with ground colour blackish-grey; basal area white; fringe white; underside blackish-grey, outlined with pure white.

Wing Venation: Forewing with Cu_2 from well before two-third of lower angle of cell; Cu_1 from well before lower angle of cell; M_3 from lower angle of cell; M_2 from above lower angle of cell; M_1 from upper angle of cell; R_5–R_2 highly stalked just before upper angle of cell. Hindwing with Cu_2 from two-third of lower angle of cell; Cu_1 from just before lower angle of cell; M_3 from lower angle of cell; M_2 absent; M_1 and Rs stalked from upper angle of cell; Sc+R_1 from base of wing anastomosing with discal cell beyond its middle.

Wingspan: Male: 24–32 mm; female: not Eeamined.

Body length: Male: 12–13 mm; female: not examined.

Male genitalia: Uncus of moderate size, well sclerotized, basal half triangular, distal half laterally compressed with blunt apex, appears pointed in lateral view; tegumen quite broad, U-shaped, quite narrow towards vinculum; vinculum narrow, moderately sclerotized ending into quite long, narrow saccus with rounded end; juxta well developed, well sclerotized, ring-like, a backwardly directed projection from inner side of distal end. Valva simple, semi-sclerotized; setosed; saccular area broad; distal end narrow, round having a slight protrusion/hump on saccular margin; valva ending well above the level of uncus. Aedeagus of moderate size; proximal end flap-like; slightly more sclerotized; ductus ejaculatorius entering directly from proximal end; distal end armed with backwardly directed spine, circumferenced with fine denticles; vesica without any distinct cornuti.

Material examined: PUP-LYM-29i, 09.x.2013, 1 male, Baijnath (32.052°N & 76.648°E, 998m), Himachal Pradesh, coll. Gagan Bali; PUP-LYM-29ii, 11.ix.2013, 1 female, Lamberi (33.077°N & 74.324°E, 336m), Jammu & Kashmir, coll. Gagan Bali; PUP-LYM-29iii, 22.vi.2015, 1 female, Berinag (29.775°N & 80.055°E, 1,860m), Uttarakhand, coll. Gagan Bali.

Distribution: India (Jammu & Kashmir, Himachal Pradesh, Uttarakhand); China; Nepal; Sri Lanka; Indonesia; Java.

Remarks: Kollar (1848) originally described the present species, *xanthorrhoea* under *Liparis* Ochsenheimer, 1810 from Sri Lanka. Hampson (1892) transferred it to genus *Porthesia* Stephens. Swinhoe (1922) studied it under *Arctornis* Gremar, 1810. Kishida (1993) considered it as *Euproctis xanthorrhoea* Kollar 1848 and described its male genitalic features. Holloway (1999) placed it under *Sphrageidus* Maes on the basis of its definitative male genitalic features which completely conforms the characterization of the genus. Though Chao (2003) followed Hampson's nomenclature but its placement proposed by Holloway (1999) has been followed. The species under reference closely resembles with *Sphrageidus simlensis* Gupta in general appearance. The morphological features such as black hindwings with white basal area; underside of both wings uniformly black outlined by white and distally narrow valva with a slight protrusion/hump on saccular margin in male genitalia further makes it a distinct species.

In insects, genitalic features are highly species-specific (particularly in Lepidoptera) and play a significant role in species identification and delimitation. In the present study, the external morphological characters including wing maculation, venation and particularly the genitalic features proved significant from taxonomic point of view. The male genitalic features of all the three species such as robust uncus; long saccus; simple, slightly upcurved valva; ring-like juxta and reversed spine at the apex of aedeagus in male genitalia and distinct wing venation, i.e., absence of vein M_2 in hindwing completely conforms the characterization of the present genus.

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SHORT COMMUNICATION

Early stages of Nilgiri Grass Yellow *Eurema nilgiriensis* (Yata, 1990) (Lepidoptera: Pieridae), with a note on its range extension in the Kerala part of the Western Ghats, India

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Abstract: Complete documentation of the early stages of *Eurema nilgiriensis* (Yata) on the larval host plant *Ventilago bombaiensis* (Rhamnaceae) is presented in this paper. In addition to this, notes on the range extensions of this species in southern Western Ghats in Kannur, Kozhikode, Wayanad, Malappuram, and Palakkad districts in Kerala is also provided. Field records from the northern Kerala part of the Western Ghats and the complete biology are reported for the first time since its description in 1990. Photographic records from seven locations since 2011 were confirmed by comparing with the original descriptions and in consultation with the author of the species. Eggs collected from field were reared at home, and every stage observed is also reported, as well as the discovery of the host plant *Ventilago bombaiensis*. It is concluded that the species is widespread in forested areas at elevations from 70m to 1,000m.

Keywords: *Eurema andersoni*, host plant, *Ventilago bombaiensis*.

The Nilgiri Grass Yellow *Eurema nilgiriensis* (Yata, 1990), is a small yellow butterfly belonging to the 'sari' subgroup of the genus *Eurema* Hübner (1819) (Lepidoptera, Pieridae). The species was described from Nilgiri Hills by Osamu Yata in 1990 from personal collections in Japan (Yata 1990). This species is closely related to other species of grass yellows such as *E. andersoni* (Moore, 1886), *E. ormistoni* (Walkins, 1925), *E. celebensis* (Wallace, 1867), and *E. beatrix* (Toxopeus, 1939), these five taxa forming a group called the 'andersoni complex' (Yata, 1989, 1990, 1991, 1992). Of these, *E. andersoni* and *E. nilgiriensis* are seen in the southern Western Ghats including Kerala, Karnataka, and Tamil Nadu (Larsen 1987; Gaonkar 1996; Kehimkar 2016; Kunte 2018). According to Yata (1990), *E. nilgiriensis* shows very distinct morphological characteristics (wing pattern), and the very distinct male genitalia distinguishes it from *E. andersoni*.

Basic morphological identification keys that separate *E. nilgiriensis* from *E. andersoni* are given below (Yata 1990).

1. Male (upperside of the forewing): Ground colour yellow. Black distal border broad with its inner edge more or less irregularly incurved from costa to vein 4, much obtuse angled at vein 4, more deeply excavated in space 2 than in space 3; while the distal border is

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more deeply excavated in space 3 than in space 2, in *E. andersoni* (see Image 24–27).

2. Female (upperside of the forewing): Ground colour pale lemon yellow. Black distal border fairly broad with its inner edge oblique and uniform from costa to vein 4, strongly angled midway, almost right-angled at vein 4, more deeply excavated in space 2 than in space 3; while the distal border is equally excavated in both spaces 2 and 3 in *E. andersoni*.

Materials and Methods

While on a usual butterfly watching trip in the forested tracts of the Kerala part of the Western Ghats, we encountered a female Nilgiri Grass Yellow laying eggs on a climber in a private plantation near a stream at Kakkad (11.494°N & 75.962°E, 50m) near Engapuzha, Kozhikode District, Kerala, on 24 December 2017 at 11.25h. The eggs were collected and reared in closed plastic containers at room temperature (25–30°C) with fresh leaves of the larval food plant. Eggs, various larval stages, pupa and the eclosed adult were photographed using a Canon 5D Mark III DSLR with a 100mm macro lens and a Kenko 1x1.4 teleconverter.

Results and Observations

Early stages

Female laid eggs on the tender shoots of the host plant. The eggs were white and spindle-shaped, having a narrow base as in other *Eurema* species. We collected two eggs. The eggs along with the hostplant leaves were kept in closed containers, wiping the condensed moisture at least twice daily. The same method of keeping the caterpillars and the host plant in closed containers were followed throughout the rearing process to keep the leaves fresh. The containers were cleaned of used up leaves, caterpillar droppings and the moisture condensed inside the jar. The transparent container was kept on window sill to expose the caterpillars to sunlight. The eggs hatched after four days. The small, slender caterpillar (Image 2a, 2b) was creamy white in colour. Later the colour turned yellow, with the caterpillar resting

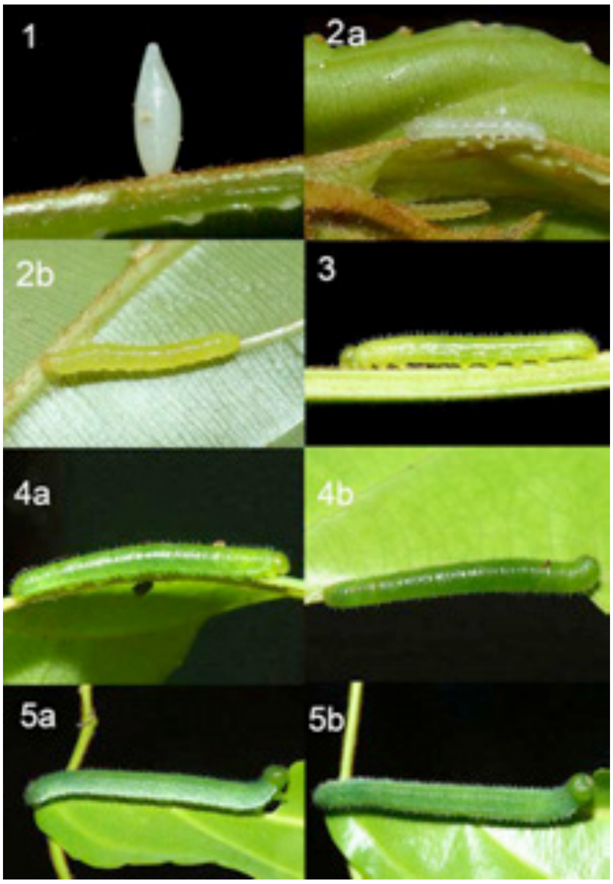

Image 1–5. Early stages of *Eurema nilgiriensis*: 1—Egg | 2(a–b)—First instar larva | 3—Second instar larva | 4(a,b)—Third instar larva | 5(a,b)—Fourth instar larva. © Chandrasekharan V.K.

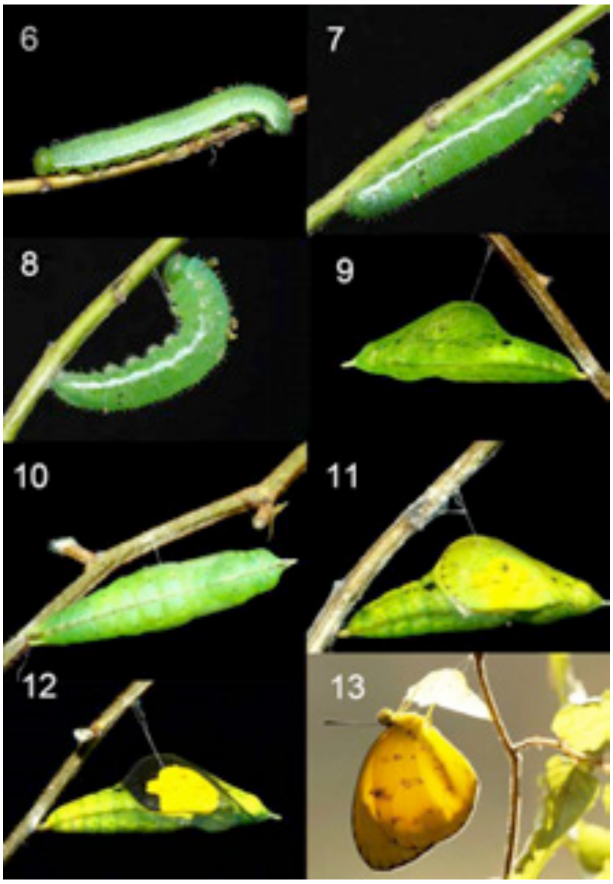

Image 6–7. Early stages of *Eurema nilgiriensis*: 6—Fifth instar larva | 7,8—Prepupation larva | 9,10—Pupa | 11—Pupa a day before eclosion | 12—Pupa before eclosion | 13—eclosed butterfly. 6–12 © Chandrasekharan VK, 13 © Balakrishnan Valappil.

Image 14–15. Imago *Eurema nilgiriensis*: 14—Upperside | 15—Underside. 14 © Balakrishnan Valappil, 15 © Chandrasekharan V.K.

near the yellowish veins of the tender leaves in perfect camouflage. In the second instar, the caterpillar became greenish-yellow and had a thin lateral longitudinal line near the legs. In the third instar, the caterpillar turned more greenish and the lateral line became distinct. In the fourth instar, the caterpillar started eating semi-mature leaves and rested on the upper side of the leaf along the midrib facing the tip. The final-instar caterpillar was leaf green and the white longitudinal line near the legs had

Image 16–21. Earliest field records of *Eurema nilgiriensis*: 16—Parambikulam TR | 17—Malabar WS |18—Aaralam WS | 19—Wayanad | 20—Wayanad | 21—Nelliyampathy Hills | 22—Malabar WS | 23—Karimpuzha WS. 16 © Balakrishnan Valappil, 17 © Sasi Gayathri, 18–23 © Chandrasekharan V.K.

a continuous suffused white patch above, which faded towards the dorsum. The head was pale green having thin dark hairs. There were conical tubercles all over its body with each tubercle bearing a long hair. The longer hairs had drops of a transparent liquid at their tips. The final-instar caterpillar measured 21mm in length.

Pupation took place on the host plant twig kept in a

Table 1. Earliest photographic records of *Eurema nilgiriensis* in northern Kerala.

	Date of record	Location	Elevation (in m)	Area	Recorded by	Figure
1	05.xi.2011	Peruvannamuzhi	70	Malabar Wildlife Sanctuary, Kozhikode District	Sasi Gayathri	17
2	26.xi.2011	Meenmutty falls	150	Aralam Wildlife Sanctuary, Kannur District	VKC	18
3	12.x.2013	Kunhome.	741	Wayanad District	VKC	19, 20
4	10.x.2016	Kariyanshola	650	Parambikulam Tiger Reserve, Palakkad District	BV	16
5	30.ix.2017	Kakkayam	755	Malabar Wildlife Sanctuary, Kozhikode District	VKC	22
6	13.x.2017	Nelliyampathy	1000	Nelliyampathy Hills, Palakkad District	VKC	21
7	08.xii.2018	Panappuzha	70	Karimbuzha Wildlife Sanctuary, Nilambur, Malappuram District	VKC	23

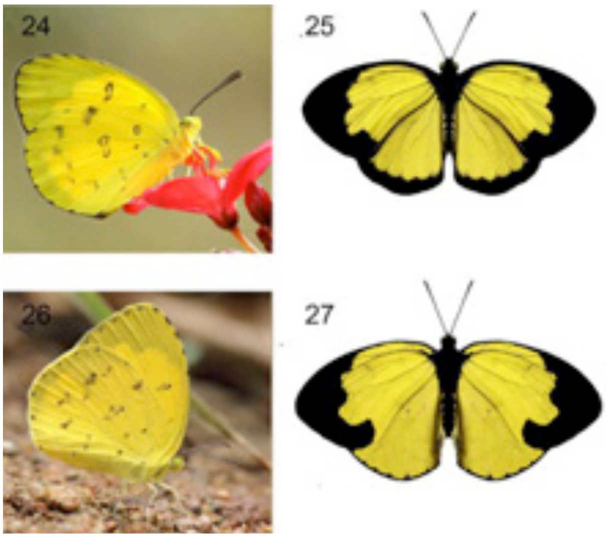

Image 24–27. Comparison of *Eurema nilgiriensis* and *Eurema andersoni*, 24–25. *Eurema nilgiriensis*: 24—Underside, phtograph | 25—Upperside, graphic representation | 26–27—*Eurema andersoni*: 26—Underside, photograph | 27— Upperside, graphic representation. © Balakrishnan Valappil.

Image 28–29. Larval food plant of *Eurema nilgiriensis*: Ventilago bombaiensis, Family Rhamnaceae. © Chandrasekharan V.K.

jar. Before pupation, the caterpillar shrank and turned translucent green, with the white patch being reduced to a longitudinal line that discontinued at the 4th segment (Image 7,8). The freshly formed pupa was shiny green and translucent (Image 9,10); it later turned opaque and solid. It had pale black spots on both sides of the mid-dorsum and pale black blotches on the wing case. The pupal head had a conical pointed projection, of which the upper half was white in colour. The pupa measured 16 mm in length. The egg-to-pupa duration was 28 days. The adult butterfly emerged eight days after pupation. The total period from egg to adult butterfly was 36 days.

Larval food plant

Ventilago bombaiensis, Synonym *Smythea bombaiensis*, Family Rhamnaceae; Common name: Bombay smythea, Malayalam name: Vembada Valli, Image 28,29.

Range extension

Since the description of this species, no images of the live butterfly were published until November 2016. This was not due to the rarity of the species, but rather all images of the species taken from the Western Ghats were erroneously identified as One-spot Grass Yellow (*E. andersoni*), without detailed scrutiny. During an annual butterfly survey conducted at Parambikulam Tiger Reserve, Palakkad District, Kerala, in October 2016, BV photographed the upperside and underside of a *Eurema* species from Kariyanshola. With reference to the original description, it was found that the morphological features of the specimen photographed matched with those of *E. nilgiriensis* (Yata 1990). Subsequently, after a detailed review, some previous images that were considered to be *E. andersoni* from Western Ghats, Kerala, were found to be *E. nilgiriensis*, while some recent records are also confirmed as being *Eurema nilgiriensis*. We attach a table for ready reference summarising the confirmed records based on the external morphology (Table 1).

These sight records show that the species is very active during post-monsoon months, throughout the forested tracts of surveyed localities in Kannur, Kozhikode, Wayanad, Malappuram, and Palakkad districts of Kerala from elevations 60–1000 m in the Western Ghats. These records add to the recently published range extensions of this species from Kodagu District, Karnataka and Agasthyamalais, Kerala (Sujitha et al. 2019). From the above field records and the records already published (Sujitha et al. 2019), we presume that this species is active from September to May in the Western Ghats, October–November being the primary season. Males are often found engaged in mud-puddling along banks of streams and damp soil in well-wooded forests. Both

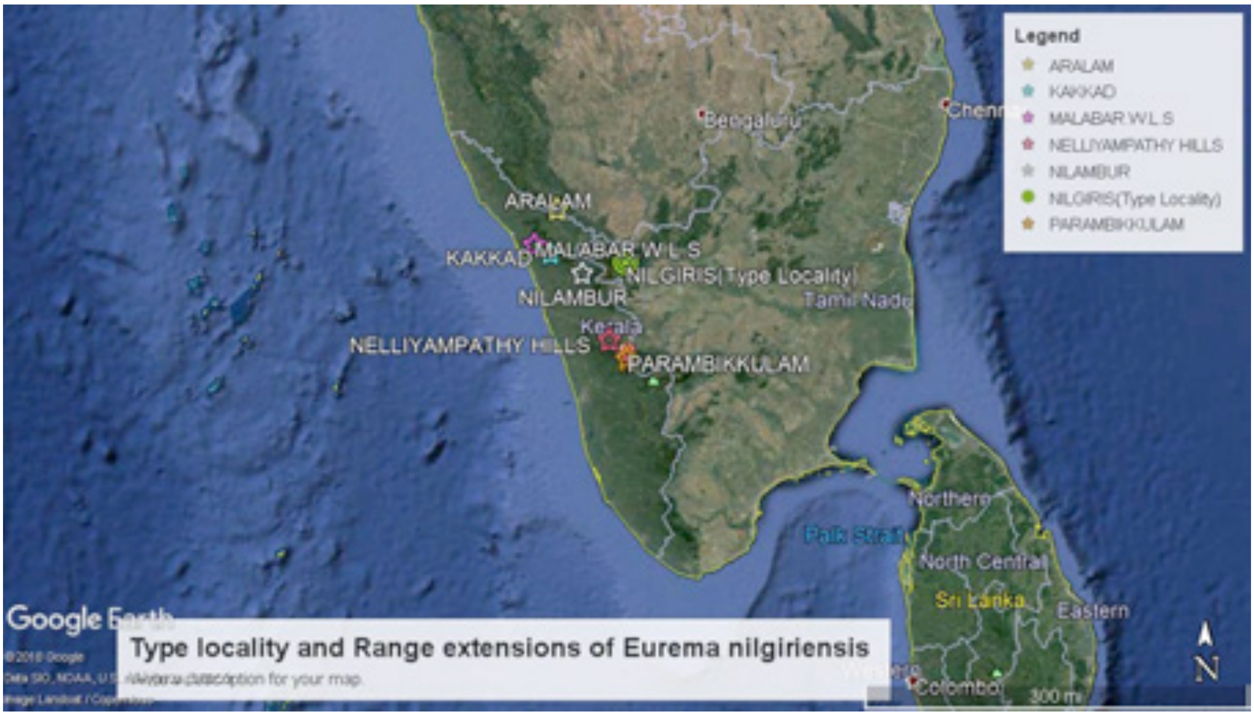

Image 30. Field records of *Eurema nilgiriensis* along with the type locality.

sexes can be found feeding on small flowers and flying along sunlit forest paths and along banks of streams, with females searching for the larval host plants, which are likely to be found on the edges of forest streams.

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NOTE

Breeding site records of three sympatric vultures in a mountainous cliff in Kahara-Thathri, Jammu & Kashmir, India

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Vultures occupy a vital position in an ecosystem as efficient scavengers. They are believed to have evolved with ungulates who provided the food in the form of sick, injured or depredated individuals (Mundy et al. 1992). Of late, they have started exploiting the vast food resources created by man in terms of animal waste (Naoroji 2006). They are hence considered the most successful raptors world over. Once abundant in the region, their population in the Indian subcontinent is on a continuous decline. It is mostly attributed to the food shortage, diclofenac, non-steroidal anti-inflammatory drugs (NSAIDs) poisoning, pesticides, and diseases among others (BirdLife International 2006, 2008; Swan et al. 2006; Prakash et al. 2007, 2012, 2019; Cuthbert et al. 2011a,b).

Of the nine vulture species occurring in India (Naoroji 2006; Praveen et al. 2016), six have been reported from the erstwhile state of Jammu & Kashmir (eBird 2020) and five from the upper Chenab catchment (Sharma et al. 2018). The current communication deals with the breeding records of three sympatric vultures, viz., Himalayan Vulture *Gyps himalayensis*, Egyptian Vulture *Neophron percnopterus,* and Bearded vulture *Gypaetus barbatus* from a mountain cliff in Kahara, Thathri (33.121^{0}N & 75.853^{0}E, ca. 1,500m), a part of upper Chenab catchment. The Himalayan vulture, a 'Near Threatened' species (Birdlife International 2017a) has a broad range extending from the Palearctic realms in the high altitudes of central Asian republics and the Himalaya from Afghanistan, northern Pakistan, northern India through southern Tibet and Nepal to Bhutan and central China to Singapore (Birdlife International 2020). Occurring at 600–2,500 m, they have been seen foraging up to 4,500m and even beyond (Ali & Ripley 1968; Grimmet et al. 2011)

The Egyptian Vulture, listed 'Endangered' (Birdlife International 2019), is widely distributed from northern Africa and southwestern Europe to southern Asia (Birdlife International 2020). Comparatively smaller than other vultures and an opportunist feeder (feeding on a vast range of food), it is the only living member of the genus *Neophron.* While other vulture species live in large groups, these are mostly seen either solitary or in pairs. The mating pair often remains together outside the nesting period, an unusual trait for raptors (Birdlife International 2020).

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Bearded Vulture, the only member of genus *Gypaetus* distributed across the Palearctic, Afrotropical and Indo-Malayan regions is considered rare in some areas and thought to be declining (Ferguson-Lees & Christie 2001). In India, the species is fairly common throughout the Himalayas from Kashmir to Arunachal Pradesh (Naoroji 2006). The altitudinal movements occur during the winters when individuals occasionally hover as low as 600 m (Birdlife International 2020). It is listed as 'Near Threatened' on the IUCN Red List (Birdlife International 2017b), and its declining populations coincide with poisoning (accidental and targeted) as well as habitat degradation, disturbance of breeding sites and collision with power lines (Ferguson-Lees & Christie 2001).

Vultures are usually believed to compete for several types of resources including food (Petrides 1959; Konig 1983; Mundy et al. 1992; Hertel 1994) habitat and nest sites (Fernández & Donázar 1991; Margalida & Garcia 1999; Bertran & Margalida 2002). Evidence of interspecific aggression at nest sites has also been observed between sympatric vulture species (Blanco et al. 1997; Pascual & Santiago 1991; Aykurt & Kiraç 2001). The competition, resource apportionment and population density of vultures can sometimes allow sympatric species to have considerable overlap in resource use (Wiens 1977; Steenhof & Kochert 1988). We, through this communication, present the interesting breeding sight records of three large-sized vultures in a cliff mountain. The steep mountain block is characterised by rugged rocky outgrowths with narrow grassy slopes and scattered woody patches, deciduous at the base and conifers at the top. The cliff is a potential habitat for Himalayan Goral *Naemorhedus goral*, Rhesus Macaque *Macaca mulatta*, and Kashmir Gray Langur *Semnopithecus ajax*.

On July 11, 2019, while doing a reconnaissance survey for Eurasian Otter *Lutra lutra* in the Kalnai River at Kahara in district Doda of the union territory of Jammu & Kashmir, we spotted three active nests of vultures in

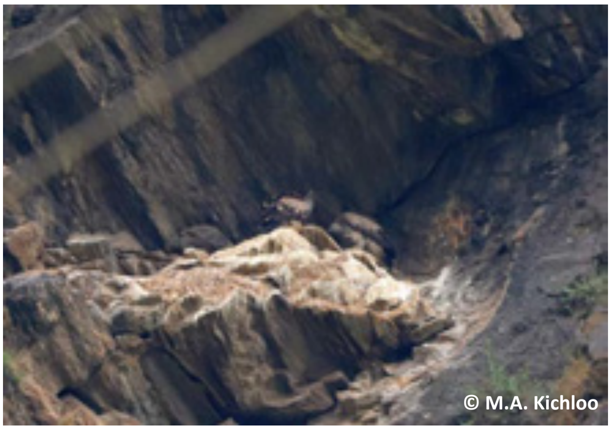

Image 1. Adult Himalayan Vultures at their nesting site.

Image 2. A Himalayan Vulture juvenile.

Image 3. Adult Bearded Vulture roosting near the nest.

Image 4. Nest of the Egyptian Vulture.

Image 5. Nest of the Bearded Vulture.

Image 6. Adult Bearded Vultures with juvenile.

rocky crevices of the cliffs (1,350–1,570 m) overlooking a deep gorge. Of these, two were of the Himalayan Vulture (Images 1 & 2) and one of Bearded Vulture (Image 3). Made of twigs and lined by dry grass, the nests mostly east-facing, were built on the ledges or in cavities and small caves on cliffs well protected from predators. The vultures preferred the inaccessible cliffs on the left bank for nesting, though a few active nests were observed along the right bank too. The right bank's drier slopes were exposed to a myriad disturbances, (road networks, habitations, stone crushers, micro-hydel power projects, etc.) and thus not ideal for nesting.

We visited the forward area again on 28 July 2019 and found two more nests, one belonging to the Egyptian and the other to the Bearded Vulture. The former made of twigs intertwined with fabric occupied one juvenile and an adult Egyptian vulture resting nearby (Image 4). The other massive nest of the Bearded Vulture (Image 5) observed a few hundred feet above, housed a juvenile and the parent birds (Image 6). The roosting sites for all the vultures were found close to the observed active nests.

From the field observations, it is evident that the mountain cliff provides potential breeding habitat for the vultures and possibly other birds of prey as well. The inaccessibility, rugged topography (for nesting) and the abundant food base (gorals, monkeys, langurs, pikas, and rodents) make it an ideal nesting location for the vultures. Further, the two adjoining townships (Thathri and Kahara) provide adequate food resources, as most of the Egyptian and Himalayan vultures are attracted to the carcases and carrion dumped at the municipal solid waste sites located ca. 8km downstream. The stony areas could possibly be used by the Bearded Vultures to break bones. The presence of iron-rich springs or rocks could be the other factors signalling their dominance. The authors further aim to study the resource apportionment and influence of habitat variables (climate, terrain, disturbance) on the nest site characteristics.

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NOTE

First distribution record of Elongated Tortoise *Indotestudo elongata* (Blyth, 1853) (Reptilia: Testudines: Testudinidae) from Bihar, India

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India has one of the most diverse chelonian fauna in the world; home to 30 species of freshwater turtles and tortoises and six marine turtles (Das & Gupta 2015). There are a total of five species of tortoises reported from India, viz.: *Indotestudo elongata* Elongated Tortoise, *Manoria emys* Asian Giant Tortoise, *Indotestudo travancorica* Travancore Tortoise, *Geochelone elegans* Indian Star Tortoise, and *Manouria impressa* Impressed Tortoise (Das & Gupta 2015; Kundu et al. 2013, 2018). The former two are listed as Critically Endangered and the later three as Vulnerable on the IUCN Red List of Threatened Species.

Indotestudo elongata which is listed as Critically Endangered under criterion A2cd (Rahman et al. 2019) by IUCN Red List and under Appendix II of CITES is protected under Schedule IV of Wildlife Protection Act 1972 in India (Das & Gupta 2015; Ihlow et al. 2016). This species is also commonly known as Yellow-headed Tortoise, Yellow Tortoise, Red-nosed Tortoise, and Pineapple Tortoise and is widely distributed across southern and southeastern Asia (Das & Gupta 2015; Rahman et al. 2019). In India, it was first recorded by Anderson (1878–79) near Chaibasa in Singhbhum District of present day Jharkhand State from where later Annandale (1913) collected a specimen of it and described it as *Testudo parallelus.* In 1983, Edward O. Moll collected two shells from south-west of Chaibasa (Crumly 1988; Swingland & Klemens 1989). There are records of *Indotestudo elongata* from Corbett National Park in Uttar Pradesh and Jalpaiguri situated in West Bengal also (Frazier 1992). In the east it is found at Dampa Tiger Reserve and Ngengpui Wildlife Sanctuary in Mizoram, Chakrashilla Wildlife Sanctuary in Dhubri District in Assam and Cachar, Karimganj, and Hailakandi districts of Barak Valley, Assam (Das & Gupta 2015). Our sighting is the first record of *Indotestudo elongata* from the present state of Bihar. However, recent publication of Khan et al. (2020) emphasis there were high probability occurrence of the species in the central Himalaya and the Upper Gangetic Plains including Valmiki Tiger Reserve, Bihar on the basis of environmental niche modelling method, too.

While on routine patrol of the Valmiki Tiger Reserve a tortoise was sighted on 05 June 2019 and 27 June 2019 in the Manguraha range (Image 1) that was subsequently identified as *Indotestudo elongata* based on descriptions in Tikader & Sharma (1985), Ahmed &

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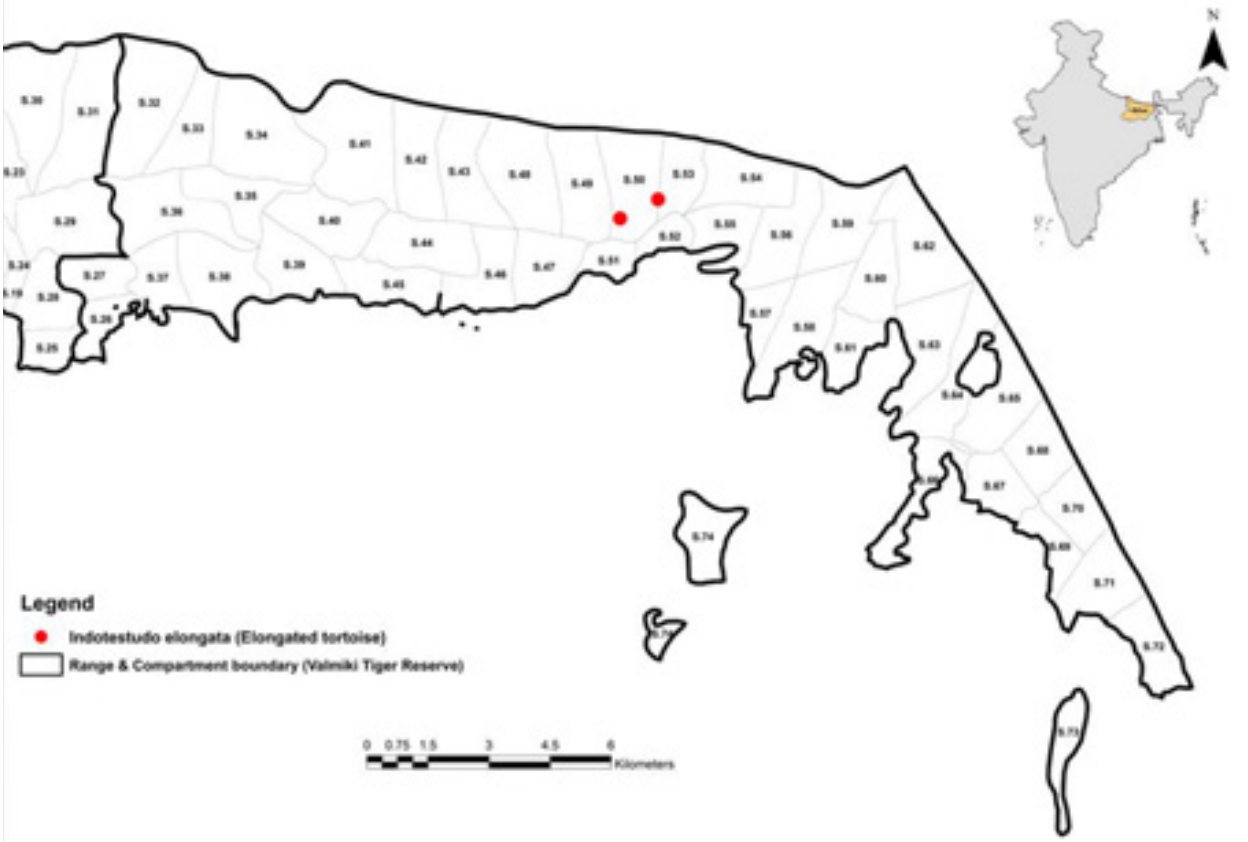

Figure 1. Manguraha range in Valmiki Tiger Reserve showing site of occurrence of *Indotestudo elongata.*

Image 1. *Indotestudo elongata* found on 5 June 2019 & 27 June 2019 in Manguraha Range, Valmiki Tiger Reserve, Bihar. © Arif.

Das (2010) and Ihlow et al. (2016). The closest published locality record for this species is in Chaibasa situated in West Singhbhum District of current day Jharkhand (Annandale 1913; Swingland & Klemens 1989), which is approximately 615km from Manguraha.

The first sighting took place around 08.27h (27.328^{0}N, 84.561^{0}E) and the second at 08.50h (27.324^{0}N, 84.551^{0}E) in an area of moist deciduous forest dominated by Sal *Shorea robusta* and Indian Laurel *Terminalia elliptica* trees. Both the sighted individuals were male and were sighted sitting at the location. The elongated carapace and plastron of the sighted individual was yellowish-brown in colour with distinct black blotches in the centre of each scute as described by Blyth (1884) and Ihlow et al. (2016). The sizes of the individuals were 21cm and 29cm and weighed 2kg and 2.9kg, respectively.

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NOTE

The niche of shrimp stocks (*Xiphopenaeus kroyeri* Heller, 1862) from southeastern Brazil: a stable isotope approach

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The penaeid shrimps are important targets in crustacean fisheries worldwide. The species *Xiphopenaeus kroyeri* Heller, 1862, known as the Atlantic Seabob Shrimp, is a penaeid species with continuous distribution in coastal waters along the western Atlantic Ocean, from 36°N to 30°S, and their stocks are highly exploited by marine coastal fisheries (FAO 2018). In Brazil, this is the second most important species of crustacean in fisheries landings (Boos et al. 2016).

Stable isotopes of carbon (^{13}C) and nitrogen (^{15}N) are applied as chemical proxies to provide complementary data on animals' trophic ecology (Fry 2008). Niche differentiation is the process by which species evolve different forms of food sources use (MacArthur 1984). Layman et al. (2007) introduced metrics from ecomorphological approaches to summarize quantitative information from stable isotopes data. Later, Jackson et al. (2011) developed a Bayesian framework for these metrics comparisons, allowing robust inferences regarding isotopic niche of animal species. Thus, stable isotopes provide quantitative information about the consumer isotopic niche, which is associated with its feeding ecology and ecological niche in the environment.

This study evaluated the niche dimensions of *X. kroyeri* (Image 1) from four stocks in southeastern Brazil through stable isotopes determinations. We hypothesize that the isotopic niche is similar among the four stocks because this shrimp is an omnivorous consumer with high feeding plasticity, consuming a broad spectrum of food sources that are abundant in its home range, such as primary sources and small animals from both benthic environment and water column (Willems et al. 2016).

The shrimps were sampled in four fishing areas from Espírito Santo and Rio de Janeiro States, southeastern Brazil: Vitória (-20.51S & -40.50W), Anchieta (-20.80S & -40.63W), Atafona (-21.61S & -41.00W), and Farol de São Tomé (-22.03S & -41.03W) (Figure 1). In June 2017, 120 individuals were sampled in the local fishing market from each fishing area, totalling 480 individuals. The abdominal muscle of each individual was removed and stored in a dry sterile vial, frozen (-20°C), freeze-dried and homogenized using mortar

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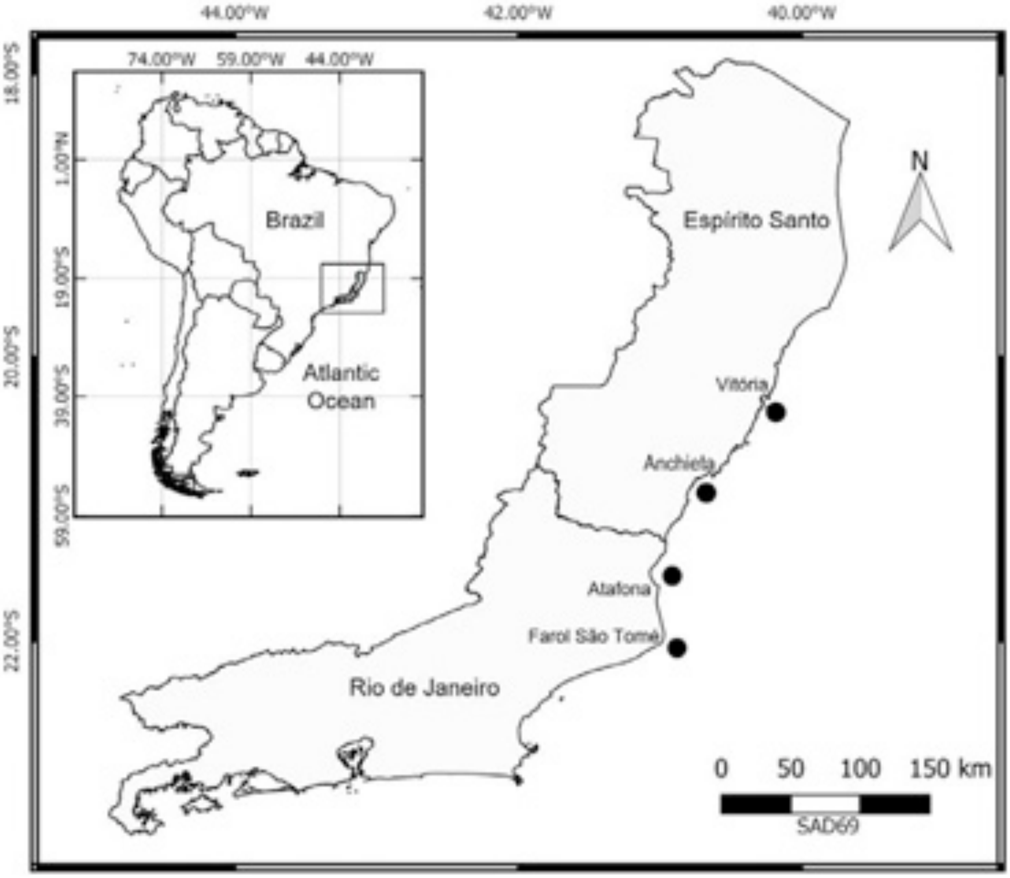

Figure 1. Location of the fishing areas in Espírito Santo (Vitória and Anchieta) and Rio de Janeiro (Atafona and Farol de São Tomé) States, southeastern Brazil.

and pestle. Samples containing 0.4g of muscle (dry weight) of each individual were analysed for Carbon and Nitrogen isotopic determination. The stable isotopes ratios ($\delta^{13}C$ and $\delta^{15}N$) of each shrimp was determined using a Delta V Advantage mass spectrometer (Thermo Scientific, Germany) coupled to an elemental analyser in Laboratório de Ciências Ambientais from Universidade Estadual do Norte Fluminense Darcy Ribeiro. The reference values for Nitrogen and Carbon stable isotopes were atmospheric Nitrogen and Pee Dee Belemnite (PDB), respectively. Samples were analysed using analytical blanks and urea analytical standards (IVA Analysentechnik-330802174; CH_4N_2O Mw = 60, C = 20%, N = 46%), using certified isotopic compositions ($\delta^{13}C$ = -39.89‰ and $\delta^{15}N$ = -0.73‰). Analytical control was done for every 10 samples using a certified isotopic standard (Elemental Microanalysis Protein Standard OAS): $\delta^{13}C$ = -26.98‰ and $\delta^{15}N$ = +5.94‰. Analytical reproducibility was based on triplicates for every 10 samples: ± 0.3‰ for $\delta^{15}N$ and ± 0.2‰ for $\delta^{13}C$.

Image 1. ***Xiphopenaeus kroyeri***

Quantitative metrics of the isotopic niche based on individuals' position in $\delta^{13}C$-$\delta^{15}N$ bi-plot space were estimated according to Layman et al. (2007) and Jackson et al. (2011). The metrics were calculated using Stable Isotope Bayesian Ellipses in R (SIBER - Jackson et al. 2011; R Core Team 2020). The first two metrics represent the stocks trophic diversity, and the last two represent the stocks trophic redundancy, or the relative position of individuals to each other within their respective

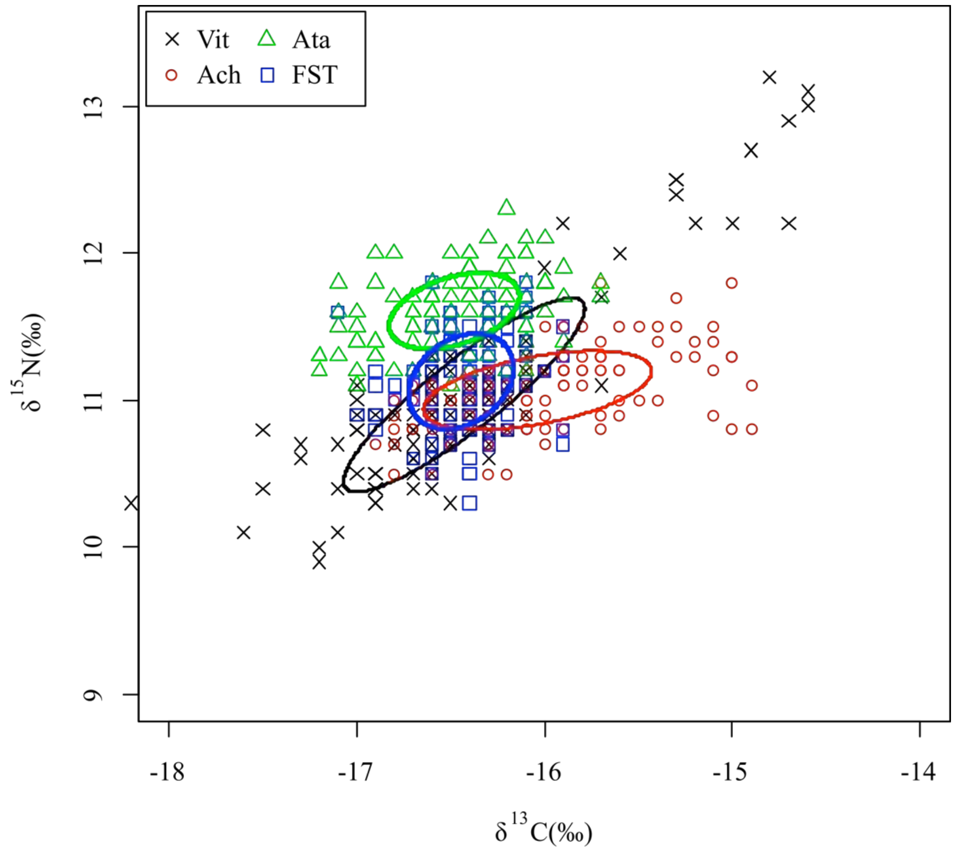

Figure 2. Isotopic values of Xiphopenaeus kroyeri stocks from Espírito Santo (Vitória and Anchieta) and Rio de Janeiro (Atafona and Farol de São Tomé) States. Colored lines represent data ellipses (40% confidence interval) for the isotopic niches. Vit—Vitória | Ach—Anchieta | Ata—Atafona | FST—Farol de São Tomé.

isotopic niches. The standard ellipse area (SEA) is the isotopic niche width of a given stock, based on bivariate distribution ellipses for each stock and sized to include 40% of the data subsequently sampled. The mean distance to centroid (CD) is the mean Euclidian distance from each individual to stock centroid (mean $\delta^{15}N$ and $\delta^{13}C$), which provides average level of trophic diversity. The mean nearest neighbour distance (MNND) is the mean Euclidian distance from each individual to the nearest neighbour in $\delta^{13}C$–$\delta^{15}N$ bi-plot space, indicating similarity in trophic ecology within stocks. The standard deviation of nearest neighbour distance (SDNND) is a measure of stock uniformity in $\delta^{13}C$–$\delta^{15}N$ bi-plot space, or the evenness of individuals' distribution within stocks. One-way ANOVA evaluated differences among stocks considering CD and MNND metrics, as these are means. SDNND metric was compared using *F-ratio* tests because it is a standard deviation. The statistical analyses were done in the R program (R Core Team 2020).

The *X. kroyeri* stocks from Espírito Santo State (Vitória and Anchieta) had highest SEA values when compared to stocks from Rio de Janeiro State (Atafona and Farol de São Tomé) (Table 1, Figure 2); and also highest values for the average level of trophic diversity (CD) (ANOVA, $F = 7.49$, $df = 3$, $p = 6.53e\text{-}05$) (Table 1). The MNND values that show the similarities in trophic ecology within stocks were low, and did not differ among the stocks (ANOVA,

Table 1. Quantitative metrics of isotopic niche of *Xiphopenaeus kroyeri* stocks from Espírito Santo and Rio de Janeiro states.

Stocks/ Fishing areas	SEA‰²			CD	MNND	SDNND
	LQ	Med	UQ			
Espírito Santo State						
Vitória	0.59	0.63	0.67	0.66	0.07	0.10
Anchieta	0.41	0.44	0.47	0.51	0.08	0.27
Rio de Janeiro State						
Atafona	0.24	0.25	0.27	0.37	0.04	0.05
Farol de São Tomé	0.25	0.26	0.28	0.36	0.04	0.12

CD—distance to centroid | MNND—mean nearest neighbour distance | SDNND—standard deviation of nearest neighbour distances | SEA—standard ellipse area | LQ—lower quartile | UQ—upper quartile | Med—Median.

F = 1.74, df = 3, p = 0.16); however, higher values were recorded for stocks from Rio de Janeiro State (Table 1). Individuals' distribution in the isotopic niche space revealed the highest and the lowest trophic uniformity (SDNND) for shrimps from Atafona and Anchieta stocks, respectively (Table 1). Comparisons using F tests showed significant results ($p < 0.01$), except for the comparison between Vitória and Farol de São Tomé stocks (p = 0.15).

The results refuted the hypothesis that the four *X. kroyeri* stocks have similar isotopic niche width because of the high feeding plasticity of this species. Shrimp stocks from Espírito Santo State (Vitória and Anchieta) had highest trophic diversity (SEA and CD metrics), indicating greater variety of food sources and wider utilization of the available food sources. The shrimps from Rio de Janeiro State (Atafona and Farol de São Tomé) had highest trophic redundancy (MNND and SDNND metrics), revealing a more homogeneous dietary pattern. In general, shrimps have high feeding plasticity, and variations in diet composition and in the amount ingested can occur among species, genders, maturity stages and seasons, even on a small spatial scale (Carnevali et al. 2012; Gutiérrez et al. 2016). The isotopic composition of the animal tissues derives from the ingested food sources and fractionation processes in these tissues, and the carbon and nitrogen isotopic values can differ both spatially and among the food sources ingested by the consumer (Fry et al. 2003; Fry 2008). Thus, the composition of food sources and availability in each fishing area might explain the variations among the *X. kroyeri* stocks regarding their isotopic niches. Further studies on the local feeding ecology of this species, such as the study conducted by Willems et al. (2016) off the coast of Suriname, are recommended to confirm this assumption.

In Suriname, a combination of stomach content and stable isotope analyses from *X. kroyeri* individuals in different life stages showed that hyperbenthic crustaceans, benthic microalgae and offshore sedimentary organic matter were important food sources, with benthic microalgae contributing up to 64% to the overall diet for all life stages, however, an ontogenetic diet shift was recorded, with adult shrimps positioned higher in the food chain ($\delta^{15}N$ more enriched), preying on larger benthic organisms (Willems et al. 2016). The isotopic data of the four *X. kroyeri* stocks from southeastern Brazil can be combined with future stomach content analysis to verify and compare the feeding preference in this region to the data from Suriname.

We can state that the isotopic niche approach allowed the discrimination of *X. kroyeri* stocks distributed at 20^{0}S (fishing areas of Espírito Santo State) and 21^{0}S–22^{0}S (fishing areas of Rio de Janeiro State). Recognizing the seafood origin allows determining the fishers' fidelity to a given fishing area (geographical origin), besides developing inferences on seafood quality from the environmental quality (Ortea & Gallardo 2015). The results will be helpful to assist fisheries management, delimitating the fishing area of local vessels and helping track the origin of the shrimps commercialized in local markets.

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NOTE

First record of the White Tufted Royal *Pratapa deva lila* Moore, [1884] (Lepidoptera: Lycaenidae: Theclinae) from Himachal Pradesh, extending its known range westwards

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The butterflies of Himachal Pradesh are quite well studied. The earliest publication of the butterflies from Himachal Pradesh was that of the Simla Hills. G.V.W. de Rhe-Philipe published a series of papers listing butterflies of the Simla Hills in 1931 (de Rhe-Philipe 1931). Subsequently, Wynter-Blyth added to the butterfly checklist of Simla through a series of publications between 1940 and 1947 (Wynter-Blyth 1941–1947). More recently, there have been numerous publications on butterflies from Himachal Pradesh by researchers and scientists.

The White Tufted Royal *Pratapa deva lila* Moore, [1884] is reported for the first time from Himachal Pradesh, during opportunistic surveys, extending its known range westwards.

Two subspecies of the lycaenid, White Tufted Royal *Pratapa deva* (Moore, [1858]) are known to occur in India. The nominate species *Pratapa deva deva* Moore, [1858] occurs in peninsular India and Sri Lanka while *Pratapa deva lila* Moore, [1888] was previously known to occur from Uttarakhand eastwards to Eastern Himalaya, northeastern India, Myanmar, and Thailand (Singh & Bhandari 2003; Varshney & Smetacek 2015; Kunte et al. 2018; Sondhi & Kunte 2018; Savela 2018).

On 1 August 2017, during a visit to Dharamshala, Kangra District in Himachal Pradesh, I recorded a male White Tufted Royal *Pratapa deva lila* Moore, [1888] at 15.39h (Image 1; Image 2). The butterfly was observed between the Chinmaya Ashram and the Himachal Pradesh Vidhan Sabha at Sidhbari (32.1793901N & 76.3779831E), a suburb of Dharamshala, at an altitude of 1,400m. The butterfly had freshly emerged and was sitting on a bush, which was covered with the parasitic creeper, *Loranthus*. Members of the genus *Pratapa* are known to use plant species of the family Loranthaceae as their larval host plants and *Loranthus tomentosus* B. Heyne ex Roth is listed as one of its hosts from India (Robinson et al. 2010).

A review of older literature on Indian butterflies (Evans 1932; Wynter-Blyth 1957; Cantlie 1963) lists the Indian distribution of *Pratata deva lila* Moore, [1888] as Uttarakhand eastwards to Eastern Himalaya. Wynter-Blyth (1957), however, mentions records of this species from the "Ambala plains" hence it has been recorded in the state of Haryana, too. Kehimkar (2016) mentions the distribution of this species as "Himachal-Arunachal,

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Image 1. Underside of male *Pratapa deva lila* Moore [1888], Sidhbari, Dharamshala, Himachal Pradesh, India.

Image 2. Upperside of male *Pratapa deva lila* Moore, [1888] Sidhbari, Dharamshala, Himachal Pradesh, India.

W. Bengal, NE" but without offering any corroboration or evidence to support its presence in Himachal Pradesh. Older publications specifically focused on Himachal Pradesh (Moore 1882; de Rhe-Philipe 1931; Ferrar 1934; Wynter-Blyth 1941–1947) including the elaborate listing from the Simla hills by de Rhe-Philipe and additional records by Wynter-Blyth do not list this species. More recent publications on Indian butterflies (Varshney & Smetacek 2015; Singh & Sondhi 2016; Sondhi & Kunte 2018) corroborate the distribution from Uttarakhand eastwards. An extensive perusal of recent butterfly literature from Himachal Pradesh (Kumar & Juneja 1977; Mehta et al. 2002; Thakur et al. 2002; Uniyal 2007; Singh 2008; Arora et al. 2009; Saini et al. 2009; Singh & Banyal 2013; Chandel et al. 2014; Sharma et al. 2015) reveals no records of this species from Himachal Pradesh. Moreover, there are no records of this species from Himachal Pradesh on the Butterflies of India website (Kunte et al. 2018) either.

Hence, this record of *Pratapa deva lila* Moore, [1888] from Dharamshala extends the range of this species westwards and it represents the westernmost record at the edge of its global distributional range. Henceforth, the Indian distribution of this subspecies should be listed as Himachal Pradesh (Dharamshala), Haryana (Ambala plains), Uttarakhand east to Eastern Himalaya and the hills of northeastern India.

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NOTE

Range extension of the Lilac Silverline *Apharitis lilacinus* to southern Rajasthan and a review of the literature

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The Lilac Silverline *Apharitis lilacinus* (taxonomy following Varshney & Smetacek 2015) is an exceedingly rare species of butterfly of the family Lycaenidae (also referred to as "the blues" or "gossamer-winged butterflies") that was first described in 1884 from a specimen with unknown origin (Moore 1884). Little is known of its ecology, distribution, and conservation status in India. In this note, we describe a recent observation of the species that constitutes a range extension. We also provide a thorough review of literature relating to this species with the intent to collate dispersed information to develop a better understanding of the ecological requirements of the Lilac Silverline.

On 18 February 2020, during a visit to the southern part of Kumbhalgarh Wildlife Sanctuary in southern Rajasthan, we spotted a lycaenid butterfly sunning itself perched on a rock in an area that was severely degraded by cattle grazing, with few scattered trees of *Butea monosperma*, *Lannea coromandelica*, *Acacia* species, and *Mallottus philippensis* amid sparse *Lantana camara* (Image 1a,b). The butterfly sighting was <50m from a dried stream bed. We uploaded images of the butterfly to the online repository iNaturalist.org as an unidentified Lycaenidae (www.inaturalist.org/observations/38831801). Multiple reviewers identified the species as the Lilac Silverline, and we too confirmed the identification with butterfly experts and with photographs available on the world wide web. The specimen we photographed was a dry season form with a part of one wing missing possibly due to a predation attempt (Image 1a). This is the first record of this butterfly species from the Aravalli Hills and is also the first record from Rajasthan State (Sharma 2014; Jangid et al. 2016). Careful observations for this species throughout the year will help to confirm if it is resident in the area or a seasonal visitor.

Historic literature points to the Lilac Silverline always being rare in locations it has been recorded in. Early collections of butterflies include a few specimens of the Lilac Silverline 40km from Rawalpindi, Pakistan in November 1885 (described incorrectly as a new species called *Azanus uranus*; Butler 1886), and from Mhow in Madhya Pradesh (described as a new species called *Aphnaeus aestivus*; Swinhoe 1886). Very small numbers of the species have also been collected from Kasauli (Himachal Pradesh), Malda (West Bengal), Bengaluru (Karnataka) and north Lakhimpur (Uttar Pradesh) of both the wet and dry forms (Riley 1925). Observations have

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been made of the species' habits at Chandigarh (Punjab), Hardwar (Uttaranchal), and at Palmaner in Chittoor District (Andhra Pradesh; Wynter-Blyth 1957). These early records point to the species being widespread but always sparse.

More recent observations of the Lilac Silverline have been few but significant. The species was rediscovered in Bengaluru after a century by A.R. Nitin on 23 December 2012 (de Nazareth 2013), and is now regularly photographed throughout the year, at Hessarghatta Lake with eggs and caterpillars indicating that the location has a resident breeding population of the species (Sheshadri et al. 2013; Sengupta et al. 2020). Another photographic record was obtained for the first time in northeastern India in May 2018 in Daying Ering Wildlife Sanctuary in Arunachal Pradesh (Kaman 2018). The Lilac Silverline was also photographed on 25 September 2019 from the Agastya Campus in Chittoor District, less than 60km from Hesaraghatta Lake in Bengaluru, constituting a rediscovery of the species in Andhra Pradesh (R. Bhanumati pers. comm. 2020). The Agastya Campus has been restored to a scrub-savanna mixture from fallow fields, and only one sighting of the Lilac Silverline has been made there despite multiple years of observations for butterflies (R. Bhanumati pers. comm. 2020).

Both historic and current observations match the distribution provided by Varshney & Smetacek (2015) for the Lilac Silverline: "Gujarat to Karnataka; Himachal Pradesh to Assam". Our record from Rajasthan adds to the distribution range, and to existing conclusions that the species is widespread in the Indian subcontinent (Wynter-Blyth 1957; Varshney & Smetacek 2015; Sengupta et al. 2020). One-time observations have been made across India in January, February, May, and September, and the species is resident in Bengaluru. Available information is therefore inadequate to comment on the seasonality of the species in other locations.

A few observations are available of the habitats required by the Lilac Silverline. Wynter-Blyth (1957) notes that the species is scarce but widespread in open plains, scrubby hills, and in gram fields. Hesaraghatta, where recent observations of the species have been made, is an urban wetland heavily disturbed by human activity (Sheshadri et al. 2013), and the recent sighting in Chittoor is from an institutional campus (R. Bhanumati pers. comm. 2020). Our observation of the Lilac Silverline was from a heavily degraded part of the Kumbhalgarh Wildlife Sanctuary (see Image 1). The observations collectively suggest that the Lilac Silverline frequents a range of habitats, perhaps most commonly using areas that experience human activity, including low levels of urbanization, cropping, and cattle grazing. The sightings at Hesaraghatta and our observation at Kumbhalgarh were made close to natural water sources suggesting that this species is often found near surface water.

It is fortunate that the Lilac Silverline is so widespread and appears to be compatible with several forms of human disturbance given the high protection status of the species (Schedule II of the Indian Wildlife Protection Act 1972; Sengupta et al. 2020). In some locations like Bengaluru, the rarity of this butterfly species has attracted photographers in large numbers whose traversing of the habitat in vehicles indiscriminately appear to be destroying its host plant species in the only site where the species is confirmed to have a breeding population (Seshadri et al. 2013). Such uncontrolled activities require to be curtailed to enable

Image 1. a—the dry season form of the Lilac Silverline photographed in Kumbalgarh Wildlife Sanctuary, Rajasthan on 18 February 2020 | b—the location where it was photographed looking toward the dried stream that flowed in the valley.

long-term persistence of the few known populations of this species. Additional surveys in locations such as Kumbhalgarh Wildlife Sanctuary, especially including locations that have human presence and are not solely protected areas, are likely to help provide additional information on the habits and conservation status of the Lilac Silverline.

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A record of gynandromorphism in the libellulid dragonfly *Crocothemis servilia* (Insecta: Odonata) from India

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Gynandromorphs are genetically and phenotypically chimeric specimens and differ from intersexes which are genetically uniform (Narita et al. 2010). Gynandromorphism can be bilateral, appearing to divide down the middle into male and female sides, or they may be a mosaic, with patches characteristic of one sex appearing in a body part characteristic of the other sex. Gynandromorphism is a rare phenomenon in nature and is usually detected in species that show distinct sexual dimorphism. It is known to occur in different arthropod taxa such as Crustacea (Farmer 2004), Arachnida, e.g., scorpions (Cokendolpher & Sissom 1988), spiders (Palmgren 1979), ticks (Labruna et al. 2002), and Insecta, e.g., stoneflies (Klotzek 1971), hymenopterans (Gjershaug et al. 2016), beetles (Le Gall 2006), butterflies (Nielsen 2010), dipterans such as mosquitoes (Kronefeld et al. 2013) and fruit flies (Morgan & Bridges 1919). In vertebrates it has been detected in reptiles (Krohmer 1989), birds (Peer & Motz 2014), and mammals (Hollander et al. 1956). Gynandromorphs occasionally afford a powerful tool in genetic, developmental, and behavioural analyses. In *Drosophila melanogaster*, for instance, gynandromorphs were used to provide evidence that male courtship behaviour originates in the brain (Hotta & Benzer 1972).

Gynandromorphism is rare in odonates (Corbet 1962) and so far has been reported from 30 individuals belonging to seven families: Calopterygidae, Coenagrionidae, Aeshnidae, Gomphidae, Cordulegastridae, Corduliidae, and Libellulidae (Tennessen 2008; Torralba-Burrial & Ocharan 2009; Pix 2011; Futahashi 2017). There are other forms of colour variation seen in odonates. Andromorphic females are common in many odonate families. They have normal female reproductive organs and are fertile (Robertson 1985; Andrew 2013). Immature male imagoes of many Anisoptera resemble females in colouration, but can be distinguished by the male reproductive structures. Gynandromorphism, on the contrary, is believed to be a genetic aberration caused by abnormal mitosis in the embryo leading to unequal distribution of sex chromosomes (May 1988). As a result, the developed individual has both male and

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Image 1. Survey location from where *Crocothemis servilia* gynandromorph was recorded.

female tissues and mixed morphological characteristics.

The Kole wetlands are low-lying areas that remain submerged under floodwater for about six months of a year. Wetland agriculture, mainly paddy (rice) cultivation is the most important activity undertaken there. They cover an area of 13,632ha and are spread across Thrissur and Malappuram districts of Kerala (Johnkutty & Venugopal 1993). Kole has been a Ramsar site since 2002, an important bird area since 2004 (Islam & Rahmani 2008), and a high value biodiversity area since 2009 (MoEF 2009). In a survey conducted at Kole wetlands on 14 July 2019 (Image 1), jointly by Kerala Agricultural University, Kole Birders, Society for Odonate Studies, and Kerala Forest Department, 33 species of odonates were recorded.

Crocothemis servilia, is a common dragonfly associated with marshes, ponds, rivers and tanks. It is widely distributed in the Oriental and Australian region (Subramanian 2009). The male has prominent blood red colouration in almost all body parts including the head, thorax, abdomen and legs. The wings are transparent with the base marked with rich amber (Image 2). The female is pale yellow with dark brown thorax and legs (Image 3).

At Puzhakkal region of the Kole wetlands (10.540^{0}N & 76.172^{0}E), an individual of *Crocothemis servilia* that looked part male and part female was photographed during the survey. The specimen could not be collected as it started raining and the individual moved into the deep marshes. Subsequent efforts to collect the specimen failed because of heavy rains that continued for the next few days, submerging the location. The species was initially identified using the field guide by Kiran & Raju (2013) and confirmed by referring to Fraser (1936).

The photographed individual showed bilateral gynandromorphism of only the thorax, half of which showed blood red colouration as in males and the other half pale yellow characteristic of females. The base of the wing of the red half was marked with rich amber, in contrast with the other wing base which was paler. The head, legs and abdomen showed typical female morphology. Status of the anal appendages could not be asserted from the photograph (Image 4). Since the female characters dominated, this cannot be considered a "balanced" gynandromorphy. The individual exhibited a genetic mosaic condition only in the thoracic region. May (1988) reported gynandromorphism in two species of family Corduliidae, namely *Somatochlora filosa* and *Somatochlora provocans* from the United States of America. The specimens he examined had mixtures of male and female external characters ranging from almost entirely female to about equally divided. They were symmetrical in development with normally dimorphic structures mostly having characters intermediate between the typical male and female

Image 2. *Crocothemis servilia* adult male.

Image 3. *Crocothemis servilia* adult female.

conditions, particularly noticeable in the development of the genital lobes, cerci, and metathoracic legs. Torralba-Burrial & Ocharan (2009) reported gynandromorphism in the libellulid *Sympetrum striolatum* from Spain. One of the two specimens they examined was a bilateral gynandromorph which looked like a female in general appearance but had male structures in the right side of the abdomen. Their second specimen resembled a male in general appearance, but had a female gonopore. Mosaic gynandromorphy in *Ischnura senegalensis* (Family: Coenagrionidae) and *Crocothemis servilia* (Family: Libellulidae) was reported by Futasahi from Japan (2017). In South Asia, gynandromorphy was reported in *Neurothemis tullia* (Family: Libellulidae) from Bangladesh (Shome et al. 2019), in which the specimen's head and thorax, including wings were bilaterally gynandromorphic. The abdomen was androchromic but had female appendages at the tip. In India, gynandromorphism was reported in *Neurothemis tullia* (Family: Libellulidae) and *Heliocypha bisignata* (Family: Chlorocyphidae) (Emiliyamma 2009), but photographs or illustrations were unavailable for confirmation or comparison. According to Siva-Jothy (1987), gynandromorphs have been reported to fail in mating because of aberrant sex organs but in the present individual the abdomen is typically female and since the internal and external female reproductive organs/genitalia are abdominal, this individual could be a fertile

Image 4. *Crocothemis servilia* gynandromorph.

female. May (1988) after observing eggs on the vulvar laminae of three *Somatochlora filosa* gynandromophic individuals proposed that they were functionally female. Gynandromorphism is a multifactorial issue caused by different genetic factors which are well documented (Narita et al. 2010), but further research has to be undertaken to investigate the influence of environmental factors on this phenomenon.

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Carcass consumption by *Nasutitermes callimorphus* (Blattodea: Isoptera) in highland forests from Brazil

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Despite the small number of species, termites (Blattodea: Isoptera) are among world's most representative organisms regarding biomass (Bignell & Eggleton 2000). These insects are mainly known from wood-feeding, which is universal among the lower termites (exporadically other items might be used as food, but no specialization in feeding habit is known), however, the higher termites (Termitidae) were able to diversify their diet and occupy many previously available niches (Bucek et al. 2019). Besides plant material, higher termites are mainly reported as feeding on fungi, lichens, humus, other termite's faeces, nest materials, dead siblings (intra-colonial cannibalism) and, rarely, on mammal carcasses (Lima & Costa-Leonardo 2007). Wood (1978) lists parts of vertebrate carrion as "special or incidental" items in the diet of these insects. Freymann et al. (2007) have observed that termites from the genus *Odontotermes* may frequently forage on carrion (hooves), but that item might represent a way to supplement on macro and micro-nutrient, rather than a main source of energy.

The termite genus with the higher number of species, *Nasutitermes* Dudley, 1890 (around 248 extant taxa), comprise wood feeding insects and is present through most of the world's tropical territory, with some species being regarded as notorious pests in the Neotropics (Constantino 2002). Despite the amount of living species only *N. corniger* (Queiroz et al. 2017), *N. nigriceps* (Thorne & Kimsey 1983) were previously reported as feeding on mammal carcasses (excluding reports of damage on archaeological sites, which we don't consider here). Here we report a third species of *Nasutitermes* feeding on mammal carrion.

The observation was made during a field trip on 11 August 2016 in the highland humid forest state reserve Mata do Pau Ferro (6.962^{0}S & 35754^{0}W) (Image 1). With 607ha of protected woodland, the park is located 9km away from the municipality of Areia, Paraíba, Brazil. The altitude ranges from 400m to 600m and observed precipitation during the sample month is registered to be 26.8mm (annual rainfall=1208.3mm) (AESA 2019).

A common house dog *Canis familiaris* skull was found partially covered by carton sheets typically made by *Nasutitermes* spp. (Image 2). Inside the skull, multiple workers and soldiers were found and collected (preserved in 80% alcohol), as well as the bones. The termites were identified as *Nasutitermes callimorphus* Mathews, 1977 (Image 3), a common species inside Brazilian evergreen forests. This species does not build a separated termitarium, rather lives within dead wood covered in carton sheets or in underground galleries. They can be commonly found in carton galleries built

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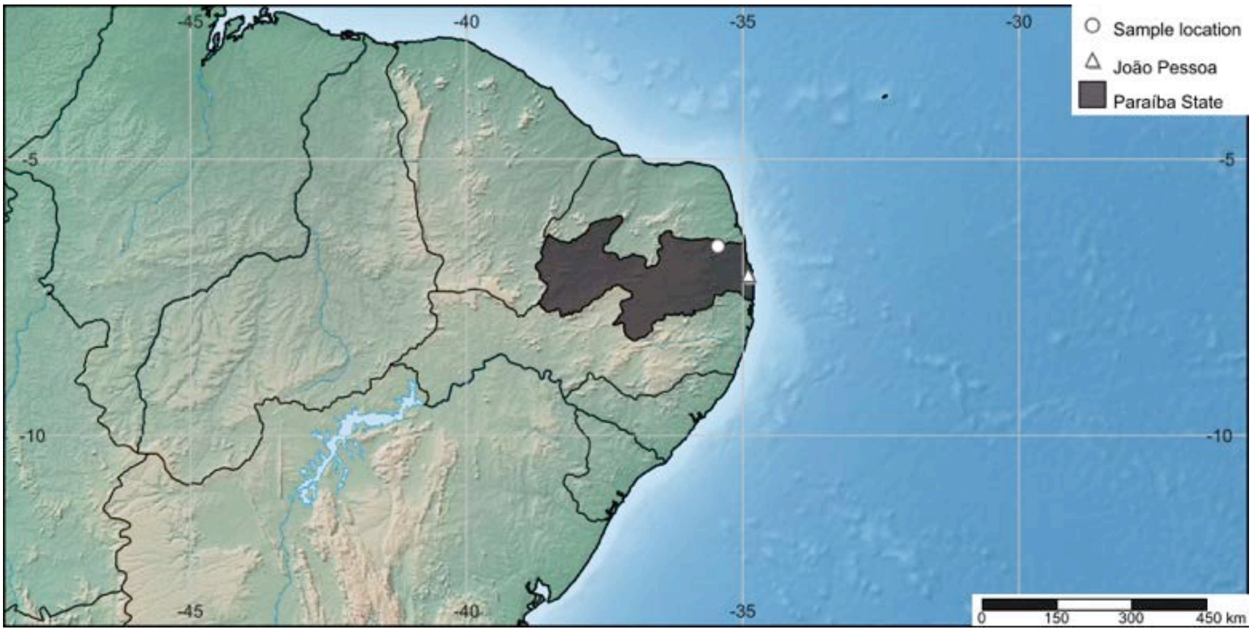

Image 1. Northeastern Brazil. Paraíba State is highlighted in dark gray. Sample location (white dot) is approximately 100km away from the state capital, João Pessoa (white triangle).

Image 2. Dog skull attacked by termites of the species *Nasutitermes callimorphus*. Note the carton sheet covering the whole palate area.

Image 3. Soldier of *Nasutitermes callimorphus*, the species found in the bones.

over the soil surface or in foraging parties constituted by many large workers and soldiers. The food content from the gut of workers collected from the carrion had a ferruginous red colouration, hinting that termites might be feeding on muscle leftovers.

Most termites species reported as carrion feedings are also reported as damage-causing in other reports (Prestes et al. 2014). These commonalities tempt one to suppose that saprophily in termites can be related to the feeding plasticity (a trait ever so frequent in pest species). However, *N. callimorphus* belongs with

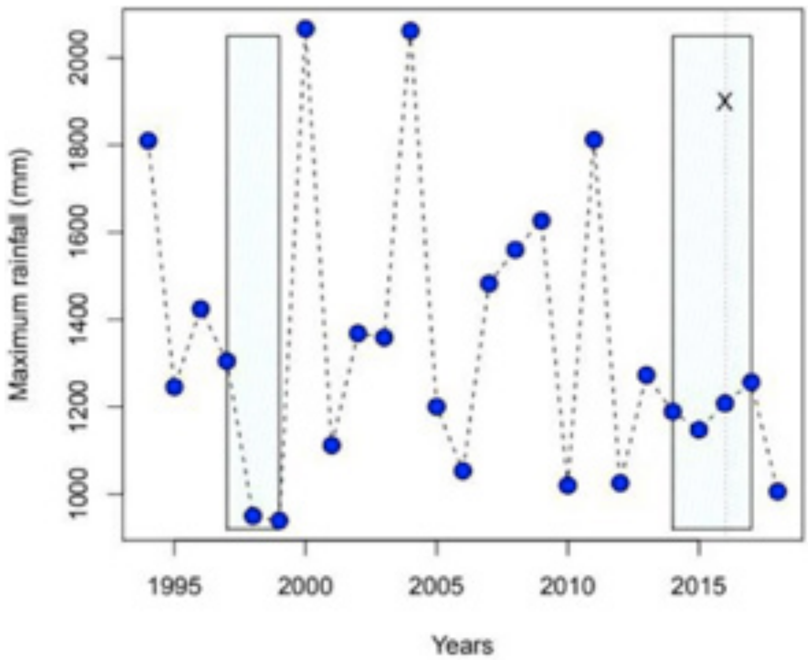

Figure 1. Time series of maximum rainfall registered for Areia municipality from 1994 to 2018. The boxes highlight the years which el niño prolonged the dry season. "X" marks the sample date. Data available online on AESA (2019).

Rhynchothermes nasutissimus (Silvestri, 1901) (Prestes et al. 2014) in a group of termites that do not represent a threat to anthropic activities such as agriculture or habitational buildings.

The majority of carrion feeding reports were made during dry seasons, suggesting that termites may explore carcasses as a supplementary source of nutrients (Thorne & Kimsey 1983). Our sample took place during a time period in which el niño had prolonged dry season into a particularly tough drought (Figure 1). This (plus previous reports) supports the hypothesis of drought being a force driving necrophagous behaviour in termites, allowing one to hypothesize that climate change may play a key role in niche exploration by termites and therefore in the rise of new adaptations.

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NOTE

New records of nasutiform termite (Nasutitermitinae: Termitidae: Isoptera) from Meghalaya, India

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Abbreviations: HFL—Hind femur length | HL—Head length without rostrum | HLR—Head length with rostrum | HW—Head width | HWC—Head width at constriction | PL—Pronotum length | PW—Pronotum width | PBH—Posterior buldge of head | PoW—Postmentum width | PoL—Postmentum length | RL—Rostrum length | TBL—Total body length.

Termites are widely distributed group of insects with around 3,106 species present worldwide (Krishna et al. 2013). They are usually more diverse and abundant in the tropical and subtropical regions (Bignell & Eggleton 2000). Among the nine families of termite, Termitidae is the largest family so far with 2072 living species under 238 genera in eight sub-families throughout the globe (Krishna et al. 2013). In India, there are 290 species of termites under 55 genera in six families (Krishna et al. 2013) with the family Termitidae having the highest species composition. The northeastern part of India harbors 76 species under 27 genera in five families (Bose 1999). Nasutitermitinae, a subfamily of Termitidae, is represented by the genera *Nasutitermes, Bulbitermes, Hospitalitermes, Roonowalitermes* from the northeastern region of India. Out of the 76 species from this region, 29 species were reported from Meghalaya under 17 genera (Bose 1999). Recently, Das and Choudhury (2020) also described a new subspecies, *Microcerotermes labioangulatus wahkdaitensis* and recorded the genus *Microcerotermes* and the species *Reticulitermes chinensis* from the state.

In this taxonomic account, which is a part of our study on the termite fauna of Meghalaya, we are reporting first record of two nasutiform termites *Hospitalitermes jepsoni* Snyder, 1934 *and Nasutitermes matangensis matangensis* Haviland, 1898. The genus *Hospitalitermes* Holmgren, 1912 is also documented first time from the state. Morphometrics for the species *H. jepsoni* has also been revised.

Materials and Methods

The specimens studied were collected from different part of Meghalaya and were preserved in 80% alcohol. Measurements of the specimens were done following Roonwal & Chhotani (1989) and Chhotani (1997) using Leica stereo zoom microscope S8AP0 and the identification was done based on available literature and taxonomic keys (Chhotani 1997). The specimens are deposited in the national repository of Zoological Survey of India in the NERC, Shillong.

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Results and Discussion

1. *Hospitalitermes jepsoni* Snyder, 1934

Materials examined: IV/ISOP/ERS/4422, 10.xii.2017, one colony (3 soldiers & 8 workers) and IV/ISOP/ERS/4427, 21.viii.2019, one colony (66 soldiers & 22 workers), Nongkhyllem Reserved Forest, Lailad, Ri Bhoi, Meghalaya, India (25.931^{0}N and 91.776^{0}E), coll. R. Thangkhiew & party and K.S. Das & party, respectively.

Hospitalitermes jepsoni (Image 1) forages above ground mostly on leaf litters in an open air processional column (Miura & Matsumoto 1998). In the procession colums, the number of soldier individuals are comparatively more than the workers. Soldiers of the species are monomorphic whereas the worker individuals are dimorphic.

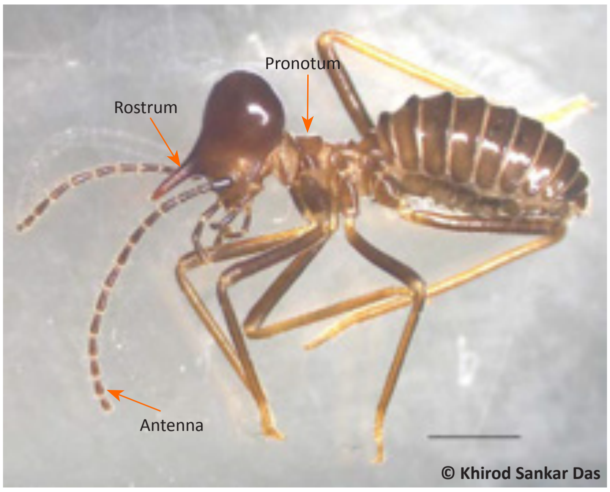

Image 1. Soldier of *Hospitalitermes jepsoni*. Scale 1mm.

Diagnostic features: The head-capsule without rostrum pyriform, strongly constricted behind antennae. Posterior portion of the head dark brown and the anterior portion reddish-brown. Head vertex with two short hairs, rostrum back with three short hairs, one near the base and two at anterior portion. Rostrum cylindrical, base dark brown and anterior portion is light brown with three to four hairs on the tip, its length is slightly more than the half of the head length without rostrum. Antennae are long with 14 segments; segment 3 about two-and-half times of 2, 4 shorter than 3. Mandibles vestigial, each with an elongate, dark brown, pointed, spine like process. Pronotum strongly saddle-shaped. Measurements: HLR 1.85–1.90; HL 1.20–1.27; HW 1.15–1.18; HWC 0.78–0.80; HWC / HW 0.70–0.72; RL 0.63; RL**/** HL 0.50–0.56; PBH 0.48–0.56; PBH/HL 0.40–0.46; PL 0.45; PW 0.60–0.70; PoL 0.28–0.30; PoW 0.45–0.48; HFL 1.80–1.90.

Workers are dimorphic. Worker major: Head-capsule subsquarish; Y-suture prominent. Antennae elongate with 15 segments; segment 3 longer than 2 or 4. Pronotum strongly saddle-shaped. Measurements: HL 1.10–1.15; HW 1.10–1.30; PL 0.40–0.55; PW 0.70–0.80. Worker minor: Antennae with 15 segments and smaller in size. Segment 3 either as long as or slightly longer than 2 or 4. Measurements: HL 0.75–0.90; HW 1.05; PL 0.40; PW 0.59–0.60.

Remarks: Variations in the morphology of the species *H. jepsoni* have not been reported earlier. In this study, we found variation both in the soldier and worker castes from the study area. In comparison to the earlier descriptions of the species available (Chhotani 1997), the head width at the constriction, rostrum length, and hind femur length are found here slightly more in case of the soldier individuals. In case of workers too, the pronotum length, pronotum width, and total body length of both the worker major and minor individuals have shown considerable variation. Though there are variations both in the soldier and worker individuals of the species, that is not enough to designate the species as a new species or subspecies. Therefore, we consider this species as *H. jepsoni* and revise its morphmetrics based on available literature (Chhotani 1997) and the present study (Table 1).

Members of the genus mostly occur in oriental regions except one from Papuan region. Indian region consist of 25 species of the genus (Chhotani 1997). Earlier report of the species *H. jepsoni* was from Assam which was the only report from India.

2. *Nasutitermes matangensis matangensis* Haviland, 1898

Materials examined: IV/ISOP/ERS/4423, 22.i.2018, one colony (3 soldiers & 1 worker), Nongkhrah, Nongpoh, Ribhoi, Meghalaya, India (25.926^{0}N & 91.889^{0}E), coll. K.S. Das & party. Samples were collected from Indian Bay leaf plantation.

Diagnostic features: In case of the species *Nasutitermes matangensis matangensis* (Image 2), the head capsule brownish-yellow to castaneous brown, almost circular, slightly wider than long, in profile not depressed, basal hump distinct. Rostrum brown, darker near tip, conical in shape. Antennae pale brown with 13–14 segments; in 13 segmented antennae, segment 3 almost twice as long as 2; in 14-segmented ones, 3 as long as 2. Mandibles vestigial; with short, spine like processes. Pronotum saddle shaped. Measurements: HLR 1.68–2.00; HL 0.95–1.23; HW 1.15–1.33; RL 0.63–0.78; RL **/** HL 0.60–0.65; PL 0.24–0.25; PW 0.39–0.69; PoL 0.28–0.33; PoW 0.35–0.40.

Workers are dimorphic. Head brown; body whitish

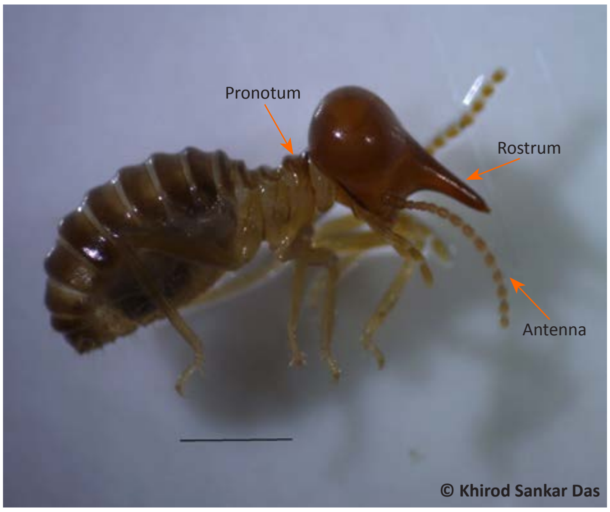

Image 2. Soldier of *N. matangensis matangensis*. Scale 1mm.

to reddish-yellow. Head and body thinly hairy. Head-capsule squarish; head sutures and fontanelle distinct. Antennae with 14 segments; segment 3 a little longer than 2, 4 shorter than 2. Pronotum saddle shaped. Worker minor. Measurements: HL 1.00; HW 1.14–1.18; PL 0.35; PW 0.53–0.58.

Remarks: In the specimens studied, some of the diagnostic characters of the soldier caste are similar to the species *Nasutitermes matangensiformis* and some are similar to *Nasutitermes matangensis matangensis*. The upper range of the head length with rostrum, head width and the rostrum length and rostrum index is similar with the values of *N. matangensis matangensis* and rest of the characters in the soldier individuals match with *N. matangensiformis*. Though the samples have shown similarity with *N. matangensis matangensis* and *N. matangensiformis* in their morphology, the characters with greater taxonomic values are similar to that of *N. matangensis matangensis*. On the other hand, the species *N. matangensiformis* has been designated elsewhere as the junior synonym of *N. matangensis matangensis* (Krishna et al. 2013; Amina et al. 2016). Thus, we consider the species as *Nasutitermes matangensis matangensis*. This species was earlier reported from Little Andamans, Nicobars, Arunachal Pradesh, and here, this species is reported for the first time from Meghalaya (Nongkhrah, Nongpoh), India.

With these two new records of nasutiform termite from Meghalaya, the number of termite species found in the state increases from 31 to 33 and the number of genera from 18 to 19. This communication will also help in the identification of the species *H. jepsoni* from this region without any confusion with its revised morphometrics in future.

Table 1. Revised morphometrics for *H. jepsoni* from Meghalaya, India.

	Soldier (in mm)	Worker major (in mm)	Worker minor (in mm)
TBL	4.00–5.20	4.00–5.20	3.00–3.75
HLR	1.78–1.95	–	–
HL	1.09–1.35	1.10–1.15	0.75–0.90
HW	0.98–1.30	1.10–1.30	1.00–1.13
HWC	0.70–0.80	–	–
HWC/HW	0.63–0.72	–	–
RL	0.55– 0.63	–	–
RL/HL	0.50–0.56	–	–
PBH	0.40–0.56	–	–
PBH/HL	0.33–0.46	-	–
PL	0.30–0.48	0.40–0.55	0.30–0.40
PW	0.60–0.70	0.70–0.80	0.50–0.60
PoL	0.28–0.30	–	–
PoW	0.45–0.48	–	–
HFL	1.70–1.90	–	–

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CORRIGENDUM

Corrections to A citizens science approach to monitoring of the Lion *Panthera leo* (Carnivora: Felidae) population in Niokolo-Koba National Park, Senegal

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Following publication of this article on 26 January 2020 (*Journal of Threatened Taxa* 12(1): 15091–15105) <https://doi.org/10.11609/jott.5549.12.1.15091-15105>, the authors were able to re-examine all of the collected photographs with Sara Blackburn, an expert in lion identification. In addition to the whisker spot patterns employed for identification in our original study, we took account of the following supplementary characteristics: (i) the shape of the whisker spot lines, (ii) the lines of additional whisker spots next to the nose, (iii) the general shape and pattern of the "creases" down and across the nose and of the "eyebrows" and (iv) the pattern of spots on the forehead (especially for photos taken within a period of three months). Only in the case of multiple matches of supplementary characteristics, correspondence of available partial whisker spot patterns, and an absence of contradictory data were two lions considered to be identical.

As a result of this analysis, for which we gratefully acknowledge the assistance of Ms. Blackburn, two nearly certain duplicate identifications and one additional potential duplicate identification were detected relative to our original article. A corrected section on **Identification of individual lions** is reproduced below; no other parts of the article require correction.

Identification of individual lions

Tourist parties submitted photographs and videos of 22 lion observations, using equipment ranging from smartphones to professional level cameras. On the basis of the best of these images, identification sheets for 8 individual lions, described in Table 4, were established and have been made available at http://niokolo-safari.com/lions.htm

It is noteworthy that three of the five identified females were re-sighted during the study (and that two of the identified females may have been a single individual), but that none of the three identified males were definitively re-sighted (although it is possible that two of them were the same individual). This is consistent with the existence during the latter part of the study period, when individual lions could be identified, of a core local population of four or more adult lionesses and a lesser number of males who may have been more mobile, possibly due to their larger home ranges and/or biome preferences as discussed below.

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Table 4. Summary of individual lions identified from photographs (* and + = possible shared identity; ? = possible re-sighting)

File number	Name of lion	Sex	Estimated birth year	First observed	Characteristics	Relationships	Re-sightings
1	Alakay*	M	2014–2015	15.i.2017	Whisker spots left side	Possibly same as Kaly, seen with three possible brothers and possible mother	
2	Fidji	M	2009–2013	09.ix.2017	Whisker spots left and right, multiple scars	Seen with Gia	
3	Gia	F	<2010	09.ix.2017	Whisker spots left and right, multiple scars, vitreous right eye	Seen with Fidji	
4	Dinbadjinma	F	2015	15.xi.2017	Whisker spots left and right sides, possible deformed right ear	Seen with Awa (possible sister) and possible mother, then with Banna	24.xii.2017 21.i.2019? 16.ii.2019
5	Awa	F	2015	15.xi.2017	Whisker spots left and right sides	Seen with Dinbadjinma (possible sister) and possible mother, then with Adama	24.xii.2017 08.ii.2018 12.ii.2018? 03.iv.2018?
6	Adama+	F	2010–2013	08.ii.2018	Whisker spots left side, scar on left hind leg	Possibly same as Banna, seen with Awa	03.iv.2018
8	Banna+	F	2013–2015	16.ii.2019	Whisker spots right side, scars on right front leg and at base of tail	Possibly same as Adama, seen with Dinbadjinma	
10	Kaly*	M	2012–2015	30.iv.2019	Whisker spots right side and partially on left, badly scarred muzzle, broken upper left canine	Possibly same as Alakay, seen with 2 other lions	

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