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43/2 Varadarajulu Nagar, 5th Street West, Ganapathy, Coimbatore, Tamil Nadu 641006, India
Registered Office: 3A2 Varadarajulu Nagar, FCI Road, Ganapathy, Coimbatore, Tamil Nadu 641006, India
Ph: +91 9385339863 | www.threatenedtaxa.org
Email: sanjay@threatenedtaxa.org

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Cover: Mauve Stinger *Pelagia noctiluca* by Swaathi Na. Medium used is soft pastels and gelly roll.

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ARTICLE

Inventory and abundance of non-volant mammals and birds in the unprotected regions of the Mount Apo Range, Philippines

Jhonnel P. Villegas [1], Jireh R. Rosales [2], Giovanne G. Tampos [3] & Jayson C. Ibañez [4]

[1] Faculty of Education and Teacher Training, Davao Oriental State University, City of Mati, Davao Oriental, 8200 Philippines.
[1] Center for Futures Thinking and Regenerative Development, Davao Oriental State University, City of Mati, Davao Oriental, 8200 Philippines.
[2,3] Faculty of Agriculture and Life Sciences, Davao Oriental State University, City of Mati, Davao Oriental, 8200 Philippines.
[4] Philippine Eagle Foundation, Davao City, Davao del Sur, 8000 Philippines.
[4] University of the Philippines Mindanao, Davao City, Davao del Sur, 8000 Philippines.
[1] jhonnel.villegas@dorsu.edu.ph (corresponding author), [2] jirehr8@gmail.com, [3] giovanne.tampos@dorsu.edu.ph,
[4] ibanez.jayson@gmail.com

Abstract: Wildlife, such as non-volant mammals and birds, play a vital role in the maintenance of ecosystem health. They are considered ecological engineers that influence forest vegetation. However, due to deforestation, habitat loss, and human persecution, its population status has declined over the years. This study aimed to conduct a species inventory and assess the relative abundance of non-volant mammals and birds in the unprotected regions of the Mt. Apo Range, Philippines, through camera trapping methods. Furthermore, the anthropogenic threats observed in the study areas were also documented. A total of 1,106 camera trap days were carried out in 2016 and another 500 days in 2020. Based on 260 independent sequences for both the 2016 and 2020 surveys, 12 species were identified, consisting of eight non-volant mammals and four birds. Among the identified species are the Endangered Philippine Brown Deer *Rusa marianna* & Philippine Long-tailed Macaque *Macaca fascicularis philippensis* and the Vulnerable Giant Scops-owl *Otus gurneyi* & the Philippine Warty Pig *Sus philippensis*. Video evidence of the Philippine Warty Pig *Sus philippensis* performing an important ecological role as an ecological engineer in the Philippine tropical forests were also captured for the first time. Another 61 independent sequences of unidentified rodents were detected in the camera traps, requiring further species monitoring techniques. Conservation must be strengthened beyond the protected landscapes of the Mt. Apo Range through community-based forest governance. This will ensure that the forest vertebrates are protected and conserved from further anthropogenic pressures.

Keywords: Forest vertebrates, species inventory, relative abundance, Mt. Apo Range, Philippines.

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INTRODUCTION

Forest health has always been linked with rich biodiversity. Vertebrate species are known to be ecologically important, playing various roles in the environment (Zhang et al. 2018, 2020; Carreira et al. 2020). Mammals regulate prey populations, facilitate seed dispersal and pollination, shape vegetation patterns, and act as bioindicators of ecosystem health (Lacher et al. 2019). On the other hand, avian species are important pollinators, scavengers, predators, seed dispersers, and ecosystem engineers (Filho & Faria 2017; Villegas et al. 2022b).

Unfortunately, the ever-increasing environmental degradation led to the rapid decline of vertebrate populations, including non-volant mammals and avian species. Several members of these taxa face extinction risks due to human persecution and narrowed geographic ranges (Ripple et al. 2017). Some of the largest mammals in Philippine forests, including Philippine Brown Deer *Rusa marianna* and Philippine Warty Pig *Sus philippensis* are now Endangered and Vulnerable, respectively (Biodiversity Management Bureau – Department of Environment and Natural Resources 2020; Ong & Richardson 2008). Just recently, the previously categorized "Near-Threatened" Philippine Long-tailed Macaques *Macaca fascicularis philippensis* is now "Endangered" in view of the continued deforestation, hunting, and trapping, among others (Hansen et al. 2022). Also, although some mammals common in Mindanao forests such as the Philippine Tree Squirrel *Sundasciurus philippinensis*, Large Mindanao Forest Rat *Bullimus bagobus*, Common Philippine Forest Rat *Rattus everetti*, Mindanao Treeshrew *Urogale everetti*, and Palm Civet *Paradoxurus hermaphroditus* are categorized as "Least Concern", many of its local sub-populations are actually undergoing declines (Heaney 1993; Ibanez et al. 2004; Roxas et al. 2005; Balete et al. 2006; Tanalgo 2015). Additionally, the population of bird species, such as the Vulnerable Giant Scops-owl *Otus gurneyi* and Mindanao Bleeding-heart *Gallicolumba crinigera* was observed to be declining due to anthropogenic pressures (BirdLife International 2017).

Mount Apo Range is an important Key Biodiversity Area (KBA) in the Philippines. Large portion of the KBA is within the 64,000 hectare (ha) Mt Apo Natural Park - a protected area under the country's National Integrated Protected Areas System (NIPAS) Act. As such, it has been the subject of several biodiversity conservation initiatives. However, a significant portion of secondary and natural forests of the mountain range are left unprotected and, thus, receive fewer conservation initiatives. More importantly, at least three ancient nesting sites of the IUCN Critically-Endangered Philippine Eagle *Pithecophaga jefferyi* were documented in these unprotected areas (Abaño et al. 2015; Sutton et al. 2023). This called for intensive forest governance and conservation programs beyond the protected landscapes.

The present study documents the non-volant mammals and bird species in the non-NIPAS unprotected areas of the Mount Apo Range. This aims to enhance baseline data of wildlife populations outside the protected zone to pursue community-based wildlife protection. Several sites were surveyed through camera trapping techniques in Davao, Magpet, and Arakan (Table 1). This is a preliminary study on the inventory and abundance of non-volant mammals and birds in these areas, which are critical to guide policymakers, implementers, and environmental advocates in the region to pursue the much-needed conservation of these taxa.

MATERIALS AND METHODS

Study Area

Figure 1 shows the study area in the unprotected regions of the Mt. Apo Range, southern Mindanao, Philippines. Mount Apo Natural Park, a portion of the range consisting of 64,000 ha, has been declared a protected landscape under the National Protected Areas System through Republic Act No. 9237. It was also included in the UN List of National Parks and Equivalent Reserves and acknowledged as an ASEAN Heritage Site. Species surveys were conducted in areas in Davao City, Arakan, and Magpet in 2016. Another expedition was completed in 2020 in Davao City.

Camera Trapping

Camera trapping has been widely used in wildlife monitoring. It is a non-invasive monitoring tool employed for many forest vertebrates such as the Philippine Pangolin *Manis culionensis*, Philippine Warty Pig *Sus philippensis*, and deer *Rusa* spp. (Ingram et al. 2019; Willcox et al. 2019; Villegas et al. 2022a,b; Ali et al. 2020). Kays et al. (2011) reported that camera trapping is ideally used when direct observation methods are difficult or costly. It is less laborious and yields robust data, which is particularly useful for obtaining baseline data for important conservation decisions.

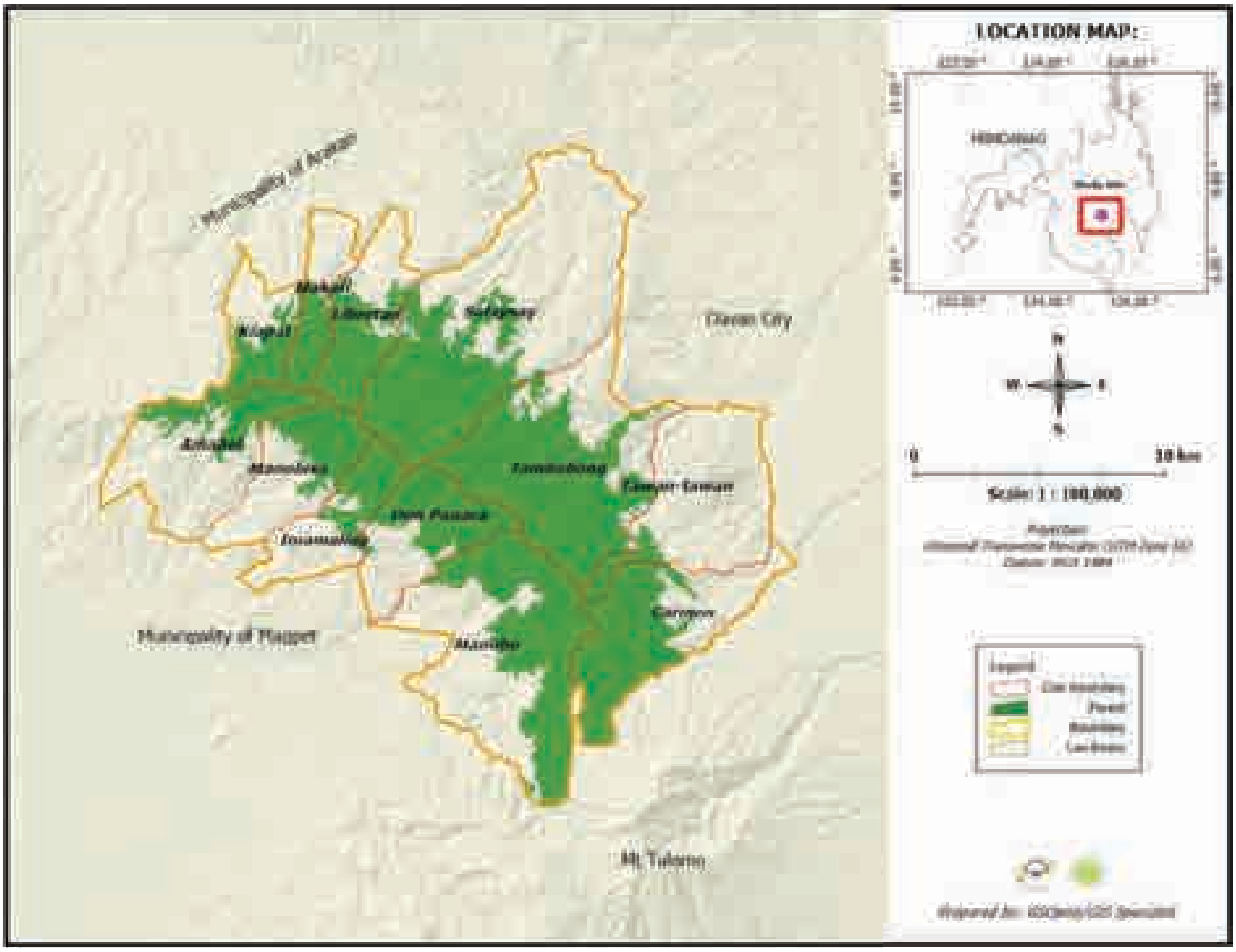

Figure 1. Study Areas within the Mount Apo Range, Philippines. (Cartographer: Guiller Opiso).

In 2016, four HCO Scoutguard SG560C camera traps were used. The cameras have a highly-sensitive passive infra-red (PIR) motion sensor that can take high-quality photos up to 8 megapixels and with a detection range of up to 25 m (82 ft). The same cameras were used in 2020, with additional six Bushnell Trophy Cam HD aggressor no-glow trail camera traps. This type also has a high PIR motion sensor, 48-LED no-glow flash, high-resolution stills, and takes up to 20 megapixels of high-definition video. These camera traps were set to capture three consecutive photos followed by a 30-second video upon detection of any movement in its range.

For the first round of the survey in 2016, a total of 79 camera stations were established in the study areas. In the Davao area, eight camera stations were installed along the 2-km transect line in Brgys. Salaysay, Tambobong, and Tawan-Tawan while 12 camera stations along 3-km transect line in Brgy. Carmen. All camera traps were left for 14 days; thus, a total of 36 camera stations and 504 camera trap days were done in Davao. In the Arakan area, eight camera stations were established along a 2-km transect line in each barangay (Brgy. Libertad, Kiapat, and Macati). These camera traps were also left for 14 days; thus, a total of 24 camera trap stations and 336 camera trap days were done in the Arakan area. Lastly, 19 camera stations were established along a 4.5-km transect in the Magpet area (Brgy. Don Panaca and Manobo) for a total of 266 camera trap days. The camera traps installed in all areas had an interval of 250 m away from the next camera trap

Table 1. Summary of the geo-coordinates and the range elevation in the sampling areas.

Sampling areas	Coordinates	Elevation range (m)
Arakan	7.1973^{0}N, 125.2404^{0}E; 7.1828^{0}N, 125.1790^{0}E	1,200–1,500
Davao	7.1255^{0}N, 125.3159^{0}E; 7.1281^{0}N, 125.3182^{0}E	1,448–1,709
Magpet	7.1727^{0}N, 125.2037^{0}E ; 7.1447^{0}N, 125.2453^{0}E	1,150–1,500

and were attached to a tree 1.5 m above the ground. Overall, a total of 1,106 camera trap survey days were conducted to monitor the mammals and bird species in these areas.

In the second set of surveys in 2020, a total of 40 camera stations (Brgy. Carmen, Salaysay, Tambobong, and Tawan-Tawan) in Davao City were installed. A 2.5-km transect line was established in the forested areas of each barangay. Ten camera traps were left within the transect line for 12.5 days (125 camera trap days) before they were moved to the next barangay. Each camera was set at least 250 m away from another camera and approximately 1.5 m above the ground attached to a tree. Overall, 500 camera trap days were completed in all four stations in the 2020 survey.

Image and video sequences were downloaded and stored in a computer hard drive, in an external hard drive and a backup at the Google drive. Each image sequence with captured species are properly marked and labeled including the species, group size, date, time, and location (Kays et al. 2011) to show frequency of detection of each species and the temporal distribution of activity. The image sequence was also rated dependent or independent following Data et al. (2008); independent sequence are a) consecutive photographs of different individuals of the same or different species, b) consecutive photographs/videos of individuals of the same species taken more than 0.5 h apart, and c) non-consecutive photos of individuals of the same species.

Relative Abundance Index (RAI)

Relative Abundance Index is the most widely used index for camera-trapping data. In this study, RAI is the ratio between non-volant mammals and birds detection based on the photographic capture rates from camera trap surveys and the entire trapping days. To get the RAI, the total number of independent sequences detected is divided by the total trapping days and then multiplied by 100 (Jenks et al. 2011). Image sequences were rated or classified as dependent or independent following Tanwar et al. (2021). Only the independent sequences were used to compute the RAI.

Ethics

This study is based on a community-solicited project for efficient forest governance within the surveyed culturally-protected landscapes. It is part of the continuing project led by the Philippine Eagle Foundation in partnership with the local indigenous communities. The Obu Manuvu tribal leaders and elders signed Resolution No. 1, s. 2019, permitting the investigators to gather data in the study sites. Community rituals were also conducted before the fieldwork according to the tradition of the indigenous community.

RESULTS AND DISCUSSION

Species Composition

The survey conducted in the Davao, Arakan, and Magpet areas of Mt. Apo Range in 2016 reached a total of 1,106 camera trapping days, whereas surveys conducted in 2020 in Davao area yielded a total of 500 camera trapping days, for a total of 1,606 camera trapping days. From these surveys, 12 different forest vertebrate species were detected, of which eight species are non-volant mammals, while four species are forest birds (Table 2). The non-volant mammals include the Philippine Brown Deer, Philippine Warty Pig, Philippine long-tailed macaque, Common Palm Civet *Paradoxurus hermaphroditus*, Mindanao Tree Shrew *Urogale everetti*, Philippine Pygmy Squirrel, Philippine Forest Rat *Rattus everetti*, and Mindanao Bullimus *Bullimus bagobus* (Image 1). On the other hand, the avian species documented were the Giant Scops-owl, Bagobo babbler *Leonardina woodi*, Wild Jungle Fowl *Gallus gallus*, and Crested Goshawk *Accipiter trivirgatus*.

Non-Volant Mammals

Non-volant mammals from the 2020 survey recorded 61 individuals (independent sequences) representing six species (and some unidentified species of probably the same genus *Bullimus* and *Rattus*). The same species were observed in the 2016 surveys, which recorded 199 individuals (independent sequences) representing eight species, including *R. marianna*, *S. philippensis*, *M. fascicularis philippinensis*, *P. hermaphroditus*, *U. everetti*, *E. concinnu*, *R. everetti*, and *B. bagobus*. Among these, 7 out of 8 species are endemic in the Philippines (Table 3). The endemic *R. marianna* was recently categorized by the Department of Environment and Natural Resources Administrative Order (DAO) No. 2019 (2019) as endangered, while *S. philippensis* is Vulnerable. The endemic *M. fascicularis philippinensis* was also recently categorized from Vulnerable to Endangered by Hansen et al. (2022), while the remaining three endemic species *U. everetti*, *E. concinnus*, and *R. everetti* were categorized as Least Concern. Finally, the southeastern Asian endemic *P. hermaphroditus* was also categorized as Least Concern (Duckworth et al. 2016).

Sus philippensis was the most abundant species

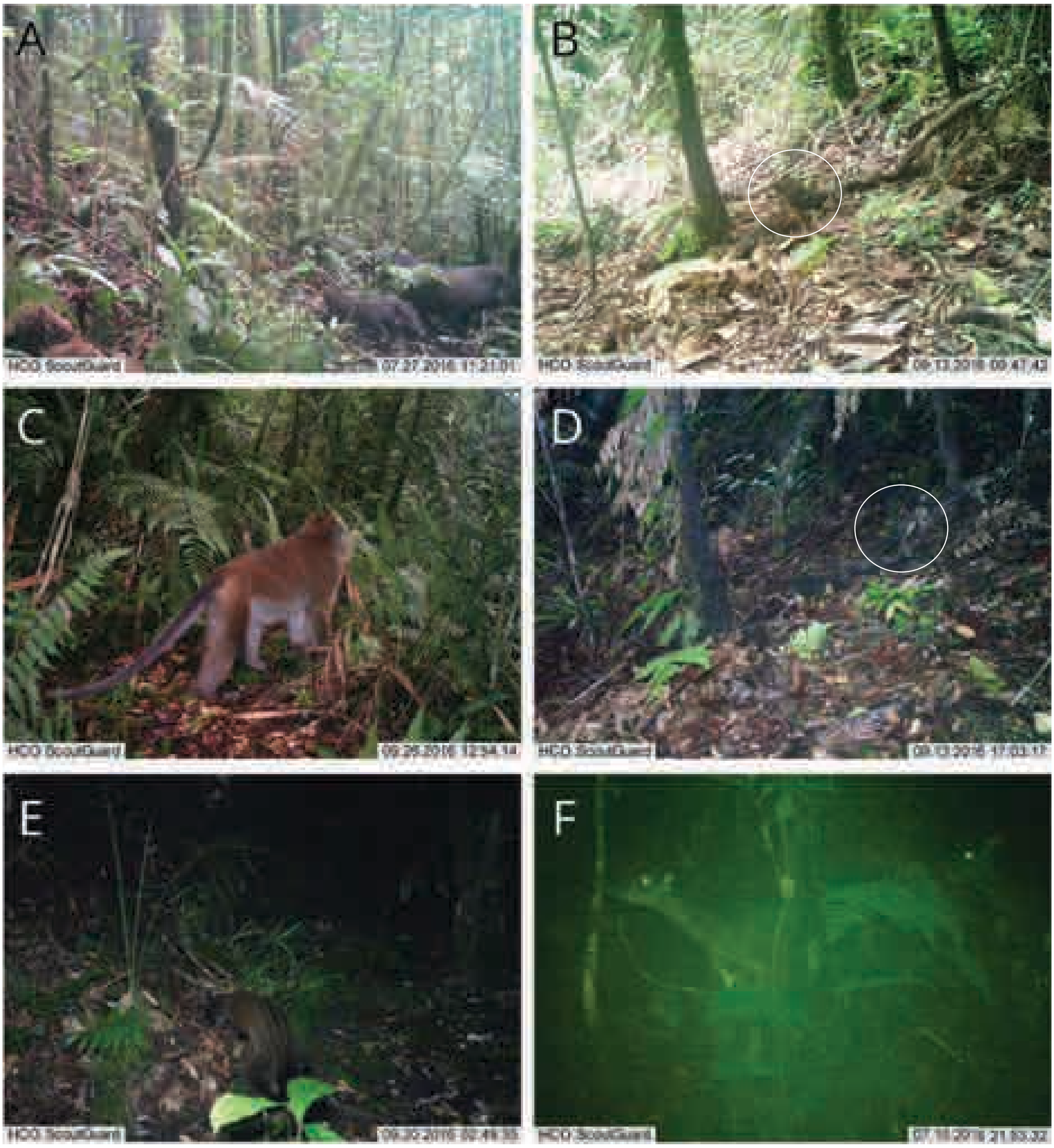

Image 1. Documented species in the Mount Apo Range: a—*Sus philippensis* Nehring, 1886 | b—*Urogale everetti* (Thomas, 1892) | c—*Macaca fascicularis philippinensis* (I. Geoffroy, 1843) | d—*Exilisciurus concinnus* (Thomas, 1888) | e—*Paradoxurus hermaphroditus* (Pallas, 1777) | f—*Rusa marianna* (Desmarest, 1822). © DOrSU, PEF, USAID, UNDP, GEF.

from the 2020 survey in the four barangays of the Davao area (10 individuals, RAI = 2.0). Similarly, it also had the highest number of individual counts from the 2016 survey in the Davao Area (15 individuals) and Arakan (18 individuals). Meanwhile, the *M. fascicularis philippinensis* was the most abundant species in Magpet Area (14 individuals) during the 2016 survey. The number of photographed individuals of the other five species from the 2020 survey ranged from one to nine (Table 3). In the 2016 survey, *M. fascicularis philippinensis* (RAI = 2.71), *P. hermaphroditus* (RAI = 2.26), and *U. everetti* (RAI = 2.35) have an almost similar number of individuals with 30, 25, and 26 captured individuals, respectively. The remaining four species

Table 2. Relative abundance index (RAI) of non-volant mammal and bird species in Mount Apo Range, Philippines (2016).

Species	Common name	Independent sequences			Total	Trap-days	RAI
		Davao	Arakan	Magpet			
Mammals							
Bullimus bagobus Mearns, 1905	Mindanao Bullimus	1	0	0	1	1,106	**0.09**
Exilisciurus concinnus (Thomas, 1888)	Philippine Pygmy Squirrel	3	1	0	4	1,106	**0.36**
Macaca fascicularis philippinensis (I. Geoffroy, 1843)	Philippine Long-tailed Macaque	13	3	14	30	1,106	**2.71**
Paradoxurus hermaphroditus (Pallas, 1777)	Asian Palm Civet	11	11	3	25	1,106	**2.26**
Rusa marianna (Desmarest, 1822)	Philippine Brown Deer	5	6	2	13	1,106	**1.18**
Rattus everetti (Günther 1879)	Philippine Forest Rat	2	10	0	12	1,106	**1.08**
Sus philippensis Nehring, 1886	Philippine Warty Pig	15	18	4	37	1,106	**3.35**
Urogale everetti (Thomas, 1892)	Mindanao Treeshrew	4	17	5	26	1,106	**2.35**
Unidentified Rodent		18	9	13	40	1,106	**3.62**
Birds							
Accipiter trivirgatus (Temminck, 1824)	Crested Goshawk	0	1	0	1	1,106	**0.09**
Gallus gallus (Linnaeus, 1758)	Red junglefowl	0	1	0	1	1,106	**0.09**
Leonardina woodi (Mearns, 1905)	Bagobo babbler	0	1	5	6	1,106	**0.54**
Otus gurneyi (Tweeddale, 1879)	Giant Scops-owl	0	3	0	3	1,106	**0.27**

Table 3. Relative abundance index (RAI) of non-volant mammal species in Davao area of Mount Apo Range, Philippines (2020).

Species	Common name	Independent sequences				Total	Trap-days	RAI
		Tambobong	Salaysay	Tawan-tawan	Carmen			
Mammals								
Exilisciurus concinnus (Thomas, 1888)	Philippine Pygmy Squirrel	2	0	1	1	4	500	**0.8**
Macaca fascicularis philippinensis (I. Geoffroy, 1843)	Philippine Long-tailed Macaque	0	4	1	0	5	500	**1.0**
Paradoxurus hermaphroditus (Pallas, 1777)	Asian Palm Civet	0	4	2	3	9	500	**1.8**
Rusa marianna (Desmarest, 1822)	Philippine Brown Deer	0	1	1	1	3	500	**0.6**
Sus philippensis Nehring, 1886	Philippine Warty Pig	4	6	0	0	10	500	**2.0**
Urogale everetti (Thomas, 1892)	Mindanao Treeshrew	2	1	2	4	9	500	**1.8**
Unidentified rodent		1	6	4	9	21	500	**4.2**

have an individual count ranging from 1 to 13 (Table 3). Both surveys recorded 21 individual sequences (2020) and 40 individual sequences (2016) of rodents that cannot be identified at the genus and species level.

Birds

The camera traps also recorded interesting bird behavior during the survey in 2016, particularly in Magpet and Arakan areas, while none was observed in Davao City both in the 2016 and 2020 surveys. Four species of birds were recorded, initially identified as the two endemic *O. gurneyi*, and *L. woodi*. The other two are the non-endemic *G. gallus* and *A. trivirgatus*. Among these, the *O. gurney* was categorized as Vulnerable (BirdLife International 2017), while the three remaining species were categorized as Least Concern (Table 3).

The Giant Scops-owl *O. gurneyi* and Crested Goshawk *A. trivirgatus* were recorded in a puddle of water occupied previously by *S. philippensis*. Most of the behavior recorded was during daytime and nighttime. *O. gurneyi* and *A. trivirgatus* were captured bathing in the same puddle. It was observed and recorded that more rainfall occurred at night, forming a wet patch. This only shows the importance of resource availability, including rich soil, abundant moisture, many trees, and regular inputs of nutrients and biological materials from the

Table 4. Distribution and conservation status of non-volant mammal and bird species in Mount Apo Range, Philippines.

Species	Common name	Geographic range	Site distribution	Conservation	References
Mammals					
Exilisciurus concinnus	Philippine Pygmy Squirrel	Endemic	Davao, Arakan	Least Concern	IUCN, 2016
Bullimus bagobus	Mindanao Bullimus	Endemic	Davao	Least Concern	IUCN, 2016
Macaca fascicularis philippinensis	Philippine Long-tailed Macaque	Endemic	Davao, Arakan, Magpet	Endangered	IUCN, 2022
Paradoxurus hermaphroditus	Common Palm Civet	Southeast Asia	Davao, Arakan, Magpet	Least Concern	IUCN, 2016
Rusa marianna	Philippine Brown Deer	Endemic (introduced in Guam)	Davao, Arakan, Magpet	Endangered	DENR DAO 2019-09
Sus philippensis	Philippine Warty Pig	Endemic	Davao, Arakan, Magpet	Vulnerable	DENR DAO 2019-09
Urogale everetti	Mindanao Tree shrew	Endemic	Davao, Arakan, Magpet	Least Concern	IUCN, 2019
Rattus everetti	Philippine Forest Rat	Endemic	Davao, Arakan	Least Concern	IUCN, 2016
Birds					
Accipiter trivirgatus	Crested Goshawk	Resident	Arakan	Least Concern	IUCN, 2016
Gallus gallus	Red Junglefowl	Resident	Arakan	Least Concern	IUCN, 2016
Leonardina woodi	Bagobo Babbler	Endemic	Arakan, Magpet	Least Concern	IUCN, 2016
Otus gurneyi	Giant Scops-owl	Endemic	Arakan	Vulnerable	IUCN, 2017

forest. These parameters are essential for avian species, especially those understory key species (Klapproth & Johnson 2009; Mohagan et al. 2015).

The most abundant species of bird based on captured individual sequences was the endemic *L. woodi* (six individuals, RAI = 0.54), followed by the vulnerable *O. gurneyi* (three individuals, RAI = 0.27), and then the non-endemic *G. gallus* and *A. trivirgatus* (one individual, RAI = 0.09) (Table 3). Regarding species richness, the Arakan area of the Mt. Apo range had the highest species account (four species), followed by the Magpet area (one species), while none was observed in the Davao area.

The number of detected bird species and their RAIs is relatively low compared to the other bird survey studies using the camera trap method. No published studies are available yet in the Philippines on bird surveys using the camera trap method, but several studies from nearby countries are available. Naing et al. (2015) documented 16 species of birds in the Hukaung Valley of Northern Myanmar using 403 camera traps for a total of 7,452 trap-nights, whereas Pla-ard et al. (2021) recorded 23 species of birds in the limestone habitats in Central Thailand using 40 camera traps over a period of two years. Possible reasons for the low species richness in this study could be the number of camera trap stations and camera trap days used. Kays et al. (2020) recommended that a total of 25 to 35 camera trap locations should be used per study area to monitor the diversity of wildlife within an area. Moreover, another factor could be the location of the camera trap. It is recommended to also place the camera trap at a distance of 2.5 to 5 m above the ground in order to capture birds at the mid-canopy or upper canopy of the trees (Meek et al. 2012; Pla-ard et al. 2021). Because the camera traps were placed close to the ground, it was biased towards capturing birds of the forest floor.

Distribution and Conservation Status

Of all the recorded mammals, *S. philippensis*, *M. fascicularis philippinensis*, *R. marianna*, *P. hermaphroditus*, and *U. everetti* were common since they were detected in all the study areas (Table 4). Unfortunately, some previously recorded mammal species on Mt. Apo, such as the Mindanao Flying Squirrel *Petinomys mindanensis* and the threatened Philippine Tarsier *Carlito syrichta* were not observed in this study. This could be because they inhabit other areas not covered in this study. On the other hand, the rarely encountered Mindanao Bullimus *Bullimus bagobus* was recorded only in the Davao area and was absent in both Arakan and Magpet areas. Overall, these endemic species and other flora and fauna made Mindanao the most important island in the Philippines, followed by Luzon and Palawan in terms of species richness and degree of endemicity (Lewis 1988).

S. philippensis was observed in all study areas and recorded the highest number of individuals. This could be attributed to the camera trap locations within the forest interior with recorded human activities. It can be found in the forest's innermost or remote areas since it is sensitive to human disturbances. However, others have noted that it also tends to be active in areas with fewer anthropogenic disturbances (Podgorski et al. 2013; Johann et al. 2020; Villegas et al. 2022a,b). Moreover, it is also noted to roam in groups, searching for food (Relox et al. 2009). Warty pigs were observed roaming at night, but most were photographed during the day.

M. fascicularis philippinensis was the second most abundant species in the study areas. It is known to be distributed in anthropogenic and non-anthropogenic areas (Hansen et al. 2021). Long-tailed Macaques, due to their synanthropic nature, can inhabit diverse habitats, including deciduous forests, evergreen forests, savannah, mangroves, and beaches, from sea level up to 1900 m (Fooden 1995; Thierry 2007; Yanuar et al. 2009; Gumert et al. 2011a; Hansen et al. 2021). It can also consume various diets, including human foods (Sha & Hanya 2013; Hansen et al. 2021). On the other hand, *P. hermaphroditus* can be found in agricultural, lower, and upper montane forests from sea level up to at least 2,400 m. Accordingly, it is active mostly at night, feeding on a wide range of fruits, invertebrates, and vertebrates (Heaney et al. 2016). However, it was also observed during the daytime in this study.

The endemic and endangered *R. marianna* was also observed in all study areas in the 2016 survey but was rare during the 2020 survey in the Davao area. Most of the deer were documented grazing at night in the upper montane forest from 1000 m and higher.

However, footprints and fecal pellets were observed in the lower montane forest. Because they are highly sensitive to human presence, severely hunted, and limited in habitat, they are now found only in isolated forests (Oliver et al. 1992; Heaney et al. 1999, 2006).

The non-volant small mammals *U. everetti* and *R. everetti* were present in all study areas, while *B. bagobus* was absent in Arakan and Magpet, and *E. concinnus* was absent in the Magpet area. *R. everetti* is known to tolerate a range of habitat modifications, while *U. everetti* occurs in the primary forest from 750 m to 2,500 m (Heaney et al. 1998, 2006). On the other hand, *E. concinnus* can be found in primary and secondary lowland and montane forests from sea level to 2,000 m, while *B. bagobus* is widespread in lowland to the mossy forest from 200 m to 1,800 m (Heaney et al. 1998, 2006). The same observations were found in the present study. The low captures of these species can be attributed to the methods used. A combination of local traps and camera trapping methods might result in more detections of these species in the forest (Balete et al. 2006).

Low number of species richness was observed for bird species. Only four species were captured in the camera traps, including two Mindanao PAIC endemics, Giant Scops-owl *Otus gurneyi* and Bagobo Babbler *Leonardina woodi*, and the resident species Crested Goshawk *Accipiter trivirgatus* and Red Jungle Fowl *Gallus gallus*. Of these, the Giant Scops-owl is categorized as Vulnerable by BirdLife International (2017) in view of the rapid decline of its small population and severe fragmentation due to extensive deforestation. The remaining three species are still considered Least Concern by International Union for Conservation of Nature. The Mindanao endemic *L. woodi* was observed in both Arakan and Magpet, while the remaining three species were documented only in Arakan areas. Consistently, no species of birds were recorded in Davao areas both in the 2016 and 2020 surveys despite having almost the same forest structure and degree of disturbance with Arakan and Magpet. The possible reason for this might be the location of the camera trap. Davao area still has a large forest cover compared to Magpet and Arakan, where only limited forest cover remains due to the expansion of human settlement. Given that Magpet and Arakan only have a limited forest cover, bird species richness and relative abundance might be lower at these sites. Another probable reason for the documented low bird species richness is the elevation of the study areas. Several studies have shown that elevation has inverse effects on the diversity and richness of birds because it also negatively affects the vegetation structure (Kattan & Franco 2004; McCain 2009; Derhe et al. 2022). Tanalgo et al. (2019) and Gracia et al. (2021) revealed that more endemic and threatened species of birds were observed in lowland forests in Mt. Hilong-hilong and other areas in southern Mindanao. Given that in this study, the sites were found in Montane to the mossy forest with an elevation ranging 1,100–1,700 m, it could account for the low bird species detection rate. However, this result should be carefully analyzed as the number of camera trap days per site vary. Additionally, the camera trapping method employed in this study has limitations, such as the limited range the camera can detect and the location of the camera trap in the tree where it was installed. Additional surveys should be conducted utilizing various methods aiming for bird diversity and richness to understand the ecology of this taxon in the unprotected areas of the Mt. Apo Range.

Philippine Warty Pigs as ecological engineers

A single camera trap during the 2016 survey captured videos of at least three species that used the same Philippine Warty Pig wallowing hole as drinking and bathing spots at different times of the day. At nighttime, *R. marianna* and *O. gurneyi* used the wallowing hole, while *A. trivirgatus* used it during daytime. This is the first documentation in the Philippines of other forest vertebrates drinking and bathing from the wallowing pit of a Philippine Warty Pig. Wallowing is a very important behavior and provides multiple physiological and welfare benefits to warty pigs (Bracke 2011; Bracke & Spoolder 2011). Wild pigs are regarded as ecological engineers because of their ability to disturb the soil and enhance vegetation succession (Fujinuma & Harrison 2012). The videos provide evidence that warty pigs also create important water holes that fulfill the physiological and other welfare needs of its wildlife co-inhabitants.

Anthropogenic Threats

Camera trapping methods recorded at least three species of IUCN "threatened" species (one endangered, and two vulnerable species) and one IUCN "Near-Threatened" species. Mt Apo Range was once declared by the IUCN as one of the world's most threatened protected natural areas (Lewis 1988). Parts of the unprotected regions of the Mt. Apo Range overlap with the Obu Manuvu Ancestral Domain (OMAD), inhabited mainly by the Obu Manuvu people. They consider the forest as 'Pusaka', an indigenous practice to sanctify biotic and abiotic materials that have cultural value to the community (Villegas et al. 2022a,b). With these, hunting any wildlife species in most parts of the forest is highly prohibited. Only traditional hunting at certain places is allowed, provided a ritual must be performed before hunting. Thus, the use of camera traps to conduct surveys in their lands gained a positive response from the local inhabitants since no wildlife, which they believe to be 'Pusaka', was harmed during the duration of the study. Despite such indigenous conservation practices, the following are the other threats observed in the area.

Unregulated Forest Clearing

The most severe pressure documented at the site is the unregulated clearing of forested areas. Around three hectares of forest clearing was observed in Carmen and Tawan-tawan at 1,500 m. The clearing appeared to be slash-and-burn farming. The large trees were not felled, but the saplings and ferns in the understory were thoroughly clean.

Further downstream of the Kalatong River, a large tract of area (>10 ha), which is part of the Ancestral Domain, was converted as a grazing ground for cows. It is already located beyond 1,200 m. According to locals, the site was previously farmed with cassava, and after cropping, they started to haul cows to the site. Remains and feces of cows are running off into the bodies of Kalatong rivers and creeks, affecting their turbidity and, most likely, the water quality. Kalatong River is an important tributary of the Tamugan rivers, where it joins at the slopes of Mount Tipolog. Furthermore, forested portions adjacent to the ranch were also cleared as probably part of ranch expansion.

Another clearing was observed in Kagawasan, Barangay Tambobong at 1,200 m. At least 100 individuals were starting to occupy the area. These people mostly came from Baguio and Marilog Districts. The occupants were clearing a large area for their village. They had already built transient houses and bunkhouses made up of round timbers, and they used tarpaulins as temporary roofing. These people cleared at least 5 ha of forests in ecologically advanced succession forests.

In Salaysay, there were portions cleared for Kaingin even beyond 1,500 m. These areas are commonly planted with Kamote *Ipomoea batatas*, Corn *Zea mays*, and Gabi *Colocasia esculenta*. Two areas of least 0.25—0.5 ha were newly opened during density assessment. Some alleged individuals also have started to occupy the forest in anticipation of the Magpet-Davao road.

Indiscriminate Trapping

Hunting animals using snares is still very common within the study areas. The survey team documented several snares beside the trail during the assessment. In Tawan-tawan, two snares were found on the trail; one was intended for *S. philippensis,* while the other was meant for smaller mammals. Unfortunately, the smaller trap captured a Bukidnon Woodcock *Scolopax bukidnonensis*, a species endemic only to Mindanao. This was not documented in the camera traps, however, probably because the traps were established in the areas where mammals are expected to appear. *S. bukidnonensis* is known to be shy and secretive inhabiting extremely remote and rugged habitats. Thus, camera traps should be placed in areas they were previously observed (Kennedy et al. 2001). In Tambobong and Salaysay, the team found at least 15 traps along the trail. Most of the traps in Salaysay were intended for deer and warty pigs, while Tambobong traps can even capture smaller animals like birds and rodents. The team documented one rodent and two birds hanging on the traps, with one of them already decomposing. Tanalgo (2017) listed down the most hunted species in Mt. Apo Range based on the local interviews, which include large mammal species (i.e., wild pigs, deer, bats, and wildcats), reptiles (monitor lizards, pythons), and birds. While the trapping method could capture individuals not recorded in the camera traps, the magnitude of the effects on wildlife could endanger other species, particularly rare and threatened species. If this indiscriminate trapping continues, forest vertebrate populations will continue to decline and face the threat of extinction.

Conservation Initiatives

The ancestral domain owners of the Obo Manuvu of Magpet have declared 8,626 hectares of forests as an Indigenous and Community Conserved Area or ICCA in 2018 and has since been managing it as an Indigenous protected area (Philippine Eagle Foundation 2019). Similarly, the Obu Manuvu of Davao City has declared forest lands and several wildlife species as protected.

The Obu Manuvu indigenous community has been known for its Pusaka philosophy, declaring several wildlife species to be culturally and historically valuable. They have declared the Philippine Eagle *Pithecophaga jefferyi,* Philippine Brown Deer *Rusa marianna*, Philippine Warty Pig *Sus philippensis*, Palm Civet *Paradoxurus hermaphroditus*, Philippine Long-tailed Macaque *Macaca fascicularis philippensis*, Rufous Hornbill *Buceros hydrocorax*, Malay Civet *Viverra tangalunga*, White-eared Brown Dove *Phapitreron leucotis*, Yellow-breasted Fruit Dove *Ptilinopus occipitalis*, Tarictic Hornbill *Penelopides affinis*, and woodpecker *Picidae* sp. as Pusaka species. Consequently, these species were afforded several protection and conservation initiatives (Donato 2011).

One monitoring approach is the forest guarding scheme, wherein locals were capacitated to conduct regular biodiversity assessments and monitoring (Villegas et al. 2022a). Their mandates include foot patrolling activities in selected sites within the ancestral domain. They monitor the wild flora and fauna and document various anthropogenic threats. All observations were endorsed by the local government and several non-government organizations (NGOs). In this way, the indigenous community is heavily invested in conserving and managing natural resources.

The forest guards receive small remuneration and support for their ecosystem services. Consequently, they look for other economic opportunities to support their family's needs, making conservation work a lesser priority. Their provisions in monitoring activities, such as food, equipment, and materials, were also limited. This concern affected their effectiveness and efficiency. Fund support and continuous capacity and values-development programs are needed to enhance the support mechanisms for this conservation initiative.

CONCLUSION

The present study documented eight species of non-volant mammals and four species of birds in the unprotected areas of the Mt. Apo Range. This includes the endangered Philippine Brown Deer *Rusa marianna* and Philippine Long-tailed Macaque *Macaca fascicularis philippinensis*, and the Vulnerable Philippine Warty Pig *Sus philippensis*, and the Giant Scops-owl *Otus gurneyi*. This only showed that threatened species could also be found beyond the protected areas of the Mt. Apo Range. Thus, there is a need to continue monitoring the forest vertebrate species by supporting forest guarding initiatives, given that unsustainable human activities might continue to threaten the already-dwindling mammal and avian species population. A holistic approach in forest governance is necessary to reduce the anthropogenic pressures causing wildlife population decline. Future studies employing longer camera trap monitoring combined with other varying sampling methods and approaches are important to understand and explore the ecology of the documented species and the other species that might not be recorded in the study. This has been demonstrated by Tanalgo et al. (2019) and Gracia et al. (2021), which indicates that integrating findings from multiple datasets, such as those from rapid surveys and assessments, is an effective way to understand local biodiversity, especially in unprotected forested areas of the country. Although it yields limited data, camera trapping has been widely accepted by the community as a wildlife monitoring tool and has given them sufficient information to pursue local conservation initiatives. The data obtained were used as a baseline for championing wildlife conservation and fostering positive perception among locals.

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Filipino Abstrak: Ang ihalas nga mga mananap, sama sa mga non-volant mammals ug mga langgam, adunay importante nga papel sa pagmintinar sa kahimsog sa ekosistema. Gikonsiderar sila nga mga ecological engineers nga nag-impluwensya sa komposisyon sa mga tanum sa lasang. Apan tungod sa pagkaguba sa kalasangan, pagkawala sa puy-anan, ug paglutos sa tawo, ang populasyon niini mikunhod sa nilabay nga mga katuigan. Kini nga pagtuon naninguha sa pagpahigayon ug imbentaryo sa mga mananap ug pagkuwenta sa gidaghanon sa non-volant mammals ug mga langgam gawas sa protektadong luna sa Mt. Apo Range, Philippines, pinaagi sa camera trapping method. Dugang pa, gitun-an ang mga tawhanong hulga nga nakita sa mga nahisgotang lugar. Sa kinatibuk-an, 1,106 ka adlaw sa camera trapping ang gihimo sa 2016 ug laing 500 ka adlaw sa 2020. Base sa 260 ka independent sequences para sa 2016 ug 2020 nga mga survey, 12 ka mananap ang giila, nga naglangkob sa walo ka non-volant mammals ug upat ka langgam. Lakip sa giila nga mga mananap mao ang Endangered Philippine Brown Deer Rusa marianna ug ang Philippine Long-tailed Macaque Macaca fascicularis philippensis. Nakita usab ang Vulnerable Giant Scops-owl Otus gurneyi ug ang Philippine Warty Pig Sus philippensis. Nakuha usab sa unang higayon ang mga video nga ebidensya sa Philippine warty pig Sus philippensis nga naghimo ug importanteng papel isip ecological engineer sa tropikal nga kalasangan sa Pilipinas. Laing 61 ka independent sequences sa wala mailhi nga mga ilaga ang nakit-an sa mga camera traps, nga nanginahanglan dugang pang mga teknik sa pagmonitor sa mga mananap. Kinahanglang palig-onon ang konserbasyon lapas sa giprotektahan nga mga luna sa Mt. Apo Range pinaagi sa pagdumala sa kalasangan nga nakabase sa komunidad. Kini magsiguro nga ang mga mananap sa lasang mapanalipdan ug makonserba gikan sa dugang nga tawhanong hulga.

Author details: Jhonnel P. Villegas is a licensed professional teacher, biologist, and early career researcher from Mindanao Island, Philippines. His studies primarily focus on wildlife ecology, conservation biology, and regenerative education. He specializes in the ecology and conservation of the Philippine brown deer Rusa marianna and other non-volant mammals in tropical forests. Jireh R. Rosales is a senior lecturer in the Bachelor of Science in Biology program of the Faculty of Agriculture and Life Sciences at the Davao Oriental State University. He has been an advocate of the conservation of the Philippine terrestrial vertebrates and focuses his studies on Philippine mammals and amphibians. Giovanne G. Tampos is an instructor of the Bachelor of Science in Biology program under the Faculty of Agriculture and Life Sciences at the Davao Oriental State University. He is also the Assistant Supervisor of the Institute of Terrestrial Regenerative Biodiversity of the University Research Complex of Davao Oriental State University. Jayson C. Ibanez is Director of Research and Conservation at the Philippine Eagle Foundation. He is also a Senior Lecturer at the University of the Philippines in Mindanao and an Adjunct Associate Professor at the Graduate School of the University of the Philippines in Los Baños. He champions biodiversity research and the meaningful and just engagement of Indigenous communities in conservation.

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ARTICLE

Floral biology of *Baccaurea courtallensis* – an endemic tree species from peninsular India

Karuppiah Nandhini [1], **Vincent Joshuva David** [2], **Venugopal Manimekalai** [3] & **Perumal Ravichandran** [4]

[1,2,4] Department of Plant Science, Manonmaniam Sundaranar University, Abishekapatti, Tirunelveli, Tamil Nadu 627012, India.
[3] Department of Botany, Sri Parasakthi College for Women, Courtallam, Tamil Nadu 627802, India.
[1] nandhuwin19@gmail.com, [2] joshuvadavi@gmail.com, [3] sehimaravi@gmail.com, [4] grassravi@msuniv.ac.in (corresponding author)

Abstract: *Baccaurea courtallensis,* a member of the Phyllanthaceae family is a tree species endemic to peninsular India. Despite the fact that this plant is naturally propagated through seeds, there is no information on its reproductive biology. To understand the reproductive biology of this species, its floral biology is very important. Hence, this study was conducted to comprehend the detailed aspects of its flowering and fruiting characters. Blooms occur during February–May; fruits develop and mature from June to September. Flowers are unisexual, and dioecious. The present study reports on the rare occurrence of monoecious flowers in many inflorescences of a few trees. Crimson red fruits are arranged in a racemose type of inflorescence and hang in symmetric clusters. Inflorescence clusters are observed all along the trunk from base upwards. Wind and insect pollinations were observed in this species during field visits: honey bees and black ants were observed as the major floral visitors. Pollen grains showed 96.24% fertility in the acetocarmine glycerin test and 80% viability in the fluro-chromatic reaction test. Pollen germination was 63.1% in Brewbaker and Kwack's medium containing 10% sucrose. The detailed aspects of flower and fruit morphology and anatomy respectively are reported for the first time.

Keywords: Anthesis, blooms, frugivores, phenology, pollen germination, monoecious, pollen viability, pollination, seed biology.

Tamil: *Baccaurea courtallensis* (மூட்டுப்பழம்), Phyllanthaceae குடும்பத்தைச் சேர்ந்த ஒரு மர சிற்றினம். தீபகற்ப இந்தியாவில் மட்டுமே வாழும் இட வாரிய தாவரம். விதைகள் மூலமாக மட்டுமே இனப்பெருக்கம் இம்மரத்தில் நடைபெறுகிறது. எனினும் இம்மரத்தை பற்றிய இனப்பெருக்க உயிரியல் ஆய்வுகள் போதுமானதாக இல்லை. ஒரு தாவரத்தின் இனப்பெருக்க உயிரியல் பற்றி அறிந்து கொள்ள அத்தாவரத்தின் மலர் பண்புகள், மகரந்தச் சேர்க்கை நிகழ்வுகள், கருவுறுதல் மற்றும் கனி நிலை வளர்ச்சி போன்றவை மிகவும் அவசியமானதாக கருதப்படுகின்றன. எனவே, அவற்றை விரிவாக புரிந்துகொள்ள இந்த ஆய்வு நடத்தப்பட்டது. ஆண் மற்றும் பெண் மரங்கள் தனித்தனியாக காணப்படுகின்றன. ஒரு பால் மலர்கள், ஈரில்லத் தாவரங்களில் காணப்படுகிறது. மலர்களின் பூக்கும் காலம் பிப்ரவரி முதல் மே வரை ஆகும். பழங்கள் ஜூன் முதல் செப்டம்பர் வரை உருவாகி முதிர்ச்சியடையும். பொதுவாக மலர்கள் ஒருபாலினம், அரிதாக இருபாலின மலர்கள் சில மரங்களில் காணப்படுகின்றன. சிவப்புநிற பழங்கள் ஒரு வகை நுனி வளர் மஞ்சரிகளில் அமைக்கப்பட்டு சீரான கொத்துகளில் அடிப்பகுதியில் இருந்து மேல்நோக்கி தண்டு முழுவதும் காணப்படுகிறது. அயல் மகரந்தச்சேர்க்கை காற்று மற்றும் பூச்சிகளின் மூலமாக நடைபெறுகிறது. குறிப்பாக தேனீக்கள் மற்றும் கருப்பு எறும்புகள் முக்கிய மலர் வருகையாளர்களாகும். மகரந்த துகள்கள் அசிட்டோகார்மைன் கிளிசரின் சோதனையில் 96.24% மற்றும் ஃப்ளூரோ-குரோமடிக் சோதனையில் 80% வளமானதாக காணப்படுகிறது. 10% சுக்ரோஸைக் கொண்ட ப்ரூபேக்கர் மற்றும் குவாக்கின் ஊடகத்தில் மகரந்த முளைப்புத்திறன் 63.1% ஆக இருந்தது. மலர் மற்றும் பழங்களின் உருவவியல் மற்றும் உள்ளமைப்பியல் பற்றிய விரிவான ஆய்வுக்கட்டுரை இதுவே முதன்முறையாகும்.

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INTRODUCTION

Baccaurea courtallensis (Wight). Müll. Arg., an endemic species to peninsular India (Kumar 2012; Narasimhan & Irwin 2021) requires special conservation measures to increase its population. The species survives the wet tropical biome and occasionally grows along river or stream banks in the moist deciduous forests of southern India. It is locally called Muttakaipu or Muttathuri in Malayalam and Mootupazham, Pulichampazham in the Tamil language. The habit is a medium-sized tree, growing to a height of 15–25 m, and produces crimson-red edible fruits, sour to sweet in taste when fully ripe. The fruit is reported to be a good source of vitamin 'C' and antioxidants (Nazarudhin 2010). This tree species has ornamental value as well, at full bloom it is a treat to watch the color contrast of inflorescences (Yogeesha et al. 2016). Tropical evergreen forests of the southern Western Ghats, Eastern Ghats, and Odisha (Balakrishnan & Chakrabarty 2007; Narasimhan & Irwin 2021) are the home of this evergreen tree. It is distributed in evergreen and semi-evergreen forest areas in the Western Ghats especially the southern Sahyadri and central Sahyadri (up to the Coorg region). Understory trees in low and medium-elevation evergreen forests up to 1,000 m (Abhishek et al. 2011). *B. courtallensis* is an underutilized fruit tree. In the broadest sense, the term "underutilized fruit tree" refers to a group of fruit trees that are currently growing in a dispersed and unattended manner on roadsides, homestead land, and wasteland despite having the potential for intensive utilization (Jisha et al. 2015). Fruits are crimson red in colour and acidic in taste. Only the local tribal population of the Western Ghats region consumes these fruits and it's not widely known to others. Fruits of *B. courtallensis* are eaten for their medicinal properties too. Fruits are used to induce fertility in men and women (Daniel et al. 2005). Fruits are also used to prepare jam, squashes, and wine. The fruits are also consumed in greater quantities by tortoises and Sloth Bears, which possibly reduces the likelihood of natural regeneration (Mohan 2009). The flowering period of *B. courtallensis* starts in February and extends up to April; the peak flowering month is March and the fruits develop and mature from June to September, during the rainy season. Literature on the reproductive biology or floral biology of this tree is sporadic. The present investigation was carried out to study plant morphology, flower, fruit morphology, anatomy, pollen biology, and fruit set.

MATERIALS AND METHODS

Study area

The present research work was carried out from 2018 to 2022, in the southern Western Ghats of Tamil Nadu and Kerala. The Western Ghats is a magnificent mountain range, next only to the Himalaya, and has rich biological wealth with a high degree of endemism. Southern Western Ghats is one of the richest areas of India in the context of floristic, diversity, composition, holding a large number of endemic taxa. *B. courtallensis* is one among the endemic species of south Western Ghats and is distributed in Tenkasi, Tirunelveli, and Kanyakumari districts of Tamil Nadu and in Kerala, it is located in all districts but more abundantly in Kollam, Thiruvananthapuram, Pathanamthitta, and Idukki districts. To locate the candidate species, field expeditions were made to the forests in the KMTR zones, especially the Mundanthurai range of Ullaru, Kannikatti, and Kodamaadi beats, Kadayam range of Kadana beat, Therkumalai, and Mylodai estate, as well as at Kollam forest division of Achenkovil forest range. A total of about 2,500 individuals were found in the Ullaru (1700), Kodamadi (600), and Achenkovil (200) forest areas. Detailed field investigations on the reproductive biology and phenology of the species were conducted in these forest areas (Figure 1).

Selection of trees

Baccaurea courtallensis is an evergreen medium-sized tree that grows up to 15–25 m in height. It is a dioecious tree; the morphological characters are similar in both male and female trees, except for the stem region. The distinguishing factor for the identification of male and female trees during the non-flowering season is based on the scars on the trunk. The inflorescence-arising zones of the male tree are numerous, while those of the female tree are fewer. The trunk size of the female tree is larger than the male tree and scars of several floral primordia regions were observed in the entire male tree. For the purpose of observing plant morphological traits, 25 female, and 25 male trees from fourteen population sites were chosen. The tree's height and width, stem, bark colour, branching pattern, leaf arrangement, and the places where inflorescences emerge in both sexes were all documented in the field.

Floral phenology

Flowering phenology was observed in a sequential manner from the bud to the seed maturity stage. Twenty-five healthy trees were selected randomly from the study

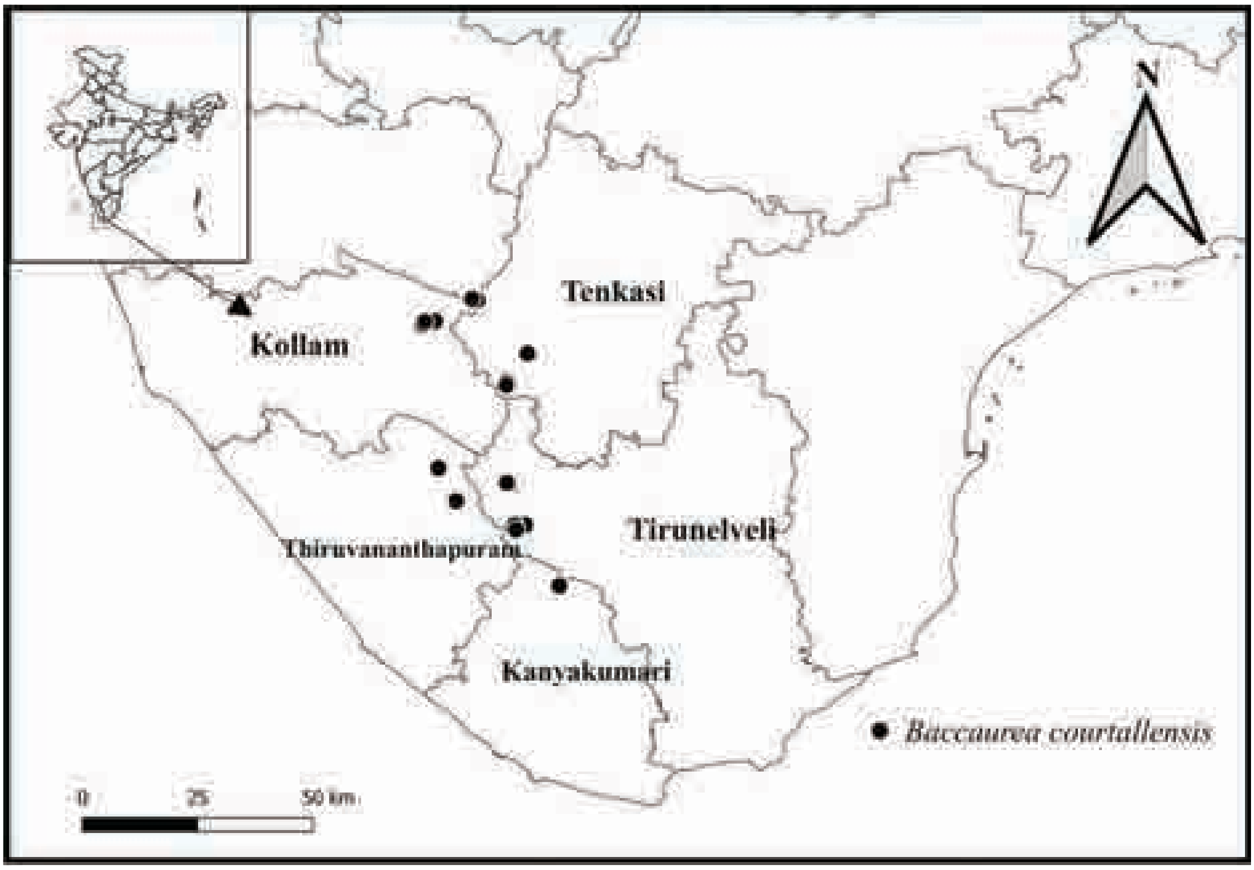

Figure 1. Distribution of *Baccaurea courtallensis* populations from southern Western Ghats.

sites, during the period 2018–2022. Observations were made on the reproductive phases of plants, with respect to the ontogeny of the floral primordium, development of flowers, maturation, anthesis, pollination, and natural withering of flowers. Floral visitors were also recorded among these plants (Image 1 F, G & Image 2 I, J).

Inflorescence and floral morphology

Male and female inflorescences and floral morphologies were noted. The inflorescence type, position, average number of inflorescences per cluster, floral characteristics, and flowering time were all closely monitored. A Nikon SMZ 800 stereomicroscope fit with a digital dark box and facilitated with Nikon NIS-Elements basic research imaging software was used for standard research applications such as analysis and photo documentation of fluorescent imaging, four-dimensional acquisition, and advanced device control capabilities.

Male and female flowers

Flowers are one of the key characters to distinguish male and female trees of *B. courtallensis*, however, it is hard to distinguish male and female inflorescences at the very early stages of their development and it's difficult to count male and female inflorescences from cluster racemes of primordial regions due to several clusters. Twenty-five flowering trees, as mentioned earlier, of both sexes were selected in a population for counting inflorescences and flower buds. The mean number of clustered inflorescences and flower buds of males and females was calculated and tabulated (Table 3).

Fruit morphology and anatomy

The fresh and mature fruits were harvested and brought to the laboratory immediately. After harvest, the collection was completely randomized without seeing the size. The collected fruits were stored in plastic bags and kept in a refrigerator. Fruits' fresh and dry weights were measured using a digital balance. The maximum length (linear distance between peduncular and stylar ends) and maximum diameter (linear distances across the width of the fruits) were measured using a digital Vernier caliper.

Free hand cross and longitudinal sections of fruit and seed were taken and observed under Nikon 80i fluorescent microscope fitted with a digital photography workstation and SNZ stereo microscope. Specific stains and reagents such as Toluidine Blue 'O', Safranin, and oil red were used to detect specialized structures. After staining, sections were mounted on clean micro-slides using glycerin, as a mounting solution. The anatomical features were observed and microphotographs were taken.

Pollen Biology

Pollen-Ovule ratio

Healthy, undehisced mature flower buds were taken to determine the pollen-ovule ratio. Mature and fresh anthers from 20 flowers were randomly collected during the early morning and squashed separately in a mixture of ethanol (0.5%), methylene blue, and detergent (0.9ml+0.3ml+0.4ml) (Dafni et al. 2005). Thus, collected pollen grains were mixed thoroughly by the repeated drawing of the liquid into a disposable syringe and expelling it with force. Pollen suspensions of 100 µl were taken on a clean hemocytometer and the total number of pollen grains were counted in a sample under the light microscope. The procedure was repeated with 10 samples of a suspension and the average number of pollen grains was calculated. Twenty young pistils were collected from the flowers used for ovule count and the average number of ovules per ovary was determined by dissecting the ovaries under the microscope. The pollen-ovule ratio was calculated by the following formula (Cruden 1977). The percent of fruit set was calculated by dividing the mean number of matured fruits by the mean number of female mature flowers in an inflorescence.

The pollen-ovule ratio is the mean number of pollen grains per flower/mean number of ovules per flower.

Pollen fertility

The dye acetocarmine and glycerine reagent method was used to determine the fertile pollen grains by the colour change of cytoplasm alone into deep red and the pollen wall remained uncoloured (Shivanna & Rangaswamy 1992). Fresh pollen grains were collected from ten flowers and transferred to a clean slide and two drops of the acetocarmine glycerine mixture were added in a ratio of 3:1 and mixed thoroughly. After 15 minutes the slides were examined under a light microscope. The number of stained and unstained pollen grains was counted. The stained pollen grains were considered as fertile and the unstained as sterile.

Pollen viability

The viability of pollen grains was examined by three different reagents such as flurochromatic reaction test (FCR), 2, 3, 5-Triphenyl Tetrazolium Chloride (TTC) and Iodine-Potassium-iodide test (I_2KI). The pollen grain was considered viable if it appeared green in FDA (Fluorescein diacetate) under a fluorescent microscope (Heslop-Harrison, 1970), dark red in TTC test (Shivanna & Rangaswamy 1992), and brown in the I_2KI test (Sulusoglu & Cavusoglu 2014) under a light microscope. Viable and non-viable pollen grains were counted in each field of view for calculating the percentage of viable and non-viable pollen grains.

In vitro pollen germination

Fresh pollen grains were collected on the day of anthesis for pollen germination studies. *In vitro* pollen germination was conducted in Brewbaker and Kwack (BK) medium (Brewbaker & Kwack 1963) in different levels of sucrose (5, 10, 15, and 20% solutions), in order to determine the effect of different nutrients like boron, and calcium nitrate at various concentrations of sucrose. The fresh pollen samples were placed into the BK medium and kept in petri dishes lined with moist filter paper and incubated for 12 hours. After incubation for twelve hours, pollen samples were observed under a light microscope. The observed data was recorded and the percentage of pollen germination was calculated using the following formula.

Percent of pollen germination = Number of pollen grains germinated / Total number of pollen grains observed × 100

Floral visitors

During the flowering period field visits were carried out to record floral visitors and pollinators. The flowers are small and red in colour and male flowers emit mild musky fragrance. Floral visitors and their behaviour were recorded from 0700 h to 1330 h at each study site using Canon D-SLR Camera. Insect visitation starts around 0730 h. Observations were made on insect floral visitors, visiting time, the purpose of visiting, foraging activity and time spent on each flower. Floral visitors were photographed using a Canon D-SLR camera. Some of these floral visitors were collected and preserved for identification.

RESULTS

Distribution and morphology of the plant

The selected trees were found at altitudes between 180 to 1,000 m in forest areas of Kadana, Kannikatti, Ulllaru, Ingikuzhi, Kodamadi, Ueipattrai and Valaiyaru, of Tirunelveli District and Courtallam of Tenkasi District (as per state government orders) of Tamil Nadu. In Kerala, it is located from Achenkovil and Thenmala of Kollam District and Kallaru, and Bonacaud Estate on the way to Ponmudi, at an elevation of 400 to 700 m in the Thiruvananthapuram District (Figure 1). It is a shade-loving understory tree that can reach a height of 15 to 25 m, like other evergreen trees found in the Western Ghats. It is a slow-growing, dioecious tree and rarely monecious. Few monoecious trees were identified in Ullaru and Kodamadi forest regions. *B. courtallensis* trees are closely associated with *Antidesma menasu*, *Elaeocarpus venustus*, *Eugenia singampattiana*, *Polyalthia korintii*, *Celosia polygonoides*, *Calamus* sp., *Hydnocarpus pentandra,* and *H. alpina*.

Fourteen population sites were selected for observing the stand height, GBH, and density of the selected candidate species. Among the 14 populations, only a few forest areas had a large number of trees specifically Ullaru, Kodamadi, and Achenkovil. The distribution of the population was observed continuously to a stretch of 10 km in Ullaru, while in Kodamadi the distribution was discontinuous and broken into smaller groups. The population size in Ullaru and Kodamadi forest areas was about 250 individuals per 5 km radius whereas in Kadana, Achenkovil, and Kallaru to Ponmudi the population size was 50–100 (Table 1). The number of adult individuals, stand height and GBH was quantified using population structural data. In every population, there were more male trees (77.56%) than female (22.43%) trees. The height of male trees ranges from 10–25 m, whereas the female trees were 10–20 m. Male trees' mean GBH was 54 cm, whereas female trees' mean GBH was 58 cm.

The main threats to candidate species are natural landslides, habitat disturbance, formation of roads and dams, and other non-forestry activities, since mud roads have been extended and anthropogenic activities have made the species more susceptible. The majority of populations were found along roadsides and in neighboring regions. If no specific precautions are taken for this plant across the sites, the species will be more vulnerable to catastrophic events resulting in a reduction of populations.

Baccaurea courtallensis grows up to 15–25 m tall (Image 1A & Image 2A). The colour of the bark is grey usually smooth or scaly, blaze light orange covered by lichens. Branchlets terete, glabrous. Leaves simple, alternate, clustered at twig ends, stipules ovate, acute, hairy, and caducous. 1.2–3.8 cm long, swollen at both ends, terete, puberulous when young. Leaf lamina 7.5–17.8 × 3–7.6 cm, oblanceolate, apex bluntly caudate acuminate, base cuneate, glabrous, midrib slightly raised above, secondary nerves 4–8, ascending, tertiary nerves slender, distantly per count. As per earlier reports, the trees are unisexual and dioecious. The present study reports for the first time that the trees are rarely monoecious (Image 4). At two different forest locations namely Kodamadi and Ullaru a few trees were observed

Table 1. *Baccaurea courtallensis* populations in selected forest areas of Western Ghats.

	District	Forest location	GPS coordinates			No. of Individuals	
			Latitude	Longitude	Altitude (in m)	Male	Female
1	Tirunelveli	Kannikatti	8.63083	77.27417	795	26	12
		Ullaru	8.62875	77.29455	615	160	50
		Ingikuzhi	8.61955	77.27647	644	24	7
		Kodamadi - Ueipattrai	8.70730	77.26643	496	60	12
		Vethalakan odai	8.71018	77.26237	457	40	19
		Kalkatodai	8.71197	77.25870	482	44	23
		Kadana	8.966466	77.299725	181	13	4
2	Tenkasi	Courtallam-Therkumalai estate	8.90412	77.25780	569	9	2
		Courtallam- Mayilodai estate	8.91028	77.25760	734	36	9
3	Kollam	Achenkovil	9.07085	77.20057	382	65	7
		Thenmala	9.02872	77.09707	672	27	5
4	Thiruvananthapuram	Kallaru	8.74087	77.12062	394	14	2
		Ponmudi - on the way	8.74045	77.12377	482	11	2
		Bonacaud estate	8.67570	77.15845	514	7	1
	Percentage distribution of male and female trees					77.56%	22.43%

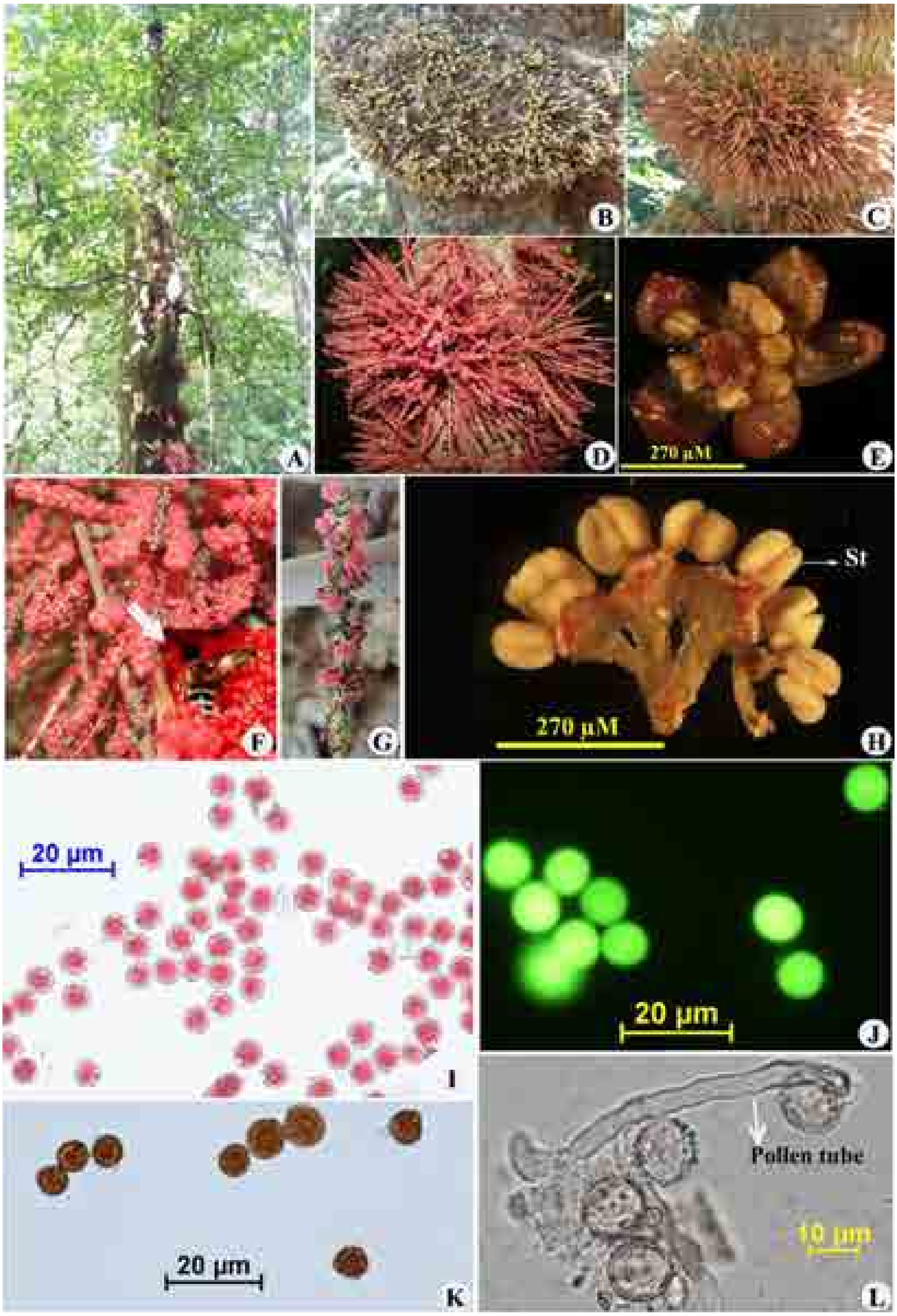

Image 1. A—Habit of 15 m tall male tree in flowering | B—Five day's old male inflorescence arose from the male tree trunk | C—Fourteen days old male inflorescence | D—Twenty-four days old male inflorescence with a drastic change in colour | E—Close up view of a male flower with seven stamens | F—Honey bee taking nectar from male flowers | G—Activity of Black ants on male flowers | H—Dissected male flower bud showing prominent stamens | I—Light microscopic image of viable pollens stained with Acetocarmine | J—Fluorescent microscopic image of Pollen grains - FCR test for viability | K—Light microscopic view of viable pollen grains - I2KI test for viability | L—In vitro pollen germination in 10% sucrose in BK medium | St—Stamen. © All authors at MSU- Tirunelveli and SPC- Courtallam.

with monoecious flowering conditions.

Floral phenology

The term 'phenology' describes how living things react to climatic and seasonal changes in a cyclic manner. Seasonal patterns are observed in a variety of reproductive processes known as pheno-events in flowering plants, including the commencement of flowering, fruiting, and seed distribution (Shivanna & Tandon 2014). The phenological data of *B. courtallensis* was observed and recorded based on repeated field observations. When the tree attains maturity (nearly 10–12 years), floral primordia appear from the base to the middle portion of the main trunk, from which crimson-red flowers emerge (Yogeesha et al. 2016). *Baccaurea courtallensis* was confirmed as unisexual, dioecious, and infrequently monoecious trees. The seasonal and climatic changes influence the flowering phenology of evergreen trees as witnessed over a period of four years. *Baccaurea courtallensis* begins flowering in the month of February and extends up to May, however, reaches mass flowering during March. Both male and female floral buds primordial are eventually developed into brown buds and then mature into dark red coloured buds (Image 1B,D). The flower buds take 16–24 days from initiation to full bloom. Flowers open in the morning from 6.30–10.00 h and anther dehiscence was noticed around 1330 h after anthesis. However, seasonal and climatic changes have made a strong impact on the flowering of *B. courtallensis* (Image 4). Continuous observations helped us to determine the flowering period, occasionally flowering occurred in early February and in some other times cauliflorous initiates from March and extended up to May (Image 4). These changes occur due to rainfall and other environmental factors and such factors significantly influence the flowering phenomenon of these trees.

Floral morphology

The inflorescence is cauliflory, a large population of trees that produce dark crimson colour flowers, in densely clustered slender racemes on the old stem. Rarely trees were observed in the monoecious status where male and female flowers are produced in the same inflorescence stalk but such cases have yielded fewer fruits (Image 5). The flower size of candidate species was observed in female flowers with 3–4 mm (Image 2C,D) and in male flowers 1 mm to 1.5 mm (Image 1E). Female flowers are relatively larger than male flowers and the tepals of the female are also larger than the male flower (Image 5). Both male and female flowers emit a mild musky odour. Floral traits of *B. courtallensis* are listed in (Table 2).

Table 2. Floral characteristics of *Baccaurea courtallensis*.

	Criteria	Result
1.	Flowering period	February to March/ May
2.	Flower type	Unisexual, dioecious, and rarely monoecious
3.	Flower colour	Crimson red
4.	Odour	Musky fragrance
5.	Presence of nectar	Present, at the base of stamens
6.	Anthesis time	0630–1000 h
7.	Anther dehiscence time	0900–1145 h
8.	No. of anthers per flower	7 to 8
9.	Total no. of pollen grains in a male flower	Approximately 1,500
10.	No. of ovule per flower	6 (3 locules, 2 ovules in each locule)
11.	Pollen size	10 to 12 μM
12.	Stigma type	3-flabellate
13.	Pollen fertility	Fertile (tested by I_2KI, TTC, Acetocarmine and FDA)
14.	Fruit type	Capsule/Fleshy berry
15.	Pollination	Wind assisted insect pollination
16.	Floral visitors	Honey bees, flies, black ants, spiders

Male flowers

The male inflorescence appears in clustered racemes on short tubercles all over the trunk, red in colour. Bracts, linear lance-shaped or triangular, free, conduplicate, encircling the base of lateral branches; tepals 4–5, 1.5–2 x 1 mm, linear, oblong, elliptic, nearly round or inverted lance-shaped, glabrous or sparsely puberulous; stamens 6–7, free and fertile; anthers basifixed; pistillode club-shaped (Image 1H).

Several clustered racemes are found all over the trunk. The stem shows several dark brown coloured scars, where the floral primordium abscised. The male flower buds take 5 to 24 days from initiation to maturation (Image 1B,C,D). At the time of blooming each cluster produces numerous inflorescences. Each cluster has a maximum of 96 male inflorescences, a minimum of 13, and an average was 58.32. The single inflorescence consists of many of floral buds, maximum numbers of floral buds were 85, the minimum was 39 and the average number of buds was 64.32. The length of male inflorescence was also measured; the maximum length was 19 cm; the minimum was 7.5 cm and the average was 12.10 cm (Table 3).

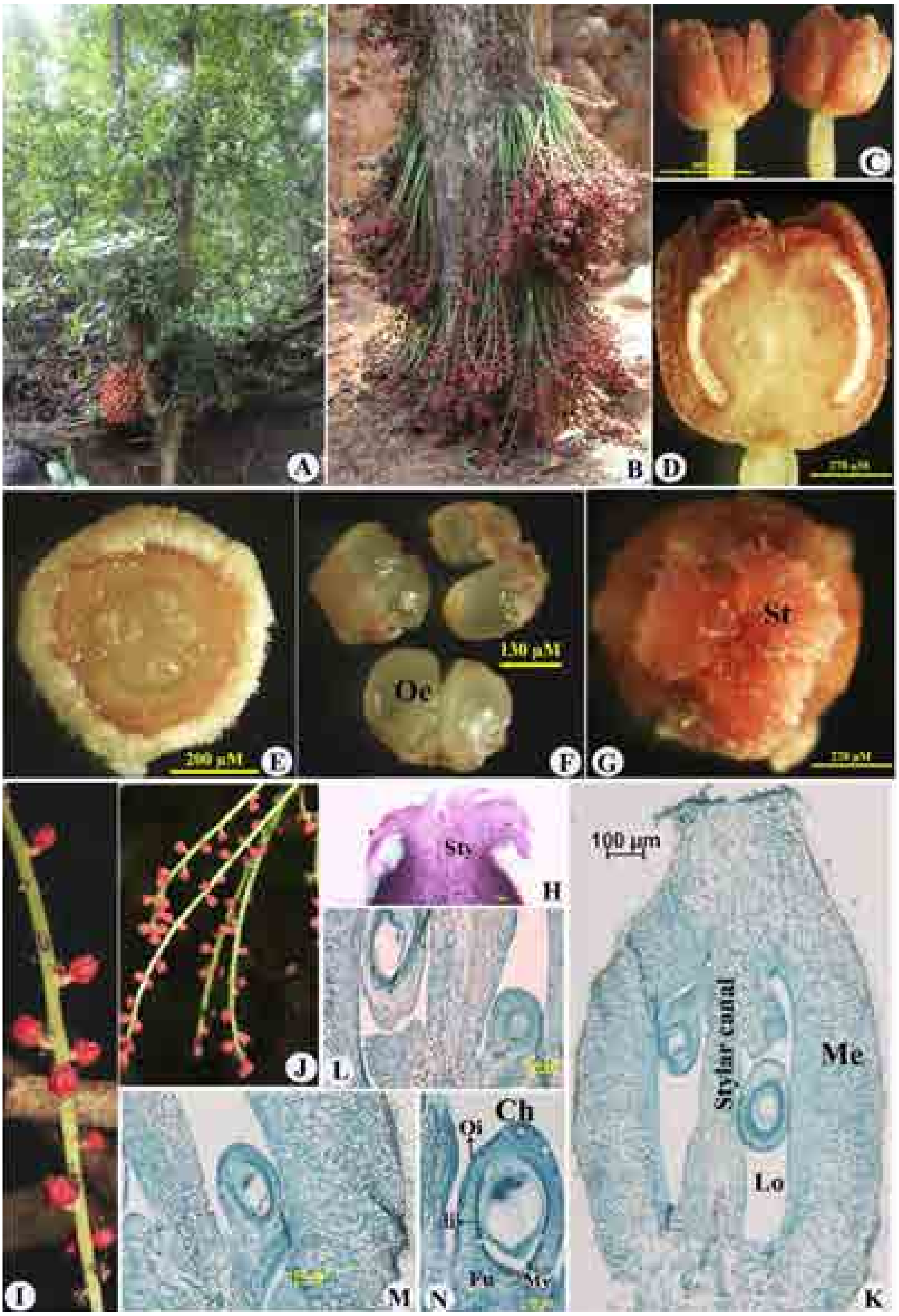

Image 2. A—Female tree showing bunches of ripened fruits at the base of trunk | B—Clustered female inflorescences emerged from the base of tree trunk | C—Close up view of female flower buds | D—Longitudinal section of a female flower bud | E—Cross section of female flower bud showing trilocular ovary and immature ovules | F—Dissected immature ovules from a female flower | G—Close up top view of stigma | H—Longitudinal section of portion of ovary, style and stigma | I–J—Foraging activity of honey bee and a spider in female inflorescence | K—Longitudinal section of fertilized female flower with ovules in 0.8 cm size fruit | L–M—Close up view of female flower showing 2 distinct ovules | N—Enlarged view of fertilized ovules | Oe—Ovule | St—Stigma | Ch—Chalazal region | My—Micropylar region | Oi—Outer integument | Ii—Inner integument | Fu—Funicle | Lo—Locule | Me—Mesocarp. © All authors at MSU- Tirunelveli and SPC- Courtallam.

Table 3. Number of inflorescences, buds, and length of female and male flowers.

Traits	Sex of the trees	Sample size (n)	Mean±SD	Std. Error	Minimum	Maximum
No. of Inflorescences in a cluster	Female	25	10.56±3.428	.68576	6.00	19.00
	Male	25	58.32±22.24	4.4496	13.00	96.00
	One-way ANOVA		F = 112.535, P <0.01%			
Length of Inflorescences in cm	Female	25	18.22±2.665	.53314	13.00	25.00
	Male	25	12.10±3.034	.60690	7.50	19.00
	One-way ANOVA		F = 57.396, P <0.01%			
No. of flower buds	Female	25	34.00±5.751	1.1503	23.00	45.00
	Male	25	64.32±13.06	2.6132	39.00	85.00
	One-way ANOVA		F = 112.765, P <0.01%			

Female flowers

Female inflorescences are born on clustered racemes mostly confined to the base of the trunk (Image 2B). Small projections were observed on such trunks where the female inflorescence arises. Each cluster had a maximum of 19 female inflorescences, a minimum of 6, and an average of 10.56. The single inflorescence contained many flower buds with a maximum number of 45 buds, a minimum of 23, and an average of 34. The length of female inflorescence was also measured by using a scale; the maximum length was 25 cm, the minimum was 13 cm, and the average was 18.22 cm (Table 3).

Bracts 1–1.5 mm long, lance-shaped; tepals 4–5, 2.5–3 x 0.6–1.5 mm, linear, oblong or oblong-elliptic, sparsely puberulous to hairless, fringed with hairs; the ovary is superior, woolly, 3-angled, 2.5 x 2–3 mm, ovoid or sub-spherical, trilocular; ovules 2 in each locule (Image 2F); as the flower is trimerous stigma is with three flabellate sticky surfaces to be successful by wind pollination (Image 2G,H). Style and stigma are reduced close to the gynoecium. The ovule structure of *B. courtallensis* is anatropous with amphistomal making up the micropyle, crassinucellate, origin from axile placentation, bitegmic integuments, and obturator forming a nucellar beak. The position of the ovule is ventral epitropous. The ovary normally has two ovules in a locule. The embryo is chlorophyllous and the endosperm is cellular in nature. Seeds are arillate with white mucus fibers on the surface. The cross-section of the flower showed three distinct locules (Image 2E), in each fruit two–three seeds are produced at the time of maturation and the remaining ovules are either aborted or unfertilised.

Fruit morphology and anatomy

The fruit is a capsule and Bacca (fleshy fruit) thus the name *Baccaurea* (Image 3A). Fruits are crimson to brown after maturity, globose, beaked, 1.5–2.5 cm across; ribbed, pubescent when young, seeds broad composed with fleshy aril and have exocarp, mesocarp, and stony endocarp (Image 3B). The fruit shows tricarpellary ovary with well-developed three locules (Image 3D). The average fruit size in length is 25.36 mm and its width is 25.30 mm. The thickness of the fruit varies from place to place with a range of 23.91 to 35.38 mm. Similarly, the fresh weight of the fruit varies from 19.5 to 26.52 g (average 22.77 g), and the dry weight has an average of 5.22 g. The fruit has about 77.06 % of moisture content at the time of harvest.

Exocarp is made of a single layer of epidermis with thin wall cells (Image 3F), rectangular in shape, it contains more amount of anthocyanin pigment, and chloroplast is deposited within the epidermis cells. The size of the epidermis has a maximum length of 229.79 µm and a minimum of 103.08 µm (average 155.93 µm) and width maximum of 134.28 µm and a minimum of 60.04 µm (average 106.45 µm). Fruit cover has stomata of cyclocytic type. Stomata are surrounded by one or two narrow rings of subsidiary cells and two guard cells. The pubescent nature of fruits is due to the presence of trichomes and hooked hair-like structures with thick-walled cells (Image 3E). Mesocarp is 2 to 3 mm thick and has approximately 40–50 layers of parenchymatous cells. Mesocarp consists of two types of cells, thick-walled cells, and thin-walled cells. The size of thin-walled cells has a maximum of 267.62 x 239.82 µm and a minimum of 118.94 x 124.42 µm. Consequently, the thick-walled cells have a maximum of 195.13 x 179.48 and a minimum of 63.63 x 76.49 µm.

Seeds are covered with an extra, fleshy layer outside the seed coat. This fleshy layer more or less envelops the seed coat and it is known as aril (Image 3C). In transverse sections, the mucilage layer is present below the testa, and mucilage cells are thin-walled in nature, with fiber-

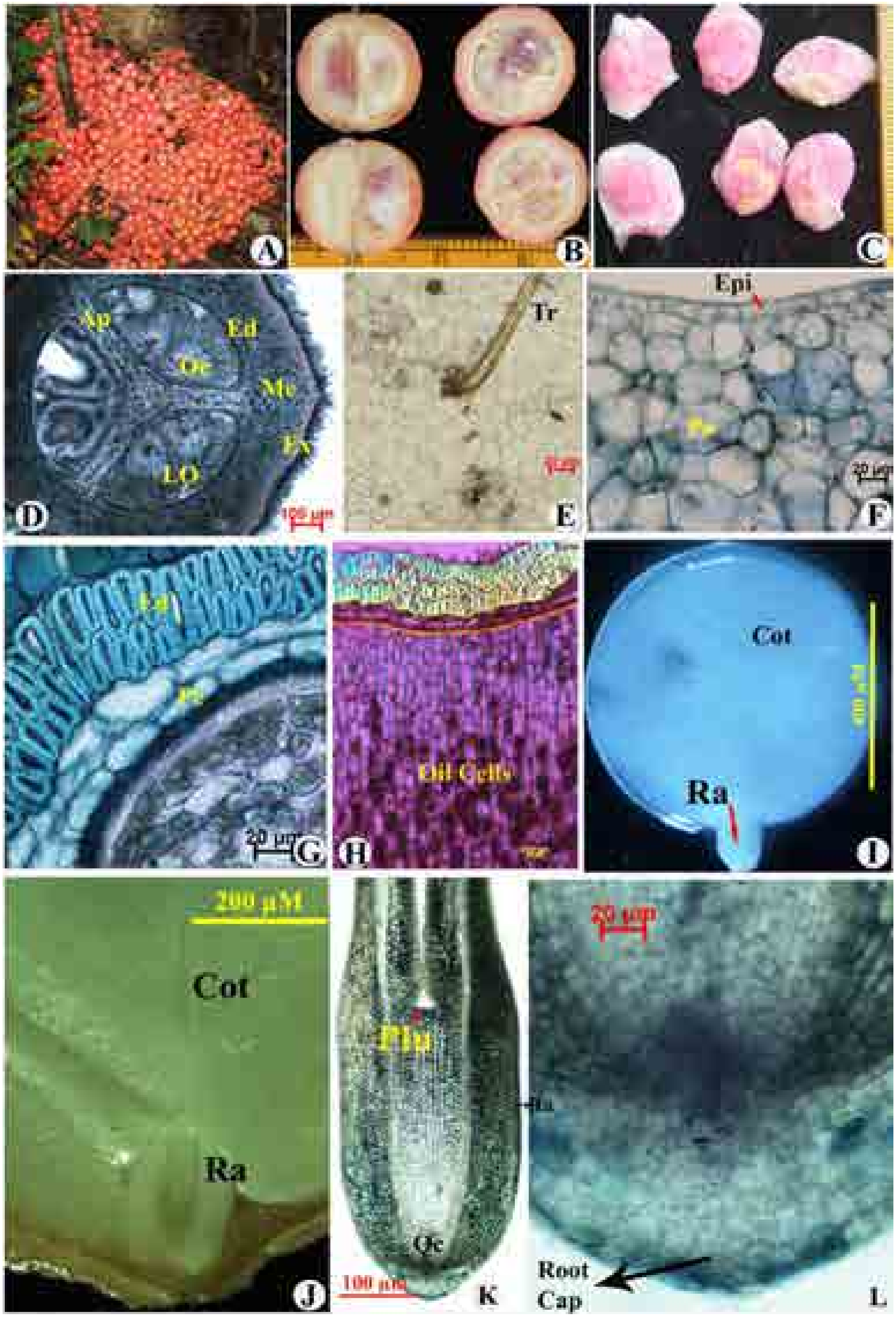

Image 3. A—Clustered crimson red mature fruits | B—Longitudinal and cross sections of mature fruits | C—Fleshy arillate seeds | D—Cross section of immature fruit stained with TBO observed under a light microscope showing tricarpellary ovary with ovules | E—Epidermal peeling of immature fruit rind shows cyclocytic type of stomata and hooked trichomes | F—Cross section of mesocarp region stained with TBO showing parenchymatous cells | G—Cross section of endocarp stained with TBO showing mucilage layer and testa | H—Longitudinal section of seed observed under polarized light microscope showing testa (stone cells) and oil cells in the endosperm | I—Close-up view of an immature embryo showing well-developed radicle and etiolated cotyledon | J—Longitudinal section of a mature embryo showing developed radicle region and faint plumule region | K—Longitudinal section of radicle showing root cap, cortex, and central cylinder | L—Enlarged view of the root cap. Ex—exocarp | Pe—perisperm layer | Me—mesocarp | Ap—axile placentation | Lo—locule | Pa—parenchyma cells | Mu—mucilage layer | Tr—trichome | Cot—cotyledon | Pu—plumule | Ra—radicle. © All authors at MSU- Tirunelveli and SPC- Courtallam.

like structures containing polyphenol compounds (Image 3G,H). Endocarp or testa is made of stone cells, it covers the endosperm, and two to five layers of cells are tightly packed; the length of a stone cell varies 73.04–37.85 µm (average 52.89 µm), and its thickness is between 95.61–216 µm (average 140.82 µm). The testa is followed by a palisade layer of thin-walled cells, 2 to 6 layers occur below the endocarp; a group of large-size druse crystals is located in the palisade layer. The length of the palisade cell varies from 86.54–343.21 µm (average 205.29 µm) and its width is 49.35–133.58 µm. Almost the entire region of the endosperm is occupied by the developing embryo with large etiolated cotyledons which are fleshy in texture and circular in shape (Image 3I). The length of endosperm cells varies from 94.04–167.95 µm (average 128.39 µm) and its width is between 48.75–198.9 µm (average 108.2 µm). The longitudinal section of the embryo axis shows developing cotyledons, hypocotyl region, and radicle with root primordium (root meristematic region) and well-developed root cap region (Image 3J,K,L).

Image 4. *Baccaurea courtellensis* male and female flowers. © All authors at MSU- Tirunelveli and SPC- Courtallam.

Image 5. *Baccaurea courtallensis*: Evidence for variation in in flowering and fruiting period. © All authors at MSU- Tirunelveli and SPC- Courtallam.

Pollen Biology

Pollen morphology and production

The male flowers have a reduced pistillode and well-developed anthers (Image 1H). Pollen grains are spherical, trilobed, or four-lobed, circular in polar view, tricolporate to tetracolporate, colpus slender, and pore elongate with an unclear outline. The estimation of pollen production is important to understand many aspects of pollen biology. The amount of pollen produced in each anther/flower varies greatly. In *B. courtallensis* each anther produces a minimum of 1,648 to a maximum of 2,144 pollen grains; the mean number of pollen grains in a single anther was 1,446. The sizes of pollen grains vary from 10–12 µm in diameter.

Pollen ovule ratio

The study on pollen ovule ratios was used to predict the efficiency of pollination in a particular species (Oskay 2017). The cross-section of a pistil shows three locules and each locule has two ovules. The total number of ovules in an ovary is six. A single anther consists of around 1,446 pollen grains and thus a flower has around 10,122 pollen grains. The pollen ovule ratio was counted as 1687:1. This study indicates that external agents are needed for pollination and successful fruit set. The percent of fruit set for the candidate species is 74.

Pollen fertility and viability

Pollen fertility and viability is a critical factor, which is considered important parameter of pollen quality (Dafni & Firmage 2000). Pollen grains treated with reagents such as acetocarmine, TTC, and I_2KI essentially impart colouration to the cytoplasmic contents of the pollen to indicate whether the pollen grains are fertile or not. The stained pollen grains were considered fertile and the unstained as sterile (Image 1I). This technique revealed that 96.24% of pollen grains are fertile on the day of anthesis and this is used to know the pollen longevity. Pollen viability was determined by using the Flurochromatic reaction test (FCR), 2, 3, 5-Triphenyl Tetrazolium chloride (TTC) test, and the Iodine Potassium iodide (I_2KI) test. The percentage of pollen viability on the day of anthesis in the FCR test showed 80.00% (Image 1J) TTC test was 86.72% and the I_2KI test was 91.03% (Image 1K). Among the three staining tests I_2KI expressed the highest pollen viability (91.03%).

In vitro pollen germination

Pollen germination was carried out in Brewbaker and Kwack medium at different concentrations of sucrose such as 5%, 10%, 15%, and 20%. The maximum percentage of pollen germination was observed in 10% sucrose after 12 hours of incubation. Pollen germination was low in 5, 15, and 20% levels of sucrose-supplemented BK medium. BK medium augmented with 10% of sucrose, showed 63.15% of pollen germination. (Image 1L). Increasing the concentration of sucrose beyond 10% inhibits pollen germination in *B. courtallensis*. A similar kind of response was reported in *Tectona grandis* tree (Hine et al. 2019) and this study corroborates such a finding.

Floral visitors

The candidate species is a unisexual-dioecious tree; male and female trees produce flowers separately, so obviously, cross-pollination is predetermined. Dioecious plants have a great advantage over other plants wherein their cross-fertilisation is guaranteed (Renner 2014). Further, the cluster of inflorescences and the miniature size of flowers also designate that they may be cross-fertilised by wind and biotic means. During the flowering period, many floral visitors were observed. In female flowers; black ants and spiders were found however in male flowers, honeybees were also observed. During many such field visits, black ants and honeybees were detected in male flowers abundantly (Image 1F,G Image 2 I,J). Though, floral visitors were observed in large numbers, the presence of nectar glands or nectar organs in either male or female flowers could not be located. Floral visitation happens from 0730 h to 1000 h. The flowers are small, dark crimson colour with a mild musky fragrance. The floral visitors are attracted by the mass flowering with contrasting colour combinations.

DISCUSSION

The knowledge of phenology, and flower biology is essential to understand the persistence, dispersion, pollination, and breeding systems of plants (Munguia-Rosa et al. 2011). Phenological studies are essential to increase knowledge of the specific functions of plants in natural populations and they must be taken into account in conservation and rational management schemes (Oskay 2020). The development of successful conservation and sustainable use strategies for endangered, indigenous plants depends on comprehensive knowledge of their reproductive biology. The current findings revealed the species floral phenology, male and female flower morphology, and pollen biology. The selected species is an understory semi-evergreen to evergreen tree, endemic to Southern Western Ghats and Eastern Ghats. Fruits of this tree are edible and used by Kani, Kadar, Muthuvan tribes for medicinal purposes specifically to treat infertility problems (direct conversation with them).

An altitudinal gradient, which supports the significance of elevation in the distribution of a tree species, is the foundation upon which a forest community depends for its survival (Liu et al. 2007; Barni et al. 2012). Based on our random and repeated field observations this tree occurs from 200 m to 1000 m altitude in Tamil Nadu and Kerala forest areas. This tree prefers a canopy region to grow and reach up to 15 m in height. The current investigation revealed that the vegetative phase of both sexual plants displayed similar phenological characteristics throughout the season. Both male and female trees share a similar kind of morphological pattern except for the stem portion. Only the flowering phenomenon helps to identify both sexes.

Baccaurea courtallensis is found to be unisexual and dioecious tree in abundance however; monoecious trees were also recorded sporadically based on our findings. Though, Monoeceae status was reported by Yogeesha et al. (2016) where the male and female flowers were observed in different inflorescence stalks, however, the present study reports that both male and female flowers are present in the same inflorescence stalks. A similar kind of morpho-variation was observed in *Jatropha curcas* flowers (Singh et al. 2010). This tree begins to flower in February and continues till April, with a peak flowering period being recorded in March. In comparison to female flowers, male trees begin flowering earlier. These changes might be influenced by local climate and edaphic conditions. In dioecious species, the timing of flowering varies between the sexes, with the male typically starting to flower before the female tree (Lloyd & Webb 1977; Beach 1981). In dioecious species, male plants often produce a greater number of flowers than female plants (Vaughtton & Ramsey 1998) to provide sufficient pollen grains for successful pollination. Fruit growth and development were observed from April and need 4–5 months to attain full maturation. Fruits that have matured fall off from June to September. Fruits are eaten by frugivores especially elephants, sloth bears, monkeys, squirrels, bats, and tortoises. The tortoises possibly consume a greater number of fruits than any other due to the nature of cauliflory and close abundance to the floor. As a consequence of this behavior, seeds are also dispersed by these frugivores. The plant and animal interactions signify a mutualistic network of seed dispersal systems in *B. courtallensis*.

Studying anthesis and anther dehiscence is essential for understanding how pollen grains disperse into the atmosphere (Bhattacharya & Datta 1992). Flowers of *B. courtallensis* open in the morning 6.30–10.00 hours, male flowers are short-lived compared to females. Dehiscence of anthers was observed after 30–45 minutes of a flower opening. The mean number of pollen grains in a single anther was 1,446. In the acetocarmine glycerin and the flurochromatic tests, pollen grains displayed a 96.24% fertility rate and an 80% of viability rate, respectively. However, I_2KI test showed 91.03% of pollen viability, it may be due to more amount of starch content present in the pollen grains. This method is commonly used to stain the starch content in pollen grains (Bolat et al. 1999). Iodine broke up in a watery arrangement of potassium iodide the tri-iodide-anion edifices with starch, and it distinguishes the viable and non-viable pollen grains. The same kind of result was observed in hybrid banana pollen grains (Ssali et al. 2012). It has been known that pollen viability is an important factor in assessing the good quality of pollen (Sulusoglu et al. 2014). Brewbaker and Kwack's medium supplemented with 10% sucrose had a pollen germination rate of 63.1%. Pollen germination rate was higher in 10% sucrose-containing medium in many Euphorbiaceae species. 71% of pollen germination rate was observed in *Jatropha curcas* in a medium containing sucrose (Abdelgadir et al. 2012). Sucrose serves as a nutritive resource for pollen germination and assists in the maintenance of the osmotic balance between pollen cytoplasm and germinated medium (Johri & Vasil 1961). However, a higher concentration of sucrose inhibits the growth of pollen tubes (Hine et al. 2019). Pollination efficiency and pollinator availability are influenced by the timing of flowering (Bawa 1983). Female flowers have a lifespan of 5–7 days, while male flowers have a lifespan of 2–3 days after anthesis. Female flowers have pistils and reduced staminodes, and male flowers have well-developed anthers and diminished pistillode. Cross-pollination is facilitated in *B. courtallensis* by the flower architecture.. In the present study honey bees, black ants, and spiders were observed in male and female flowers. Black ants and spiders were considered floral visitors because they were found on both male and female flowers. A male flower offers nectar and pollen grains as food resources to floral visitors. There is a possibility for pollination by these floral visitors. A comparable type of insect visitation and pollination that occurred in *Phyllanthus emblica* was reported by Halder et al. (2019). Amla tree flowers are mostly cross-pollinated by wind and honey bees. The pollen ovule ratio is an important factor that determines the fruit set rate (Cruden 1977). The mean number of pollen/ovule ratio was 1687:1 and the percentage of fruit set was 74. Successful pollination and fruit set are greatly influenced by pollinators, as well as, by the abundance of male trees (Dafni et al. 2005).

The fruit is a bacca (berry) which has a thick and juicy pericarp with a coloured exocarp, fleshy mesocarp, and a membranous endocarp. The contrasting inference is offered by a few authors that fruits of phyllanthaeceae are dehiscent schizocarps (Fahn & Zohary 1955; Roth 1977; Gagliardi et al. 2013). However, the fruit of *Baccaurea courtallensis* is a bacca which is dehiscent naturally. The mesocarp encloses a fragile aril that develops from one of the structures like funiculus, raphe, or integuments (Fahn 1967). Arils are very common in tropical and subtropical plants. These arillate seeds are well adapted to dispersal by animals (Corner 1976). The fruit is a dehiscent type and develops from three carpels. Species of Phyllanthaceae have tricarpellary ovary with two ovules in each locule (Gagliardi et al. 2013). Though, fertilization takes place uniformly in a flower the number of seeds set at maturity is either one or two per fruit. Thus, out of six ovules, only one or two become fertile seeds and the rest either abort or are underdeveloped. As the flower and fruit set ratio is unbalanced a large number of flowers are produced on the tree trunks in order to increase the availability of fertile seeds. The fruits are fleshy and edible and hence, they attract animals which subsequently help in seed dispersal. Fleshy fruits are opened by dispersing animals or naturally by the rotting of the outer tissues (Mauseth 1988).

The seed is covered by a protective layer of cells called testa which is made of an outer thick layer with macrosclerides and thin inner layers (Gagliardi et al. 2013). The scleride nature of these cells is easily distinguished while observing under polarized light facilitated with first order red plate. The thickness of the testa varies from region to region within a seed. Below the testa, two degrading layers of cells are found during the developmental stage which may be the perisperm and endosperm (Image 3G). Just beneath the digesting endosperm layer, the storage cells of cotyledon are found abundantly. These storage cells house starch and oil bodies enormously. Oil bodies in cotyledons are distinguished by rhodamine stain and Sudan III (Image 3H).

There is inadequate information in the literature on most of the aspects of the reproductive biology of *B. courtallensis* like phenology, floral description, pollen biology, pollination, and embryo development. The present study has carried out floral biology, phenology, pollen biology, and some aspects of fruit development for the first time in *B. courtallensis*, which may be useful for efforts on the conservation of this endemic, underutilized wild edible fruiting tree.

CONCLUSION

Baccaurea courtallensis is one of the few interesting and important members of the family Phyllanthaceae, which is endemic and occurs from 180 m to 1,000 m elevations in the Western Ghats of peninsular India. This taxon attracts attention due to its cauliflory and the bright red flowers and fleshy fruits that are attributed with curative properties. Apart from the ornamental purpose, the fruits of this tree are rich in nutritional value and possess medicinal properties. Due to anthropogenic activities and habitat destruction, this species has reduced in population. Being devoured by animals and exploited by local trade, the species is represented sparsely by fewer individuals. Successful management of forest resources requires knowledge of blooming phenology, the time, duration, and frequency of distinct phenoevents, particularly for species of forest trees. The conservation of this species depends heavily on the understanding of its reproductive biology, floral biology, pollen biology, and pollination. Thus, the flowering phenology, floral morphology, fruit anatomy, and pollen biology are reported in the current study in detail so as to better understand them for future applications. Future efforts to protect this unique tree might benefit a lot from this report.

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Author details: Karuppiah Nandhini is a Ph.D. research scholar & worked as Assistant Professor (Temporary) in the Department of Plant Science at Manonmaniam Sundaranar University. She is very passionate about the field of Plant Tissue culture and is also strongly interested in the fields of plant reproductive biology and molecular biology. She is keenly interested in the conservation of IUCN red-listed plants of Western Ghats. Vincent Joshuva David, a DBT Junior Research Fellow, is currently working on his Ph.D. in the Department of Plant Science, Manonmaniam Sundaranar University, Tirunelveli. He has a keen interest in practical exposure to Biodiversity, Plant Reproductive Biology, Plant Molecular and Biotechnology, Plant anatomy, and Conservation of Biodiversity. Venugopal Manimekalai is currently working as an Assistant Professor in the Department of Botany, Sri Parasakthi College for Women, Courtallam. Her fields of research include Plant anatomy and histochemistry, Natural dyeing of miscellaneous plant fibres, Plant tissue culture, and Plant reproductive biology. She was a recipient of the DST young women scientist (WOSB) award. She has bagged three times best student's research project awards from the Tamil Nadu State Council for Science and Technology. Perumal Ravichandran is working at present as a Professor in Manonmaniam Sundaranar University. His fields of research are the Conservation of Biodiversity, Agrostology, Grassland Management, Natural Dyeing, and Plant Biotechnology. He has over 25 years of teaching and research experience. He has extensively surveyed the Western Ghats and other forest areas in India for Botanical and Ecological investigations. He was a member of IUCN – SSC- Indian Sub-Continent Plant Specialist Group (ISPSG).

Author contributions: KN – Field & experimental study, data collection, compilation, writing, VJD- Field study, Field Photography, and Photo editing, Map preparation, VM-writing, proofreading and editing, PR- Field study, Hypothesis, conceptualization, Microphotography, writing, editing, and supervision.

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ARTICLE

Plant species diversity in the riparian forests of the Moyar River in southern India

Muthu Karthick Nagarajan [1] & Avantika Bhaskar [2]

[1] Department of Botany and Research Centre, Scott Christian College, Nagercoil, Tamil Nadu 629003, India.
[1,2] Care Earth Trust, No. 3, Sixth Street, Thillaiganga Nagar, Chennai, Tamil Nadu 600061, India.
[1] nmk.sam@gmail.com (corresponding author), [2] avantikabhaskar@gmail.com

Abstract: Riparian forests are among the most rapidly disappearing vegetation types throughout the world. River Moyar cascades through gorges and links the Western Ghats with the southernmost segments of the Eastern Ghats. Considering the relatively well-preserved state of the Moyar riparian vegetation and being amongst the least explored forests in southern India, an assessment of angiosperm diversity was undertaken. The study used an array of belt transects along and perpendicular to the river course so that the entire elevation gradient of the gallery could be covered. A total of 172 species representing 126 genera belonging to 47 families, including 100 monotypic genera and 17 monotypic families, were recorded from both the transects in the study area. 131 woody angiosperm species representing 100 genera in 41 families were recorded along the river. The perpendicular gallery transects recorded 111 woody angiosperm species representing 86 genera in 36 families. Thirteen monotypic families were found in both transects, and 70 species were found in both transects. The dominant families with the maximum species were Fabaceae, Rubiaceae and Phyllanthaceae. Shannon diversity index ranged between 2.0 to 3.27 along the river transects and 1.51 to 2.67 along the galleries. The study concludes that Moyar riparian zone merits high conservation value as it supports significant species diversity, including red-listed species and habitat-specific plants, and functions as a vital wildlife corridor in the landscape.

Keywords: Angiosperm diversity, flora, gallery, Nilgiris, riparian vegetation, Tamil Nadu, Western Ghats.

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Author details: Muthu Karthick Nagarajan is pursuing his PhD and works largely in the landscape of Western Ghats on various aspects like riparian forests and invasive alien species. Avantika Bhaskar, project manager (R&D) is a researcher working on various aspects of ecological conservation in Tamil Nadu.

Author contributions: NMK did the floristic assessments and data analyses, and AB wrote the manuscript.

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INTRODUCTION

Riparian forests are among the most rapidly-disappearing vegetation community types, largely owing to direct human actions and the indirect effects of modifying river courses for navigation and building of dams (Kauffman et al. 1997). Riparian forests are directly adjacent to rivers and streams, including active floodplains and nearby terraces (Naiman et al. 2001), and their vegetation interacts with terrestrial as well as aquatic ecosystems (Nilsson et al. 1994). Riparian communities are structurally and compositionally diverse, and vary from patchy forests with dense moss in cold regions, to deciduous trees and shrubs in floodplains, to well-developed forests with distinct plant zonation in the deltas (Nilsson & Svedmark 2002). The riparian zone is inhabited by specialist plants that are resilient to frequent disturbances like flooding, sedimentation, abrasion, breakage, etc. (Naiman et al. 1993). Riparian vegetation performs various ecological functions, such as providing food, organic matter, shelter and habitat, regulating stream water temperature, filtering sediments and nutrients, dissipating stream energy, preventing erosion and regulating the flow of litter from the forest floor into the stream (Gregory et al. 1991; Naiman & Decamps 1997; Naiman et al. 2001; Bowler et al. 2012; Jackson et al. 2015).

Rivers in India have historically seen the flourishing of human cultures, and in recent times they have been dammed and transformed considerably, with major consequences for riparian vegetation. While riparian vegetation structure is fairly similar along free-flowing rivers, it varies along regulated rivers due to changing water level conditions (Nilsson et al. 1997). High rates of disturbances make the riparian zone susceptible to invasions by alien species that are generally early seral species (Richardson et al. 2007). Studies have shown that riparian plant community structure is related to land use, and areas adjacent to agricultural and urban stretches have been found to have high invasive species cover and richness, respectively (Meek et al. 2010; Méndez-Toribio et al. 2014).

Our study is focused on the river Moyar that flows eastwards from the Western Ghats, a global biodiversity hotspot (Myers et al. 2000). River Moyar originates in the higher elevation zones of Nilgiri Biosphere Reserve, the first UNESCO recognized biosphere reserve in India. The riparian vegetation of the Moyar River is heterogeneous, and is undergoing gradual degradation owing to the construction of hydroelectric projects, pollution from factory effluents, local tourism pressure, widespread agriculture and excessive use of pesticides. An integrated conservation plan that includes participatory micro-plans has been made for the entire course of the river. As one of the first steps of this plan, we explored the riparian vegetation and enumerated the angiosperm species. The preliminary results of the study are presented in the sections below.

STUDY AREA AND METHODS

The Moyar River originates (11.5143^{0}N 76.5353^{0}E) in the upper reaches of the Niligiri Biosphere Reserve and meanders about 90 km through the Mudumalai and Sathyamangalam Tiger Reserves before joining Bhavani River at Bhavanisagar reservoir (11.4760^{0}N; 77.0553^{0}E). Pykara and Sigur are the major streams that feed the Moyar River. To the south, a few smaller streams like Kukkulthorai, Kedrahalla, and Kahanhalla drain into the river (Sukumar 1989; Lannerstad & Molden 2009) (Figure 1). Moyar River is also important, as it is a part of the larger Cauvery River basin.

Moyar River is known for its rich biodiversity, especially the large threatened animals such as Asian Elephants, Gaurs, feral water buffalos, Bengal Tigers, Marsh Crocodiles, Indian Rock Pythons, and vultures. The riparian vegetation sustains a small nesting colony of the 'Critically Endangered' Indian White-rumped Vulture. Around 90 species of fish have been reported from this river (Sukumar 1989; CEPF Project Report 2012), which contributes enormously to both fisheries in the state of Tamil Nadu and also local subsistence fishing throughout its length. The total study area falls under the protected area network of India. The Tamil Nadu Forest Department gave permission to carry out this research in the landscape.

The 90 km long Moyar River was sampled (during the period 2010–2011, spanning the wet and dry seasons) for angiosperm species richness and diversity using 20 transects, each of 4 km in length, along the river course (longitudinal transects). To capture the variations in species composition caused by the gallery (Yang et al. 2011), 24 supplementary or perpendicular transects (1 km each) were laid such that they cut across the lateral slopes. The supplementary transects were perpendicular to the river course transects. The width of the belt along transects was limited to five metres on either side. The elevation of the study area ranged 267–947 m.

Woody plants were identified and enumerated within the belts. Woody plants with girth at breast height (GBH) of more than one centimetre were enumerated. Plants

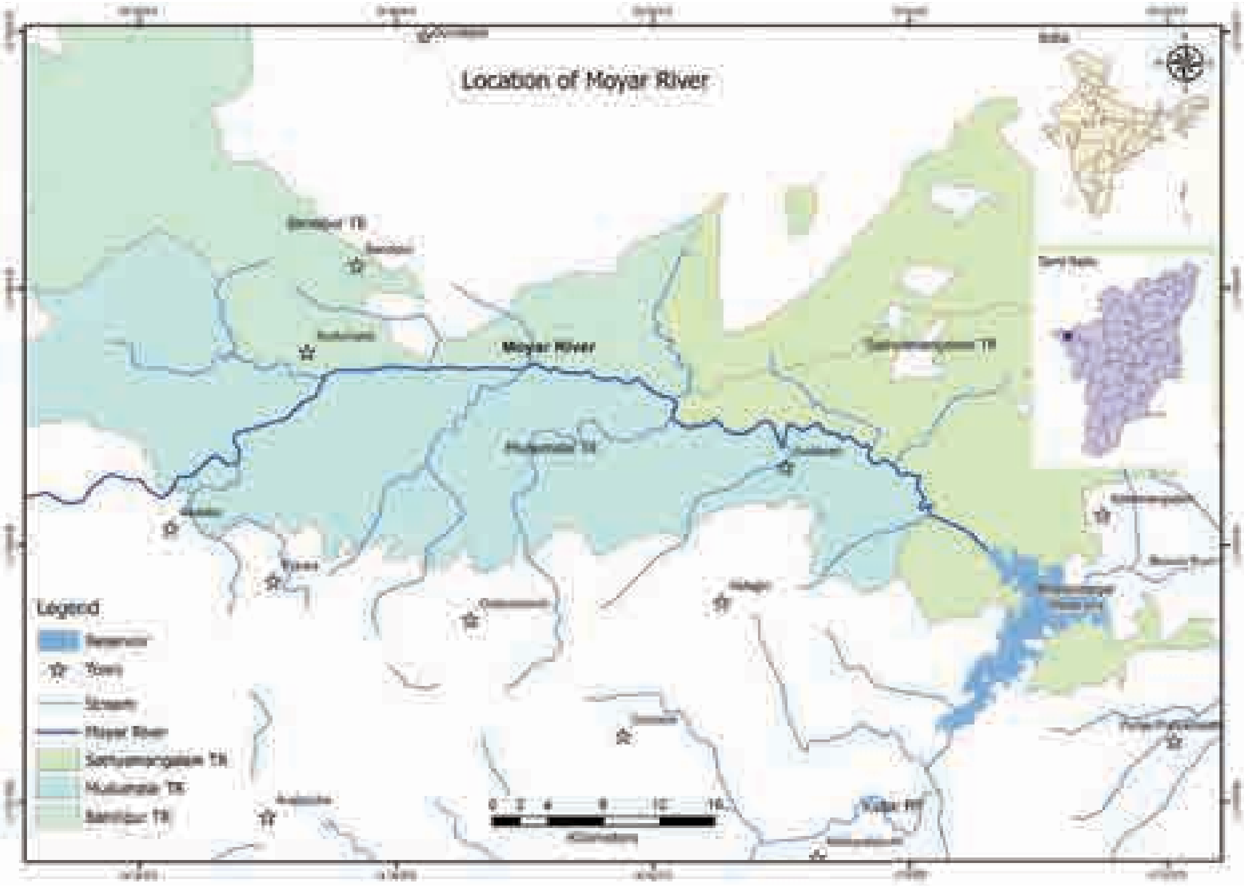

Figure 1. Map of the study area along the Moyar River in Tamil Nadu, India.

were identified using available guides, Floras and with the help of reference photographs. Hand-held lenses and measuring scales were used in the field and lab for plant identification. Some flowers from tall trees were observed and identified with the help of binoculars. In cases where field identification was not possible, voucher specimens were collected, preserved and identified using standard references such as Bentham & Hooker (1862–1883), Gamble & Fischer (1915–1936), and Mathew (1983). Nomenclature and classification were adopted from the Angiosperm Phylogeny Group IV system (Stevens 2001). Nomenclatural information was verified with online portals such as Tropicos (http://www.tropicos.org/), Plants of the World Online (POWO 2022), International Plant Names Index (IPNI 2022), and World Flora Online (WFO 2022). The nomenclature and distribution information were further verified using Flowering Plants of Tamil Nadu: A Compendium (Narasimhan & Irwin 2021). The erstwhile traditionally recognized families of Caesalpinaceae and Mimosaceae were reduced to the subfamily level and included under the family Fabaceae with the recent phylogenetic analyses by the Legume Phylogeny Working Group (LPWG 2017).

Vegetation classification was done using 'Map of the Nilgiri Biosphere Reserve (1/100,000): land use and vegetation' (Prabhakar & Pascal 1996) and 'A Revised Survey of Forest Types of India' (Champion & Seth 1968). The extent of each vegetation type in the study area was visually interpreted using Google Earth software. The woody angiosperm species were classified based on their life form into trees, shrubs and lianas.

Diversity was calculated using Shannon's diversity index (Shannon & Weaver 1949), and Pielou's index was used to determine evenness in the community (Pielou 1966).

RESULTS

River Moyar flows from west to east. Following is the vegetation types from its origin to towards the reservoir; Southern Moist Mixed Deciduous Forests (3B/C2), Dry Savannah Forests (5/DS3), Southern Dry Mixed

Deciduous Forests (5A/C3), and Southern Thorn Scrub Forests (6A/DS1). The forest types are classified based on Champion & Seth (1968).

From the East to west, the vegetation along the Moyar River course, according to Champion & Seth (1968), is composed of Southern Thorn Scrub Forests (6A/DS1), Southern Dry Mixed Deciduous Forests (5A/C3), Dry Savannah Forests (5/DS3), Southern Moist Mixed Deciduous Forests (3B/C2) vegetation, Southern Tropical Riverine Forest (5/B1) and Tropical Riparian Fringing Forests (4E/RS1).

The manual visual interpretation of the study area in Google Earth software reveals that vegetation of the Moyar River valley is heterogeneous and largely composed of riparian (32%), scrub (25%), deciduous (14%), plantation (13%), savanna (11%), and infested (5%) vegetation (Figure 2). Based on the dominance of certain species, the riparian vegetation of the Moyar River could be broadly classified into three types, namely *Terminalia–Pongamia–Syzygium* type, *Prosopis*-infested type, and *Bamboo–Mangifera* type (Images 1–3).

Life-form composition of angiosperm species was trees (78.6%), shrubs (15.3%), and lianas (6.1%) along the river-bank, and correspondingly, 73%, 24.3% and 2.7%, along the perpendicular transects, suggesting an overall dominance of trees. A higher percentage of shrubs was however observed in the galleries.

When analyzing the family richness, it was found that there are no significant differences in families representing different species in both types of transects, suggesting the dominance of few families in both zones (Figure 3). The families dominating the river course transects included Fabaceae (20 species and 16 genera), Phyllanthaceae (nine species and seven genera) and Rubiaceae (nine species and nine genera). In comparison, the perpendicular gallery transects were dominated by Fabaceae (21 species and 18 genera) Rubiaceae (eight species and eight genera), and Malvaceae (six species and three genera) families. Fabaceae has been the dominant family in Tamil Nadu state and it includes four clades, viz., Caesalpinioideae (including Mimosoid group), Cercidoideae, Detarioideae, and Faboideae (Narasimhan & Irwin 2021).

A total of 172 species representing 126 genera belonging to 47 families, including 100 monotypic genera and 17 monotypic families, were recorded from all the transects in the entire study area (Table 1); 131 woody species representing 100 genera belonging to 41 families, including 82 monotypic genera and 13 monotypic families, were enumerated in the longitudinal transects along the river course. Additionally, 111 species representing 86 genera belonging to 36 families, including 68 monotypic genera and 13 monotypic families, were recorded in the perpendicular gallery transects. Seventy species were found in both the transects, dominated by Fabaceae with 10 genera and 12 species alone. In the case of riverine vegetation, the Shannon diversity index ranged 2.0–3.27 and evenness (Pielou-index) was of the order of 0.59–0.85; whereas, in perpendicular gallery transects, the diversity was 1.5–2.67 with an evenness of 0.53–0.86. This data indicates that the riparian zone was more diverse. However, the variations in the number of species between the two communities were not very different.

Species like *Filicium decipiens* (Wight & Arn.) Thwaites, *Homonoia riparia* Lour., *Salix tetrasperma* Roxb., *Vitex leucoxylon* L.f., and *Walsura trifoliolata* (A.Juss.) Harms were predominantly riparian. Dominant tree species found along the river-course transects included *Terminalia arjuna* (Roxb. ex DC.) Wight & Arn., *Pongamia pinnata* (L.) Pierre and *Syzygium cumini* (L.) Skeels, *Diospyros malabarica* (Desr.) Kostel., while *Catunaregam spinosa* (Thunb.) Tirveng., *Albizia amara* (Roxb.) Boivin, *Prosopis juliflora* (Sw.) DC. and *Cordia monoica* Roxb. were the common trees observed in the perpendicular gallery transects (Photographs of

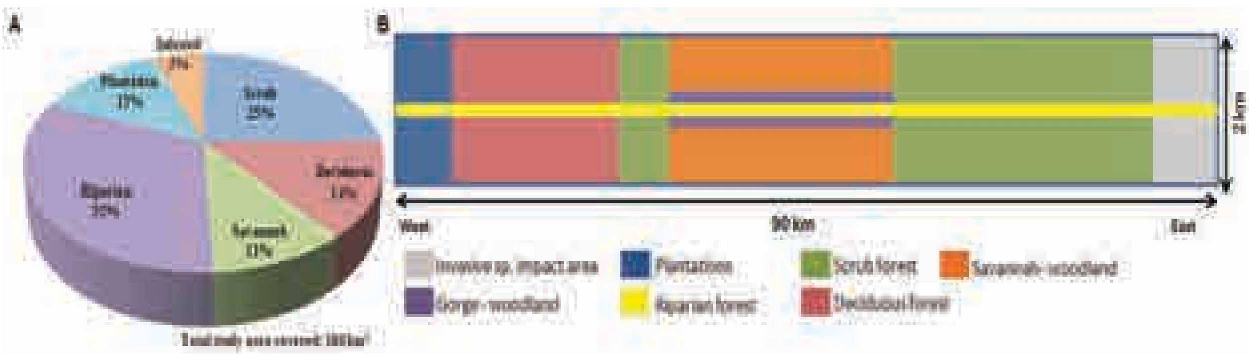

Figure 2. A—Vegetation composition along Moyar River | B—Schematic diagram showing the distribution of vegetation along Moyar River.

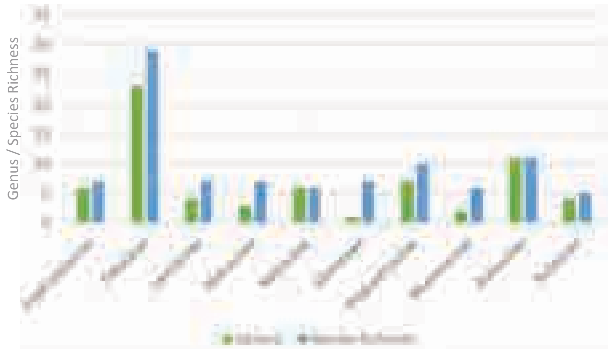

Figure 3. Dominant families along Moyar River.

a few representative species are shown in Images 4–6). Seventy-two species in both communities are categorised as 'Least Concern', while seven species are assigned with 'Vulnerable' status in the IUCN global Red List data (IUCN 2022). *Pterocarpus marsupium* Roxb. and *Swietenia mahagoni* (L.) Jacq. are the 'Near Threatened' species found in both the transects (http://www.iucnredlist.org) (Table 1). The taxa observed in both transects included 160 indigenous species and 12 non-native woody plant species.

Non-native species found in the riparian zone included *Bixa orellana* L., *Delonix regia* (Bojer ex Hook.) Raf., *Jatropha curcas* L., *Ricinus communis* L., and *Senna didymobotrya* (Fresen.) H.S.Irwin & Barneby. The predominant invasive species commonly observed here were *Chromolaena odorata* (L.) R.M.King & H.Rob., *Lantana camara* L., *Opuntia monocantha* Haw., *Prosopis juliflora*, and *Senna spectabilis* (DC.) H.S.Irwin & Barneby.

DISCUSSION

Riparian vegetation studies conducted earlier along the Chalakudy River (Bachan 2003), the Pamba River (Paul & George 2010) and the Benin River (Natta 2003), revealed Euphorbiaceae (including Phyllanthaceae), Fabaceae and Rubiaceae as the dominant families, as in this study. The dominance of these families along the rivers has been attributed to the thriving of these species in flooded and highly humid regions and improved adaptation of legume trees to waterlogged conditions owing to symbiotic nitrogen-fixing organisms (Koponen et al. 2004; Bognounou et al. 2009; Sambaré et al. 2011).

The high value of woody species richness, similar to the present study, has been previously reported in many riparian forests (Pither & Kellman 2002; Suzuki et al. 2002; Ward et al. 2002; Natta 2003; Tiegs et al. 2005; Sambaré et al. 2011). The Shannon diversity index of angiosperms in riparian forests along the Cauvery River basin has been reported to be 2.7±0.51 (Sunil et al. 2010). It ranged 1.0–2.95 in the case of the Meenachil River basin, Kerala, southern India (Vincy et al. 2015). The diversity index of angiosperms in Moyar is comparable to those of the riverine forests in Indonesia (Richter 2000), the southeastern United States (Burton et al. 2005), and Burkina Faso (Sambaré et al. 2011). The observed heterogeneity in vegetation along the gallery can be attributed to variations in geomorphology, soil drainage, moisture availability and light conditions (Gregory et al. 1991).

The long history of human interference has made the riparian zone a corridor for invasion and spread of

Image 1. Riparian habitat in the lower elevation (*Terminalia-Pongamia-Diospyros* zone). © Muthu Karthick.

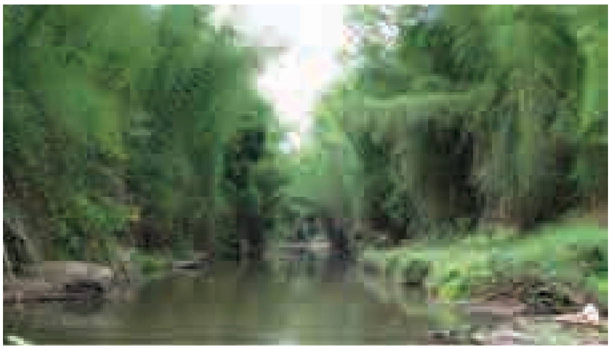

Image 2. Riparian habitat in the upper elevation (*Bamboo-Mangifera* zone). © Muthu Karthick.

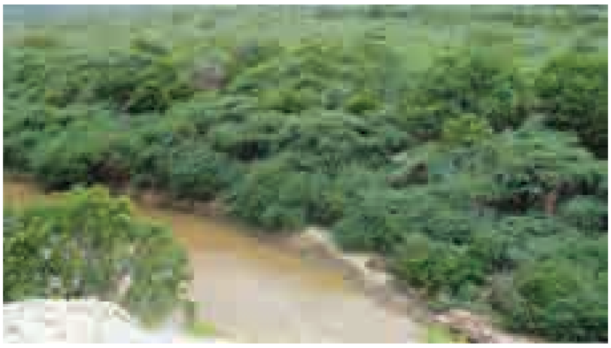

Image 3. Riparian habitat showing the *Prosopis*-infested zone. © Muthu Karthick.

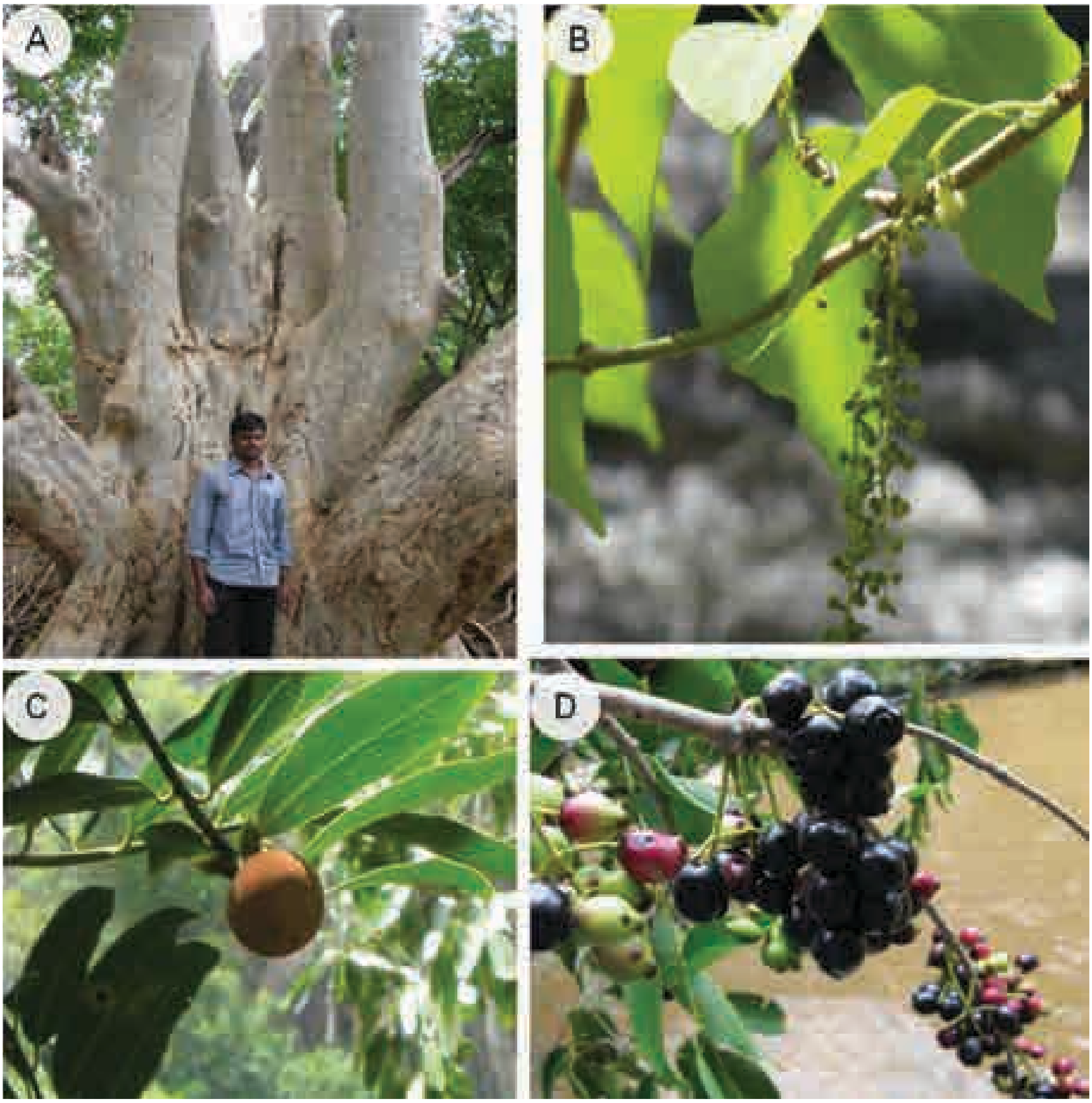

Image 4. Dominant trees of the gallery vegetation along the Moyar River: A—*Terminalia arjuna* (Combretaceae) | B—*Mallotus nudiflorus* (Euphorbiaceae) | C—*Diospyros malabarica* (Ebenaceae) | D—*Syzygium cumini* (Myrtaceae). © Muthu Karthick & Chenna Krishnan.

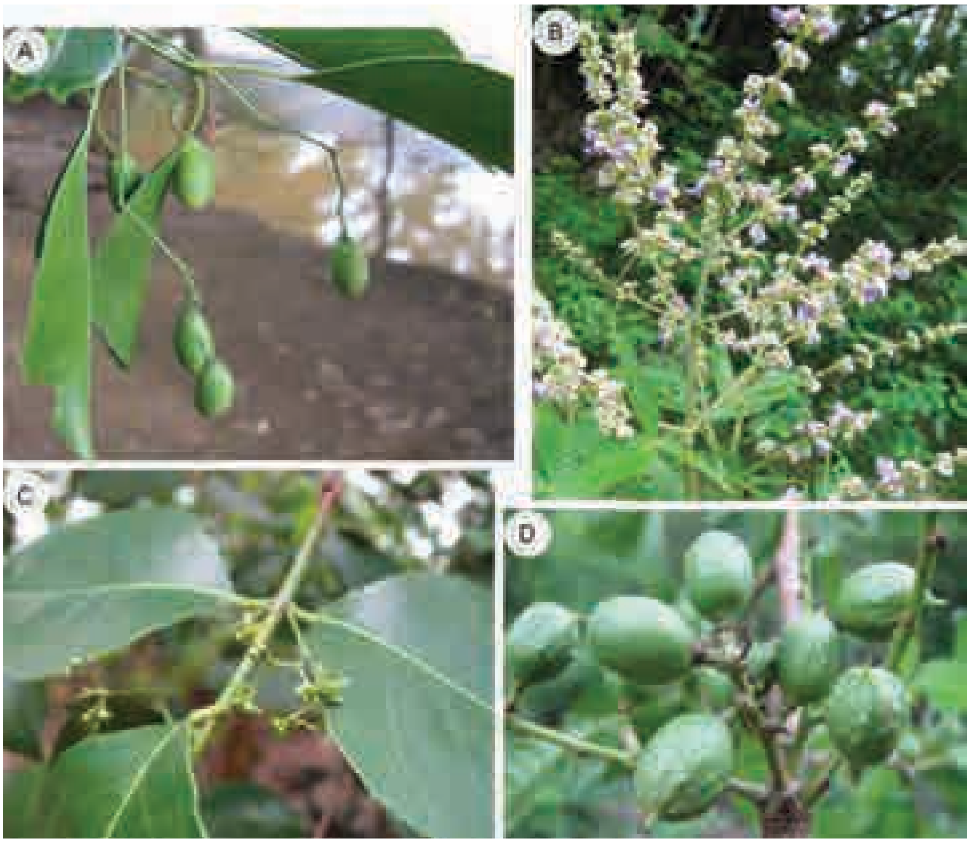

Image 5. Common trees in the upper elevation regions of the Moyar River system: A—*Pleurostylia opposita* (Celastraceae) | B—*Vitex altissima* (Lamiaceae) | C—*Elaeodendron glaucum* (Celastraceae) | D—*Schleichera oleosa* (Sapindaceae). © Muthu Karthick.

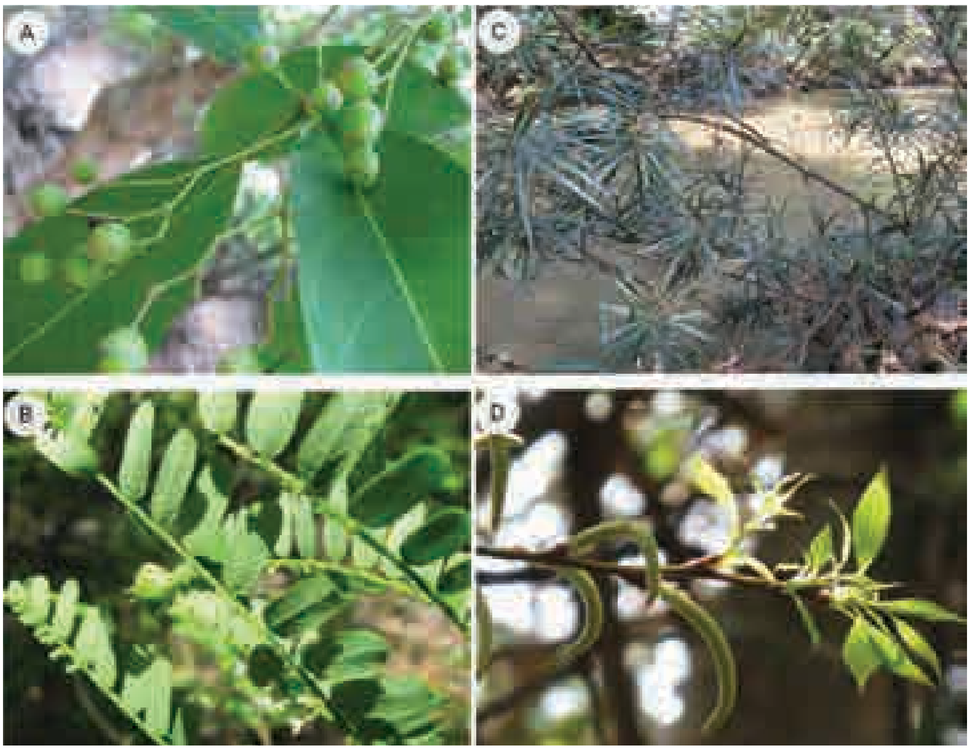

Image 6. Strict riparian species of the Moyar River system: A—*Vitex leucoxylon* (Lamiaceae) | B—*Homonoia riparia* (Euphorbiaceae) | C—*Phyllanthus racemosus* (Phyllanthaceae) | D—*Salix tetrasperma* (Salicaceae). © Muthu Karthick.

Table 1. Woody species recorded in the longitudinal (LT) and perpendicular transects (PT) along the Moyar River.

	Family	Species	Habit	Origin	IUCN Status	Voucher no.	LT	PT
1	Acanthaceae	*Strobilanthes cordifolia* (Vahl) J.R.I.Wood	Shrub	I	NE	CET 555		Y
2	Anacardiaceae	*Lannea coromandelica* (Houtt.) Merr.	Tree	I	LC	#		Y
3	Anacardiaceae	*Mangifera indica* L.	Tree	I	DD	#	Y	Y
4	Anacardiaceae	*Searsia mysorensis* (G.Don) Moffett	Shrub	I	NE	#		Y
5	Anacardiaceae	*Spondias pinnata* (L.f.) Kurz	Tree	I	NE	#	Y	
6	Apocynaceae	*Carissa carandas* L.	Shrub	I	NE	#	Y	Y
7	Apocynaceae	*Carissa spinarum* L.	Shrub	I	LC	#		Y
8	Apocynaceae	*Rauvolfia verticillata* (Lour.) Baill.	Shrub	I	NE	CET 552		Y
9	Apocynaceae	*Wrightia arborea* (Dennst.) Mabb.	Tree	I	LC	CET 512	Y	
10	Apocynaceae	*Wrightia tinctoria* (Roxb.) R.Br.	Tree	I	NE	#	Y	Y
11	Asteraceae	*Orbivestus cinerascens* (Sch.Bip.) H.Rob.	Shrub	I	NE	CET 554		Y
12	Bignoniaceae	*Dolichandrone arcuata* (Wight) C.B.Clarke	Tree	I	NE	CET 533	Y	Y
13	Bignoniaceae	*Dolichandrone atrovirens* (Roth) K.Schum.	Tree	I	NE	#	Y	Y
14	Bignoniaceae	*Dolichandrone falcata* (Wall.ex DC.) Seem.	Tree	I	NE	CET 551	Y	Y
15	Bignoniaceae	*Radermachera xylocarpa* (Roxb.) K.Schum.	Tree	I	NE	#	Y	
16	Bignoniaceae	*Stereospermum colais* (Buch.-Ham. ex Dillwyn) Mabb.	Tree	I	NE	CET 513	Y	Y
17	Bixaceae	*Bixa orellana* L.	Tree	TAm	LC	#	Y	
18	Boraginaceae	*Cordia macleodii* (Griff.) Hook.f. & Thoms.	Tree	I	NE	CET 567		Y
19	Boraginaceae	*Cordia monoica* Roxb.	Tree	I	LC	#	Y	Y
20	Boraginaceae	*Cordia obliqua* Willd.	Tree	I	NE	#	Y	
21	Burseraceae	*Boswellia serrata* Roxb.	Tree	I	NE	#		Y
22	Burseraceae	*Commiphora caudata* (Wight & Arn.) Engl.	Tree	I	NE	#	Y	Y
23	Burseraceae	*Garuga pinnata* Roxb.	Tree	I	NE	CET 560	Y	Y
24	Cactaceae	*Opuntia monocantha* Haw.	Shrub	TAm	NE	#		Y
25	Cannabaceae	*Celtis timorensis* Span.	Tree	I	LC	CET 511	Y	Y
26	Cannabaceae	*Trema orientalis* (L.) Blume	Tree	I	LC	#	Y	
27	Capparaceae	*Capparis brevispina* DC.	Shrub	I	NE	CET 556		Y
28	Capparaceae	*Capparis divaricata* Lam.	Tree	I	NE	CET 559		Y
29	Capparaceae	*Capparis sepiaria* L.	Shrub	I	LC	#		Y
30	Caprifoliaceae	*Viburnum punctatum* Buch.-Ham. ex D.Don	Liane	I	NE	CET 516	Y	
31	Celastraceae	*Elaeodendron glaucum* (Rottb.) Pers.	Tree	I	NE	CET 558	Y	Y
32	Celastraceae	*Gymnosporia heyneana* (Roth) M.A.Lawson	Shrub	I	NE	#	Y	Y
33	Celastraceae	*Pleurostylia opposita* (Wall.) Alston	Tree	I	LC	CET 517	Y	
34	Combretaceae	*Combretum ovalifolium* Roxb.	Liane	I	NE	CET 536	Y	
35	Combretaceae	*Terminalia anogeissiana* Gere & Boatwr.	Tree	I	NE	#	Y	Y
36	Combretaceae	*Terminalia arjuna* (Roxb. ex DC.) Wight & Arn.	Tree	I	NE	#	Y	Y
37	Combretaceae	*Terminalia bellirica* (Gaertn.) Roxb.	Tree	I	LC	#	Y	Y
38	Combretaceae	*Terminalia elliptica* Willd.	Tree	I	NE	CET 562	Y	Y
39	Cornaceae	*Alangium salviifolium* (L.f.) Wangerin	Tree	I	LC	CET 583	Y	
40	Dipterocarpaceae	*Shorea roxburghii* G.Don.	Tree	I	VU	#	Y	
41	Ebenaceae	*Diospyros ferrea* (Willd.) Bakh.	Tree	I	NE	CET 572	Y	Y
42	Ebenaceae	*Diospyros malabarica* (Desr.) Kostel.	Tree	I	NE	CET 588	Y	
43	Ebenaceae	*Diospyros montana* Roxb.	Tree	I	NE	#	Y	Y
44	Erythroxylaceae	*Erythroxylum monogynum* Roxb.	Tree	I	NE	CET 522	Y	Y
45	Euphorbiaceae	*Euphorbia antiquorum* L.	Tree	I	LC	#		Y
46	Euphorbiaceae	*Givotia moluccana* (L.) Sreem.	Tree	I	NE	#	Y	Y

	Family	Species	Habit	Origin	IUCN Status	Voucher no.	LT	PT
47	Euphorbiaceae	*Homonoia riparia* Lour.	Shrub	I	LC	CET 571	Y	Y
48	Euphorbiaceae	*Jatropha curcas* L.	Shrub	TAm	NE	#	Y	
49	Euphorbiaceae	*Jatropha gossypiifolia* L.	Shrub	I	LC	#		Y
50	Euphorbiaceae	*Mallotus nudiflorus* (L.) Kulju & Welzen	Tree	I	LC	CET 521	Y	
51	Euphorbiaceae	*Ricinus communis* L.	Shrub	TAm	NE	#	Y	
52	Fabaceae	*Albizia amara* (Roxb.) Boivin	Tree	I	LC	#	Y	Y
53	Fabaceae	*Albizia lebbeck* (L.) Benth.	Tree	I	LC	#	Y	Y
54	Fabaceae	*Bauhinia racemosa* Lam.	Tree	I	NE	CET 520	Y	Y
55	Fabaceae	*Brachypterum scandens* (Roxb.) Miq.	Liane	I	NE	#	Y	Y
56	Fabaceae	*Butea monosperma* (Lam.) Kuntze	Tree	I	LC	#		Y
57	Fabaceae	*Cassia fistula* L.	Tree	I	LC	#	Y	Y
58	Fabaceae	*Dalbergia lanceolaria* subsp. *paniculata* (Roxb.) Thoth.	Tree	I	NE	#	Y	Y
59	Fabaceae	*Dalbergia latifolia* Roxb.	Tree	I	VU	CET 504	Y	Y
60	Fabaceae	*Delonix regia* (Bojer ex Hook.) Raf.	Tree	M	LC	#	Y	
61	Fabaceae	*Dichrostachys cinerea* (L.) Wight & Arn.	Tree	I	LC	#		Y
62	Fabaceae	*Entada rheedei* Spreng.	Liane	I	NE	CET 527	Y	
63	Fabaceae	*Erythrina variegata* L.	Tree	I	LC	#	Y	
64	Fabaceae	*Hardwickia binata* Roxb.	Tree	I	LC	#		Y
65	Fabaceae	*Mundulea sericea* (Willd.) A.Chev.	Tree	I	LC	CET 573		Y
66	Fabaceae	*Pongamia pinnata* (L.) Pierre	Tree	I	LC	#	Y	Y
67	Fabaceae	*Prosopis juliflora* (Sw.) DC.	Tree	TAm	NE	#	Y	Y
68	Fabaceae	*Pterocarpus marsupium* Roxb.	Tree	I	NT	#		Y
69	Fabaceae	*Pterolobium hexapetalum* (Roth.) Santapau & Wagh	Liane	I	NE	#	Y	
70	Fabaceae	*Samanea saman* (Jacq.) Merr.	Tree	TAm	LC	#	Y	
71	Fabaceae	*Senegalia chundra* (Roxb. ex Rottler) Maslin	Tree	I	NE	#		Y
72	Fabaceae	*Senegalia pennata* (L.) Maslin.	Liane	I	LC	#	Y	
73	Fabaceae	*Senna didymobotrya* (Fresen.) H.S.Irwin & Barneby	Shrub	I	LC	#	Y	
74	Fabaceae	*Senna occidentalis* (L.) Link	Shrub	TAm	LC	#	Y	
75	Fabaceae	*Senna spectabilis* (DC.) H.S.Irwin & Barneby	Tree	TAm	LC	CET 515	Y	Y
76	Fabaceae	*Sophora velutina* Lindl.	Shrub	I	NE	CET 576		Y
77	Fabaceae	*Spatholobus purpureus* Benth. ex Baker	Liane	I	NE	CET 580		Y
78	Fabaceae	*Tamarindus indica* L.	Tree	M	LC	#	Y	Y
79	Fabaceae	*Vachellia leucophloea* (Roxb.) Maslin, Seigler & Ebinger	Tree	I	LC	CET 532	Y	Y
80	Fabaceae	*Vachellia planifrons* (Wight & Arn.) Ragup., Seigler, Ebinger & Maslin	Tree	I	NE	#		Y
81	Hernandiaceae	*Gyrocarpus americanus* Jacq.	Tree	I	LC	#	Y	Y
82	Lamiaceae	*Gmelina arborea* Roxb. ex Sm.	Tree	I	LC	#		Y
83	Lamiaceae	*Gmelina asiatica* L.	Shrub	I	LC	#		Y
84	Lamiaceae	*Premna mollissima* Roth	Tree	I	NE	CET 592	Y	Y
85	Lamiaceae	*Premna tomentosa* Willd.	Tree	I	LC	#		Y
86	Lamiaceae	*Tectona grandis* L.f.	Tree	I	NE	#	Y	Y
87	Lamiaceae	*Vitex altissima* L.f.	Tree	I	NE	CET 541	Y	
88	Lamiaceae	*Vitex leucoxylon* L.f.	Tree	I	LC	CET 542	Y	
89	Loganiaceae	*Strychnos nux-vomica* L.	Tree	I	NE	#	Y	Y
90	Loganiaceae	*Strychnos potatorum* L.f	Tree	I	NE	CET 525	Y	Y
91	Lythraceae	*Lagerstroemia microcarpa* Wight	Tree	I	NE	CET 586	Y	Y
92	Lythraceae	*Lagerstroemia parviflora* Roxb.	Tree	I	LC	#		Y

	Family	Species	Habit	Origin	IUCN Status	Voucher no.	LT	PT
93	Lythraceae	*Lawsonia inermis* L.	Shrub	I	LC	#	Y	
94	Malvaceae	*Bombax ceiba* L.	Tree	I	LC	CET 557		Y
95	Malvaceae	*Grewia hirsuta* Vahl	Shrub	I	LC	CET 595	Y	Y
96	Malvaceae	*Grewia orbiculata* Rottler	Shrub	I	NE	#		Y
97	Malvaceae	*Grewia orientalis* L.	Shrub	I	NE	CET 543		Y
98	Malvaceae	*Grewia serrulata* DC.	Tree	I	NE	#	Y	
99	Malvaceae	*Grewia tiliifolia* Vahl	Tree	I	NE	#	Y	Y
100	Malvaceae	*Helicteres isora* L.	Shrub	I	NE	#	Y	Y
101	Melastomataceae	*Memecylon grande* Retz.	Tree	I	VU	CET 526	Y	
102	Melastomataceae	*Memecylon umbellatum* Burm.f.	Tree	I	NE	#	Y	
103	Meliaceae	*Aglaia elaeagnoidea* (A.Juss.) Benth.	Tree	I	LC	CET 505	Y	
104	Meliaceae	*Azadirachta indica* A.Juss.	Tree	IC	LC	#	Y	Y
105	Meliaceae	*Cipadessa baccifera* (Roxb. ex Roth) Miq.	Tree	I	LC	#	Y	Y
106	Meliaceae	*Soymida febrifuga* (Roxb.) A.Juss.	Tree	I	NE	CET 581		Y
107	Meliaceae	*Swietenia mahagoni* (L.) Jacq.	Tree	I	NT	#	Y	
108	Meliaceae	*Walsura trifoliolata* (A.Juss.) Harms	Tree	I	NE	#	Y	
109	Moraceae	*Ficus benghalensis* L.	Tree	I	NE	#	Y	
110	Moraceae	*Ficus benjamina* L.	Tree	I	LC	#	Y	Y
111	Moraceae	*Ficus hispida* L.f.	Tree	I	LC	#	Y	
112	Moraceae	*Ficus microcarpa* L.f.	Tree	I	LC	CET 506	Y	Y
113	Moraceae	*Ficus mollis* Vahl	Tree	I	NE	#	Y	Y
114	Moraceae	*Ficus racemosa* L.	Tree	I	LC	#	Y	
115	Moraceae	*Ficus tsjakela* Burm.f.	Tree	I	NE	CET 529	Y	
116	Moringaceae	*Moringa concanensis* Nimmo ex Dalzell & A.Gibson	Tree	I	NE	CET 537	Y	Y
117	Myrtaceae	*Psidium guajava* L.	Tree	I	LC	#	Y	
118	Myrtaceae	*Syzygium cumini* (L.) Skeels	Tree	I	LC	#	Y	Y
119	Myrtaceae	*Syzygium grande* (Wight) Walp.	Tree	I	NE	#	Y	
120	Olacaceae	*Olax scandens* Roxb.	Liane	I	NE	CET 509	Y	
121	Olacaceae	*Olea dioica* Roxb.	Tree	I	NE	#	Y	
122	Pandanaceae	*Pandanus odorifer* (Forssk.) Kuntze	Shrub	I	LC	#	Y	
123	Phyllanthaceae	*Aporosa acuminata* Thwaites	Tree	I	NE	CET 503	Y	
124	Phyllanthaceae	*Bischofia javanica* Blume	Tree	I	LC	#	Y	
125	Phyllanthaceae	*Breynia vitis-idaea* (Burm.f.) C.E.C.Fisch.	Shrub	I	LC	CET 502	Y	
126	Phyllanthaceae	*Bridelia retusa* (L.) A.Juss.	Tree	I	LC	CET 577	Y	Y
127	Phyllanthaceae	*Flueggea leucopyrus* Willd.	Shrub	I	LC	#		Y
128	Phyllanthaceae	*Glochidion zeylanicum* (Gaertn.) A.Juss.	Tree	I	LC	CET 501	Y	
129	Phyllanthaceae	*Phyllanthus emblica* L.	Tree	I	LC	CET 535	Y	Y
130	Phyllanthaceae	*Phyllanthus indofischeri* Bennet	Tree	I	VU	CET 534	Y	
131	Phyllanthaceae	*Phyllanthus racemosus* L.f.	Tree	I	NE	#	Y	
132	Phyllanthaceae	*Phyllanthus reticulatus* Poir.	Shrub	I	LC	#	Y	
133	Poaceae	*Bambusa bambos* (L.) Voss	Tree	I	NE	#	Y	Y
134	Poaceae	*Dendrocalamus strictus* (Roxb.) Nees	Shrub	I	NE	#	Y	Y
135	Primulaceae	*Ardisia solanacea* Roxb.	Tree	I	NE	CET 508	Y	
136	Putranjivaceae	*Putranjiva roxburghii* Wall.	Tree	I	LC	#	Y	
137	Rhamnaceae	*Scutia myrtina* (Burm. f.) Kurz	Shrub	I	LC	CET 524		Y
138	Rhamnaceae	*Ziziphus glabrata* B.Heyne ex Roth	Tree	I	NE	#	Y	
139	Rhamnaceae	*Ziziphus mauritiana* Lam.	Tree	I	LC	#	Y	Y

	Family	Species	Habit	Origin	IUCN Status	Voucher no.	LT	PT
140	Rhamnaceae	*Ziziphus oenopolia* (L.) Mill.	Liane	I	LC	#	Y	Y
141	Rhamnaceae	*Ziziphus rugosa* Lam.	Tree	I	NE	#		Y
142	Rhamnaceae	*Ziziphus xylopyrus* (Retz.) Willd.	Tree	I	NE	#	Y	Y
143	Rubiaceae	*Canthium coromandelicum* (Burm.f.) Alston	Shrub	I	NE	CET 530	Y	
144	Rubiaceae	*Catunaregam spinosa* (Thunb.) Tirveng.	Tree	I	LC	#	Y	Y
145	Rubiaceae	*Coffea wightiana* Wall. ex Wight & Arn.	Shrub	I	LC	CET 538	Y	Y
146	Rubiaceae	*Deccania pubescens* var. *candolleana* (Wight & Arn.) Tirveng.	Tree	I	NE	CET 589		Y
147	Rubiaceae	*Ixora pavetta* Andrews	Tree	I	NE	#	Y	Y
148	Rubiaceae	*Mitragyna parvifolia* (Roxb.) Korth.	Tree	I	NE	#	Y	Y
149	Rubiaceae	*Morinda coreia* Buch.-Ham.	Tree	I	NE	#	Y	
150	Rubiaceae	*Pavetta indica* L.	Shrub	I	NE	#	Y	Y
151	Rubiaceae	*Psydrax dicoccos* Gaertn.	Tree	I	VU	#	Y	Y
152	Rubiaceae	*Tamilnadia uliginosa* (Retz.) Tirveng. & Sastre	Tree	I	NE	#		Y
153	Rubiaceae	*Wendlandia thyrsoidea* (Schult.) Steud.	Shrub	I	NE	#	Y	
154	Rutaceae	*Atalantia monophylla* (L.) DC.	Tree	I	NE	#	Y	Y
155	Rutaceae	*Chloroxylon swietenia* DC.	Tree	I	VU	#	Y	Y
156	Rutaceae	*Glycosmis mauritiana* (Lam.) Tanaka	Shrub	I	LC	#	Y	
157	Rutaceae	*Glycosmis pentaphylla* (Retz.) DC.	Shrub	I	LC	#		Y
158	Rutaceae	*Pleiospermium alatum* (Wall. ex Wight & Arn.) Swingle	Tree	I	NE	CET 531	Y	Y
159	Salicaceae	*Flacourtia ramontchi* L'Hér.	Tree	I	NE	CET 523	Y	
160	Salicaceae	*Salix tetrasperma* Roxb.	Tree	I	LC	#	Y	
161	Salvadoraceae	*Salvadora persica* L.	Tree	I	LC	CET 519	Y	Y
162	Santalaceae	*Santalum album* L.	Tree	I	VU	#		Y
163	Sapindaceae	*Dodonaea viscosa* Jacq.	Shrub	I	LC	#		Y
164	Sapindaceae	*Filicium decipiens* (Wight & Arn.) Thwaites	Tree	I	LC	CET 510	Y	
165	Sapindaceae	*Sapindus emarginatus* Vahl	Tree	I	NE	#	Y	Y
166	Sapindaceae	*Schleichera oleosa* (Lour.) Oken	Tree	I	LC	#	Y	Y
167	Sapotaceae	*Madhuca longifolia* (J.Koenig ex L.) J.F.Macbr.	Tree	I	NE	CET 540	Y	Y
168	Sapotaceae	*Mimusops elengi* L.	Tree	I	LC	#	Y	
169	Simaroubaceae	*Ailanthus excelsa* Roxb.	Tree	I	NE	#	Y	
170	Solanaceae	*Solanum pubescens* Willd.	Shrub	I	NE	#		Y
171	Verbenaceae	*Lantana camara* L.	Shrub	TAm	NE	#	Y	
172	Verbenaceae	*Lantana indica* Roxb.	Shrub	I	NE	CET 596		Y

DD—Data Deficient | NE—Not Evaluated | LC—Least Concern | NT—Near Threatened | VU—Vulnerable | I—Indigenous | M—Madagascar | TAm—Tropical America | IC—Indo-China | LT—longitudinal transect | PT— perpendicular transect | Y—present| #—specimen not collected

invasive species (Johansson et al. 1996; Hood & Naiman 2000; Tockner & Stanford 2002). Many non-native and invasive species were observed along Moyar River which can be a potential threat to the riparian forest in the future. Succession is usually fast in riparian zones but is often slowed by invasive species. Invasive species also alter watershed hydrology and riparian ecology (Richardson et al. 2007). For instance, the invasion of *Tamarix ramosissima* Ledeb. in North America caused an increase in channel roughness and trapping of sediments, eventually narrowing the streams (Zavaleta 2000).

Riparian vegetation along the Moyar River remains intact in some stretches, and needs to be preserved as it supports high biodiversity. This forest serves as a habitat and corridor for many wildlife, especially threatened species such as Asian Elephants, tigers, otters, vultures, and over a hundred species of birds. However, the areas that have been extensively invaded by alien species such as *Prosopis juliflora* and *Senna spectabilis* need to be restored using the scientific approach. Studies have shown that the loss of riparian vegetation can have far-reaching effects on the ecosystem as they support high biodiversity (Sabo et al. 2005).

Moyar riparian vegetation is gradually degrading due to many factors. The river is dammed at the Bhavanisagar reservoir, where it is joined by river Bhavani, in addition to the upstream hydroelectric projects causing degradation. The construction of dams affects seed dispersal and alters the extent and composition of riparian communities (Jansson et al. 2000). Other anthropogenic activities such as cultivation, logging, grazing, water extraction and recreation also negatively impact riparian vegetation. In southern India, fragmentation and agro-forestry plantations have been found to alter riparian species composition in Cauvery and Chalakudy River basins (Bachan 2003; Sunil et al. 2011). Alteration of riparian forests can result in changes in the intensity of sunlight, nutrient availability, increased soil deposition, eutrophication, lowering of the water table and modification of both terrestrial and aquatic habitats (Decamps et al. 1988; Dudgeon 2000; Jansson et al. 2000; Aguiar et al. 2009; Wootton 2012; Kamp et al. 2013). Loss of riparian forests has also been reported to result in declines in bird species richness and diversity in the area (Arizmendi et al. 2008; Villaseñor-Gomez 2008).

Riparian vegetation characteristics reveal the water and habitat quality, and can be used to restore riparian habitats (Stockan et al. 2012). The present riparian vegetation analysis can also support water and landscape planning by involving the local community in restoration and conservation efforts. Moyar riparian zone merits high conservation value as it is a vital wildlife corridor, sustains Red Listed and important medicinal plants, and is under increasing anthropogenic pressure.

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ARTICLE

Diversity of bracket fungi (Basidiomycota: Agaricomycetes: Polyporaceae) in Jammu Division, Jammu & Kashmir, India

Brij Bala

School of Bio-Sciences, RIMT University, M82H+998, Delhi-Jalandhar GT Road (NH1), Gobindgarh, Punjab 147301, India.
mattoobalabrij777@gmail.com

Abstract: The 24 taxa comprising of 13 genera belonging to Polyporaceae (Basidiomycota, Agaricomycetes) are described and illustrated on the basis of basidiome collected during the rainy season in the years from 2014–2019 in Doda, Jammu, Kathua, Kishtwar, Ramban, and Udhampur districts of Jammu division of the Union Territory of Jammu & Kashmir. Of these, five (*Dichomitus campestris*, *Perenniporia adnata*, *Pilatoporus bondartsevae*, *Polyporus efibulatus*, and *Tyromyces amazonicus*) are new records for India, 14 (*Abortiporus biennis*, *Cerrena zonata*, *Favolus glaber*, *Fuscopostia leucomallella*, *Hexagonia nitida*, *Lenzites elegans*, *Lenzites warnieri*, *Perreniporia fraxniea*, P. *ochroleuca*, *Poriella subacida*, *Polyporus alveolaris*, *Pycnoporus sanguineus*, *Tyromyces chioneus*, and *Trichaptum biforme*), are new records for the Union territory of Jammu & Kashmir, two (*Pycnoporus cinnabarinus* and *Polyporus squamosus*), and the remaining three (*Fomes fomentarius*, *Lenzites betulina*, and *Trichaptum abietinum*) are re-recorded from the study area.

Keywords: Brown rot, northwestern Himalaya, poroid fungi, white rot.

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Author details: Dr. Brij Bala, M.Sc Botany and Ph.D. in mycology and plant pathology from Department of Botany, Punjabi University, Patiala. Currently working as assistant professor of Botany, in School of Bio-Sciences. RIMT University, Gobindgarh Punjab. Fungal taxonomist, area of specialization includes molecuar biology, plant patholgy, forest ecology and plant bio-diversity.

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INTRODUCTION

Polyporaceae (Agaricomycetes, Basidiomycota) is featured by annual to perennial, resupinate to effused-reflexed to pileate, sessile to stipitate basidiomes, having unilateral hymenium which forms the fertile layer surrounding the tubes that open on the hymenial surface in the variable shapes (circular, angular, daedaleoid, lamellate or irregular) of pores. Polypores act as decomposers and play an important role in the forest ecosystem (recycling the carbon and other nutrients) because of the secretion of lignolytic and cellulase enzymes causing white rot and brown rot, respectively. Along with this, some of these fungi show medicinal properties (Stavinoha 1991; Galor et al. 2011; Badalyan & Gharibyan 2016; Ján et al. 2016).

The Jammu division shows a wide spectrum of variation in altitude and climate. The forests in the Jammu division are categroised into six types, according to Champion & Seth (1968) they range from subtropical dry evergreen forests (*Acacia catechu*, *Eucalyptus* spp., *Olea ferruginea*, *Quercus baloot*, *Albizzia* spp., and *Nerium indicum*) to subtropical pine forests (dominated by *Pinus roxburghii*), other plant species also predominate (*Albizzia* spp., *Murraya indica*, *Olea cuspidata*, *Acacia catechu*, *Dalbergia sissoo*, *Emblica officinalis*, and *Rosa moschata*) to Himalayan dry temperate forests (*Acer* spp., *Abies pindrow*, *Aesculus indicus*, *Juglans regia, Cedrus deodara*, *Emblica officinalis*, and *Rosa moschata*) to Himalayan moist temperate forests (*Cedrus deodara*, *Abies pindrow*, *Pinus wallichiana*, *Picea smithiana*, *Fraxinus floribunda*, *Quercus leucotrichophora*, and Q. *dilata*) to subalpine forests (*Abies pindrow*, *Betula utilis*, *Rhododendron* spp., *Populus ciliata*, and *Quercus* spp.), and alpine vegetation (*Lonicera*, *Berberis* spp., and *Geranium* spp.).

MATERIAL AND METHODS

The polypore basidiomes were collected during excursions carried out in Doda, Jammu, Kathua, Kishtwar, Ramban, and Udhampur districts of Jammu Division in the rainy months (July–September) in the years 2014–2019. These basidiomes were detached from their substratum using a hammer and chisel. The macromorphological details, i.e., nature of the basidiome, mode of attachment, hymenial and abhymenial surface, and margins, were recorded. A piece of the fertile portion of the basidiome was used for getting the spore print on a micro slide. After drying (sun or electric drier), the collected basidiome were packed in zip-lock airtight bags. The micro morphological characters were studied by making preparations in water, 3%/5%/10% KOH, 1% phloxine, 1% Congo red, and 1% cotton blue (in distilled water/lactophenol). The cyanophilous and amyloid reaction of different microscopic structures were studied in 1% cotton blue and Melzer's reagent (Iodine 0.5 g, Potassium Iodide 1.5 g, Chloral hydrate 20.0 g, and distilled water 20.0 ml) respectively. The line diagrams of the microscopic structures were drawn with the help of a Camera Lucida mounted on a compound microscope at 100x, 400x, and 1,000x magnification. Finally, the specimens were identified on the basis of comparison of the description with the literature and online repository (Bakshi 1971; Dhanda 1977; Rattan 1977; Thind & Dhanda 1979, 1980a,b; Roy & De 1996; Leelavathy & Ganesh 2000; Sharma 2012; Kaur 2013; Ryavrden & Melo 2014; Kaur et al. 2017; Mycobank 2022). The identified specimens were finally submitted to the Herbarium, Department of Botany, Punjabi University, Patiala (PUN) using standard packing protocol.

RESULTS

The 24 described species are classified under 13 genera of family Polyporaceae; the key to the all genera pertaining the described species is given here.

Abortiporus biennis (Bull.: Fr) Singer, Mycologia 36: 68, 1944.

≡ *Boletu biennis* Bull., Herbier de la France 10: t. 449:1 (1790). (Image 1–7)

Basidiome annual, pileate, solitary, laterally stipitate; pilei flabelliform, up to 4×3×1.5 cm.

Abhymenial surface azonate, tomentose, dark brown to light brown when fresh, not changing much on drying; margin acute, concolorus, entire.

Hymenial surface poroid, pale buff to brown when fresh, not changing much on drying; margin concolorus, sterile up to 3 mm.

Pores angular to daedeloid, 3–4 per mm; dissepiments entire/lacerate, up to 75 µm in thickness.

Tube layer greyish-brown, up to 0.5 cm deep.

Context duplex; outer zone soft and fibrous, greyish-brown; inner zone corky and firm, lighter than outer zone; each zone up to 0.5 cm in thickness.

Stipe dorso-lateral, cylindrical, solid, tomentose, up to 2 × 0.7 cm.

Hyphal system monomitic. Generative hyphae

Key to the genera

1. Hyphal system strictly monomitic 2
1. Hyphal system mono/di/tri 3
2. Basidiospores cylindrical to allantoid .... *Fuscopostia*
2. Basidiospores subglobose to ellipsoid-rarely cylindrical .... *Abortiporus*
3. Basidiome strictly annual 4
3. Basidiome annual to perennial 6
4. Pores irpiciform .... *Cerrena*
4. Pores angular to polygonal 5
5. Generative hyphae simple septate/clamped .... *Pilatoporus*
5. Generative hyphae always clamped .... *Favolus*
6. Basidiome strictly pileate 7
6. Basidiome resupinate/effused/effused reflexed 10
7. Basidiome orange red to bright red .... *Pycnoporus*
7. Basidiome not as above 8
8. Hymenial surface comprises lamellate to somewhat deadeloid pores ....*Lenzites*
8. Hymenial surface comprises circular/round/elongated 9
9. Basidiome harder, woody; context duplex or homogenous .... *Fomes*
9. Basidiome comparatively softer; context always homogenous .... *Nigrofomes*
10. Basidiospores truncate .... *Perenniporia*
10. Basidiospores convex but not flat or truncate 11
11. Generative hyphae generally dichotomously branched .... *Dichomitus*
11. Generative hyphae randomly branched 12
12. Basidiome usually in shade brown; pores hexagonal to polygonal .... *Hexagonia*
12. Basidiome usually whitish; pores circular to angular .... *Poriella*

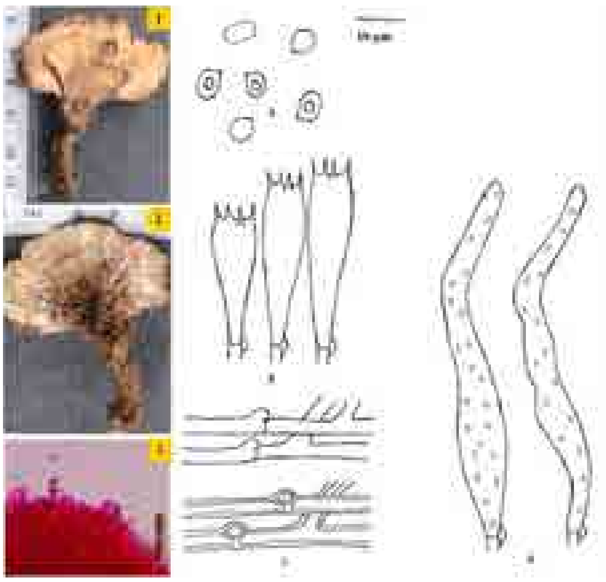

Image 1–7. *Abortiporus biennis*: 1–2—Basidiome showing abhymenial and hymenial surface | 3—Photomicrograph showing portion of hymenium with basidiospores | 4—Basidiospores | 5—Basidia | 6—Gloeocystidia | 7—Generative hyphae.

hyaline, thin- to thick-walled, clamped, branched, up to 5 µm in width.

Hyphal arrangement: subhymenium dominated by thin-walled, irregularly branched, loosely arranged generative hyphae. Trama composed of thick-walled, loosely to moderately compact generative hyphae. Context formed of thick-walled, rarely clamped, rarely branched, compactlypacked generative hyphae.

Gloeocystidia cylindrical to irregular, clamped at the base, smooth, originate in the hymenium, 50–85 ×7–10 µm; projecting up to 30 µm from hymenial surface,.

Basidia clavate, thin-walled, tetrasterigmate, clamped at the base, 25–40× 7–10 µm; sterigmata up to 3 µm in length.

Basidiospores broadly ellipsoid to ovoid, thin-walled, smooth, hyaline, no reaction in Melzer's reagent and cotton blue, 5–7.5 × 3.5–5 µm.

Material examined: 11222(PUN), 10.ix.2016, Jammu & Kashmir, Jammu, Patnitop on gymnospermous wood, coll. Brij Bala.

Notes: *Abortiporus bieenis* is charactertized by laterally stipitate pilei, duplex context, monomitic hyphal system, cylindrical gloeocystidia, and broadly ellipsoid to ovoid basidiospores. It is being reported for the first time from Jammu & Kashmir. The only earlier record is from Himachal Pradesh (Thind & Rattan 1971; Sharma 2012).

Cerrena zonata (Berk.) Ryvarden, Boletín de la Sociedad Argentina de Botánica 28: 228 (1992).

≡ *Irpex zonatus* Berk., Hooker's Journal of Botany and Kew Garden Miscellany 6: 168 (1854). (Image 8–14)

Basidiome annual, pileate, imbricate, sessile, narrowly attached; pileidimidiate, applanate, up to 5 × 4 × 0.6 cm.

Abhymenial surface glabrous, smooth, faintly zonate, pale orange to greyish-orange when fresh, not changing much on drying; margin concolorus, acute, entire, curved inside on drying.

Hymenial surface poroid, becoming irpicoid with age, yellowish-white when fresh, not changing much on drying; marginwavy, entire, concolorus, curved inside after drying.

Pores round to angular, 2–3 per mm; dissepiments lacerate, up to 50 µm thickness.

Tube layer orange white, up to 0.3 cm deep.

Context homogenous, yellowish-white, up to 0.3 cm deep.

Hyphal system dimitic. Generative hyphae hyaline, clamped, thin-walled, branched, up to 3.5 µm in width. Skeletal hyphae pale-yellowish, thick-walled, unbranched, aseptate, up to 5.5 µm in width.

Hyphal arrangement: subhymenium composed of thin-walled, loosely arranged, irregularly branched generative hyphae. Trama contains loosely to moderately compact, generative hyphae and skeletal hyphae. Context dominated by moderately to compactly arranged generative and skeletal hyphae.

Cystidia subventricose to ventricose, hyaline, thin-walled, smooth, clamped at the base, originate in the hymenium and subhymenium, 35–60 × 5–7.8 µm; embedded in hymenium.

Basidia sub-clavate, thin-walled, tetrasterigmate, clamped at the base, 15.5–24 × 5.5–10.5 µm; sterigmata up to 2 µm in length.

Basidiospores ellipsoid, hyaline, smooth, thin-walled, no reaction in Melzer's reagent and cotton blue, 5–6.7 × 2.7–3.5 µm.

Material examined: 11201 (PUN), 27.ix.2017 Jammu & Kashmir, Kathua, Billawar, Mandli, on angiospermous stump, Brij Bala; 11202 (PUN), 3.x.2017, Kathua, Billawar, Sukrala, on angiospermous stump, Brij Bala; 11203 (PUN), 26.ix.2015, Kathua, on angiospermous stump, Brij Bala.

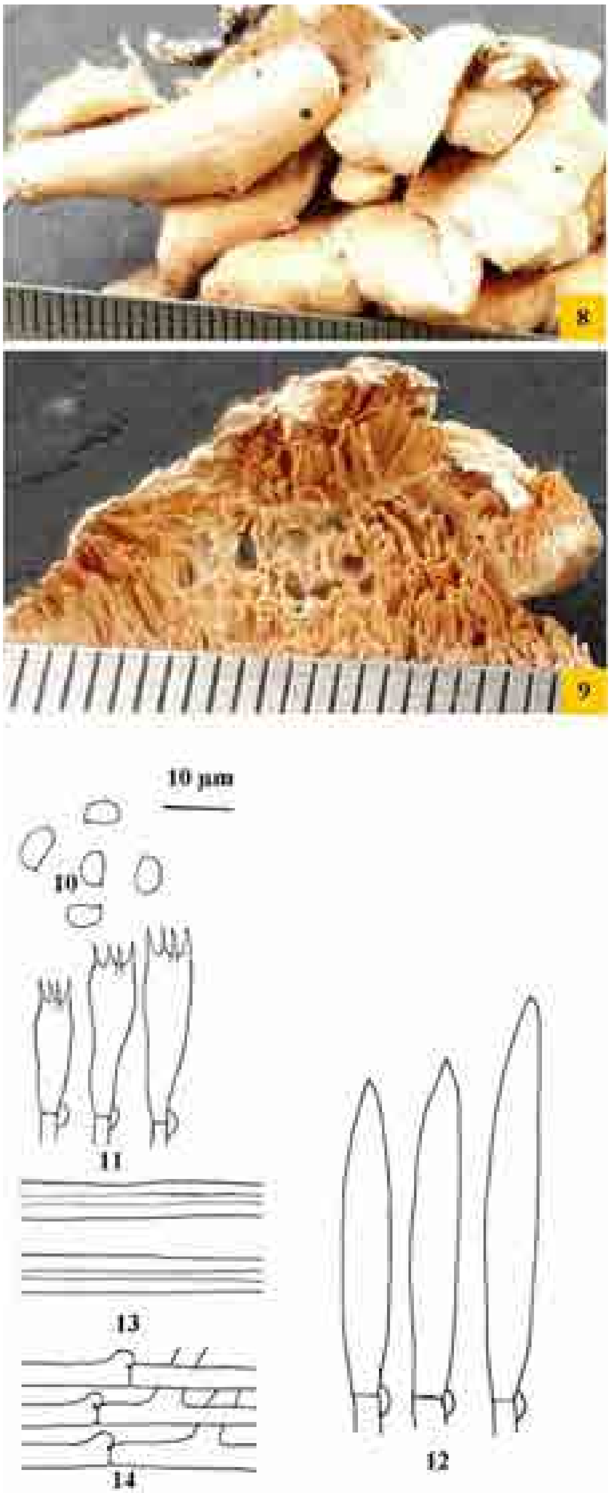

Image 8–14. *Cerrena zonata*: 8–9—Basidiome showing abhymenial and hymenial suface | 10—Basidiospores | 11—Basidia | 12—Cystidia | 13—Skeletal hyphae | 14—Generative hyphae.

Notes: It is unique in having adimitic hyphal system, subventricose to ventricose cystidia and oblong ellipsoid basidiospores. It is being reported for the first time from Jammu & Kashmir.

Dichomitus campestris (Quél.) Domanski & Orlicz, Acta Soc. Bot. Pol.: 627 (1966).

≡*Trametes campestris* Quél., Mémoires de la Société d'Émulation de Montbéliard ser. 2, 5: 286 (1872). (Image 15–19)

Basidiome annual, resupinate, adnate, effused, cushion shaped, soft when fresh, becomes coriaceous on drying, easily separable from the substrate; up to 4 mm thick in cross-section.

Hymenial surface poroid, yellowish-white when fresh, not changing much on drying; margin concolorus, adnate, entire, sterile up to 2 mm.

Pores round to angular to elongated, 2–3 per mm; dissepiments entire, up to 50 µm in thickness.

Tube layer orange white, up to 2 mm deep.

Subiculum homogenous, yellowish-white, up to 2 mm thick.

Hyphal system dimitic. Generative hyphae hyaline, thin-walled, branched, clamped, up to 3 µm in width. Skeletal hyphae pale yellowish, thick-walled, aseptate, unbranched, up to 4.5 µm in width.

Hyphal arrangement: subhymenium dominated by loosely arranged, branched generative hyphae. Trama formed of loosely to moderately compact, branched generative hyphae and skeletal hyphae. Subiculum composed of moderately compact, branched generative hyphae and skeletal hyphae.

Basidia sub-clavate to clavate, thin-walled, with oil contents, tetrasterigmate, clamped at the base, 25–28 × 4–9 µm; sterigmata up to 3 µm in length.

Basidiospores cylindrical, hyaline, thin-walled, smooth, with oil droplets, no reaction in Melzer's reagent and cotton blue, 8.8–11.6 × 4.4–5.8 µm.

Material examined: 11361 (PUN), 16.ix.2015, Jammu & Kashmir, Doda, Attalgarh, on *Cedrus deodara* branch, Brij Bala.

Notes: *Dichomitus campestris* differs in having a cushion like resupinate basidiome with cylindrical basidiospores. It is being reported for the first time from India. Earlier it was reported from Norway, Arizona, New Mexico, and Idhao (Ryvarden & Melo 2014; Mycobank 2022).

Favolus glaber (P. Brauv.) Ryvaden, Mycotaxon 72: 216, 1999.

≡*Favolus glaber* P. Beauv., Fl. Oware et Benin 2:76, 1819. (Image 20–26)

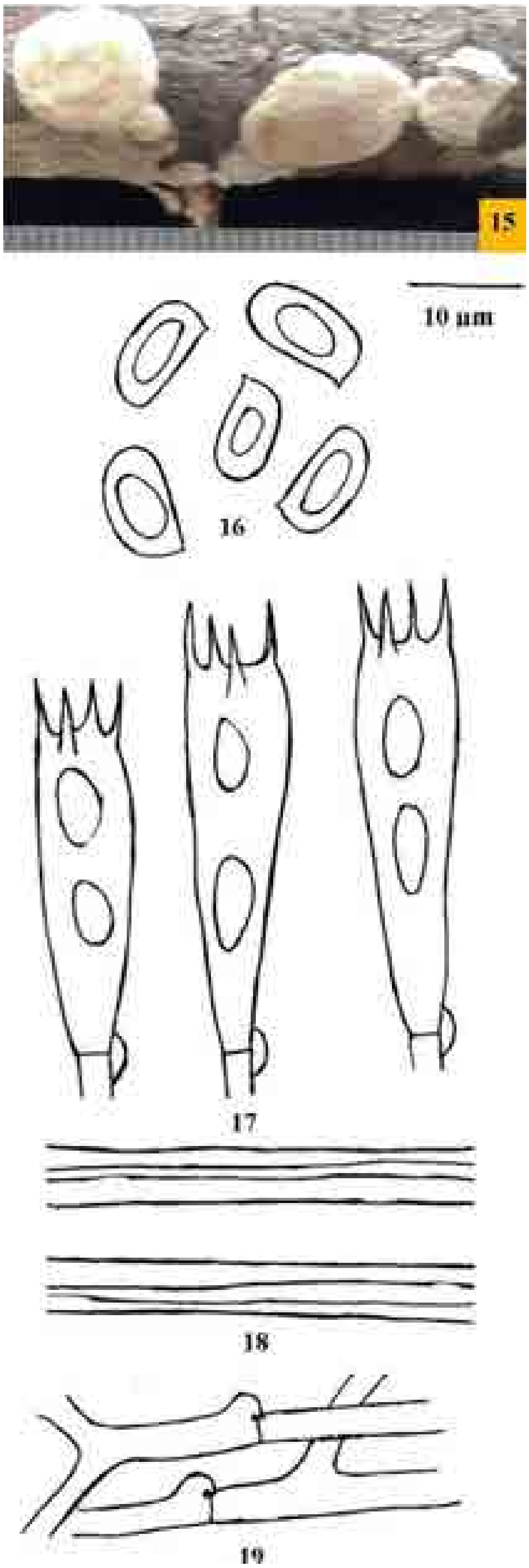

Image 15–19. *Dichomitus campestris*: 15—Basidiome showing hymenial surface | 16—Basidiospores | 17—Basidia | 18—Skeletal hyphae | 19—Generative hyphae.

Basidiome annual, pileate, sessile, broadly attached, solitary, coriaceous, thin; pilei semicircular, dimidiate, up to 4.2 × 2 × 0.2 cm.

Abhymenial surface glabrous, smooth, concentrically zonate, reddish brown to dark brown when fresh, not changing much on drying; margin light brown when fresh, not changing much on drying, acute, entire.

Hymenial surface poroid, brownish-grey to greyish-brown when fresh, not changing much on drying; margin light brown when fresh, not changing much on drying, sterile up to 2 mm.

Pores polygonal, 1–2 per mm; dissepiments entire, up to 20 mm in thickness.

Tube layer greyish-brown, up to 1 mm deep.

Context homogenous, light brown, up to 1 mm in thickness.

Hyphal system trimitic. Generative hyphae hyaline to sub hyaline, thin-walled, branched, clamped, up to 3.7 µm in width. Binding hyphae subhyaline, irregularly branched, thick-walled, aseptate, up to 4 µm in width. Skeletal hyphae dark brown, thick-walled, aseptate, unbranched, up to 5 µm in width.

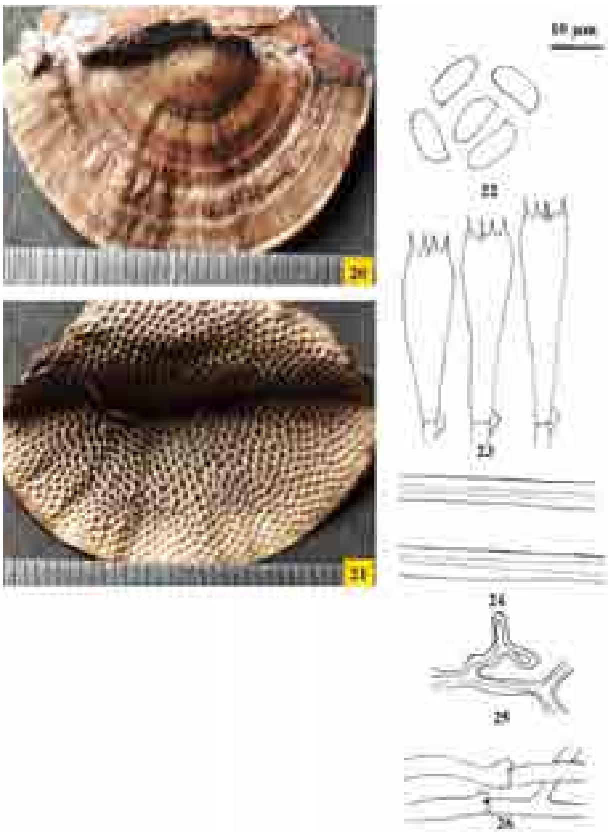

Image 20–26. *Favolus glaber*: 20–21—Basidiome showing abhymenial and hymenial surface | 22—Basidiospores | 23—Basidia | 24—Skeletal hyphae | 25—Binding hyphae | 26—Generative hyphae.

Hyphal arrangement: Subhymenium contains, thin-walled, moderately compact, branched generative hyphae. Trama composed of comparatively compactly arranged generative hyphae, binding hyphae and skeletal hyphae. Context formed of compactly arranged generative and skeletal hyphae.

Basidia clavate to sub-clavate, hyaline, thin-walled, tetrasterimate, clamped at the base, 32.5–40 × 8.5–10 µm; sterigmata up to 2.5 µm in length.

Basidiospores cylindrical, subhyaline, thin-walled, smooth, no reaction in Melzer's reagent and cotton blue, 10.5–14 × 3.8–5.4 µm.

Material examined: 11232 (PUN), 16.ix.2015 Jammu & Kashmir, Jammu, Roop nagar, on an angiospermous stump, Brij Bala .

Notes: *Favolus glaber* is distinct in having coriaceous, comparatively thinner glabour basidiome with larger polygonal pores and cylindrical basidiospores. Previously, Kaur (2013) reported it as *Hexagonia glaber* from Himachal Pradesh. It is a new addition to the list of polypores of Jammu & Kashmir.

Fomes fomentarius (L.) Fr., Summa vegetabilium Scandinaviae: 321, 1849.

≡*Boletus fomentarius* L., Species Plantarum: 1176, 1753. (Image 27–36)

Basidiome perennial, pileate, sessile, solitary, broadly attached; pilei ungulate, up to 10 × 8 × 8 cm.

Abhymenial surface concentrically zonate, sulcate, tomentose, crustose, yellowish-grey when fresh, changing to brownish grey on drying; margin, slightly lighter, obtuse, entire.

Pilear crust up to 2 mm in thickness, dominated equally with generative hyphae and skeletal hyphae.

Hymenial surface poroid, grey when fresh, changing to brownish-orange on drying; margin slightly lighter, sterile up to 1 mm.

Pores round to angular, 4–5 per mm; dissepiments entire, up to 95 µm in thickness.

Tube layer stratified, greyish-brown, two layered, each layer up to 3 cm deep.

Context duplex; outer zone greyish brown, corky, up to 0.8 cm thick; inner zone brown, fibrous, up to 1.2 cm thick.

Hyphal system trimitic. Generative hyphae hyaline to pale yellowish, thinto thick-walled clamped, branched, up to 4 µm in width. Binding hyphae hyaline to subhyaline, arboriform thick-walled, up to 5 µm in width. Skeletal hyphae rusty brown to pale yellowish, thick-walled, unbranched, up to 6 µm in width.

Hyphal arrangement: Subhymenium formed of

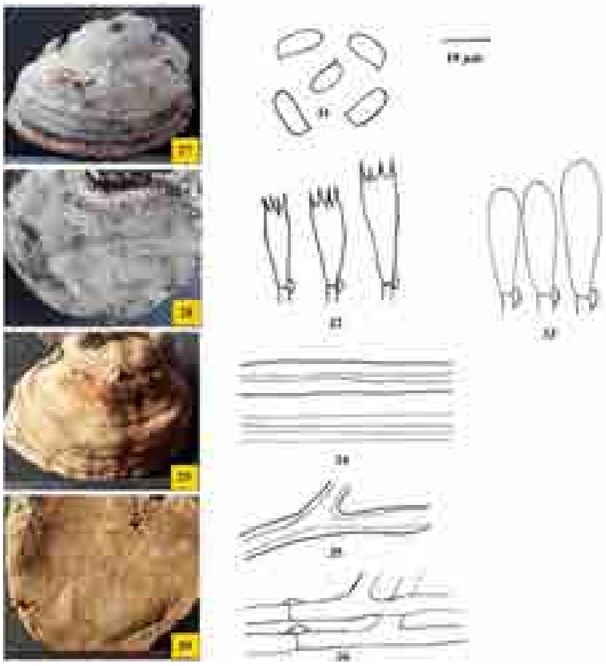

Image 27–36. *Fomes fomentarius*: 27–28—Basidiome showing abhymenial and hymenial surface (fresh) | 29–30—Basidiome showing abhymenial and hymenial surface (dry) | 31—Basidiospores | 32—Basidia | 33—Cystidia | 34—Skeletal hyphae | 35—Binding hyphae | 36—Generative hyphae.

loosely arranged irregularly branched generative hyphae and binding hyphae. Trama composed of somewhat compactly arranged generative, binding and skeletal hyphae. Context consitituted compactly arranged generative, binding and skeletal hyphae.

Cystidioles fusoid, thin-walled, tetrasterigmate, clamped at the base, 18–24.5 × 5–7 µm, originate in the subhymenium; projecting slightly outward from the hymenium.

Basidia sub-clavate, thin-walled, tetrasterigmate, clamped at the base, 16–25 × 6–7; sterigmata up to 3 µm in length.

Basidiospores cylindrical, hyaline, thin-walled, smooth, no reaction in Melzer's reagent and cotton blue, 8–14 × 3–4µm

Material examined: 11319 (PUN), 12.ix.2016, Jammu & Kashmir, Doda, Bhaderwah, Attalgarh, on angiospermous wood, Brij Bala; 11363 (PUN), 13.ix.2016 Attalgarh, on angiospermous wood, Brij Bala.

Notes: *Fomes fomentarius* is peculiar in having ungulate pilei with a hard glabrous, sulcate crust, trimitic hyphal system and cylindrical larger basidiospores. It is recorded from the study area.

Fuscopostia leucomallella (Murrill) B.K. Cui, L.L. Shen & Y.C. Dai, Persoonia 42: 119 (2018).

≡ *Tyromyces leucomallellus* Murrill, Bulletin of the Torrey Botanical Club 67(1): 63 (1940). (Image 37–43)

Basidiome annual, pileate, solitary, sessile, broadly attached, soft and fleshy when fresh, becoming hard and brittle on drying; pilei dimidiate, applantae, up to 5 × 1.5 × 0.5 cm.

Abhymenial surface sulcate, faintly zonate, glabrous, light brown to brownish-orange when fresh, not changing much on drying; margin concolorus, acute, wavy, entire.

Hymenial surface poroid, greyish white when fresh, changing to pale yellowish on drying, margin concolorus, sterile up to 1 mm.

Pores angular to round, 4–6 per mm; dissepiments entire, up to 45 µm in thickness.

Tube layer yellowish-white, up to 0.2 mm deep.

Context homogenous, orange white, up to 0.3 cm thick.

Hyphal system monomitic. Generative hypahe hyaline, thin-to thick-walled, clamped, richly branched, up to 4.5 µm in width.

Hyphal arrangement: subhymenium consists of loose to moderately compactly arranged, generative hyphae. Trama formed of moderately compact generative hyphae. Context formed of compactly arranged generative hyphae.

Basidia clavate, thin-walled, tetrasterigmate, clamped at the base, 12–25 × 4–6 µm; sterigmata up to 2 µm in length.

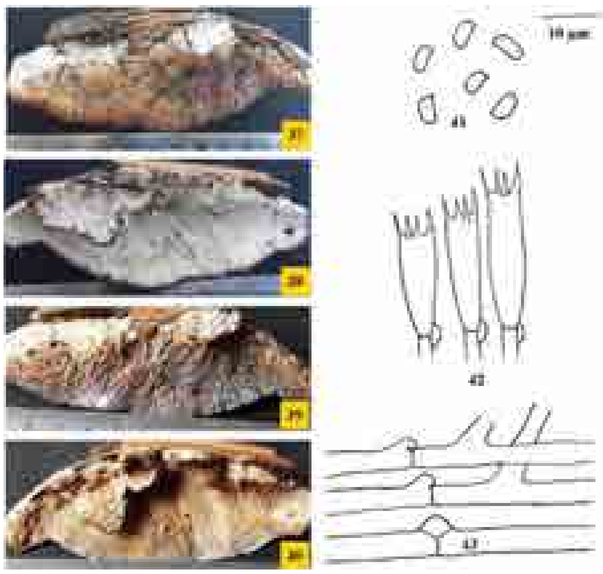

Image 37–43. *Fuscopostia leucomallella*: 37–38—Basidiome showing abhymenial surface and hymenial surface (fresh) | 39–40—Basidiome showing abhymenial and hymenial surface (dry) | 41—Basidiospores | 42—Basidia | 43—Generative hyphae.

Basidiospores cylindrical to suballantoid, hyaline, thin-walled, smooth, with oily contents, no reaction in Melzer's reagent and cotton blue, 3.5–6.5 × 1.4–2.4 µm.

Material examined: 11273 (PUN), 21.viii.2017, Jammu and Kashmir, Doda, Shunushir, on *Cedrus deodara* stump, Brij Bala, 21.viii. 2017.

Notes: *Fuscopostia leucomallella* is unique in having soft and fleshy basidiome, monomitic hyphal system and cylindrical to suballantoid basidiospores. Earlier it was reported from Himachal Pradesh by Kaur (2013) as *Tyromyces leucomallus*. It is a new record for Jammu & Kashmir.

Hexagonia nitida Durieu & Mont., Exploration scientifique de l'Algérie 1–5: t.33: 1 (1846). (Image 44–49)

Basidiome annual, resupinate to rarely effused-reflexed, soft and corky when fresh, not changing much on drying; up to 2 mm thick in cross-section.

Hymenial surface poroid, light brown when fresh, not changing much on drying, margin sterile up to 3 mm.

Pores polygonal, 2–3 per mm; dissepiments entire, up to 85 µm in thickness.

Tube layer light brown, up to 1 mm deep.

Subiculum homogenous, greyish-brown, up to 1 mm in thickness.

Hyphal system trimitic. Generative hyphae subhyaline, thin-to thick-walled, clamped, branched, up to 3.5 µm in width. Binding hyphae subhyaline, thick-walled, aseptate, strongly branched, tortuous in context and with sword like side branches in the trama, never projecting in the hymenium, up to 4 µm in width. Skeletal hyphae subhyaline, thick-walled to solid, aseptate, unbranched, up to 5.5 µm in width.

Hyphal arrangement: subhymenium formed of thin-walled, moderately compact, irregularly branched generative hyphae. Trama composed of loosely arranged, generative hyphae, strongly branched binding hphae with sword like branchessand skeletal hyphae. Context dominated with compactly arranged generative hyphae, tortuous binding hyphae, and skeletal hyphae.

Basidiaclavate to sub-clavate, hyaline, thin-walled, tetrasterigmate, clamped at the base, 16–28 × 5–9.5 µm; sterigmata up to 3 µm in length.

Basidiospores cylindrical, hyaline, thin-walled, smooth, no reaction in Melzer's reagent and cotton blue, 7–14 × 3.2–4.6 µm.

Material examined: Jammu & Kashmir, Jammu, Roop Nagar, on an angiospermous stump, Brij Bala 11227(PUN), 16.ix.2015; Doda, Bhaderwah, Nalthi, on angiospermous stump, Brij Bala 11235 (PUN), 12.ix.2016.


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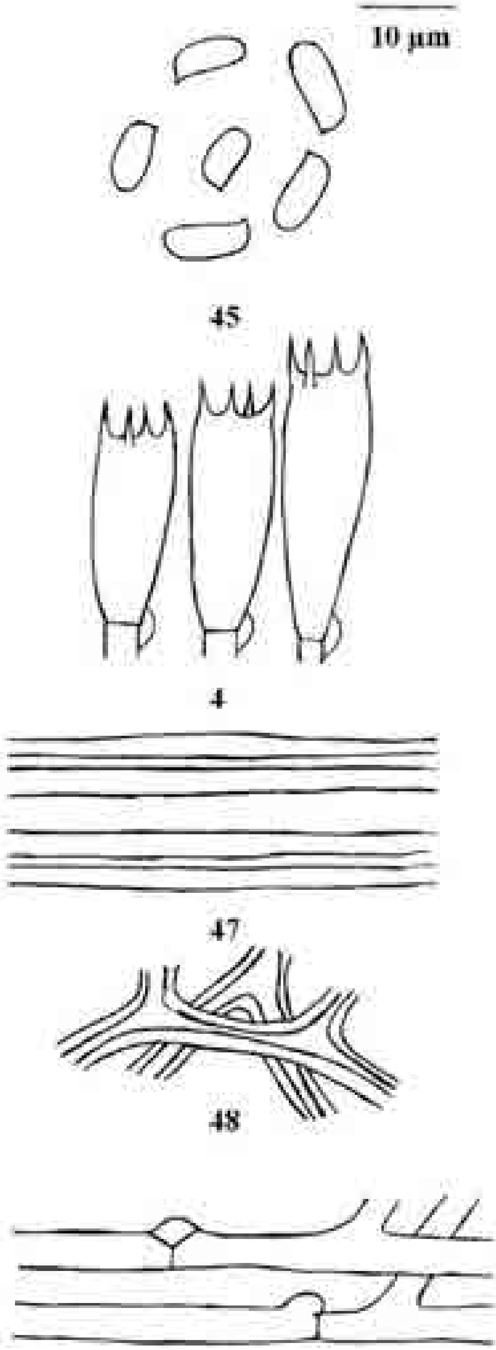

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Image 44–49. *Hexagonia nitida*: 44—Basidiome showing hymenial surface | 45—Basidiospores | 46—Basidia | 47—Skeletal hyphae | 48—Binding hyphae | 49—Generative hyphae.

Notes: *Hexagonia nitida* is characterized by resupinate to effused-reflexed basidiome with trimitic hyphal system and cylindrical basidiospores. It is reported for the first time from Jammu & Kashmir.

Lenzites betulina (L.) Fr., Epicrisis Systematis Mycologici: 405 (1838).

≡ *Agaricus betulinus* L., Species Plantarum: 1176 (1753). (Image 50–58)

Basidiome annual, pileate, solitary, sessile, broadly attached; pilei applanate, dimidiate, up to 3 × 2 × 0.8 cm.

Abhymenial surface tomentose, concentrically zonate, greyish when fresh, not changing much on drying; margin white when fresh, changing to pale yellowish on drying, acute, entire.

Hymenial surface lamellate, white when fresh, changing to pale yellowish on drying; margin concolorus, sterile up to 1 mm.

Pores lamellate, 1–1.5 per mm; dissepiments entire, up to 200 µm in thickness.

Tube layer orange white, up to 2 mm deep.

Context homogenous, yellowish-white, azonate, up to 4 mm thick.

Hyphal system trimitic. Generative hyphae hyaline to pale yellowish, thin- to thick-walled, clamped, up to 4 µm in width. Binding hyphae subhyaline, sword like, thick-walled, asepatate, branched up to 4.5 µm in width. Skeletal hyphae rusty brown to pale yellowish, thick walled, aseptate, unbranchedup to 5 µm in width.

Hyphal arrangement: Subhymenium consists of branched generative and binding hyphae. Trama formed of moderately compactly arranged generative hyphae, sword like bindinghyphae and skeletal hyphae. Context composed of compactly arranged binding and skeletal hyphae.

Basidia sub-clavate, thin-walled, tetrasterigmate, clamped at the base, 33.5–41 × 6–8; sterigmata up to 3 µm in length.

Basidiospores cylindrical, hyaline, thin-walled, smooth, no reaction in Melzer's reagent and cotton blue, 5–8.5 × 2–3.5 µm.

Material examined: 11338 (PUN), 21.ix.2015, Jammu & Kashmir, Jammu, Doda, Chinta, on gymnospermous wood, Brij Bala; 11339 (PUN), 21.viii.2017, Kishtwar, on way to Sinthon top, on gymnospermous wood, Brij Bala.

Notes: *Lenzites betulina* is peculiar in having lamellate pores, binding hyphae with sword like branches and comparatively smaller basidiospores. It is being re-reported from Jammu division as Dhanda (1977) described it from Ramban District.

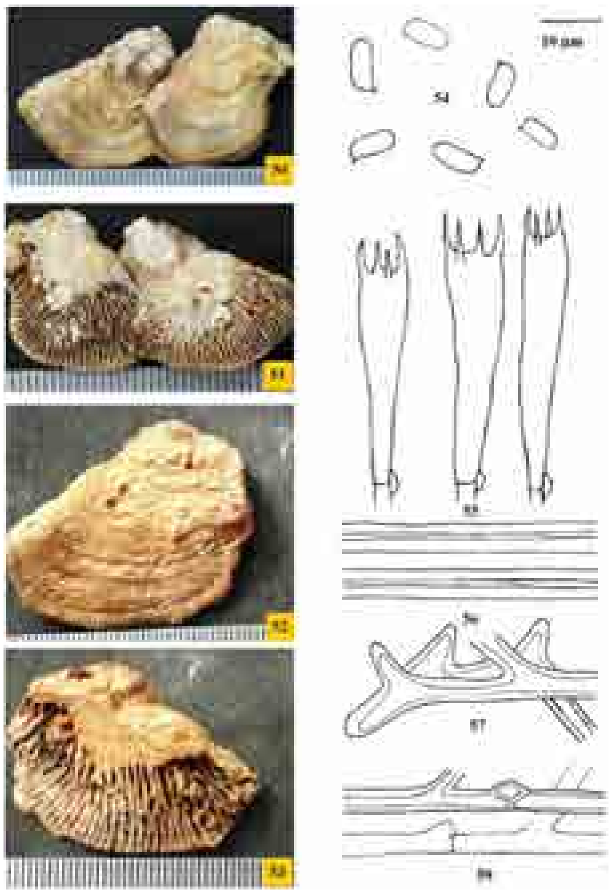

Image 50–58. *Lenzites betulina*: 50–51—Basidiome showing abhymenial and hymenial surface (fresh) | 52–53—Basidiome showing abhymenial and hymenial surface (dry) | 54—Basidiospores | 55—Basidia | 56—Skeletal hyphae | 57—Binding hyphae | 58—Generative hyphae.

Lenzites elegans (Spreng.) Pat., Essai taxonomique surles familles et les genres des Hyménomycètes: 89 (1900).

≡ *Daedalea elegans* Spreng., Kongliga Svenska Vetenskapsakademiens Handlinger Ser. 3, 8: 51 (1820). (Image 59–68)

Basidiome annual, pileate, sessile, solitary, narrowly attached, somewhat flexible when fresh, becomes harder on drying; pilei ungulate, up to 7 × 3.5 × 3.5 cm.

Abhymenial surface glabrous, tuberculate, concentrically zonate, sulcate, white when fresh, changing to pale yellowish on drying; margin paler concolorus, acute, entire.

Hymenial surface deadeloid to sinuous to lamellate, white when fresh, changing to brownish-orange to greyish-brown on drying; margin paler concolorus, sterile up to 2 mm.

Pores daedeloid to sinuous to lamellate, 0.5 to 1 per

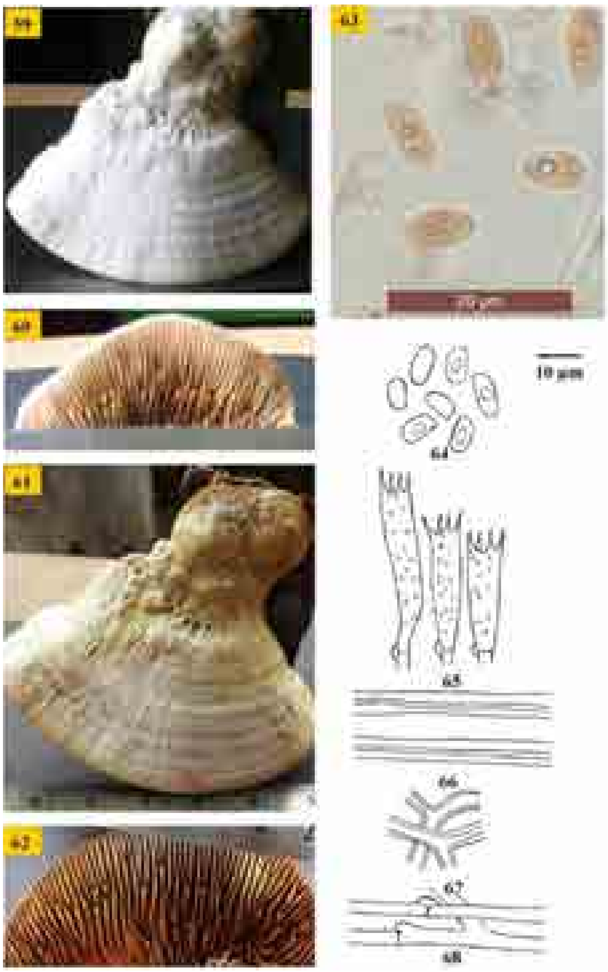

Image 59–68. *Lenzites elegans*: 59–60—Basidiome showing abhymenial and hymenial surface (fresh) | 61–62—Basidiome showing abhymenial and hymenial surface (dry) | 63—Photomicrograph showing basidiospores | 64—Basidiospores | 65—Basidia | 66—Skeletal hyphae | 67—Binding hyphae | 68—Generative hyphae.

mm; dissepiments entire, up to 250 µm in thickness.

Tube layer yellowish-white, up to 1 cm deep.

Context homogenous, yellowish white, fibrous, azonate, up to 1.5 cm in thickness.

Hyphal system trimitic. Generative hyphae hyaline, thin-walled, clamped, branched, up to 2.5 µm in width. Binding hyphae subhyaline, thick-walled, aseptate, branched up to 5 µm in width. Skeletal hyphae light brown, thick-walled, aseptate, unbranched, up to 8.3 µm in width.

Hyphal arrangement: Subhymenium contains loosely arranged, irregularly branched generative hyphae and projecting binding hyphae. Trama formed of loosely arranged, generative, binding and skeletal hyphae. Context mainly composed of compactly arranged binding and skeletal hyphae.

Basidia clavate, thin-walled, tetrasterigmate, clamped at the base, 21.5–43.5 × 3.5–7 µm; sterigmata up to 3 µm in length.

Basidiospores ellipsoid to cylindrical, thin-walled, guttulate, smooth, no reaction in Melzer's reagent and cotton blue, 6–9.5 × 2.5–4.4 µm.

Material examined: 11368 (PUN), 22.ix.2016, Jammu & Kashmir, Udhampur, on way from Patnitop to Sanasar, on *Abies pindrow* stump, Brij Bala

Notes: *Lenzites elegans* is characterized by daedeloid to sinuous to lamellate pores and ellipsoid to cylindrical basidiospores. It is described for the first time from Jammu & Kashmir.

Lenzites warnieri Durieu & Mont., Annales des Sciences Naturelles Botanique 14: 182 (1860). (Image 69–77)

Basidiome annual, pileate, sessile, broadly attached, soft and flexible when fresh, becomes hard and stiff on drying; pileidimidiate, applanate, semicircular, up to 5 × 2 × 0.7 cm.

Abhymenial surface tomentose, sulcate, concentrically zonate, tuberculate, orangish brown (towards proximal end) to yellowish white (towards distal end) when fresh, changing to brownish orange towards (proximal end) to pale yellowish (towards distal end) on drying; margin concolorus, acute, entire.

Hymenial surface lamellate, yellowish white when fresh, not changing much on drying; margin concolorus, sterile up to 1 mm.

Pores lamellate, lamellae bifurcating, 1–1.5 per mm, dissepiments entire, up to 150 µm in thickness.

Tube layer yellowish-white, up to 2 mm deep.

Context homogenous, light brown, up to 5 mm in thickness.

Hyphal system trimitic. Generative hyphae hyaline, thinto thick-walled, clamped, branched, up to 4.2 µm in width. Binding hyphae subhyaline, thick-walled, aseptate, branched, arboriform, up to 6 µm in width. Skeletal hyphae rusty brown to pale yellowish, thick walled, aseptate, unbranched, up to 5.6 µm in width.

Hyphal arrangement: Subhymenium composed of irregularly branched generative and binding hyphae. Trama constituted of loosely to compactly arranged generative, binding and skeletal hyphae. Context mainly formed loosely arranged binding and skeletal hyphae. Basidia sub-clavate to subcylindrical, thin-walled, tetrasterigmate, clamped at the base, 23.5–35 × 5.5–7.1; sterigmata up to 3 µm in length.

Basidiospores cylindrical to subcylindrical, hyaline, smooth, thin-walled, no more reaction in Melzer's

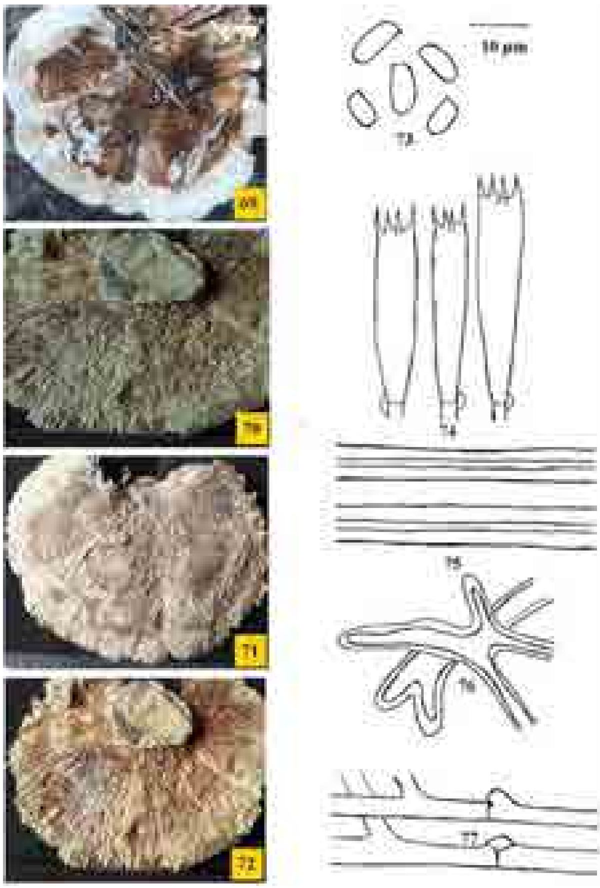

Image 69–77. *Lenzites warnieri*: 69–70—Basidiome showing abhymenial and hymenial surface (fresh) | 71–72—Basidiome showing abhymenial and hymenial surface (dry) | 73—Basidiospores | 74—Basidia | 75—Skeletal hyhae | 76—Binding hyphae | 77—Generative hyphae.

reagent and cotton blue, 5.5–8.5 × 3-–4.2 µm.

Material examined: 11267 (PUN), 27.ix.2014, Jammu and Kashmir, Doda, Bhaderwah, Duggi, on angiospermous wood, Brij Bala.

Notes: *Lenzites warnieri* is characteristic in having tomentose, tuberculate abhymenial surface and frequently bifurcating lamellae. It is being described as new to Jammu & Kashmir.

Perenniporia adnata Corner, Beiheftezur Nova Hedwigia 96: 101 (1989). (Image 78–82)

Basidiome annual, resupinate, adnate, effused, soft when fresh, becomes coriaceous after drying, easily separable from the substrate; up to 3 mm thick in cross-section.

Hymenial surface poroid, whitish-grey when fresh, not changing much on drying; margin concolorus, adnate, sterile up to 2 mm.

Pores round to angular, 8–10 per mm; dissepiments entire, up to 65 µm in thickness.

Tube layer whitish grey, up to 2 mm deep.

Subiculum homogenous, concolorus to tube layer, up to 1mm thick.

Hyphal system dimitic. Generative hyphae hyaline, thin-walled, clamped, branched, up to 4 µm in width. Skeletal hyphae pale-yellowish, thick-walled, aseptate, unbranched, up to 6.5 µm in width.

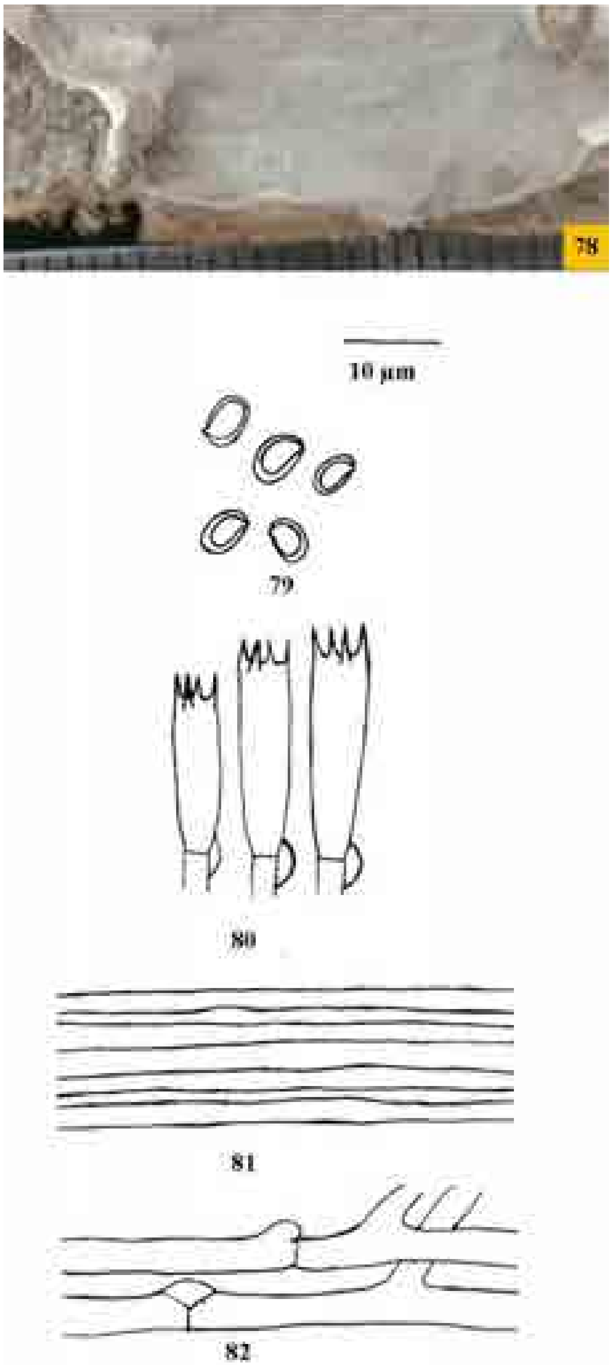

Image 78–82. *Perreniporia adnata*: 78—Basidiome showing hymenial surface | 79—Basidiospores | 80—Basidia | 81—Skeletal hyphae | 82—Generative hyphae.

Hyphal arrangement: Subhymenium mainly composed of loosely arranged, irregularly branched generative hyphae. Trama formed by moderately compact generative and skeletal hyphae. Subiculum composed of compactly packed generative and skeletal hyphae.

Basidia sub-clavate, thin-walled, tetrasterigmate, clamped at the base, 14–21.5 × 4.5–6 µm, sterigmata up to 3 µm in length.

Basidiospores broadly ellipsoid, hyaline, thick-walled, smooth, no reaction in Melzer's reagent and cotton blue, 4.5–6.5 × 2.5–4 µm.

Material examined: 11241(PUN), 12.ix.2016, Jammu & Kashmir, Jammu, Doda, Bhaderwah, Nalthi, on angiospermous wood, Brij Bala; 11341(PUN), 5.x.2017, Kathua, Dyalchak, on angiospermous wood, Brij Bala .

Notes: *Perreniporia adnata* is characterized by resupinate basidiome, dimitic hyphal system and broadly ellipsoid, thick-walled basidiospores. It is recorded as new to India and was earlier described from Singapore (Mycobank 2022).

Perreniporia fraxniea (Bull.) Ryvarden, Nova Hedwigia 27: 158 (1976).

≡*Boletus fraxineus* Bull., Herbier de la France 10: t. 433: 2 (1790). (Image 83–89)

Basidiome annual, pileate, imbricate, sessile, broadly attached, corky when fresh, becoming woody on drynig; pilei ungulate, triquetrous, up to 8 × 4.6 × 4.5 cm.

Abhymenial surface azonate, sulcate, velutinate to smooth, white when fresh, changing to pale yellowish on drying; margin concolorous, obtuse, entire.

Hymenial surface poroid, white when fresh, changing to pale yellowish on drying, margin concolorous, sterile up to 2 mm.

Pores round to angular, 4–5 per mm; dissepiments entire, up to 54 µm in thickness.

Tube layer yellowish-white, separated by thin gelatanious layer from context, up to 2 cm deep.

Context homogenous, pale yellowish, tough, fibrous, up to 2.5 cm thick.

Hyphal system dimitic. Generative hyphae hyaline, thin-walled, clamped, branched, up to 4.5 µm in width. Skeletal hyphae subhyaline, thick-walled, aseptate, unbranched, strongly dextrinoid, up to 5 µm in width.

Hyphal arrangement: Subhymenium chiefly formed of loose to somewhat compact generative hyphae. Trama consists of moderately compact generative and skeletal hyphae. Context usually formed of comparatively narrower, compactly arranged generative and skeletal hyphae.

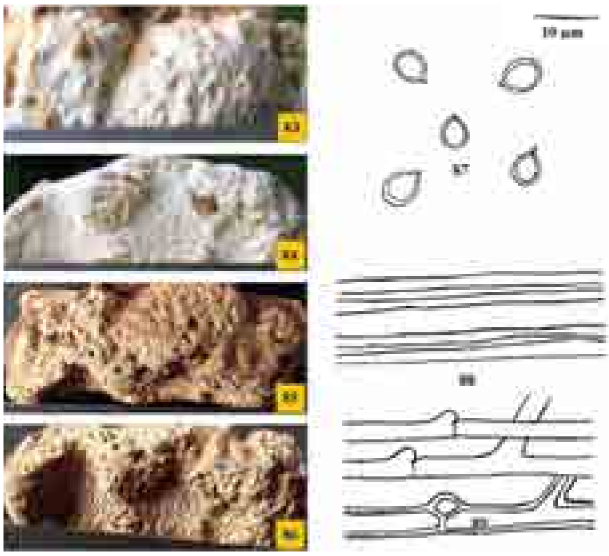

Image 83—89. *Perreniporia fraxinea*: 83–84—Basidiome showing abhymenial and hymenial surface (fresh) | 85–86—Basidiome showing abhymenial and hymenial surface (dry) | 87—Basidiospores | 88—Skeletal hyphae | 89—Generative hyphae.

Basidia not seen.

Basidiospores subglobose, pale yellowish, thick-walled, smooth, spore wall slightly stained in Melzer's reagent, no reaction in cotton blue, 5.4–8.4 × 3.5– 4.0 µm.

Material examined: 11370 (PUN), 21.ix.2016, Jammu and Kashmir, Doda, Sanasar on Abies pindrow stump, Brij Bala.

Notes: *Perreniporia fraxinea* is distinct in having hard basidiome, strongly dextrinoid skeletal hyphae and subglobose, thick-walled basidiospores. It is a new record for Jammu & Kashmir.

Perenniporia ochroleuca (Berk.) Ryvarden, Norwegian Journal of Botany 19: 143 (1972).

≡ *Polyporus ochroleucus* Berk., London Journal of Botany 4: 53 (1845). (Image 91–98)

Basidiome perennial, pileate, solitary, sessile, narrowly attached; pilei applantae, ungulate, up to 4 × 3 × 1 cm.

Abhymenial surface azonate, glabrous, sulcate, white when fresh, changing to pale yellowish on drying; margin concolorous, obtuse, entire.

Hymenial surface poroid, white when fresh, changing to pale yellowish on drying; margin concolorous, sterile up to 2 mm.

Pores round to angular, 2–4 per mm; dissepiments entire, up to 60 µm in thickness.

Tube layer yellowish-white, two layered, each layer up to 2 mm deep separated by a thin layer of 1 mm thick

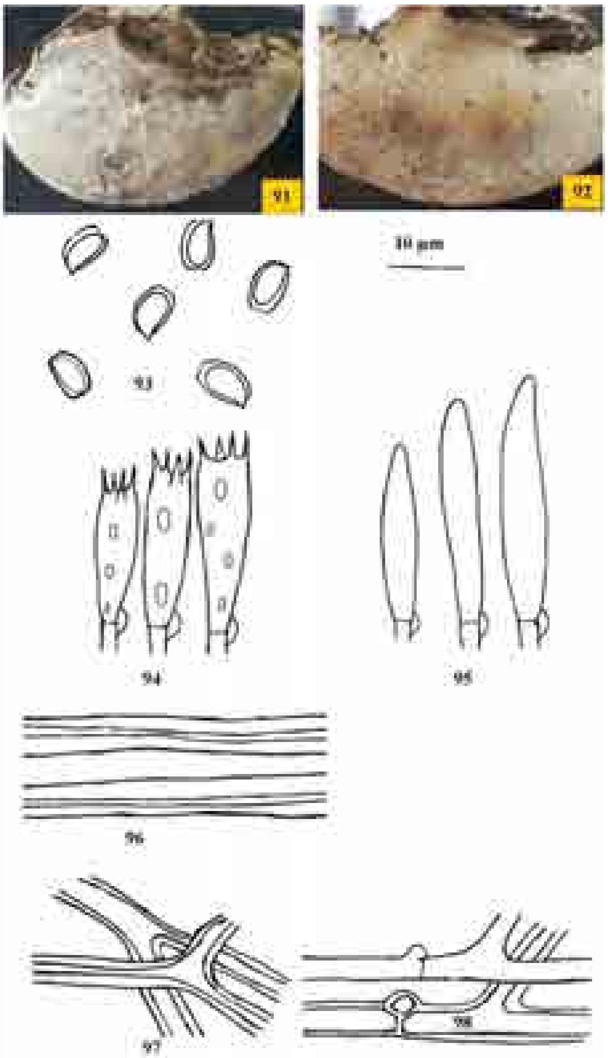

Image 91–98. *Perreniporia ochroleuca*: 91–92—Basidiome showing abhymenial and hymenial surface | 93—Basidiospores | 94—Basidia | 95—Cystidia | 96—Skeletal hyphae | 97—Binding hyphae | 98—Generative hyphae.

context.

Context homogenous, orange white, weakly zonate, with a thin cuticle, up to 0.5 cm thick.

Hyphal system trimitic. Generative hyphae hyaline, thin-walled, clamped, branched, up to 5 µm in width. Binding hyphae subhyaline, thick-walled, aseptate, branched, up to 4.5 µm in width. Skeletal hyphae golden brown, thick-walled, aseptate, unbranched, up to 6 µm in width. Hyphal wall slightly stained in Melzer's reagent.

Hyphal arrangement: subhymenium composed of loosely to moderately compact, irregularly branched generative hyphae. Trama consists of loose to moderately compact generative, binding and skeletal hyphae. Context formed of moderately to compactly arranged binding and skeletal hyphae.

Cystidioles fusoid, thin-walled, smooth, clamped at the base, originate in the subhymenium, 14–28 × 7.2–8.8 µm; projecting slightly from the hymenium.

Basidia clavate, thin-walled, with oily contents, clamped at the base, tetrasterigmate, 17.5–27 × 5–8.8 µm; sterigmata up to 3 µm in length.

Basidiospores ellipsoid, truncate at the apex, hyaline, thick-walled, smooth, spore wall slightly stained in Melzer's reagent,no reaction in cotton blue, 7.5–15 × 4–7 µm.

Material examined: 9099 (PUN), 21.ix.2016, Jammu & Kashmir, Doda, Sanasar on *Abies pindrow* stump, Brij Bala.

Notes: *Perreniporia ochroleuca* differs from *P. fraxinea* in having smaller basidiomes, trimitic hyphal system and larger truncate, dextrinoid basidiospores. It is a new record for Jammu & Kashmir.

Pilatoporus bondartsevae (Spirin) Spirin, Mycotaxon 97: 78 (2006).

≡*Antrodia bondartsevae* Spirin, Mikol.Fitopatol.: 33 (2002). (Image 99–105)

Basidiome annual, resupinate, effused, soft when fresh, becomes coriaceous after drying, easily separable from the substrate; up to 3 mm thick in cross-section.

Hymenial surface poroid, white when fresh, not changing much on drying; margin adnate, sterile up to 2 mm.

Pores round to angular, 2–3 per mm, dissepiments entire, up to 75 µm in thickness.

Tube layer yellowish-white, up to 2 mm deep.

Subiculum homogenous, greyish-white, up to 1 mm deep.

Hyphal system trimitic. Generative hyphae hyaline, thin-walled, clamped, branched up to 4 µm in width. Binding hyphae subhyaline, branched, thick-walled, up to 5 µm in width. Skeletal hyphae pale yellowish, thick-walled, unbranched aseptate, up to 6 µm in width.

Hyphal arrangement subhymenium consitituted of moderately compact, irregularly branched generative hyphae. Trama composed of loose to moderately compact generative, binding and skeletal hyphae. Context dominated with compactly arranged binding and skeletal hyphae.

Basidia sub-clavate, thin-walled, wih oily contents, clamped at the base, tetrasterigmate, 21–35 × 6–10 µm; sterigmata up to 3 µm in length.

Basidiospores subcylindrical, thin-walled, guttulate, no reaction in Melzer's reagent and cotton blue 8.5–14.5 × 5–7 µm.

Material examined: 11224 (PUN), 21.viii.2017,

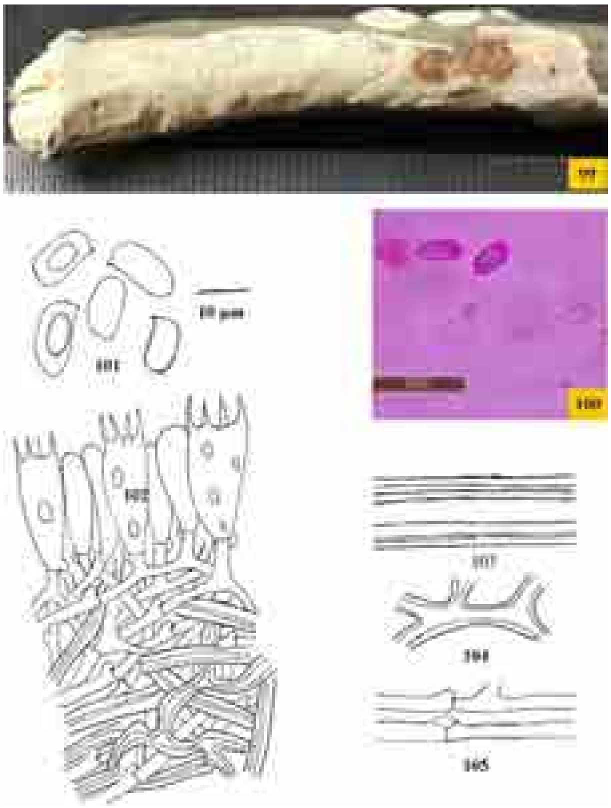

Image 99–105. ***Pilatoporus bondartsevae***: 99—Basidiome showing hymenial surface | 100—Photomicrograph showing basidiospores | 101—Basidiospores | 102—Basidia | 103—Skeletal hyphae | 104—Binding hyphae | 105—Generative hyphae.

Tube layer distinctly stratified, greyish-white, two layered, each layer up to 1 mm deep.

Hyphal system trimtic. Generative hyphae hyaline, thin-walled, clamped, branched, dextrinoid, up to 4 µm in width. Binding hyphae subhyaline, thick-walled, aseptate, branched, up to 4 µm in width. Skeletal hyphae golden brown, thick-walled, aseptate, unbranched, dextrinoid, up to 5 µm in width.

Hyphal arrangement: Subhymenium composed of loose to compactly arranged generative hyphae. Tramal zone consists of moderately compact generative and skeletal hyphae. Context consists of usually formed of compactly arranged generative and skeletal hyphae.

Subiculum homogenous, greyish-white, azonate, soft, up to 2 mm thick.

Cystidioles fusoid, thin-walled, smooth, clamped at the base, originate in the subhymenium, 14–28 × 4.5–5.5 µm; slightly projecting from the hymnenium.

Basidia clavate, thin-walled, tetrasterigmate, clamped at the base, 23–32 × 11–14 µm; sterigmata up to 3 µm in length.

Basidiospores broadly ellipsoid to subglobose, hyaline, thick-walled, smooth, with oily droplets, no reaction in Melzer's reagent and cotton blue, 6–7 ×4–6 µm.

Material examined: 11365 (PUN), 26.ix.2014. Jammu & Kashmir, Kathua, Dyalchak, on angiospermous wood, Jammu & Kashmir, Doda, Attalgarh, on Cedrus deodara branch, Brij Bala.

Notes: *Pilatoporus bondartsevae* is peculiar in having annual, resupinate basidiome, round to angular pores, trimitic hyphal system and larger, cylindrical basidiospores. It is being reported for the first time from India. The previous reports are from Russia and China (Mycobank 2022).

Poriella subacida (Peck) Donk, Persoonia 5(1): 76 (1967).

≡ *Polyporus subacidus* Peck, Annual Report on the New York State Museum of Natural History 38: 92 (1885). (Image 106–114)

Basidiome perennial, resupinate, effused-reflexed, difficult to separate from the substrate; up to 2 mm thick in cross-section.

Hymenial surface poroid, white when fresh, changing to pale yellowish on drying; margin concolorus, adnate, fimbriate, sterile up to 1 mm.

Pores round to angular, 3–4 per mm; dissepiments lacerate, up to 100 µm in thickness.

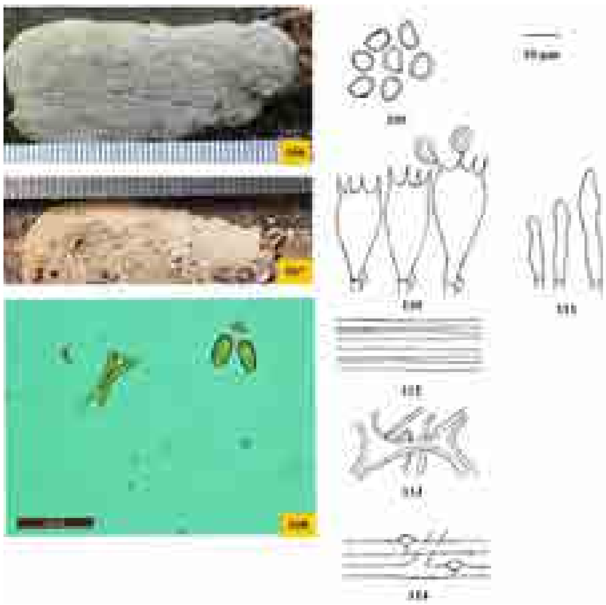

Image 106–114. ***Poriella subacida***: 106–107—Basidiome showing hymenial surface (fresh and dry) | 108—Photomicrograph showing basidiospores | 109. Basidiospores | 110—Basidia | 111—Cystidioles | 112—Skeletal hyphae | 113—Binding hyphae | 114—Generative hyphae.

Brij Bala.

Notes: The diagnostic features of *Poriella subacida* are resupinate, perennial basidiome, strongly dextrinoid hyphae, fusoid cystidioles and broadly ellipsoid to subglobose basidiospores. It is reported for the first time from Jammu & Kashmir.

Polyporus alveolaris (DC.) Bondartsev & Singer, Annales Mycologici 39(1): 58 (1941).

≡ *Merulius alveolaris* DC., Flore française 6: 43 (1815) (Image 115–120)

Basidiome annual, pileate, substipitate, solitary; pilei circular to dimidiate, flabelliform, up to 4 × 3 × 0.3 cm.

Abhymenial surface tomentose, faintly concentrically zonate, white when fresh, changing to pale yellowish on drying; margin concolorus, acute, wavy, entire.

Hymenial suface reddish-grey to brownish-grey when fresh, not changing much on drying; margin concolorus, sterile up to 2 mm.

Pores angular to hexagonal, 2–3 per mm; dissepiments entire, up to 150 µm in thickness.

Tube layer brownish-orange, up to 1 mm deep.

Context homogenous, greyish-red, up to 2 mm in thickness.

Hyphal system dimitic. Generative hyphae hyaline, thin-walled, clamped, branched, up to 4.4 µm in width.

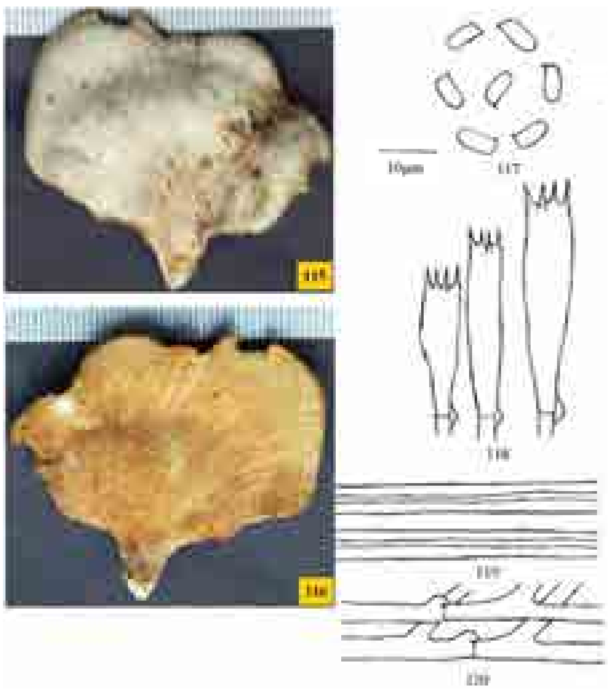

Image 115–120. *Polyporus alveolaris*: 115–116—Basidiome showing abhymenial and hymenial surface | 117—Basidiospores | 118—Basidia | 119—Skeletal hyphae | 120—Generative hyphae.

Skeleto-binding hyphae, golden brown to dark brown, thick-walled, aseptate, unbranched, up to 5.5 µm in width.

Hyphal arrangement: Subhymenium formed of branched generative hyphae only. Trama formed of loosely arranged generative and skeleto-binding hyphae. Context consists of compact generative and skeleto-binding hyphae.

Basidia sub-clavate, thin-walled, tetrasterigmate, clamped at the base, 22–42 × 6.6–9.9; sterigmata up to 2 µm in length.

Basidiospores cylindrical, hyaline, thin-walled, smooth, no reaction in Melzer's reagent and cotton blue, 6.8–8.7 × 2.6–3.2 µm.

Material examined: 9103 (PUN), 26.viii.2016, Jammu & Kashmir, Doda, Dacchin, on *Cedrus deodara* stump, Brij Bala.

Notes: *Polyporus alveolaris* characterized bycircular to dimidiate, substipitate pilei, and cylindrical basidiospores. It is being reported for the first time from Jammu & Kashmir.

Polyporus efibulatus (A.M. Ainsw. & Ryvarden) Melo & Ryvarden, Synopsis Fungorum 37: 335 (2017)

≡ *Dichomitus efibulatus* A.M. Ainsworth & Ryvarden, Synopsis Fungorum 25: 48 (2008). (Image 121–127)

Basidiome annual, resupinate, effused, soft when fresh, becomes coriaceous after drying, easy to separate from the substrate; up to 3 mm thick in cross-section.

Hymenial surface poroid, white when fresh, changing to pale yellowish on drying; margin concolorus, adnate, sterile up to 2 mm.

Pores round to angular, 2–3 per mm; dissepiments entire, up to 50 µm in thickness.

Tube layer orange white, up to 2 mm deep.

Subiculum homogenous, yellowish white, up to 1 mm thick.

Hyphal system dimitic. Generative hyphae hyaline, thin-walled, simple-septate, branched up to 4 µm in width. Skeletal hyphae pale yellowish, thick-walled, unbranched, up to 6 µm in width.

Hyphal arrangement subhymenium formed of loosely arranged, regularly to irregularly branched generative hyphae. Trama dominated with loose to moderately compact generative and skeletal hyphae. Context composed of moderately arranged generative and skeletal hyphae.

Cystidioles fusoid, thin-walled, smooth, simple-septate at the base, originate in the hymenium, 15–17 × 5–6 µm; projecting up to 10 µm from the hymenium.

Basidia sub-clavate, thin-walled, tetrasterigmate,

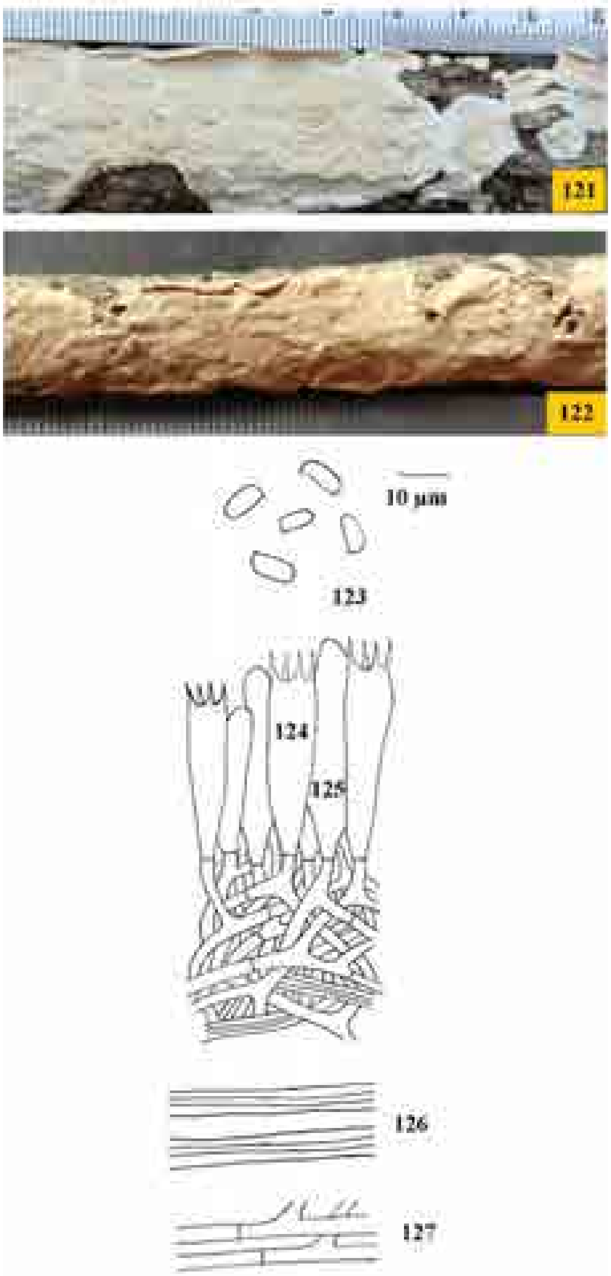

Image 121–127. *Polyporus efibulatus*: 121—Basidiome showing hymenial surface (fresh) | 122—Basidiome showing hymenial surface (dry) | 123—Basidiospores | 124—Basidia | 125—Cystidiole | 126—Skeletal hyphae | 127—Generative hyphae.

simple-septate at the base, 22–35 × 5–8 µm; sterigmata up to 2 µm in length.

Basidiospores cylindrical, hyaline, thin-walled, smooth, 7–11 × 2.8–4.5 µm, no reaction in Melzer's reagent and cotton blue.

Material examined: 11235(PUN), 21.ix.2015, Jammu & Kashmir, Jammu, Doda, Chinta, on angiospermous wood, Brij Bala.

Notes: *Polyporus efibulatus* differs in having resupinate basidiome, fusoid cystidioles and thin-walled cylindrical basidiospores. It is reported for the first time from India. Earlier it has been reported from southern and western England (Ryvarden & Melo 2014).

Polyporus squamosus (Huds.) Fr., Systema Mycologicum 1: 343–1821.

≡ *Boletus squamosus* Huds., Flora anglica: 626 (1778). (Image 128–136)

Basidiome annual, pileate, solitary, laterally stipitate, soft and fleshy when fresh, changing to corky after drying; pilei reniform, dimidiate, up to 8 × 5 × 0.5 cm.

Abhymenial surface glabrous, azonate, with blackish-brown scales, white when fresh, changing to pale yellowish on drying; margin concolorus, acute, curved inside after drying.

Hymenial surface poroid, pale yellowish when fresh, changing to light brownish on drying; margin concolorus, sterile up to 1 mm.

Pores round to angular, 0.5–1 per mm; dissepiments lacerate, up to 150 µm in thickness.

Tube layer brownish-orange, up to 0.2 cm deep.

Context homogenous, greyish-red, up to 0.3 cm in thickness.

Stipe lateral, cylindrical, solid, greyish-black, tomentose at the base, up to 3 cm and 2 cm.

Hyphal system dimitic. Generative hyphae hyaline, thin- to thick-walled, clamped, branched, up to 3 µm

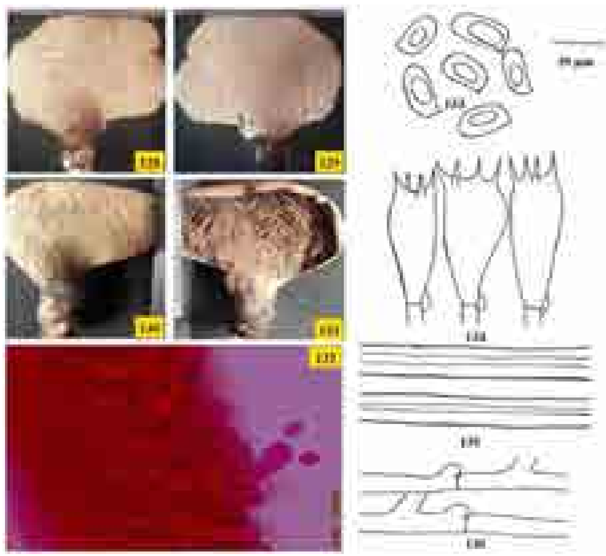

Image 128–136. *Polyporus squamosus*: 128–129—Basidiome showing abhymenial and hymenial surface (fresh) | 130–131—Basidiome showing abhymenial and hymenial surface (dry) | 132—Photomicrograph showing basidium and basidiospores | 133—Basidiospores | 134—Basidia | 135—Skeletal hyphae | 136—Generative hyphae.

in width. Skeletal hyphae subhyaline, thick-walled, aseptate, unbranched, up to 6 µm in width.

Hyphal arrangement: Subhymenium consists mainly of branched generative hyphae. Trama composed of moderately compact generative and skeletal hyphae. Context formed of compactly packed generative and skeletal hyphae.

Basidia clavate, thin-walled, tetrasterigmate, clamped at the base, 17–23 × 7–9.5 µm; sterigmata up to 3 µm in length.

Basidiospores ellipsoid to cylindrical, hyaline, thin-walled, smooth, with oil droplets, no reaction in Melzer's reagent and cotton blue, 7–10.5 × 4–5 µm.

Material examined: 11362 (PUN), 22.ix.2018, Jammu & Kashmir, Doda, Attalgarh, on *Morus alba* branch, Brij Bala .

Notes: *Polyporus squamosus* is characterized by reniform pilei with greyish black stipe, blackish-brown scales on abhymneial surface and ellipsoid to cylindric basidiospores. Bakshi (1971) described it from Srinagar District of Kashmir division. This is the first report of *P. squamosus* from Jammu division.

Pycnoporus cinnabarinus (Jacq.) P. Karst., Revue Mycologique Toulouse 3(9): 18 (1881).

≡*Boletus cinnabarinus* Jacq., Flora Austriaca 4: 2, tab. 304 (1776). (Image 137–145)

Basidiome annual, pileate, solitary, sessile, broadly attached; pilei elongated, applanate, dimidiate, somewhat leathery when fresh, up to 3 × 3 × 1 cm.

Abhymenial surface smooth, azonate to faintly zonate, reddish-orange when fresh, not changing much on drying; margin acute, entire, wavy, light orange when fresh, not changing much on drying.

Hymenial surface poroid, greyish-red when fresh, not changing much on drying; margin light orange when fresh, not changing much on drying, sterile up to 2 mm.

Pores round to angular, 4–5 per mm; dissepiments entire, up to 45 µm in thickness.

Tube layer orange red, up to 0.5 cm deep.

Context homogenous, greyish-red, up to 0.5 cm in thickness.

Hyphal system trimitic. Generative hyphae hyaline to subhyaline, thin-walled, branched, clamped, up to 4 µm in width. Binding hyphae subhyaline to yellowish-brown, thick-walled, aseptate, branched, up to 4.5 µm in width. Skeletal hyphae yellowish-brown, thick-walled, aesptate, unbranched, up to 5.2 µm in width.

Hyphal arrangement: subhymenium contains thin-walled, moderately compact, irregularly branched generative and binding hyphae. Trama formed of loosely to moderately compact, generative, binding and skeletal hyphae. Context consists of compactly arranged binding and skeletal hyphae.

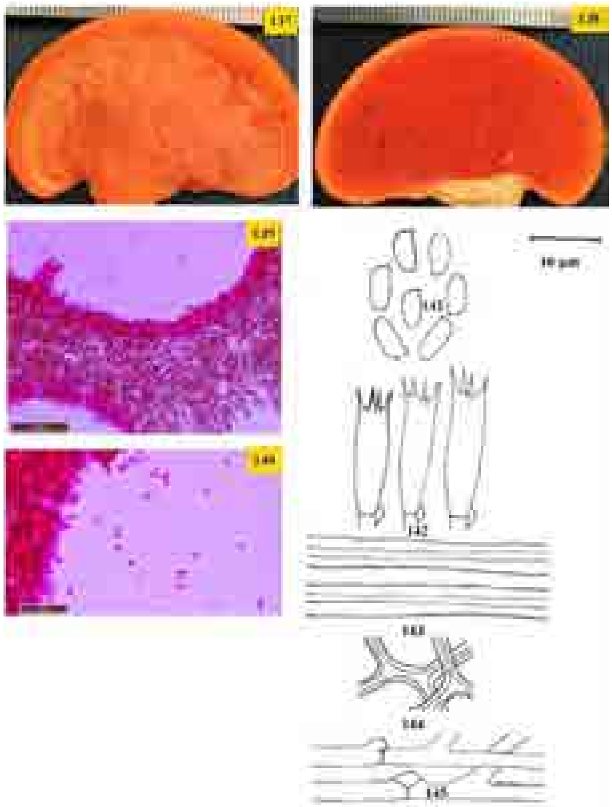

Image 137–145. *Pycnoporus cinnabarinus*: 137–138—Basidiome showing abhymenial and hymenial surface | 139–140—Photomicrograph showing | 139—hymenium | 140—basidiospores | 141—Basidiospores | 142—Basidia | 143—Skeletal hyphae | 144—Binding hyphae | 145—Generative hyphae.

Cystidia absent.

Basidia sub-clavate, thin-walled, tetrasterigmate, clamped at the base, 15–28 × 4–5.5; sterigmata up to 3 µm in length.

Basidiospores ellipsoid to cylindrical, hyaline, thin-walled, smooth, no reaction in Melzer's reagent and cotton blue, 5.5– 6.5 × 2.3–2.8 µm.

Material examined: 11263 (PUN), 17.viii.2017, Jammu & Kashmir, Doda, Bhaderwah, Shunushir, on *Cedrus deodara* log, Brij Bala; 11327 (PUN), 21.viii.2017, Kishtwar, Dacchin, on *C. deodara* log, Brij Bala.

Notes: *Pycnoporus cinnabarinus* is characterized by reddish-orange basidiome with thin-walled, ellipsoid to cylindrical basidiospores. It is reported for the first time from the study area. Earlier Murril (1924) and Roy & De (1996) reported it from the Gulmarg District of Kashmir.

Pycnoporus sanguineus (L.) Murrill, Bulletin of the Torrey Botanical Club 31(8): 421(1904).

≡ *Boletus sanguineus* L., Species Plantarum: 1646 (1763). (Image 146–154)

Basidiome annual, pileate, solitary, sessile, broadlyattached; pilei dimidiate, applanate, up to 5 × 4 × 0.4 cm.

Abhymenial surface glabrous, azonate, smooth, reddish-orange when fresh, brownish-red to reddish brown on drying; margin acute, entire, wavy, light orange when fresh, not changing much on drying.

Hymenial surface poroid, light orange when fresh, not changing much on drying; margin concolorus, sterile up to 2 mm.

Poresround to angular, 5–6 pores per mm; dissepiments entire, up to 45 µm in thickness.

Tube layer orangish-white to orange grey, up to 0.2 cm deep.

Context homogenous, orange grey, up to 0.2 cm in thickness.

Hyphal system trimitic. Generative hyphae hyaline, thin-walled, branched, clamped, up to 3.5 µm in width. Binding hyphae subhyaline, thick-walled, branched, aseptate, up to 3.5 µm in width. Skeletal hyphae subhyaline, thick-walled, unbranched, aseptate, up to 5 µm in width.

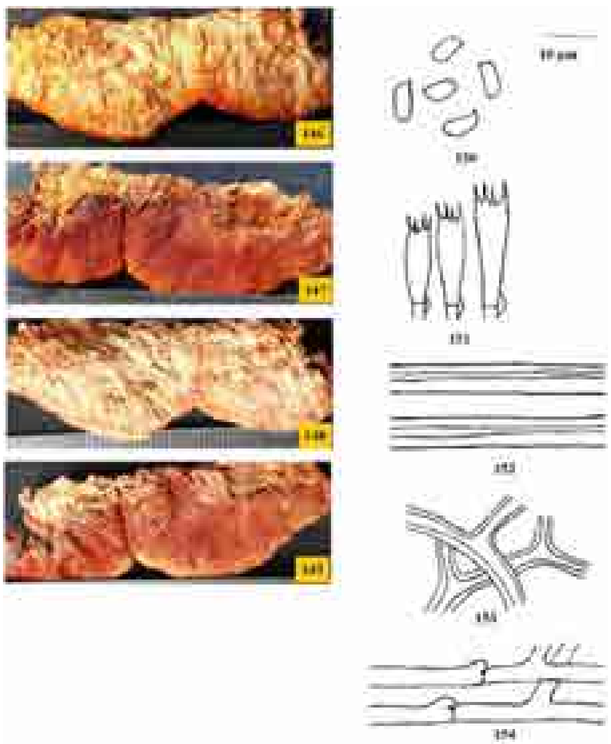

Image 146–154. *Pycnoporus sanguienus*: 146–147—Basidiome showing abhymenial and hymenial surface (fresh) | 148–149—Basidiome showing abhymenial and hymenial surface (dry) | 150—Basidiospores | 151—Basidia | 152—Skeletal hyphae | 153—Binding hyphae | 154—Generative hyphae.

Hyphal arrangement: Subhymenium formed thin-walled, loosely arranged, irregularly branched generative hyphae. Trama dominated with loosely arranged, generative hyphae and skeletal hyphae. Context composed of compactly arranged generative and skeletal hyphae.

Cystidia absent.

Basidia sub-clavate, thin-walled, tetrasterigmate, clamped at the base, 11–19 × 4–3.6 µm; sterigmata up to 3 µm in length.

Basidiospores cylindrical to slightly bent, hyaline, smooth, thin-walled, no reaction in Melzer's reagent and cotton blue, 4–7.5 × 2.5–3.5 µm.

Material examined: 11263 (PUN), 17.viii.2017, Jammu & Kashmir, Doda, Bhaderwah, Shunushir, on *Cedrus deodara* log, Brij Bala; 11327(PUN), 21.viii.2017, Kishtwar, Dacchin, on *C. deodara* log, Brij Bala,.

Notes: *Pycnoporus sanguineus* is unique in having reddish basidiome with comparatively smaller pores and cylindrical to slightly bent basidiospores. It is a new record for Jammu & Kashmir.

Tyromyces amazonicus A.M.S. Soares & Ryvarden, Fungal Diversity 87: 195 (2017). (Image 155–164)

Basidiome annual, pileate, solitary, sessile, broadly attached; pilei dimidiate, applanate; up to 2 × 0.05 × 0.5 cm.

Abhymenial surface sulcate, azonate, white when fresh, changing to pale yellow to orange white on drying; margin acute, concolorus, wavy, entire.

Hymenial surface poroid, brownish white to orange white when fresh, changing to reddish-white to greyish-red on drying; margin concolorus, sterile up to 1 mm.

Pores angular to round, 3–4 per mm; dissepiments entire, up to 45 µm in thickness.

Tube layer orange white, up to 0.2 mm deep.

Context homogenous, yellowish-white, azonate, up to 0.3 cm thick.

Hyphal system dimitic. Generative hypahe hyaline, thin- to thick-walled, clamped, branched up to 3 µm in width. Skeletal hyphae golden brown, thick-walled, aseptate, unbranched, up to 5.5 µm in width.

Hyphal arrangement: Subhymenium composed of loosely arranged irregularly branched generative hyphae. Trama composed of loosely to moderately compact generative and skeletal hyphae. Context formed of compactly arranged generative and skeletal hyphae.

Cystidioles fusoid, thin-walled, clamped at the base, 19–25 × 3–5 µm; originate in the hymenium; projecting 10 µm from hymenium.

Basidia clavate, thin-walled, tetrasterigmate,

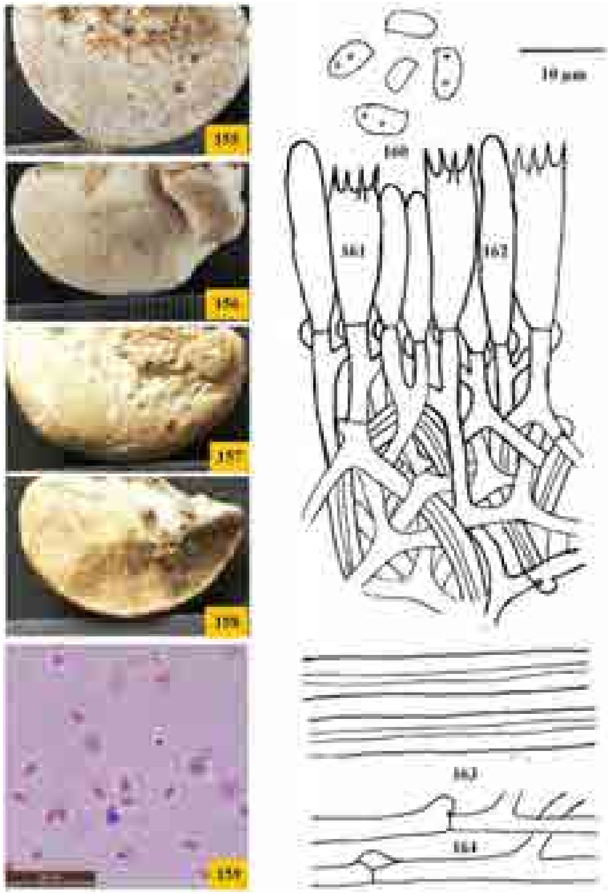

Image 155–164. *Tyromyces amazonicus*: 155–156—Basidiome showing abhymenial and hymenial surface (fresh) | 157–158—Basidiome showing abhymenial and hymenial surface (dry) | 159—Photomicrograph showing basidiospores | 160—Basidiospores | 161—Basidia | 162—Cystidiole | 163—Skeletal hyphae | 164—Generative hyphae.

clamped at the base, 15–18.6 × 5–6.2 µm; sterigmata up to 2 µm in length.

Basidiospores ellipsoid to broadly ellipsoid, hyaline, thin-walled, smooth, with oily contents, no reaction in Melzer's reagent and cotton blue, 3–5.7 × 2–3 µm.

Material examined: Jammu & Kashmir, Kishtwar, Dacchin, on Cedrus deodara stump, Brij Bala 11330 (PUN), 21.ix.2017.

Notes: *Tyromyces amazonicus* is characterized by applanate, basidiome, fusoid cystidioles and ellipsoid to broadly ellipsoid basidiospores. It is reported for the first time from India. Earlier it has been recorded from Brazil by Hyde at al. (2017).

Tyromyces chioneus (Fr.) P. Karst., Revue Mycologique Toulouse 3(9): 17 (1881).

≡ *Polyporus chioneus* Fr., Observationes mycologicae 1: 125 (1815). (Image 165–170)

Basidiome annual, pileate, solitary, subsessile, soft and fleshy when fresh, becoming hard and brittle on drying, somewhat aromatic when fresh; pilei dimidiate, up to 4 × 3.2 × 0.6 cm.

Abhymenial surface sulcate, faintly concentrically zonate, finely tomentose to glabrous, scrupose, white when fresh, changing to pale yellowish on drying; margin concolorus, obtuse, wavy, entire.

Hymenial surface poroid, brownish white to orange white when fresh, changing to reddish white to greyish red on drying; margin concolorus, sterile up to 2 mm.

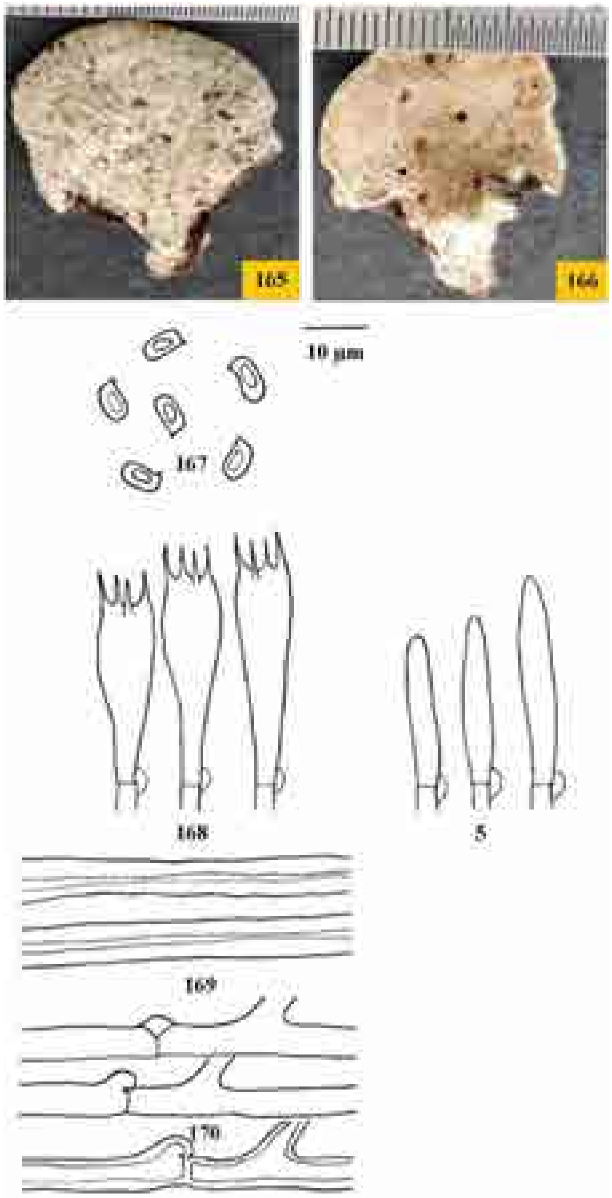

Image 165–170. *Tyromyces chioneus*: 165–166—Basidiome showing abhymenial and hymenial surface | 167—Basidiospores | 168—Basidia | 168—Cystidioles | 169—Skeletal hyphae | 170—Generative hyphae.

Pores angular to round, 5–6 per mm; dissepiments entire, up to 350 µm in thickness.

Tube layer yellowish-white, up to 0.3 mm deep.

Context homogenous, greyish-white, azonate, up to 0.3 cm thick.

Hyphal system dimitic. Generative hypahe hyaline, branched, thin- to thick-walled, clamped, branched, up to 5.5 µm in width. Skeletal hyphae pale-yellowish, thick-walled, aseptate, unbranched, up to 6.6 µm in width.

Hyphal arrangement: subhymenium dominated by generative hyphae. Trama formed of loosely arranged to moderately compact generative and skeletal hyphae. Context consists of moderately compact generative and skeletal hyphae.

Cystidioles fusoid, clamped at the base, originate in the subhymenium, 20.5–33.5 × 2.5–4.5 µm; projecting slightly from the hymenium.

Basidia clavate, thin-walled, clamped at the base, tetrasterigmate, 24–33 × 7.5–8 µm; sterigmata up to 2 µm in length.

Basidiospores cylindrical to slightly bent, thin-walled, smooth, 4.4–6.6 × 2–3.5 µm, no reaction in Melzer's reagent and cotton blue.

Material examined: 9103 (PUN), 26.viii.2016, Jammu & Kashmir, Doda, Bhaderwah, on *Cedrus deodara* stump, Brij Bala; 11276 (PUN), 17.viii.2017, Bhaderwah, on *C. deodara* stump, Brij Bala.

Notes: *Tyromyces chioneus* differs in having subsessile basidiome, which are somewhat aromatic in the field, finely tomentose to glabrous abhymenial surface and cylindrical to slightly bent basidiospores. Earlier it has been reported by Lloyd (1922) from southern India, Sharma (2012) and Kaur (2013) from Himachal Pradesh. This is the first record of *T. chioneus* from Jammu & Kashmir.

Trichaptum abietinum (Pers. ex J.F. Gmel.) Ryvarden, Norwegian Journal of Botany 19: 237 (1972).

≡ *Boletus abietinus* Pers. ex J.F. Gmel., Systema Naturae 2(2): 1437 (1792). (Image 171–176)

Basidiome annual, effused-reflexed to pileate, imbricate, sessile, narrowly attached; pilei applanate, up to 2.2 × 0.4 × 0.4 cm.

Abhymenial surface faintly concentrically zonate, hirsute, greyish white when fresh, not changing much on drying; margin concolorus, acute, entire.

Hymenial surface poroid, purplish-grey when fresh, not changing much on drying; margin concolorus, sterile up to 4 mm.

Pores angular to elongated, 4–6 per mm; dissepiments lacerate, up to 90 µm in thickness.

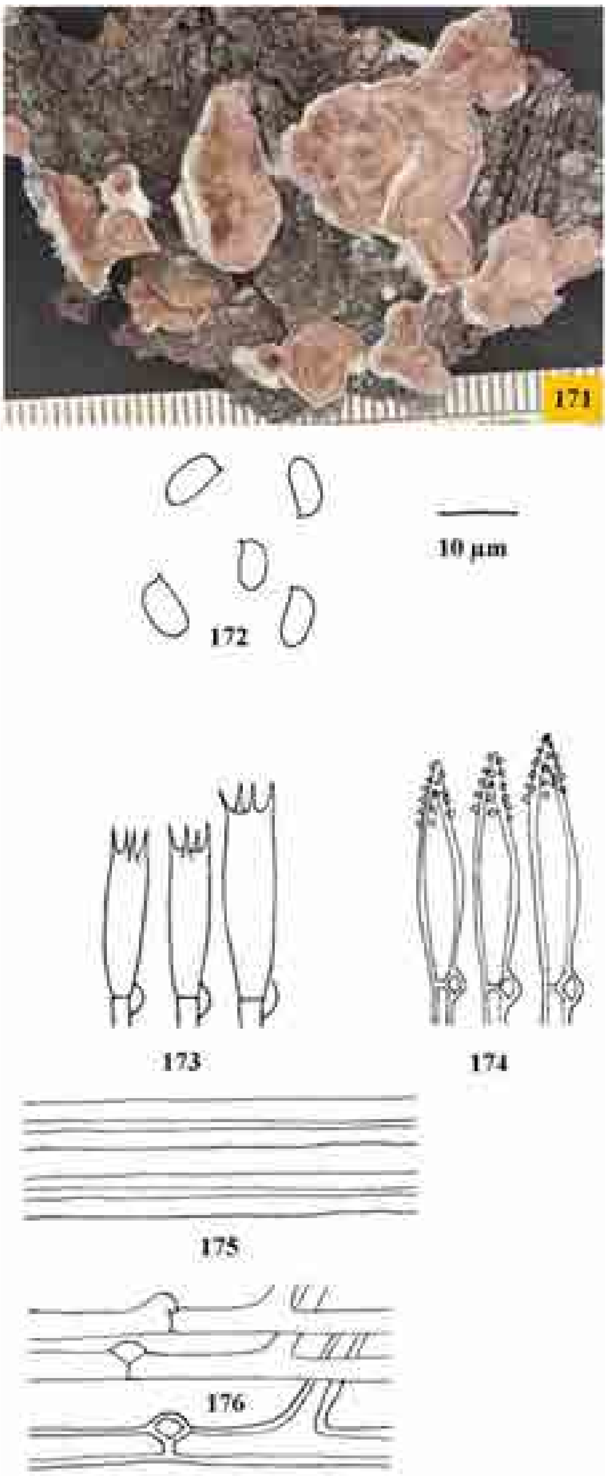

Image 171–176. *Trichaptum abietinum*: 171—Basidiome showing hymenial surface | 172—Basidiospores | 173—Basidia | 174—Cystidia | 175—Skeletal hyphae | 176—Generative hyphae.

Tube layer purplish-grey, separated by thin gelatinous layer from context; up to 1 mm deep.

Context duplex; outer zone whitish-grey, soft, up to

1 mm thick; inner zone orange white, fibrous, up to 2 mm thick.

Hyphal system dimitic. Generative hyphae hyaline, thin- to thick-walled, clamped, branched, up to 5.5 µm in width. Skeletal hyphae subhyaline, thick- walled, aseptate, unbranched, up to 6 µm in width.

Hyphal arrangement: Subhymenium dominated by branched generative hyphae. Trama constituted of loosely arranged generative and skeletal hyphae. Context mainly composed of somewhat loose to compactly arranged generative and skeletal hyphae.

Cystidia sub-clavate, thick-walled, apically encrusted, clamped at the base, originate in the subhymenium, 27.5–33 × 4.6–6.6 µm; projecting up to 10 µm from the hymenium.

Basidia sub-clavate, thin-walled, clamped at the base, tetrasterigmate, 19.8–24.2 × 5–6.6 µm; sterigmata up to 3 µm in length.

Basidiospores cylindrical, slightly bent, hyaline, thin-walled, smooth, no reaction in Melzer's reagent and cotton blue, 6–8 × 2.5–4 µm.

Material examined: 9102 (PUN), 26.ix.2016, Jammu & Kashmir, Doda, Bhaderwah, Attalgarh, on pinus stump, Brij Bala.

Notes: *Trichaptum abietinum* is amongst the early colonizers of fallen twigs, logs, and stumpsIt is unique in having effused-reflexed to pileate basidiome with somewhat narrower base. It is reported for the second time from the study area. Previously, Dhanda (1977) described it from Ramban District of Jammu Division.

Trichaptum biforme (Fr.) Ryvarden, Norwegian Journal of Botany 19: 237,1972.

≡*Polyporus biformis* Fr., Linnaea 8: 486, 1833. (Image 177–186)

Basidiome annual, pileate, imbricate, sessile, broadly attached; pilei dimidiate, flabelliform, up to 4 × 0.3 × 0.2 cm.

Abhymenial surface faintly concentrically zonate, hirsute, greyish-white when fresh, not changing much on drying; margin concolorus, acute, entire.

Hymenial surface poroid, purplish-grey to reddish-grey when fresh, not changing much on drying; margin concolorus, sterile up to 4 mm.

Pores round to angular to elongated, 3–5 per mm; dissepiments lacerate, up to 45 µm in thickness.

Tube layer brownish-orange, up to 1 mm deep.

Context homogeneous, azonate, fibrous, greyish red, up to 1 mm in thickness.

Hyphal system dimitic. Generative hyphae hyaline, thin-walled, clamped, branched, up to 5 µm in width.

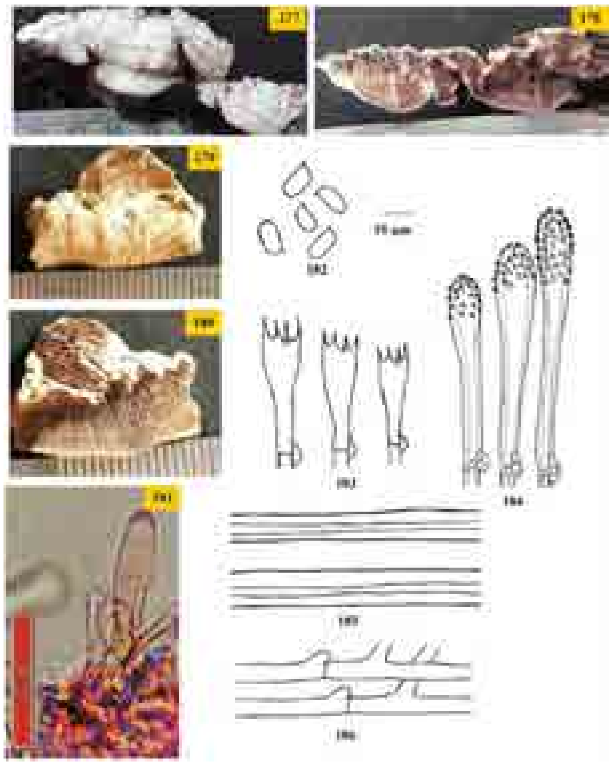

Image 177–186. *Trichaptum biforme*: 177–178—Basidiome showing abhymenial surface and hymenial surface (fresh) | 179–180—Basidiome showing abhymenial and hymenial surface (dry) | 181—Photomicrograph showing cystidium | 182—Basidiospores | 183—Basidia | 184—Cystidia | 185—Skeletal hyphae | 186—Generative hyphae.

Skeletal hyphae subhyaline, thick- walled, aseptate, unbranched, up to 8.4 µm in width.

Hyphal arrangement: subhymenium formed of moderately compact, regularly branched generative hyphae. Trama dominated with generative and skeletal hyphae. Context constituted of compactly arranged generative and skeletal hyphae.

Cystidia fusoid, thick-walled, apically encrusted, clamped at the base, originate in the hymenium, 40–80 × 5–10 µm; projecting up to 20 µm from the hymenium.

Basidia sub-clavate, thin-walled, tetrasterigmate, clamped at the base, 18–35 × 5.5–11.5 µm; sterigmata up to 3 µm in length.

Basidiospores cylindrical, somewhat curved, hyaline, thin-walled, smooth, no reaction in Melzer's reagent and cotton blue, 5–10 × 2.5–5 µm.

Material examined: 11254 (PUN), 21.ix.2017, Jammu & Kashmir, Kishtwar, Chatroo, on *Cedrus deodara* branch, Brij Bala; 11275 (PUN), 21.ix.2017, Dacchin, on *C. deodara* log, Brij Bala .

Notes: *Trichaptum biforme* is diffentitated from *T. abietinum* by the absence of a gelatinous layer separating context from tube layer. It is being reported for the first time from Jammu & Kashmir.

DISCUSSION

About 54 species of polyporoid fungi are reported from the Union Territory of Jammu & Kashmir by earlier workers (Dhanda 1977; Rattan 1977; Thind & Dhanda 1979, 1980a,b; Bala 2022a,b) which are categorised under 24 genera, eight families and four orders of *Agaricomycetes* (Basidiomycota). The present contribution adds five new records for India, 14 new to the Union Territory of Jammu & Kashmir, two new records for Jammu division, thus increasing the number of polypores in Jammu & Kashmir from 54 to 71.

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ARTICLE

Identification, prioritization, and management of biodiversity hot specks: a case study of Western Ghats of Maharashtra, India

Shivam Trivedi [1] & Erach Bharucha [2]

[1] Naoroji Godrej Centre for Plant Research, 431, Lawkim Campus, Shindewadi, Shirwal, Satara, Maharashtra 412801, India.
[2] Bharati Vidyapeeth Institute of Environment Education and Research, Bharati Vidyapeeth University, Dhankawadi, Pune, Maharashtra 411043, India.
[1] trivedi.shivam07@gmail.com (corresponding author), [2] kapilabharucha@gmail.com

Abstract: The Western Ghats are globally recognized as a hotspot of rich, endemic, and threatened biodiversity. Within this hotspot of biological diversity, there are islands of natural landscapes that can be termed as 'hot specks'. These hot specks require careful prioritization and specific management strategies as they vary in objectives and ownership. Conserving hot specks of biodiversity is of great relevance because creating new protected areas with wildlife corridors between them has become relatively impossible in the present context of intensive land-use change in this rapidly developing region. Management strategies, however, must be based on scientific assessment and using a set of prioritization criteria for selecting the most appropriate forms of management. The conservation action plan for the Western Ghats has become a controversial issue based on the findings in the report submitted by the Western Ghats Expert Ecological Panel and the High Level Work Group on Western Ghats. In the present context of rapidly changing land-use patterns, economic development, forest fragmentation, isolation of habitats, linear intrusion, neo-urbanization and industrial growth are threats to the pristine nature of the ghats. Thus, there is an urgent need to identify, prioritize and manage the smaller fragments of biological importance within the larger ecologically sensitive landscape. A prioritization model for different types of hot specks is essential so that it can be easily replicated by training frontline forest staff, community-based organizations, Biodiversity Management Committees, and non-government organizations for implementing a strategy and action plans for the sites by using the Biological Diversity Act, 2002. Support of the local Biodiversity Management Committees and the State Biodiversity Board is essential for the conservation management of these biodiversity-rich sites. This study presents an innovative approach to prioritize areas outside the formally notified boundaries of the national parks and wildlife sanctuaries to assess the conservation value of hot specks of diversity through a rapid biodiversity assessment tool. This can lead to a rational conservation strategy that conservation planners and practitioners can use.

Keywords: Biological diversity, forts, hotspot, hot specks, management strategies, plateaus, rapid biodiversity assessment tool, sacred groves.

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Author details: Dr. Shivam Trivedi is a scientist at the Naoroji Godrej Centre for Plant Research. He is an experienced environment researcher and a nature conservation expert with a demonstrated history of working in the biodiversity and natural capital conservation research, corporate social responsibility, sustainability and academic sector for over 10 years. Dr. Trivedi is also a member of the international Education for Sustainable Development Expert Net Committee. Dr. Erach Bharucha is the director at the Bharati Vidyapeeth Institute of Environment Education and Research. He is a surgeon by profession, and a biodiversity conservation expert by passion. He has been active in the field of wildlife and nature conservation over the past five decades and has extensively studied the protected areas and tribal cultures of India. He is also the ex-chairman of the Maharashtra State Biodiversity Board.

Author contributions: ST—manuscript writing and editing, data (collection, interpretation and analysis) and photography. EB—guidance on writing, editing manuscript and data interpretation.

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INTRODUCTION

Western Ghats – a global biodiversity hotspot

The term 'biodiversity hotspot' was first introduced in the late 1980s by Norman Myers as 'specific areas on earth's land surface harbouring disproportionately large numbers of extant species' (Reid 1998). At first, a list of 18 biodiversity hotspots was identified based on the richness of higher plant species (Mittermeier et al. 1998). Later new areas were included, and the list of biodiversity hotspots was increased to 25 (Fisher & Christopher 2007; Laurance 2007b). Currently, 35 global biodiversity hotspots have been identified (Laurance 2007a; Williams et al. 2011).

The Western Ghats are one of the first 18 globally identified biodiversity-rich hotspots. The mountain range is believed to be older than the Himalayas and spreads across six western states of India, in Gujarat, Maharashtra, Goa, Karnataka, Tamil Nadu, and Kerala (Kumara & Singh 2004; Pai 2005). Among these six states, Maharashtra is the most urbanized and industrialized region making it vital to create a locale-specific viable management strategy for this ecologically sensitive area (Mohan & Pant 1982; Ghatge et al. 2013).

Biodiversity conservation – a significant concern

The impacts on the landscape of the Ghats have initiated unsustainable patterns of land management in the Western Ghats (Panayotou & Ashton 1992; Menon & Bawa 1997). This has become a serious concern for biodiversity conservation as new protected areas are not a feasible option in the present context. The notified protected areas are being conserved through the Wildlife Protection Act, 1972 and various rules and regulations. These formally recognized protected areas were considered an adequate strategy for conserving biodiversity two to three decades ago (Beresford & Phillips 2000). However, recent studies have shown that a large part of the floral and faunal species diversity is present in the landscape elements outside the protected area network (Bhagwat & Rutte 2006). The current protected areas are thus insufficient for conserving the species and ecosystems, which are critical biological assets at global, national and local scales (Lindenmayer & Franklin 2002; Bhagwat et al. 2005; Lindenmayer et al. 2006; Shrestha et al. 2010).

Due to the current rapid growth of urbanization, industrialization, mining, transportation facilities, and infrastructure development, it is not feasible to notify new protected areas under the Wildlife Protection Act, 1972 or extend the boundaries of the existing protected areas, or create viable corridors between the protected areas is also a contentious issue (Mathur & Sinha 2008). The existing pressures are leading to a loss of species diversity in the protected areas and potential forested corridors connecting them (Gardner et al. 2010). However, there are several small and large landscape elements in the Western Ghats with high species concentrations that are not confined within the boundaries of existing protected areas in this ecologically sensitive area (Gadgil et al. 2011). The surrounding landscape elements of the protected areas form a matrix of cultural landscape elements that are permeable to several species such as small mammals, avifauna, amphibia, reptiles and insect life. The specialized habitat fragments surrounded by human-dominated land-use are representatives of small patches of natural or semi-natural ecosystems of the Western Ghats (Anand et al. 2010). These biodiversity-rich islands of forests are referred to as 'hot specks' (Cherian 1995). As defined, these hot specks are miniscule areas of species concentration, varying in size from five to rarely a few hundreds or more square meters falling within of far outside todays recognized hotspots where species-packing of diverse groups, including many endemics is found (Cherian 2000). They constitute a mix of varied elements that are effective as a support system for biodiversity conservation and could constitute a second line of reserves that act as biodiversity rich islands between the protected areas for a variety of floral and faunal elements (Bharucha 2006a, b).

Need for identifying biodiversity hot specks

A greater ecosystem is present in the landscape matrix dominated by socio-ecological elements outside the protected area boundaries. Conserving this large ecosystem is not a possible solution considering the human dependency on these landscapes. There is a need to identify key locations within this ecosystem for managing important ecological functions (DeFries et al. 2007). Identifying and conserving the biodiversity-rich 'hot specks' in a mosaic of cultural landscapes has become a priority for developing a network of biodiversity rich islands that will support the effective movement of wild fauna between the protected areas, as creating continuous corridors between protected areas is not a feasible option (Bhagwat et al. 2014; Trivedi et al. 2018). The increasing pressures on land use thus requires an innovative strategy aimed at conserving these multiple biodiversity rich hot specks that can act as areas that fauna can use to cross from one forest patch to another. Hot specks of diversity nested between existing protected areas are essential elements within the matrix of man-modified cultural landscapes.

Purpose of the study

The purpose of this study was to:

1. Identify the different important landscape element typologies of hot specks present with the Western Ghats of Maharashtra (Figure 1).
2. Prioritize each site within these different landscape elements using a set of scientific assessment parameters based on the evaluation of their biodiversity and anthropogenic threats that affect them adversely.
3. Suggest a unique management strategy based on the prioritization of these hot specks.

This study can act as an up scalable model for the rest of a large number of hot specks in the Western Ghats.

METHODS

Identification of hot specks

A survey of relevant literature provided a list of 14 possible hot speck typologies (Bharucha 2010; Trivedi & Bharucha 2019). Based on the available secondary data, sacred groves, forts, and plateaus were selected for the survey as they are key areas easily demarcated and can be managed (Naravane 1995; Deshmukh et al. 1998; Watve 2013). Hot specks under the three typologies (sacred groves, forts and plateaus) were plotted on a study area map and were selected for the ground survey through a purposive sampling technique.

Assessment of the hot specks

The Rapid Biodiversity Assessment Tool was developed consisting of important parameters categorized into biodiversity and anthropogenic threats that were further divided into several relevant subcategories (Figure 2). These parameters included shape and size, structure of the forest and its condition, presence of faunal diversity, special features, surrounding matrix (Hopkins & Skellam 1954; Adams et al. 1998; Ranta et al. 1998; Vázquez-García & Givnish 1998; Plumptre 2000; Ricketts 2001; Hill et al. 2005; Ormsby 2011; Trivedi et al. 2018). Anthropogenic threats include various types of gradually increasing local livelihood threats such as clearing natural landscapes for expanding agriculture and grazing, forest fires, felling of trees and lopping branches and current modern threats arising from the rapid sale of land, development of roads and transportation, powerlines, mining, windmills, industries, neo-urbanization and tourism were included as a part of the evaluation (Padhye et al. 2006; Davidar et al. 2007; Anitha et al. 2009; Subramanian et al. 2011; Mehta & Kulkarni 2012; Trivedi et al. 2018). The assessment parameters were quantified using a score from 0 to 10 (0 – absent, 2.5 – poor/ low, 5 – fair/ moderate, 7.5 – good/ significant, and 10 – very good/ high) (Trivedi et al. 2018). This scoring system was developed based on the assessment technique used for assessing the management effectiveness evaluation (MEE) of tiger reserves in India (Mathur et al. 2011).

The rapid biodiversity assessment tool (RBAT) is modified from the rapid assessment and prioritization of protected area management (RAPPAM) technique developed for WWF's 'Forest for Life' programme (Ervin 2003a; Getzner et al. 2012). These tools were modified so that they can be used by ground level practitioners such as forest department staff and the local Biodiversity Management Committees under the provisions of the Biological Diversity Act, 2002 (National Biodiversity Authority 2002).

A set of questions was designed for conducting semi-structured interviews with the local people (Longhurst 2003). The interview data is an essential part of the RBAT. It fills the one-time temporal gaps from the survey and provides a time series over the last couple of decades. Interviews can be done relatively quickly and provide local insights that are not obvious in a biodiversity and vegetation-based site analysis (Ervin 2003b). Thus, social issues and cryptic faunal values have emerged through this exercise.

Developing a geospatial database of the hotspecks

A normalized difference vegetation index' (NDVI) was processed using LANDSAT 8 satellite images for the entire study area. The technique was first used in the early 1970s, and it uses visible and near-infrared bands of the electromagnetic spectrum for identifying the presence of live vegetation on the ground (Sahebjalal & Dashtekian 2013). A buffer of 2 km^2 was created around the hot specks surveyed to study the peripheral vegetation cover. The GPS coordinates of hot specks were documented during ground-truthing and were plotted for the Western Ghats of Maharashtra using the ArcGIS platform.

Road network was acquired from Open Street Map and overlaid on the study area to identify the type of road connectivity to the hot specks. A buffer of 2 km^2 was created around all the identified hot specks from the secondary database to develop a network of hot specks forming a potential wildlife corridor. The database of all the three hot speck typologies was linked with the hot speck maps, and a geospatial database was developed

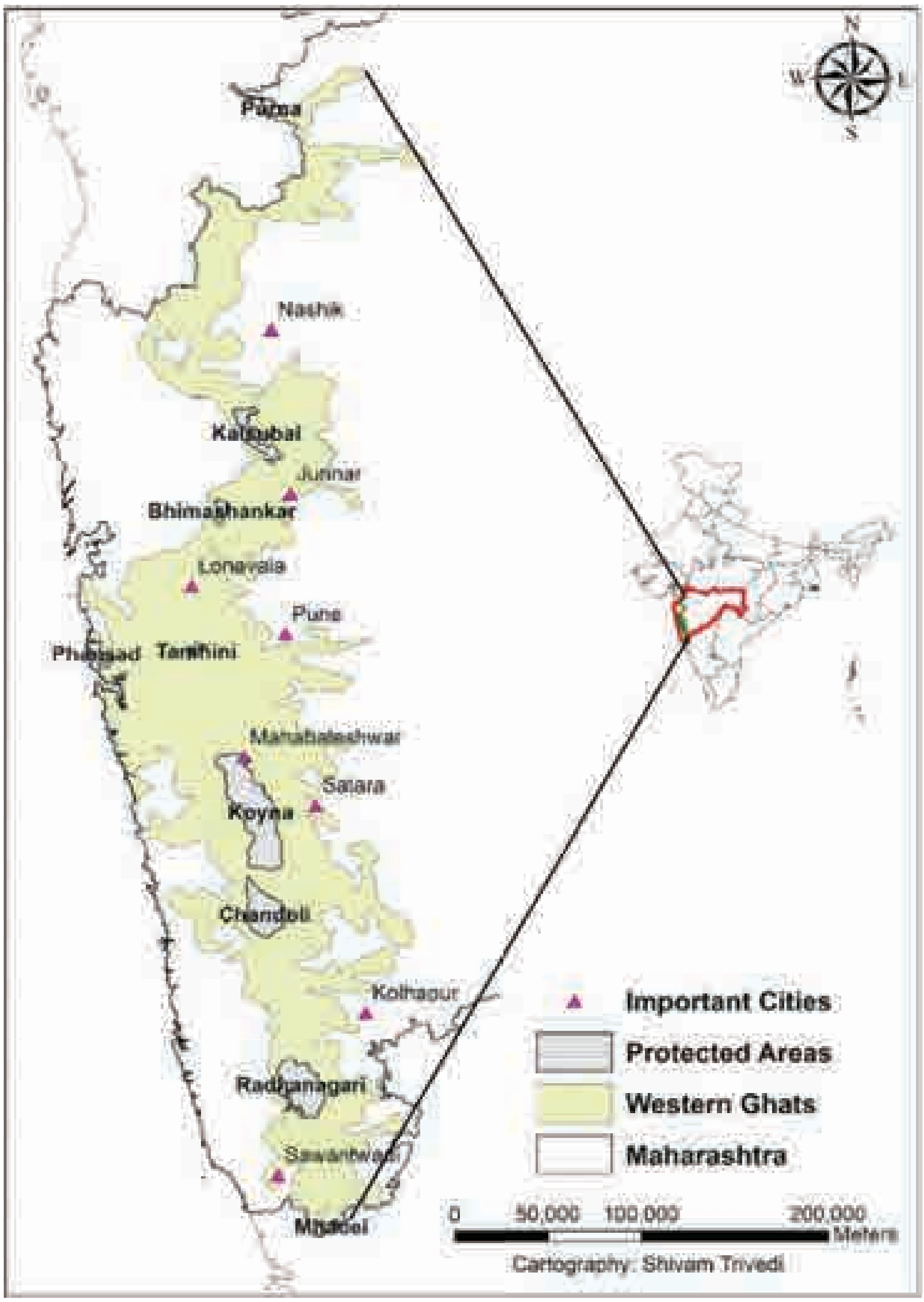

Figure 1. Study area – The Western Ghats of Maharashtra.

to acquire additional information on the hot specks (Kushwaha & Roy 2002).

A prioritization matrix was developed consisting of 16 categories for prioritizing the surveyed hot specks. These hot specks were then categorized in the matrix based on the biodiversity and anthropogenic threat values obtained from the field survey (Trivedi et al. 2018).

Developing management strategy for hot specks in the Western Ghats

Notifying these biodiversity hot specks as protected areas under the Wildlife Protection Act, 1972 can create new conflict issues. However, the Biological Diversity Act, 2002 is a feasible option since several local and tribal communities are dependent on these hot specks for their livelihood, and local Biodiversity Management

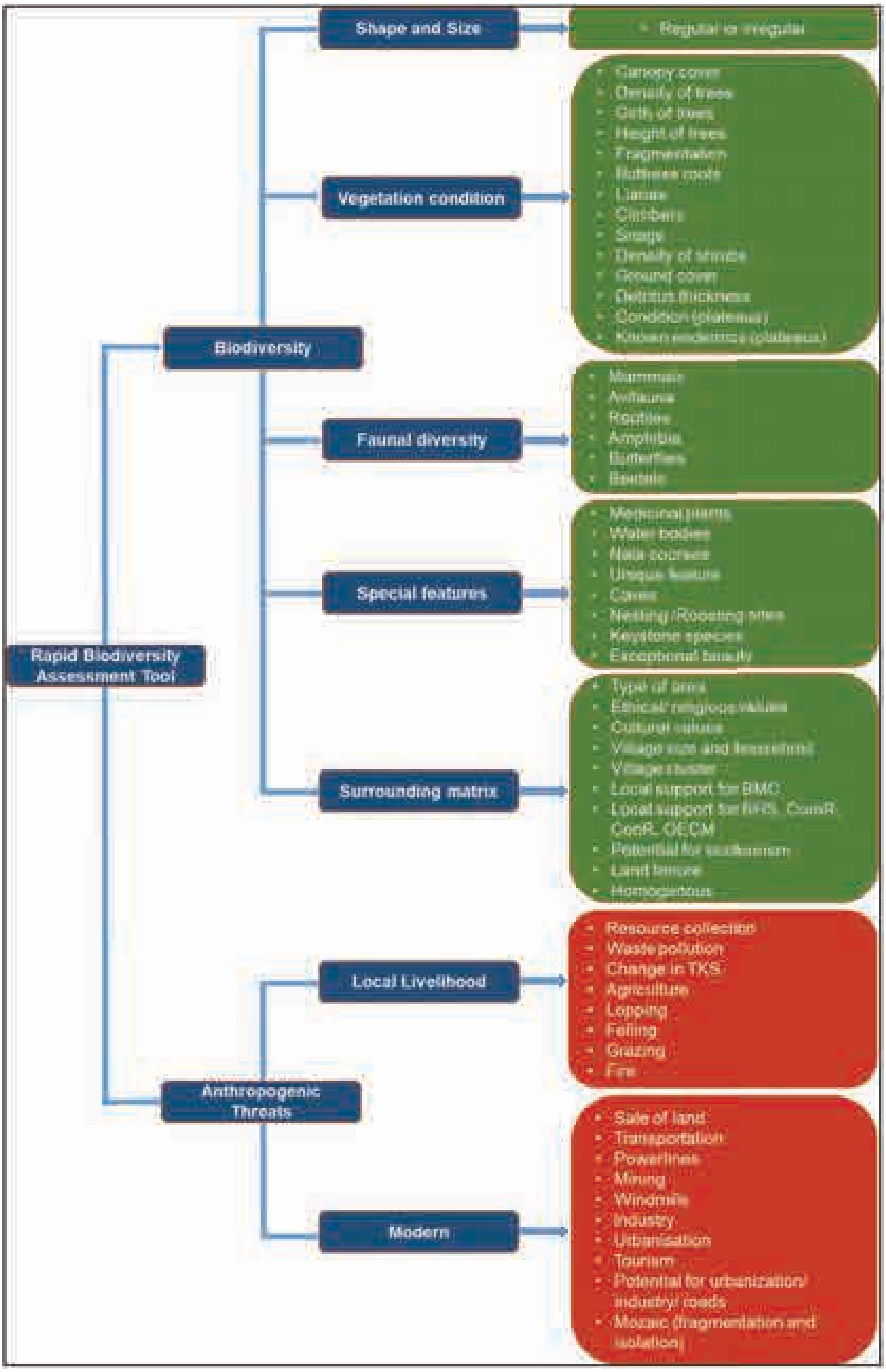

Figure 2. Rapid Biodiversity Assessment Tool.

Committees are empowered to legally take on this task (West & Brockington 2006). The conservation of these areas requires an innovative approach through which multi-stakeholder participation is incorporated into the management of the hot specks (Miller 2005).

A detailed literature of traditional, existing and new conservation approaches was reviewed for defining possible management strategies. Several new approaches under the rules and guidelines of the Convention on Biological Diversity and the Biological Diversity Act, 2002 were identified and can be used for conserving the prioritized hot specks based on the scores from assessment of biodiversity and anthropogenic threats (Gadgil et al. 2011).

The conservation of these hot specks requires active participation of various stakeholders. Government departments, especially the Forest Department and the Maharashtra State Biodiversity Board, as well as educational institutes and non-government organizations, have a crucial role in building and strengthening the capacity of the local communities and generating awareness for conserving these islands of rich biodiversity (Singh & Rahman 2012).

The Companies Act, 2013 has provided a potential pathway for corporates to initiate biodiversity conservation through their Corporate Social Responsibility (Ministry of Corporate Affairs 2013). Additional funding through corporates is an option for supporting these programs (National Biodiversity Authority 2019).

RESULTS

A sample size of 51 hot specks (19 sacred groves, 15 forts and 17 plateaus) were identified for the ground survey through purposive sampling from a total of 376 hot specks (Figure 3 & 4). The data collected from the ground survey and interviews were assessed for their biodiversity and anthropogenic threat scores (Table 1). They were depicted graphically and plotted in the prioritization matrix (Figure 5, 6 & 7; Table 2, 3 & 4). The combination of biodiversity and anthropogenic threats show that one sacred grove, one fort and one plateau recorded high biodiversity asset values. There is a significant negative correlation between biodiversity and anthropogenic threat scores, indicating that as anthropogenic threats increase, the value of biodiversity decreases (Table 5). Assessment of threats indicated that there had been a loss of traditional knowledge practices such as spiritual importance, agriculture and grazing while tourism, transportation, and urbanization had a more significant role in degrading the biodiversity of the hot specks and had spread across the surrounding matrix in the landscape.

Geospatial analysis

The results of geospatial analysis indicated that the scores of biodiversity and anthropogenic threats could be closely linked to the road connectivity of the hot specks (Figure 8). It provided an indicator of the overall anthropogenic threats that were degrading the biodiversity values of the hot specks. The anthropogenic threats showed that roads were linked to other threats as a cause- and- effect phenomenon which has increased over time. The effect of one threat that led to degrading the hot speck became a driving force for other threats. The analysis of road network connectivity to the hot specks has indicated that a total of nine hot specks (five sacred groves, two forts and two plateaus) are connected with a national highway, seven hot specks (two sacred groves, three forts and two plateaus) are connected with state highway, two hot specks (two forts) are connected with major district road, 32 hot specks (11 sacred groves, eight forts and 13 plateaus) are connected with other district roads and one hot speck (one sacred grove) is connected with a dust road. The road connectivity to a hot speck has led to other threats causing degradation of the biodiversity in the hot specks. Moderate to high anthropogenic threats have been recorded in four of the five hotspecks connected by national highways. The results showed that 32 out of 51 hot specks were connected by other district roads, which recorded moderate to high anthropogenic threats. A further analysis indicated that the stretch of the other district roads connecting the 17 hot specks were connected indirectly to either a national or state highway. In the case of Korigad fort, Khingar, Ambral, Dandeghar, Rajapuri, Mahabaleshwar 1, 2, & 3 plateaus, the hot specks are connected by other district roads, which is further connected to major district roads. The major district roads are in the near vicinity of popular tourist destinations.

A key concern is the quality of the surrounding matrix. A buffer of 2 km^2 created for the hot specks identified from the secondary database have resulted in a potential intermittent functional wildlife corridor connecting protected areas from Kalsubai Wildlife Sanctuary in Maharashtra State to Mhadei Wildlife Sanctuary in Goa State (Figure 9).

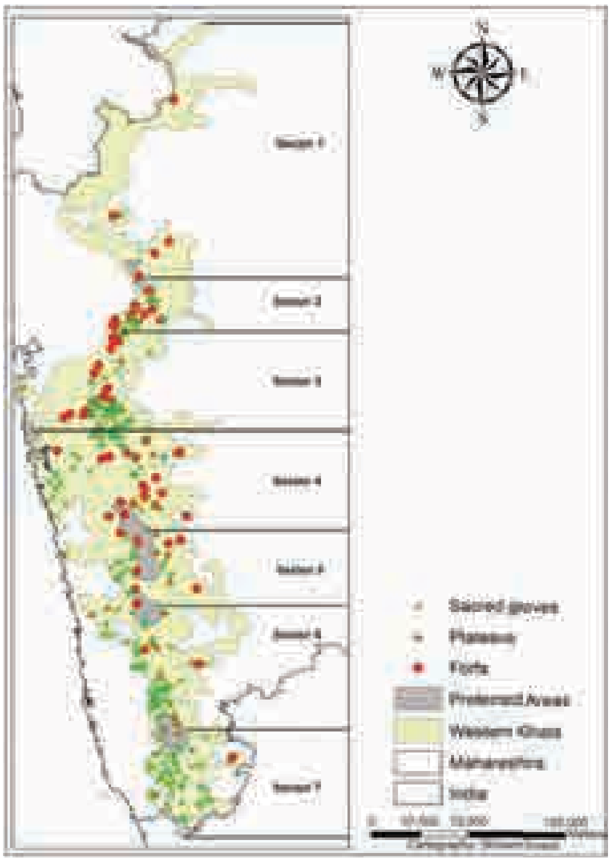

Figure 3. Hot specks identified from the secondary database.

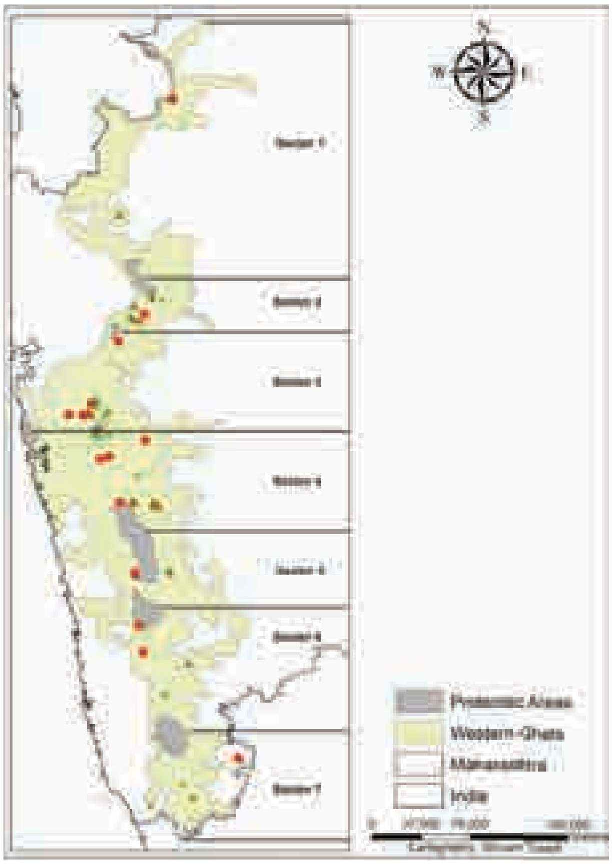

Figure 4. Hot specks identified for ground survey.

Management of hot specks – a dire need for conservation

The 51 hot specks (sacred groves, forts and plateaus) surveyed in this study are present outside the boundaries of the National Parks and Wildlife Sanctuaries. Hence, there are no stringent rules and regulations protecting these biodiversity rich hot specks. As a result, changes within the hot specks such as complete renovation or development of deity temples in the sacred groves were observed which has led to thinning of grove canopy and is attracting religious tourism (Image 1 & 2).

An important information recorded from the local interviews was that the sacred groves are not conserved for their biodiversity values but because of religious sentiments. However, the local people are aware of the changing landscapes leading to biodiversity loss. A growing demand of tourism for forts is leading to its beautification and attracting development of roads, small and medium scale eateries, and parking areas (Image 3,4).

These development processes are impacting the areas within fortified walls as well as the fort hill slopes. Unlike sacred groves and forts, plateaus are under pressure from tourism, roads passing through them, mining, power generation projects and grazing, all leading to loss of several seasonal endemic flora (Image 5).

Solid waste is a common threat observed in all the hot specks (Image 6). Land use change in the surrounding matrix is another anthropogenic threat found in hot specks that were connected to state or district highways. There is a dire need to develop and implement a sustainable management system for conserving these biodiversity hot specks taking into consideration the livelihood needs of the local communities.

DISCUSSION

The current study has highlighted that there are several fragments of biodiversity-rich areas outside the protected areas in the Western Ghats termed here as biodiversity hot specks which can act as transit areas across permeable areas for wildlife movements between protected areas (Das et al. 2006; Ray & Ramachandra 2010; Trivedi & Bharucha 2019). These hot specks

Table 1. Biodiversity and anthropogenic threat score of hot specks (SG—sacred groves, FT—forts, PL—plateaus).

	Hot specks	Hot speck code	Biodiversity	Anthropogenic threats
Sector 1: Purna Wildlife Sanctuary – Kalsubai Wildlife Sanctuary				
1	Inglaaj	SG1	4.38	5.69
2	Salher	FT1	4.51	3.97
3	Anjaneri	PL1	7.88	5.42
Sector 2: Kalsubai Wildlife Sanctuary – Bhimashankar Wildlife Sanctuary				
4	Durga	SG2	5	2.08
5	Kothmai	SG3	3.06	3.33
6	Chavand	FT2	4.44	3.68
7	Malshejghat	PL2	2.5	5.83
8	Naneghat	PL3	5.67	3.96
9	Durgawadi	PL4	4.9	0.63
10	Warsubai	PL5	3.27	2.92
11	Hatwij	PL6	3.08	2.29
Sector 3: Bhimashankar Wildlife Sanctuary – Tamhini and Phansad Wildlife Sanctuary				
12	Cheda	SG4	4.72	5.14
13	Waghjai (VS)	SG5	5.21	3.89
14	Waghjai (P)	SG6	5.21	4.44
15	Waghjai (W)	SG7	4.86	3.61
16	Waghjai (VL)	SG8	5.07	3.61
17	Bapujibuva	SG9	7.99	1.39
18	Ratnai	SG10	3.47	3.61
19	Bhorgiri	FT3	3.82	3.24
20	Korigadh	FT4	3.33	6.32
21	Ghangadh	FT5	5.28	3.53
22	Sarasgadh	FT6	2.78	6.03
23	Sudhagadh	FT7	6.32	3.59
Sector 4: Tamhini and Phansad Wildlife Sanctuary – Koyna Wildlife Sanctuary				
24	Kalkai (KR)	SG11	6.11	3.87
25	Somji	SG12	4.44	3.89
26	Somjai	SG13	0.69	6.94
27	Kalkai (KI)	SG14	4.17	4.31
28	Sinhagadh	FT8	5.28	5.15
29	Raigadh	FT9	4.58	5.15
30	Lingana	FT10	5.07	3.24
31	Pratapgadh	FT11	6.18	4.71
32	Panchgani tableland	PL7	3.75	6.88
33	Khingar	PL8	4.13	5.63
34	Dandeghar	PL9	4.04	5.42
35	Ambral	PL10	4.04	5.42
36	Rajapuri	PL11	4.04	5.42
37	Mahabaleshwar1	PL12	6.06	2.92
38	Mahabaleshwar2	PL13	5.77	2.71
39	Mahabaleshwar3	PL14	5.58	2.71
Sector 5: Koyna Wildlife Sanctuary – Chandoli National Park				
40	Mauli (SA)	SG15	3.47	7.5
41	Jungleejaygadh	FT12	7.78	1.32
42	Sadawaghapur	PL15	3.65	7.08
Sector 6: Chandoli National Park – Radhanagri Wildlife Sanctuary				
43	Marleshwar	SG16	7.15	3.33
44	Rasaai	SG17	4.79	4.58
45	Mahipatgadh	FT13	4.79	2.65
46	Vishalgadh	FT14	6.88	5.15
47	Masaai	PL16	2.31	5.21
Sector 7: Radhanagri Wildlife Sanctuary – Mhadei Wildlife Sanctuary				
48	Shankar	SG18	5.49	2.92
49	Mauli (SO)	SG19	5.07	4.03
50	Samangadh	FT15	4.38	4.85
51	Amboli	PL17	7.79	2.5

ensures the genetic viability of disjointed protected areas. There is currently sufficient evidence that they harbour significant levels of biodiversity and are used as transit areas for different species of wildlife (Trivedi et al. 2018). These identified hot specks have the potential to be developed as an additional conservation network. The hot specks support the protected areas system of National Parks and Wildlife Sanctuaries by forming multiple islands of biodiversity in a matrix of cultural landscapes by providing permeability for movement of wild faunal diversity (DeFries et al. 2007; Perfecto & Vandermeer 2008; Ormsby & Bhagwat 2010; Ray & Ramachandra 2010). These hot specks of biodiversity are essential in a situation where developing a continuous wildlife corridor is not possible due to the existing other land-use patterns (Blicharska et al. 2013). Urbanization, tourism, and windmill installation will place further stressors on conservation values in the near future.

The 'Rapid Biodiversity Assessment Tool' developed for this study is also referred to as Rapid Ecological Assessment, or 'Biorap'. This technique is used for conducting assessments for various ecosystems such as terrestrial, marine and freshwater where only a small amount of data or no information is available (Margules & Redhead 1995; Sayre et al. 1999; Patrick et al. 2014; Trivedi et al. 2018). Currently, in the Western Ghats,

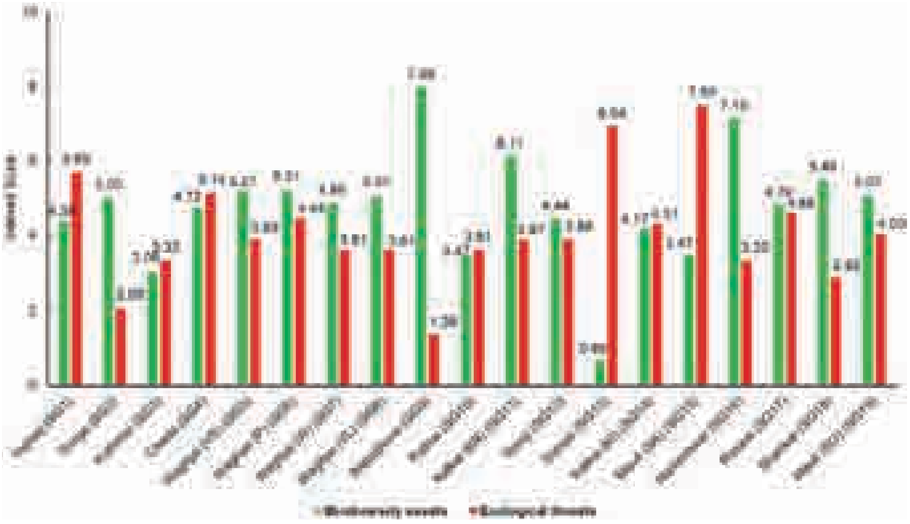

Figure 5. Sacred Groves – biodiversity and anthropogenic threats score.

Table 2. Sacred groves — prioritization matrix.

			Biodiversity		
	Prioritization matrix	**High (7.5–10)**	**Significant (5–7.5)**	**Moderate (2.5–5)**	**Low (0–2.5)**
Anthropogenic Threats	High (7.5–10)			SG15	
	Significant (5–7.5)			SG1, SG4	SG13
	Moderate (2.5–5)		SG5, SG6, SG8, SG11, SG16, SG19	SG3, SG7, SG10, SG12, SG14, SG17	
	Low (0–2.5)	SG9	SG18	SG2	

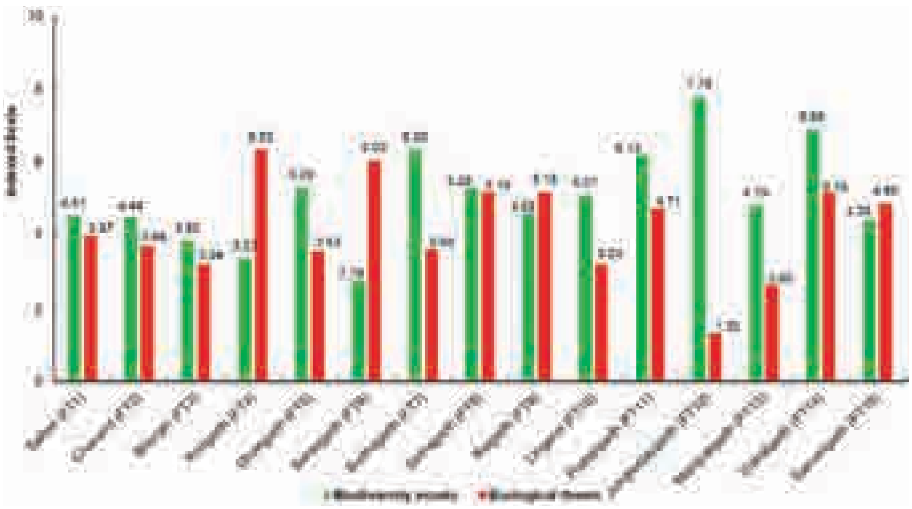

Figure 6. Forts — biodiversity and anthropogenic threats score.

Table 3. Forts — prioritization matrix

			Biodiversity		
	Prioritization matrix	**High (7.5–10)**	**Significant (5–7.5)**	**Moderate (2.5–5)**	**Low (0–2.5)**
Anthropogenic Threats	High (7.5–10)				
	Significant (5–7.5)		FT8, FT11, FT14	FT4, FT6, FT9	
	Moderate (2.5–5)		FT7	FT1, FT2, FT3, FT5, FT10, FT13, FT15	
	Low (0–2.5)	FT12			

Image 1. Old Kalkai Deity temple at Kondethar Sacred Grove.

Image 2. New Kalkai Deity temple at Kondethar Sacred Grove.

Image 3. Unsustainable tourism practices at Pratapgadh Fort.

Image 4. Expansion of parking area at Sinhagadh Fort.

Image 5. Mining on Sadawaghapur Plateau.

Image 6. Solid waste accumulation within and outside the hot specks.

there is only a list of these hot specks with little if any geospatial or quality indicators for prioritization. The RBAT has filled this gap with important information on the prioritization of areas so that management can be developed on locale-specific lines.

Participation of the local communities plays a crucial role in conserving these biodiversity rich hot specks. Under the Biological Diversity Act, 2002, the State Biodiversity Boards have formed the Biodiversity Management Committees (Venkataraman 2009; Laladhas et al. 2023). The Biodiversity Management Committees have developed Peoples Biodiversity Registers that contain information on the availability and knowledge of local biological resources present in the area (Gadgil et al. 2000). These prioritized hot specks outside the protected areas can be declared Biodiversity

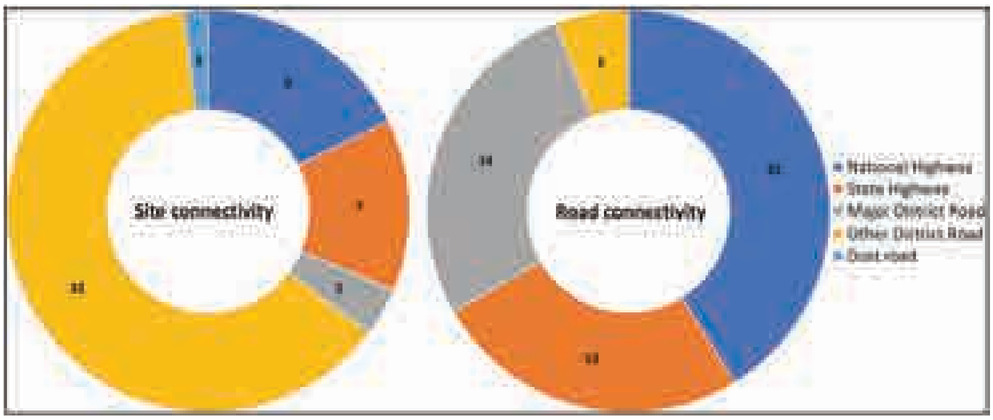

Figure 8. Road connectivity to hot specks.

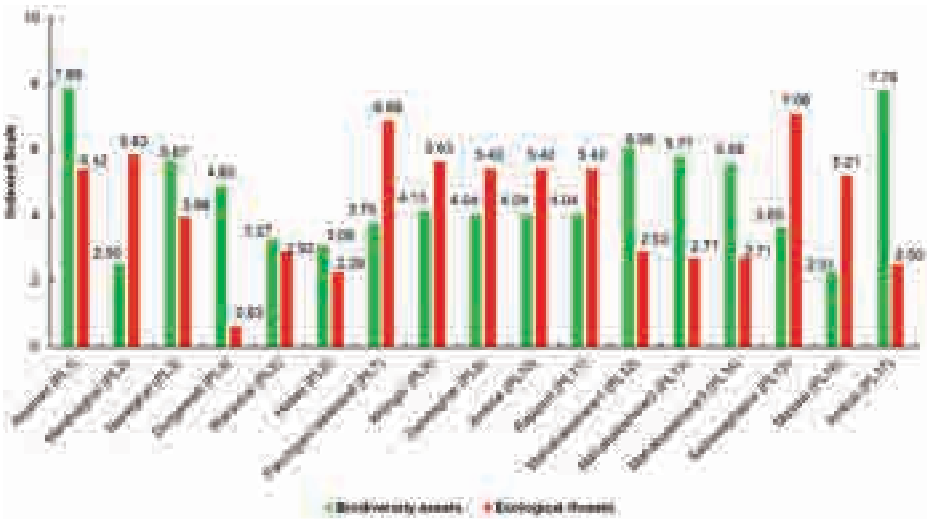

Figure 7. Plateaus — biodiversity and anthropogenic threats score.

Table 4. Plateaus — prioritization matrix.

		Biodiversity			
	Prioritization matrix	High (7.5–10)	Significant (5–7.5)	Moderate (2.5–5)	Low (0–2.5)
Anthropogenic Threats	High (7.5–10)				
	Significant (5–7.5)	PL1		PL2, PL7, PL8, PL9, PL10, PL11, PL15, PL16	
	Moderate (2.5–5)		PL3, PL12, PL13	PL5, PL14	
	Low (0–2.5)		PL17	PL4, PL6	

Heritage Sites under the Biological Diversity Act, 2002 or as Community Reserves or Conservation Reserves under the Wildlife Protection Act, 1972 (Singh & Kushwaha 2008; Raghavan et al. 2016). The RBAT helps choose an appropriate legal and administrative option.

Another approach for conservation is designating the hot specks under 'Other Effective (Area Based)

Table 5. Relation between biodiversity and anthropogenic threats.

	Hot speck type	Correlation 'r' (α = 0.05)
1	Sacred groves	-0.666 (p<0.05)
2	Forts	-0.518 (p<0.05)
3	Plateaus	-0.488 (p<0.05)

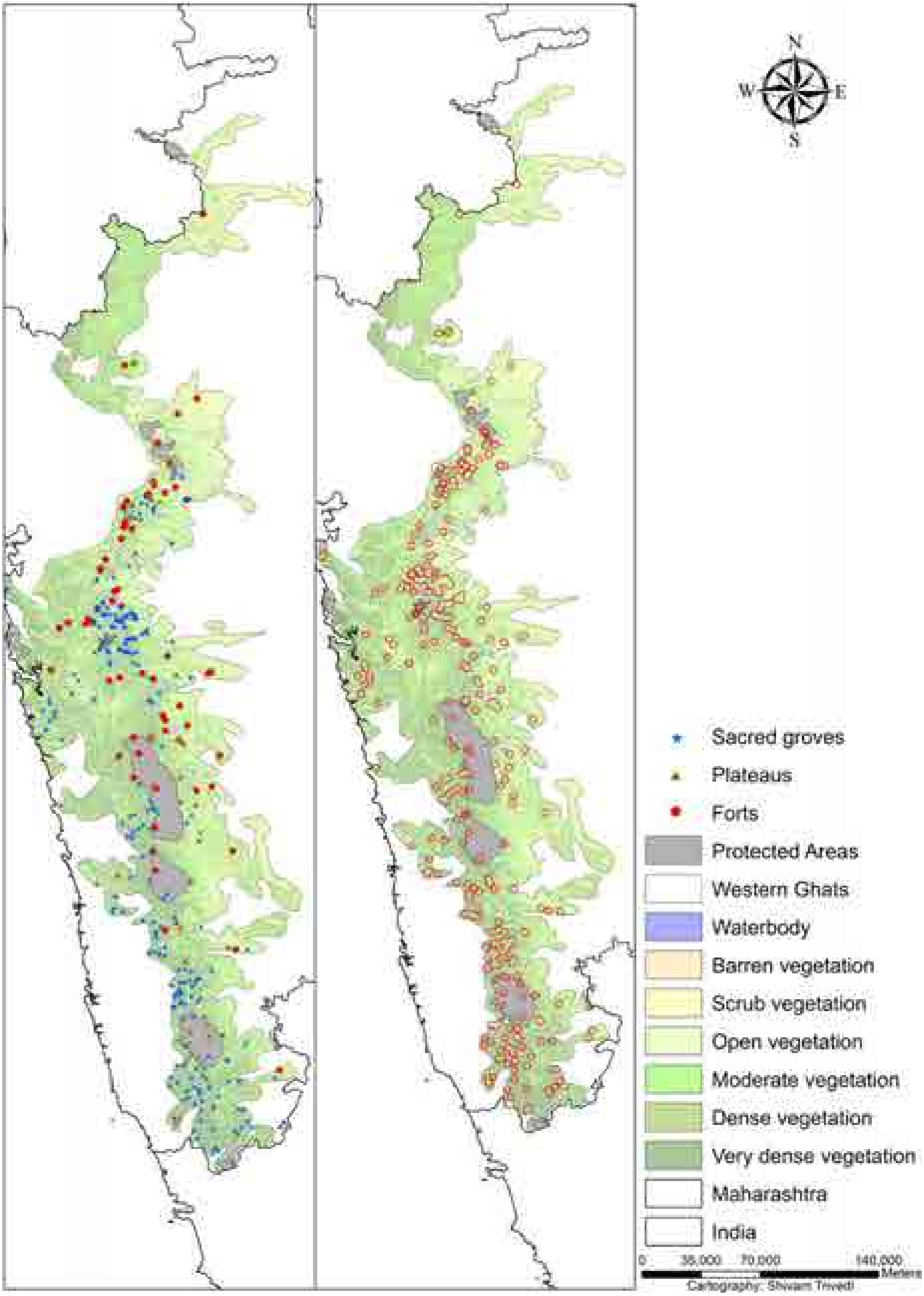

Figure 9. Hot specks - a potential network of contiguous biodiversity rich islands'

Conservation Measures' developed by the International Union for Conservation of Nature (Convention on Biological Diversity 2018). This is a strategy suggested in Sustainable Development Goals, Aichi Targets and the National Biodiversity Action Plan targets. Other stakeholders, such as corporates through their Corporate Social Responsibility, can provide funds. Non-government organizations, educational institutes and private landowners have an equally important role in supporting the local communities for conserving the hot specks (Kanagavel et al. 2013).

CONCLUSION

The Western Ghats is dotted with thousands of biodiversity rich hot specks present in the natural and cultural landscapes. The current study on 'Identification, prioritization, and management of hot specks in the Western Ghats of Maharashtra' has identified different typologies of biodiversity rich islands referred to as 'hot specks'. These are present in the socio-ecological landscape elements outside the boundaries of national parks and wildlife sanctuaries.

The Rapid Biodiversity Assessment Tool developed for evaluating the hot specks of biodiversity has proved to be effective in assessing sacred groves, forts and plateaus. With necessary modification, this assessment tool can be used for assessing a larger number of hot specks under different typologies present in a greater ecosystem of socio-ecological landscapes. This however requires a minimum necessary capacity building of frontline forest staff, community-based organizations, Biodiversity Management Committees, and non-government organizations for implementing the assessment tool in the field. The prioritization of hot specks based on the analysis of biodiversity and anthropogenic threat scores generated from RBAT enables the land use planners to classify the sites in 16 categories. These 16 categories mentioned in the prioritization matrix enables the planners with a freedom to identify priority categories and select hot specks that urgently need to be brought under the hot specks conservation action and management plan.

A multi-stakeholder management approach should be developed for implementing the hot speck conservation action and management plan under the National Biodiversity Action Plan. Under this management approach, funds and resources should be allocated to the State Biodiversity Board(s) which will be used by the frontline forest staff, community-based organizations, Biodiversity Management Committees for identifying and assessing hot specks and preparing peoples biodiversity hot specks register (PBHR). Peoples biodiversity hot specks register will consist of information on biodiversity and threat existing within and outside different hot specks identified and surveyed in the socio-ecological landscapes for the prioritization purpose. Once prioritized, these hot specks should then be brought under the hot speck conservation action and management plan. This can be achieved by notifying the prioritized hot specks as Biodiversity Heritage Sites, Community Reserve, Conservation Reserves, or as Other Effective (area based) Conservation Measures under the Wild Life (Protection) Act, 1972 and Biological Diversity Act, 2002. Funds can then be allocated to the respective Biodiversity Management Committee for the conservation and management of the hot specks. The capacity building and training of frontline forest staff and Biodiversity Management Committees will be an important part in this entire process which can be done with the support of non-government organizations and education institutes. A public-private partnerships could be established where corporates and other sectors can put in their funds and resources for conservation and management of these biodiversity hot specks.

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COMMUNICATION

Mammalian diversity of Debrigarh Wildlife Sanctuary, Odisha, India

Nimain Charan Palei [1], Bhakta Padarbinda Rath [2] & Sudeep Nayak [3]

[1,2] Office of the Principal Chief Conservator of Forests (Wildlife) & Chief Wildlife Warden, Odisha, Prakruti Bhawan, Plot No. 1459, Green Park Nursery, Sahidnagar, Bhubaneswar, Odisha 751007, India.
[3] Divisional Forest Officer, Hirakud Wildlife Division, Motijharan, Brooks Hill, Sambalpur, Odisha 768001, India.
[1] wildpalei@gmail.com (corresponding author), [2] bhaktamca@gmail.com, [3] hirakudwildlife1sudeep@gmail.com

Abstract: Camera traps were deployed at 123 stations in an area of 346.91 km^2 in Debrigarh Wildlife Sanctuary between 25 August 2018 and 29 December 2019 that provided the effort of 3,150 trap-days. Of the 2,767 photo captures, 1,304 were mammals belonging to 13 families and 27 large and medium-sized mammals were recorded in the study area. Carnivores were especially diverse, with 11 species recorded with particular four felidae including Tiger *Pantera tigris*, Leopard *Panthera pardus,* and globally threatened Rusty-spotted Cats which extended the range of this species. Leopard was the most captured species with the highest relative abundance (RAI = 5.68) among the carnivore species, whereas the Indian Pangolin *Manis crassicaudata* (RAI = 0.06) had the lowest abundance. We provide photographic evidence of mammalian species and highlight the importance of conservation of dry deciduous forests for threatened and vulnerable species in the study area. The current camera trap survey is expected to help in the formulation of management strategies for long-term conservation of mammalian species in Debrigarh Wildlife Sanctuary.

Keywords: Camera trapping, eastern India, livestock pressure, Odisha, photographic evidence, relative abundance index.

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Author details: Nimain Charan Palei is studying human-elephant coexistence management and implementation of corridor management for safe passage of elephants between fragmented habitats. For the past 10 years he has been studying elephant migration in Odisha. His research interest's ecology wild animal, population dynamics, human-wildlife conflict, camera trapping, photography, and videography of wildlife. Shri Bhakta Padarbinda Rath is working as a Wildlife Researcher in Odisha State since 03.07.2009. He is consistently working for conservation of wildlife and its habitat, studying the missing link between fragmented habitats and their distribution, migration, and movement pattern of wild animals in the state of Odisha. Shri Sudeep Nayak is a senior Indian Forest Service Officer and currently working as Chief Executive, State Medicinal Plant Board, Odisha. He is very concern on conservation of forest, wildlife, and natural habitat at sustainable utilization of natural resources. He has served 35 years of service in Odisha Forest Department.

Author contributions: Nimain Charan Palei - field data collection, analysis, and manuscript writing; Bhakta Padarbinda Rath- conducted field survey, camera trapping and data analysis, Sudeep Nayak- developed the idea, manuscript writing and supervised the project.

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INTRODUCTION

Camera trapping has been proved to be an effective method in monitoring elusive and nocturnal species along with population estimation of naturally marked individuals using spatially explicit capture-recapture models (Karanth & Nichols 1998; Harihar et al. 2014). Alternatively, for indistinguishable individuals of species such as ungulates, bears, and other small mammals; generally photo capture rate (photographs/ trapping effort) has been widely used to estimate the relative abundance (Datta et al. 2008; Sathyakumar et al. 2011; Palei et al. 2015, 2016, 2021; Debata & Swain 2018; Dhendup et al. 2019; Ahmed et al. 2021). Although the use of relative abundance index (RAI) generated from camera trap encounter rates is controversial as it gets biased with animal body mass and study design (Sollmann et al. 2013), there are examples of a linear relationship between RAI and abundance, estimation, especially of cryptic species (Karanth et al. 1998; Datta et al. 2008; Rovero & Marshall 2008; Rovero & Marshall 2009; Jenks et al. 2011; Gonthier et al. 2013; Lahker et al. 2018). In the Papikonda hills, northern Eastern Ghats, 23 mammal species were recorded during camera trap survey (Aditya & Ganesh 2017). In Odisha several mammalian studies were reported; (Tiwari et al. 2002) first compiled 37 species of mammals from Chandaka-Dampara Wildlife Sanctuary. Ramakrishna et al. (2006) reported 55 species of mammals from Similipal Biosphere Reserve encompassing the Similipal Wildlife Sanctuary and Similipal Tiger Reserve. Mohapatra et al. (2009, 2012, 2013) reported 36 species of mammals from different hill forests of southern Odisha, 43 species from Kotgarh Wildlife Sanctuary, and 47 species from several sacred groves in Sundargarh District. Murmu et al. (2013) also reported 23 species of mammals of Kuldiha Wildlife Sanctuary, and 42 species of mammals from Hadagarh Wildlife Sanctuary. Recently, (Debata & Swain 2020) surveyed the mammalian fauna of an urban-influenced zone of Chandaka-Dampara Wildlife Sanctuary using camera traps and reported 14 species of mammals. Debata et al. (2018) also reported 20 species of mammals of Kuldiha Wildlife Sanctuary. Palei et al. (2020) reported 22 species of mammals of Sunabeda Wildlife Sanctuary. Palei et al. (2021) reported 19 species of mammals from Hadagarh Wildlife Sanctuary. In the present study we carried out a camera trap survey in the tropical dry deciduous forest of Debrigarh Wildlife Sanctuary and provide the first photographic evidence and updated checklist of mammals in the Sanctuary.

MATERIALS AND METHODS

Study area

The Debrigarh Wildlife Sanctuary (DWS) is located between the latitudes 21.5570^{0}N and the longitudes 83.6461^{0}E (Image 1). The division shares its boundaries with Chhattisgarh State. DWS covers 346.91 km^2 and is dominated by tropical dry-deciduous forests, northern tropical dry-deciduous, and dry-mixed deciduous forests (Champion & Seth 1968). The mean daily temperatures in winters range from 8–20 ^{0}C and in summers from 28–48 ^{0}C. The average annual rainfall of the sanctuary and the nearby areas varies from 1,000–1,450 mm. Most villagers in the sanctuary are tribal, and their activities inside the forest are grazing livestock and collection of forest products (e.g., fodder for livestock, non-timber forest products).

As per (Champion & Seth 1968) classification, both the reserved forests of this Sanctuary come under the northern tropical dry deciduous forests under, dry mixed deciduous forests, and bamboo brakes. Sal *Shorea robusta* is the main species in both the forest blocks containing dry deciduous vegetation and it occurs in pure patches to occasional mixed patches in miscellaneous vegetation in the division. Vegetation on hill slopes and upper portions is predominantly miscellaneous consisting of a high proportion of Dhaura *Anogeissus latifolia*, Moi *Lannea coromandelica*, Salai *Boswellia serrata*, Karada *Cleistanth uscollinus*, and Barabakulia *Dalbergia aniculat*a. However, Sal, which is the principal species, still constitutes a major proportion of the crop as compared to the miscellaneous species but undoubtedly its survival and status, particularly regeneration status, has deteriorated over the years due to excessive biotic interferences and soil erosion. Bamboos occur in almost all parts of the sanctuary over extensive areas of forests. The species of bamboo covering large tracts of hills is *Dendrocalamus strictus* Salia bamboo throughout the sanctuary.

We first carried out an extensive reconnaissance survey in three wildlife forest ranges within Hirakud Wildlife Range, Kamgaon Wildlife Range, and Lakhanpur Wildlife Range of DWS. During the survey, signs of carnivores, viz., scats, pug-marks, claw marks, scraps, and scent marks, were recorded and geo-referenced using a geographical positioning system (GPS).

Camera positioning

We conducted a camera trapping survey from 25 August 2018–29 December 2019: first phase (43 camera trap stations), second phase (40 camera trap stations),

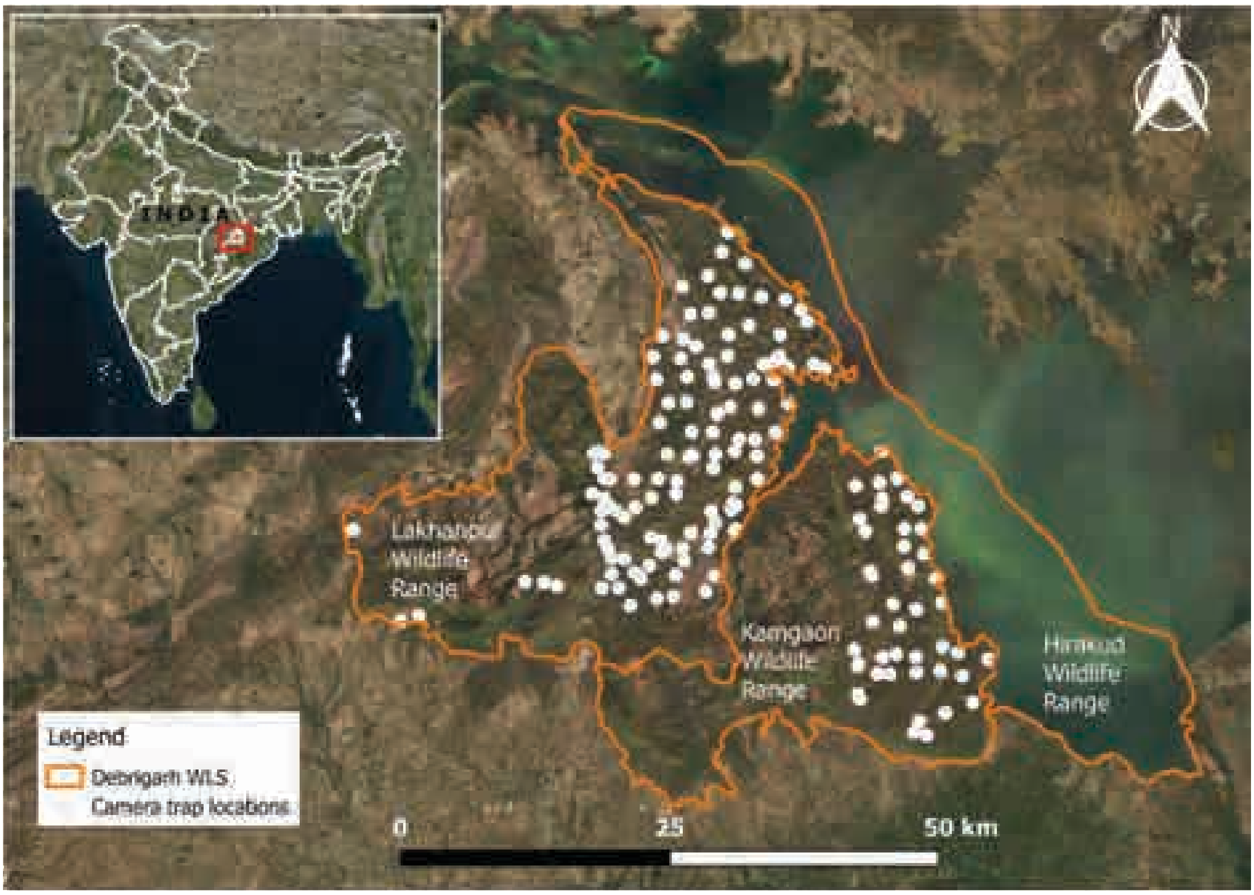

Image 1. Study area showing locations of camera traps in the Debrigarh Wildlife Sanctuary, western Odisha.

and third phase (40 camera trap stations) covering the three ranges of Hirakud, Kamgaon, and Lakhanpur Wildlife Ranges of DWS (Image 1). A total of 123 camera trap stations were established in the study area (Image 1). Most suitable camera trap stations were selected based on frequently used by the wildlife (e.g., along trails, forest roads, near stream beds, and around water holes). At each camera trap station, a pair of automated motion-triggered digital camera-traps (Cuddeback Model C1; Non Typical, Inc., Green Bay, WI) was placed on both sides of the roads, facing each other, placed around 30–40 cm above the ground without using lure or bait. Camera-trap placement at trails optimizes the capture of large as well as small animals. Cameras were checked every week to replace the batteries and memory cards and to ensure their proper functioning. Total sampling effort was calculated as the sum of the effective days across all stations that each camera was functioning (Boitani & Powell 2012). We considered photos separated by at least 30 min as independent events (Ohashi et al. 2013; Guo et al. 2017).

Data on large and medium sized mammals, human trafficking, and livestock including date, time, year, and behavior were collated from camera trap photographs. Relative abundance index (RAI) was calculated as RAI = A/NX100

Where A is the total number of independent detections of a species by all cameras and N is the total number of camera trap days by all the cameras throughout the study area following (Jenks et al. 2011). All animals captured (photographed) in the camera traps were identified to the species level and the time and date of the capture (inbuilt in the camera) were noted. Consequently, each photo was rated as a dependent or independent event. All camera trap pictures were screened for the presence of animals and all data was entered in an Office ACCESS 2010 database. Identification of the animals was done using the field guide (Menon 2014). We assessed species' conservation significance on a global and national level according to the threat categories assigned in the IUCN Red List (IUCN 2017).

RESULTS

A total of 123 locations of camera trapping effort over 3,150 trap nights with 2,767 photographs were captured; 1,304 photographs of mammals belonging to 13 families and 27 species were recorded in the study area. Table 2 shows all identified species (common and scientific names), the total number of pictures obtained, the RAI for each species as well as the total number of locations where each species was photographed (Image 4–30). Out of all the photographs, recorded during the study period, the of majority of 49% (n = 1,304) were wildlife, and mostly herbivorous mammals 30% (n = 794) followed by carnivore mammals 13% (n = 341), omnivore mammals 6% (n = 169), birds 5% (n = 130), and the remaining photographs were anthropogenic from the movement of livestock, feral dogs, and human traffic 46% (n = 1,242) (Figure 2).

Besides that, camera traps also captured 10 bird species including the Indian Pea Fowl (RAI = 1.49, 46 locations) followed by Red Jungle Fowl (RAI = 1.21, 15 locations), and the Booted Eagle & Black-necked Ibis, which were the minimum photographed species (RAI = 0.16, each 2 locations). Concerning large mammals, *Panthera pardus* represented high relative abundance (RAI = 5.68, 45 locations) among the Sloth Bear *Melursus ursinus* (RAI = 4.13, 55 locations), and the Wild Boar *Sus scrofa* (RAI = 3.81, 54 locations). Indian Pangolin *Manis crassicaudata* (RAI = 0.06, 2 locations) was represented by a relatively low abundance in the study area (Figure 1).

Among all the anthropogenic activity the highest activity inside the sanctuary, were livestock, human traffic, and feral dogs (RAI = 24.63) followed by forest department staff (RAI = 13.58) and poachers were the minimum photographed species (RAI = 0.76) (Figure 1). Detailed information on the species RAI of mammals and various anthropogenic activities throughout the sampling areas is given in (Table 1).

DISCUSSION

The Debrigarh Wildlife Sanctuary is home to 15 species of mammals represented by (Nayak 2016). Our study confirmed that of the 27 mammalian species recorded during the camera tap survey, carnivore species were the most common at each study site followed by herbivores. Only two species of medium-sized carnivores were found in our study, Jungle Cat *Felis chaus*, and Rusty-spotted Cat *Prionailurus rubiginosus*. But according to the camera trap survey in DWS there are 12 more species recorded (Dhole, Rusty-spotted Cat, Jungle Cat, Striped Hyena, Indian Fox, Jackal, Ruddy

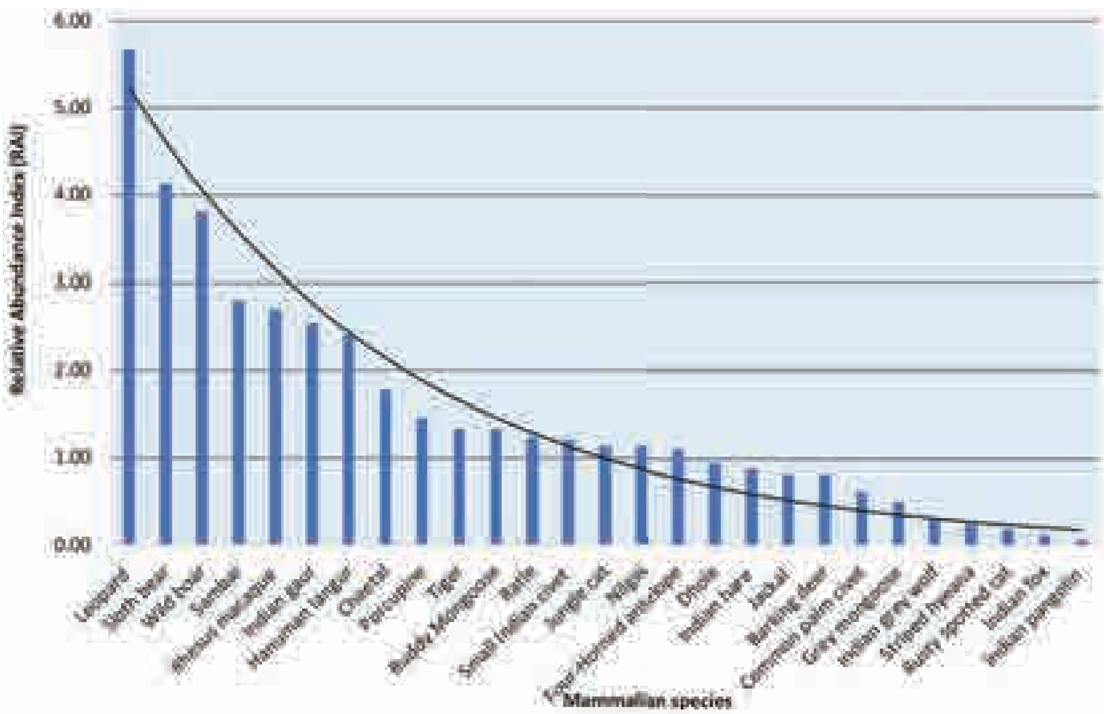

Figure 1. Relative abundance index (RAI) of different mammals in Debrigarh Wildlife Sanctuary.

Table 1. Comparative relative abundance index (RAI) of different wildlife species and others based on camera trap photographs in Debrigarh Wildlife Sanctuary during the field work with their current IUCN Red List status and type of encounter.

	Common name	Families	Scientific name	WPA Status	IUCN Status	N Camera trap stations with occurrence	%	Total Photo Captured	RAI
	Mammals								
1	Tiger	Felidae	*Panthera tigris*	Schedule-I	EN	12	9.52	42	1.33
2	Leopard	Felidae	*Panthera pardus*	Schedule-I	EN	45	35.71	179	5.68
3	Rusty-spotted Cat	Felidae	*Prionailurus rubiginosus*	Schedule-I	EN	4	3.17	6	0.19
4	Jungle Cat	Felidae	*Felis chaus*	Schedule-II	LC	25	19.84	36	1.14
5	Dhole	Canidae	*Canis alpinus*	Schedule-I	EN	10	7.94	30	0.95
6	Indian Grey Wolf	Canidae	*Cuon lupus*	Schedule-I	LC	8	6.35	10	0.32
7	Jackal	Canidae	*Canis aureus*	Schedule-II	LC	9	7.14	26	0.83
8	Striped Hyeana	Hyaenidae	*Hyaena hyaena*	Schedule-III	NT	5	3.97	8	0.25
9	Indian Fox	Canidae	*Vulpes bengalensis*	Schedule-II	LC	2	1.59	4	0.13
10	Small Indian Civet	Viverridae	*Viverricula indica*	Schedule-II	LC	20	15.87	38	1.21
11	Common Palm Civet	Viverridae	*Paradoxurus hemaphroditus*	Schedule-II	LC	12	9.52	20	0.63
12	Sloth Bear	Ursidae	*Melursus ursinus*	Schedule-I	EN	55	43.65	130	4.13
13	Wild Boar	Suidae	*Sus scrofa*	Schedule-III	LC	54	42.86	120	3.81
14	Porcupine	Hystricidae	*Hystrix indica*	Schedule-IV	LC	40	31.75	46	1.46
15	Ratel	Mustelidae	*Mellivora capensis*	Schedule-I	LC	18	14.29	39	1.24
16	Rhesus Macaque	Cercopithecidae	*Macaca mulatta*	Schedule-II	LC	34	26.98	85	2.70
17	Hanuman Langur	Cercopithecidae	*Semnopithecus entellus*	Schedule-II	LC	52	41.27	76	2.41
18	Indian Gaur	Bovidae	*Bos gaurus*	Schedule-I	VU	30	23.81	88	2.79
19	Nilgai	Bovidae	*Boselaphus tragocamelus*	Schedule-III	LC	8	6.35	36	1.14
20	Four-Horned Antelope	Bovidae	*Tetracerous quadricornis*	Schedule-I	EN	61	48.41	35	1.11
21	Sambar	Cervidae	*Rusa unicolor*	Schedule-III	VU	46	36.51	80	2.54
22	Barking Deer	Cervidae	*Muntiacus muntjak*	Schedule-III	LC	16	12.70	26	0.83
23	Cheetal	Cervidae	*Axis axis*	Schedule-III	LC	28	22.22	56	1.78
24	Indian Hare	Leporidae	*Lepus nigricollis*	Schedule-IV	LC	19	15.08	28	0.89
25	Indian Pangolin	Manidae	*Manis crassicaudata*	Schedule-I	NT	2	1.59	2	0.06
26	Grey Mongoose	Herpestidae	*Herpestes edwardsii*	Schedule-II	LC	8	6.35	16	0.51
27	Ruddy Mongoose	Herpestidae	*Herpestes smithii*	Schedule-II	LC	15	11.90	42	1.33
	Birds								
28	Crested Serpent Eagle	Accipitridae	*Spilornis cheela*	Schedule-IV	LC	2	1.59	2	0.06
29	Indian Pea Fowl	Phasianidae	*Pavo cristatus*	Schedule-I	LC	46	36.51	47	1.49
30	Red Jungle Fowl	Phasianidae	*Gallus gallus*	Schedule-IV	LC	15	11.90	38	1.21
31	Painted Spurfowl	Phasianidae	*Galloperdix lunulata*	Schedule-IV	LC	2	1.59	4	0.13
32	Black Napped Ibis	Threskiornithidae	*Pseudibis papillosa*	Schedule-IV	LC	2	1.59	5	0.16
33	Lesser Adjutant	Ciconiidae	*Leptoptilos javanicus*	Schedule-IV	VU	1	0.79	2	0.06
34	Grey Francolin	Phasianidae	*Francolinus pondicerianus*	Schedule-IV	LC	5	3.97	12	0.38
35	Brown Fish Owl	Strigidae	*Ketupa zeylonensis*	Schedule-IV	LC	8	6.35	1	0.03
36	Jungle Babbler	Leiothrichidae	*Argya striata*	Schedule-IV	LC	5	3.97	14	0.44
37	Booted Eagle	Accipitridae	*Hieraaetus pennatus*	Schedule-IV	LC	2	1.59	5	0.16
	Reptiles								
38	Monitor Lizard	Varanidae	*Varanus bengalensis*	Schedule-I	LC	2	1.59	2	0.06

	Common name	Families	Scientific name	WPA Status	IUCN Status	N Camera trap stations with occurrence	%	Total Photo Captured	RAI
	Human traffic and livestock								
39	Forest department staff					62	49.21	260	8.25
40	Department vehicle					48	38.10	168	5.33
41	Private vehicle of villagers					36	28.57	186	5.90
42	Villagers					28	22.22	154	4.89
43	Poachers					12	9.52	24	0.76
44	Cattle, goat and buffalo					64	50.79	328	10.41
45	Feral dog					35	27.78	108	3.43

EN—Endangered | NT—Near Threatened | VU—Vulnerable | LC— Least Concern | RAI—Relative abundance index | IUCN—International Union for Conservation of Nature | WPA—Wildlife Protection Act.

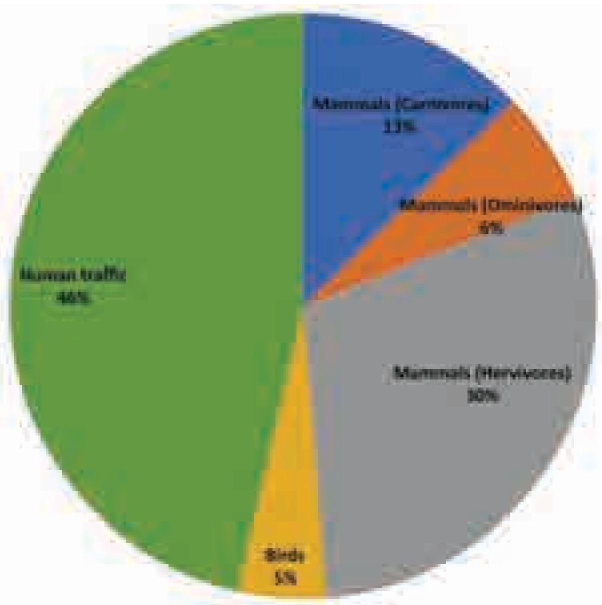

Figure 2. Different wildlife species and others activities based on camera trap photographs captured in Debrigarh Wildlife Sanctuary during the field work.

Mongoose, Small Indian Civet, Indian Pangolin, Rhesus Macaque, Barking Deer, and Ratel). As per the elephant census of 2017 there are 20 elephants recorded in the sanctuary (Palei et al. 2017) but there was no photo capture during the camera trap survey.

A small area of the sanctuary was sampled and one female tiger was photo captured (Jhala et al. 2020) from Lakhanpur Wildlife Range, and also in Kamgaon Wildlife Range of DWS during its movement. This movement was subsequently found within the sanctuary in August 2018 and photo captured in Mundamahul, Chowrasimal, Jhagadabehera, Khajuria, and Damodarpada. Among all the species, the Indian Grey Wolf *Canis lupus*, Dhole *Cuon alpinus*, Jackal *Canis aureus*, Striped Hyena *Hyaena hyena,* and Indian Fox *Vulpes bengalensis* were the less frequently photo-captured in the study area. Indian Gaur and Sambar were the most common ungulate species, while leopards were the most common carnivore species. Rusty-spotted Cat, Dhole, Hyena, Indian Fox, Indian Pangolin, Rattle, and Chowsingha were photo captured for the first time in the camera traps survey.

Feral dogs were common prey animals occurring abundantly in the sanctuary area. However, the feral dogs were detected in a few locations 35 (27.78%) out of 126 locations in the study areas and is unlikely to have any significant effect on forest mammals. Relative abundance index of livestock was higher than any other species photo-captured in the sanctuary and is indicative of the high level of human traffic and movement of livestock (RAI = 24.63; Table 1) disturbance in the sanctuary. The presence of domestic animals can have a detrimental effect on distribution and assemblage of wild animal communities and account for detections under anthropogenic disturbance in DWS, much less than in Kuldiha Wildlife Sanctuary, Sunabeda Wildlife Sanctuary, and Similipal Tiger Reserve (Palei et al. 2015, 2020; Debata & Swain 2018). Many human trails, paths, and traps were found across the study area indicating that the local people regularly go for fishing in Hirakud reservoir adjacent to the sanctuary area. It may be assumed that probably other small mammalian species which were present in the sanctuary have not been captured by the camera traps. Biotic pressure (especially non timber forest product (NTFP) collection, livestock grazing, and fishing in the Hirakud Reservoir by the local community round the year) in the forest reduces resource availability in DWS.

In conclusion, the DWS could be an important habitat and source population for mammals in western Odisha, because of abundant prey, lack of disturbance, and good habitat connectivity with the central India landscape. Certainly, further research is needed to learn about animal diversity and distribution patterns throughout the sanctuary. This study highlights the rich potential of the sanctuary in relation to the mammalian diversity in Debrigarh Wildlife Sanctuary.

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Image 2. *Panthera tigris*

Image 3. *Panthera pardus*

Image 4. *Prionailurus rubiginosus*

Image 5. *Felis chaus*

Image 6. *Canis lupus*

Image 7. *Cuon alpinus*

Image 8. *Canis aureus*

Image 9. *Hyaena hyaena*


Image 10. *Melursus ursinus*


Image 11. *Mellivora capensis*


Image 12. *Bos gaurus*


Image 13. *Boselaphus tragocamelus*


Image 14. *Rusa unicolor*


Image 15. *Axis axis*

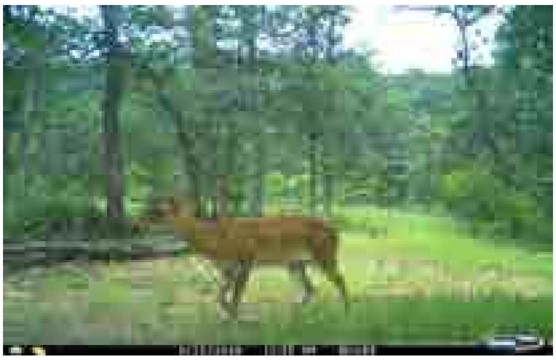
Image 16. *Tetracerus quadricornis*


Image 17. *Muntiacus muntjak*

Image 18. *Semnopithecus entellus*

Image 19. *Macaca mulatta*

Image 20. *Sus scrofa*

Image 21. *Hystrix indica*

Image 22. *Paradoxurus hemaphroditus*

Image 23. *Viverricula indica*

Image 24. *Herpestes edwardsii*

Image 25. *Herpestes smithii*

Image 26. ***Manis crassicaudata***

Image 27. ***Lepus nigricollis***

Image 28. ***Vulpes bengalensis***

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COMMUNICATION

Vertebrate road kills on State Highway 26 in Khandwa Forest Division, central India

Kamran Husain [1] & **Prachi Mehta** [2]

[1,2] Wildlife Research and Conservation Society, 1A Shreeyog, 127/3, Sus Road, Pashan, Pune, Maharashtra 411021, India.
[1] kamran.wild95@gmail.com, [2] prachimehta@wrcsindia.org (corresponding author)

Abstract: The road network is spreading rapidly in human dominated as well as forested areas in India. Roads passing through forested areas are known to negatively impact wildlife populations by contributing to wildlife-road kills besides causing habitat fragmentation, soil erosion, and disruption of gene flow. This paper documents encounters of wildlife road kills on the State Highway 26 (SH 26) passing through the forested area of Khandwa Territorial Forests in central India. Between October 2015 and June 2017 and from November 2021 to June 2022 we collected opportunistic data on wildlife mortalities on SH 26. We recorded 61 wildlife mortalities on a stretch of 34 km of SH 26. Of the road kills encountered, 71% were birds, 21% were mammals, and 8% were herpetofauna. Highest among bird kills were members of nightjars (Caprimulgidae) (26%) and owls (Strigidae) (23%). Among owls, we recorded two road kills of the endangered Forest Owlet *Athene blewitti* and individuals of five other owl species. Among other taxa, road-hits of Jungle Cat, Indian Palm Civet, Golden Jackal, Central Indian Langur, and a few snakes were recorded. Most bird kills on the road were recorded in February while the highest number of mammal and herpetofauna kills were recorded in the month of November. We report that the land use around the road and species trait contribute to vulnerability of a species to road-hit. Based on the frequency of road kills, we have identified seven hotspots of road kills on SH 26. Since road construction is one of the major mandates of the Government in India, it is suggested to carry out systematic environment impact assessment on existing and proposed roads to understand the patterns of spatio-temporal incidents of road kills. Planting of tall trees and installation of speed bumps and signboards to alert drivers should be planned at the initial stage of road construction. If appropriate mitigation measures to prevent wildlife mortalities are incorporated while the road is being constructed, it may be possible to bridge the gap between development and conservation.

Keywords: Animal-vehicle collision, conservation, Forest Owlet, Jungle Cat, Madhya Pradesh, wildlife-friendly road, wildlife mortalities.

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Author details: Kamran Husain is a research biologist with WRCS (Wildlife Research and Conservation Society). Kaman is currently working on radio-telemetry studies of owls in Melghat Tiger Reserve. Prachi Mehta is a senior scientist with WRCS and is working on ecology of owls and human-elephant coexistence mitigation in the country.

Author contributions: PM—funds for the project, concept of the paper, data analysis and writing of the paper. KH—part of field data collection, preparation of maps and compiling initial draft.

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INTRODUCTION

India has 62.16 lakh kilometres of road network, which is the second largest road network in the world after the USA (GOI 2022). While road network is critical to development, it has severe social, environmental, and ecological impacts on the biodiversity and natural resources. Vast stretches of roads passing through natural habitats are known to cause forest fragmentation (Forman & Alexander 1998), wildlife-vehicle collisions (Andrews 1990; Underhill & Angold 1999; Baskaran & Boominathan 2010; Raman 2011; Gubbi et al. 2012; Jeganathan et al. 2018; Saxena et al. 2020), increased predatory activity (Ortega & Capen 1999), habitat loss, disruption of corridors, loss of population heterogeneity, & genetic variability (Reh & Seitz 1990; Clark et al. 2010), and soil erosion, landslides, degradation of surrounding forests, & water pollution (Rajvanshi et al. 2001; Goosem et al. 2010; Raman 2011; Lyamuya et al. 2021).

While a small animal may get overridden, a large one will collide with the vehicle causing an accident and/or death. For all such instances, we have used the term wildlife-vehicle collision (WVC). Incidents of wildlife mortalities due to collision with speeding vehicles (WVC) in forested landscapes has far-reaching implications compared to poaching, hunting or natural death as WVC can also affect healthy individuals, leading to loss of genetic flow, subsequently resulting in population decline or isolation (Sutherland et al. 2010; Jackson & Fahrig 2011). Roadkill rates are attributed to the type of road, speed of the vehicles, and traffic volume (Forman & Alexander 1998; Underhill & Angold 1999; Clevenger et al. 2003; Saxena et al. 2020). Land use by the roadside has a major impact on accelerated rates of road kills. Presence of agricultural fields, forest patches, ditches, wetlands, canal crossing, shrubby vegetation and uneven height of road have been identified as hotspots of road kills (Main & Allen 2002; Mackinnon et al. 2005; Özcan & Ozkazanc 2017). Species traits such as group living animals, large home ranges, high dispersal rate,s and poikilothermic species are most likely targets of road kills (Saxena et al. 2020). Diet and morphometry of a species contributes to their vulnerability to road kills. Species feeding on rodents, insects, and carcass are vulnerable to road causalities since their life traits make them an easy victims of road kills (Adams & Geis 1983; Main & Allen 2002; Silva et al. 2019; Underhill & Angold 1999; Medrano-Vizcaíno et al. 2022).

The studies on road kills from India and outside India have commonly reported mortalities of mammals (Reed et al. 1979; Lavsund & Sandegren 1991; Behera & Borah 2010; Gubbi et al. 2012; Saxena et al. 2020; Lyamuya et al. 2022), birds (Channing 1958; Dunthorn & Errington 1964; Dhindsa et al. 1988; Sundar 2004; daRosa & Bager 2012; Bishop & Brogan 2013; Siva & Neelnarayanan 2020; Sacramento at al. 2022), and herpetofauna (Vos & Chardron 1998; Aresco 2005; Langen et al. 2007; Glista et al. 2008; Baskaran & Boominathan 2010; Bhupathy et al. 2011; Quintero-Ángel et al. 2012; Samson et al. 2016; Jegannathan et al. 2018; Pallares & Joya 2018; Hastings et al. 2019). In India, the majority of studies on WVC have been carried out on national highways (NH) passing through protected areas of Western Ghats (Kumara et al. 2002; Seshadri et al. 2009; Baskaran & Boominathan 2010; Santhoshkumar et al. 2017), Madhya Pradesh (Pragatheesh 2011; Pragatheesh & Rajvanshi 2013; Saxena et al. 2020), Karnataka (Hatti & Mubeen 2019), Rajasthan (Sharma & Dhakad 2020; Kumawat & Purohit 2020), Himalayan region (Kumar & Srinivasulu 2015; Kichloo et al. 2020), and Assam (Das et al. 2007; Choudhury & Ghosh 2008; Sur et al. 2022).

The state of Madhya Pradesh has a vast network of roads measuring up to 70,156 km which includes 8,000 km of national highways, 8,728 km of state highways (SH), 22,129 km of district roads, and 28,623 km of rural and other roads (GOI 2022). Earlier studies on wildlife road kills from Madhya Pradesh have been carried out on NHs passing through Pench Tiger Reserve and Satpura Tiger Reserve (Pragatheesh 2011; Pragatheesh & Rajvanshi 2013; Saxena et al. 2020) but there is no published information on road kills outside the protected areas in the state. In this paper, we describe wildlife mortalities encountered on the State Highway 26 (SH 26) passing through the forested area of Khandwa District. The objectives of our study were (i) to assess which taxa are represented in the road kills and (ii) to identify the locations that record most wildlife mortalities. In the light of a recent notification on SH 26 proposed to be widened from a 2-lane state highway to a 4-lane national highway, the findings and recommendations of this paper would be of considerable importance since we describe the hotspots of the road kills and suggest precautionary measures and mechanisms to reduce wildlife kills on SH 26.

Study Area

We recorded the road kills on the SH 26 that passes through Khandwa Forest Division in Khandwa District (21.8259^{0}N, 76.3678^{0}E) of Madhya Pradesh (Figure 1). Both sides of the road were bordered by dry deciduous teak *Tectona grandis* forests and crop fields. Teak is the dominant species in the forests with

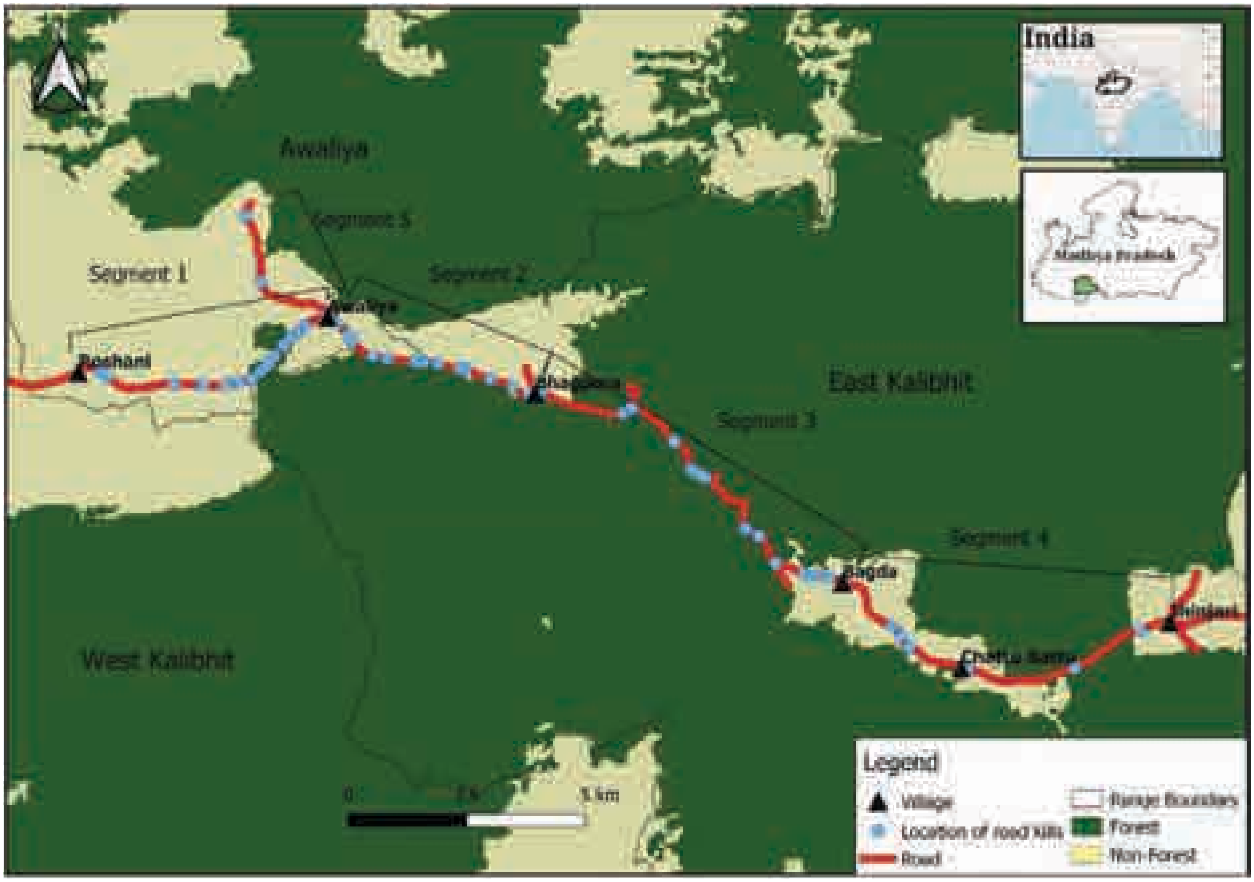

Figure 1. Location of State Highway 26 and incidents of road kills in different segments.

associated species such as *Anogeissus latifolia*, *Lannea coromendelica*, *Terminalia alata*, *Butea monosperma*, *Diospyros melanoxylon*, and *Garuga pinnata*. Bamboo was found mainly in hilly region of the road. Very few houses were close to the highway as villages were settled further away from the road. The topography in the area is hilly with gently sloping terrain interspersed with plain tracts of land. The elevation ranges 300–700 m. Among large mammals, the presence of Bengal Tiger *Panthera tigris,* Leopard *Panthera pardus fusca,* Jungle Cat *Felis chaus,* Chinkara *Gazella benettii*, Sambar *Rusa unicolor*, Nilgai *Boselaphus tragocamelus,* Four-horned Antelope *Tetracerus quadricornis,* and Wild Boar *Sus scrofa* have been recorded from the area (Shukla 2013). The area supports diverse avifauna and notable among them is the presence of the 'Endangered' and a central India endemic Forest Owlet *Athene blewitti.* Among other owls, the widely distributed Barn Owl *Tyto alba*, Indian Eagle Owl *Bubo bengalensis*, Mottled Wood Owl *Strix ocellata*, Indian Scops Owl *Otus bakkamoena*, Jungle Owlet *Glaucidium radiatum*, and Spotted Owlet *Athene brama* have been recorded from here (Mehta et al. 2018). The region is inhabited by Korku and Gond tribes who practice sustenance agriculture. From June to December, farmers grow Paddy, Wheat, Maize, and pulses. Crop harvesting takes place during January to March, and the fields are fallow in April and May.

The SH 26 connects Khargone District to Amarkantak District in Madhya Pradesh State. This stretch of 45 km passes through Ashapura Village till Jhinjari Village in Khandwa Forest Division traversing the forests of Kalibhit connecting the Khandwa District to Betul District. Heavy vehicles such as multi-axle trucks, passenger buses, other four wheelers and two wheelers drive through the SH from morning to night. Most of the highway passes through teak dominant and teak-mixed forests of East Kalibhit, West Kalibhit, and Awaliya, having several crop fields and very few habitations by the roadside.

Methods

Since 2012, we have been carrying out ecological research on the Forest Owlet and other owls in Khandwa District of Madhya Pradesh. Every day, between 0600 h & 1100 h and 1600 h & 1900 h, we used to drive at the speed of 20 to 40 km/h by a jeep or a motorcycle on the road to monitor locations of owls for a stretch of 34 km from Roshani to Jhinjari. On the way, we often observed carcasses of dead animals by the roadside. From October 2015 to June 2017 and again between November 2021 to June 2022, we maintained a record of the road kills observed while driving on the road. The data were collected opportunistically, i.e., as, and when we came across a road kill. When we spotted a dead animal on the road, we recorded the following information: date, time of observation, species killed, and GPS location of the kill. To estimate approximate time of the kill, we categorised the road kills in two broad categories, as fresh (killed within last 24 hours) and old (killed over last 24 hours), based on the status of the carcass, skin texture, and blood condition (after Baskaran & Boominathan 2010). To assess the topography at the accident spot, we recorded the gradient of the road as plain, gently sloping, and hilly. For understanding the land use near the accident spot, we classified the habitat as teak forest, teak mix forest, agriculture, human habitation, and a combination of the given categories. After obtaining the data indicated above, we removed the carcass from the road to prevent double counting (Gomes et al. 2009).

Study segments

In order to have better understanding and interpretation of the WVC patterns we divided the road into five segments according to the location of nearby villages and recorded the landscape features on either side of the segment (Table 1). Study areas 2 and 4 differ in their extent and pattern of cover over agriculture land and teak forests. We used non-parametric Mann-Whitney U test to compare the frequency of road kills among different taxa and the number of mortalities between different road segments. All species encountered in road kills were classified in three broad categories of feeding guilds (Table 1). We used the software PAST 4.0 for the analysis.

Table 1. Description of habitat and land use on different segments of SH 26.

Segment number	Location name	Terrain	Road length (km)	Habitat and land use
1	Roshani to Awaliya	Plain	7.5	Agriculture with some patches of teak forests and a few habitations
2	Awaliya to Kalighodi	Plain	6	Teak forests interspersed with agriculture
3	Kalighodi to Bagda	Hilly	7.5	Teak mix forests
4	Bagda to Jhinjari	Plain	9	Mainly agriculture with very few patches of teak forests
5	Awaliya to Harda	Plain	4	Agriculture with very few patches of open forests

RESULTS

Type of road kills

During the study, we recorded 61 vertebrate road kills belonging to 31 species from 23 families (Table 2). Of these, 43 (71%) mortalities were of birds, 13 (21%) kills of mammals and 5 kills (8%) belonged to herpetofauna (Figure 2). In the study area, birds were more affected taxa in road kills than mammals (Mann Whitney U = 64, $P = 0.001$), and herpetofauna (U = 23, P <0.000).

Among the birds, family Caprimulgidae (Nightjars) represented the highest (26%) number of kills followed by Strigidae (Owls) (23%), and Cuculidae (Cuckoos) (14%). The most frequently encountered bird kill was that of the nightjars followed by Greater Coucal *Centropus sinensis*, Indian Roller *Coracias benghalensis*, and the Spotted Owlet Athene brama. One species of dove could not be identified because of its decomposed body. Among the mammals, members of the family Sciuridae (Squirrels) were most killed species (31%) followed by Viverridae (Civets) (15%), and Muridae (rats & mice; 15%) (Figure 4; Image 2–9). Of the herpetofauna road kills, we found three species of snakes belonging to two families and one species of toad on the road during the survey. We found an almost equal number of mortalities of diurnal and nocturnal species (Table 2).

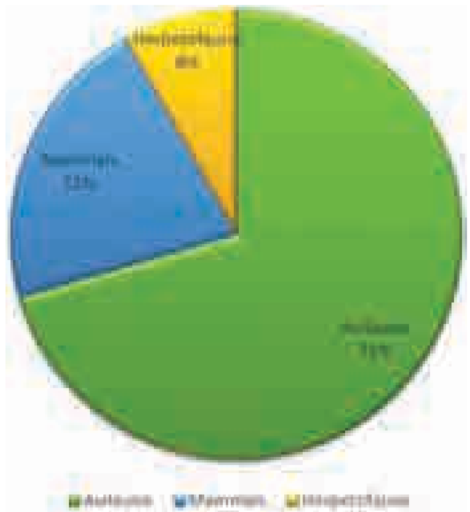

Figure 2. Percentage vertebrate mortalities on SH 26 during 2015–2017 and 2021–2022 in Khandwa District.

Table 2. Percentage frequency, activity pattern, and feeding guilds of mammals, birds, and herpetofauna road kills on SH 26.

	Taxa	Scientific name	Activity pattern	Feeding guild	No. of individuals (% of total)
	MAMMALS				
I	**Family Canidae**				
	1. Golden Jackal	*Canis aureus*	N	C/I	1 (7.69)
II	**Family Cercopithicidae**				
	2. Central Indian Langur	*Semnopithecus entellus*	D	S/G	1 (7.69)
III	**Family Felidae**				
	3. Domestic Cat	*Felis catus*	N	C/I	1 (7.69)
	4. Jungle Cat	*Felis chaus*	N	C/I	1 (7.69)
IV	**Family Viverridae**			C/I	
	5. Small Indian Civet	*Viverricula indica*	N	C/I	2 (15.38)
V	**Family Leporidae**				
	6. Rufous-tailed Hare	*Lepus nigricolis*	N	S/G	1(7.69)
VI	**Family Muridae**				
	Mus spp.	*Mus* spp.	N	S/G	2 (15.38)
VII	**Family Sciuridae**				
	Indian Palm Squirrel	*Funambulus palmarum*	D	S/G	2 (15.38)
	Northern Palm Squirrel	*Funambulus pennantii*	D	S/G	2 (15.38)
	Total				**13**
	BIRDS				
I.	**Family Caprimulgidae**				
	1. Nightjar Species	*Caprimulgus spp.*	N	I	11 (25.58)
II.	**Family Cisticolidae**				
	2. Grey-breasted Prinia	*Prinia hodgsonii*	D	I	1 (2.33)
III	**Family Columbidae**				
	3. Laughing Dove	*Spilopelia senegalensis*	D	S/G	2(4.65)
IV	**Family Coraciidae**				
	4. Indian Roller	*Coracias benghalensis*	D	I	3 (6.98)
V	**Family Cuculidae**				
	5. Greater Coucal	*Centropus sinensis*	D	I	6 (13.95)
VI	**Family Estrildidae**				
	6. Indian Silverbill	*Euodice malabarica*	D	S/G	1(2.33)
VII	**Family Leiothrichidae**				
	7. Jungle Babbler	*Argya striata*	D	I	1(2.33)
VIII	**Family Motacillidae**				1(2.33)
	8. Pipit Species		D	I	
IX	**Family Paridae**				
	9. Great Tit	*Parus major*	D	I	2(4.65)
X	**Family Strigidae**				
	10. Spotted Owlet	*Athene brama*	N	C/I	2 (4.65)
	11. Forest Owlet	*Athene (Heteroglaux) blewitti*	D	C/I	2 (4.65)
	12. Jungle Owlet	*Glaucidium radiatum*	D	C/I	1(2.33)
	13. Mottled Wood-Owl	*Strix ocellata*	N	C/I	1(2.33)
	14. Rock Eagle-Owl	*Bubo bengalensis*	N	C/I	1(2.33)
	15. Indian Scops-Owl	*Otus bakkamoena*	N	C/I	2 (4.65)
XI	**Family Tytonidae**				
	16. Barn Owl	*Tyto alba*	N	C/I	2(4.65)
XII	**Family Sturnidae**				
	17. Common Myna	*Acridotheres tristis*	D	I	3 (6.98)
	18. Unidentified Dove Species			S/G	1(2.33)
	Total				**43**
	HERPETOFAUNA				
I	**Family Bufonidae**				
	1. Common Indian Toad	*Duttaphrynus melanostictus*	N	I	2 (40.00)
II	**Family Elapidae**				
	2. Common Krait	*Bungarus caeruleus*	N	C	1 (20.00)
III	**Family Colubridae**				
	3. Bronzeback Tree Snake	*Dendrelaphis tristi*	N	C	1 (20.00)
	4. Indian Ratsnake	*Ptyas mucosa*	N	C	1 (20.00)
	Total				**5**

Feeding guild: C—Carnivore | G—Fruit/ Granivores I—Insectivore | S—Seed.

Type of habitat

Total number of road kills were significantly higher on segment 2 compared to segment 4 (Mann-Whitney U = 484, P = 0.049) and segment 5 (U = 463, P = 0.039). Segment 1 recorded more road kills than segment 4 (U = 453, P = 0.03, Figure 3). Bird, mammal and herpetofauna road kills were found on segment 1, 2, 3, & 4 while on segment 5 we found road kills of two Three-striped Palm Squirrels *Funambulus palmarum*. However, we did not find significant differences in number of road kills of

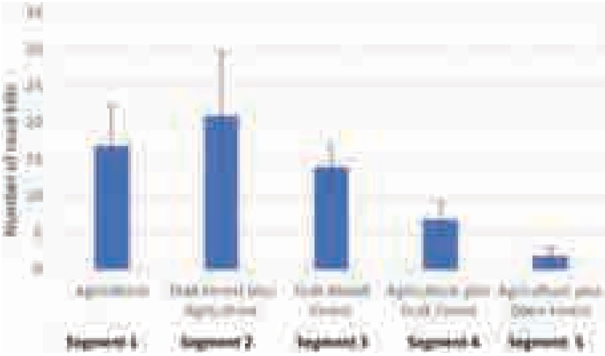

Figure 3. Total number of road kills on different segments of SH 26 in Khandwa district. Study areas 2 and 4 differ in their extent and pattern of cover by agriculture land and teak forests, as mentioned in Table 1.

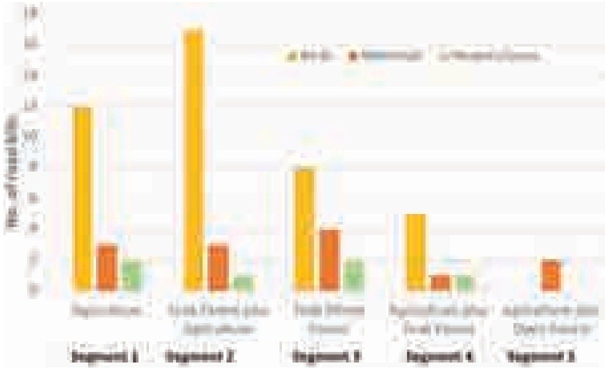

Figure 4. Number of road kills of different taxa on different study segments of during 2015–2017 and 2021–2022 on SH 26 in Khandwa District.

different taxa between different segments (Figure 4).

Monthly patterns of road kills

Most bird road kills were recorded in February, while the highest number of mammal and herpetofauna kills were recorded in the month of November (Figure 5). The number of bird road kills per month was significantly higher than that of mammal kills (U = 16.5, P = 0.033) and herpetofauna kills (U = 8, P < 0.00) per month.

A comparison of percentage of foraging guilds encountered as road kills revealed that the members of insectivore and carnivore-insectivore guilds were getting killed throughout the year while seed/fruit/grain feeders were killed mainly between January to May (Figure 6). Carnivore-insectivore road kills were seen mainly in July and December. We do not have road kill data of August and September as we did not monitor the road during those two months.

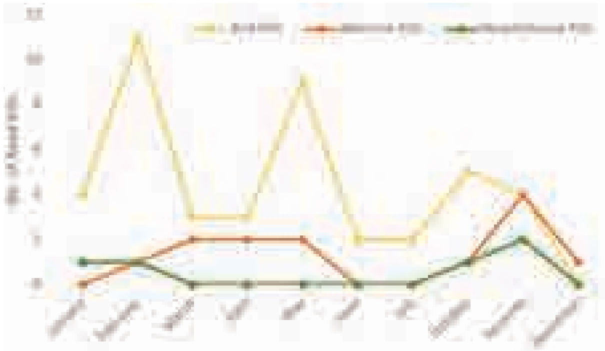

Figure 5. Monthly number road kills of different taxa on SH 26 in Khandwa District.

DISCUSSION

Herpetofauna Road Kills

In India, most studies on road kills have commonly reported high mortality of amphibians, reptiles, and mammals (Kumara 2000; Das et al. 2007; Baskaran & Boominathan 2010; Gubbi et al. 2012; Jeganathan et al. 2018; Kumawat & Purohit 2020; Saxena et al. 2020; Sur et al. 2022). Among herpetofauna, snakes are commonly reported taxa of WVC. Ectothermic animals like snakes utilise roadways to regulate their body temperature during the winter season by resting on them, which makes them easy victims of road fatalities (Rosen & Lowe 1994). Snakes visit agricultural fields hunting for rodents (Pragatheesh & Rajvanshi 2013) and are at the greatest risk of death because their movement is slower on a smooth road than on other surfaces (Row et al. 2007). The higher road mortality of amphibians and reptiles could be attributed to their slow mobility, not reacting quickly to vehicles and the fact that drivers are less likely to notice these animals because of personal disregard for the species (Pragatheesh & Rajvanshi 2013). In our study, we found only four road kills of herpetofauna, including three species of snakes and one species of Common Indian Toad. We report road kills of Common Krait, Rat Snake, and Bronze-back Tree Snake, which appear to be victims of road kills commonly (Das et al. 2007; Baskaran & Boominathan 2010; Pragatheesh & Rajvanshi 2013; Jeganathan et al. 2018). Bronze-back Tree Snake is an arboreal species and its presence on the road is indicative of loss of canopy connectivity induced by road construction (Pragatheesh & Rajvanshi 2013). The above studies have reported the maximum mortalities of amphibians and reptiles during the monsoon months. The lower number of herpetofauna kills in our study may be explained by the fact that we

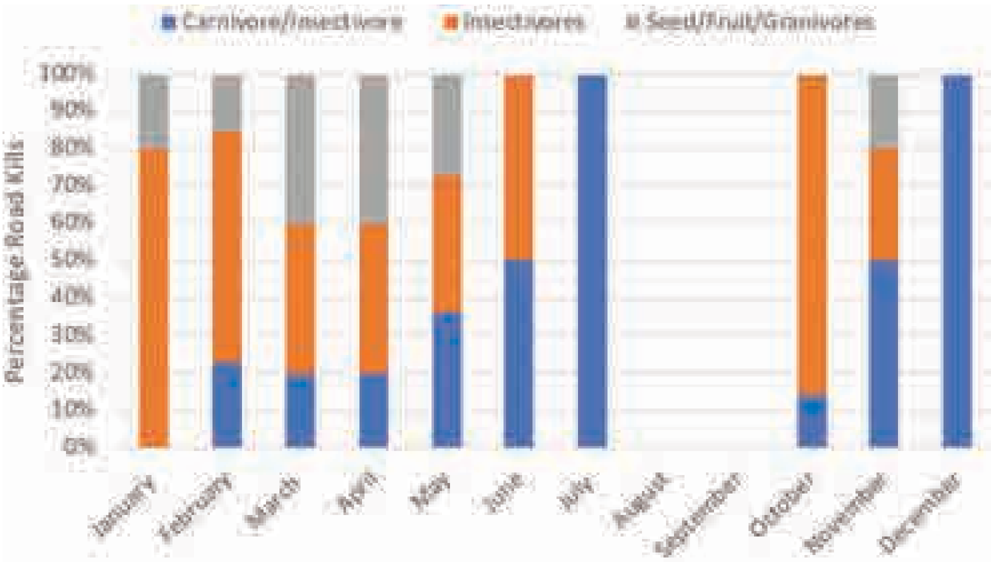

Figure 6. Feeding guilds of monthly road kills encountered on SH 26.

could not monitor SH 26 during the rainy months of August and September.

Mammal road kills

Among mammals, we found carcasses of Jungle Cat, Jackal, Domestic Cat, Rufous-tailed Hare, Palm Civet, and Palm Squirrels which have also been reported as road kills by other studies (Kumara 2000; Sundar 2004; Behera & Borah 2010; Baskaran & Boominathan 2010; Borah 2010; Jeganathan et al. 2018; Saxena et al. 2020; Sur et al. 2022). Nocturnal mammals (carnivores) often forage near the open areas by the road side hunting for small mammals and insects, and get temporarily blinded by powerful headlights thus making them victims of speeding vehicles (Orlowski & Nowak 2006). However, there was also a kill of a Central Indian Langur, which is a diurnal species. Langurs and Macaques often sit on the road to pick fallen fruits and grab food that is thrown out to them from passing vehicles. Langurs are group living animals and many of them run across the roads, thus increasing their chances of collisions with vehicles (Baskaran & Boominathan 2010).

Bird road kills

In India, a handful of studies have discussed the frequency of bird road kills (Dhindsa et al. 1988; Sundar 2004; Siva & Neelanarayanan 2020). Outside India, several studies have highlighted the frequency of bird road kills (Hodson 1962; Erritzoe et al. 2003; Gomes et al. 2009; Cook & Blumstein 2013; Husby 2016). Every year several millions of birds are estimated to die due to road hits in USA, UK, and Europe (Erickson et al. 2005; Bishop & Brogan 2013; Bíl et al. 2020), indicating the vulnerability of birds to speeding vehicles.

Our study also reports that avifauna were the major (71%) victims of the WVC. We recorded 33.33% mortalities of nocturnal birds, which included 11 individuals of nightjars and 11 individuals of owls belonging to seven owl species (Table 2). Nocturnal birds of prey move along the road side to hunt for insects collected near street lamps. Pools of water ditches, and wells by the road side make ideal feeding grounds for predatory birds feeding on amphibians and reptiles, and therefore get into collision with vehicles (Hernandez 1988). Studies reporting road kills of nightjars have surmised that nightjars often sit on the roads to feed on the insects near light posts. Also, during the breeding season nightjars sit by the road side to incubate their eggs because roads become warmer at night. The sudden flash of headlights temporarily blinds the nightjar, and they are unable to fly off (Erritoze et al. 2003).

Among owls, we recorded two road kills of the Forest Owlet. In 2015, one breeding male Forest Owlet was found dead on the road. After the incident, we could not locate the juvenile and the female in the area. It is likely that the female may have abandoned the area because the provisioning male had died. In 2022, one more breeding male Forest Owlet was found dead on the road. Although the Forest Owlet is a diurnal owl, they hunt during low-light hours during dusk and dawn (Prachi Mehta pers. obs. 2013). Losing an endangered species to road kill is a matter of grave concern as it has a direct implication on its in-situ conservation. We also report road kills of large owl species such as the Barn

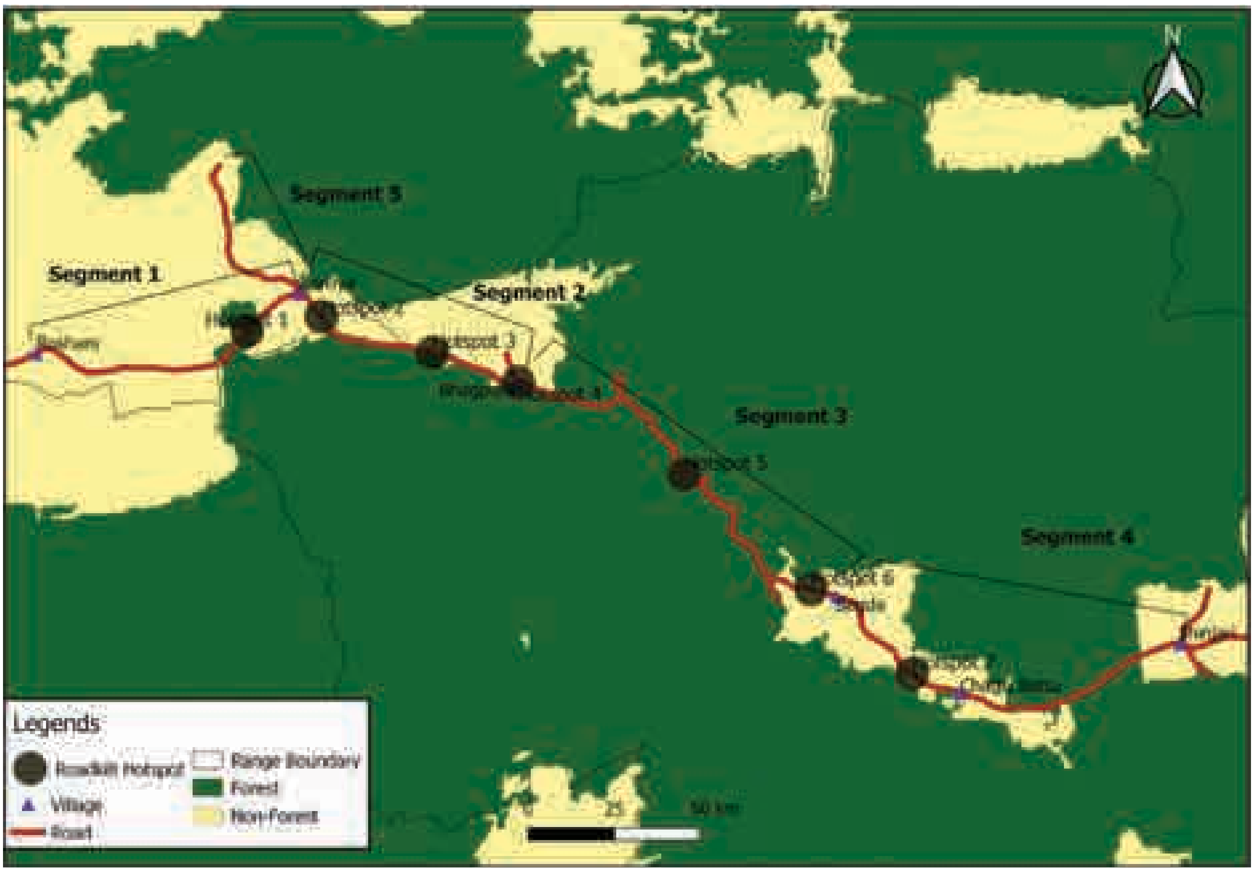

Figure 7. Locations of roadkill hotspots on SH 26 in Khandwa District.

Owl, Mottled Wood Owl, Indian Eagle Owl, and smaller owl species such as the Jungle Owlet, Indian Scops Owl, and the Spotted Owlet.

Several studies have documented Strigiformes to be common victim of WVC (Hernandez 1988; Gomes et al. 2009; Baskaran & Boominathan 2011; Le Gouar et al. 2011; Guinard et al. 2012; Siva & Neelanarayanan 2020; Sur et al. 2022). Authors have attributed greater road kills of Strigiformes to the hunting techniques of owls. Owls, unlike diurnal birds of prey, do not use hot wind currents to soar in the air but use perch and pounce technique (Mikkola 1983). Many owl species use trees, posts, fences, and cables as perches to scan the ground for prey (Mehta et al. 2018). Barn Owl and Eagle Owl often sit on the light pole near agricultural fields to prey on rodents. Smaller owls such as the Spotted Owlet often perch on low bushes, near a light source or on the edge of the road to catch insects (Mehta et al. 2018) and may be getting overrun by a speeding vehicle. Also, illuminated roads attract invertebrates, which in turn, attract the owls (Hernandez 1988). Abundance of prey attract owls to roads and flying from one bush to another can get them killed (Nero & Copland 1981). A combination of hunting technique and availability of open areas make owls an easy victim of road kills. Large numbers of mortalities of Strigiformes due to WVC is an issue of serious conservation concern as it can affect their population structure (Forman & Alexander 1998; Le Gouar et al. 2011; this study).

Among the diurnal bird kills, we observed the carcass of doves, pipits, and coucal, who often feed by the roadside on the grains (Dhindsa et al. 1988). Most bird-vehicle collisions occur because of the bird's quick flight ability and their tendency to fly across the road (Rilley et al. 2014). Also, roads that have agricultural land by the side is preferred by birds for feeding on spilled grains from the agricultural land or feeding on rodents from the crop field (Dhindsa et al. 1988; Erritoze et al. 2003).

Monthly patterns of road kills

From January to May, crops are harvested and bagged. During this process, there is a spill over of grains on the road and an influx of insects and rodents in the crop fields, which in turn attracts the movement of insectivores, carnivore-insectivores and seed/fruit/grain feeders near the road. Further monitoring and data will be required to understand the influence of diet on the taxa encountered in road kills.

Habitat surrounding the road

On SH 26, road segments 1, 2, & 3 passed through plain terrain and the road side habitat was mainly teak forests interspersed with agriculture. Segment 4 passed through hilly terrain and had teak mixed forests all along the road. Segment 5 passed through plain terrain with agriculture fields and open forests by the road side. We found maximum wildlife mortalities of doves, munias, rollers, babblers, nightjars, coucals, owls and mammals such as Jungle Cats, civets, Jackal on segments 1, 2 and 3. Most of the above species feature in other studies as road kills (Dhindsa et al. 1988; Sundar 2004). Agriculture fields have plentiful spilled over grains for granivores, insects for insectivores, and rodents for birds of prey. Additionally, interspersion of agriculture and forests forms 'edge' habitat which offers foraging opportunities for a variety of bird (Dhindsa et al. 1988) and mammal species (Baskaran & Boominathan 2010). The speed of the vehicle also contributes to the frequency of road kills (Erritzoe et al. 2003; Saxena et al. 2020). Segments 1, 2, & 3 had plain terrain therefore vehicles move faster on this stretch of the road. Segment 4 passed through hilly portion, so the vehicles must slow down while driving through this segment. This could be the reason for relatively lower numbers of road kills on segment 4. Studies have reported lower frequencies of animal collision on roads passing through farm lands but much higher frequencies of causalities on roads passing through a mix of crop fields and forests (see review in Erritzoe et al. 2003). This may be a possible explanation of lowest number of road kills on Segment 5, which had mainly crop fields and patches of open forests.

CONCLUSION AND RECOMMENDATIONS

The road kills encountered in the present study shows that diverse wildlife exist outside the protected areas, and they move between different habitats such as agriculture fields, forests, and forest edge for foraging, and other ecological requirements. Our study reports that the vehicular traffic on SH 26 is taking a toll on the wildlife in the area. Numerous kills of Nightjars and different species of owls, including two individuals of the endangered Forest Owlet, is alarming as it indicates that these species use the road frequently and are at high risk of getting into collisions with vehicles. Through this paper we have provided information on type of species killed, the locations of road kills and monthly patterns of WVC. Our findings could be used as a baseline information to prevent further wildlife mortalities on SH 26.

Based on the frequency of road kills, we have identified seven hot spots for the accidents on SH 26 (Figure 7). Installation of speed bumps and rumblers are effective in controlling speeding vehicles. We suggest installation of speed rumblers at each hotspot.

For preventing mortalities of nocturnal animals, we suggest removing shrubs from the roadside and planting tall native trees on either side of the hotspots and all along the roadside on SH 26. On hotspots 1, 2, & 3, the road level is uneven, which allows accumulation of water in ditches. This can attract owls and other mammalian predators for hunting of small prey. The height of the road should be made even to prevent water accumulation.

Generalist species like Domestic Cat, Jungle Cat, Jackals, Langurs, babblers, robins, rollers, and mynas have got exposure to a variety of habitats and therefore are not wary of crossing the roads. Such species often come on to the road to scavenge and become a victim of road hits (Medrano-Vizcaíno et al. 2022). The habitat around hotspots 1, 2, 3, 6, & 7, is mainly agricultural fields interspersed with patches of forests. The owners of the crop fields should be requested to keep the road side free of grains, and fruits that may be attracting animals for foraging. The highways should be kept free of carcasses too as it attracts bird and mammalian scavengers.

Animal crossing signages and reflectors are helpful in alerting the driver to watch out for wildlife crossing the roads. We have recently put up a few such signboards on SH 26 urging the drivers to maintain slow driving speed (Figure 8). The signboards should be shifted to new locations every few months, because if the signboards are at the same place, it will not invite the attention of regular drivers as they get used to seeing it (Sullivan et al. 2004).

The proposed widening of SH 26 for making into a four-lane road will lead to an increase in traffic intensity, vehicle speed and is expected to increase the wildlife death toll. This calls for attention of such studies to be carried out on a wider scale across the country to understand the impact of roads passing through forested areas.

Considering the rapid rate at which roads are being constructed in the country, it is imperative and urgent to carry out systematic and rigorous impact assessment on existing and proposed roads. Further, it is important to institutionalise a mechanism through which effective

Image 1. Awareness poster urging the drivers to go slow on SH 26 installed by WRCS.

Image 2. Langur road kill

Image 3. Jungle Cat road kill

mitigation measures could be implemented which will enable biodiversity conservation and infrastructure development in a compatible manner.

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Image 4. Scops Owl road kill

Image 5. Jungle Owlet road kill

Image 6. Nightjar road kill

Image 7. Indian Roller road kill

Image 8. Snake road kill

Image 9. Barn Owl road kill

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COMMUNICATION

Terrestrial vertebrate and butterfly diversity of Garbhanga Landscape, Assam, India

Pranjal Mahananda [1], Shah Nawaz Jelil [2], Sanath Chandra Bohra [3], Nilutpal Mahanta [4], Rohini Ballave Saikia [5] & Jayaditya Purkayastha [6]

[1,3] Department of Zoology, Gauhati University, Gopinath Bardoloi Nagar, Guwahati, Assam 781014, India.
[2] House no. 20, Namghar Path, Panjabari, Guwahati, Assam 781037, India.
[4] TOFI, CIFOR-ICRAF National Agricultural Science Complex Dev Prakash Shastri Marg, Pusa Campus New Delhi 110012, India.
[5] Assam Forest Department, Aranya Bhawan, Panjabari Rd, Batahguli, Guwahati, Assam 781037, India.
[6] Help Earth, 16, Raghunath Choudhury Path, Lachitnagar, Guwahati, Assam 781007, India.
[1] pranjalmahananda@gmail.com, [2] shahnawazjelil@gmail.com, [3] sreptilian6@gmail.com, [4] nilutpal.mahanta1@gmail.com, [5] rohinibsaikia@gmail.com, [6] mail.jayaditya@gmail.com (corresponding author)

Abstract: A study was conducted on the current status of terrestrial vertebrates and butterflies in Garbhanga Reserve Forest. Data were compiled from field surveys and secondary sources like existing literature, and citizen science databases. We found that Garbhanga is represented by 254 species of butterflies (6 families), 29 species of amphibians (7 families), 64 species of reptiles (12 families), 307 species of birds (68 families) and 31 species of mammals (19 families). In Garbhanga, amongst the studied group, two species are 'Critically Endangered' (CR), six species are 'Endangered' (EN), 14 species are 'Vulnerable' (VU), eight species are 'Near Threatened' (NT), eight species are 'Data Deficient' (DD), 411 species are 'Least Concern' (LC), and 236 species are not assessed (denoted by blank space). This shows a huge gap in research and status evaluation of understudied species. This in turn also provides further research opportunities on the lesser known species.

Keywords: Birds, butterfly, checklist, frog, inventory, lizard, mammal, northeast India, snake, turtle.

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Author details: Pranjal Mahananda is a PhD candidate of Gauhati University, India. He is interested in avian ecology and conservation, and is currently studying raptor ecology in Eastern Himalayas, Assam. He is presently working as coordinator in Assam State Biodiversity Board. Shah Nawaz Jelil has major interests in quantitative and spatial ecology, wildlife and biodiversity assessment and conservation. He has completed his PhD from Wildlife Institute of India - Saurashtra University and currently works as a consultant at Arcadis India Private Limited. Sanath Chandra Bohra is a PG student of Gauhati University, India. His study interest is primarily focused on herpetofauna and butterflies of Northeast India. Nilutpal Mahanta is an ornithology researcher with a field experience of nine years. He is keenly interested in wildlife research. Rohini Ballave Saikia Rbs is an IFS officer of Assam-Meghalaya Cadre of 2012 batch and is currently posted as Divisional Officer of Kamrup East Division. Jayaditya Purkayastha primarily works on systematics of herpetofauna of Northeast India. He is currently working as consultant in Assam State Biodiversity Board.

Author contributions: PM contributed in drafting the manuscript, data analysis and creating the checklists of the birds. SNJ did the cartography and contributed to the data pertaining to mammals. SCB created the checklist for the butterflies. NM contributed in creating the checklist of birds and contributed in cartography. RBS contributed forest data pertaining to the study area and oversaw the preparation of the manuscript. JP conceptualised the manuscript, contributed in drafting of the manuscript along with preparation of the checklist of amphibians and reptiles.

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INTRODUCTION

Documentation of biodiversity is essential for effective conservation and management efforts, as it provides a comprehensive understanding of the species and habitats that are present in an area. It helps to identify the species and habitats that are most in need of protection. This information can be used to prioritize conservation efforts and support the development of targeted management plans (Vane-Wright et al. 1991). Documentation of biodiversity can support efforts to monitor changes in species populations and the health of ecosystems over time. This information can help to detect emerging threats to biodiversity, such as the spread of invasive species, disease outbreaks, or changes in land use patterns (Sala et al. 2000). The state of Assam is the most urbanized state of northeastern India with a population exceeding 31 million (Saikia 2019). The state has an area of 78,438 km^2, which comprises of 2.39% of the geographic area of India and is a part of Indo Burma biodiversity hotspot. According to the Forest Survey of India (2021) report, the total recorded forest area of the state is 28,312 km^2 which is 36.09% of the geographic area of the state and is greater than the average forested area of the country which stands at 21.71%. The forest type mostly comprises of tropical wet evergreen, tropical semi evergreen, tropical moist deciduous, sub-tropical broad-leaved hill, sub-tropical pine, littoral, and swamps. A total of 3,513 wetlands exist within the state spreading across an area of 1,012.32 km^2 (Assam Forest Department 2011–12). The faunal composition of the region is particularly interesting as it is located at a confluence of Indo-Chinese, Indo-Malayan, and Indian biogeographic regions (Ahmed et al. 2009). Assam has more than 300 reserve forests with Garbhanga being one of the largest reserve forests (Assam Forest Department 2011–12). Garbhanga Reserve Forest is situated in the north of the Guwahati city of Assam and spreads across an area of 114.6 km^2. The reserve forest is connected to Rani Reserve Forest which has an area of 437.26 km^2 and is often referred to as Rani-Garbhanga landscape (Devi et al. 2012). Together, they constitute the biggest network of reserve forested areas of Assam. Garbhanga Reserve Forest includes undulating hill ranges with altitude ranging 80–670 m. Recently, through an Assam Gazette notification (No.FRW.3/2022/44) dated 7 April 2022, an area of 117 km^2 within the Garbhanga Reserve Forest has been proposed for a wildlife sanctuary.

Many hill streams flow within the reserve forest. The main river flowing through the reserve forest is the Basistha River which finally drains into Deeporbeel Wildlife Sanctuary and Ramsar site. The forest type mostly constitutes of moist deciduous type which accounts for about 75% of the forest type with Sal *Shorea robusta* being the predominant tree species. Secondary forest constitutes mainly of scrub forest and bamboo accounting for 10% and 7%, respectively. The soil type of the reserve forest is gravelly on crests and upper slopes, deep red and clayey in the foot hills, and alluvial lower down (Devi et al. 2012).

Due to the topology, forest type and climatic condition, Garbhanga is home to a wide variety of biodiversity. Lahkar et al. (2010) recorded 128 species of birds; Modak et al. (2018) recorded 54 species of butterflies; Barua et al. (2004) recorded 29 species and subspecies of swallowtail butterflies from Garbhanga. Herein we present a detailed checklist of butterflies, amphibians, reptiles, birds, and mammals within the notified area of Garbhanga wildlife sanctuary (proposed).

MATERIALS AND METHODS

Study Area

The Rani-Garbhanga forest complex (Rani Reserve Forest: 91.5877–91.7066 ^{0}E, 26.1113–26.0208 ^{0}N; Garbhanga Reserve Forest: 91.6069–91.7958 ^{0}E; 26.0919–25.9033 ^{0}N) is located on the south bank of the river Brahmaputra in Assam. The reserve shares its borders on the eastern and northern sides with Meghalaya state. The forest is contiguous with the Nongkhyllem Wildlife Sanctuary of Meghalaya. The forest type of Rani-Garbhanga in Assam valley is tropical mixed moist deciduous forest (Champion & Seth 1968). Once known to be the original habitat of Sal species, excessive logging led it to be replaced by secondary bamboo brakes (Champion & Seth 1968). The dominant trees are *Shorea robusta*, *Tectona grandis*, *Schima wallichii*, *Michelia champaca*, *Ficus religiosa*, and *Tetrameles nudiflora.* The dominant bamboo species within the reserve is *Dendrocalamus hamiltonii* (Barua 2007). The forest also borders on the northwestern side with Deeporbeel Wildlfe Sanctuary.

The forest has four types of climatic conditions, viz.: pre-monsoon, monsoon, retreating monsoon, and winter. The maximum humidity ranges between 80–90 % (Kakati 2002). The rainfall of the area ranges between 3,000–4,500 mm, and the temperature ranges between 11–36 °C (Kakati 2002).

Data collection for checklist

The data for all the taxa groups were compiled from

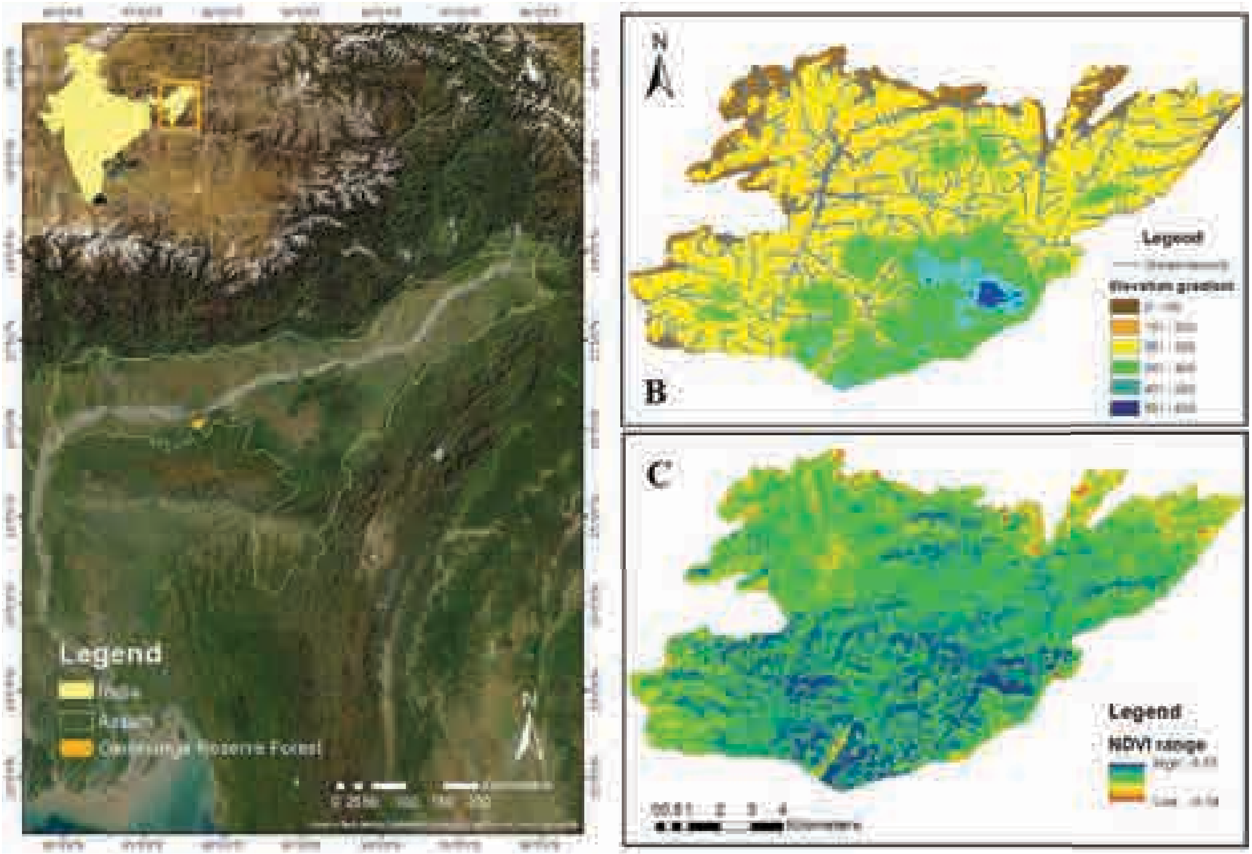

Figure 1. A—Location of study area - Garbhanga Reserve Forest in Assam, India; B—Stream network and elevation gradient | C—Normalized Difference Vegetation Index (NDVI) of study area.

multiple sources. Data were gathered employing visual encounter survey and active search (Crump & Scott 1994). Secondary data were collected from research articles (Baruah 2004; Lahkar et al. 2010; Modak et al. 2018; Purkayastha 2018; Bohra & Purkayastha 2021) and citizen science database (eBird 2022) which has bird observation information since 2008 to recent times. The taxa groups were then categorized as per the IUCN Red List criteria.

Spatial analyses/ mapping:

Elevation gradient and stream network were derived using the Hydrology tool in Arc Map 10.4 using Carto DEM Version-3 R1 (Figure 1A). We found that elevation gradient ranges 0–594 m. NDVI was calculated using Sentinel 2A data in Arc Map 10.4 (Figure 1B). Elevation and stream network map was generated using data from CartoDEM satellite (https://bhuvan-app3.nrsc.gov.in).

RESULTS

The present study found Garbhanga to be home to 254 species of butterflies (6 families), 29 species of amphibians (seven families), 64 species of reptiles (12 families), 307 species of birds (68 families), and 31 species of mammals (19 families). According to the IUCN Red List data (IUCN 2023), in Garbhanga more than 1% (1.16%) species are 'Near Threatened', 60% species belong to 'Least Concern', more than 1% (1.16%) species are 'Data Deficient', and 34% (34.45%) species are not assessed.

Butterflies

A total of 254 species of butterflies representing six families were recorded from the study site. Only 30 species are categorized under different categories as per the IUCN Red List including Common Duffer *Discophora sondaica* which is considered as 'Near Threatened' while all the other species are not assessed (Figure 2, Table 1). Family Nymphalidae was observed to be the most dominant family, accounting for 100 species from the

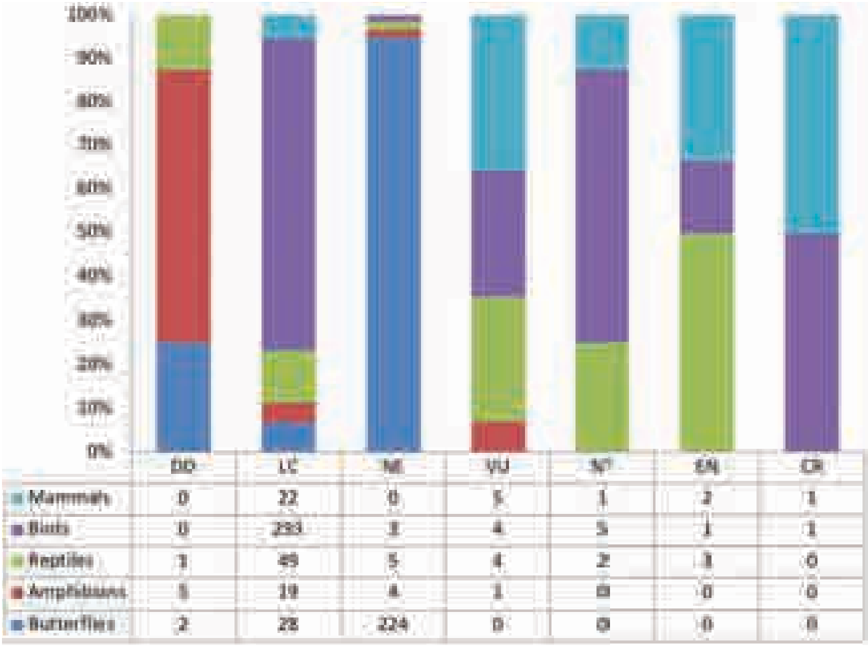

Figure 2. Representation of studied taxa groups of Garbhanga falling under different IUCN Red List categories.

study area.

Amphibia

We recorded 29 species of amphibians representing two orders (Anura and Gymnophiona) and seven families. The family Dicroglossidae was found to be the most species rich represented by eight species whereas the family Bufonidae was represented by just a single species. According to the IUCN Red List, 19 species were 'Least Concern', five species were 'Data Deficient', one 'Vulnerable', and four species are not assessed (Figure 3, Table 2).

Reptilia

We recorded 64 species of reptiles representing three orders and 12 families. Lizards were represented by 21 species, snakes by 39 species and turtles by four species. Amongst lizards, family Gekkonidae was found to be dominant and had nine representative species. Colubridae was the most species rich family among snakes accounting for 29 species. According to the IUCN redlist, three species are 'Endangered', four species were 'Vulnerable', two species were 'Near Threatened', one species was 'Data Deficient', 49 species were 'Least Concern', and five species are not assessed (Figure 3, Table 3).

Birds

We recorded 307 species of birds belonging to 68 families from the study site. Among them, the family Muscicapidae was found to be dominating in terms of species richness represented by 34 species. According to the IUCN Red List there are one 'Critically Endangered' species, one 'Endangered' species, four 'Vulnerable' species, five 'Near Threatened' species, 293 'Least Concern' species and three species are yet to be assessed (Figure 3, Table 4).

Mammals

Garbhanga harbours 31 species of mammals belonging to 19 families. According to the IUCN Red List, one species is 'Critically Endangered', two species are 'Endangered', five species are 'Vulnerable', one species is 'Near Threatened', the remaining 22 species are 'Least Concern' (Figure 3, Table 5).

DISCUSSION

The data reported above indicate that the Garbhanga landscape is extremey rich in biodiversity and merits more protection through a legal status. It is noteworthy that vide notification number FRW.3/44. dated 28 march 2022, a preliminary notification was passed in The Assam Gazette dated 7 April 2022 showing the intent of the Governor of Assam to declare an area of 117 km^2 of Garbhanga as a wildlife sanctuary. This step will help enhance protection and conservation of the

Table 1. Butterflies of Garbhanga, Assam, India.

Family	Common name	Scientific name	IUCN Red List status
Papilionidae	Common Batwing	*Atrophaneura varuna* White, 1842	LC
	Common Windmill	*Byasa polyeuctes* Doubleday, 1842	
	Tailed Jay	*Graphium aggamemnon* Linnaeus, 1758	
	Four-bar Swordtail	*Graphium agetes* Westwood, 1843	
	Five-bar Swordtail	*Graphium antiphates* Cramer, 1775	LC
	Glassy Bluebottle	*Graphium cloanthus* Westwood, 1841	LC
	Common Jay	*Graphium doson* C. & R. Felder, 1864	LC
	Lesser Zebra	*Graphium macareus* Godart, 1819	
	Common Bluebottle	*Graphium sarpedon* Linnaeus, 1758	LC
	White Dragontail	*Lamproptera curius* Fabricius, 1787	
	Common Rose	*Pachliopta aristolochiae* Fabricius, 1775	LC
	Common Raven	*Papilio castor* Westwood, 1842	
	Common Mime	*Papilio clytia* Linnaeus, 1758	
	Great Jay	*Papilio eurypylus* Linnaeus, 1758	
	Lime Butterfly	*Papilio demoleus* Linnaeus, 1758	
	Red Helen	*Papilio helenus* Linnaeus, 1758	
	Great Mormon	*Papilio memnon* Linnaeus, 1758	LC
	Yellow Helen	*Papilio nephelus* Boisduval, 1836	
	Paris Peacock	*Papilio paris* Linnaeus, 1758	
	Common Mormon	*Papilio polytes* Linnaeus, 1758	
	Spangle	*Papilio protenor* Cramer, 1775	
	Golden Birdwing	*Troides aeacus* C.& R. Felder, 1860	LC
	Common Birdwing	*Troides helena* Linnaeus, 1758	LC
	Great Windmill	*Byasa dasarada* Moore, 1858	LC
Pieridae	Common Albatross	*Appias albina* Boisduval, 1836	
	Plain Puffin	*Appias indra* Moore, 1858	
	Spot Puffin	*Appias lalage* Doubleday, 1842	
	Chocolate Albatross	*Appias lyncida* Cramer, 1777	
	Striped Albatross	*Appias olferna* Swinhoe, 1890	
	Common Emigrant	*Catopsilia pomona* Fabricius, 1775	
	Mottled Emigrant	*Catopsilia pyranthe* (Linnaeus, 1758)	
	Lesser Gull	*Cepora nadina* Lucas, 1852	
	Common Gull	*Cepora nerissa* Fabricius, 1775	
	Red spot Jezebel	*Delias descombesi* Boisduval, 1836	
	Red base Jezebel	*Delias pasithoe* Linnaeus, 1767	
	Tailed Sulpher	*Dercas verhuelli* Hoeven, 1839	
	One-spot Grass Yellow	*Eurema andersonii* Moore, 1886	LC
	Three-spot Grass Yellow	*Eurema blanda* Boisduval, 1836	
	Small Grass Yellow	*Eurema brigitta* Stoll, 1780	LC
	Common Grass Yellow	*Eurema hecabe* Linnaeus, 1758	
	Tree Yellow	*Gandaca harina* Horsfield, 1829	
	Great Orange Tip	*Hebomoia glaucippe* Linnaeus, 1758	
	Yellow Orange Tip	*Ixias pyrene* Linnaeus, 1764	
	Psyche	*Leptosia nina* Fabricius, 1793	
	Common Wanderer	*Pareronia hippia* Fabricius, 1787	
	Large Cabbage White	*Pieris brassicae* Linnaeus, 1758	
	Indian Cabbage White	*Pieris canidia* Linnaeus, 1768	
Lycaenidae	Common Hedge Blue	*Acetolepis puspa* Horsfield, 1828	
	Common Ciliate Blue	*Anthene emolus* Godart, 1824	
	Pointed Ciliate Blue	*Anthene lycaenina* Felder, 1868	
	Indian Oakblue	*Arhopala atrax* Hewitson, 1862	
	Lilac Oakblue	*Arhopala camdeo* Moore, 1858	
	Centaur Oakblue	*Arhopala centaurus* Fabricius, 1775	
	Green Oakblue	*Arhopala eumolphus* Cramer, 1780	
	Spotless Oakblue	*Arhopala fulla* Hewitson, 1862	
	Yellowdisc Tailless Oakblue	*Arhopala perimuta* Moore, 1858	
	Plane	*Bindahara phocides* Fabricius, 1793	
	Angled Pierrot	*Caleta decidia* Hewitson, 1876	LC
	Elbowed Pierrot	*Caleta elna* Hewitson, 1876	LC
	Common Pierrot	*Castalius rosimon* Fabricius, 1775	
	Common Tinsel	*Catapaecilma major* Druce, 1895	
	Silver Forget-me-not	*Catochrysops panormus* C. Felder, 1860	
	Forget -me –not	*Catochrysops strabo* Fabricius, 1793	
	Common Imperial	*Cheritra freja* Fabricius, 1793	LC

Family	Common name	Scientific name	IUCN Red List status
	Lime Blue	*Chilades lajus* Stoll, 1780	
	Plains Cupid	*Chilades pandava* Horsfield, 1829	LC
	Broad Tail Royal	*Creon cleobis* Godart, 1824	
	Angled Sunbeam	*Curetis acuta* Moore, 1877	
	Saronis Sunbeam	*Curetis saronis* Moore, 1877	
	Cornelian	*Deudorix epijarbas* Moore, 1858	
	Banded Blue Pierrot	*Discolampa ethion* Westwood, 1851	
	Gram Blue	*Euchrysops cnejus* Fabricius, 1798	
	Purple Sapphire	*Heliophorus epicles* Godart, 1824	
	Common Onyx	*Horaga onyx* Moore, 1857	
	Common Tit	*Hypolycaena erylus* Godart, 1824	
	Silver Streak Blue	*Iraota timoleon* Stoll, 1790	
	Metallic Cerulean	*Jamides alecto* Felder, 1860	LC
	Dark Cerulean	*Jamides bochus* Stoll, 1782	
	Common Cerulean	*Jamides celeno* Cramer, 1775	
	Glistening Cerulean	*Jamides elpis* Godart, 1824	
	White Cerulean	*Jamides pura* Moore, 1886	
	Peablue	*Lampides boeticus* Linnaeus, 1767	
	Yamfly	*Loxura atymnus* Stoll, 1780	
	Malayan	*Megisba malaya* Horsfield, 1828	
	Common Mottle	*Miletus chinensis* Felder, 1862	
	Common Quaker	*Neopithecops zalmora* Butler, 1870	
	Common Gem	*Poritia hewitsoni* Moore, 1866	
	Banded Lineblue	*Prosotas aluta* Druce, 1873	
	Tailless Lineblue	*Prosotas dubiosa* (Semper, [1879])	
	Common Lineblue	*Prosotas nora* (C. Felder, 1860)	
	Pale Grass Blue	*Pseudozizeeria maha* Kollar, 1844	
	Common Red Flash	*Rapala iarbas* Fabricius, 1787	
	State Flash	*Rapala manea* Hewitson, 1863	
	Copper Flash	*Rapala pheretima* Hewitson, 1863	
	Chocolate Royal	*Remelana jangala* (Horsfield, [1829])	
	Apefly	*Spalgis epius* Westwood, 1851	
	Long Banded Silverline	*Spindasis lohita* Horsfield, 1829	

Family	Common name	Scientific name	IUCN Red List status
	Red Imperial	*Suasa lisides* Hewitson, 1863	LC
	Common Acacia Blue	*Surendra quercetorum* Moore, 1858	
	Zebra Blue	*Leptotes plinius* Fabricius, 1793	
	Forest Pierrot	*Taraka hamada* Druce, 1875	
	Common Guava Blue	*Virachola isocrates* Fabricius, 1793	
	Fluffy Tit	*Zeltus amasa* Hewitson, 1865	
	Dark Grass Blue	*Zizeeria karsandra* Moore, 1865	
Riodinidae	Plum Judy	*Abisara echerius* Stoll, 1790	
	Punchinello	*Zemeros flegyas* Cramer, 1780	
Nymphalidae	Yellow Coster	*Acraea issoria* Hübner, 1818	
	Tawny Coster	*Acraea terpsicore* Linnaeus, 1758	
	Angled Castor	*Ariadne ariadne* Linnaeus, 1763	
	Common Castor	*Ariadne merione* Cramer, 1777	
	Himalayan Studded Sergeant	*Athyma asura* Moore, [1858]	
	Colour Sergeant	*Athyma inara* Westwood, 1850	
	Dot Dash Sergeant	*Athyma kanwa* Moore, 1858	
	Common Sergeant	*Athyma perius* Linnaeus, 1758	
	Blackvein Sergeant	*Athyma ranga* Moore, 1857	
	Staff Sergeant	*Athyma selenophora* Kollar, 1844	
	Commodore	*Auzakia danava* Moore, 1857	
	Red Lacewing	*Cethosia biblis* Drury, 1770	
	Leopard Lacewing	*Cethosia cyane* Drury, 1770	
	Pallid Nawab	*Charaxes arja* Felder & Felder, 1866	
	Tawny Rajah	*Charaxes bernardes* Fabricius, 1793	
	Common Nawab	*Charaxes bharata* Felder & Felder, 1867	
	Stately Nawab	*Charaxes dolon* Westwood, 1848	
	Variegated Rajah	*Charaxes kahruba* Moore, 1895	
	Yellow Rajah	*Charaxes marmax* Westwood, 1847	
	Black Rajah	*Charaxes solon* Fabricius, 1793	
	Indian Red Maplet	*Chersonesia rahrioides* Martin, 1895	LC
	Common Maplet	*Chersonesia risa* Doubleday, 1848	
	Large Yeoman	*Cirrochroa aoris* Doubleday, 1847	
	Common Yeoman	*Cirrochroa tyche* Felder & Felder, 1861	

Family	Common name	Scientific name	IUCN Red List status
	Rustic	*Cupha erymanthis* Drury, 1773	
	Common Map	*Cyrestis thyodamas* Doyère, 1840	
	Plain Tiger	*Danaus chrysippus* Linnaeus, 1758	LC
	Common Tiger	*Danaus genutia* Cramer 1779	
	Constable	*Dichorragia nesimachus* Doyère, 1840	
	Common Duffer	*Discophora sondiaca* Boisduval, 1836	
	Autumn Leaf	*Doleschallia bisaltide* Cramer, 1777	
	Common Palmfly	*Elymnias hypermnestra* Linnaeus, 1763	
	Spotted Palmfly	*Elymnias malelas* Hewitson, 1863	
	Blue striped Palmfly	*Elymnias patna* Westwood, 1851	
	Dusky Diadem	*Ethope himachala* Moore, 1857	
	Long Branded Blue Crow	*Euploea algea* Godart, 1819	
	Common Crow	*Euploea core* Cramer, 1780	LC
	Blue Spotted Crow	*Euploea midamus* Linnaeus, 1758	
	Striped Blue Crow	*Euploea mulciber* Cramer, 1777	
	Double Branded Crow	*Euploea sylvester* Fabricius, 1793	
	Courtesan	*Euripus nyctelius* Doubleday, 1845	
	Common Baron	*Euthalia aconthea* Cramer, 1777	
	Grey Baron	*Euthalia anosia* Moore, 1858	
	Gaudy Baron	*Euthalia lubentina* Cramer, 1777	
	Powdered Baron	*Euthalia monina* Fabricius, 1787	
	White-edged Blue Baron	*Euthalia phemius* Doubleday, 1848	
	Common Faun	*Faunis canens* Hübner, 1826	
	Pasha	*Herona marathus* Doubleday, 1848	
	Great Eggfly	*Hypolimnas bolina* Linnaeus, 1758	
	Peacock Pansy	*Junonia almana* Linnaeus, 1758	LC
	Grey Pansy	*Junonia atlites* Linnaeus, 1763	
	Yellow Pansy	*Junonia hierta* Fabricius, 1798	LC
	Chocolate Pansy	*Junonia iphita* Cramer, 1779	
	Lemon Pansy	*Junonia lemonias* Linnaeus, 1758	
	Blue Pansy	*Junonia orithya* Linnaeus, 1758	LC
	Orange Oakleaf	*Kallima inachus Doyere, 1840*	
	Blue Admiral	*Kaniska canace* (Linnaeus, 1763)	
	Knight	*Lebadea martha* Fabricius, 1787	
	Angled Red Forester	*Lethe chandica* Moore, 1857	
	Banded Treebrown	*Lethe confusa* Aurivillius, 1898	
	Bamboo Treebrown	*Lethe europa* Fabricius, 1775	DD
	Common Red Forester	*Lethe mekara* Moore, 1857	
	Common Treebrown	*Lethe rhoria* Fabricius, 1787	
	Dark Archduke	*Lexias dirtea* Fabricius, 1793	
	Common Evening Brown	*Melanitis leda* Linnaeus, 1758	LC
	Dark Evening Brown	*Melanitis phedima* Cramer, 1780	
	Great Evening Brown	*Melanitis zitenius* Herbst, 1796	
	Purple Emperor	*Mimathyma ambica* Kollar, 1844	
	Commander	*Moduza procris* Cramer, 1777	
	White-bar Bushbrown	*Mycalesis anaxias* Hewitson, 1862	
	Dark Brand Bushbrown	*Mycalesis mineus* Linnaeus, 1758	
	Common Bushbrown	*Mycalesis perseus* Fabricius, 1775	
	Long Brand Bushbrown	*Mycalesis visala* Moore, 1857	
	Sullied Sailor	*Neptis clinia* Moore, 1872	
	Common Sailor	*Neptis hylas* Linnaeus, 1758	
	Clear Sailor	*Neptis nata* Moore, 1857	
	False Dingy Sailor	*Neptis pseudovikasi* Moore, 1899	
	Nigger	*Orsotrioena medus* Fabricius, 1775	
	Common Lascar	*Pantoporia hordonia* Stoll, 1790	
	Glassy Tiger	*Parantica aglea* Stoll, 1782	
	Chestnut Tiger	*Parantica sita* Kollar, 1844	
	Clipper	*Parthenos sylvia* Cramer, 1775	
	Small Leopard	*Phalanta alcippe* Stoll, 1782	
	Common Leopard	*Phalanta phalantha* Drury, 1773	LC
	Tabby	*Pseudergolis wedah* Kollar, 1844	
	Black Prince	*Rohana parisatis* Westwood, 1851	LC
	Popinjay	*Stibochiona nicea* (Gray, 1846)	
	Northern Jungle Queen	*Stichophthalma camadeva* Westwood, 1848	
	Spotted Jester	*Symbrenthia hypselis* Godart, 1823	

Family	Common name	Scientific name	IUCN Red List status
	Common Jester	*Symbrenthia lilaea* Hewitson, 1864	DD
	Common Earl	*Tanaecia julii* Lesson, 1837	
	Grey Count	*Tanaecia lepidea* Butler, 1868	
	Jungle Glory	*Thaumantis diores* Doubleday, 1845	
	Vagrant	*Vagrans egista* Cramer, 1780	
	Painted Lady	*Vanessa cardui* Linnaeus, 1758	LC
	Indian Red Admiral	*Vanessa indica* Herbst, 1794	
	Common Fivering	*Ypthima baldus* Fabricius, 1775	
	Common Fourring	*Ypthima hubenri* Kirby, 1871	
	Cruiser	*Vindula erota* (Fabricius, 1793)	
	Blue Tiger	*Tirumala limniace* (Cramer,1775)	
Hesperiidae	Chocolate Demon	*Ancistroides nigrita* Latreille, 1824	
	Atkinson's Bob	*Arnetta atkinsoni* Moore, 1878	
	Forest Hopper	*Astictopterus jama* Felder & Felder, 1860	
	Small Paint-brush Swift	*Baoris chapmani* Evans, 1937	
	Black Paint-brush Swift	*Baoris unicolor* Moore, (1884)	
	Small Green Awlet	*Burara amara* Moore, [1866]	
	Harisa Orange Awlet	*Burara harisa* Moore, 1865	
	Branded Orange Awlet	*Burara oedipodea* (Swainson, 1820)	
	Common Spotted Flat	*Celaenorrhinus leucocera* Kollar, 1844	
	Plain Palm Dart	*Cephrenes acalle* (Höpffer, 1874)	
	Indian Awlking	*Choaspes benjaminii* (Guérin-Méneville, 1843)	
	Wax Dart	*Cupitha purreea* Moore, 1877	
	Common Yellow-breast Flat	*Gerosis bhagava* Moore, 1866	
	Dusky Yellow-breasted Flat	*Gerosis phisara* Moore, 1884	
	White Yellow-breasted Flat	*Gerosis sinica* C. & R. Felder, 1862	
	Gold-spotted Ace	*Halpe homolea* Swinhoe, 1893	
	Moore's Ace	*Halpe porus* Mabille, 1877	
	Banded ace	*Halpe zema* (Hewitson, 1877)	

Family	Common name	Scientific name	IUCN Red List status
	Common Banded Awl	*Hasora chromus* (Cramer, [1780])	
	Tree Flitter	*Hyarotis adrastus* Stoll,1780	
	Dark Velvet Bob	*Koruthaialos butleri* de Nicéville, 1883	
	Chestnut Bob	*Lambrix salsala* Moore, 1866	
	Common Redeye	*Matapa aria* Moore, 1866	
	Black Veined Redeye	*Matapa sasivarna* Moore, 1865	
	Restricted Demon	*Notocrypta curvifascia* (C. & R. Felder, 1862)	
	Common Banded Demon	*Notocrypta paralysos* (Wood-Mason & de Nicéville, 1881)	
	Tiger Hopper	*Ochus subvittatus* Moore, 1878	
	Chestnut Angle	*Odontoptilum angulata* Felder, 1862	
	Common Dartlet	*Oriens gola* Moore, 1877	
		Parnara sp.	
	Great Swift	*Pelopidas assamensis* de Nicéville, 1882	
	Small Branded Swift	*Pelopidas mathias* (Fabricius, 1798)	
	Large Branded Swift	*Pelopidas subochracea* (Moore, 1878)	
		Ponthanus sp.	
	Fulvous Pied Flat	*Pseudocoladenia dan* Fabricius, 1787	
	Common Small Flat	*Sarangesa dasahara* Moore, 1866	
	Khasi Hills Bob	*Scobura isota* Swinhoe, 1893	
	Malay Forest Bob	*Scobura phiditia* (Hewitson, [1866])	
	Indian Skipper	*Spialia galba* Fabricius, 1793	
	Indian Palm Bob	*Suastus gremius* (Fabricius, 1798)	
	Suffused Snow Flat	*Tagiades gana* Moore,1866	
	Common Snow Flat	*Tagiades japetus* Stoll, 1781	
	Water Snow Flat	*Tagiades litigiosa* Möschler, 1878	
	Pale Palm Dart	*Telicota colon* (Fabricius, 1775)	
	Grass Demon	*Udaspes folus* Cramer, 1775	
	Purple and Gold Flitter	*Zographetus satwa* de Nicéville, 1884	
	Tricoloured Pied Flat	*Coladenia indrani* (Moore, [1866])	
	Myanmarrese Large forest Bob	*Scobura cephaloides* (de Nicéville, 1889)	

Table 2. Amphibians of Garbhanga, Assam, India.

Family	Common name	Scienific name	IUCN Red List status
Bufonidae	Common Asian Toad	*Duttaphrynus melanostictus* (Schneider, 1799)	LC
Megophryidae	Red-Eyed Frog	*Leptobrachium smithi* (Matsui et al. 1999)	LC
	Big Headed Horned Frog	*Megophrys megacephala* (Mahony, Sengupta, Kamei, & Biju, 2011)	
	White-lipped Horned Toad	*Megophrys major* (Boulenger, 1908)	LC
	Indian Balloon Frog	*Uperodon globulosus* (Günther, 1864)	LC
Microhylidae	Mymensingh Narrow-mouthed Frog	*Microhyla mymensinghensis* Hasan, Islam, Kuramoto, Kurabayashi, & Sumida, 2014	
	Berdmore's Narrow-mouthed Frog	*Microhyla berdmorei* (Blyth, 1856)	LC
Rhacophoridae	Garo Hills Bush Frog	*Philautus garo* (Boulenger, 1919)	VU
	Six-lined Tree Frog	*Polypedates leucomystax* (Gravenhorst, 1829)	LC
	Twin-spotted Tree Frog	*Rhacophorus bipunctatus* Ahl, 1927	LC
	Annandale's Tree Frog	*Chiromantis simus* (Annandale, 1915)	LC
	Baibung Small Treefrog	*Theloderma baibungense* (Jiang, Fei, & Huang, 2009)	DD
Dicroglossidae	Nepal Cricket Frog	*Minervarya nepalensis* (Dubois, 1975)	LC
	Pierre's Cricket Frog	*Minervarya pierrei* (Dubois, 1975)	LC
	Small Cricket Frog	*Minervarya syhadrensis* (Annandale, 1919)	LC
	Terai Cricket Frog	*Minervarya teraiensis* (Dubois, 1975)	LC
	Skittering Frog	*Euphlyctis cyanophlyctis* (Schneider, 1799)	LC
	Indian Bull Frog	*Hoplobatrachus tigerinus* (Daudin, 1802)	LC
	Littoral Bull Frog	*Hoplobatrachus litoralis* Hasan, Kuramoto, Islam, Alam, Khan, and Sumida, 2012	
	Khasi Wart Frog	*Limnonectes khasianus* (Anderson, 1871)	DD
Ranidae	Assam Hills Frog	*Clinotarsus alticola* (Boulenger, 1882)	LC
	Theobald's Ranid Frog	*Hylarana tytleri* (Theobald, 1868)	LC
	Bhamo Frog	*Humerana humeralis* (Boulenger, 1887)	LC
	Cope's Assam Frog	*Hydrophylax leptoglossa* (Cope, 1868)	LC
	Sengupta's Cascade Frog	*Amolops assamensis* (Sengupta, Hussain, Choudhury, Gogoi, Ahmed, & Choudhury, 2008)	DD
	Gerbil Stream Frog	*Amolops gerbillus* (Annandale, 1912)	LC
Ichthyophidae	Garo Hills Caecilian	*Ichthyophis garoensis* (Pillai & Ravichandran, 1999)	DD
	Manipur Moustached Ichthyophis	*Ichthyophis moustakius* Kamei et al. 2009	DD
	Gaiduwan's Chikila	*Chikila gaiduwani* Kamei, Gower, Wilkinson, & Biju, 2013	

forest which is in the vicinity of the biggest metropolis of northeastern India, the Guwahati City. The forest is under tremendous pressure from the anthropogenic activities such as stone mining, illegal felling of trees, and unsustainable non-timber forest products collection. Also, the busy concrete road connecting the forest with Meghalaya adds to the threats (Lahkar et al. 2010). The dynamite blast in the stone quarries is having a negative impact on its biodiversity (Purkayastha 2018). All these factors disturb the ecological functioning of the area.

Recent discovery of a new species of Bent-toed Gecko *Cyrtodactylus urbanus* from the fringes of Garbhanga (Purkayastha et al. 2020), new locality record for Yellow-throated Marten (Kakati et al. 2021) along with the findings of 254 species of butterflies, 29 species of amphibians, 64 species of reptiles, 307 species of birds and 31 species of mammals stress on the importance of the landscape in terms of its rich biodiversity. Garbhanga is also a favorable elephant habitat, supporting a good population, connected by corridors to Meghalaya (Borah et al. 2004).

Many species of different taxa groups in Garbhanga are of conservation concerns. 3% (3.2%) of all the recorded species were found to be threatened according to IUCN red list. Also 34% (34.5%) of the species are yet to be evaluated highlighting the huge gap in research

Table 3. Reptiles of Garbhanga, Assam, India.

Family	Common name	Scienific name	IUCN Red List status
Agamidae	Common Garden Lizard	*Calotes versicolor* (Daudin, 1802)	LC
	Khasi Hills Forest Lizard	*Calotes maria* Gray, 1845	LC
	Blue-throated Lizard	*Ptyctolaemus gularis* (Peters, 1864)	LC
	Spotted Gliding Lizard	*Draco maculatus* (Gray, 1845)	LC
	Smooth-Scaled Mountain Lizard	*Cristidorsa planidorsata* (Jerdon, 1870)	LC
Gekkonidae	Common House Gecko	*Hemidactylus frenatus* (Duméril & Bibron, 1836)	LC
	Brook's House Gecko	*Hemidactylus brookii* (Gray, 1845)	LC
	Garnot's House Gecko	*Hemidactylus garnotii* (Duméril & Bibron, 1836)	LC
	Flat-tailed House Gecko	*Hemidactylus platyurus* (Schneider, 1792)	LC
	Northern House Gecko	*Hemidactylus aquilonius* (McMahan & Zug, 2007)	LC
	Tokay Gecko	*Gekko gecko* (Linnaeus, 1758)	LC
	Assamese Day Gecko	*Cnemaspis assamensis* (Das & Sengupta, 2000)	VU
	Urban bent-toed Gecko	*Cyrtodactylus urbanus* Purkayastha, Das, Bohra, Bauer & Agarwal, 2020	
	Guwahati bent-toed Gecko	*Cyrtodactylus guwahatiensis* Agarwal, Mahony, Giri, Chaitanya & Bauer, 2018	DD
Lacertidae	Khasi Hill's Long-tailed Lizard	*Takydromus khasiensis* Boulenger, 1917	LC
Scincidae	Bronze Skink	*Eutropis macularia* (Blyth, 1853)	LC
	Many-lined Sun Skink	*Eutropis multifasciata* (Kuhl, 1820)	LC
	Spotted Forest Skink	*Sphenomorphus maculatus* (Blyth, 1853)	LC
	White-spotted Supple Skink	*Lygosoma albopunctata* (Gray, 1846)	LC
Varanidae	Bengal Monitor Lizard	*Varanus bengalensis* (Daudin, 1802)	NT
	Yellow monitor Lizard	*Varanus flavescens* (Gray, 1827)	EN
Typhlopidae	Brahminy Blindsnake	*Indotyphlops braminus* (Daudin, 1803)	LC
	Diard's Blindsnake	*Argyrophis diardii* (Schlegal, 1839)	LC
Pythonidae	Burmese Python	*Python bivittatus* (Kuhl, 1820)	VU
Colubridae	Rainbow Water Snake	*Enhydris enhydris* (Schneider, 1799)	LC
	Common Wolf Snake	*Lycodon aulicus* (Linnaeus, 1758)	LC
	Zaw's wolf Snake	*Lycodon zawi* Slowinski, Pawar, Win, Thin, Gyi, Oo, & Tun, 2001	LC
	Twin-spotted Wolf Snake	*Lycodon jara* (Shaw, 1802)	LC
	Rat Snake	*Ptyas mucosa* (Linnaeus, 1758)	LC
	Indo-Chinese RatSnake	*Ptyas korros* (Schlegal, 1837)	NT
	Heller's Red-necked Keelback	*Rhabdophis helleri* (Schmidt, 1925)	
	Himalayan Keelback	*Rhabdophis himalayanus* (Günther, 1864)	LC
	Painted Bronzeback	*Dendrelaphis proarchos* (Wall, 1909)	
	Blue Bronzeback	*Dendrelaphis cyanochloris* (Wall, 1921)	LC
	White-barred Kukri Snake	*Oligodon albocinctus* (Cantor, 1839)	LC
	Günther's Kukri Snake	*Oligodon cinereus* (Günther, 1864)	LC
	Cantor's Kukri Snake	*Oligodon cyclurus* (Cantor, 1839)	LC
	Gray's Kukri Snake	*Oligodon dorsalis* (Gray & Hardwicke, 1835)	LC
	Black-banded Trinket Snake	*Oreocryptophis porphyraceus* (Cantor, 1839)	LC
	Assam Snail-eater	*Pareas monticola* (Cantor, 1839)	LC
	Buff Striped Keelback	*Amphiesma stolatum* (Linnaeus, 1758)	LC
	Eastern Cat Snake	*Boiga gokool* (Gray, 1835)	LC
	Green Cat Snake	*Boiga cyanea* (Duméril et al. 1854)	LC
	Assamese Cat Snake	*Boiga quincunciata* (Wall, 1908)	LC
	Thai Cat Snake	*Boiga siamensis* (Nutaphand, 1971)	LC
	Checkered Keelback	*Fowlea piscator* (Schneider, 1799)	LC

Family	Common name	Scienific name	IUCN Red List status
	Common Mock Viper	*Psammodynastes pulverulentus* (Boie, 1827)	LC
	Copper-headed Trinket Snake	*Coelognathus radiates* (Schlegal, 1837)	LC
	Trinket Snake	*Coelognathus helena* (Daudin, 1803)	LC
	Laudankia Vine Snake	*Ahaetulla laudankia* Deepak, Narayanan, Sarkar, Dutta, & Mohapatra, 2019	LC
	Asian Vine Snake	*Ahaetulla prasina* (Boie, 1827)	LC
	Ornate Flying Snake	*Chrysopelea ornate* (Shaw, 1802)	LC
	Mock Cobra	*Pseudoxenodon macrops* (Blyth, 1855)	LC
Elapidae	Monocled Cobra	*Naja kaouthia* (Lesson, 1831)	LC
	King Cobra	*Ophiophagus hannah* (Cantor, 1836)	VU
	Banded Krait	*Bungarus fasciatus* (Schneider, 1801)	LC
	Lesser Black Krait	*Bungarus lividus* Cantor, 1839	LC
	Greater Black Krait	*Bungarus niger* Wall, 1908	LC
Viperidae	Salazar's Pit Viper	*Trimeresurus salazar* Mirza, Bhosale, Phansalkar, Sawant, Gowande, & Patel, 2020	
	Maya's Pit Viper	*Trimeresurus mayaae* Rathee, Purkayastha, Lalremsanga, Dalal, Biakzuala, Muansanga, & Mirza, 2022	
Trionychidae	Peacock Soft-shelled Turtle	*Nilssonia hurum* (Gray, 1831)	EN
	Indian Flap-shelled Turtle	*Lissemys punctata* (Bonnaterre, 1789)	VU
Geoemydidae	Indian Tent Turtle	*Pangshura tentoria* (Gray, 1834)	LC
	Spotted Pond Turtle	*Geoclemys hamiltonii* (Gray, 1831)	EN

and status evaluation of understudied species. This in turn also provides further research opportunities on the lesser- known species.

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Table 4. Birds of Garbhanga, Assam, India.

Family	Common name	Scientific name	IUCN Red List status
Accipitridae	Black Kite	*Milvus migrans* (Boddaert, 1783)	LC
	Pied Harrier	*Circus melanoleucos* (Pennant, 1769)	LC
	Crested Serpent-Eagle	*Spilornis cheela* (Latham, 1790)	LC
	Jerdon's Baza	*Aviceda jerdoni* (Blyth, 1842)	LC
	Black Baza	*Aviceda leuphotes* (Dumont, 1820)	LC
	Crested Goshawk	*Accipiter trivirgatus* (Temminck, 1824)	LC
	Oriental Honey-buzzard	*Pernis ptilorhynchus* (Temminck, 1821)	LC
	Shikra	*Accipiter badius* (Gmelin, 1788)	LC
	Long-legged Buzzard	*Buteo rufinus* (Cretzschmar, 1829)	LC
	Hen Harrier	*Circus cyaneus* (Linnaeus, 1766)	LC
	Eastern Marsh-Harrier	*Circus spilonotus* Kaup, 1847	LC
	Changeable Hawk-Eagle	*Nisaetus cirrhatus* Gmelin, *1788*	LC
	Himalayan Griffon	*Gyps himalayensis* Hume, 1869	NT
	Eurasian Sparrowhawk	*Accipiter nisus* Linnaeus, 1758	LC
	Black Eagle	*Ictinaetus malaiensis* Temminck, 1822)	LC
	White-rumped Vulture	*Gyps bengalensis* Gmelin, 1788	CR
	Greater Spotted Eagle	*Clanga clanga* (Pallas, 1811)	VU
	Black-winged Kite	*Elanus caeruleus* (Desfontaines, 1789)	LC
Acrocephalidae	Thick-billed Warbler	*Arundinax aedon* (Pallas, 1776)	LC
Aegithinidae	Common Iora	*Aegithina tiphia* Linnaeus, 1758	LC
Alaudidae	Bengal Bushlark	*Mirafra assamica* Horsfield, 1840	LC
Alcedinidae	White-throated Kingfisher	*Halcyon smyrnensis* (Linnaeus, 1758)	LC
	Common Kingfisher	*Alcedo atthis* (Linnaeus, 1758)	LC
	Ruddy Kingfisher	*Halcyon coromanda* (Latham, 1790)	LC
	Stork-billed Kingfisher	*Pelargopsis capensis* (Linnaeus, 1766)	LC
	Black-backed Dwarf-Kingfisher	*Ceyx erithaca* (Linnaeus, 1758)	LC
	Pied Kingfisher	*Ceryle rudis* (Linnaeus, 1758)	LC
	Blue-eared Kingfisher	*Alcedo meninting* Horsfield, 1821	LC
Anatidae	Cotton Pygmy-Goose	*Nettapus coromandelianus* Gmelin, 1789	LC
	Lesser Whistling-Duck	*Dendrocygna javanica* Horsfield, 1821	LC
Apodidae	Asian Palm-Swift	*Cypsiurus balasiensis* Gray, 1829	LC
	House Swift	*Apus nipalensis* (Hodgson, 1837)	LC
Ardeidae	Cattle Egret	*Bubulcus ibis* (Linnaeus, 1758)	LC
	Grey Heron	*Ardea cinerea* Linnaeus, 1758	LC
	Great Egret	*Ardea alba* Linnaeus, 1758	LC
	Indian Pond-Heron	*Ardeola grayii* (Sykes, 1832)	LC
	Intermediate Egret	*Ardea intermedia* Wagler, 1829	LC
	Purple Heron	*Ardea purpurea* Linnaeus, 1766	LC
	Little Egret	*Egretta garzetta* (Linnaeus, 1766)	LC
	Striated Heron	*Butorides striata* (Linnaeus, 1758)	LC
	Cinnamon Bittern	*Ixobrychus cinnamomeus* Gmelin, 1789	LC
	Malayan Night Heron	*Gorsachius melanolophus* (Raffles, 1822)	LC
Artamidae	Ashy Woodswallow	*Artamus fuscus* Vieillot, 1817	LC
Bucerotidae	Great Hornbill	*Buceros bicornis* Linnaeus, 1758	VU
	Oriental Pied-Hornbill	*Anthracoceros albirostris* (Shaw, 1808)	LC
Campephagidae	Black-winged Cuckooshrike	*Lalage melaschistos* (Hodgson, 1836)	LC
	Large Cuckooshrike	*Coracina macei* (Lesson, 1831)	LC
	Long-tailed Minivet	*Pericrocotus ethologus* Bangs & Phillips, 1914	LC
	Scarlet Minivet	*Pericrocotus speciosus* (Latham, 1790)	LC
	Small Minivet	*Pericrocotus cinnamomeus* (Linnaeus, 1766)	LC
	Short-billed Minivet	*Pericrocotus brevirostris* (Vigors, 1831)	LC

Family	Common name	Scientific name	IUCN Red List status
	Rosy Minivet	*Pericrocotus roseus* (Vieillot, 1818)	LC
Caprimulgidae	Large-tailed Nightjar	*Caprimulgus macrurus* Horsfield, 1821	LC
	Savanna Nightjar	*Caprimulgus affinis* Horsfield, 1821	LC
Charadriidae	Red-wattled Lapwing	*Vanellus indicus* (Boddaert, 1783)	LC
Chloropseidae	Golden-fronted Leafbird	*Chloropsis aurifrons* (Temminck, 1829)	LC
	Orange-bellied Leafbird	*Chloropsis hardwickii* Jardine & Selby, 1830	LC
	Blue-winged Leafbird	*Chloropsis cochinchinensis* Gmelin, 1789	LC
Ciconiidae	Lesser Adjutant	*Leptoptilos javanicus* (Horsfield, 1821)	VU
	Asian Openbill	*Anastomus oscitans* (Boddaert, 1783)	LC
	Greater Adjutant	*Leptoptilos dubius* Gmelin, 1789	EN
Cisticolidae	Common Tailorbird	*Orthotomus sutorius* (Pennant, 1769)	LC
	Rufescent Prinia	*Prinia rufescens* Blyth, 1847	LC
	Dark-necked Tailorbird	*Orthotomus atrogularis* Temminck, 1836	LC
	Gray-breasted Prinia	*Prinia hodgsonii* Blyth, 1844	LC
	Plain Prinia	*Prinia inornata* Sykes, 1832	LC
Columbidae	Oriental Turtle-Dove	*Streptopelia orientalis* (Latham, 1790)	LC
	Spotted Dove	*Streptopelia chinensis* (Scopoli, 1786)	LC
	Yellow-footed Green-Pigeon	*Treron phoenicopterus* (Latham, 1790)	LC
	Asian Emerald Dove	*Chalcophaps indica* (Linnaeus, 1758)	LC
	Wedge-tailed Green-Pigeon	*Treron sphenurus* (Vigors, 1832)	LC
	Thick-billed Green-Pigeon	*Treron curvirostra* Gmelin, 1789	LC
	Red Collared-Dove	*Streptopelia tranquebarica* Hermann, 1804	LC
	Rock Pigeon	*Columba livia* Gmelin, 1789	LC
	Ashy-headed Green-Pigeon	*Treron phayrei* (Blyth, 1862)	NT
	Orange-breasted Green-Pigeon	*Treron bicinctus* (Jerdon, 1840)	LC
	Green Imperial Pigeon	*Ducula aenea* (Linnaeus, 1766)	LC
	Pin-tailed Green-Pigeon	*Treron apicauda* Blyth, 1846	LC
	Eurasian Collared-Dove	*Streptopelia decaocto* Frivaldszky, 1838	LC
Coraciidae	Indochinese Roller	*Coracias affinis* McClelland, 1839	LC
	Dollarbird	*Eurystomus orientalis* (Linnaeus, 1766)	LC
Corvidae	House Crow	*Corvus splendens* Vieillot, 1817	LC
	Large-billed Crow	*Corvus macrorhynchos* Wagler, 1827	LC
	Common Green-Magpie	*Cissa chinensis* (Boddaert, 1783)	LC
	Rufous Treepie	*Dendrocitta vagabunda* (Latham, 1790)	LC
	Grey Treepie	*Dendrocitta formosae* Swinhoe, 1863	LC
Cuculidae	Asian Koel	*Eudynamys scolopaceus* (Linnaeus, 1758)	LC
	Green-billed Malkoha	*Phaenicophaeus tristis* (Lesson, 1830)	LC
	Indian Cuckoo	*Cuculus micropterus* Gould, 1838	LC
	Banded Bay Cuckoo	*Cacomantis sonneratii* (Latham, 1790)	LC
	Greater Coucal	*Centropus sinensis* (Stephens, 1815)	LC
	Asian Emerald Cuckoo	*Chrysococcyx maculatus* Gmelin, 1788	LC
	Lesser Coucal	*Centropus bengalensis* Gmelin, 1788	LC
	Violet Cuckoo	*Chrysococcyx xanthorhynchus* Horsfield, 1821	LC
	Square-tailed Drongo-Cuckoo	*Surniculus lugubris* Horsfield, 1821	LC
	Common Hawk-Cuckoo	*Hierococcyx varius* Vahl, 1797	LC
	Common Cuckoo	*Cuculus canorus* Linnaeus, 1758	LC
	Plaintive Cuckoo	*Cacomantis merulinus* Scopoli, 1786	LC
	Chestnut-winged Cuckoo	*Clamator coromandus* Linnaeus, 1766	LC
	Lesser Cuckoo	*Cuculus poliocephalus* Latham, 1790	LC
	Large Hawk-Cuckoo	*Hierococcyx sparverioides* Vigors, 1832	LC
	Hodgson's Hawk-Cuckoo	*Hierococcyx nisicolor* (Blyth, 1843)	LC
	Pied Cuckoo	*Clamator jacobinus* Boddaert, 1783	LC

Family	Common name	Scientific name	IUCN Red List status
Dicaeidae	Plain Flowerpecker	*Dicaeum minullum* Swinhoe, 1870	LC
	Scarlet-backed Flowerpecker	*Dicaeum cruentatum (*Linnaeus, 1758)	LC
	Yellow-vented Flowerpecker	*Dicaeum chrysorrheum* Temminck, 1829	LC
Dicruridae	Black Drongo	*Dicrurus macrocercus* Vieillot, 1817	LC
	Bronzed Drongo	*Dicrurus aeneus* Vieillot, 1817	LC
	Greater Racket-tailed Drongo	*Dicrurus paradiseus* (Linnaeus, 1766)	LC
	Hair-crested Drongo	*Dicrurus hottentottus* (Linnaeus, 1766)	LC
	Lesser Racket-tailed Drongo	*Dicrurus remifer* (Temminck, 1823)	LC
	Ashy Drongo	*Dicrurus leucophaeus* Vieillot, 1817	LC
Estrildidae	Scaly-breasted Munia	*Lonchura punctulata* Linnaeus, 1758	LC
	White-rumped Munia	*Lonchura striata* Linnaeus, 1766	LC
Eurylaimidae	Long-tailed Broadbill	*Psarisomus dalhousiae* Jameson, 1835	LC
	Silver-breasted Broadbill	*Serilophus lunatus* Gould, 1834	LC
Falconidae	Eurasian Kestrel	*Falco tinnunculus* Linnaeus, 1758	LC
	Collared Falconet	*Microhierax caerulescens* Linnaeus, 1758	LC
Fringillidae	Common Rosefinch	*Carpodacus erythrinus* (Pallas, 1770)	LC
Hirundinidae	Striated Swallow	*Cecropis striolata* (Schlegel, 1844)	NA
	Barn Swallow	*Hirundo rustica* Linnaeus, 1758	LC
	Red-rumped Swallow	*Cecropis daurica* (Laxmann, 1769)	LC
	Nepal House-Martin	*Delichon nipalense* Moore, 1854	LC
Irenidae	Asian Fairy-Bluebird	*Irena puella* (Latham, 1790)	LC
Jacanidae	Bronze-winged Jacana	*Metopidius indicus* (Latham, 1790)	LC
Laniidae	Grey-backed Shrike	*Lanius tephronotus* (Vigors, 1831)	LC
	Long-tailed Shrike	*Lanius schach* Linnaeus, 1758	LC
	Brown Shrike	*Lanius cristatus* Linnaeus, 1758	LC
Leiothrichidae	Greater Necklaced Laughingthrush	*Pterorhinus pectoralis* Gould, 1836	LC
	Lesser Necklaced Laughingthrush	*Garrulax monileger* (Hodgson, 1836)	LC
	Jungle Babbler	*Argya striata* (Dumont, 1823)	LC
	Nepal Fulvetta	*Alcippe nipalensis* (Hodgson, 1837)	LC
	Blue-winged Minla	*Actinodura cyanouroptera* (Hodgson, 1837)	LC
	Striated Babbler	*Argya earlei* (Blyth, 1844)	LC
	White-crested Laughingthrush	*Garrulax leucolophus* (Hardwicke, 1816)	LC
Locustellidae	Striated Grassbird	*Megalurus palustris* Horsfield, 1821	LC
	Baikal Bush Warbler	*Locustella davidi* (La Touche, 1923)	LC
	Spotted Bush Warbler	*Locustella thoracica* (Blyth, 1845)	LC
Megalaimidae	Blue-throated Barbet	*Psilopogon asiaticus* (Latham, 1790)	LC
	Coppersmith Barbet	*Psilopogon haemacephalus* Muller, 1776	LC
	Great Barbet	*Psilopogon virens* (Boddaert, 1783)	LC
	Lineated Barbet	*Psilopogon lineatus* (Vieillot, 1816)	LC
	Blue-eared Barbet	*Psilopogon duvaucelii* Lesson, 1830	LC
Meropidae	Chestnut-headed Bee-eater	*Merops leschenaulti* Vieillot, 1817	LC
	Green Bee-eater	*Merops orientalis* Latham, 1801	LC
	Blue-bearded Bee-eater	*Nyctyornis athertoni* Jardine & Selby, 1828	LC
	Blue-tailed Bee-eater	*Merops philippinus* Linnaeus, 1767	LC
Monarchidae	Black-naped Monarch	*Hypothymis azurea* (Boddaert, 1783)	LC
	Blyth's Paradise-Flycatcher	*Terpsiphone affinis* (Blyth, 1846)	LC
Motacillidae	Paddyfield Pipit	*Anthus rufulus* Vieillot, 1818	LC
	Olive-backed Pipit	*Anthus hodgsoni* Richmond, 1907	LC
	Gray Wagtail	*Motacilla cinerea* Tunstall, 1771	LC
	White Wagtail	*Motacilla alba* Linnaeus, 1758	LC
	White-browed Wagtail	*Motacilla maderaspatensis* Gmelin, 1789	LC
	Forest Wagtail	*Dendronanthus indicus* Gmelin, 1789	LC

Family	Common name	Scientific name	IUCN Red List status
	Eastern Yellow Wagtail	*Motacilla tschutschensis* Gmelin, 1789	LC
	Citrine Wagtail	*Motacilla citreola* Pallas, 1776	LC
Muscicapidae	Blue Whistling-Thrush	*Myophonus caeruleus* (Scopoli, 1786)	LC
	White-rumped Shama	*Copsychus malabaricus* (Scopoli, 1786)	LC
	Oriental Magpie-Robin	*Copsychus saularis* Linnaeus, 1758	LC
	Taiga Flycatcher	*Ficedula albicilla* (Pallas, 1811)	LC
	Black-backed Forktail	*Enicurus immaculatus* (Hodgson, 1836)	LC
	Pale-chinned Blue Flycatcher	*Cyornis poliogenys* Brooks, 1880	LC
	Small Niltava	*Niltava macgrigoriae* Burton, 1836	LC
	Snowy-browed Flycatcher	*Ficedula hyperythra* (Blyth, 1843)	LC
	Dark-sided Flycatcher	*Muscicapa sibirica* Gmelin, 1789	LC
	Lesser Shortwing	*Brachypteryx leucophris* (Temminck, 1828)	LC
	Pygmy Flycatcher	*Ficedula hodgsoni* Moore, 1854	LC
	Grey Bushchat	*Saxicola ferreus* Gray & Gray, 1847	LC
	White-tailed Robin	*Myiomela leucura* (Hodgson, 1845)	LC
	Brown-breasted Flycatcher	*Muscicapa muttui* Layard, 1854)	LC
	Blue-throated Flycatcher	*Cyornis rubeculoides* (Vigors, 1831)	LC
	Little Pied Flycatcher	*Ficedula westermanni* (Sharpe, 1888)	LC
	Pale Blue Flycatcher	*Cyornis unicolor* Blyth, 1843	LC
	Asian Brown Flycatcher	*Muscicapa dauurica* Pallas, 1811	LC
	Blue Rock-Thrush	*Monticola solitaries* (Linnaeus, 1758)	LC
	Slaty-backed Forktail	*Enicurus schistaceus* (Hodgson, 1836)	LC
	Black Redstart	*Phoenicurus ochruros* Gmelin, 1774	LC
	Verditer Flycatcher	*Eumyias thalassinus* (Swainson, 1838)	LC
	Plumbeous Redstart	*Phoenicurus fuliginosus* (Vigors, 1831)	LC
	White-capped Redstart	*Phoenicurus leucocephalus* (Vigors, 1831)	LC
	Spotted Forktail	*Enicurus maculatus* Vigors, 1831	LC
	Slaty-blue Flycatcher	*Ficedula tricolor* (Hodgson, 1845)	LC
	Chestnut-bellied Rock-Thrush	*Monticola rufiventris* (Jardine & Selby, 1833)	LC
	Rufous-gorgeted Flycatcher	*Ficedula strophiata* (Hodgson, 1837)	LC
	Rufous-bellied Niltava	*Niltava sundara* Hodgson, 1837	LC
	Siberian Rubythroat	*Calliope calliope* (Pallas, 1776)	LC
	White-crowned Forktail	*Enicurus leschenaulti* (Vieillot, 1818)	LC
	Large Niltava	*Niltava grandis* (Blyth, 1842)	LC
	Daurian Redstart	*Phoenicurus auroreus* (Pallas, 1776)	LC
	Sapphire Flycatcher	*Ficedula sapphire* (Blyth, 1843)	LC
Nectariniidae	Crimson Sunbird	*Aethopyga siparaja* (Raffles, 1822)	LC
	Ruby-cheeked Sunbird	*Chalcoparia singalensis* Gmelin, 1789	LC
	Streaked Spiderhunter	*Arachnothera magna* (Hodgson, 1836)	LC
	Little Spiderhunter	*Arachnothera longirostra* (Latham, 1790)	LC
	Purple Sunbird	*Cinnyris asiaticus* (Latham, 1790)	LC
	Black-throated Sunbird	*Aethopyga saturate* (Hodgson, 1836)	LC
Oriolidae	Black-hooded Oriole	*Oriolus xanthornus* (Linnaeus, 1758)	LC
	Maroon Oriole	*Oriolus traillii* (Vigors, 1832)	LC
	Black-naped Oriole	*Oriolus chinensis* Linnaeus, 1766	LC
Paridae	Cinereous Tit	*Parus cinereus* Vieillot, 1818	LC
	Fire-capped Tit	*Cephalopyrus flammiceps* Burton, 1836	LC
	Sultan Tit	*Melanochlora sultanea* (Hodgson, 1837)	LC
Passeridae	Eurasian Tree Sparrow	*Passer montanus* (Linnaeus, 1758)	LC
	House Sparrow	*Passer domesticus* (Linnaeus, 1758)	LC
	Russet Sparrow	*Passer cinnamomeus* (Gould, 1836)	LC
Pellorneidae	Puff-throated Babbler	*Pellorneum ruficeps* Swainson, 1832	LC

Family	Common name	Scientific name	IUCN Red List status
	Abbott's Babbler	*Malacocincla abbotti* Blyth, 1845	LC
	Buff-breasted Babbler	*Pellorneum tickelli* Blyth, 1859	LC
Phalacrocoracidae	Little Cormorant	*Microcarbo niger* (Vieillot, 1817)	LC
Phasianidae	Kalij Pheasant	*Lophura leucomelanos* (Latham, 1790)	LC
	Red Junglefowl	*Gallus gallus* (Linnaeus, 1758)	LC
	White-cheeked Partridge	*Arborophila atrogularis* (Blyth, 1849)	NT
	Black Francolin	*Francolinus francolinus* (Linnaeus, 1766)	LC
	Gray Peacock-Pheasant	*Polyplectron bicalcaratum* (Linnaeus, 1758)	LC
Phylloscopidae	Blyth's Leaf Warbler	*Phylloscopus reguloides* (Blyth, 1842)	LC
	Whistler's Warbler	*Phylloscopus whistleri* Ticehurst, 1925	LC
	White-spectacled Warbler	*Phylloscopus intermedius* Moore, 1854	LC
	Yellow-browed Warbler	*Phylloscopus inornatus* (Blyth, 1842)	LC
	Lemon-rumped Warbler	*Phylloscopus chloronotus* Gray & Gray, 1847	LC
	Tickell's Leaf Warbler	*Phylloscopus affinis* (Tickell, 1833)	LC
	Yellow-vented Warbler	*Phylloscopus cantator (*Tickell, 1833)	LC
	Dusky Warbler	*Phylloscopus fuscatus* (Blyth, 1842)	LC
	Greenish Warbler	*Phylloscopus trochiloides* (Sundevall, 1837)	LC
	Hume's Warbler	*Phylloscopus humei* Brooks, 1878	LC
	Gray-hooded Warbler	*Phylloscopus xanthoschistos* Gray & Gray, 1847	LC
	Green-crowned Warbler	*Phylloscopus burkii* (Burton, 1836*)*	LC
	Ashy-throated Warbler	*Phylloscopus maculipennis* Blyth, 1867	LC
	Gray-cheeked Warbler	*Phylloscopus poliogenys* (Blyth, 1847)	LC
	Chestnut-crowned Warbler	*Phylloscopus castaniceps* (Hodgson, 1845)	LC
Picidae	Grey-capped Pygmy Woodpecker	*Yungipicus canicapillus* (Blyth, 1845)	NA
	Grey-headed Woodpecker	*Picus canus* Gmelin, 1788	LC
	Lesser Yellow naped Woodpecker	*Picus chlorolophus* Vieillot, 1818	LC
	Greater Flameback	*Chrysocolaptes guttacristatus* (Tickell, 1833)	LC
	Rufous Woodpecker	*Micropternus brachyurus* (Vieillot, 1818)	LC
	White-browed Piculet	*Sasia ochracea* Hodgson, 1837	LC
	Black-rumped Flameback	*Dinopium benghalense* (Linnaeus, 1758)	LC
	Speckled Piculet	*Picumnus innominatus* Burton, 1836	LC
	Pale-headed Woodpecker	*Gecinulus grantia* (Horsfield, 1840)	LC
	Greater Yellownape	*Chrysophlegma flavinucha* Gould, 1834	LC
	Streak-throated Woodpecker	*Picus xanthopygaeus* Gray & Gray, 1846	LC
	Fulvous-breasted Woodpecker	*Dendrocopos macei* (Vieillot, 1818)	LC
	Great Slaty Woodpecker	*Mulleripicus pulverulentus* (Temminck, 1826)	VU
	Bay Woodpecker	*Blythipicus pyrrhotis* (Hodgson, 1837)	LC
Pittidae	Hooded Pitta	*Pitta sordida* Muller, 1776	LC
	Blue-naped Pitta	*Hydrornis nipalensis* Hodgson, 1837	LC
Ploceidae	Baya Weaver	*Ploceus philippinus* Linnaeus, 1766	LC
Pnoepygidae	Pygmy Cupwing	*Pnoepyga pusilla* Hodgson, 1845	LC
Psittaculidae	Red-breasted Parakeet	*Psittacula alexandri* (Linnaeus, 1758)	NT
	Rose-ringed Parakeet	*Psittacula krameri* (Scopoli, 1769)	LC
	Alexandrine Parakeet	*Psittacula eupatria* (Linnaeus, 1766)	NT
Pycnonotidae	Red-vented Bulbul	*Pycnonotus cafer* (Linnaeus, 1766)	LC
	Ashy Bulbul	*Hemixos flavala* Blyth, 1845	LC
	Black Bulbul	*Hypsipetes leucocephalus* Gmelin, 1789	LC
	Black-crested Bulbul	*Rubigula flaviventris* (Tickell, 1833)	LC
	White-throated Bulbul	*Alophoixus flaveolus* (Gould, 1836)	LC
	Red-whiskered Bulbul	*Pycnonotus jocosus* (Linnaeus, 1758)	LC
	Striated Bulbul	*Pycnonotus striatus* (Blyth, 1842)	LC
Rallidae	Gray-headed Swamphen	*Porphyrio poliocephalus* (Latham, 1801)	LC

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	White-breasted Waterhen	*Amaurornis phoenicurus* (Pennant, 1769)	LC
	Brown Crake	*Zapornia akool* (Sykes, 1832)	LC
	Black-tailed Crake	*Zapornia bicolor* (Walden, 1872)	LC
Recurvirostridae	Black-winged Stilt	*Himantopus himantopus* (Linnaeus, 1758)	LC
Rhipiduridae	White-throated Fantail	*Rhipidura albicollis* (Vieillot, 1818)	LC
Scolopacidae	Marsh Sandpiper	*Tringa stagnatilis* (Bechstein, 1803)	LC
	Green Sandpiper	*Tringa ochropus* Linnaeus, 1758	LC
Scotocercidae	Yellow-bellied Warbler	*Abroscopus superciliaris* (Blyth, 1859)	LC
	Gray-bellied Tesia	*Tesia cyaniventer* Hodgson, 1837	LC
	Mountain Tailorbird	*Phyllergates cucullatus* (Temminck, 1836)	LC
Sittidae	Velvet-fronted Nuthatch	*Sitta frontalis* Swainson, 1820	LC
	Chestnut-bellied Nuthatch	*Sitta cinnamoventris* Blyth, 1842	LC
Stenostiridae	Grey-headed Canary-Flycatcher	*Culicicapa ceylonensis* (Swainson, 1820)	LC
Strigidae	Asian Barred Owlet	*Glaucidium cuculoides* (Vigors, 1831)	LC
	Spot-bellied Eagle-Owl	*Bubo nipalensis* Hodgson, 1836	LC
	Oriental Scops-Owl	*Otus sunia* (Hodgson, 1836)	LC
	Collared Owlet	*Taenioptynx brodiei* Burton, 1836	LC
	Spotted Owlet	*Athene brama* (Temminck, 1821)	LC
	Brown Boobook	*Ninox scutulata* (Raffles, 1822)	LC
	Collared Scops Owl	*Otus lettia* (Hodgson, 1836)	LC
	Mountain Scops Owl	*Otus spilocephalus* (Blyth, 1846)	LC
	Brown Wood Owl	*Strix leptogrammica* Temminck, 1832	LC
Sturnidae	Asian Pied Starling	*Gracupica contra* (Linnaeus, 1758)	LC
	Chestnut-tailed Starling	*Sturnia malabarica* Gmelin, 1789	LC
	Common Hill Myna	*Gracula religiosa* Linnaeus, 1758	LC
	Common Myna	*Acridotheres tristis* (Linnaeus, 1766)	LC
	Jungle Myna	*Acridotheres fuscus* (Wagler, 1827)	LC
	Great Myna	*Acridotheres grandis* Moore, 1858	LC
	Spot-winged Starling	*Saroglossa spilopterus* (Vigors, 1831)	LC
Timaliidae	Rufous-capped Babbler	*Cyanoderma ruficeps,* (Blyth, 1847)	LC
	Pin-striped Tit-Babbler	*Mixornis gularis* (Horsfield, 1822)	LC
	White-browed Scimitar-Babbler	*Pomatorhinus schisticeps* Hodgson, 1836	LC
	Gray-throated Babbler	*Stachyris nigriceps* Blyth, 1844	LC
	Buff-chested Babbler	*Cyanoderma ambiguum* (Harington, 1915)	NA
	Large Scimitar-Babbler	*Erythrogenys hypoleucos (*Blyth, 1844)	LC
Trogonidae	Red-headed Trogon	*Harpactes erythrocephalus* (Gould, 1834)	LC
Turdidae	Eyebrowed Thrush	*Turdus obscurus* Gmelin, 1789	LC
	Gray-winged Blackbird	*Turdus boulboul* (Latham, 1790)	LC
	Orange-headed Thrush	*Geokichla citrina* (Latham, 1790)	LC
	Red-throated Thrush	*Turdus ruficollis* Pallas, 1776	LC
Tytonidae	Oriental Bay-Owl	*Phodilus badius* (Horsfield, 1821)	LC
Upupidae	Eurasian Hoopoe	*Upupa epops* Linnaeus, 1758	LC
Vangidae	Common Woodshrike	*Tephrodornis pondicerianus* Gmelin, 1789	LC
	Large Woodshrike	*Tephrodornis virgatus* Temminck, 1824	LC
	Bar-winged Flycatcher-shrike	*Hemipus picatus* (Sykes, 1832)	LC
Vireonidae	White-bellied Erpornis	*Erpornis zantholeuca* Blyth, 1844	LC
Zosteropidae	Oriental White-eye	*Zosterops palpebrosus* (Temminck, 1824)	LC
	Whiskered Yuhina	*Yuhina flavicollis* Hodgson, 1836	LC

Table 5. Mammals of Garbhanga, Assam, India.

Family	Common name	Scienific name	IUCN Red List status
Cercopithecidae	Capped Langur	*Trachypithecus pileatus* (Blyth, 1843)	VU
	Pig-tailed Macaque	*Macaca leonina* (Blyth, 1863)	NT
	Rhesus Macaque	*Macaca mulatta* (Zimmermann, 1780)	LC
Hylobatidae	Western Hoolock Gibbon	*Hoolock hoolock* (Harlan, 1834)	VU
Lorisidae	Bengal Slow Loris	*Nycticebus bengalensis* (Lacépède, 1800)	EN
Elephantidae	Asiatic Elephant	*Elephas maximus* Linnaeus, 1758	EN
Bovidae	Gaur	*Bos gaurus* Smith, 1827	VU
Suidae	Wild Boar	*Sus scrofa* Linnaeus, 1758	LC
Cervidae	Barking Deer	*Muntiacus muntjak* (Zimmermann, 1780)	LC
Felidae	Leopard	*Panthera pardus* (Linnaeus, 1758)	VU
	Jungle Cat	*Felis chaus* Schreber, 1777	LC
	Leopard Cat	*Prionailurus bengalensis* (Kerr, 1792)	LC
Canidae	Golden Jackal	*Canis aureus* Linnaeus, 1758	LC
Herpestidae	Indian Mongoose	*Herpestes javanicus* (Hilaire, 1818)	LC
	Crab-eating Mongoose	*Herpestes urva* (Hodgson, 1836)	LC
	Small Indian Civet	*Viverricula indica* (Hilaire, 1803)	LC
	Common Palm Civet	*Paradoxurus hermaphroditus* (Pallas, 1777)	LC
Mustelidae	Smooth-coated Otter	*Lutrogale perspicillata* (Hilaire, 1826)	VU
	Yellow-throated Marten	*Martes flavigula* (Boddaert, 1785)	LC
Leporidae	Indian Hare	*Lepus nigricollis* Cuvier, 1823	LC
Manidae	Chinese Pangolin	*Manis pentadactyla* Linnaeus, 1758	CR
Soricidae	Asian House Shrew	*Suncus murinus* Linnaeus, 1766	LC
Hystricidae	Asiatic Brush-tailed Porcupine	*Atherurus macrourus* Linnaeus, 1758	LC
Sciuridae	Hoary-bellied Squirrel	*Callosciurus pygerythrus* (Hilaire, 1832)	LC
	Particolored Flying Squirrel	*Hylopetes alboniger* (Hodgson, 1836)	LC
Muridae	Black Rat	*Rattus rattus* (Linnaeus, 1758)	LC
	House mouse	*Mus musculus* Linnaeus, 1758	LC
	Lesser Bandicoot Rat	*Bandicota bengalensis* (Gray, 1835)	LC
Pteropodidae	Indian Flying Fox	*Pteropus giganteus* (Brünnich, 1782)	LC
	Short-nosed Fruit Bat	*Cynopterus sphinx* (Vahl, 1797)	LC
Vespertilionidae	Indian Pipistrelle	*Pipistrellus coromandra* (Gray, 1838)	LC

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COMMUNICATION

The avian diversity of Chemmattamvayal Wetlands and adjacent areas of Kasaragod District, Kerala, India

Sreehari K. Mohan [1], R. Anjitha [2] & K. Maxim Rodrigues [3]

[1] Rebuild Kerala Development Programme, Forest Headquarters, Vazhuthakkad, Thiruvananthapuram, Kerala 695014, India.
[2] Nambisans Compound, Ramdas Nagar, Kudlu, Kasaragod, Kerala 671124, India
[3] Kasaragod Birders, Kasaragod, Kerala, India, 671121
[1] sreeharikmohan007@gmail.com (corresponding author), [2] anjitha896@gmail.com, [3] maxim.rodrigus@gmail.com

Abstract: The avian diversity of Chemmattamvayal Wetlands and adjacent areas, in Kasaragod District, Kerala State, was recorded from December 2014 to March 2018. The methodology followed was mainly incidental observations using binoculars. Findings presented here are also based on the data collected from eBird, a citizen science based online platform. A total of 145 bird species, belonging to 17 orders and 50 families were recorded during the study. Among them, 42 species were winter migrants and 97 were seen throughout the year. The highest number of birds were recorded during the month of January and the lowest in June. The present work gains importance as a literature on the avian fauna of the district. White-throated Kingfisher *Halcyon smyrnensis*, Indian Pond Heron *Ardeola grayii*, and Spotted Dove *Spilopelia chinensis* were recorded highest in terms of relative abundance. The importance of these wetlands and adjacent areas as the stepping stone for trans-continental migrants is discussed.

Keywords: Bird diversity, checklist of birds, relative abundance, guild analysis.

Editor: Anonymity requested. **Date of publication:** 26 April 2023 (online & print)

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Author details: Sreehari K. Mohan is a wildlife biologist who completed his masters in forestry with specialization in wildlife science under the guidance of Dr. P.O. Nameer from Kerala Agricultural University, Thrissur. His interest lies in studying the ecology of mammals, trees, and birds. Anjitha R. is a research enthusiast with an endless passion for zoology and wildlife conservation. Being a Kasaragod birder, she has a history of active participation in the Bird Atlas survey, environmental activities, and as the editor of a nature conservation magazine. She obtained her B.Sc. in Zoology from Kannur University and M.Sc. in Animal Science from Central University of Kerala. Maxim Rodrigues, K. is an avid bird watcher from Kasaragod and founder of Kasaragod Birders team, who works on wildlife studies and conservation mainly through birds in his home district in Kasaragod through citizen science. He obtained his B.Sc. in Geography from Kannur University and M.Sc. in Marine Geology from Mangalore University.

Author contributions: SKM has contributed in field data collection, writing of manuscript, preparation of diagrams, mapping the study area, and detailed analysis of the collected data. AR has contributed in consolidation of data, preparation of checklists, editing the manuscript, proofreading, and referencing. MRK has contributed in field data collection, editing the manuscript, and analysis of the collected data.

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INTRODUCTION

Wetlands are beautiful landscapes. They are important habitats for fishes, amphibians, insects, reptiles, birds, and other wildlife (Hosetti 2002). Wetland ecosystems occur in places where precipitation exceeds the rate of evapotranspiration leaving behind an accumulated water surplus (Mitsch & Gosselink 1993). About one-third of India's land area falls under this category, and wetland systems are, thus, common throughout the country (Hosetti 2002).

Ecologically, wetland systems are important ecotones, transitions between open waters and land, having a definite structure and function to perform specific ecological roles (Mahajan et al. 1981a,b; Mahajan 1988). They are productive areas and need to be treated as ecological treasure houses. The hydrology of the landscapes influences and changes the physiochemical environment, which in turn, shapes the biotic communities that are found in here (Mitsch et al. 2009). Lal (2008) opined that to maintain the atmospheric carbon cycle, restoration of wetlands around the world is crucial.

The major objective of the Ramsar Convention is to conserve the global degradation of wetlands through sensible use and sustainable management (Roy et al. 2022). During the Ramsar Convention, it was demonstrated that wetlands were the most fertile waterbodies required for migratory birds and other aquatic biota (Uttangi 2001). Roy et al. (2022) emphasized the importance of Ramsar sites as social-ecological systems that focuses on socio-political, cultural and economic elements that induces biotic and abiotic features to recover. The convention also prescribed the conservation of wetlands as waterfowl habitats (Uttangi 2001). As of now, Kerala has three Ramsar sites namely Vembanad-Kol Wetland, Sasthamkotta Lake, and Ashtamudi Wetland (Ramsar Sites information Service 2023).

Since 1953, studies have documented avian fauna in the wetlands of Kerala and adjacent areas. Nair (1994) studied birds of Aakkulam-Veli back waters. Sivaperuman & Jayson (2000) and Jayson (2002) documented the avian diversity in Kole wetlands, Thrissur. Kumar (2006) made a checklist of avifauna of the Bharathapuzha River Basin, Kerala. Narayanan et al. (2011) documented ornitho-fauna and the importance of its conservation in the Kuttanad Wetland. Recently, Chandran et al. (2023) updated the checklist of birds of Kerala. Apart from the studies on avian diversity, more comprehensive species studies were also conducted in many parts of Kerala. Ravindran (1993) documented the breeding of Purple Swamphen *Porphyrio porphyrio* in the Kole lands of Kerala, followed by Menon (2004) evaluating the ecology of this species. Narayanan et al. (2006) studied the nesting behaviour of Great Cormorant *Phalacrocorax carbo*. In this present study, an attempt has been made to document the diversity of birds in the wetlands of Chemmattamvayal and adjacent areas.

MATERIALS AND METHODS

Study area

Chemmattamvayal and adjacent wetland areas are located 4 km from Kanhangad, Kasaragod District, Kerala (Figure 1, Image 1). It lies in between 12.28°–12.32° N & 75.10°–75.12° E and is located very close to the Kariangodu River. The wetland has a total area of 330.24 ha (825.6 acres) and the adjacent habitat includes paddy fields, freshwater marshes, ponds, backyards, plantations of coconut, arecanut, plantain and vegetable fields. Major habitats in this region include non-tidal, freshwater systems dominated by grasses, sedges, and other freshwater emergent hydrophytes (Image 2a,b,c). The average temperature in summer is 35°C while the average winter temperature is around 20°C. The area receives both south-west and north-east monsoons, however, the south-west monsoon tends to dominate. The area falls under the tropical monsoon climate (Köppen 1936).

Methods

The study was conducted between December 2014 to March 2018. Regular surveys were conducted by establishing fixed transects through different habitats across the study area. Birds were observed in the morning at 0630–0930 h and in the evening at 1600–1800 h using 8 x 42 Bushnell and 10 x 50 Olympus binoculars. Opportunistic records were also collected during other times of the day. Records were collected as multiple 15-minutes checklists and all the birds observed in a span of 15 minutes were counted as one checklist. Records included species of birds, number of individuals, habitat types, and other habitat & behavioural notes including the breeding observations, if any.

Wherever possible, observations were supplemented with photographs. In most cases, observations were recorded and uploaded to the online platform 'eBird'.

The birds were identified with the help of field guides (Neelakandan et al. 1993; Sashikumar et al. 2011; Rasmussen & Anderton 2012; Grimmett et al. 2014). The

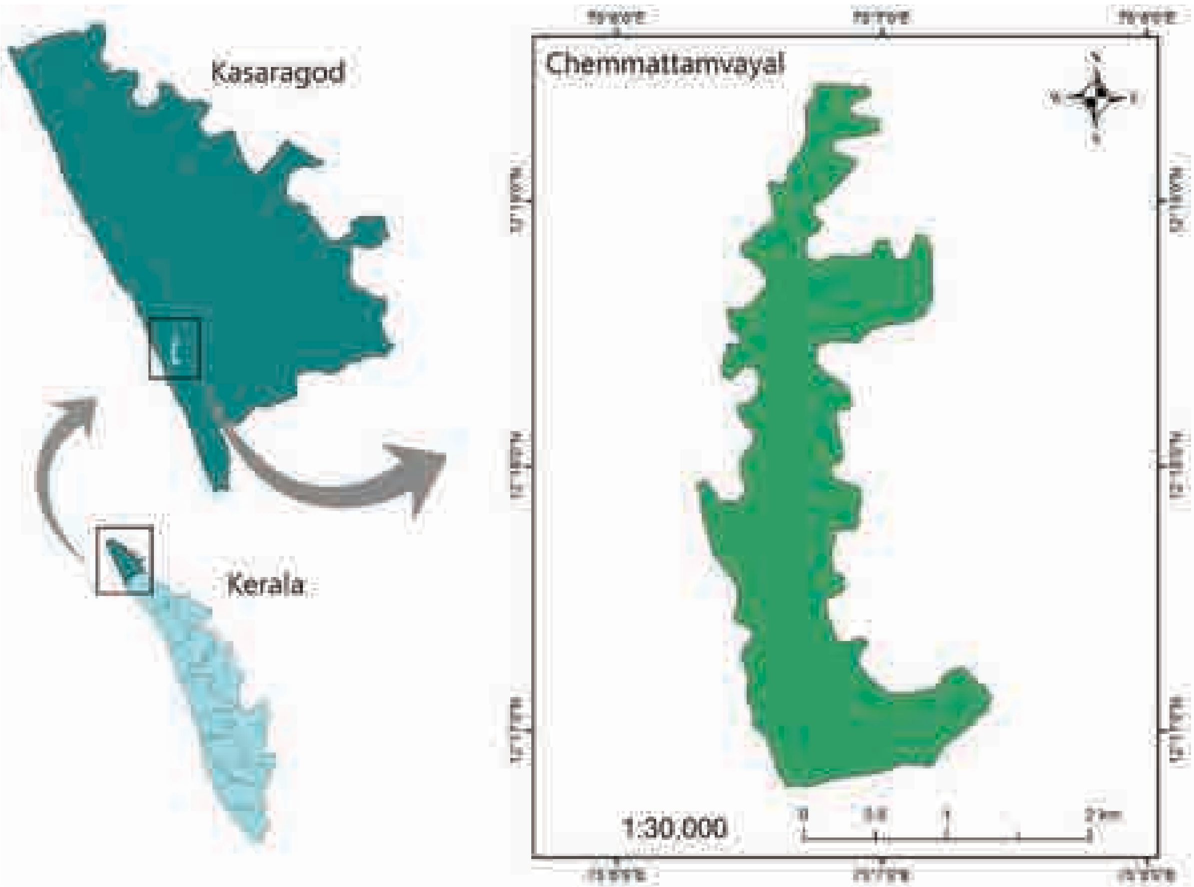

Figure 1. Location of Chemmattamvayal wetlands.

Image 1. Chemmattamvayal wetlands and adjacent areas.

nomenclature, status, and classification of the species follow Praveen (2015), Praveen et al. (2018, 2019), and Praveen & Jayapal (2023).

Following the protocol established by Kumar & Gupta (2009), the status of the species was categorized on the basis of number of sightings as: Common (Co), i.e., recorded 8–10 times out of 10 visits, Uncommon (U) recorded 4–7 times out of 10 visits, and Rare (R) recorded 1–3 times out of 10 visits. Birds were also categorized as Year-round (YR), Winter Migrant (WM), and Uncertain (UC). UC are those species that pop up anytime without a predictable pattern or are those that do not have clear data on sightings.

A measure of relative abundance of all birds was calculated. It is the percentage of occurrence of a species in a checklist which is calculated by the number of checklists in which a bird is recorded, divided by the total number of checklists. This includes checklists that did not report species and provides a measure of how frequently a species was reported relative to other species in the region. Relative abundance was analyzed for different ecological groups of birds such as parasitic cuckoos, primary hole-nesters, raptors and woodland understory birds. We assigned all species to different feeding guilds based on their dietary categories and foraging strata (Ding et al. 2015, 2019; Harisha et al. 2021; Panda et al. 2021; Jangral & Vashishat 2022; Rodrigues et al. 2023).

$$\text{Relative abundance} = \frac{\text{Number of checklists in which a bird is recorded}}{\text{Total number of checklists}} \times 100$$

RESULTS

A total of 565 checklists of birds were created with a duration of 15 minutes each. A total of 145 species of birds belonging to 17 orders (Figure 2) and 50 families were recorded. Among them, 42 species were winter migrants and 97 species were seen throughout the year (Table 1). The highest number of birds was recorded during the month of January (~5,000 birds) and the lowest in June (~400 birds). The most abundant birds of Chemmattamvayal wetlands were the White-throated Kingfisher *Halcyon smyrnensis*, Indian Pond Heron *Ardeola grayii*, and Spotted Dove *Spilopelia chinensis*. The species of Chemmattamvayal wetlands included, three 'Near Threatened' species—Black-headed Ibis *Threskiornis melanocephalus*, Oriental Darter *Anhinga melanogaster*, and Woolly-necked Stork *Ciconia episcopus*—on the IUCN Red List. The Chemmattamvayal Wetlands also has one species endemic to the Western Ghats, the Malabar Starling *Sturnia malabarica blythii*. Additionally, 14 species (Table 1) observed in Chemmattamvayal wetlands are included

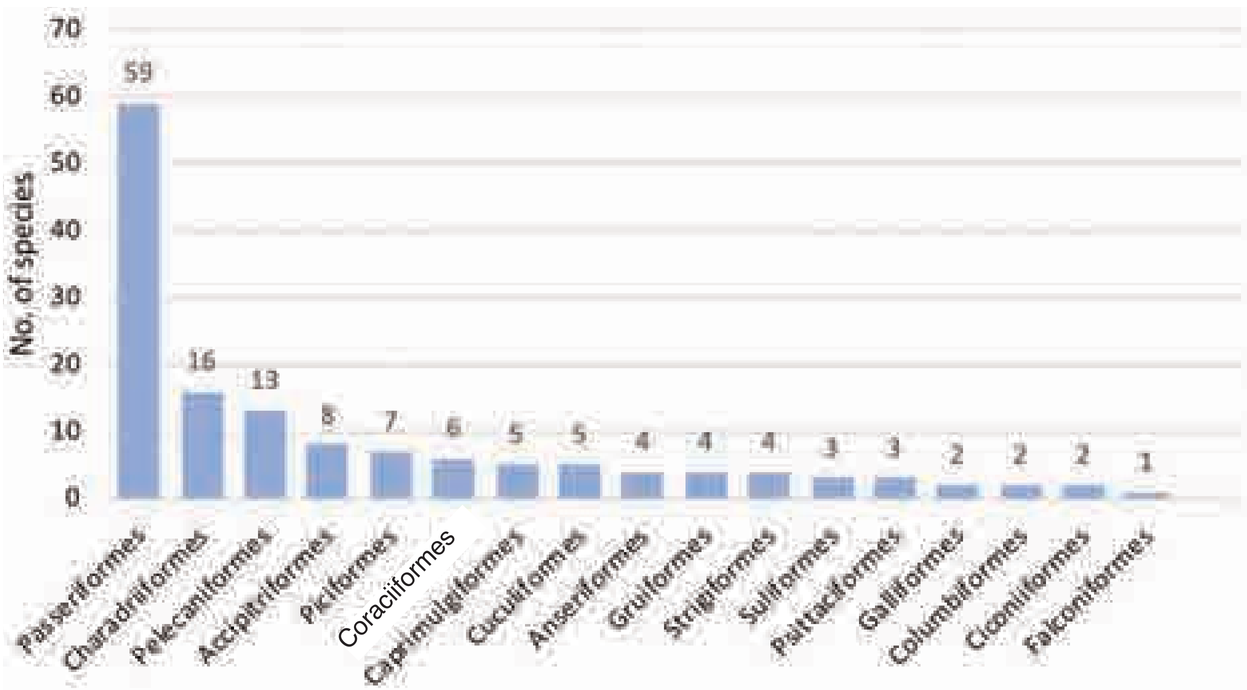

Figure 2. The number of species of birds per different bird orders recorded from Chemmattamvayal Wetlands in Kasaragod, Kerala.

Table 1. Checklist of birds of Chemmattamvayal Wetlands, Kasaragod, Kerala.

	Order	Family	English Name	Scientific Name	IUCN	WPA	CITES	Status	Occurrence	Feeding Guild	Relative Abundance
1	Anseriformes	Anatidae	Lesser Whistling Duck [Image 3]	*Dendrocygna javanica*	LC	Sch. II		YR	Co	O	39.51
2	Anseriformes	Anatidae	Garganey	*Spatula querquedula*	LC	Sch. II		WM	Co	H	7.41
3	Anseriformes	Anatidae	Common Teal (Eurasian Teal, Green-winged Teal)	*Anas crecca*	LC	Sch. II		WM	U	H	1.23
4	Anseriformes	Anatidae	Cotton Teal (Cotton Pygmy-Goose)	*Nettapus coromandelianus*	LC	Sch. I		YR	Co	H	3.7
5	Galliformes	Phasianidae	Indian Peafowl	*Pavo cristatus*	LC	Sch. I		YR	Co	O	1.23
6	Galliformes	Phasianidae	Red Spurfowl	*Galloperdix spadicea*	LC	Sch. II		YR	Co	G	1.23
7	Columbiformes	Columbidae	Rock Pigeon (Rock Dove)	*Columba livia*	LC	Sch. IV		YR	Co	G	27.16
8	Columbiformes	Columbidae	Spotted Dove	*Spilopelia chinensis*	LC	Sch. II		YR	Co	G	41.98
9	Caprimulgiformes	Caprimulgidae	Jerdon's Nightjar	*Caprimulgus atripennis*	LC	Sch. II		YR	Co	I	1.23
10	Caprimulgiformes	Caprimulgidae	Savanna Nightjar	*Caprimulgus affinis*	LC	Sch. II		UC	Co	I	0.62
11	Caprimulgiformes	Apodidae	Asian Palm Swift	*Cypsiurus balasiensis*	LC	Sch. II		YR	Co	I	13.58
12	Caprimulgiformes	Apodidae	Indian House Swift (Little Swift)	*Apus affinis*	LC	Sch. II		YR	Co	I	5.56
13	Cuculiformes	Cuculidae	Greater Coucal	*Centropus sinensis*	LC	Sch. II		YR	Co	O	35.8
14	Cuculiformes	Cuculidae	Blue-faced Malkoha	*Phaenicophaeus viridirostris*	LC	Sch. II		YR	Co	O	5.56
15	Cuculiformes	Cuculidae	Pied Cuckoo (Pied Crested Cuckoo, Jacobin Cuckoo)	*Clamator jacobinus*	LC	Sch. II		UC	U	I	0.62
16	Cuculiformes	Cuculidae	Asian Koel	*Eudynamys scolopaceus*	LC	Sch. II		YR	Co	O	18.52
17	Cuculiformes	Cuculidae	Grey-bellied Cuckoo	*Cacomantis passerinus*	LC	Sch. II		WM	U	I	0.62
18	Cuculiformes	Cuculidae	Common Hawk Cuckoo	*Hierococcyx varius*	LC	Sch. II		YR	Co	I	7.41
19	Gruiformes	Rallidae	White-breasted Waterhen	*Amaurornis phoenicurus*	LC	Sch. II		YR	Co	O	25.93
20	Gruiformes	Rallidae	Watercock	*Gallicrex cinerea*	LC	Sch. II		YR	Co	O	3.09
21	Gruiformes	Rallidae	Purple Swamphen (Grey-headed Swamphen) [Image 4]	*Porphyrio porphyrio*	LC	Sch. II		YR	Co	O	33.62
22	Gruiformes	Rallidae	Common Coot (Eurasian Coot)	*Fulica atra*	LC	Sch. II		WM	U	O	1.23
23	Ciconiiformes	Ciconiidae	Asian Openbill [Image 5]	*Anastomus oscitans*	LC	Sch. II		WM	Co	C	11.5
24	Ciconiiformes	Ciconiidae	Woolly-necked stork (Asian Woollyneck)	*Ciconia episcopus*	NT	Sch. II		WM	Co	C	0.62
25	Pelecaniformes	Ardeidae	Yellow Bittern	*Ixobrychus sinensis*	LC	Sch. II		YR	Co	C	8.85
26	Pelecaniformes	Ardeidae	Black-crowned Night Heron	*Nycticorax nycticorax*	LC	Sch. II		YR	Co	C	11.15
27	Pelecaniformes	Ardeidae	Striated Heron (Green-backed Heron, Little Heron)	*Butorides striata*	LC	Sch. II		YR	Co	C	6.19
28	Pelecaniformes	Ardeidae	Indian Pond Heron	*Ardeola grayii*	LC	Sch. II		YR	Co	C	46.3
29	Pelecaniformes	Ardeidae	Cattle Egret	*Bubulcus ibis*	LC	Sch. II		YR	Co	C	30.86

	Order	Family	English Name	Scientific Name	IUCN	WPA	CITES	Status	Occurrence	Feeding Guild	Relative Abundance
30	Pelecaniformes	Ardeidae	Grey Heron	*Ardea cinerea*	LC	Sch. II		YR	Co	C	24.77
31	Pelecaniformes	Ardeidae	Purple Heron	*Ardea purpurea*	LC	Sch. II		YR	Co	C	35.8
32	Pelecaniformes	Ardeidae	Great Egret	*Ardea alba*	LC	Sch. II		YR	Co	C	30.08
33	Pelecaniformes	Ardeidae	Intermediate Egret	*Ardea intermedia*	LC	Sch. II		YR	Co	C	34.57
34	Pelecaniformes	Ardeidae	Little Egret	*Egretta garzetta*	LC	Sch. II		YR	Co	C	16.63
35	Pelecaniformes	Ardeidae	Western Reef Egret (Western Reef Heron)	*Egretta gularis*	LC	Sch. II		UC	U	C	1.41
36	Pelecaniformes	Threskiornithidae	Black-headed Ibis [Image 6]	*Threskiornis melanocephalus*	NT	Sch. II		YR	Co	C	21.6
37	Pelecaniformes	Threskiornithidae	Glossy Ibis	*Plegadis falcinellus*	LC	Sch. II		WM	Co	C	23
38	Suliformes	Phalacrocoracidae	Little Cormorant	*Microcarbo niger*	LC	Sch. II		YR	Co	C	34.57
39	Suliformes	Phalacrocoracidae	Indian Cormorant	*Phalacrocorax fuscicollis*	LC	Sch. II		YR	Co	C	31.32
40	Suliformes	Anhingidae	Oriental Darter	*Anhinga melanogaster*	NT	Sch. II		YR	Co	C	14.2
41	Charadriiformes	Recurvirostridae	Black-winged Stilt	*Himantopus himantopus*	LC	Sch. II		WM	Co	C	6.19
42	Charadriiformes	Charadriidae	Pacific Golden Plover	*Pluvialis fulva*	LC	Sch. I		WM	Co	C	7.07
43	Charadriiformes	Charadriidae	Little-ringed Plover [Image 7]	*Charadrius dubius*	LC	Sch. II		WM	Co	C	9.91
44	Charadriiformes	Charadriidae	Grey-headed Lapwing	*Vanellus cinereus*	LC	Sch. II		WM	R	NR	0.53
45	Charadriiformes	Charadriidae	Red-wattled Lapwing [Image 8]	*Vanellus indicus*	LC	Sch. II		YR	Co	C	38.27
46	Charadriiformes	Jacanidae	Pheasant-tailed Jacana	*Hydrophasianus chirurgus*	LC	Sch. II		WM	U	O	4.07
47	Charadriiformes	Jacanidae	Bronze-winged Jacana	*Metopidius indicus*	LC	Sch. II		YR	Co	O	13.09
48	Charadriiformes	Scolopacidae	Common Snipe	*Gallinago gallinago*	LC	Sch. II		WM	Co	O	4.07
49	Charadriiformes	Scolopacidae	Common Sandpiper	*Actitis hypoleucos*	LC	Sch. II		WM	Co	C	14.51
50	Charadriiformes	Scolopacidae	Green Sandpiper	*Tringa ochropus*	LC	Sch. II		WM	U	C	2.12
51	Charadriiformes	Scolopacidae	Common Greenshank	*Tringa nebularia*	LC	Sch. I		WM	Co	C	3.18
52	Charadriiformes	Scolopacidae	Wood Sandpiper	*Tringa glareola*	LC	Sch. II		WM	Co	C	20.88
53	Charadriiformes	Scolopacidae	Marsh Sandpiper	*Tringa stagnatilis*	LC	Sch. II		WM	U	C	1.41
54	Charadriiformes	Glareolidae	Little Pratincole (Small Pratincole) [Image 9]	*Glareola lactea*	LC	Sch. II		WM	Co	I	4.24
55	Charadriiformes	Laridae	Gull-billed Tern	*Gelochelidon nilotica*	LC	Sch. I		WM	Co	C	6.54
56	Charadriiformes	Laridae	Whiskered Tern [Image 10]	*Chlidonias hybrida*	LC	Sch. II		YR	Co	C	21.23
57	Accipitriformes	Accipitridae	Oriental Honey Buzzard (Crested Honey Buzzard)	*Pernis ptilorhynchus*	LC	Sch. II	App. II	WM	Co	C	3.7
58	Accipitriformes	Accipitridae	Crested Serpent Eagle	*Spilornis cheela*	LC	Sch. I	App. II	YR	Co	C	5.56
59	Accipitriformes	Accipitridae	Booted Eagle	*Hieraaetus pennatus*	LC	Sch. I	App. II	WM	Co	C	1.85
60	Accipitriformes	Accipitridae	Western Marsh Harrier (Eurasian Marsh-Harrier)	*Circus aeruginosus*	LC	Sch. I	App. II	WM	Co	C	3.09

	Order	Family	English Name	Scientific Name	IUCN	WPA	CITES	Status	Occurrence	Feeding Guild	Relative Abundance
61	Accipitriformes	Accipitridae	Crested Goshawk	*Accipiter trivirgatus*	LC	Sch. I	App. II	YR	U	C	0.62
62	Accipitriformes	Accipitridae	Shikra	*Accipiter badius*	LC	Sch. I	App. II	YR	Co	C	5.56
63	Accipitriformes	Accipitridae	Brahminy Kite	*Haliastur indus*	LC	Sch. I	App. II	YR	Co	C	27.16
64	Accipitriformes	Accipitridae	Black Kite [Image 11]	*Milvus migrans*	LC	Sch. II	App. II	YR	Co	C	13.58
65	Strigiformes	Strigidae	Jungle Owlet	*Glaucidium radiatum*	LC	Sch. II	App. II	YR	Co	C	1.85
66	Strigiformes	Strigidae	Spotted Owlet	*Athene brama*	LC	Sch. II	App. II	YR	Co	C	3.09
67	Strigiformes	Strigidae	Indian Scops Owl	*Otus bakkamoena*	LC	Sch. II	App. II	YR	Co	C	1.85
68	Strigiformes	Strigidae	Mottled Wood Owl	*Strix ocellata*	LC	Sch. I	App. II	YR	Co	C	1.85
69	Piciformes	Picidae	Lesser Golden-backed Woodpecker (Black-rumped Flameback) [Image 12]	*Dinopium benghalense*	LC	Sch. II		YR	Co	O	17.28
70	Piciformes	Picidae	Rufous Woodpecker	*Micropternus brachyurus*	LC	Sch. II		YR	Co	O	1.23
71	Piciformes	Picidae	Lesser Yellow-naped Woodpecker (Lesser Yellownape)	*Picus chlorolophus*	LC	Sch. II		YR	Co	O	1.23
72	Piciformes	Picidae	Greater Golden-backed Woodpecker (Greater Flameback)	*Chrysocolaptes guttacristatus*	LC	Sch. II		UC	R	O	0.35
73	Piciformes	Picidae	Brown-capped Pygmy Woodpecker	*Dendrocopos nanus*	LC	Sch. II		YR	Co	O	2.47
74	Piciformes	Megalaimidae	White-cheeked Barbet	*Psilopogon viridis*	LC	Sch. II		YR	Co	F	26.54
75	Piciformes	Megalaimidae	Coppersmith Barbet	*Psilopogon haemacephalus*	LC	Sch. II		YR	Co	F	12.35
76	Coraciiformes	Meropidae	Green Bee-eater	*Merops orientalis*	LC	Sch. II		YR	Co	I	32.1
77	Coraciiformes	Meropidae	Blue-tailed Bee-eater	*Merops philippinus*	LC	Sch. II		WM	Co	I	30.25
78	Coraciiformes	Alcedinidae	Common Kingfisher	*Alcedo atthis*	LC	Sch. II		YR	Co	C	27.78
79	Coraciiformes	Alcedinidae	Pied Kingfisher	*Ceryle rudis*	LC	Sch. II		YR	Co	C	12.38
80	Coraciiformes	Alcedinidae	Stork-billed Kingfisher	*Pelargopsis capensis*	LC	Sch. II		YR	Co	C	7.96
81	Coraciiformes	Alcedinidae	White-throated Kingfisher (White-breasted Kingfisher)	*Halcyon smyrnensis*	LC	Sch. II		YR	Co	C	56.17
82	Falconiformes	Falconidae	Peregrine Falcon [Image 13]	*Falco peregrinus*	LC	Sch. I	App. I	WM	U	C	0.35
83	Psittaciformes	Psittaculidae	Plum-headed Parakeet	*Psittacula cyanocephala*	LC	Sch. II	App. II	YR	Co	F	12.74
84	Psittaciformes	Psittaculidae	Rose-ringed Parakeet	*Psittacula krameri*	LC	Sch. II		YR	Co	F	9.55
85	Psittaciformes	Psittaculidae	Vernal Hanging Parrot	*Loriculus vernalis*	LC	Sch. II	App. II	YR	Co	F	16.63
86	Passeriformes	Campephagidae	Small Minivet	*Pericrocotus cinnamomeus*	LC	Sch. I		YR	Co	I	3.71
87	Passeriformes	Campephagidae	Orange Minivet (Scarlet Minivet)	*Pericrocotus flammeus*	LC	Sch. II		YR	Co	I	6.01
88	Passeriformes	Campephagidae	Large Cuckooshrike	*Coracina javensis*	LC	Sch. II		YR	Co	I	4.77
89	Passeriformes	Campephagidae	Black-headed Cuckooshrike	*Lalage melanoptera*	LC	Sch. II		UC	Co	I	1.41

	Order	Family	English Name	Scientific Name	IUCN	WPA	CITES	Status	Occurrence	Feeding Guild	Relative Abundance
90	Passeriformes	Oriolidae	Black-hooded Oriole	*Oriolus xanthornus*	LC	Sch. II		YR	Co	O	8.14
91	Passeriformes	Oriolidae	Indian Golden Oriole	*Oriolus kundoo*	LC	Sch. II		WM	Co	O	6.54
92	Passeriformes	Artamidae	Ashy Woodswallow	*Artamus fuscus*	LC	Sch. II		YR	Co	I	9.91
93	Passeriformes	Vangidae	Common Woodshrike	*Tephrodornis pondicerianus*	LC	Sch. II		YR	Co	I	6.19
94	Passeriformes	Aegithinidae	Common Iora	*Aegithina tiphia*	LC	Sch. II		YR	Co	I	18.76
95	Passeriformes	Dicruridae	Black Drongo	*Dicrurus macrocercus*	LC	Sch. II		YR	Co	O	40.74
96	Passeriformes	Dicruridae	Ashy Drongo	*Dicrurus leucophaeus*	LC	Sch. II		WM	Co	O	20.17
97	Passeriformes	Dicruridae	Bronzed Drongo	*Dicrurus aeneus*	LC	Sch. II		YR	Co	O	24.07
98	Passeriformes	Dicruridae	Greater Racket-tailed Drongo	*Dicrurus paradiseus*	LC	Sch. II		YR	Co	O	20.88
99	Passeriformes	Laniidae	Brown Shrike	*Lanius cristatus*	LC	Sch. II		WM	Co	I	2.65
100	Passeriformes	Corvidae	Rufous Treepie	*Dendrocitta vagabunda*	LC	Sch. II		YR	Co	O	17.52
101	Passeriformes	Corvidae	House Crow	*Corvus splendens*	LC	Sch. V		YR	Co	O	41.98
102	Passeriformes	Corvidae	Large-billed Crow (Indian Jungle Crow)	*Corvus macrorhynchos*	LC	Sch. II		YR	Co	O	21.9
103	Passeriformes	Monarchidae	Black-naped Monarch	*Hypothymis azurea*	LC	Sch. II		YR	Co	I	4.95
104	Passeriformes	Monarchidae	Indian Paradise-flycatcher (Asian Paradise-flycatcher)	*Terpsiphone paradisi*	LC	Sch. II		WM	Co	I	3
105	Passeriformes	Dicaeidae	Pale-billed Flowerpecker	*Dicaeum erythrorhynchos*	LC	Sch. II		YR	Co	N	8.14
106	Passeriformes	Nectariniidae	Little Spiderhunter	*Arachnothera longirostra*	LC	Sch. II		YR	U	O	12.21
107	Passeriformes	Nectariniidae	Purple-rumped Sunbird	*Leptocoma zeylonica*	LC	Sch. II		YR	Co	N	27.16
108	Passeriformes	Nectariniidae	Purple Sunbird [Image 14]	*Cinnyris asiaticus*	LC	Sch. II		YR	Co	N	9.38
109	Passeriformes	Nectariniidae	Loten's Sunbird (Long-billed Sunbird) [Image 15]	*Cinnyris lotenius*	LC	Sch. II		YR	Co	N	7.25
110	Passeriformes	Chloropseidae	Golden-fronted Leafbird	*Chloropsis aurifrons*	LC	Sch. II		YR	Co	O	6.37
111	Passeriformes	Chloropseidae	Jerdon's Leafbird	*Chloropsis jerdoni*	LC	Sch. II		YR	Co	O	3.89
112	Passeriformes	Ploceidae	Baya Weaver [Image 16]	*Ploceus philippinus*	LC	Sch. II		YR	Co	G	9.38
113	Passeriformes	Estrildidae	White-rumped Munia	*Lonchura striata*	LC	Sch. II		YR	Co	G	8.14
114	Passeriformes	Estrildidae	Scaly-breasted Munia [Image 17]	*Lonchura punctulata*	LC	Sch. II		YR	Co	G	5.13
115	Passeriformes	Motacillidae	Paddyfield Pipit	*Anthus rufulus*	LC	Sch. II		YR	Co	I	4.24
116	Passeriformes	Motacillidae	Western Yellow Wagtail	*Motacilla flava*	LC	Sch. II		WM	Co	I	6.37
117	Passeriformes	Motacillidae	Grey Wagtail	*Motacilla cinerea*	LC	Sch. II		WM	U	I	0.88
118	Passeriformes	Motacillidae	White-browed Wagtail	*Motacilla maderaspatensis*	LC	Sch. II		YR	Co	I	4.77
119	Passeriformes	Motacillidae	White Wagtail	*Motacilla alba*	LC	Sch. II		WM	Co	I	0.7
120	Passeriformes	Cisticolidae	Ashy Prinia [Image 18]	*Prinia socialis*	LC	Sch. II		YR	Co	I	0.62

	Order	Family	English Name	Scientific Name	IUCN	WPA	CITES	Status	Occurrence	Feeding Guild	Relative Abundance
121	Passeriformes	Cisticolidae	Plain Prinia	*Prinia inornata*	LC	Sch. II		YR	Co	I	4.94
122	Passeriformes	Cisticolidae	Common Tailorbird	*Orthotomus sutorius*	LC	Sch. II		YR	Co	I	18.52
123	Passeriformes	Acrocephalidae	Blyth's Reed Warbler	*Acrocephalus dumetorum*	LC	Sch. II		WM	Co	I	6.79
124	Passeriformes	Acrocephalidae	Clamorous Reed Warbler	*Acrocephalus stentoreus*	LC	Sch. II		WM	Co	I	6.01
125	Passeriformes	Hirundinidae	Streak-throated Swallow	*Petrochelidon fluvicola*	LC	Sch. II		WM	R	I	0.88
126	Passeriformes	Hirundinidae	Red-rumped Swallow	*Cecropis daurica*	LC	Sch. II		YR	Co	I	3.89
127	Passeriformes	Hirundinidae	Wire-tailed Swallow	*Hirundo smithii*	LC	Sch. II		YR	Co	I	1.9
128	Passeriformes	Hirundinidae	Barn Swallow	*Hirundo rustica*	LC	Sch. II		WM	Co	I	5.3
129	Passeriformes	Pycnonotidae	Red-whiskered Bulbul	*Pycnonotus jocosus*	LC	Sch. II		YR	Co	O	19.82
130	Passeriformes	Pycnonotidae	Red-vented Bulbul	*Pycnonotus cafer*	LC	Sch. II		YR	Co	O	16.99
131	Passeriformes	Pycnonotidae	White-browed Bulbul	*Pycnonotus luteolus*	LC	Sch. II		YR	Co	O	7.78
132	Passeriformes	Pycnonotidae	Yellow-browed Bulbul	*Acritillas indica*	LC	Sch. II		YR	Co	O	3.89
133	Passeriformes	Phylloscopidae	Green Leaf Warbler (Green Warbler)	*Phylloscopus nitidus*	LC	Sch. II		WM	Co	I	3.18
134	Passeriformes	Phylloscopidae	Greenish Leaf Warbler (Greenish Warbler)	*Phylloscopus trochiloides*	LC	Sch. II		WM	U	I	1.41
135	Passeriformes	Pellorneidae	Puff-throaten Babbler	*Pellorneum ruficeps*	LC	Sch. II		YR	Co	I	4.32
136	Passeriformes	Leiothrichidae	Jungle Babbler	*Turdoides striata*	LC	Sch. II		YR	Co	O	1.23
137	Passeriformes	Leiothrichidae	Yellow-billed Babbler	*Turdoides affinis*	LC	Sch. II		YR	Co	O	19.14
138	Passeriformes	Sturnidae	Rosy Starling	*Pastor roseus*	LC	Sch. II		WM	Co	O	0.88
139	Passeriformes	Sturnidae	Chestnut-tailed Starling	*Sturnia malabarica*	LC	Sch. II		WM	Co	O	1.94
140	Passeriformes	Sturnidae	Malabar Starling	*Sturnia malabarica blythii*	LC	Sch. II		UC	Co	O	0.35
141	Passeriformes	Sturnidae	Common Myna	*Acridotheres tristis*	LC	Sch. II		YR	Co	O	27.78
142	Passeriformes	Sturnidae	Jungle Myna	*Acridotheres fuscus*	LC	Sch. II		YR	Co	O	18.05
143	Passeriformes	Muscicapidae	Oriental Magpie Robin	*Copsychus saularis*	LC	Sch. II		YR	Co	I	21.6
144	Passeriformes	Muscicapidae	Asian Brown Flycatcher	*Muscicapa dauurica*	LC	Sch. II		WM	Co	I	1.23
145	Passeriformes	Muscicapidae	Siberian Stonechat	*Saxicola maurus*	LC	Sch. II		WM	U	I	1.23

YR—Year-round | WM—Winter Migrant | UC—Uncertain | Co—Common | U—Uncommon | R—Rare | O—Omnivore | H—Herbivore | G—Granivore | I—Insectivore | C—Carnivore | F—Frugivore | N—Nectarivore | NR—Not recorded.

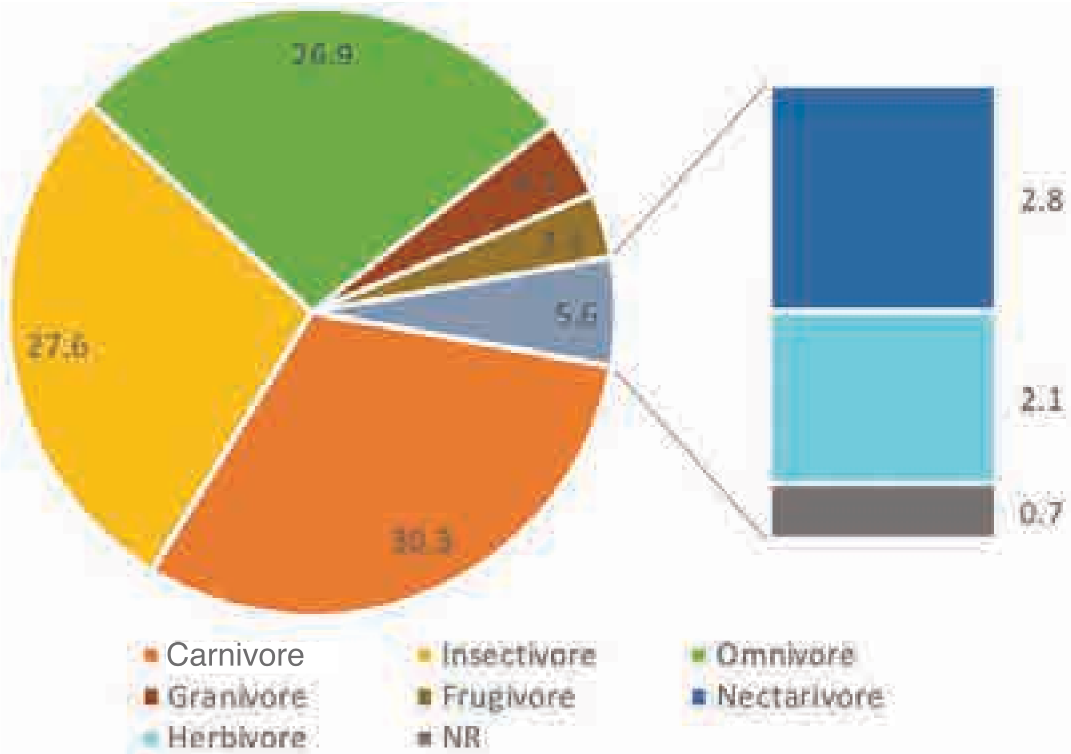

Figure 3. The feeding guild structure of the birds of Chemmattamvayal Wetlands in Kasaragod, Kerala.

in Schedule I and one species, i.e., the Peregrine Falcon *Falco peregrinus* is mentioned in Appendix 1 of CITES, according to the Wild Life (Protection) Amendment Act, 2022 (The Gazette of India 2023). Among the waterfowls, the Lesser Whistling Duck is a resident and is commonly seen in the region, and all other Anseriformes found here are migrants.

Relative abundance of the birds of Chemmattamvayal indicates that the White-throated Kingfisher is the most abundant species, followed by the Indian Pond Heron and Spotted Dove. The survey also documented indicator species such as primary hole nesters, which include, White-cheeked Barbet *Psilopogon viridis*, Coppersmith Barbet *Psilopogon haemacephalus*, and Black-rumped Flameback *Dinopium benghalense*. The presence of primary hole nesting birds is highly significant as they are considered to be keystone species and the existence of the secondary hole nesting birds such as parakeet, myna, and starling are dependent on the primary hole nesters. The present study reported four species of parasitic cuckoos such as Asian Koel *Eudynamys scolopaceus*, Common Hawk Cuckoo *Hierococcyx varius*, Pied Cuckoo *Clamator jacobinus*, and Grey-bellied Cuckoo *Cacomantis passerinus*. The study site recorded 12 species of raptors. The presence of a healthy population of raptorial birds is an indication of healthy habitat. Brahminy Kite *Haliastur indus* was the most common raptor, followed by Black Kite *Milvus migrans*. The presence of the understory dependent birds indicates that areas adjacent to the wetland has sufficient undergrowth. The study location recorded 15 species of birds dependent on the presence of understory. The feeding guild analysis of birds of the study area is given in Figure 3. The canopy-insectivores (18%) form the dominant guild followed by the aquatic-insectivores (13%).

DISCUSSION

Some factors, which threaten the wetland ecosystem and consequently the wetland bird population were identified during the study. Landscape alteration was identified as one of the major factors that leads to biodiversity loss in these wetlands. Areas adjacent to the wetland are being converted into concrete structures and some farmers are trying to convert their paddy fields into vegetable gardens. These altered land use practices have significantly reduced the presence of wetland dependent birds in these areas. Such anthropogenic influences adversely affecting wetlands were also

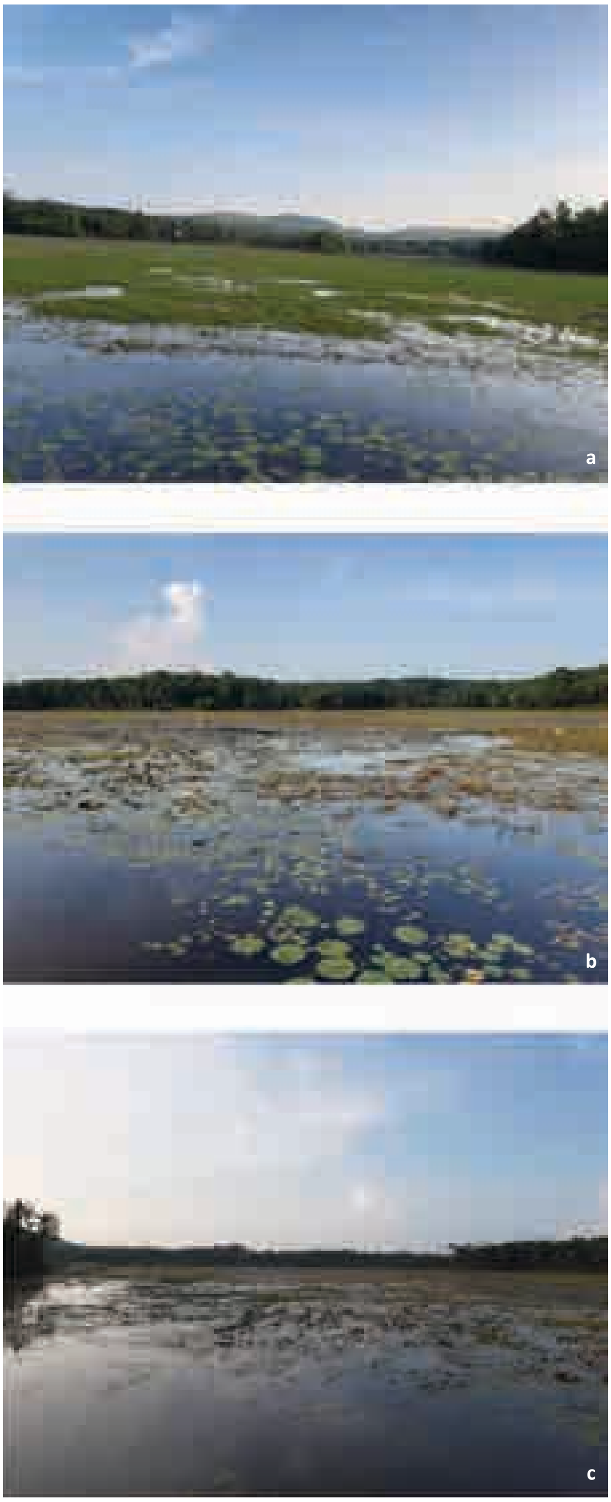

Image 2a,b,c. Chemmattamvayal Wetlands. © Sreehari K. Mohan.

demonstrated by Galatowitsch (2018) and Ostad-Ali-Askari (2022). The researchers of the present study noted that farmers complaining about the reduction in paddy-yield mainly due to Grey-headed Swamphen *Porphyrio porphyrio.* Additionally, the farmers were observed to frequently use fire crackers to scare the birds away. At the same time, majority of the people living here are much more concerned about the beauty of this wetland and the birds visiting here.

The presence of the exotic vegetation such as *Eichhornia crassipes* and *Salvinia molesta* was also noticed during the study. However, the density of these exotics are relatively less as compared to similar wetland habitats. It would be prudent to establish mitigation measures to control the spread of these two wetland weeds. Information on other faunal groups dependent on the Chemmattamvayal Wetlands is currently lacking; thus, further steps are needed to document the other forms of biodiversity in this region. Regular biodiversity monitoring of the wetland is needed to study the temporal variation and associated changes in the response of various flora and fauna. Environmental education and awareness with the involvement of local stakeholders is required to stop the vulnerability of inland wetlands (Shah & Atisa 2021). Thus, conservation of these wetlands and adjacent areas can be effectively done with the involvement and support of the local people.

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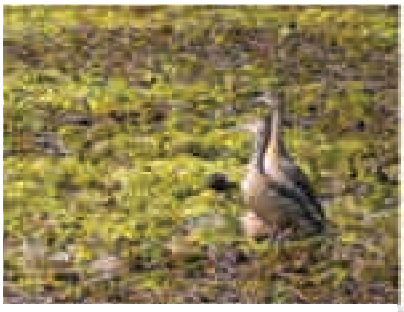

Image 3. Lesser Whistling Duck. © Sreehari K. Mohan.

Image 5. Asian Openbill. © Maxim Rodrigues K.

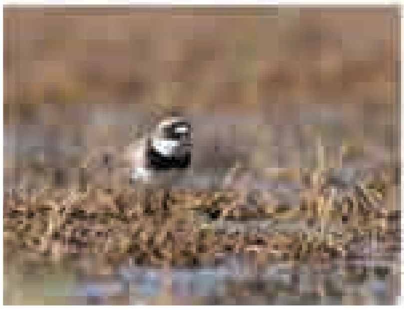

Image 7. Little-ringed Plover. © Sreehari K. Mohan.

Image 12. Black-rumped Flameback. © Sreehari K. Mohan.

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Image 8. Red-wattled Lapwing. © Sreehari K. Mohan.

Image 13. Peregrine Falcon. © Prashantha Krishna M.C.

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Image 14. Purple Sunbird. © Sreehari K. Mohan.

Image 15. Loten's Sunbird. © Sreehari K. Mohan.

Image 16. Baya Weaver. © Sreehari K. Mohan.

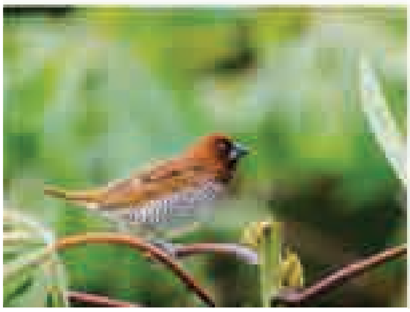

Image 17. Scaly-breasted Munia. © Sreehari K. Mohan.

Image 18. Ashy Prinia. © Sreehari K. Mohan.

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COMMUNICATION

Westward range extension of Burmese Python *Python bivittatus* in and around the Ganga Basin, India: a response to changing climatic factors

Pichaimuthu Gangaiamaran [1], Aftab Alam Usmani [2], C.S. Vishnu [3], Ruchi Badola [4] & Syed Ainul Hussain [5]

[1–5] Wildlife Institute of India, P.O. Box 18, Chandrabani, Dehradun, Uttarakhand 248002, India.
[1] bnhsgangai@gmail.com, [2] aftab.a.usmani@gmail.com, [3] vishnusreedharannair@gmail.com, [4] ruchi@wii.gov.in,
[5] ainul.hussain@gmail.com (corresponding author)

Abstract: The range extension of animals is influenced by various factors, particularly environmental variables and ecological requirements. In this study, we have attempted to quantify the potential current distribution range of the Burmese Python *Python bivittatus* in and around the Ganga Basin. We collected the Burmese Python sightings between 2007 and 2022 from various direct and indirect sources and recorded 38 individuals, including eight females and five males; the rest were not examined for their sex. Out of these, 12 individuals were rescued from human habitations. Most python sightings were observed in Uttarakhand and Uttar Pradesh (n = 12 each), followed by Bihar (n = 6). The expanded minimum convex polygon (MCP) range was calculated as 60,534.2 km^2. In addition, we quantified the potential current distribution status of this species using 19 bioclimatic variables with the help of MaxEnt software and the SDM toolbox in Arc GIS. The suitable area for the python distribution was calculated as 1,03,547 km^2. We found that the following variables influenced the python distribution in the range extended landscape: Annual Mean Temperature (20.9 %), Precipitation of Wettest Quarter (6.4 %), Precipitation of Driest Quarter (30.1 %), Precipitation of Warmest Quarter (0.3%), Isothermality (0.1%), Temperature Annual Range (18.7 %), Mean Temperature of Wettest Quarter (11.4 %), Mean Temperature of Driest Quarter (2.2 %), Land use/land cover (3.3 %), and Elevation (6.6 %). These results will support the field managers in rescuing individuals from conflict areas and rehabilitating them based on the appropriate geographical region.

Keywords: Distribution, expansion, habitat, prediction, reptiles, suitability, survivorship, temperature, topography, vulnerable.

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Author details: Pichaimuthu Gangaiamaran is a research biologist (NMCG-Birds) at the Wildlife Institute of India. Aftab Alam Usmani is a research associate (NMCG-Birds) at the Wildlife Institute of India. C.S. Vishnu is a Ph.D. scholar at the Wildlife Institute of India. Ruchi Badola is a principal investigator (NMCG), Dean, and scientist-G at the Wildlife Institute of India. Syed Ainul Hussain is a project manager (NMCG) and former scientist-G at the Wildlife Institute of India.

Author contributions: SAH and RB supervised the study. PG and SAH conceived the idea. PG, AAU, and CSV collected field data. PG prepared the initial draft, and CSV wrote the final draft. SAH reviewed the manuscript. CSV did the analysis and visualization. All authors revised subsequent versions. All authors agreed upon the final version.

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INTRODUCTION

Reptiles are poikilothermic and are extremely sensitive to the thermal features of the environment (Carranza et al. 2018); hence highly vulnerable to climate change (Sinervo et al. 2016). Minute changes in the environmental temperatures also affect their daily activities, biology, and survival (Wilms et al. 2011; Ribeiro et al. 2012). Several studies have recorded the influence of climatic variables in the distribution of species, i.e., altitude (El-Gabbas et al. 2016), precipitation (Sanchooli 2017), temperature (Javed et al. 2017), and vegetation cover (Fattahi et al. 2014). Studies have concluded that reptiles are more influenced by climate-related variables rather than topographical variables (Guisan & Hofer 2003). Reptiles are being threatened for many reasons, including conversion and loss of habitat, invasive species, and the pet trade, apart from the changes in climate and topographical features, which adversely disturb their spatial distribution (Cox et al. 2012). Pythons, one of the largest reptile groups and apex predators, perform a significant role in the ecological system like other carnivores (Pearson et al. 2005), by controlling the population of ungulates, reptiles, birds, and other small mammals (Bhupathy et al. 2014). Identifying the potential distribution range of species and predicting future potential distribution based on changing environmental conditions have become necessary due to population declines and expansion (Todd et al. 2010; Urban 2015). Many species appear to adapt to rising temperatures associated with climate changes by shifting their ranges to higher latitudes or elevations (Chen et al. 2011; Jose & Nameer 2020)

The Burmese Python *Python bivittatus* is considered one of the largest snake species in the world (Barker & Barker 2008), and it can grow up to a length of 6 m (20 ft) (Clark 2012). Kuhl (1820) has formally distinguished the Burmese Pythons from other python species. *P. bivittatus* is a squamate reptile of the Pythonidae family, the top of the body is dark brownish- or yellowish-grey, with a series of 30 to 40 large irregular squarish, black-edged, dark chocolate-grey blotches on the top and sides of the body; it has dark and dark grey dorsal and lateral spots; it has a sub-ocular stripe; and the belly is greyish with dark spots on the outer scale rows (Das 2012). The body is thick and cylindrical; the head is lance-shaped and distinct from the neck; sensory pits can be found in the rostrals as well as on some supralabials and infralabials (Das 2012). The spurs are small; the tail is short and prehensile; and there are cloacal spurs (Das 2012).

Python bivittatus is one of three native python species found in India along with *Python molurus* and *Malayopython reticulatus* (Rashid & Khan 2018). The Burmese Python is native to the tropical rainforests and subtropical jungles of India, Myanmar, southern China, southeastern Asia, and some extent of the Indonesian archipelago (McDiarmid et al. 1999). The distribution of *P. bivittatus* in Southeastern Asia encompasses eastern parts of India, Nepal, Bhutan, Bangladesh, Myanmar, Thailand, Cambodia, Vietnam, northern Malaysia, and southern China (Barker & Barker 2008, 2010). Some isolated observations in the Gangetic plain have recently been reported by Rashid & Khan (2018). The *P. bivittatus* is an invasive species in the United States. Due to climatic suitability, the pythons in the everglades might spread quickly into many parts of the U.S. (Dorcas et al. 2012; McCleery et al. 2015; Sovie et al. 2016). Global warming trends were predicted to increase suitable habitats significantly that promotes the range expansion among them (Pyron et al. 2008).

In the native range, *P. bivittatus* has been listed under the 'Vulnerable' category by the IUCN Red List of Threatened Species (Stuart et al. 2012). Also, they are included in Schedule-I (Part II) of the Indian Wild Life (Protection) Act, 1972 (IWPA) and Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Burmese Pythons occupy habitats ranging from hardwood forests to mangrove swamps in the introduced range in the USA (Walters et al. 2016), however in the native range, they dwell in the tropical lowlands, grassland forests and within areas modified for human use (Barker & Barker 2008; Cota 2010; Rahman et al. 2014).

In this study, we have attempted to quantify the potential current distribution range of Burmese Pythons in and around the Ganga Basin. Also, identified the bioclimatic variables that contributed to their range expansion.

MATERIALS AND METHODS

Study Area

The *P. bivittatus* live in subtropical or tropical forests, which include dry forests, mangrove vegetation, swamps, moist montane grasslands, wetlands, and permanent freshwater marshes/pools (Stuart et al. 2012). According to the IUCN, the Burmese Python's distribution range as being in northeastern states of India, including West Bengal. The current study focuses on six major Indian states: Uttarakhand, Uttar Pradesh, Bihar, Jharkhand, West Bengal, and Odisha; all apart from Odisha are situated in the Gangetic Basin, however, some Burmese Python sighting records have gathered from the Odisha as well, since it is a neighbouring state of West Bengal.

Ganga is the national river of India which passes through three separate biogeographic zones, the Himalaya, the Gangetic Plain, and the eastern coast, which has a unique biodiversity assemblage (NMCG-WII GBCI 2019). The Ganga River Basin occupies nearly one-third of the geographical area of India (Jain et al. 2007). Presently this region is experiencing a high urbanisation rate and almost 45% of India's population lives in the Ganga basin (Quadir 2022). The temperature of the Gangetic plain doesn't fall under an average of 21^{o}C, the daily maximum temperature in the warmest month rises to 40^{o}C (EMSF 2019); thus, the atmospheric temperature is very suitable for *P. bivittatus*. Here, we report the extended native range of *P. bivittatus* in and around the Gangetic Basin.

Methods and Analysis

The direct sightings of Burmese Pythons have been obtained with photographic evidence from various parts of the study area, with the help of forest staff, researchers, and local people (Image 1). Also, we collected secondary pieces of information from the published works (Table 2). With the available coordinates, a range extension map has been made and the expansion area was estimated by the minimum convex polygon (MCP) in Arc GIS (Supplementary Figure 4). Additionally, the current potential distribution status of this species has been identified with 19 bioclimatic layers, which were obtained from Worldclim dataset. Further, the layers were prepared with the SDM toolbox in Arc GIS and run the model with the help of MaxEnt (Figure 1).

Species distribution for the Burmese Python was modelled using MaxEnt (version 3.4.1.; Phillips et al. 2004, 2006) because it is the most widely used and popular choice for species distribution modelling, providing high extrapolative accuracies even with low presence-only data (Bosso et al. 2018; Soucy et al. 2018; Zhang et al. 2018). This study has only used presence data and to generate pseudo-absences, 10,022 background points were randomly selected by the MaxEnt model.

The presence data was split into 75% random samples for calibrating the model and 25% for evaluating model performance. We used a subsampling technique to generate a stable model because of its advantages over cross-validation (Anderson & Raza 2010), and bootstrap (Rospleszcz et al. 2014), and three replications were chosen to run the model. Regularization multipliers are used to prevent overfitting of predicted values and to balance the model fit (Phillips & Dudík 2008). The model provides settings for assessing model complexity by varying feature classes and regularisation multipliers. Threshold selection was done, the logistic output format ranging between 0 (unsuitable) and 1 (maximum suitability), was used for the model results, which shows habitat suitability (presence probability) of

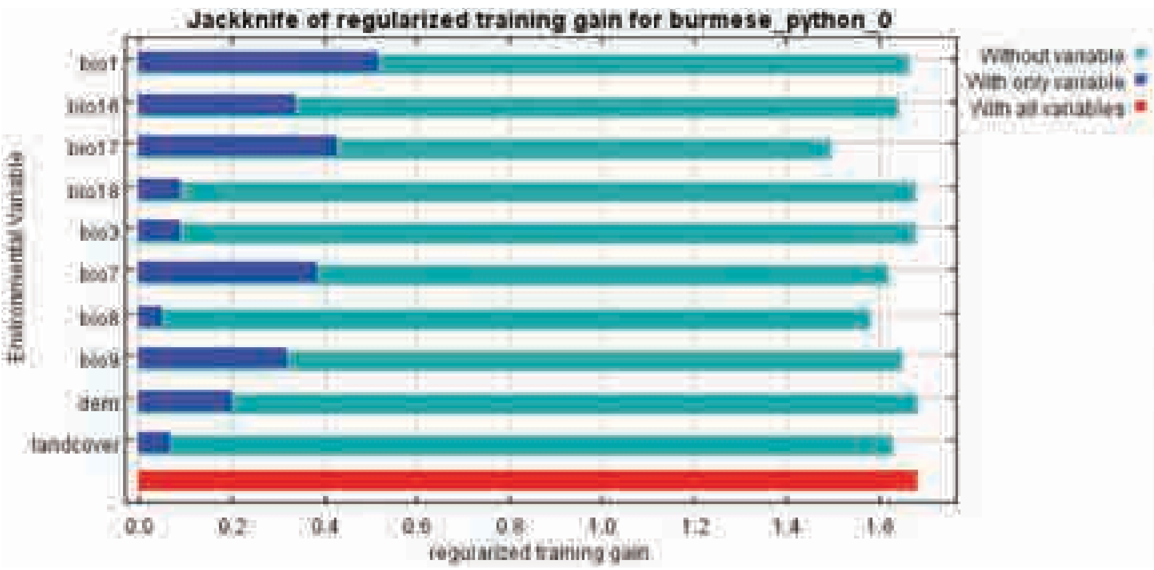

Figure 1. The Jackknife test for evaluating the relative importance of environmental variables for *P. bivittatus* in and around Ganga Basin. (Note: "Bio1" is Annual Mean Temperature; "Bio16" is Precipitation of Wettest Quarter; "Bio17" is Precipitation of Driest Quarter; "Bio18" is Precipitation of Warmest Quarter; "Bio3" is isothermality; "Bio7" is Temperature Annual Range; "Bio8" is Mean Temperature of Wettest Quarter; "Bio9" is Mean Temperature of Driest Quarter; "Land Cover" is land cover layer; "Dem" is Elevation.

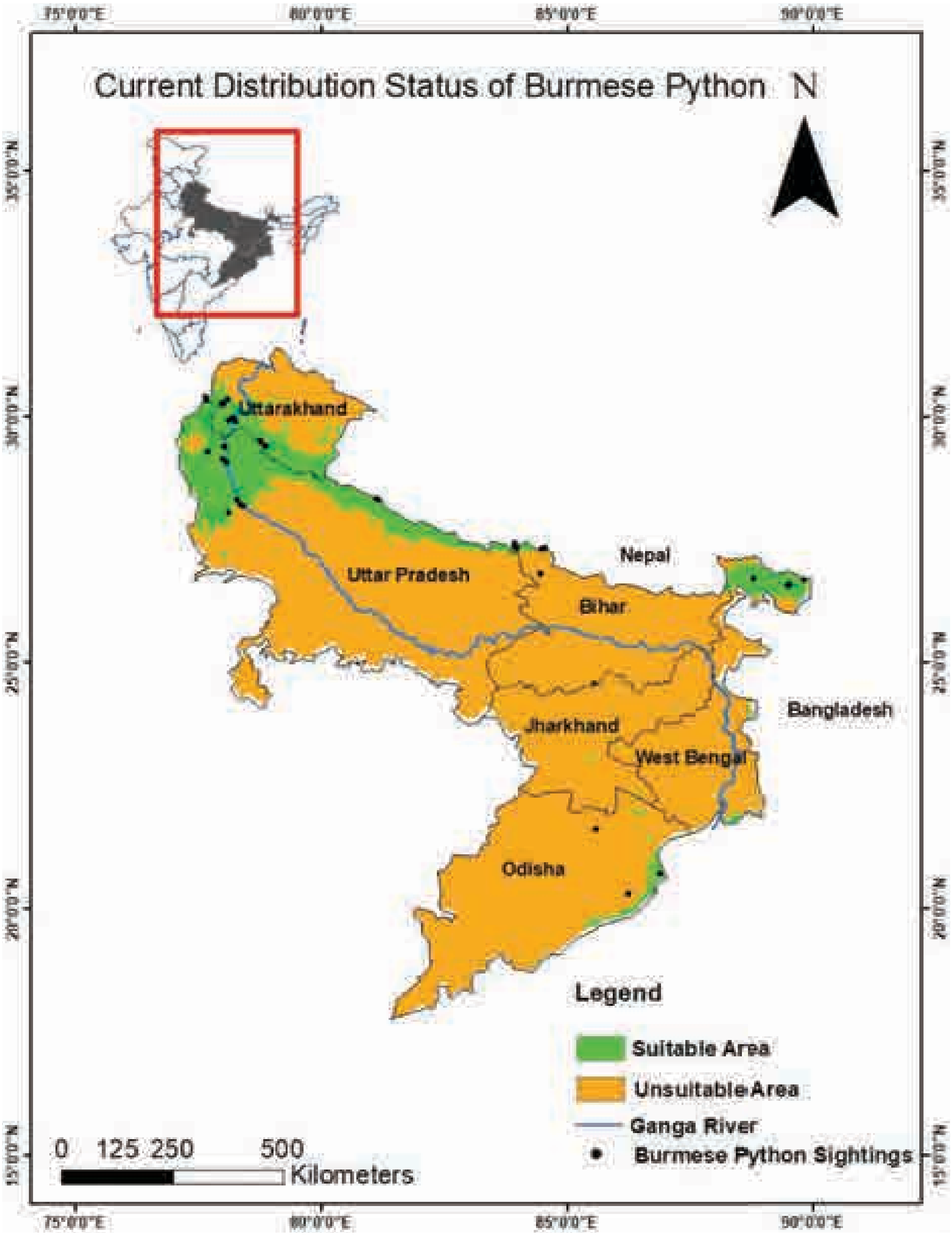

Figure 2. Westward range extension of Burmese Python *P. bivittatus* in and around the Ganga Basin.

targeted species (Phillips et al. 2004). Binary suitable/unsuitable map was prepared accordingly.

RESULTS AND DISCUSSION

We collected the details of Burmese Pythons in the Ganga Basin and adjacent areas. The data has been collected from both direct and indirect sources (Table 2). A total of 38 sighting records were obtained, including eight females, five males, and the remaining unsexed. The pythons were identified using photographs and morphological features from the field guide by Whitaker & Captain (2004).

The Burmese Pythons are known as the sister species of Indian Rock Python *P. molurus* and the Burmese Python differs from the Rock Python in several ways. Supralabials touching the eye, the tongue, and some parts of the head are pale pinkish in Indian Rock Python. The supralabials are separated from the eye by subocular scales in the Burmese Python and the tongue is bluish-black with no pink colour on the head (Whitaker & Captain 2004). Also, the Indian Python being 'yellowish' while the Burmese Python is 'greyish' in colour (Whitaker & Captain 2004).

From these, 10 individuals were rescued from human habitations. Also, a mating event was observed in August by the NMCG Team of WII, and a brooding female was observed by Rashid & Khan (2018) in May. Das et al. (2012) reported earlier breeding records of Burmese Python such as egg shell remains and earlier nesting activities in the Gangetic Basin, at the Katerniaghat and Dudhwa regions. Most of the python sightings were recorded from the state of Uttarakhand and Uttar Pradesh (n = 12 each), followed by Bihar (n = 6), West Bengal (n = 4), Odisha (n = 3), and Jharkhand (n = 1) respectively. The expanded MCP range was calculated as 60,534.2 km^2 (Supplementary Figure 4). The most python sighting records were obtained in the year of 2017 (n = 8), followed by the year 2021 (n = 6) (Figure 3).

In addition, we found that some environmental variables have a considerable role in the distribution of *P. bivittatus* (Table 1 and Supplementary Table 1). The suitable area for the potential distribution of *P. bivittatus* was predicted as 1,03,547 km^2. The Gangetic Plain and its adjacent places have a favourable temperature for the species rapid expansion.

From the Jackknife evaluation, these results were consistent. The model output yielded satisfactory results with the training and test data; the final model had accuracy with an AUC value of 0.865.

The present model outputs show that 10 variables influence the python distribution. Some variables, however, have a high proportion. Temperature and precipitation both play a significant role in their distribution.

An optimum temperature is essential for their survival and dispersal. According to research, excessively cold temperatures make it difficult for pythons to survive (Mazzotti et al. 2011). The reported lethal temperature in the low land species is approximately 38–42°C (Brattstrom 1968; Snyder & Weathers 1975), and the increased temperatures can affect the population sex ratios of reptiles (Bickford et al. 2010). A study conducted in China among 50 snake species found that the distribution of species was related to changes

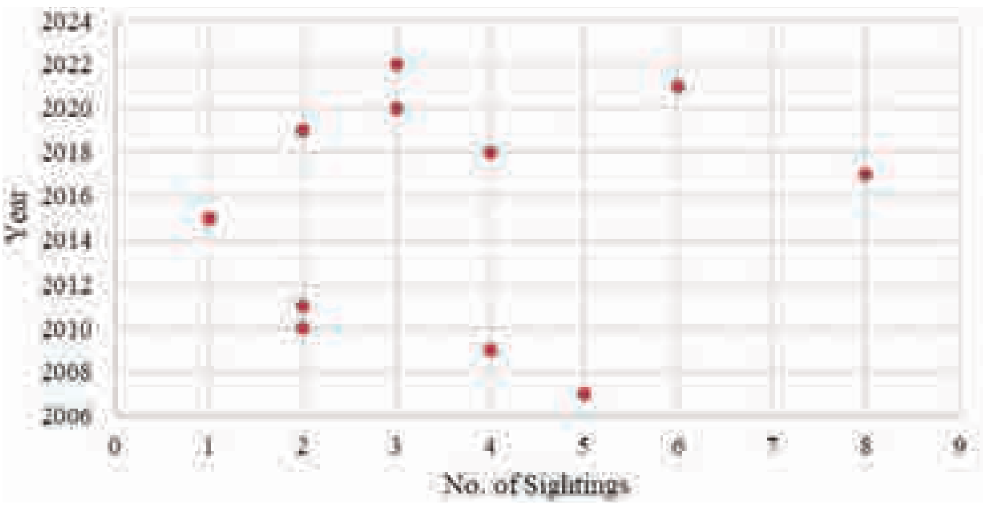

Figure 3. Annual sighting frequency of Pythons *P. bivittatus*.

Table 1. The list of environmental variables used in the model and their percent contribution and permutation importance in the model.

Variable	Description	Unit	Percent contribution (%)	Permutation importance (%)
bio17	Precipitation of Driest Quarter	mm	30.1	17.7
bio1	Annual Mean Temperature	°C	20.9	22
bio7	Temperature Annual Range (bio5-bio6)	°C	18.7	8.9
bio8	Mean Temperature of Wettest Quarter	°C	11.4	36.3
dem	Digital Elevation Model	m	6.6	1.8
bio16	Precipitation of Wettest Quarter	mm	6.4	2
landcover	Land Cover	-	3.3	3.2
bio9	Mean Temperature of Driest Quarter	°C	2.2	3.3
bio18	Precipitation of Warmest Quarter	mm	0.3	2.9
bio3	Isothermality (bio2/bio7)(×100)	-	0.1	2.1

in the thermal index and precipitation or potential evapotranspiration (Wu 2016).

The Jackknife evaluation results revealed that the Wettest Quarter Mean Temperature, Annual Mean Temperature, and Driest Quarter Precipitation were the primary factors influencing the *P. bivittatus* distribution (Figure 1). The percent contribution values are given in Table 1. A proper field survey in the remaining area would yield more sightings across the basin.

According to the findings, the Driest Quarter Precipitation (30.1%) is a significant influencing factor for the range extension of the Burmese Python in the Gangetic Basin, however, Penman et al. (2010) discovered that the Driest Quarter Precipitation is a major bioclimatic variable that has a significant impact on the distribution of the most endangered *Hoplocephalus bungaroides* snake species in Australia.

Similarly, Annual Mean Temperature is a significant variable that influences species distribution. Annual Mean Temperature contributed 20.9% to the Burmese Python distribution in the study area. Annual Mean Temperature is a significant bioclimatic factor for the species (Gül et al. 2015); according to a study on *Xerotyphlops vermicularis* from the western and central Black Sea Region, Annual Mean Temperature contributed 55.3% of the species' distribution (Afsar et al. 2016).

Rödder & Lötters (2010) has reported that the annual mean temperature contributes to the distribution of Greenhouse Frog *Eleutherodactylus planirostris* (13.8%). Mean Temperature of the Wettest Quarter (11.4 %) plays an important role in the distribution of the *P. bivittatus*. Studies on the invasive California Kingsnake *Lampropeltis californiae* in the Canary Islands have reported that the Mean Temperature of the Wettest Quarter and the Mean Temperature Driest Quarter have influenced its distribution.

The contribution of elevation was 6.6% and landcover was found to have 3.3%. The elevation also plays a role ecologically since it affects the temperature (Ananjeva et al. 2014; Hosseinzadeh et al. 2014). Studies have concluded that with a gain in elevation, species richness among reptiles would decline (Chettri et al. 2010).

Our findings show a trend in the westward range extension of the Burmese Python in the study area, which could be attributed to a response to changing climatic factors. In the United States, some studies have proven that less body temperature during the cold snap leads to physiological stress on this species and may lead to mortality (Mazzotti et al. 2011; Stahl et al. 2016). Jacobson et al. (2012) observed that the Burmese Pythons are projected to spread northward in response to warming winter temperature regimes. Nevertheless, Van Moorter et al. (2016) stated that animal movement is directly connected to resource use, such as habitat selection. However, recent records justify that this species having a good population along the Gangetic plain (Rashid & Khan 2018; Shafi et al. 2020).

Scarce SDM studies were conducted among reptile species in India; the primary reason is the only way to know about the occurrence localities of their collections is through publications of researchers. In many cases, a direct visit to the particular institutes is the only way to get the required data, which takes considerable time (Das & Pramanic 2018). In addition, finding them in the field is very difficult due to their highly camouflaged behaviour.

Table 2. Burmese Python location details.

	Place	Latitude	Longitude	Date	Observers
1	Rajaji National Park, Uttarakhand	29.8974	78.26666667	31-03-2007	Joshi & Singh 2015
2	Chilla Forest, Haidwar-Chilla-Rishikesh, Uttarakhand	29.9710	78.21327778	09-08-2007	Joshi & Singh 2015
3	Haridwar Forest Range, Rajaji National Park	29.9397	78.12827778	09-08-2007	Joshi & Singh 2015
4	Katerniaghat WS, Railway Station, Uttar Pradesh	28.3069	81.15638889	00-02-2009	Das et al. 2012
5	Katerniaghat WS, Uttar Pradesh	28.3373	81.12080833	00-06-2009	Das et al. 2012
6	Hastinapur Range, Uttar Pradesh	29.0809	78.06425	14-11-2009	Yadav et al. 2017
7	Forest Rest Hosue, Hastinapur Range, Uttarakhand	29.1546	77.99613889	28-12-2009	Yadav et al. 2017
8	Rispna River, Jakhan, Uttarakhand	30.3660	78.0829	15-09-2010	Joshi & Singh 2015
9	Bhitarkanika, Wildlife Sanctuary	20.7355	86.87741667	18-08-2010	Gopi 2010 (Unpubl.)
10	Timli Forest Range, Kalsa Forest Division, Uttarakhand	30.3333	77.67332778	14-10-2011	Joshi & Singh 2015
11	Lacchiwala Forest Range, Uttarakhand	30.2553	78.01666667	08-11-2011	Joshi & Singh 2015
12	Sanghagara Forest, Odisha	21.6323	85.55245278	00-00-2015	Nayak 2015 (Unpubl.)
13	Manguraha Range, Valmiki Tiger Reserve, Bihar	27.3288	84.53578611	11-03-2017	Shafi et al. 2020
14	Bijaligarh, Jawan, Aligarh, Uttar Pradesh	28.0407	78.11541667	18-05-2017	Rashid & Khan 2018
15	Narainapur village, Bihar	27.3387	83.96441667	11-08-2017	Shafi et al. 2020
16	Manor River, Ganauli Range, Bihar	27.3570	83.92586111	14-08-2017	Shafi et al. 2020
17	Dhaltangarh Forest, Odisha	20.3118	86.23827778	00-09-2017	Dwibedy 2017
18	Gautam Buddha, Wildlife Sanctuary, Bihar, Jharkhand	24.5797	85.54165556	00-09-2017	WII team 2017(Unpubl.)
19	Gandak barrage, Valmiki Nagar Range, Bihar	27.4333	83.92374444	04-11-2017	Shafi et al. 2020
20	Buxa, North Bengal	26.5667	89.45494444	00-11-2017	Dash 2017 (Unpubl.)
21	Udaipur Wildlife Sanctuary, Bettiah, Valmiki Tiger Reserve, Bihar	26.8137	84.43378056	14-01-2018	Shafi et al. 2020
22	Manguraha Range, Valmiki Tiger Reserve, Bihar	27.3189	84.46808333	24-01-2018	Shafi et al. 2020
23	WII, Campus, Chandrabani, Dehradun, Uttarakhand	30.2810	77.97494167	13-03-2018	Singh 2018 (Unpubl.)
24	Rooth Bangar, Anupshahr, Uttar Pradesh	28.3129	78.289875	14-10-2018	NMCG-WII 2019 (Unpubl.)
25	Gorumara, North Bengal	26.7185	88.77230278	00-08-2019	Dash 2019 (Unpubl.)
26	Buxa, North Bengal	26.6000	89.51839444	00-10-2019	Dash 2020 (Unpubl.)
27	Amangarh, Bijnor, Uttar Pradesh	29.4027	78.85969167	09-12-2020	Hushangabadkar 2019 (Unpubl.)
28	Barkala Range, Shivalik Forest Division	30.3946	77.63166667	20-02-2020	Pawar 2020 (Unpubl.)
29	Bijnor barrage, Uttar Pradesh	29.3733	78.03776944	26-07-2020	NMCG-WII 2020 (Unpubl.)
30	Dhumpara forest, West Bengal	26.6983	89.80184444	11-04-2021	Sarkar 2021 (Unpubl.)
31	Narora, Ganga Bas, Bulandshahr, Uttar Pradesh	28.1973	78.40184444	18-08-2021	NMCG-WII 2021 (Unpubl.)
32	Rajaji National Park, Uttarakhand	29.9685	78.20027778	12-11-2021	Kumar 2021 (Unpubl.)
33	Nawalpur, Bijnor, Uttar Pradesh	29.4037	78.02267778	20-11-2021	NMCG-WII 2021(Unpubl.)
34	Narora, Bulandshahr, Uttar Pradesh	28.2079	78.35157778	27-11-2021	NMCG-WII 2021(Unpubl.)
35	Narora, Barrage downstream, Bulandshahr, Uttar Pradesh	28.1891	78.39691389	19-12-2021	NMCG-WII 2021(Unpubl.)
36	Khatauli, Muzaffarnagar, Uttar Pradesh	29.2860	77.67954722	21-01-2022	Yadav 2022 (Unpubl.)
37	Corbett Tiger Reserve	29.5335	78.77368	10-10-2022	NMCG-WII 2022(Unpubl.)
38	Corbett Tiger Reserve	29.4924	78.762801	11-10-2022	NMCG-WII 2022(Unpubl.)

CONCLUSION

According to prediction results, the potential distribution of the Vulnerable Burmese Python has expanded westward from the northeastern region to the Ganga Basin. The Burmese Python's expanding range can be interpreted as a bioindicator of changing climate. A comprehensive study on future predictions, habitat suitability, and phylogeny will aid their conservation in the range-extended landscape and reveal the population

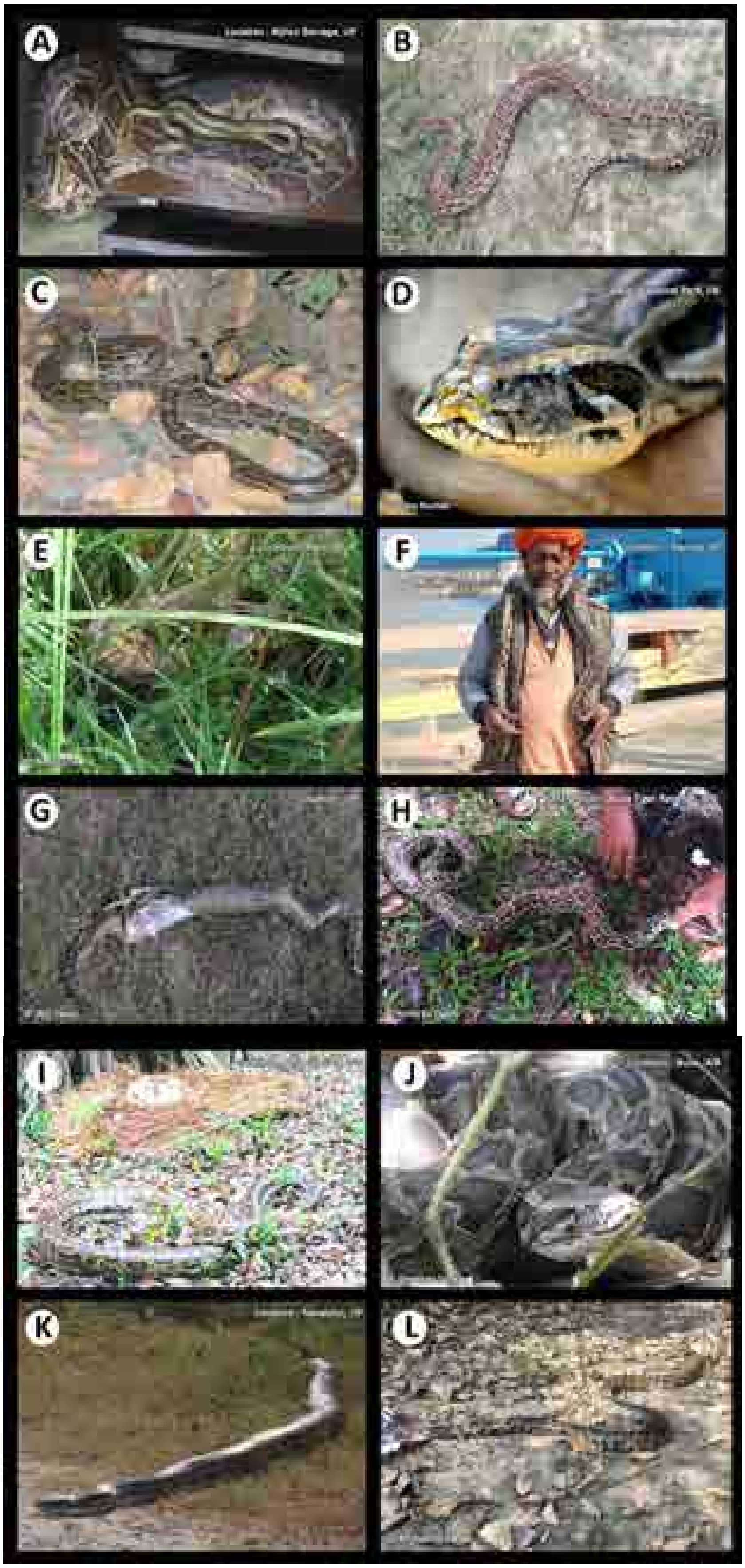

Image 1. Photographs of Burmese Pythons from the range extended landscape in and around the Ganga Basin.
© A,E,F,K - NMCG Team | B - Johny Valayil Jusappan | C - Kamalendar Singh | D - Sipu Kumar | G - WII Team | H - Suraj Kumar Dash | I - Akshay Nayak | J - Shekher Sarakar | L - Mohanlal Yadav.

divergence. This research will also assist field managers in successfully reintroducing Burmese Pythons into suitable habitats.

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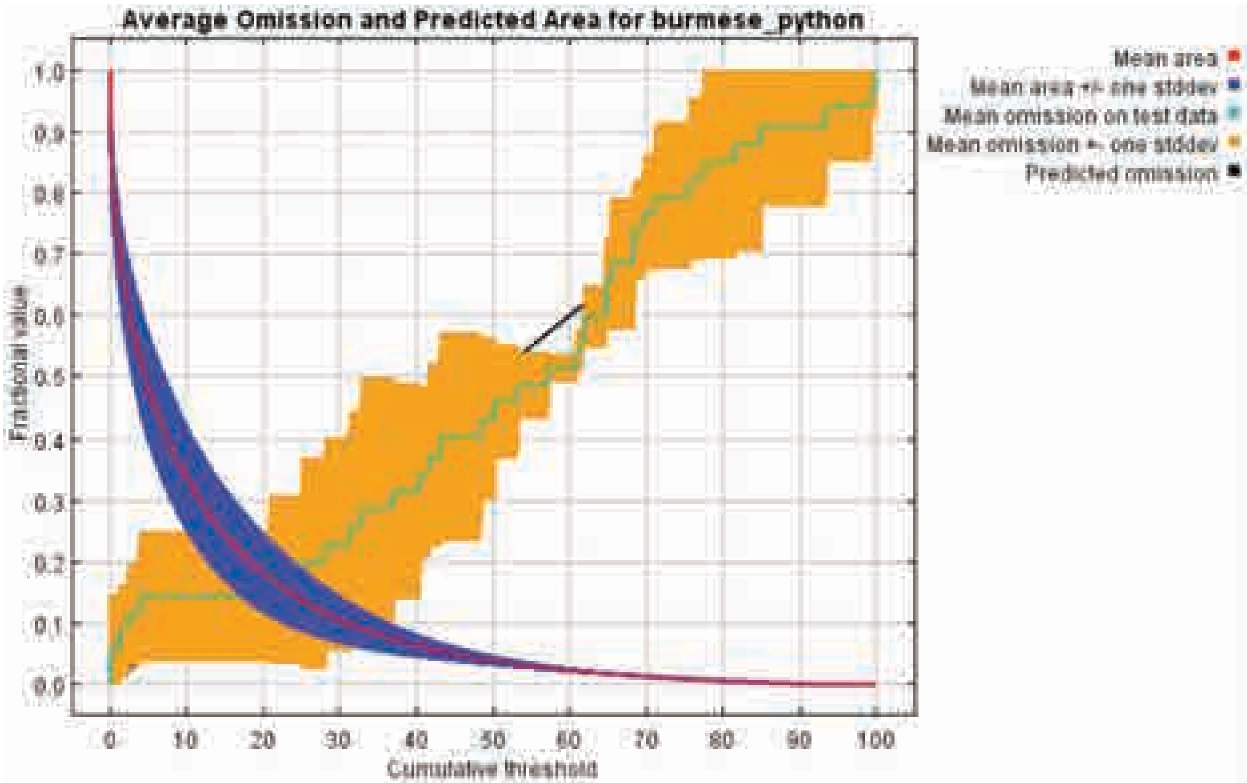
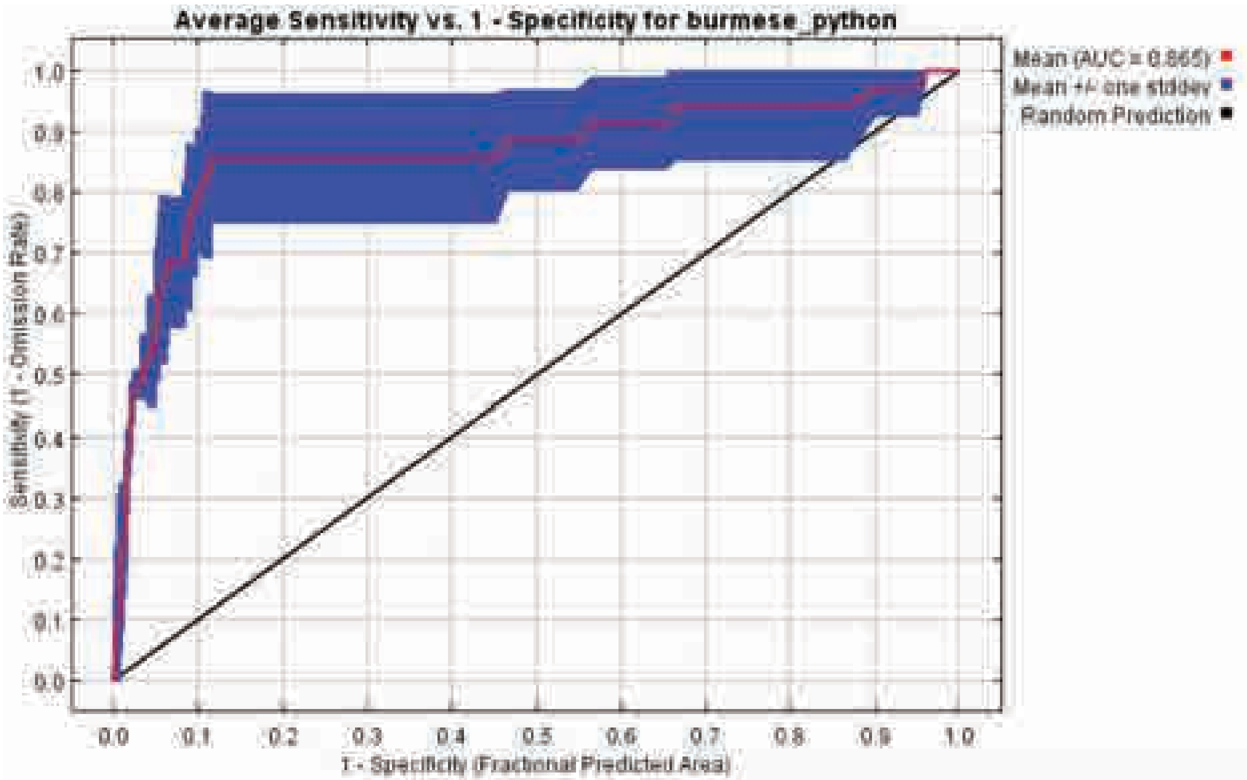
Supplementary Table 1. Correlation matrix of 19 bioclimatic variables for the study area.

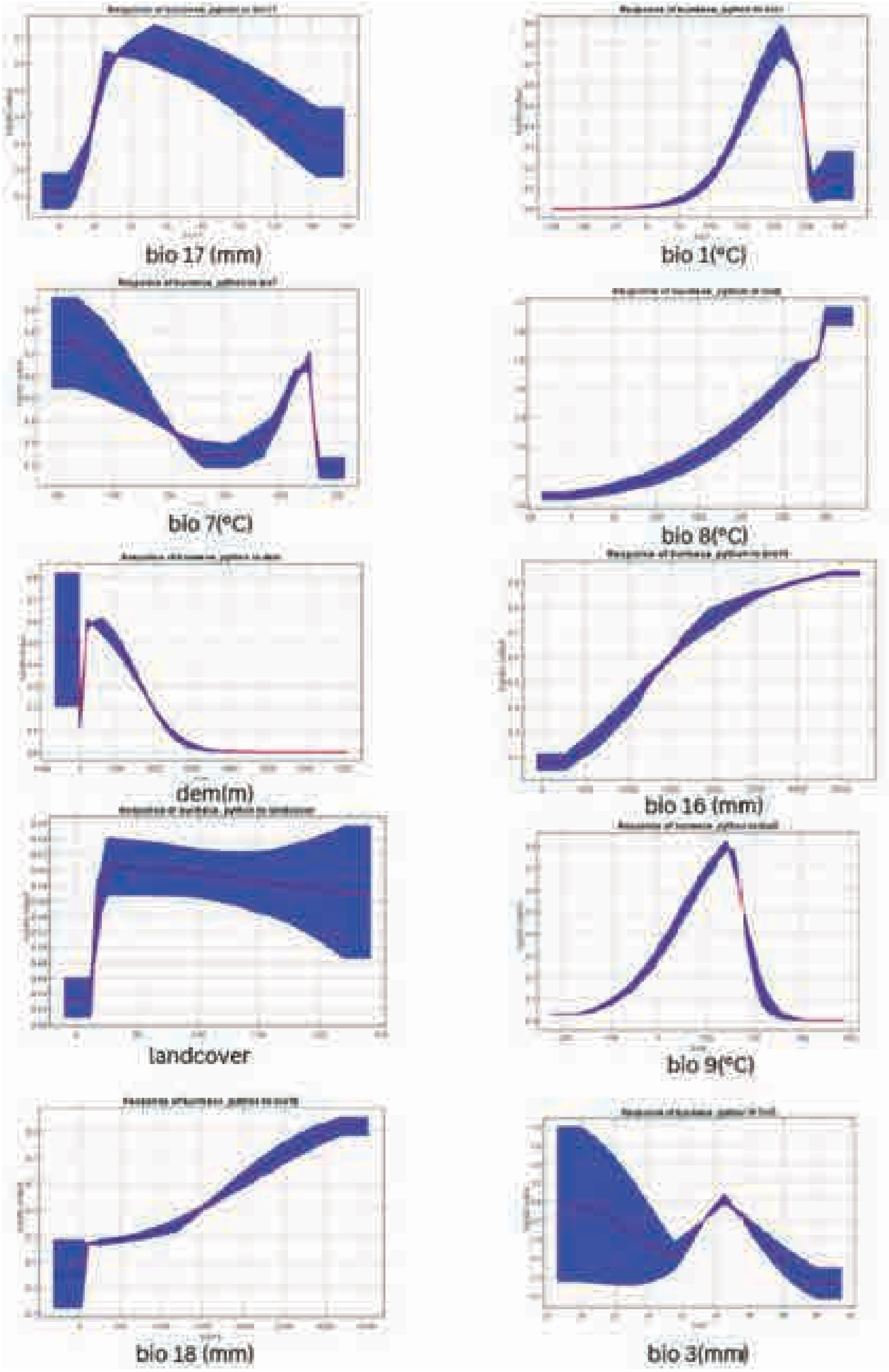
	bio1	bio2	bio3	bio4	bio5	bio6	bio7	bio8	bio9	bio10	bio11	bio12	bio13	bio14	bio15	bio16	bio17	bio18	bio19
bio1		-0.14779	0.08760	-0.42869	0.90153	0.92267	-0.14922	0.93389	0.81279	0.95163	0.95119	-0.21245	-0.16153	-0.81734	0.34291	-0.17860	-0.81841	-0.51654	-0.88703
bio2			-0.31464	0.81630	0.26648	-0.46219	0.95392	0.04286	-0.08663	0.12559	-0.37663	-0.54222	-0.20902	-0.11059	0.71472	-0.20688	-0.13034	-0.24952	0.31944
bio3				-0.67003	-0.09922	0.33385	-0.57486	-0.15161	0.02123	-0.06728	0.31439	0.44121	0.31085	0.08710	-0.43401	0.31909	0.14107	0.05773	-0.20499
bio4					-0.07045	-0.73224	0.90814	-0.13176	-0.31550	-0.17097	-0.68083	-0.43057	-0.17476	0.11897	0.55119	-0.17553	0.10056	0.09052	0.57134
bio5						0.70464	0.26739	0.89828	0.77905	0.98525	0.76266	-0.47444	-0.27734	-0.81398	0.66332	-0.29209	-0.84760	-0.65693	-0.72143
bio6							-0.49526	0.74698	0.74665	0.78795	0.99414	0.02268	-0.03898	-0.64307	0.04283	-0.05124	-0.64382	-0.41728	-0.89227
bio7								0.08541	-0.06010	0.13623	-0.41631	-0.61165	-0.28660	-0.12328	0.75396	-0.28802	-0.16343	-0.23760	0.32843
bio8									0.73185	0.93858	0.79022	-0.30953	-0.20348	-0.84934	0.47888	-0.22488	-0.83284	-0.42588	-0.76364
bio9										0.80841	0.76968	-0.22410	-0.13860	-0.64973	0.38786	-0.15809	-0.66989	-0.44216	-0.71539
bio10											0.83473	-0.38515	-0.22971	-0.82624	0.58044	-0.24640	-0.84637	-0.59264	-0.78426
bio11												-0.03064	-0.06362	-0.69210	0.11125	-0.07652	-0.68949	-0.45954	-0.90313
bio12													0.89080	0.33208	-0.47576	0.89701	0.38875	0.74506	0.08170
bio13														0.19523	-0.06113	0.99339	0.23411	0.67848	0.10474
bio14															-0.51010	0.21465	0.89777	0.43282	0.77657
bio15																-0.07259	-0.57791	-0.34106	-0.17024
bio16																	0.25888	0.67644	0.12540
bio17																		0.47692	0.80538
bio18																			0.39553
bio19																			



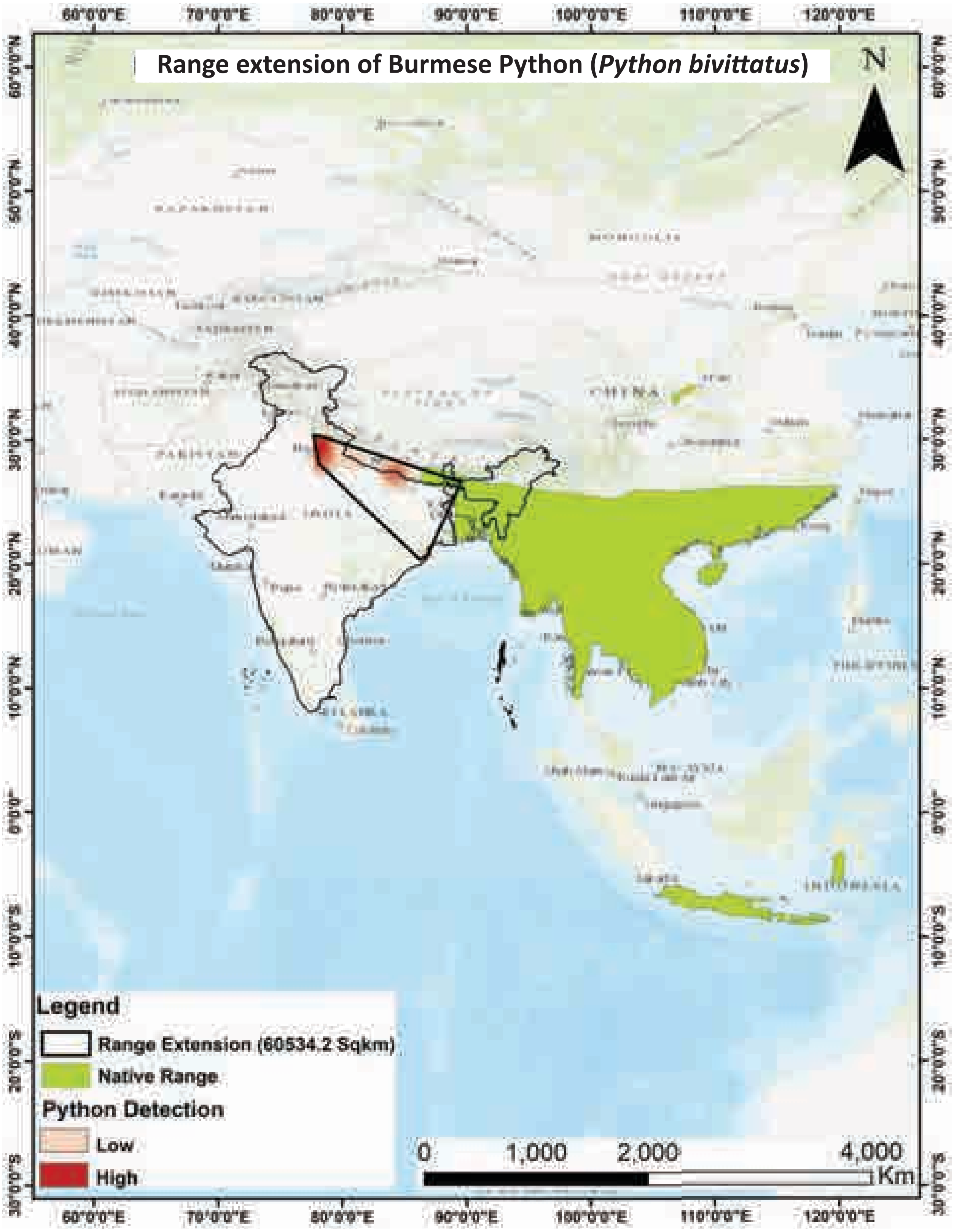
Supplementary Figure 1. Average Omission and Predicted Area for Burmese Python.



Supplementary Figure 2. Average specificity curve of Burmese Python (AUC=0.865).



Supplementary Figure 3. Probability of Response curves (Logistic Output).



Supplementary Figure 4. MCP range of the Burmese Python in the range extended landscape.

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COMMUNICATION

First record of *Tanaorhinus viridiluteata* Walker, 1861 (Lepidoptera: Geometridae: Geometrinae) from Mizoram, India

B. Lalnghahpuii [1], **Lalruatthara** [2] & **Esther Lalhmingliani** [3]

[1,2,3] Systematics and Toxicology Laboratory, Department of Zoology, Mizoram University, Aizawl, Mizoram 796004, India

[1] lalnanaui@gmail.com, [2] ruatthara@gmail.com, [3] es_ralte@yahoo.in (corresponding author)

Abstract: Very little work has been done to document the moth fauna of the Mizoram state in northeast India. An emerald moth collected from three localities in Aizawl District of Mizoram was identified as *Tanaorhinus viridiluteata* Walker, 1861 based on morphological and molecular studies. This species has been described briefly with colour photographs of male and female genitalia. Partial mitochondrial COI gene was amplified from these specimens for molecular analysis. This study represents a first record of the genus *Tanaorhinus* and species *T. viridiluteata* from Mizoram State.

Keywords: COI, genitalia, maximum likelihood, morphology, northeastern India, type locality.

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Author details: B. Lalnghahpuii is currently a PhD candidate in the Department of Zoology, Mizoram University, Aizawl Mizoram. Her research interest is on the taxonomy of moths of the family Geometridae based on morphological and molecular approach. Lalruatthara is currently a PhD candidate in the Department of Zoology, Mizoram University, Aizawl, Mizoram. His area of interest includes morphological and molecular studies on Sphingid moths of Mizoram. Esther Lalhmingliani is an associate professor in the Department of Zoology, Mizoram University, Aizawl, Mizoram. Her research interest is on systematic and taxonomic studies of moths and herpetofauna.

Author contributions: BL—field survey, curation, morphological & molecular data collection, data analyses, writing original draft; LA—field survey, curation, morphological data collection, data analysis; EL—conceptualization, methodology analysis, morphological & molecular data analyses, writing original draft & review & editing, supervision.

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INTRODUCTION

Mizoram State is situated in the southernmost tip of northeastern India, sandwiched by Myanmar in the east and Bangladesh in the west. Though the area falls within the Indo-Burma biodiversity hotspot (Mittermeier et al. 2004), the flora and fauna of the area are poorly documented. However, recent studies taken up in the area resulted in the description of several species new to science (e.g., Lalronunga et al. 2013; Giri et al. 2019; Kirti et al. 2019; Naumann & Lalhmingliani 2019). Hebert et al. (2003) proposed the use of the mitochondrial gene cytochrome c oxidase I (COI) as a reliable marker for accurate species identification, particularly in animals. Though faced with many criticisms and pitfalls (e.g., Tautz et al. 2003; Blaxter 2004), it is a useful tool for the identification of lepidopterans in general (Hajibabaei et al. 2006; Kim et al. 2020) and geometrid moths in particular (Brehm et al. 2016; Kumar et al. 2019).

Geometrinae (commonly known as emerald moths) is the fourth largest subfamily in the family Geometridae, with more than 27,006 valid species-group names, including 23,872 species and 3,123 subspecies worldwide (Rajaei et al. 2022). The genus *Tanaorhinus* Butler, 1879 contains 16 nominal species and five subspecies (Scoble & Hausmann 2007; Orhant 2014; Tautel 2014; Rajaei et al. 2022) all are restricted to Asia (Scoble 1999). However, Ban et al. (2018) revealed that the genus *Geometra* and *Tanaorhinus* are polyphyletic and revived the genus *Loxochila* Butler 1881 to accommodate *G. burmensis*, *G. fragilis*, *G. sinoisaria*, *G. smaragdus*, *T. kina*, and *T. tibeta*. They further speculated *Tanaorhinus* to be a junior synonym of *Geometra*. However, further molecular studies with the inclusion of more taxa are required for formal taxonomic action (Ban et al. 2018). Five species, *viz*., *T. celebensis* Yazaki, 1995, *T. kina kina* Swinhoe, 1893, *Tanaorhinus kina embrithes* Prout, 1934, *T. rafflessi* (Moore, [1860]), *T. reciprocate reciprocata* (Walker, 1861), and *T. viridiluteata* (Walker, 1861), were recorded from India (Kirti et al. 2019). Walker (1861) described *T. viridiluteata* from Darjeeling in West Bengal State of India. Apart from the type locality, the species was further recorded from Arunachal Pradesh, Assam, and Nagaland states in northeastern India, southern China, Taiwan, and Sundaland (Anonymous 2021; Holloway 2021). The species is characterized by dark green colour with two black cell specks enclosed by a bluish tinge on both sides of the forewing, ante and post medial waved lines closed together with irregular white suffusion on dorsal side of the body. The ventral side of the forewing is heavily suffused with brown and mauve and inner margin of the hindwing is excised forming heart shaped gap. This species is most similar to *T. rafflesia*, but can be distinguished from it by the presence of broad, uniform, rufous border in the ventral hindwing (vs. narrower and separated from the margin by a yellow zone in *T. rafflesia*) in males; and harpe in male genitalia more spatulated (vs. more acute in *T. rafflesia*). Herein, we report the first distribution records of *T. viridiluteata* from the state Mizoram in northeastern India.

MATERIALS AND METHODS

Surveys were conducted in Mizoram State (see materials examined section under results and discussion for details) using a 160 W mercury vapour bulb on a 4 ft. by 6 ft. white cloth screen with a Honda™ EP1000 portable generator as a power source. Specimens were killed in a killing jar containing petroleum ether, which were then removed and placed on butter paper with their wings folded vertically. Pinning, spreading, and labeling of specimens were done in the laboratory. Specimens were deposited in the Entomological Collections of the Systematics and Toxicology Laboratory, Mizoram University, Mizoram, India (MZUEC). Tissue (three legs each) was collected in a 2 ml centrifuge tube for genomic DNA extraction. The genitalia of each specimen were dissected following Sondhi (2020). Genomic DNA was extracted from the tissue sample using 10 µl of 20 mg/ml of Proteinase K with 56°C overnight treatment following standard Phenol: Chloroform: Isoamyl alcohol method (Sambrook & Russell 2001). We amplified a partial mitochondrial COI gene using the primer pair LCO-1490 and HCO-2198 (Folmer et al. 1994). PCR amplification was carried out in 25 µl aliquots containing 12.5 µL of EmeraldAmp® GT PCR Master Mix (2X) (TaKaRa Bio, Japan), 1 µl of each forward and reverse primer, 2 µl of genomic DNA, and 8.5 µl of molecular grade H2O using ProFlex™ 3 x 32-well PCR system (Applied Biosystems™, USA). The PCR conditions were as follows: initial denaturation was performed at 95°C for 5 min, followed by 35 or 40 cycles of 30 s at 94°C, 30 s annealing from 42°C to 50°C (Tables S3 and S4), 30 s at 72°C, with a final 5 min extension at 72°C. Amplified PCR products were ran on 1.5% agarose gel, viewed in IG-618GD (iGene Labserve, India) gel documentation system. The purified PCR products were sequenced bidirectionally by Sanger sequencing technology at geneOmbio Technologies Private Limited (Maharashtra, India). The chromatograms and raw sequences were edited using FinchTV 1.4.0 (Geospiza Inc., USA) and the consensus sequences were checked by BLAST search (https://blast.ncbi.nlm.nih.gov/Blast.cgi) and ORF finder (https://www.ncbi.nlm.nih.gov/orffinder/). The generated sequences (615–618 base pairs) were submitted to GenBank (NCBI) to acquire the accession numbers (MW855164–MW855166). The newly generated sequences were compared with other sequences of *Tanaorhinus* available in GenBank (Supplementary Table 1). Based on the lowest BIC (Bayesian Information Criterion) and AICc scores (Akaike Information Criterion, corrected), best fit nucleotide substitution model for the present COI dataset was GTR+G+I. A Maximum Likelihood (ML) tree was constructed with 1000 bootstraps in MEGA X (Kumar et al. 2018). The barcode data of *Chlorozancla falcatus* (MG014741) was used as an outgroup in the present phylogenetic analysis. The uncorrected pairwise genetic distances (p-distances) between and within the studied species were estimated by MEGA X (Kumar et al. 2018).

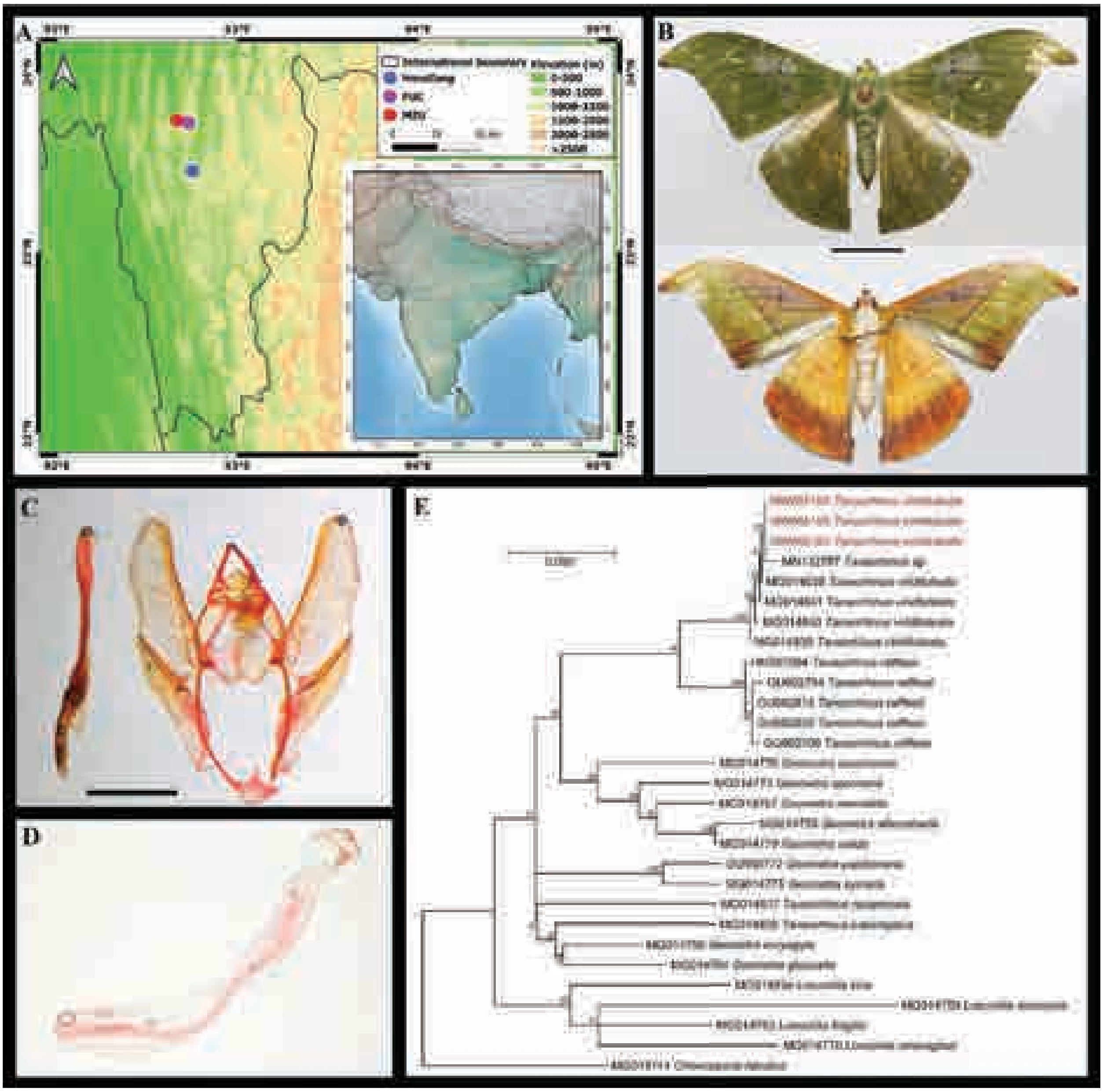

Image 1 . A—Collection localities of *Tanaorhinus viridiluteata* from Mizoram, India | B—Dorsal and ventral aspects of male individual (MZUEC 20210008); scale bar 1 cm | C—Male genitalia (MZUEC 20210004); scale bar 1 mm | D—Female genitalia (MZUEC 20210006), scale bar 1 mm | E—Maximum likelihood (ML) tree of the 29 COI sequence dataset; letters in red indicates the newly generated sequences for the present study. © B, C & D—B. Lalnghahpuii.

Material examined

MZUEC 20210001–20210005; 03.xii.2020; Hmuifang community forest reserve, Aizawl District, Mizoram; coll. B. Lalnghahpuii & party; (23.0051^{0}N 92.7521^{0}E, elevation 1,480 m). MZUEC 20210006–20210007; 23.x.2020; 01 female (wingspan 62 mm), 01 male (wingspan 65 mm); Mizoram University Campus, Aizawl District, Mizoram; coll. B. Lalnghahpuii & party; (23.7370^{0}N 92.6636^{0}E, elevation 790 m). MZUEC 20210008–20210009; 15.xi.2019; 01 female (wingspan 68 mm), 01 male (wingspan 60); Pachhunga University Campus, Aizawl District, Mizoram; coll. B. Lalnghahpuii & party; (23.7234^{0}N 92.7307^{0}E, elevation 815 m (Image 1A)).

Diagnosis: Wingspan 60–64 mm in male (four specimens) and 72 mm in female (one specimen). Upperside of forewing dark green in colour with two black cell specks enclosed by a bluish tinge; ante and post medial waved lines closed together with irregular white suffusion on dorsal side of the body; lunulate markings absent beyond the postmedial line; obscure white marks on submarginals. Underside of forewing green with costal area to beyond cell purplish-grey; oblique postmedial line with rufous patches at apex and outer angle; inner margin white. Upperside of hind wing dark green in colour except for costa which is white. Underside of hindwing yellowish with traces of postmedial line; outer area rufous; outer marginal areas yellowish (Image 1B).

The specimens collected from the three localities in Mizoram agreed with the description of *Tanaorhinus viridiluteata* in possessing the following characters: dark green colour with two black cell specks enclosed by a bluish tinge on both sides of the forewing; ante and post medial waved lines closed together with irregular white suffusion on the dorsal side of the body; ventral side of forewings heavily suffused with brown and mauve; presence of a broad, uniform, rufous border in the ventral hindwing in males; slightly spatulated harpe in male genitalia. The maximum likelihood (ML) tree (Image 1E) further revealed that the sample sequences from Mizoram, India, formed a clade with the sequences of *T. viridiluteata* along with an undetermined species of *Tanaorhinus* with an uncorrected genetic distance (p-distance) of only 0.002–0.008. In the ML tree, *T. viridiluteata* and *T. rafflesia* are sister species, which is not surprising as the two species are very similar morphologically. The genetic distance between the two species ranges from 0.053–0.061.

DISCUSSION AND CONCLUSION

As far as Mizoram is concerned, little work has been done to document the moth fauna of the state (Ghosh 2007; Kirti & Singh 2014, 2016; Kirti et al. 2014, 2019; Lalhmingliani et al. 2013, 2014; Lalhmingliani 2015), but recent studies have led to the description of several new species (e.g., Kirti et al. 2019, Naumann & Lalhmingliani 2019). Ghosh (2007) and Kirti et al. (2014, 2019) reported on geometrid moths from Mizoram State but did not mention the genus *Tanaorhinus*. The present study on *Tanaorhinus viridiluteata* from Mizoram represents the first record for this genus and species in the state.

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Supplementary Table 1. Cytochrome Oxidase subunit I (COI) gene sequences used for molecular analysis in this study.

	Species	Voucher code	Collection Locality	GenBank accession number	References
1	*Tanaorhinus viridiluteatus*	IOZ LEP M 10029	Fujian, China	MG014838	Ban et al. 2018
2	*Tanaorhinus viridiluteatus*	IOZ LEP M 2325	Hainan, China	MG014839	Ban et al. 2018
3	*Tanaorhinus viridiluteatus*	IOZ LEP M 8110	Hainan, China	MG014840	Ban et al. 2018
4	*Tanaorhinus viridiluteatus*	IOZ LEP M 8283	Guangdong, China	MG014841	Ban et al. 2018
5	*Tanaorhinus viridiluteatus*	MZUEC 20210004	Mizoram, India	MW855164	Present study
6	*Tanaorhinus viridiluteatus*	MZUEC 20210006	Mizoram, India	MW855165	Present study
7	*Tanaorhinus viridiluteatus*	MZUEC20210008	Mizoram, India	MW855166	Present study
8	*Tanaorhinus rafflesii*	RMNH.INS.13846	Kalimantan Timur, Indonesia	HM387094	GenBank
9	*Tanaorhinus rafflesii*	RMNH.INS.14079	Kalimantan Timur, Indonesia	GU662706	GenBank
10	*Tanaorhinus rafflesii*	RMNH.INS.13847	Kalimantan Timur, Indonesia	GU662754	GenBank
11	*Tanaorhinus rafflesii*	RMNH.INS.13845	Kalimantan Timur, Indonesia	GU662818	GenBank
12	*Tanaorhinus rafflesii*	RMNH.INS.13843	Kalimantan Timur, Indonesia	GU662820	GenBank
13	*Tanaorhinus* sp.	Lep8581	China	MN132787	Wang et al. 2019
14	*Tanaorhinus luteivirgatus*	IOZ LEP M 16545	Yunnan, China	MG014835	Ban et al. 2018
15	*Tanaorhinus reciprocata*	IOZ LEP M 17064	Gansu, China	MG014837	Ban et al. 2018
16	*Geometra albovenaria*	IOZ LEP M 5523	Shaanxi, China	MG014759	Ban et al. 2018
17	*Geometra euryagyia*	IOZ LEP M 16429	Shaanxi, China	MG014760	Ban et al. 2018
18	*Geometra glaucaria*	IOZ LEP M 16501	Beijing, China	MG014764	Ban et al. 2018
19	*Geometra neovalida*	IOZ LEP M 4763	Shaanxi, China	MG014767	Ban et al. 2018
20	*Geometra papilionaria*	NS03	Avinurme, Estonia	GU580772	Wahlberg et al. 2010
21	*Geometra sponsaria*	IOZ LEP M 8581	Liaoning, China	MG014773	Ban et al. 2018
22	*Geometra symaria*	IOZ LEP M 9287	Hubei, China	MG014775	Ban et al. 2018
23	*Geometra ussuriensis*	IOZ LEP M 4682	Shaanxi, China	MG014776	Ban et al. 2018
24	*Geometra valida*	IOZ LEP M 8567	Liaoning, China	MG014779	Ban et al. 2018
25	*Loxochila fragilis*	IOZ LEP M 9212	Yunnan, China	MG014763	Ban et al. 2018
26	*Loxochila kina*	IOZ LEP M 17078	Tibet, China	MG014834	Ban et al. 2018
27	*Loxochila sinoisaria*	IOZ LEP M 9457	Sichuan, China	MG014769	Ban et al. 2018
28	*Loxochila smaragdus*	IOZ LEP M 16551	Yunnan, China	MG014770	Ban et al. 2018
29	*Chlorozancla falcatus*	IOZ LEP M 20201	Guangxi, China	MG014741	Ban et al. 2018

Supplementary Table 2. Uncorrected p-distances between Cytochrome Oxidase subunit I (COI) gene sequences used in the study. GenBank accession numbers are listed after the name of the species. Letters in bold indicates the newly generated sequences in this study.

	Species	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
1	*Geometra albovenaria* (MG014759)																													
2	*Geometra euryagyia* (MG014760)	0.089																												
3	*Geometra fragilis* (MG014763)	0.093	0.091																											
4	*Geometra glaucaria* (MG014764)	0.078	0.048	0.089																										
5	*Geometra neovalida* (MG014767)	0.042	0.070	0.068	0.055																									
6	*Geometra papilionaria* (GU580772)	0.091	0.078	0.112	0.074	0.086																								
7	*Geometra sinoisaria* (MG014769)	0.118	0.116	0.095	0.106	0.112	0.116																							
8	*Geometra smaragdus* (MG014770)	0.131	0.112	0.086	0.110	0.112	0.129	0.105																						
9	*Geometra sponsaria* (MG014773)	0.065	0.061	0.089	0.057	0.040	0.089	0.122	0.116																					
10	*Geometra symaria* (MG014775)	0.093	0.076	0.110	0.067	0.084	0.044	0.114	0.131	0.082																				
11	*Geometra ussuriensis* (MG014776)	0.072	0.068	0.086	0.065	0.049	0.087	0.110	0.118	0.061	0.084																			
12	*Geometra valida* (MG014779)	0.023	0.072	0.082	0.057	0.029	0.087	0.114	0.118	0.042	0.082	0.059																		
13	*Tanaorhinus viridiluteata* (MG014838)	0.099	0.089	0.112	0.078	0.087	0.103	0.118	0.125	0.089	0.103	0.097	0.087																	
14	*Tanaorhinus* sp. (MN132787)	0.097	0.087	0.114	0.080	0.086	0.106	0.120	0.125	0.087	0.106	0.093	0.086	0.008																
15	***Tanaorhinus viridiluteata* (MG014841)**	0.097	0.087	0.110	0.076	0.086	0.103	0.116	0.124	0.087	0.103	0.095	0.086	0.002	0.006															
16	***Tanaorhinus viridiluteata* (MG014840)**	0.097	0.091	0.112	0.080	0.086	0.105	0.116	0.127	0.089	0.105	0.091	0.086	0.006	0.006	0.004														

	Species	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
17	***Tanaorhinus viridiluteata* (MG014839)**	0.095	0.086	0.110	0.078	0.084	0.106	0.120	0.122	0.086	0.106	0.091	0.084	0.008	0.004	0.006	0.006													
18	*Tanaorhinus rafflesii* (HM387094)	0.095	0.086	0.106	0.080	0.082	0.101	0.120	0.127	0.080	0.097	0.074	0.074	0.055	0.055	0.053	0.057	0.051												
19	*Tanaorhinus rafflesii* (GU662818)	0.097	0.087	0.108	0.082	0.084	0.101	0.124	0.127	0.082	0.097	0.076	0.076	0.059	0.059	0.057	0.061	0.055	0.004											
20	*Tanaorhinus rafflesii* (GU662820)	0.097	0.087	0.108	0.082	0.084	0.101	0.124	0.127	0.082	0.097	0.076	0.076	0.059	0.059	0.057	0.061	0.055	0.004	0.000										
21	*Tanaorhinus rafflesii* (GU662706)	0.097	0.087	0.108	0.082	0.084	0.101	0.124	0.127	0.082	0.097	0.076	0.076	0.059	0.059	0.057	0.061	0.055	0.004	0.000	0.000									
22	*Tanaorhinus rafflesii* (GU662754)	0.095	0.086	0.106	0.080	0.082	0.099	0.122	0.129	0.080	0.095	0.074	0.074	0.057	0.057	0.055	0.059	0.053	0.006	0.002	0.002	0.002								
23	*Tanaorhinus viridiluteata* (MW855166)	0.099	0.091	0.114	0.080	0.087	0.105	0.118	0.127	0.089	0.105	0.095	0.087	0.002	0.006	0.004	0.004	0.006	0.057	0.061	0.061	0.061	0.059							
24	*Tanaorhinus viridiluteata* (MW855164)	0.099	0.091	0.114	0.080	0.087	0.105	0.118	0.127	0.089	0.105	0.095	0.087	0.002	0.006	0.004	0.004	0.006	0.057	0.061	0.061	0.061	0.059	0.000						
25	*Tanaorhinus viridiluteata* (MW855165)	0.099	0.091	0.114	0.080	0.087	0.105	0.118	0.127	0.089	0.105	0.095	0.087	0.002	0.006	0.004	0.004	0.006	0.057	0.061	0.061	0.061	0.059	0.000	0.000					
26	*Tanaorhinus kina* (MG014834)	0.114	0.078	0.072	0.080	0.099	0.103	0.091	0.097	0.097	0.095	0.082	0.105	0.114	0.118	0.112	0.114	0.114	0.097	0.099	0.099	0.099	0.097	0.116	0.116	0.116				
27	*Tanaorhinus reciprocata* (MG014837)	0.099	0.061	0.112	0.067	0.086	0.095	0.131	0.127	0.087	0.097	0.087	0.084	0.099	0.095	0.097	0.095	0.093	0.097	0.099	0.099	0.099	0.097	0.099	0.099	0.099	0.106			
28	*Tanaorhinus luteivirgatus* (MG014835)	0.097	0.078	0.099	0.067	0.080	0.093	0.101	0.122	0.093	0.078	0.080	0.086	0.097	0.099	0.097	0.095	0.101	0.101	0.105	0.105	0.105	0.103	0.097	0.097	0.097	0.099	0.080		
29	*Chlorozancla falcatus* (MG014741)	0.112	0.097	0.097	0.082	0.089	0.108	0.118	0.120	0.097	0.105	0.099	0.101	0.099	0.105	0.101	0.103	0.101	0.110	0.114	0.114	0.114	0.112	0.099	0.099	0.099	0.097	0.105	0.087	

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COMMUNICATION

The giant clam commensal shrimp *Anchistus miersi* (de Man, 1888) (Decapoda: Palaemonoidae) new to Lakshadweep Sea, India

Manu Madhavan [1], Purushothaman Paramasivam [2], S. Akash [3], T.T. Ajith Kumar [4] & Kuldeep Kumar Lal [5]

[1–5] ICAR – National Bureau of Fish Genetic Resources, Canal Ring Road, P.O. Dilkusha, Lucknow, Uttar Pradesh 226002, India.
[1,4] Kerala University of Fisheries and Ocean Studies, Kochi, Kerala 682506, India.
[1] manumadhavan060@gmail.com, [2] purushothgene@gmail.com, [3] akash03jack@gmail.com
[4] ttajith87@gmail.com (corresponding author), [5] kuldeepklal@gmail.com

This article is dedicated to the late Dr. P. Purushothaman, the second author.

Abstract: The genus *Anchistus* Borradaile, 1898 is a colourful shrimp from the commensal group. In this study, we are reporting a new occurrence of Giant Clam commensal shrimp *Anchistus miersi* (de Man, 1888 [in de Man, 1887–1888]) caught from Agatti Island, Lakshadweep Sea during February 2020. The present specimens (one each matured male and female) were collected from the mantle cavity of the Giant Clam, *Tridacna maxima* (Roding, 1798) in the coral lagoon at a depth of 4 m. *Anchistus miersi* is morphologically very similar to *Anchistus demani,* which is easily distinguished by the presence of a strong antennal spine and conspicuous accessory spinules in the third–fifth pereopods and presence of small blue spots all over the body. The molecular analysis confirms that, the morphological identification of the present Indian specimens displays an intraspecific genetic divergence of 0.3–1.2%. Besides, the remarkable taxonomic features and colour patterns, distributional ranges are also attested with the report of the species from the present area.

Keywords: Agatti Island, distributional range, giant clam association, Lakshadweep, morphology.

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Competing interests: The authors declare no competing interests.

Author details: Manu Madhavan is working as PhD, research scholar at the ICAR-National Bureau of Fish Genetic Resources. Purushothaman Paramasivam is a researcher at the ICAR-National Bureau of Fish Genetic Resources. S. Akash is working as PhD, research scholar at the ICAR-National Bureau of Fish Genetic Resources. T.T. Ajith Kumar is working as principal scientist at the ICAR-National Bureau of Fish Genetic Resources. He known for his contribution to marine ornamental aquaculture for conservation and livelihood. Kuldeep Kumar Lal was the former director of the ICAR-National Bureau of Fish Genetic Resources and presently the director of the ICAR - Central Institute Brackishwater Aquaculture, have vast experience in conservation genetics.

Author contributions: MM—animal collection and morphological identification of the specimen. PP—species confirmation by morphological and molecular analysis and preparation of the manuscript. SK—animal collection and morphological identification of the specimen. TTAK—manuscript revision. KKL—conceptualization.

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INTRODUCTION

The shrimp fauna of Indian waters was studied majorly in the zones of western and eastern coasts. The insight knowledge on the caridean shrimps from Lakshadweep waters is still very narrow with the current status. Recently, a few surveys have exposed new distributional coral-associated carideans (Baby et al. 2016; Bharathi et al. 2019; Madhavan et al. 2019; Akash et al. 2020; Prakash & Marimuthu 2020).

In general, some of the palaemonid shrimps are endo-commensal species, enticing and fascinating in their colour patterns. These shrimps inhabit mantle cavities and gastric regions of host organisms such as sponges, bivalves, and tunicates (Kemp 1922; Johnson & Liang 1966; Bruce 1977; De Grave 1999). The genus *Anchistus* Borradaile, 1898 is one such taxa and has been symbolized as a commensal group, usually associated with bivalves (mostly in the subfamily Tridacninae) (Bruce 1972, 2000; Jayachandran 2001). In the symbiotic relationship, the giant clam gain benefits from the shrimps with cleaning service, which helps to maintain the health of its tissues. Simultaneously, the shrimps get benefits from the giant clams like safety from predator, stable environment, as well as access to food. This symbiotic relationship was dynamic and can change over time. For example, a cleaner shrimp may become a parasite, if it begins feeding on the giant clam's tissues rather than just its parasites.

Typically, this genus covers seven species which are distributed in the Indo-Pacific regions at shallow water depths (Jayachandran 2001; De Grave & Fransen 2011). Four species are reported from the Indian waters notably in Andaman and Nicobar Islands; *Anchistus custos* (Forskål, 1775), *A. demani* Kemp, 1922, *A. miersi* (de Man, 1888 [in de Man, 1887–1888]), and *Anchistus pectinis* Kemp, 1925 (Samuel et al. 2016). The morphological features of *Anchistus* are distinguished from other groups of palaemonid shrimps by the presence of their movable spine in the lateral border of uropods, rostrum downwards, laterally compressed and extended to the distal end of eyes. Also, the distolateral spine of antennal scaphocerite is not overreaching the distal margin and has a convex structure in the inner margin of the dactylus of 3rd pereopods.

During the recent survey undertaken at Lakshadweep waters, a pair of *Anchistus* specimens were collected at shallow depth lagoon regions of Agatti Island. These specimens were carefully examined and have been identified as *A. miersi,* which is a new distributional record to the Lakshadweep Sea. The authors also provided taxonomic notes on morphological and molecular features, habitat, and coloration of this species in a unique manner.

MATERIALS AND METHODS

Sampling

A pair of *A. miersi* specimens were caught out from the mantle cavity of the Giant clam, *T. maxima* (Roding, 1798) from the lagoon area of Agatti island at the depth of 4 m (10.8533N & 72.1872E; Image 1). The specimens were picked up using a hand net during snorkeling in the reef region of the lagoon. The specimens were transferred alive to the Germplasm Resource Centre of the ICAR - National Bureau of Fish Genetic Resources (NBFGR) located at Agatti, Lakshadweep, India for further analysis. After transportation, the colouration of the species was captured with a camera (Canon G1X), followed by maintaining the specimens in live condition. However, mortality was noticed on the second day, it might be happened due to the absence of host organisms. Further, the dead specimens were preserved in 95% of ethanol for detailed morphological examination.

Morphology

The preserved specimens were taken to the Peninsular and Marine Fish Genetic Resources (PMFGR) Centre of the ICAR-NBFGR, Kochi, India for further studies. Careful examination with a stereo zoom microscope (0.5–8X) with Nikon SMZ1270 digital camera has been carried out. A compound microscope, Leica ICC50 was used for observation of dactylus and mouth structures. The illustrative images for morphological characteristics were drawn using the GNU Image Manipulation Program (Version 2.10.12) and edited with Adobe Photoshop CS2. The morphological identification and diagnosis were carried out by following the literature of Holthuis (1952), Bruce (1973), and Jayachandran (2001). The examined material was deposited in the National Fish Museum and Repository of the ICAR-NBFGR, Lucknow, India. The measurement of carapace length (CL) was taken from the posterior orbit angle to the posterior margin of the cephalothorax with Vernier caliper (0.1 mm accuracy). The measure of CL is considered as a standard length for both individuals.

DNA barcoding

The partial sequences of barcoding gene mitochondrial cytochrome c oxidase I (COI) data were generated for this species adopting Akash et al. (2020).

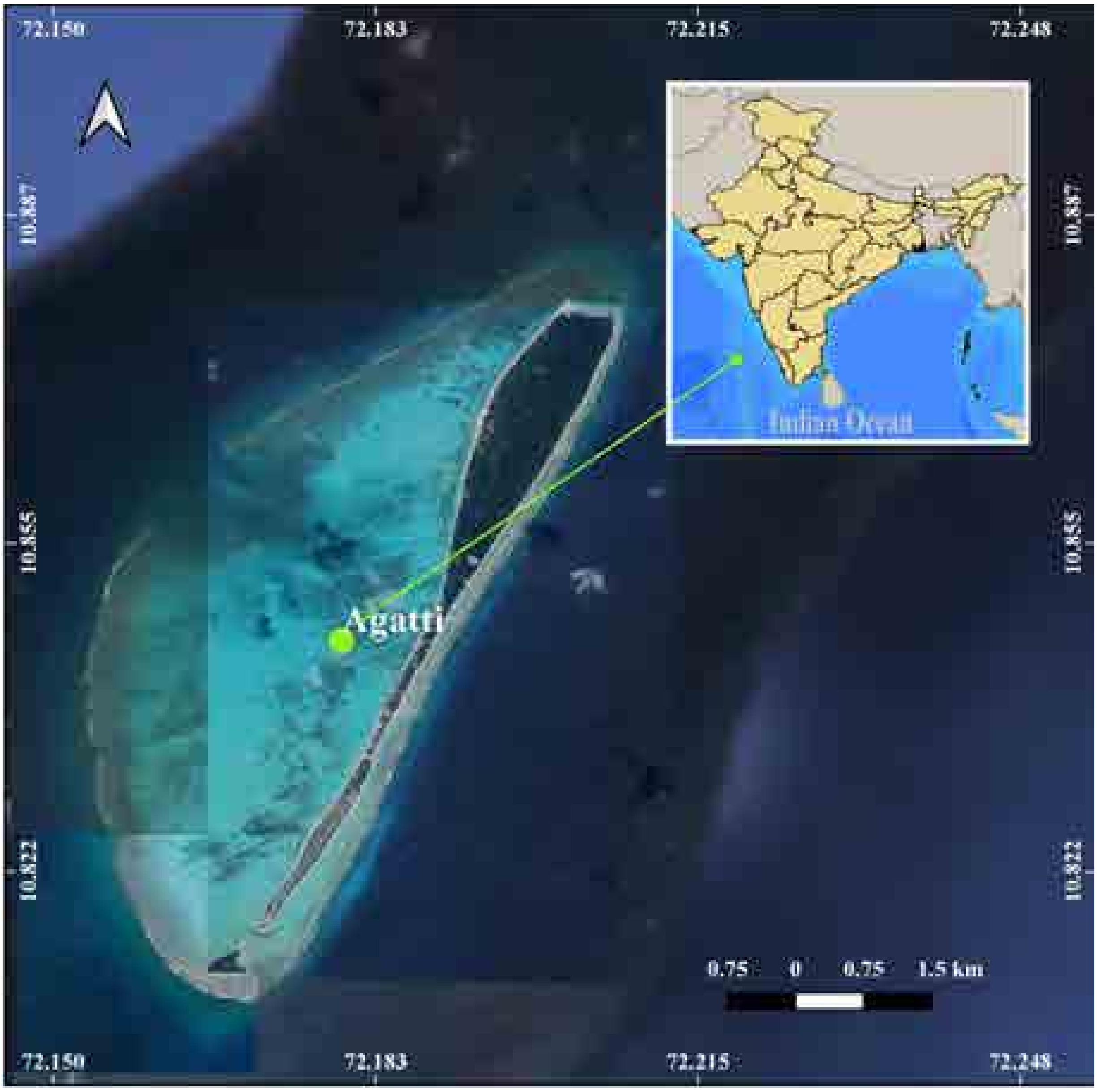

Image 1. Collection site of *Anchistus miersi* (de Man, 1888 [in de Man, 1887–1888]) from a Giant clam, Tridacna maxima at Agatti island, Lakshadweep, India.

BioEdit software v. 5.0.9 (Thompson et al. 1994) was used to align and correct the sequence data. The corrected sequences were blasted in Blastn (https://blast.ncbi.nlm.nih.gov/Blast.cgi) of NCBI to find out similarity ranges. 12 COI sequences of *Anchistus* species were retrieved from NCBI (https://www.ncbi.nlm.nih.gov/) and were used in this analysis. MEGA X software was used to estimate the pairwise genetic distances and reconstruct the Maximum Likelihood (ML) tree (Kumar et al. 2018) with the implementation of 1,000 replications.

Taxonomic Status

Order Decapoda Latreille, 1802
Infraorder Caridea Dana, 1852
Superfamily Palaemonoidea Rafinesque, 1815
Family Palaemonidae Rafinesque, 1815
Genus *Anchistus* Borradaile, 1898
Species *Anchistus miersi* (de Man, 1888 [in de Man, 1887–1888]) (Images. 2, 3 & 4)

Harpilius miersi De Man, 1888 : 274, Plate 17, figs 6–10 [type locality : Elpninstone Island. Mergui Archipelago. Burma].

A. miersi. – Holthuis. 1952 : 110–111, Fig 45. – Bruce, 1973 : 136, Fig. 1c–e. – Monod, 1976 : 24–26, figs 29–36. De Grave, 1999: 132–133.

Material examined

NBFGR/PALAMIE.01, female (CL: 3.0 mm, ID no: DBTLD224) and 1 male (CL 2.5 mm, ID no: DBTLD186), coral reef lagoon at Agatti Island, Lakshadweep, Arabian Sea, Indian Ocean (10.8533N & 72.1872E), 4 m depth, associated with *T. maxima*, temperature 28.2^0 C, Salinity 35 ppt, February 2020.

Diagnosis

Carapace (Image 2) glabrous and more or less dorsally convex with a strong antennal tooth. Rostrum Fig 1A) short and directed downwards, slightly reaching the distal end of second antennular peduncle; terminal end rounded and bearing 2–3 teeth on the upper border, ventral of the terminal end rounded with few plumose setae. Abdomen tergites dorsally rounded and somewhat compressed. The posteroventral angle of the 4th & 5th somite rounded, 6th somite bearing a strong tooth in postero-ventrally. The nature of the telson smooth and thin, about 1.6 times as long as 6th abdominal somites, and bears two pairs of dorsolateral spines; terminal end rounded and bears with small 4 pairs of posterior-distal spines (Figure 1B). Uropod rounded posteriorly and bearing with a movable tooth in the lateral side, slightly exceeded in the distal end of telson. Basal antennular peduncle (Figure 1C) with anterolateral tooth, second and third segments short. Stylocerite acute distally and exceeding to middle of the first antennular segment; both flagella almost equal, upper antennular flagellum fused with 13 segments and free ramus with 11 segmented, which has few hairy setae in distally. The antennal scale (Figure 1D) with a strong anterolateral spine, and distinctly exceeded distal end with few long plumose setae. Third maxilliped with well-developed exopod; the antepenultimate segment about 1.5 times as long as the penultimate segment with few lateral setae, ultimate segment short and fringed with numerous setae. The first pereopod slender, merus slightly longer than carpus. The ventral side of the carpus with few long setae and fingers with nine groups of setae present dorsally. Second pereopods (Image 2) symmetrical, carpus short, and triangle-shaped with palm stout, dactylus curved hook like structure at anteriorly and proximally with strong tooth and few small teeth; female pereopods somewhat similar in length, dactylus about 0.5 lengths of palm, whereas in male, major dactylus is about 0.5 in the length of the palm and minor dactylus is 0.64 length of the palm.

Image 2. Picture representation of *Anchistus miersi* (de Man, 1888 [in de Man, 1887–1888]) collected from Agatti island, Lakshadweep, India (Ethanol preserved). © Purushothaman Paramasivam.

Pereopods III–VI (Figure 1E–J) similar in size; propodus have few long setae at the distal end, their dactylus short and hook liked structure with a microscopic tooth in flexor margin. The third and fourth pereopods stout and similar in structures, merus about 2.3 times as long as carpus; propodus subequal to merus, about 7.3 lengths of dactylus. Fifth pereopods slightly compressed, merus about 1.9 times as long as carpus, propodus about 1.1 times as long as merus, 2.1 times as long as carpus, and 8.5 times of dactylus.

Colouration in life

The body and appendages are commonly translucent with scattered small blue spots (Image 3). Rostrum with few blue dots, antennal scale, and antennular peduncle with blue spots, but flagellum is transparent. The second pereopods are translucent with lined blue dots dorsally. The third–fifth pereopods are transparent without any marks. Eyes are translucent with small dark blue dots in eyestalk, cornea with dark black with translucent. The ovary is greenish.

Habitat and Distribution

The present species was caught from the mantle cavity of the Giant clam, *T. maxima* (Röding, 1798) (Image 4) in the lagoon region of Agatti island (10.8533N & 72.1872E), Lakshadweep at the depth of 4 m. *A. miersi* is widely distributed in Indo-Pacific regions, ranging from the Red Sea, eastern Africa to the Gambier Archipelago through Maldive and Chagos Islands, Seychelles; Zanzibar, Kenya, Tanganyika, Madagascar, Andaman Islands, and the Philippines. In common, this species is associated with the *Tridacna* clam (subfamily Tridacninae). However,

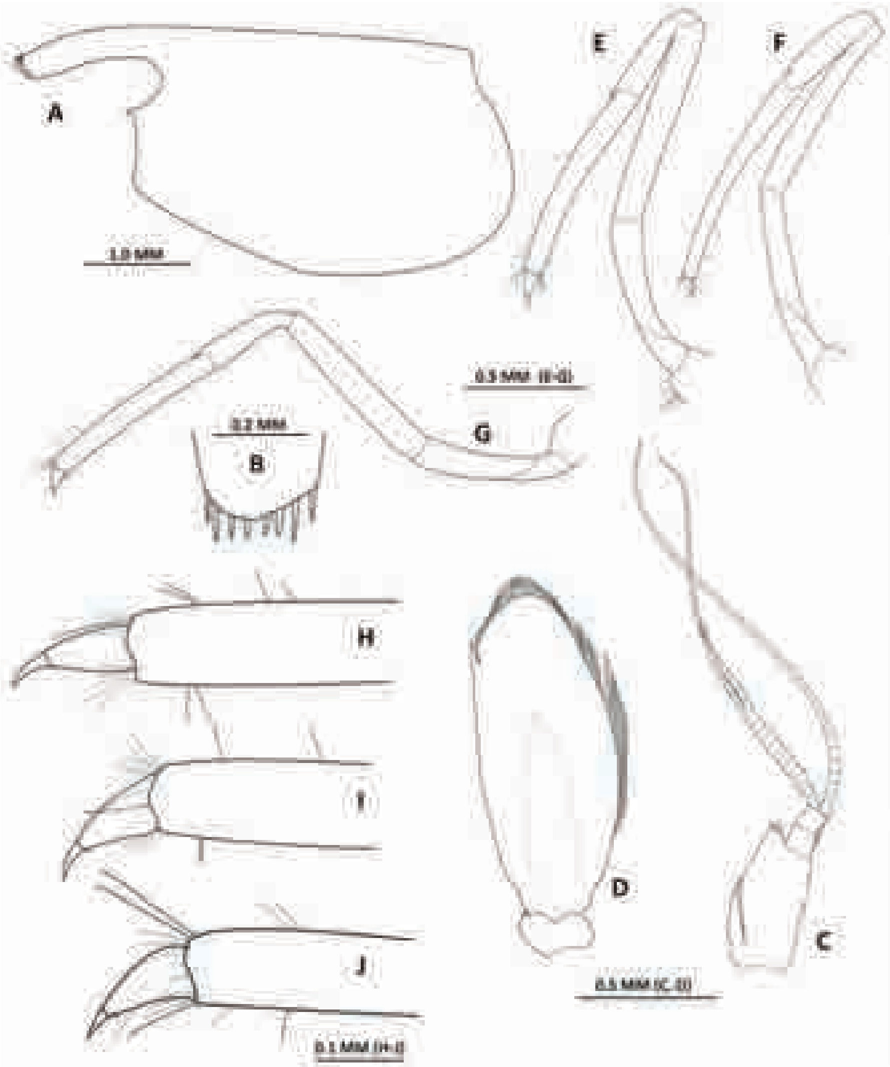

Figure 1. *Anchistus miersi* (de Man, 1888 [in de Man, 1887–1888]) from Agatti Island, Lakshadweep, India: A—Lateral view of carapace | B—Posterior end of the telson (Closer view) | C—Dorsal view of antennular peduncle | D—Dorsal view of antennal scale | E—Lateral view of the third pereopod | F—Lateral view of forth pereopod | G—Lateral view of the fifth pereopod | H–J—Closer view of dactylus of Last three pereopods.

it also occurred within bivalve of the genera *Hippopus, Pinna, Magnavicula*, and *Meleagrina* (Bruce 1978; Chace & Bruce 1993; De grave 1999; Neo et al. 2014).

Remarks

The present Indian specimens were agreed well with previous descriptions of De Man (1888) and Kemp (1922) with their key characteristics of Jayachandran (2001) with carapace and architecture of rostrum, presence of antennal spines, dactylus dentation of second pereopods, and its colour patterns. The general appearance of the Indian materials is similar with earlier finding, but a female individual is bigger than the male. Also, some remarkable differences were noticed in the present organisms, upper antennular flagellum fused with 13 segments and free ramus segmented with 11 articles (where de Man mentioned few segments fused in basally), the antepenultimate segment of third maxilliped is broader much than the penultimate segment. Dactylus of ambulatory pereopods with hook-like distal end with a microscopic tooth in flexor margin, fifth pereopod slightly compressed and longer than third and fourth pereopods. However, minute spinules or granules were not able to observe on the anterior border on the dactylus, where Fujino (1975) described the minute granules with the help of scanning electron microscopy.

The present individuals of *A. miersi* had an appealing colour pattern in their overall body with transparent and small dark blue spots, which also agree well with the previous descriptions of Bruce (1976) and Neo et

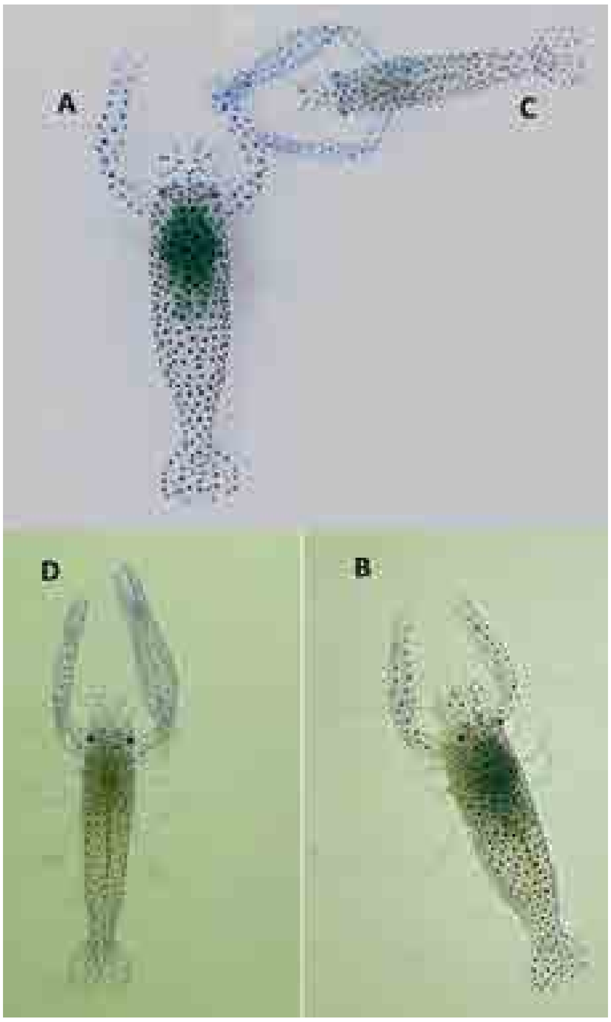

Image 3. The live colouration of *Anchistus miersi* (de Man, 1888 [in de Man, 1887–1888]) from Agatti Island, Lakshadweep, India: A–B—Female | C–D—Male. © Purushothaman Paramasivam.

al. (2014). However, he has noticed two different colour spots (red and blue) over the body and appendages. Commonly, *Anchistus* shrimps live as pairs in the host animals, especially bivalves (Bruce 1975; Fujino 1975). This colour variation is caused due to sexual dimorphism and based on their dwelling habitats (Bruce 1976). De Grave (1999) reported red dots and transparent colour in both the animals obtained from the Hansa Bay associated with *Magnavicula penguin* at the depth of 19 m. Neo et al. (2015) also noticed red dots in the male organism, wherein female blue dots were noticed, which were associated with a fluted giant clam, *Tridacna squamosa* from Singapore waters. In the present study, both the sex had dark blue spots in the body, which were associated with Giant clam, *T. maxima* from Agatti Island, Lakshadweep. In morphological and colour patterns wise, *A. miersi* is closely related to *A. demani.*

Image 4. A Giant Clam *Tridacna maxima* at Agatti island, Lakshadweep, India, where *Anchistus miersi* was collected. © Purushothaman Paramasivam.

However, *A. miersi* differed by the presence of a strong antennal spine (vs absent in *A. demani*), very minute and conspicuous accessory spinules in the third-fifth pereopods (vs inconspicuous and blunt in *A. demani).* The colour patterns also differed between these two species, small blue spots over the body for *A. miersi* and comparatively bigger in size of blue spots for *A. demani* individuals (Kemp 1922*;* Jayachandran 2001).

DNA Barcoding

The COI DNA barcoding has been commonly applied for revealing cryptic species complex, taxonomic ambiguities, delineating species boundaries of crustaceans (Hebert et al. 2003; Schwentner et al. 2013; Chan et al. 2017). The present study generated two COI sequences for Indian materials of *A. miersi* with greater than 650 bp (Accession No: MW897781 & MW897782). The NCBI has only 12 COI sequences of the *Anchistus* species, which have been retrieved and used for the present analysis where, two sequences are from *A. australis*, four from *A. miersi*, and another four from *A. custoides*. It should also be noted that the sequences of *A. demani* (KP759379 & KC706757) are not used for the present analysis due to the close homogeneity with the sequences of *A. miersi.* It reveals that misidentified sequences are there in NCBI for *A. demani* (KP759379 from Madagascar and KC706757 from French Polynesia), which have >99.5% sequences similarity with the present Indian materials of *A. miersi.* Overall, the present study reveals that the intraspecific genetic divergence for *A. miersi* is 0.3–1.2 % and the highest interspecific divergences were showed between these three species which ranged from 9.7–23.9% (Table 1). On the other hand, a sequence of *A. custoides* (MH287043) showed the greatest intraspecific divergences with the Malaysian materials (Fransen & Reijnen 2012) which has to be restudied with integrative

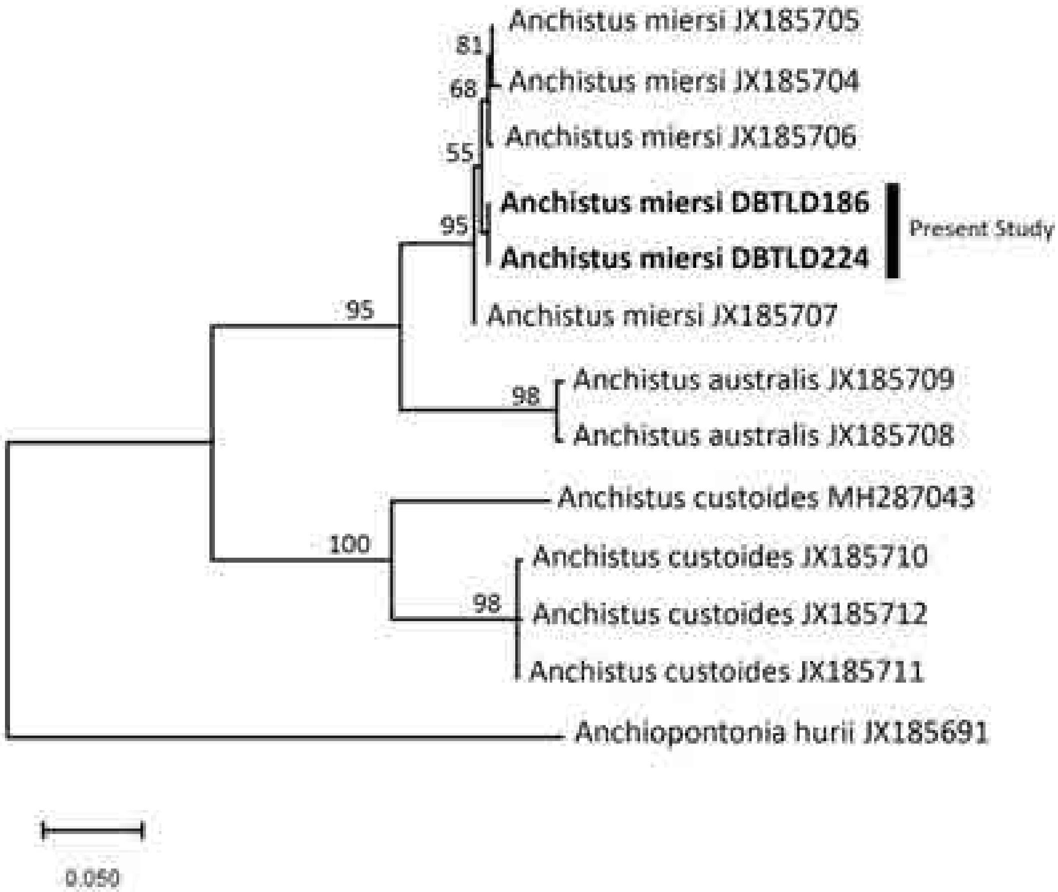

Image 2. Picture representation of *Anchistus miersi* (de Man, 1888 [in de Man, 1887–1888]) collected from Agatti island, Lakshadweep, India (Ethanol preserved).

Table 1. Pairwise genetic distances for *Anchistus* species using COI gene sequence data.

	Species	1	2	3	4	5	6	7	8	9	10	11	12
1	*Anchistus miersi* JX185707												
2	*Anchistus miersi* JX185706	0.008											
3	*Anchistus miersi* JX185705	0.008	0.003										
4	*Anchistus miersi* JX185704	0.012	0.007	0.003									
5	***Anchistus miersi* DBTLD224**	0.007	0.008	0.008	0.012								
6	***Anchistus miersi* DBTLD186**	0.007	0.008	0.008	0.012	0.000							
7	*Anchistus custoides* JX185712	0.221	0.227	0.230	0.237	0.221	0.221						
8	*Anchistus custoides* JX185711	0.217	0.224	0.227	0.233	0.217	0.217	0.002					
9	*Anchistus custoides* JX185710	0.221	0.227	0.230	0.237	0.221	0.221	0.003	0.002				
10	*Anchistus australis* JX185709	0.097	0.097	0.101	0.106	0.101	0.101	0.239	0.239	0.242			
11	*Anchistus australis* JX185708	0.099	0.099	0.104	0.108	0.104	0.104	0.229	0.229	0.232	0.005		
12	*Anchistus custoides* MH287043	0.201	0.196	0.199	0.204	0.196	0.196	0.125	0.122	0.120	0.227	0.224	

approaches in the future. Additionally, the phylogenetic tree constructed with the Maximum Likelihood analysis for available sequences among the *Anchistus* species is represented in Figure 2. The *A. miersi* sequences from India formed a clade with the other sequences of *A. miersi* which were retrieved from NCBI and it confirms the morphological identification of the present Indian materials.

Overall, the present study reports new occurrence of small commensal shrimp associated with Giant clam, *T. maxima* (Roding 1798) in the lagoon regions of Agatti Island, Lakshadweep at the depth of 4 m, which distribution extended Andaman Sea–Lakshadweep Sea towards. Additionally, taxonomic, habitat details are represented discussed in detail. The present report is also strengthening the caridean fauna of the Lakshadweep waters.

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COMMUNICATION

Earthworm (Annelida: Clitellata) fauna of Chhattisgarh, India

M. Nurul Hasan [1], **Shakoor Ahmed** [2], **Kaushik Deuti** [3] & **Nithyanandam Marimuthu** [4]

[1,2,3,4] Zoological Survey of India (Ministry of Environment, Forest and Climate change, Government of India), FPS Building, Indian Museum Campus, 27 JL Nehru Road, Kolkata, West Bengal 700016, India.
[1] nhasan.mld@gmail.com, [2] shakoorahmed204@gmail.com (corresponding author), [3] kaushikdeuti@gmail.com, [4] marinemari@hotmail.com

Abstract: Present communication is the first study on earthworm fauna of Chhattisgarh in central India. A total of nine species belonging to seven genera and five families—Moniligastridae, Eudrilidae, Lumbricidae, Megascolecidae, and Octochaetidae—were collected from different parts of the state. Among the families, Megascolecidae is most dominant with maximum number of species; other families are represented by a single species in each. The earthworm fauna of the state is comprised of both native (5 species) and exotic peregrine (4 species). A brief description, distribution and identification key for the recorded species is provided. Further surveys are required, which could lead to finding of more species.

Keywords: Diversity, distribution, identification key, deccan peninsula endemism exotic, native, taxonomy, new records, oligochaeta.

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Author details: Md. Nurul Hasan, enrolled his PhD at University of Calcutta, Kolkata, and a budding researcher in the field of earthworm taxonomy. Dr. Shakoor Ahmed a post-doctoral fellow at Zoological Survey of India, currently working on the earthworm ecology and taxonomy. Dr. Kaushik Deuti, scientist D at Zoological Survey of India and PhD guide of Md. Nurul Hasan. Dr. Nithyanandam Marimuthu, scientist E and officer in-charge of General Non-Chordata section, Zoological Survey of India, facilitating the research activities.

Author contributions: NM and KD—conceived the research work, MNH—conducted the survey and compiled the information, SA—Identification, prepared illustration and manuscript. All the authors revised the draft and approved final version of the manuscript.

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INTRODUCTION

In the year 2000, the state Chhattisgarh was curved out of Madhya Pradesh, comprising 1,35,192 km^2, which constitutes about 4.11 percent of the country's land area. The state (GPS coordinates: 17.7833^{0}N to 24.1000^{0}N; 80.2500^{0}E to 84.4000^{0}E) is a part of the Deccan peninsula, a huge plateau between Eastern Ghats and Western Ghats biodiversity hotspots. It is part of the East Deccan physiographic zone and has three distinct agro-climatic zones: the Chhattisgarh plains, the northern hills of Chhattisgarh, and the Bastar Plateau. The Deccan Peninsula in central India is home to a large area of tropical dry deciduous and tropical moist deciduous forest, making it one of the most important ecosystems and biodiversity hotspots. Forests cover around 44% of the state's total area, and they are the source of some major river systems including the Mahanadi, Indravati, and Narmada.

The soil fauna plays a key role in functioning of soil ecosystems, such as recycling of organic matter, primary production and maintenance of soil structure (Verhoef 2004). Among soil invertebrates earthworm constitute the largest biomass in various ecosystems (Bhadauria & Saxena 2010; Ahmed et al. 2022). Earthworms are known as ecosystem engineers, and their activities in the soil play an important role in maintaining a healthy and productive environment (Lavelle et al. 2006). Because earthworms are sensitive to habitat changes, they are considered as important bio-indicators and are widely used in environment assessment and pollution surveys (Howmiller & Beeton 1971; Julka 1988; Weber 2007; Martins et al. 2008; Ozdemir et al. 2011; Pelosi & Römbke 2016; Velki & Ečimović 2017). In addition, earthworms provide the essential conditions for transforming all sorts of decomposable organic wastes into recyclable micro-nutrients and organic fertilizers, and thus enhance the soil fertility (Dash & Senapati 1986; Reynolds & Eggen 1993).

Currently the earthworm fauna of India is represented by 453 species accredited to 10 families: Moniligastridae, Lumbricidae, Almidae, Rhinodrilidae, Acanthodrilidae, Eudrilidae, Ocnerodrilidae, Benhamiidae, Octochaetidae and Megascolecidae (Narayanan et al. 2020, 2021; Tiwari et al. 2021; Ahmed et al. 2022; Narayanan et al. 2022). India occupies about two percent of the total world surface area, but it harbours 10.5% of the globally known earthworm species (Julka et al. 2009). Endemism, both at the generic and species levels is extremely high, around 71% of genera and 85% of earthworm species are native to the country (Julka & Paliwal 2005). In India, the Western Ghats and western coastal plains are rich in earthworm fauna, accounting for about 58.4 percent of the country's total earthworm diversity (Goswami 2018; Narayanan et. al. 2020).

Although earthworms occur in all types of terrestrial habitats (except desert, and areas under snow & ice), but still several ecosystems are unexplored. As part of our study to assess the earthworm diversity of Deccan peninsula biogeographic zone, we sampled various habitats like agroecosystems, grassland, pasture, forest, and garbage sites. The listing of species is important for developing conservation strategies at a time when habitat shrinkage, climate change, and invasion poses a threat to sustaining biological diversity.

MATERIALS AND METHODS

Earthworms were collected from different habitats, viz., agroecosystems, grassland, pasture, forest, and garbage by digging and hand sorting method as proposed by Julka (1990). Collected specimens were washed in water and anesthetized in 70% alcohol and then after 24 hours were transferred to 5% formaldehyde solution for preservation. The anatomical observations were made by dorsal dissection under a binocular stereomicroscope (Leica EZ4). Specimens were identified following the monographs of Stephenson (1923); Gates (1945, 1972); Julka (1988); Blakemore (2012), and Bantaowong et al. (2016). After identification, specimens were deposited and registered in General Non-Chordata (ZSI-GNC) section of Zoological Survey of India, Kolkata for future reference. A map is provided showing distribution of earthworm species in state Chhattisgarh (Figure 1)

RESULTS AND DISCUSSION

A total of nine earthworm species belonging to seven genera and five families—Moniligastridae, Eudrilidae, Lumbricidae, Megascolecidae, and Octochaetidae—were collected from different parts of Chhattisgarh State. Among them, four species—*Metaphire houlleti* (Perrier, 1872), *Metaphire planata* (Gates, 1926), *Eisenia fetida* (Savigny, 1826), and *Eudrilus eugeniae* (Kinberg, 1867)—are non-native whereas the remaining five species—*Lampito mauritii* Kinberg, 1867, *Perionyx excavatus* Perrier, 1872, *Perionyx sansibaricus* Michaelsen, 1891, *Drawida calebi* Gates, 1945 and *Octochaetona surensis* Michaelsen, 1910—are native to India (Table 1). Further, a good population of earthworm species were

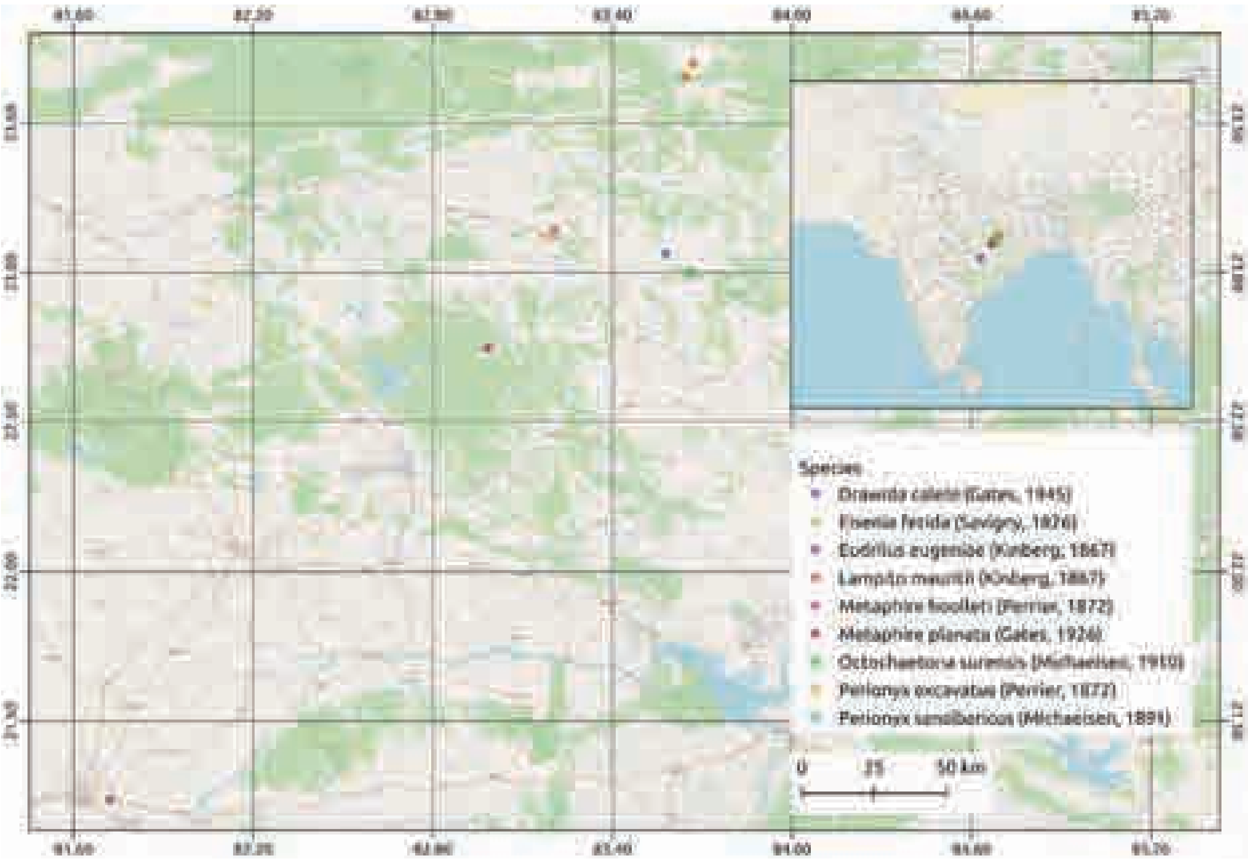

Figure 1. Map showing species distribution localities.

Table 1. Record of earthworm species from state Chhattisgarh.

Family	Species	Biogeographic origin	Ecological category	Habitats
Megascolecidae	*Lampito mauritii* Kinberg, 1867	Native	Epi-endogeic	Forest, Grassland, Cultivation
	Metaphire houlleti (Perrier, 1872)	Non-native	Epi-endogeic	Cultivation, grassland
	Metaphire planata (Gates, 1926)	Non-native	Epi-endogeic	Forest
	Perionyx excavatus Perrier, 1872	Native	Epigeic	Cultivation, grassland
	Perionyx sansibaricus Michaelsen, 1891	Native	Epigeic	Nursery
Lumbricidae	*Eisenia fetida* (Savigny, 1826)	Non-native	Epigeic	Cultivation, grassland
Eudrilidae	*Eudrilus eugeniae* (Kinberg, 1867)	Non-native	Epigeic	Cultivation
Octochaetidae	*Octochaetona surensis* Michaelsen, 1910	Native	Endogeic	Forest
Moniligastridae	*Drawida calebi* Gates, 1945	Native	Endogeic	Forest

found in the forest, grassland and agroecosystems, except surveyed garbage sites. Systematic account, brief description and distribution of earthworm species is provided.

Systematic Account

Phylum Annelida; Class Clitellata; Subclass Oligochaeta; Order Moniligastrida

Family Moniligastridae

Genus *Drawida* Michaelsen, 1900

Drawida calebi Gates, 1945 (Image 1)

1945. *Drawida calebi*, Gates, *Proc. Indian Acad. Sci*., 21: 211.

Origin: Native; Type locality: Jubbulpore (Jabalpur), Madhya Pradesh, India.

Material examined: India, Chhattisgarh, Ditenkhali (23.062425ºN, 83.578335º E); elev. 1,100 m; 23ex (ZSI-GNC-An 6221/1); 28.x.2021, coll. M. Nurul Hasan; Sanjay

Image 1. *Drawida calebi* Gates, 1945. (SPP—Spermathecal pores | MP—Male pores | GM—Genital markings | GZ—Gizzards | PG—Prostate glands | TS—Testis).

National Park, Ambikapur (23.144452º N, 83.207862º E); elev. 577 m; 12 ex (ZSI-GNC-An 6222/1); coll. M. Nurul Hasan, Sarguja, Bakurma (22.747080º N, 82.983390º E); elev. 651 m; 03 ex (ZSI-GNC-An 6258/1); 29.x.2021; coll. M. Nurul Hasan; Jamnatpur (23.70083º N, 83.66960º E); elev. 443.8 m; 03 ex (ZSI-GNC-An 6259/1); 25. x.2021; coll. M. Nurul Hasan.

Brief description: Length 20–56 mm, diameter 2–4 mm, segments 103–184. Male pores paired, in a transverse slits in intersegmental furrow 10/11 at mid *bc* setal lines. Spermathecal pores paired in 7/8 at *bc* slightly median to *c* setal line. Genital markings small, pre and or postsetal, in segment 7,8,9 and 12, one of the paired markings sometimes absent. Nephridiopores in a single series close to *d* setal lines. Gizzards 4, in segments 12–17; intestine begins in segment 25. Vas deferens short, in a small column of loops in segments 9–10, entering the antero-median of the prostate directly. Prostates almost spheroidal and muscular. Spermathecal ampulla spheroidal, duct long, atrium conical, in segment 8.

Distribution: India (Chhattisgarh (present record), Jharkhand, Karnataka, Odisha, Madhya Pradesh, Uttar Pradesh).

Order Opisthopora
Family Megascolecidae
Genus *Lampito* Kinberg, 1867
Lampito mauritii Kinberg, 1867 (Image 2)
1867. *Lampito mauritii* Kinberg, *Ofvers. K. Vetens. Akad. Forhandl. Stockholm*, 23:103.

Origin: Native; Type locality: Mauritius.

Material examined: India, Chhattisgarh, Balarampur, Aujhariya (23.655820º N, 83.644874º E); elev. 483 m; 11ex (ZSI-GNC-An 6168/1); 25.x.2021; coll. M. Nurul Hasan; Sanjay National Park, Ambikapur (23.144452º N, 83.207862º E); elev. 577 m; 01 ex (ZSI-GNC-An 6212/1); 28.x.2021; coll. M. Nurul Hasan; Jamnatpur (23.70083º N, 83.66960º E); elev. 443 m; 02 ex (ZSI-GNC-An 6260/1); 25.x.2021; coll. M. Nurul Hasan.

Brief description: Length 45–95mm, diameter 3–4mm, segments 128–163. Prostomium epilobous, tongue closed. First dorsal pore in 11/12. Clitellum annular on segments 13–17. Male pores in a slightly raised porophores in segment 18. Female pore in segment 14. Spermathecal pores paired in intersegmental furrows 6/7/8/9. Gizzard in segment 5; intestine begins in segment 15. Last pair of hearts in segment 13. Testis and funnels in segments 10 and 11; seminal vesicles in segments 9 and 12. Penial setae present. Spermathecae paired in segments 7–9, each with two digiform diverticula.

Distribution: India (Andaman & Nicobar Islands, Andhra Pradesh, Assam, Chhattisgarh (present record), Delhi, Goa, Gujarat, Haryana, Jammu & Kashmir, Jharkhand, Karnataka, Kerala, Lakshadweep Islands, Madhya Pradesh, Maharashtra, Odisha, Puducherry, Punjab, Rajasthan, Tamil Nadu, Telangana, Tripura, Uttarakhand, Uttar Pradesh, and West Bengal), Australia, Bangladesh, Cambodia, China, Hong Kong, Indonesia, Laos, Madagascar, Maldives, Malaysia, Mauritius,

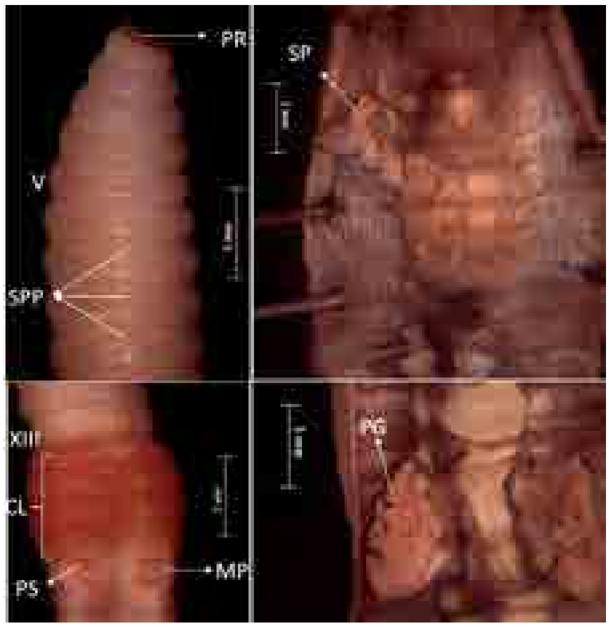

Image 2. *Lampito mauritii* Kinberg, 1867. (PR—Prostomium | SPP—Spermathecal pores | CL—Clitellum | MP—Male pores | PS—Penial setae | SP—Spermathecae | PG— Prostate glands).

Myanmar, New Caledonia, Pakistan, Philippines, Seychelles, Singapore, Sri Lanka, Thailand, Tanzania, United States and Vietnam.

Genus *Metaphire* Sims & Easton, 1972

Metaphire houlleti (Perrier, 1872) (Image 3)

1872. *Perichaeta houlleti* Perrier, *Nouv. Arch. Mus. Hist. Nat. Paris*, 8: 99.

Origin: Exotic; Type locality: Calcutta (Kolkata), India.

Material examined: India, Chhattisgarh, Sarguja, Bagicha (23.00327º N, 83.65952º E); elev. 884 m; 02 ex (ZSI-GNC-An 6216/1); 28.x.2021; coll. M. Nurul Hasan.

Brief description: Length 83–95 mm, diameter 3–3.5 mm, segments 99–103. Prostomium epilobous, tongue open; first dorsal pore in intersegmental furrow 11/12. Clitellum annular, on segments 14–16. Setae, perichaetine. Spermathecal pore in intersegmental furrows 6/7–8/9. Male pore in segment 18. Female pore in segment 14. Gizzard in segment 8; intestine begins in segment 15; intestinal caeca simple. Last pair of hearts in segment 13. Testis and funnels in segment 10 and 11, seminal vesicles in segment 11 and 12. Ovaries in segment 13. Prostates gland racemose 17–20; Spermathecae in segments 7, 8 and 9.

Distribution: India (Andaman & Nicobar Islands, Chhattisgarh (present record), West Bengal), Burma, Indonesia, and Malay Peninsula.

Metaphire planata (Gates, 1926) (Image 4)

1926. *Pheretima planata* Gates, *Ann. Mag. Nat. Hist*., 9: 411.

Origin: Exotic; Type locality: Rangoon, Myanmar.

Material examined: India, Chhattisgarh, Sarguja, Bakurma (22.747080º N, 82.983390º E); elev. 651; 02ex (ZSI-GNC-An 6257/1); 29.x.2021; coll. M. Nurul Hasan.

Brief description: Length 125 mm, diameter 4 mm, segment number 142, Prostomium small epilobous, tongue open; first dorsal pore in intersegmental furrow 11/12. Clitellum annular, 14–16. Genital markings absent. Setae, perichaetine. Spermathecal pore 6/7 and 7/8. Male pore in segment 18; female pore in segment 14. Gizzard in segment 8; intestine begins in segment 15; intestinal caeca simple. Last pair of hearts in segment 13. Testis and funnels in segment 10 and 11, seminal vesicles in segment 11 and 12. Ovaries in segment 13.

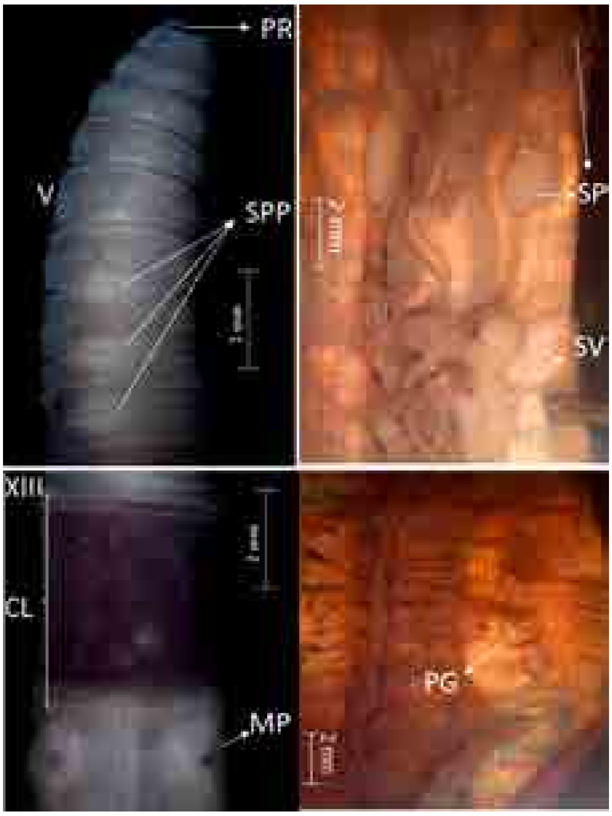

Image 3. *Metaphire houlleti* (Perrier, 1872). (PR—Prostomium | SPP– Spermathecal pores | CL—Clitellum | MP—Male pores | SP—Spermathecae | SV—Seminal vesicles | PG—Prostate glands).

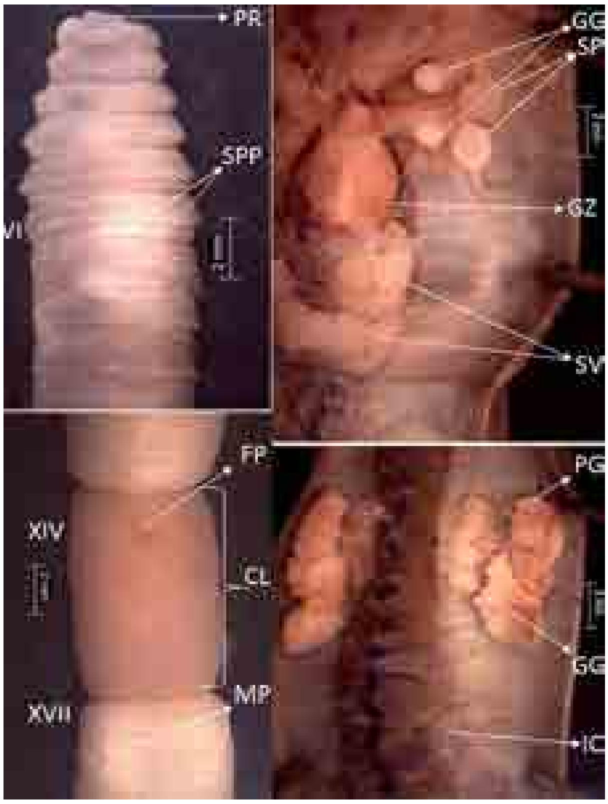

Image 4. *Metaphire planata* (Gates, 1926): PR—Prostomium | SPP—Spermathecal pore | FP—Female pore | CL—Clitellum | MP—Male pore | GG—Genital marking glands | SP—Spermathecae | GZ—Gizzard | SV—Seminal vesicles | PG—Prostate glands | IC—Intestinal caecae.

Prostates gland racemose 17–19, 20; Spermathecae in segments 7 and 8; diverticulum longer than combine length of duct and ampulla. Marking gland stalked, coelomic present inner side of spermathecae; and sessile glands in segments 17–19.

Distribution: India (Andaman & Nicobar Islands, Chhattisgarh (present record), West Bengal), Burma, Indonesia, and Malay Peninsula.

Genus *Perionyx* Perrier, 1872

Perionyx excavatus Perrier, 1872 (Image 5)

1872. *Perionyx excavatus* Perrier, *Nouv. Archs. Mus. Hist. nat. Paris*, 8:126.

Origin: Native; Type locality: Saigon, Vietnam.

Material examined: Chhattisgarh, Sarguja, Bagicha (23.00327º N, 83.65952º E); elev. 884 m; 12ex (ZSI-GNC-An 6219/1); 28.x.2021; coll. M. Nurul Hasan.

Brief description: Length 35–106 mm, diameter 2–4 mm. Segments 85–149. Colour reddish-brown dorsally and pale ventrally. Prostomium open epilobous. First dorsal pore in 4/5. Setae perichaetine. Clitellum annular on segments 13–17. Male pores in a transversely oval small depressed area, each on a small transversely oval papilla with black tips of 5–6 penial setae. Spermathecal pores in intersegmental furrows 7/8 and 8/9. Gizzard vestigial in segment 6. Intestine begins in segment 15. Last heart in segment 12. Testis and funnels free in segments 10 and 11. Seminal vesicles in segments 9–12. Prostates small, confined to segment 18, duct short and straight. Spermathecae with large ovoid ampulla, duct short, diverticula one to four small wart-like on the duct. Penial setae in a group of 4–6 on each side, medial from the male pores.

Distribution: India (Andaman & Nicobar islands, Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Chhattisgarh (present record), Himachal Pradesh, Jammu & Kashmir, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Odisha, Puducherry, Sikkim, Tamil Nadu, Tripura, Uttarakhand, Uttar Pradesh, and West Bengal), Australia, Barbados, China, Jamaica, Fiji, Indonesia, Japan, Korea, Madagascar, Malaysia, Mexico, Mozambique, Myanmar, New Zealand, Philippines, Reunion, Samoa, South Africa, Sri Lanka, Taiwan, Trinidad and Tobago, United Kingdom, United States and Vietnam.

Perionyx sansibaricus Michaelsen, 1891 (Image 6)

1891. *Perionyx sansibaricus* Michaelsen, *Mt. Mus. Hamburg*, 9: 4

Origin: Native; Type locality: Zanzibar, Tanzania.

Material examined: India, Chhattisgarh, Raipur, Green Patel Nursery (21.236533° N, 81.721063° E); elev.

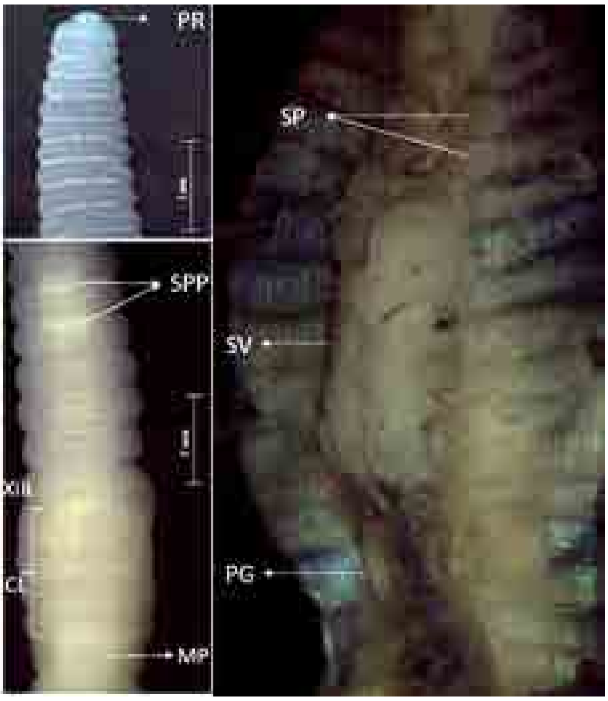

Image 5. *Perionyx excavatus* Perrier, 1872. (PR—Prostomium | SPP—Spermathecal pores | CL—Clitellum | MP—Male pores | SP—Spermathecae | SV—Seminal vesicles | PG—Prostate glands).

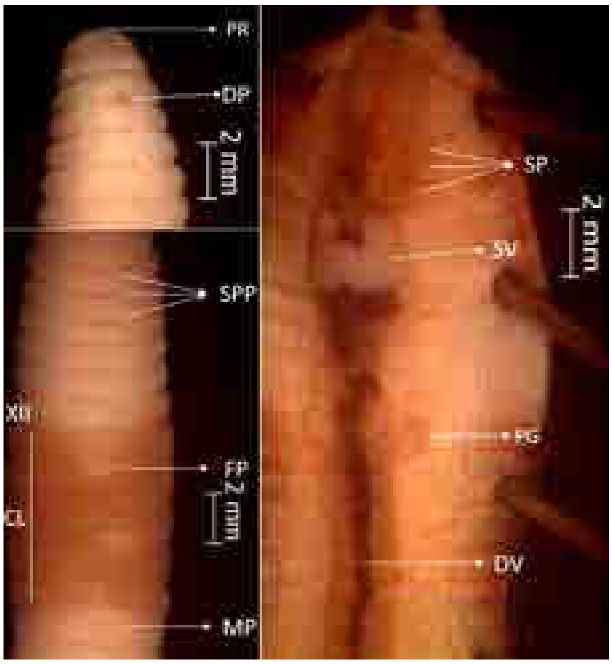

Image 6. *Perionyx sansibaricus* Michaelsen, 1891. (PR—Prostomium | DP—Dorsal pores | SPP—Spermathecal pores | CL—Clitellum | MP—Male pores | FP—Female pore | SP—Spermathecae | SV—Seminal vesicles | PG—Prostate glands | DV—Dorsal blood vessel).

293 m; 05 ex; 08.iii.2021; coll. Basant Patel.

Brief description: Length 45–95 mm, diameter 2–3.5 mm, 94–106 segments. Prostomium epilobous. First dorsal pore in intersegmental furrow 2/3. Clitellum annular on segment 13–17. Setae perichaetine. Male pores near mid-ventral line in a slightly depressed transverse male field in segment 18. Spermathecal pores three pairs in intersegmental furrow 6/7/8/9. Genital markings absent. Gizzard slightly developed in segment 6; intestine begins in segment 16. Last pair of hearts in segment 12. Testis and funnels free in segments 10 and 11; seminal vesicles in segments 11 and 12. Penial setae absent. Spermathecae paired, in segments 7–9.

Distribution: India (Chhattisgarh (present record), Delhi, Gujarat, Himachal Pradesh, Jammu & Kashmir, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Odisha, Punjab, Rajasthan, Tamil Nadu, Uttarakhand, Uttar Pradesh, and West Bengal), China, Philippines, Tanzania, and Thailand.

Family Lumbricidae

Genus *Eisenia* Malm, 1877

Eisenia fetida (Savigny, 1826) (Image 7)

1826. *Enterion fetidum* Savigny, *Mem. Acad. Sci. Inst. France,* 5: 182.

Origin: Exotic; Type locality: Paris, France.

Material examined: India, Chhattisgarh, Green Patel Nursery (21.236533° N, 81.721063° E); elev. 293 m; 29 ex (ZSI-GNC-An 6436/1); 08.iii.2021; coll. Basant Patel.

Brief description: Length 35–74 mm; diameter 3–4.5 mm. Segments 85–108. Prostomium open epilobous. First dorsal pores in intersegmental furrow 4/5. Clitellum 24, 25–32; tubercula pubertatis straight on segments 27, 28–30. Setae lumbricine, closely paired. Spermathecal pores paired close to dorsal line in 9/10 and 10/11. Female pore in segment 14 just lateral to *b* setal line. Gizzard in segment 17–18. Nephridia holoic. Last pair of hearts in segment 11. Testis and funnels in segments 10 and 11; seminal vesicles in segments 9–12. Ovaries in segment 13. Spermathecae adiverticulate, spherical ampulla in segment 9 and 10.

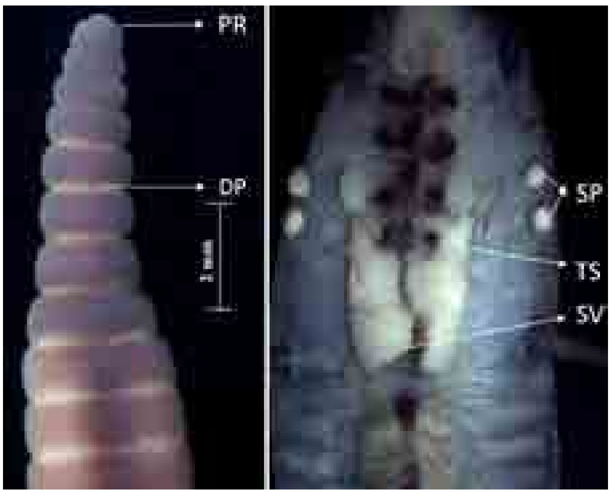

Image 7. *Eisenia fetida* (Savigny, 1826). (PR—Prostomium | DP—Dorsal pores | SP—Spermathecae | SV—Seminal vesicles | TS—Testis)

Distribution: India (Andaman & Nicobar Island, Assam, Chandigarh, Chhattisgarh (present record), Delhi, Himachal Pradesh, Jammu & Kashmir, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Sikkim, Tamil Nadu, Uttarakhand, Uttar Pradesh and West Bengal), Argentina, Australia, Brazil, Cambodia, Canary Islands, China, Chile, Colombia, Carpathian Basin, Ecuador, Greenland, Hawaii, Israel, Japan, Jordan, Korea, Mexico, New Zealand, Russia, South Africa, Turkestan, and Turkey.

Remarks: In several specimens sperm pockets were found attached on ventral in the intersegmental furrows 21/22 and 22/23, mostly in 22/23.

Family Eudrilidae

Genus *Eudrilus* Perrier, 1871

Eudrilus eugeniae (Kinberg, 1867) (Image 8)

1867. *Lumbricus eugeniae* Kinberg, *Ofvers. K. Vetensk. Akad. Forhandl. Stockholm*, 23: 98.

Origin: Exotic; Type locality: St. Helena Island (British protectorate), South Atlantic.

Material examined: India, Chhattisgarh, Green Patel Nursery (21.236533° N, 81.721063° E); elev. 293 m; 08 ex (ZSI-GNC-An 6437/1); 08.iii.2021; coll. Basant patel.

Brief description: Body length 60–98 mm, width 3–4.2; Segments 156–181. Colour dark brown dorsally light ventrally. Setae lumbricine, closely paired; Prostomium open epilobous; dorsal pores absent. Nephropores from segment 3 in c setal line. Clitellum on segments 13, 14–18 and interrupted ventrally. Male pores in posterior margin of segment 17 at *bc* close to *b* setal line. Female pores combined with modified spermathecal pores presetal in segment 14 openings just anterior to *c* setae. Gizzard weakly muscular in segment 5. Intestine begins in segment 14. Intestinal caeca and typhlosole absent. Nephridia holoic. Last hearts in segment 11. Calciferous glands in segments 10 and 11. Ovaries in segment 14. Testis in segments 10 and 11; seminal vesicles in segments 11 and 12. Prostates paired, digiform, with white muscular sheen extending from segment 18 up to segment 22. Spermathecal atrium tubular long in segment 14.

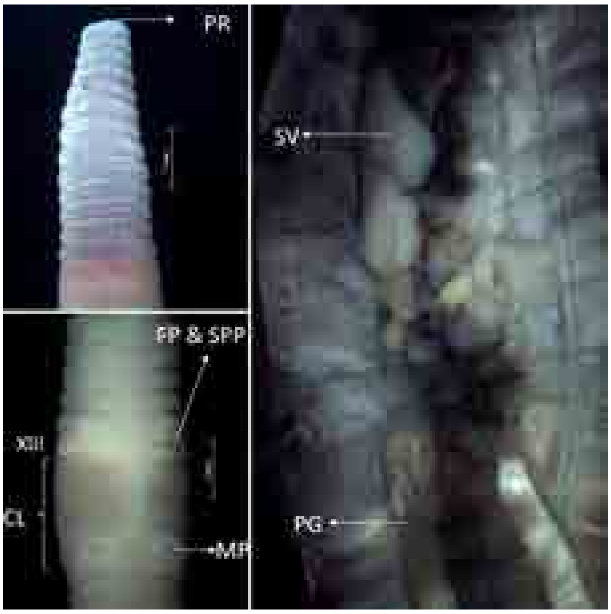

Image 8. *Eudrilus eugeniae* (Kinberg, 1867). (PR—Prostomium | FP—Female pore | SPP—Spermathecal pores | CL—Clitellum | MP—Male pores | SV—Seminal vesicles | PG—Prostate glands)

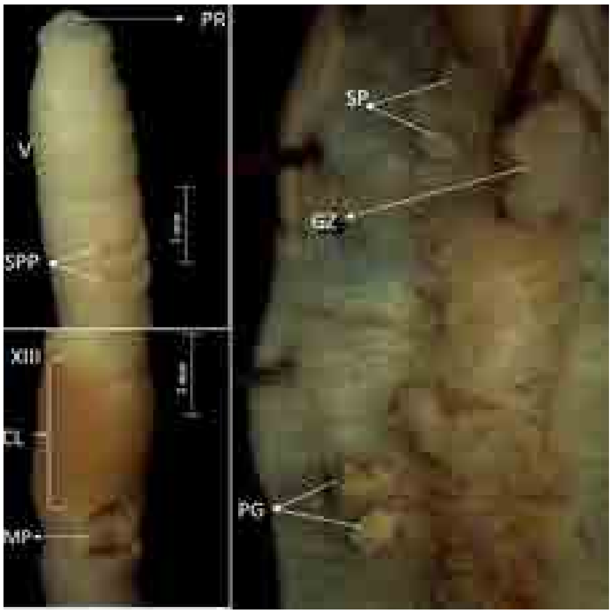

Image 9. *Octochaetona surensis* Michaelsen, 1910. (PR—Prostomium | SPP—Spermathecal pores | CL—Clitellum | MP—Male pores | SP—Spermathecae | GZ—Gizzard | PG—Prostate glands)

Distribution: India (Chandigarh, Chhattisgarh (present record), Karnataka, Kerala, Madhya Pradesh, Puducherry, Tamil Nadu and Uttarakhand), Sri Lanka, Madagascar, Comoros Islands, New Caledonia, USA, Australia, and Europe.

Family Octochaetidae
Genus *Octochaetona* Gates, 1962
Octochaetona surensis (Michaelsen, 1910) (Image 9)
1910. *Octochaetus surensis* Michaelsen, *Abh. Geb. Naturw., Hamburg*, 19(5): 88

Origin: Native; Type locality: Sur Lake , Puri, Odisha, India.

Material examined: India, Chhattisgarh, Sarguja, Bagicha (23.00327º N, 83.65952º E); elev. 884 m; 01 ex (ZSI-GNC-An 6207/1); 28.x.2021; coll. M. Nurul Hasan.

Brief description: Body length 120 mm, width 4; Segments 132. Setae lumbricine, closely paired; Prostomium closed epilobous; first dorsal pore in intersegmental furrow 12/13. Clitellum on segments 13–17. Male pores in segment 18, slightly median to *b* setal line. Prostatic pores in segments 17 and 19 at *b* setal line. Female pores paired, median in segment 14. Genital markings invisible. Gizzard large between segments 4/5 and 8/9. Intestine begins in segment 17. Last heart is in segment 13. Testis and funnels in segment 10 and 11. Seminal vesicles in segments 9 and 12. Penial setae present. Diverticulate, duct longer than ampulla. Genital marking glands lacking.

Distribution: India (Andhra Pradesh, Assam, Chhattisgarh (present record), Karnataka, Madhya Pradesh, Odisha, Tamil Nadu, Uttarakhand, Uttar Pradesh, and West Bengal) and Myanmar.

Climate change critically affects the biodiversity (Sintayehu 2018), and loss of an individual species can alter the structure and functions of an ecosystem and the services they provided to the society (Díaz et al. 2019; Weiskopf et al. 2020). Moreover, the invasive species also influence the existence of indigenous species (Migge-Kleian et al. 2006; Addison 2009; Bradley et al. 2019; Linders et al. 2019). Listing of species in the form of status assessment is important for developing future conservation strategies at a time when the habitat loss, climate change and invasion poses a major threat to existence of biological diversity which negatively reflect the functioning of ecosystems. Till date there is no report on earthworm species from Chhattisgarh.

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Key to the identification of earthworm species (Modified from Julka 2008)

1	Setae lumbricine, eight on each segment	2
1'	Setae perichaetine, more than eight on each segment	5
2	Male pores in intersegment furrow 10/11	*Drawida calebi*
2'	Male pores behind 10/11	3
3	Male pores on segment 15	*Eisenia fetida*
3'	Male pores behind segment 15	4
4	Male pores on segment 18	*Octochaetona surensis*
4'	Male pores on posterior margin of segment 17	*Eudrilus eugeniae*
5	Clitellum covering three segments	6
5'	Clitellum covering more than three segments	7
6	Spermathecal pores two pairs, in intersegmental furrows 6/7 and 7/8	*Metaphire planata*
6'	Spermathecal pores three pairs, in intersegmental furrows 6/7-8/9	*Metaphire houlleti*
7	Spermathecal pores three pairs, located away from the mid ventral line	*Lampito mauritii*
7'	Spermathecal pores two or three pairs, located closed to the mid ventral line	8
8	Spermathecal pores two pairs in intersegmental furrows 6/7 and 7/8	*Perionyx excavatus*
8'	Spermathecal pores three pairs in intersegmental furrows 6/7-8/9	*Perionyx sansibaricus*

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OPEN ACCESS

COMMUNICATION

Recent Foraminifera from the coast of Mumbai, India: distribution and ecology

Ganapati Ramesh Naik [1], **Manisha Nitin Kulkarni** [2] & **Madhavi Manohar Indap** [3]

[1,3] Department of Zoology, Central Research Laboratory, D.G. Ruparel College of Arts, Science & Commerce, Senapati Bapat Marg, Mahim, Mumbai, Maharashtra 400016, India.

[2] Department of Zoology, The Institute of Science, 15, Madam Cama Road, Mumbai, Maharashtra 400032, India.

[1] gnsrnaik@gmail.com, [2] harmonium.mnk@gmail.com, [3] madhaviindap@yahoo.com (corresponding author)

Abstract: Foraminifera have been used in biostratigraphy and paleoenvironmental research. They are useful environmental indicators for monitoring the marine environment. Intertidal sediment samples were analysed for their diversity in relation to physicochemical parameters and sediment characteristics along the Mumbai coast of India. Thirty-five species were found, divided into five orders and 18 families. The orders Rotaliida and Miliolida were identified to be dominant. Foraminifera were observed to be inversely related to sand particle size in relation to sediment and physicochemical parameters of water. Canonical correlation analysis explained the relationship between species abundance and water physicochemical parameters.

Keywords: Abundance, anthropological activities, environmental indicators, foram, grain size, marine coastal area, physicochemical factors, Protista

Abbreviations: CCA—Canonical correlation analysis | DO—Dissolved oxygen | MON—Monsoon | MPCB—Maharashtra Pollution Control Board | OC—Organic carbon | OM—Organic matter | POM—Post-monsoon | PRM—Pre-monsoon | TFN—Total foraminifera number | WNT—Winter.

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Author details: Mr. Ganapati Ramesh Naik, PhD research scholar at D G Ruparel College's Department of Zoology, Central Research Laboratory. Has spent the last six years working in the subject of marine ecology. Dr. Manisha Nitin Kulkarni is currently a professor in the Department of Zoology at The Institute of Science in Mumbai. Her scientific interests include biodiversity and endocrinology. Dr. Madhavi Manohar Indap is an emeritus professor. Adjunct faculty at D G Ruparel College's Central Research Laboratory in Mumbai. Her areas of interest in study include biodiversity, ecology, and marine biotechnology.

Author contributions: Madhavi Indap (MI) had conceptualized the study, directed and finalized the manuscript. Ganapati Naik (GN) collated in the information, evaluated the data and wrote the manuscript. Manisha Kulkarni (MK) had supervised the manuscript.

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INTRODUCTION

Mumbai, the state capital of Maharashtra, has a population of about 22 million people. It is also the largest and busiest port on India's west coast. Intertidal zone of Mumbai represents the peak of adaptability by most types of marine life to harsh environmental circumstances such as wave action, desiccation and other associated aspects generated by the tides of the sea (Kameswara & Srinath 2002). Among marine microorganisms, foraminifera are exceptionally varied and widely spread (Cushman et al. 1928). They are distinguished as protists by having an external test and streaming granular ectoplasm. Their tests are composed of calcium carbonate or agglutinated sediments, which are well preserved after death (Vidya & Patil 2014). They are considered good ecological indicators for detection and monitoring of coastal pollution (Pravasini & Patra 2012). According to Fabrizio et al. (2013), *Ammonia tepida* has a high resistance to environmental stress while *Ammonia parkinsoniana* is sensitive to pollution. These are the most widely used fossil species for biostratigraphy, sediment correlation and palaeoenvironmental research (Murray 2006) and their usage as bio-indicators in offshore oil drilling operations is well documented (Mariéva et al. 2010). Abninath & Biswas (1954), Devi & Rajashekhar (2009), and Subhadra & Patil (2012) conducted intertidal studies of foraminifera from the Mumbai coast on diversity studies in the intertidal region. Coastal water is vulnerable to contamination since 38% of the world's population lives within 100 kilometres of the coast (Pravasini & Patra 2012). Coastal pollution is caused by point and non-point wastewater sources from cities, which include sewage water, waste from industry and harbours, beach tourism and fishing crafts activities. Pollution has a negative impact on organisations at all levels, from the organism to the community and the environment (Francisco et al. 2011).

The current study was undertaken to document the Foraminifera at several sites along the Mumbai coast. The objective was to determine the relationship between foram abundance and various physicochemical factors, as well as anthropological activities. This information will aid in the creation of a database of foraminifera along Mumbai's coastline and contribute to understanding the effects of natural and anthropogenic events on Foraminifera.

Study Area

Mumbai is located at 19.0760° N & 72.8777° E, with an overall coast length of 149 km. Four coastal locations with distinct ecology were chosen for sampling. These sites range from north to south along the Mumbai shoreline (Figure 1). Gorai beach (M1) is located in Mumbai's northwestern outskirts. It is regarded as one of Mumbai's cleanest beaches. Juhu beach (M2) has a five-kilometre coastline. Dadar beach (M3) is situated on the south-west side of Mahim Island. Girgaon beach (M4) is located on Mumbai Island's south-west coast. M2, M3, and M4 are well-known tourist attractions. Mumbai's water quality is deteriorating as a result of pollutants from wastewater treatment facilities, sewage discharges, and discharges from point and non-point sources in the creek and along the shore (Ritesh et al. 2015).

MATERIAL AND METHODS

Sediment samples were collected in two phases: September 2013–August 2014 and December 2016–November 2017, from four stations: M1, M2, M3, and M4. The sampling was divided into four seasons: pre-monsoon (March–May), monsoon (June–August), post-monsoon (September–November), and winter (December–February).

Using a scientific spatula, the upper one cm layer of sand sediment was collected in duplicates between the intertidal zone during low tide. Forams were stained using Rose Bengal solution and stored in 70% isopropyl alcohol (Walton et al. 1952). The materials were washed through a 63 µm sieve and oven-dried at 60°C for analysis. A stereo microscope was used to examine one gram of sand from each station. The total number of specimens (live + dead) was used to calculate abundance. Foram tests were hand-picked and put on micro-paleontological slides using a foram sorting brush. 'JEOL JSM - 5800VS' scanning electron microscope (SEM) was used to image selected specimens. The Loeblich & Tappan (1988) classification system and the e-site "World Foraminifera Database" (Hayward et al. 2022) were used for taxonomic analysis.

Temperature, pH, salinity, dissolved oxygen (DO), phosphates and nitrates were chosen as water physicochemical parameters. A digital thermometer was used to record the temperature of the water at sample sites. pH, salinity and DO were measured with a "Thermo Scientific Eutech PCD-650 multi-parameter metre." Nutrients nitrate and phosphate were estimated

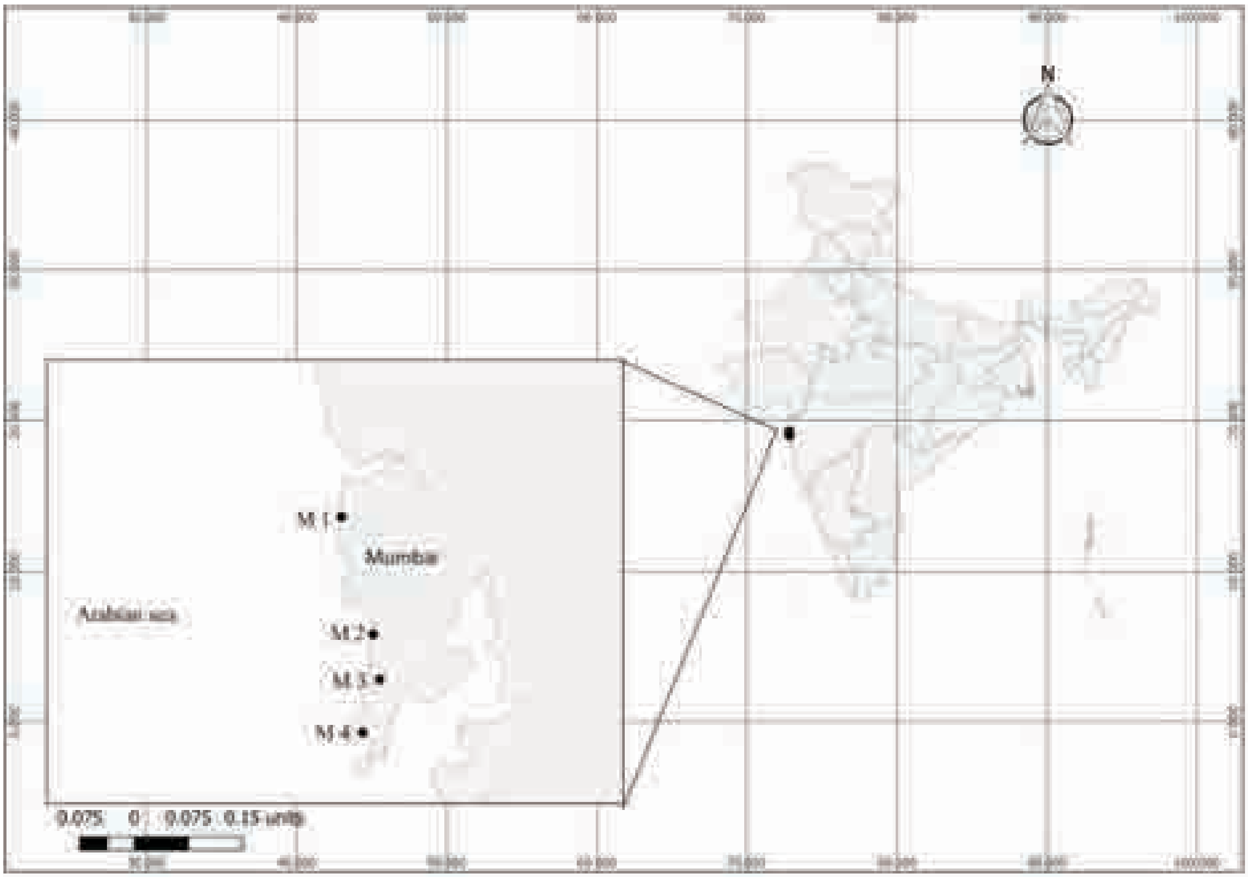

Figure 1. Map depicting the study area with sampling sites.

using standard methods given in the APHA manual (Lenore et al. 1999).

Another batch of sand sediment was collected for measurement of organic carbon by titration with ammonium ferrous sulphate using the Walkley-Black technique with suitable modification (Syed et al. 2011). To determine the texture of sand sediment, samples were sieved through multiple mesh sizes. The soil textural triangle approach (Derek et al. 2015) was used to determine their type. Past 3 v4.03 software was used to calculate diversity indices including the Shannon index, Simpson index, Evenness, Margalef index, canonical correlation, and Q-mode cluster.

RESULTS AND DISCUSSION

Foraminifera Assemblage & Physicochemical Parameters

The current study revealed the existence of 35 species from four orders, 18 families and 21 genera (Table 1). These 35 species were divided into 33 benthic and two planktonic species. M1, M2, M3, and M4 stations revealed the presence of 34, 32, 33, and 22 species, respectively. Order Rotaliida was dominant with 19 species, followed by order Miliolida, which had 11 species. The dominant species identified along Mumbai's shore were *Nonion scaphum* (17.8%), *Ammonia beccarii* (15.7%), *A. dentata* (12%), *Elphidium hispidulum* (8.9%), and *Bolivina striatula* (5.7%). Table 2 has a Foraminifera checklist. Images 1 (1–20) and 2 (1–19) displays SEM images that illustrate the morphological trait of species.

The total Foraminifera number (TFN) is the total number of individuals found in one gram of sediment. TFN values in samples ranged from 590 at M2 to 178 at M4 per gram. Northern Mumbai stations (M1, M2) showed greater values, whereas southern Mumbai stations recorded lesser values (M3, M4).

Shannon index (H) represented both species abundance and evenness in areas ranging from 2.06 (M4) to 2.77 (M2). Simpson index of dominance (D) revealed the dominance of cosmopolitan species with values 0.08 (M2) to 0.21 (M4). Equitability index revealed species evenness (e^H/S) with values ranging from 0.41 (M3) to 0.67 (M4). The Margalef index of species richness ranged from 2.09 (M4) to 5.04 (M1), and is directly related to taxonomic numbers 12 (M4) and 32 (M1). Table 3 presents the diversity indices.

The water parameters including pH, temperature, salinity, dissolved oxygen, phosphate, and nitrate were considered for study of various seasons including, pre-monsoon, monsoon, post-monsoon, and winter, which are represented in Table 4.

The pH ranged from 6.54 at M2 during post-monsoon to 7.89 at M4 during monsoon. Water temperatures in the intertidal zone ranged from 25°C reflecting monsoon at M4 to 29°C representing pre-monsoon at M1. Salinity at all sites varied with the seasons, ranging from 17 during the monsoon at M1 to 41 during the pre-monsoon at M2.

Dissolved oxygen, phosphate and nitrate showed variations in its concentrations. DO levels were highest during the pre-monsoon (7.4 mg/l) and lowest during the winter (3.1 mg/l) at M1. Similarly, in monsoon, M4 station had the lowest phosphate and nitrate levels, viz., 0.14 mg/l and 0.1 mg/l and M3 in winter revealed the greatest phosphate and nitrate ranges 0.56mg/l to 1.5mg/l, respectively.

The sediment type study revealed that silt type occurred at the M1 and M2, loamy sand at the M3 and sandy loam at the M4. The organic carbon percentage of sediment varied between stations, ranging from 0.28% to 0.37% (Table 4).

Pearson Correlation & Canonical Correlation Analysis (CCA)

For the water parameters and diversity indices, a Pearson correlation matrix was calculated (Table 5). The pH and dissolved oxygen correlated positively with species evenness but negatively with the other indices. Temperature correlated positively with the number of taxa, the H index and the Margalef index. Salinity only correlated positively with species dominance. Phosphate and nitrate had a significant negative correlation with species evenness.

CCA defined a relationship between species, stations and environmental parameters (Figure 2). For this analysis, species having a total population more than 1% was chosen, which included population of 18 species. Phosphate and dissolved oxygen defined axis one, whereas nitrate, pH, salinity, and temperature defined axis two. According to CCA analysis nitrate, pH and salinity correlated positively, but temperature correlated negatively with all other physicochemical parameters. All of the water parameters were found to have a significant correlation with 12 species.

Ammonia beccarii, *E. repandus*, *A. dentata*, and *S. raphana* were abundant at three sample stations displayed in the top-right quadrant of the graph. *T. oblonga*, *A. intricata*, *T. tricarinata*, and *E. hispidulum* peaked at five stations in the bottom right quadrant of the graph. *Q. vulgaris*, *U. senticosa*, *N. scaphum*, and *B. pseudoplicata* showed the highest abundance at five stations represented at top-left quadrant of graph and species *B. marginata*, *R. globularis*, *B. striatula*, *C. lobatulus*, *Q. tropicalis*, and *E. advenum* were most abundant at three stations represented at bottom-left quadrant of graph.

A. beccarii and *A. dentata* are mainly found in waters with high nitrate levels. *N. scaphum* was well associated with ambient temperature and phosphate concentration. *B. striatula*, *C. lobatulus* and *Q. tropicalis* held the average positions for all parameters. *E. hispidulum* and *T. tricarinata* were significantly correlating with DO, pH, and salinity.

Species-ecological Relationship

This research attempted to investigate the relation of foraminifera to intertidal benthic ecology at different stations. Data from physicochemical parameters were correlated with dominant species using specific indices.

At M1 TFN ranged from 533 to 450 individuals per gram, it was represented by 34 species. *N. scaphum* (28.33%), *A. dentata* (12.3%), *E. hispidulum* (8%) and *A. beccarii* (7.64%) were dominant species representing the area. According to Kumar & Manivannan (2001) *N. scaphum* has shown positive correlation to an increase in temperature and DO, our data support this statement. During the winter, the Simpson's index 0.14 is correlating with nitrate value. There is cumulative impact of nitrate and temperature with bleaching response on foraminifera (Martina et al. 2017), allowing only tolerant species to thrive. Thirty-one species have been identified at M2, with a maximum foraminifera test count of 590 in pre-monsoon. Here major taxa were again *N. scaphum* (21%), *A. dentata* (10.82%), and *A. beccarii* (10.59%). Phosphate has long been recognized as a calcite formation inhibitor, adsorbing onto the calcite surface and inhibiting active crystal growth sites (Aldridge et al. 2011), which might account for lower test numbers than M1. After *A. beccarii*, the dominant species was *B. striatula* (8.12%). *Lagena*, *Fissurina*, *Bolivina*, *Bulimina*, and *Uvigerina* species are found in finer sediments and exist in the shelf to slope area, according to Rajiv et al. (1986); however their prevalence in the study area

Table 1. Foraminiferal taxa composition along with the stations of Mumbai coast.

	Order	Family	Genus	Species
1	Rotaliida	Nonionidae	*Nonion*	*Nonion scaphum*
2		Ammoniidae	*Ammonia*	*Ammonia beccarii*
3				*Ammonia dentata*
4		Bolivinitidae	*Bolivina*	*Bolivina striatula*
5				*Bolivina pseudoplicata*
6		Siphogenerinoididae	*Spiroloxostoma*	*Spiroloxostoma glabra*
7			*Siphogenerina*	*Siphogenerina raphana*
8				*Siphogenerina* sp.
9		Elphidiidae	*Elphidium*	*Elphidium hispidulum*
10				*Elphidium advenum*
11				*Elphidium* sp.
12		Rosalinidae	*Rosalina*	*Rosalina globularis*
13		Eponididae	*Eponides*	*Eponides repandus*
14		Cibicididae	*Cibicides*	*Cibicides lobatulus*
15		Discorbinellidae	*Discorbinella*	*Discorbinella* sp.
16		Buliminidae	*Bulimina*	*Bulimina marginata*
17		Uvigerinidae	*Uvigerina*	*Uvigerina senticosa*
18		Globigerinidae	*Globigerina*	*Globigerina bulloides*
19			*Globigerinoides*	*Globigerinoides* sp.
20	Miliolida	Hauerinidae	*Quinqueloculina*	*Quinqueloculina tropicalis*
21				*Quinqueloculina porterensis*
22				*Quinqueloculina vulgaris*
23				*Quinqueloculina polygona*
24				*Quinqueloculina agglutinans*
25			*Triloculina*	*Triloculina tricarinata*
26				*Triloculina oblonga*
27		Spiroloculinidae	*Spiroloculina*	*Spiroloculina antillarum*
28				*Spiroloculina communis*
29		Cribrolinoididae	*Adelosina*	*Adelosina intricata*
30		Cornuspiridae	*Cornuspira*	*Cornuspira involvens*
31	Nodosariida	Lagenidae	*Lagena*	*Lagena vulgaris*
32				*Lagena sulcata*
33				*Lagena laevis*
34	Polymorphinida	Ellipsolagenidae	*Fissurina*	*Fissurina cucullata*
35				*Fissurina* sp.

may be due to wave action. M3 receives water runoff from the Mithi River and had low salinity during the monsoon due to monsoon water, in addition to large amount of sewage and industrial garbage from the Mithi (Jayasiri et al. 2014). At the M3, 33 distinct taxa were present. *A. beccarii* (24.18%), *A. dentata* (15.2%), and *E. hispidulum* (12.21%) dominated the station. M4 had taxa count 20 with a maximum of 198 individuals. The dominant species representing the area were *A. beccarii* (32.67%), *T. tricarinata* (15.02%), and *E. hispidulum* (11.55%).

The distribution of benthic Foraminifera is influenced by organic carbon (OC) and sediment type (Elakkiya & Manivannan 2013). Benthic foram have been shown to be closely associated with variations in percent gravel, organic carbon flux, temperature and salinity (Alexandra

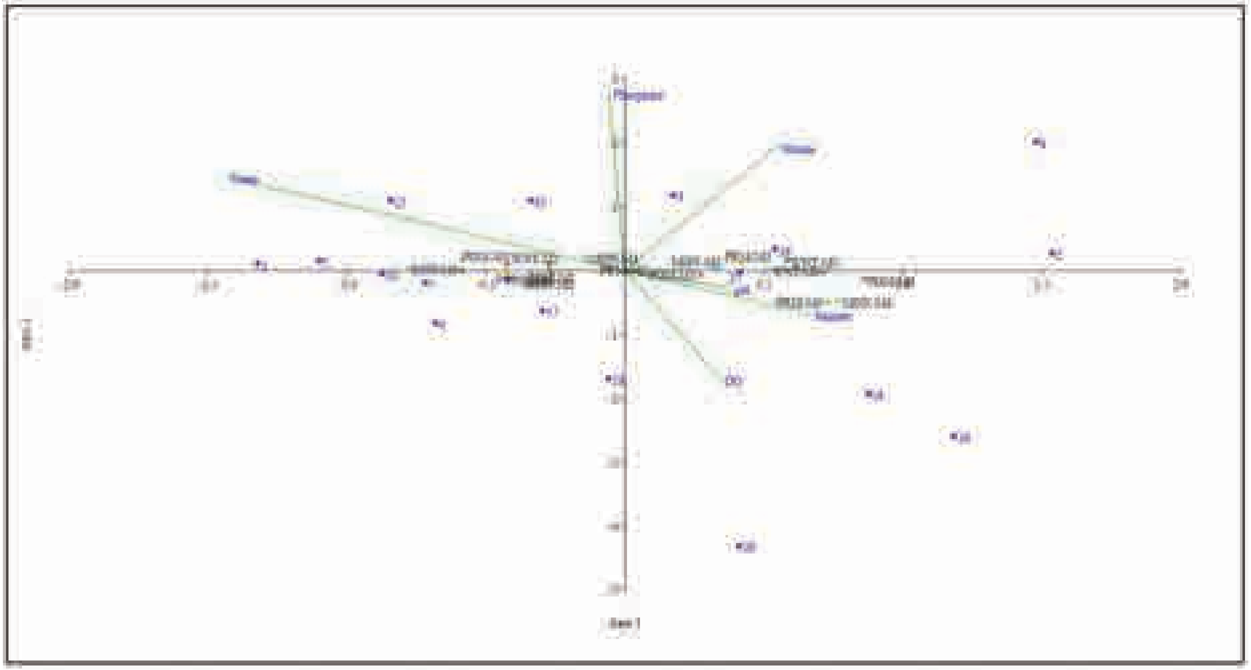

Figure 2. Canonical correlation analysis (CCA) of abundant species with relation to physico-chemical parameters of water and station distribution.

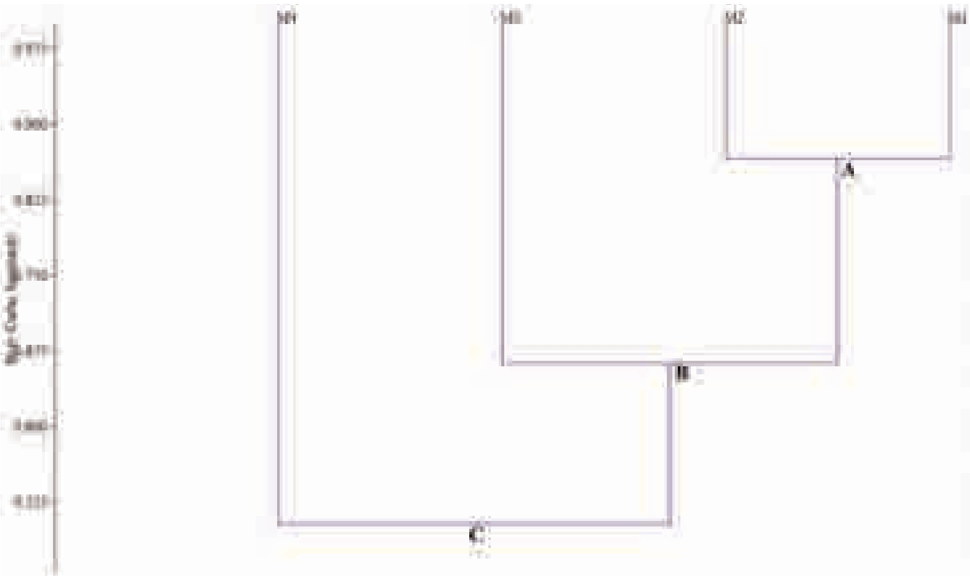

Figure 3. Bray-Curtis hierarchical cluster analysis for sampling stations.

et al. 2007). The sediment at stations M1 and M2 was silt type, with 0.34% and 0.28% organic carbon, respectively. At M1 Margalef index of 5.04 and at M2 Shannon value of 2.77 were both positively correlated with sediment type, as sand mixed with shelly fragments and silt or clay support the richest standing crop of foraminifera (Chaturvedi et al. 2000). Station M3 had loamy sand with the highest organic carbon content of 0.37% of all stations. Water discharge from Mahim Creek has the highest percentage of organic carbon, as the creek is the largest sink for the most of waste created by residential complexes and small-scale industry (Singare et al. 2015). Station M4 is associated with 0.31% organic carbon with sediment particle size larger than other stations. According to Elena et al. (2019) stations exposed to the open sea and intensified currents were

Table 2. Distribution of Foraminifera species along four stations of Mumbai coast.

	Species	M1	M2	M3	M4
1	*Nonion scaphum*	+	+	+	+
2	*Ammonia beccarii*	+	+	+	+
3	*Ammonia dentata*	+	+	+	+
4	*Bolivina striatula*	+	+	+	+
5	*Bolivina pseudoplicata*	+	+	+	+
6	*Spiroloxostoma glabra*	+	+	+	-
7	*Siphogenerina raphana*	+	+	+	+
8	*Siphogenerina* sp.	+	+	+	-
9	*Elphidium hispidulum*	+	+	+	+
10	*Elphidium advenum*	+	+	+	+
11	*Elphidium* sp.	+	-	+	+
12	*Rosalina globularis*	+	+	+	+
13	*Eponides repandus*	+	+	+	+
14	*Cibicides lobatulus*	+	+	+	+
15	*Discorbinella* sp.	-	-	+	-
16	*Bulimina marginata*	+	+	+	+
17	*Uvigerina senticosa*	+	+	+	+
18	*Globigerina bulloides*	+	+	+	-
19	*Globigerinoides* sp.	+	+	+	-
20	*Quinqueloculina tropicalis*	+	+	+	+
21	*Quinqueloculina porterensis*	+	+	+	-
22	*Quinqueloculina vulgaris*	+	+	+	+
23	*Quinqueloculina polygona*	+	+	+	+
24	*Quinqueloculina agglutinans*	+	-	-	-
25	*Triloculina tricarinata*	+	+	+	+
26	*Triloculina oblonga*	+	+	+	+
27	*Spiroloculina antillarum*	+	+	+	+
28	*Spiroloculina communis*	+	+	+	+
29	*Adelosina intricata*	+	+	+	+
30	*Cornuspira involvens*	+	+	+	-
31	*Lagena vulgaris*	+	+	+	-
32	*Lagena sulcata*	+	+	+	-
33	*Lagena laevis*	+	+	-	-
34	*Fissurina cucullata*	+	+	+	-
35	*Fissurina* sp.	+	+	+	-

defined by coarser sediments. As M4 had sandy loam type of sediment suggesting good wave action due to its association with open sea. The moderate value of OC at this station is associated with sediment type, since in coarse-grained sand, interstitial water may travel easily through pore spaces, resulting in less organic particle settling (Hiroshi 1994).

A. beccarii and *A. dentata* correlated negatively with DO values from all stations, making them adaptable to anoxic conditions (Fatin et al. 2012; Sundara et al. 2016). *B. striatula* which thrived well in low oxygen stations (Abhijit & Nigam 2014) and was positively associated to salinity since it is an opportunistic species that can thrive in both high and low salinity conditions (Patricia et al. 2019). The dominance of *Ammonia* sp. and *Elphidium* sp. in study area indicated that they are resistant to decreased salinity, pH or a combination of the two factors (Laurie et al. 2018).

N. scaphum adapted to environments characterized by high organic matter (OM) quality and it indicates affinity for OM-rich sediments (Pierre et al. 2016), so its distribution is well associated with M1 and M2 as compared to M4 which had more coarse type of sediment. *A. dentata* and *E. hispidulum* was abundant at M1, M2 and M3 as silt sand is preferred by the species over coarse sandy sediment (Elakkiya & Manivannan 2013), with affinity for larger amount of organic carbon values (Maria et al. 2012). However, based on our understanding of above work on foraminifera, we may conclude that the cosmopolitan species *A. beccarii*, *A. dentata*, *B. striatula*, *N. scaphum*, and *E. hispidulum* thrive well in Mumbai waters.

Hierarchical Cluster Analysis

Foraminifera species were tested to a Bray-Curtis cluster analysis in relationship to stations (Figure 3). It divided stations into three groups: Cluster A (M1 + M2), Cluster B (Cluster A + M3), and Cluster C (Cluster B + M4).

Cluster A consists of two stations (M1 + M2) that share 32 species. It had a similar type of sediment, silt with physicochemical properties. CCA analysis showed these stations near to one other on the middle and left sides of Axis one. The main representatives of this cluster were *N. scaphum* (21–28.3%), *A. beccarii* (7.6–10.5%), *A. dentata* (10.8–12.3%), *B. striatula* (6.6–8.1%), *B. pseudoplicata* (5.5–5.6%), *C. lobatulus* (4.7–5.5%), *Q. tropicalis* (3.5–6.4%), *E. hispidulum* (6.5–8%), *U. senticosa* (2.9–3.7%), *T. tricarinata* (1.8–3.5%) and *B. marginata* (2.8–3.1%). Species like *N. scaphum*, *A. dentata*, and *B. striatula* have more affinity for fine sediment like silt than coarse type of sediment.

Cluster B comprised of three stations (Cluster A + M3) with 31 species in common. In this cluster M3 is having more similarity with M2 than M1. The cluster had silt and loamy sand sediment which showed a little correlation with one another. The main species represented by the cluster were *N. scaphum* (8.2–28.3%), *A. beccarii* (7.6–24.1%), *A. dentata* (10.8–15.2%), *E. hispidulum*

Table 3. Biodiversity indices of Foraminifera for Mumbai coast.

Station	Season	Taxa	Individuals	Dominance	Shannon	Evenness	Margalef
M1	Pre-monsoon	32	467	0.1249	2.646	0.4407	5.044
	Monsoon	28	533	0.1224	2.529	0.4479	4.3
	Post-monsoon	29	476	0.1203	2.585	0.4575	4.541
	Winter	28	450	0.1474	2.525	0.446	4.42
M2	Pre-monsoon	29	590	0.1039	2.671	0.4983	4.389
	Monsoon	27	431	0.087	2.776	0.5945	4.286
	Post-monsoon	28	414	0.08698	2.757	0.5625	4.481
	Winter	27	486	0.1057	2.625	0.5113	4.203
M3	Pre-monsoon	27	363	0.1259	2.528	0.4638	4.411
	Monsoon	29	385	0.1069	2.681	0.5035	4.703
	Post-monsoon	26	328	0.09856	2.644	0.5411	4.316
	Winter	29	389	0.1413	2.484	0.4132	4.695
M4	Pre-monsoon	19	193	0.1416	2.317	0.5339	3.42
	Monsoon	12	192	0.1593	2.086	0.6711	2.092
	Post-monsoon	17	178	0.2122	2.064	0.4632	3.088
	Winter	20	198	0.1662	2.297	0.4971	3.593

(6–12.2%), *T. tricarinata* (1.8–6.2%), *E. repandus* (0.9–3.3%), *C. lobatulus* (3.2–5.5%), *B. striatula* (3.1–8.1%), and *Q. tropicalis* (3.2–6.4%).

Cluster C comprised of all four stations (Cluster B + M4) that share 22 species in common. In this cluster M4 had more similarity with M3 as compared with Cluster A. As M3 and M4 had loamy sand and sandy loam sediment, which had more similarity with each other. Having a more coarse type of sediment was responsible for more resistant taxa to sediment particle movements by wave action. The main species represented by the cluster were *A. beccarii* (1.9–28.3%), *T. tricarinata* (1.8–15%), *E. hispidulum* (6.5–11.5%), *A. dentata* (8.5–15.2%), *E. repandus* (0.9–5.2%), *E. advenum* (1.6–4.1%), *T. oblonga* (0.8–3.1%), and *R. globularis* (1.1–2.3%).

Test Deformity

Environmental stress induced by large fluctuations in environmental factors such as salinity, DO, temperature, pH, sedimentation, pollution and hydrodynamics has been connected to a significant percentage of abnormal tests in foraminiferal assemblages (Rehab et al. 2011). Mumbai is India's economic hub, and increased urbanization and industrialization have resulted in an increase in marine discharges to coastal areas (Jayasiri et al. 2014). According to Maharashtra Pollution Control Board (MPCB) data on Maharashtra's water quality condition, water at stations Juhu (M2), Dadar (M3), and Girgaon (M4) had a bad water quality index (MPCB 2013–14, 2016–17). In the present study *Quinqueloculina* sp. (M3), *Triloculina* sp. (M3), *Siphogenerina raphana* (M2, M3) and an Undetermined taxa showed the abnormal formation of shells. These deformed tests have been shown in Image 2 (15–19).

Quinqueloculina sp. (M3) showed reduced chambers, *Triloculina* sp. (M3) had twisted chambers, *Siphogenerina raphana* (M2, M3) represented by enlarged chambers and uneven costae lines, and the undetermined taxa had unusually extended chambers. These abnormalities imply that environmental conditions and industrialization have had a negative impact on foraminiferal diversity. All of these abnormalities were associated predominantly with M3 station. According to studies conducted by Shamrao & Kadam (2003), Jayasiri et al. (2014), and Ritesh et al. (2015), Dadar beach is extremely contaminated owing to effluents carried in by the Mithi River, with low-energy hydrodynamics generated by the lagoon region. According to MPCB publications (MPCB 2013–14, 2016–17), the water quality index for M3 is also rated as bad to very-bad. According to Suresh & Sonia (2012) morphological abnormalities are induced by pollution, strongly in shallow waters than deep seas. According to Jayaraju et al. (2008), heavy metal contamination has a greater negative impact on

Table 4. Physico-chemical parameters of water, organic carbon, and sediment type from sampling stations.

Station	Season	pH	Temperature (°C)	Salinity (‰)	Dissolved oxygen (mg/L)	Phosphate (mg/L)	Nitrate (mg/L)	Organic carbon %	Sediment type
M1	Pre-monsoon	7.52	29	30	7.4	0.2181	0.2	0.34	Silt
	Monsoon	7.61	28	17	7.2	0.327	0.5		
	Post-monsoon	7.33	28	35	6.2	0.349	0.44		
	Winter	7.11	27	38	3.1	0.315	0.648		
M2	Pre-monsoon	7.65	27	41	6.04	0.1455	0.95	0.28	Silt
	Monsoon	7.6	27	32	7.1	0.269	0.513		
	Post-monsoon	6.54	28	37	6.4	0.328	0.465		
	Winter	7.42	28	38	3.45	0.413	0.782		
M3	Pre-monsoon	7.43	28	38	5.8	0.264	0.65	0.37	loamy sand
	Monsoon	7.06	27	25	6.7	0.261	0.38		
	Post-monsoon	7.81	27	36	6.1	0.352	0.425		
	Winter	7.39	28	38	3.42	0.563	1.5		
M4	Pre-monsoon	7.09	29	39	6.1	0.214	0.687	0.31	Sandy loam
	Monsoon	7.89	25	29	7.4	0.1454	0.1		
	Post-monsoon	7.05	27	37	6.7	0.361	0.456		
	Winter	7.45	27	39	4.6	0.289	0.663		

Table 5. Pearson correlation analysis for diversity indices and physico-chemical parameters of water.

	pH	Temperature	Salinity	Dissolved oxygen	Phosphate	Nitrate	Taxa	Individuals	Dominance	Shannon	Evenness	Margalef
pH												
Temperature	-0.3695											
Salinity	-0.2218	0.092786										
Dissolved oxygen	0.16147	-0.10486	-0.559									
Phosphate	-0.2266	0.27571	0.1359	-0.58298								
Nitrate	-0.0683	0.26441	0.4791	-0.70243	0.57205							
Taxa	-0.127	0.53909	-0.093	-0.17265	0.27933	0.2728						
Individuals	0.08318	0.29869	-0.193	-0.093673	0.083084	0.2117	0.85011					
Dominance	-0.0449	-0.22792	0.1315	-0.10616	0.057666	-0.012	-0.6639	-0.663				
Shannon	-0.0992	0.3675	-0.073	-0.028479	0.090162	0.1115	0.87788	0.78129	-0.9176			
Evenness	0.20239	-0.58162	-0.059	0.39673	-0.49099	-0.458	-0.5564	-0.3568	-0.2039	-0.1202		
Margalef	-0.1953	0.59841	-0.038	-0.19832	0.3278	0.2943	0.98356	0.74471	-0.614	0.85002	-0.6019	

foraminiferal test morphology than agricultural and aquacultural wastes. From these damaged shells it may be concluded that they act as a sensitive taxon to environmental and anthropogenic conditions.

CONCLUSION

The present study revealed diversity and distribution of Foraminifera along Mumbai coast with presence of 35 species belonging to four orders, 18 families, and 21 genera. The orders Rotaliida and Miliolida dominated the taxa. *A. beccarii*, *N. scaphum*, *A. dentata*, and *E. hispidulum* were the most opportunistic species present at all stations. Due to similarities in sediment and species distribution, CCA and Bray-Curtis similarity analysis revealed that M1-M2 and M3-M4 were more associated with each other. *N. scaphum* served as sensitive taxa by showing affinity for oxygen and finer sediment type. *A. beccarii* and *E. hispidulum* acted

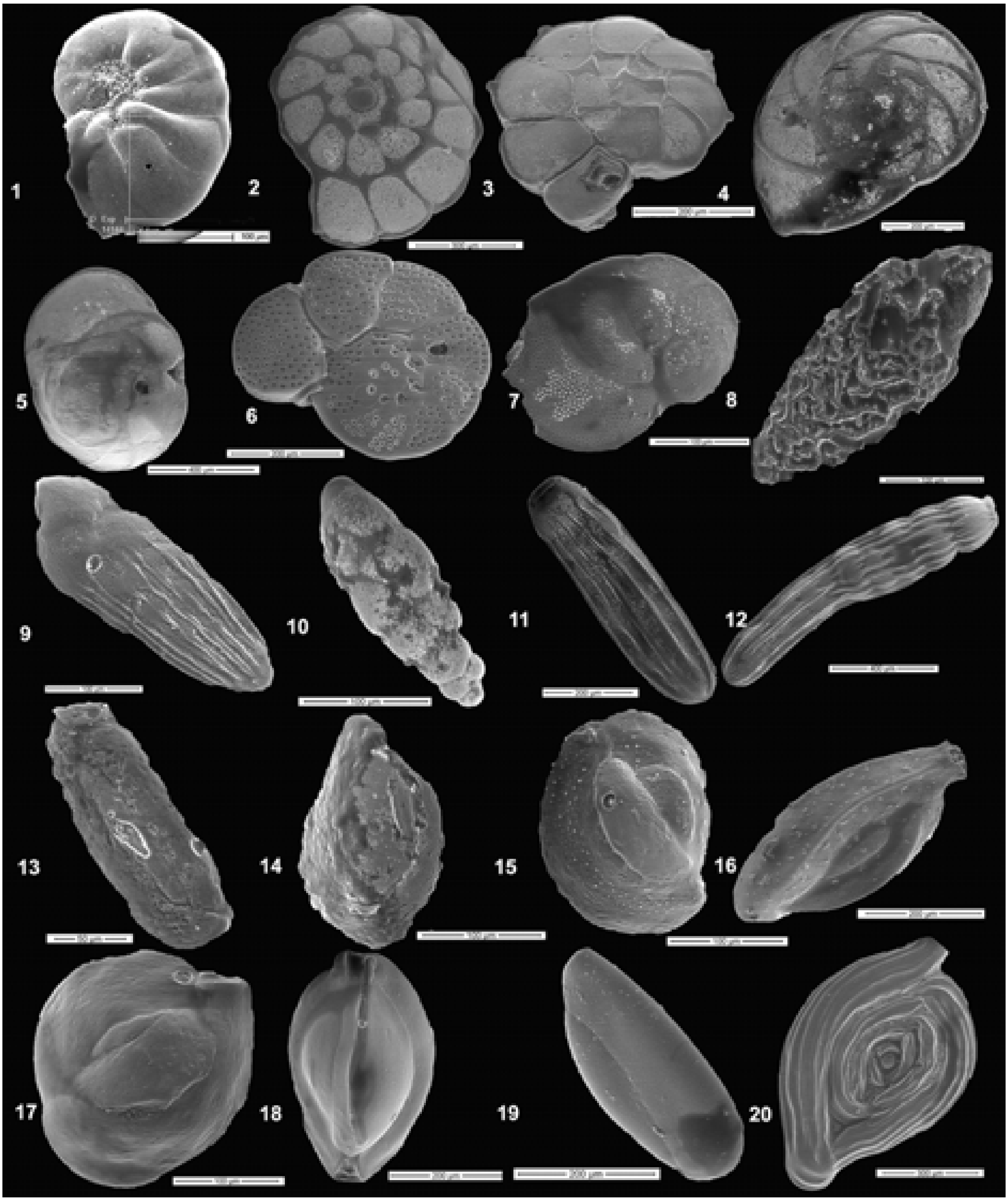

Image 1. 1 —*Nonion scaphum* | 2—*Ammonia beccarii* | 3—*Ammonia dentata* | 4—*Eponides repandus* | 5—*Rosalina globularis* | 6—*Cibicides lobatulus* | 7—*Discorbinella* sp. | 8—*Bolivina pseudoplicata* | 9—*Bolivina striatula* | 10—*Spiroloxostoma glabra* | 11—*Siphogenerina raphana* | 12—*Siphogenerina* sp. | 13—*Quinqueloculina tropicalis* | 14—*Quinqueloculina agglutinans* | 15—*Quinqueloculina vulgaris* | 16—*Quinqueloculina polygona* | 17—*Quinqueloculina porterensis* | 18—*Triloculina tricarinata* | 19—*Triloculina oblonga* | 20—*Spiroloculina antillarum*. © SEM image is created and edited by Ganapati Naik.

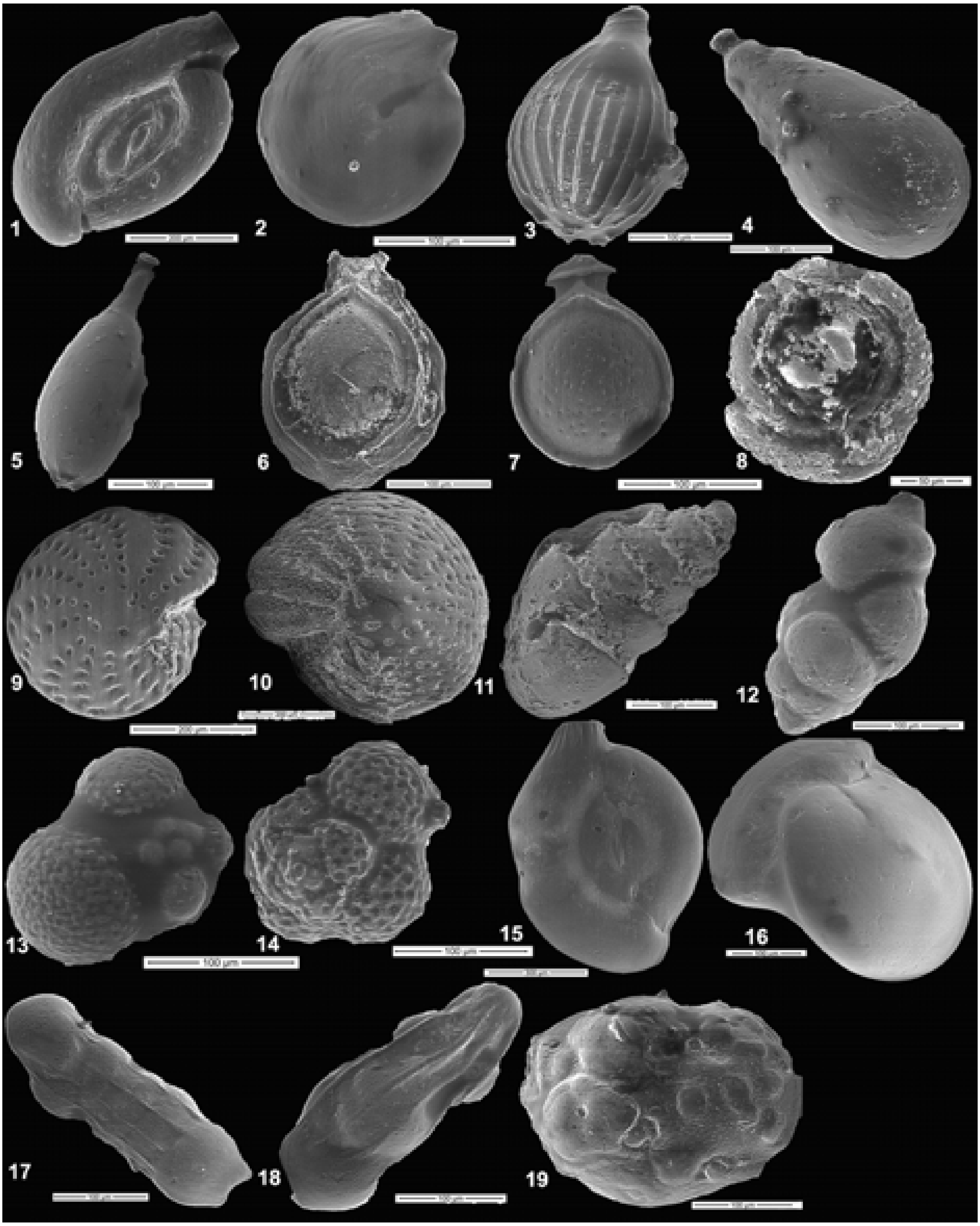

Image 2. 1—*Spiroloculina communis* | 2—*Adelosina intricata* | 3—*Lagena sulcata* | 4—*Lagena vulgaris* | 5—*Lagena laevis* | 6—*Fissurina cucullata* | 7—*Fissurina* sp. | 8—*Cornuspira involvens* | 9—*Elphidium advenum* | 10—*Elphidium hispidulum* | 11—*Bulimina marginata* | 12—*Uvigerina senticosa* | 13—*Globigerina bulloides* | 14—*Globigerinoides* sp. | 15—*Quinqueloculina* sp. | 16—*Triloculina* sp. | 17—*Siphogenerina raphana* | 18—*Siphogenerina raphana* | 19—Undetermined taxa. © SEM image is created and edited by Ganapati Naik.

as stress tolerant taxa flourishing well in fine as well as coarse sediment type. The presence of *B. striatula* indicated the hypoxic condition of water and sediment during winter season. The study found that finer to medium grain sand was associated with more species than coarse sand. Organic carbon concentrations correlated directly with fine sediment type and stations with low-energy hydrodynamic circumstances (M1, M3), allowing more organic carbon to trap between sand particles. The presence of deformed tests suggested that Mumbai's coastal water had physicochemical parameter fluctuations and received contaminated water from industrial areas. It symbolized the potential use of foraminifera in understanding the effects of urbanization and industrialization on coastal water. This creates a great need to construct foraminifera study models to comprehend long-term consequences of changing environmental and anthropogenic activities along urban coasts, since we cannot halt industrialization, but such research will assist to limit the impact of pollution on the marine environment.

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SHORT COMMUNICATION

Additional breeding records of Hanuman Plover *Charadrius seebohmi* E. Hartert & A.C. Jackson, 1915 (Aves: Charadriiformes: Charadriidae) from southeastern coast of India

H. Byju [1], N. Raveendran [2], S. Ravichandran [3] & R. Kishore [4]

[1,3] Centre of Advanced Study in Marine Biology, Annamalai University, Parangipettai, Tamil Nadu 608502, India.
[2] Iragukal Amritha Nature Trust, 61, Ramachandra Thadaga Street, Thirumangalam, Madurai, Tamil Nadu 625706, India.
[4] Sálim Ali Centre for Ornithology and Natural History, Anaikatty, Coimbatore, Tamil Nadu 641108, India.
[1] byjuhi@gmail.com (corresponding author), [2] lant.ravee@gmail.com, [3] sravicas@gmail.com, [4] kishorewfw@gmail.com

Abstract: The recent re-evaluation of the systematic status of the Kentish Plover subspecies *Charadrius alexandrinus seebohmi* to a new taxon, Hanuman Plover *Charadrius seebohmi*, highlighted the gaps in the research on shorebirds in the Central Asian Flyway. We are presenting four new breeding records of Hanuman Plover; three from the Gulf of Mannar and one from Point Calimere. These sites are the nearest south-eastern Indian sites to the Mannar region of Sri Lanka. Hence the need for Hanuman Plover's description as a regional endemic with conservation prioritization, making it a flagship species in CAF in Sri Lanka and southern India.

Keywords: Flagship species, Gulf of Mannar, plover, Point Calimere, shorebirds.

Hanuman Plover *Charadrius seebohmi* is the latest addition to the global avian species list. It is a resident shorebird found across the southern tip of India and Sri Lanka. The recent re-evaluation of the systematic status of Kentish Plover sub species *Charadrius alexandrinus seebohmi* based on the phenotype and genetic distinctiveness from migrants *C. alexandrinus* and *C. dealbatus,* the sub species *C. a. seebohmi* was elevated to species level with English name Hanuman Plover (Niroshan et al. 2023). The Kentish Plover being a widely distributed species have breeding populations across America, Europe, Asia, and African continents (del Hoyo et al. 1996; Wetlands International 2006; Meininger et al 2009; Vincze et al 2013). It is abundant across the Indian subcontinent (Sangha 2021). The Kentish Plover *Charadrius alexandrinus* is a diverse species complex, comprising of four currently recognized taxa: *C. a. alexandrinus, C. a. nivosus, C. a. dealbatus, and C. a. seebohmi,* separated geographically with some subtle morphological and plumage differences (del Hoyo et al. 1996, Kennerley et al. 2008, del Hoyo et al. 2021). Recent evaluation of the taxonomic status of the Snowy Plover *C. a. nivosus* (Küpper et al. 2009) and the Whitefaced Plover *C. a. dealbatus* (Rheindt et al. 2011, Sadanandan et al. 2019) endorsed that these taxa be elevated to species based on their genetic and phenotypic distinctiveness; which has now been adopted (del Hoyo et al. 2021; Gill et al. 2021).

As this sub species of Kentish Plover is updated as a new species, we review the literature based on the old

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findings. Ali & Ripley (1983) reported *C. a. alexandrinus* breeding from western Pakistan, Gujarat, and northern Indian regions in the Indian subcontinent. Apart from Sri Lanka, Hanuman Plover also breeds in some areas of southeastern coasts and a few areas on the western coasts of India. Breeding evidences of a small population of this species which was considered as a Kentish Plover subspecies, earlier, in peninsular India are mostly from wetlands of southern India and Maharashtra (Krebs 1956; Melluish 1966; Ali & Ripley 1983; Futehally 2006). On the east coast, the breeding sites reviewed from the literature are from Cuddalore (Krebs 1956; Ali & Ripley 1983), Chengalpattu-Chennai, and Point Calimere (Melluish 1966; Futehally 2006) of Tamil Nadu. In Pulicat and Chilika lakes, the subspecies level of identification was not done for the breeding birds (Sangha 2021). On the western side of India, the breeding reports were from Upper Wardha Dam at Vidarbha, Maharashtra (Kasambe 2007; Kasambe & Wadatkar 2007) and Vani Vilasa Sagara of Karnataka (Rao et al. 2018). Rasmussen & Anderton (2005) stated that the northern distribution limit of *C. a. seebohmi* is unknown, and Kentish Plovers recorded in the south are likely to be *C. a. seebohmi.* Considering the new taxonomy re-evaluation, we can consider these as Hanuman Plovers.

During our shorebird monitoring programme on the southeastern coast of India from 2017 to 2022, we documented four breeding accounts of Hanuman Plover from Tamil Nadu. Our breeding records are given site wise: Site1 was Pillaimadam (9.2824^{0}N, 79.1087^{0}E) (Figure 1) abutting Palk Bay, adjacent to the Rameswaram Island, is a saltwater lagoon and is bridged by a bar mouth to Palk Bay in the north. The lagoon is bounded by grassy areas on the landward side. Shorebirds, large wading birds, gulls, and terns are seen regularly. Site2 was Dhanushkodi (9.19858^{0}N, 79.3833^{0}E) (Figure 1) in the Rameswaram Island on the Gulf of Mannar (GoM) region is a lagoon with both mudflats and sandy areas. This is one of the best bird congregation sites during the coastal bird's migratory season in the GoM region. The intermittent pools and the grass like patches on the fringes serve as breeding grounds for ground-nesting birds like larks. Site3 was Valinokkam (9.1618^{0}N, 78.6284^{0}E) (Figure 1) is an area with salt pans and prawn cultures. The excess water from these is pumped out and thus a man-made lagoon formed with mudflats. Gulls, terns, shorebirds,

Figure 1. Additional breeding records of *Charadrius seebohmi* from southeastern India.

and large wading birds aggregate in good numbers here. We have observed that the presence of grassy streaks bordering the lagoon leads to some ground-nesting birds like larks breeding here regularly. Site4 was Kodiyakadu (10.3270^{0}N, 79.7768^{0}E) near Great Vedaranyam swamp (Figure 1) is bounded by grass patches with sand beds also supports shorebirds and large wading birds.

This species nests generally from February to July along the coasts and dried mudflats; between April and July at GoM (Balachandran 1995). Our present studies also registered the breeding from February itself. The breeding records from each site with details are as follows. In Site1, we documented the adults and two chicks on 15 June 2022 (Image 1). In Sites2 & 3, we spotted the nest with three eggs in the clutch (Image 2) and adult birds' incubating (Image 3) on 24 March 2017. This was confirmed after the parent bird had reached the nest with eggs and started incubating. In Site 4, we surveyed the chick and the adult on 28 February 2020. Hanuman Plover and *C. alexandrinus* can be differentiated in the field during breeding plumage by the identification pointers like the latter being slightly larger and having a rufous tinge on the crown (Hayman et al. 2011). During the breeding season, Hanuman Plover lacks the black fore-crow, which becomes darker in breeding plumage, and eye-stripe compared to Kentish Plover nominate race that arrives at GoM by September and departs by mid-March (Balachandran 1995). *C. seebohmi* also has dark grey legs in both sexes, while *C. alexandrinus* have black legs. Although it is challenging to differentiate the Kentish Plover nominate race from Hanuman Plover during the winter, we were able to characterize it from the nominate race because we recorded incubating adults, eggs, as well as adults with weeks old chicks.

Kentish plovers are ground-nesting birds (Amat & Masero 2004), often with a preference for low, open, moist nesting sites away from thick vegetation and human activity. The nests of Hanuman Plovers we observed were shallow scrapes, partially filled with pebbles, small snail shells, pieces of dry mud, and vegetation near the grass patches on the shores. In Sites1, 2 & 4, the nests were seen in areas that formed as small water pools near the lagoons / main water body. It was very difficult to identify until we patiently watched them in pairs for rather some time and in breeding plumage near the nests. Also, with chicks, the adults were seen patrolling the new-born ones.

The breeding system of Kentish plovers is unusually diverse (Székely et al. 2006). Both parents incubate the eggs, but after the eggs hatch, one parent (usually the female) may abandon the family to find a new mate, resulting in monogamy, polygyny, and polyandry within a single population (Lessells 1984; Kosztolányi & Székely 2002; Székely et al. 2006). Even though our investigation was not designed primarily to examine nest attendance, casual observations of nests of Hanuman Plover

Image 1. Adult of *Charadrius seebohmi* with two chicks at Pillaimadam.

Image 2. Clutches with three eggs of *Charadrius seebohmi* on the nest at Valinokkam.

Image 3. Adult *Charadrius seebohmi* in incubation at Valinokkam.

Image 4. Adult *Charadrius seebohmi* with single chick at Kodiyakadu.

revealed that the pairs followed a consistent schedule of nest attendance. We also observed that the chicks when hatched were mostly attended to and escorted by both parents up to the second week of hatching.

The new breeding records of Hanuman Plovers from distinct locations along Tamil Nadu on India's southeastern coast, spanning hundreds of kilometres, should lead to the need of conservation of these sites as an important step for habitat protection. This could reiterate the need to protect the breeding habitats that are in non-protected areas. As mentioned earlier, these areas also accommodate many waterbirds including Near Threatened long distant migratory species such as Bar tailed Godwit *Limosa lapponica*, Black tailed Godwit *Limosa limosa*, Red Knot *Calidris canutu*s, etc and Endangered species like Great Knot *Calidris tenustirostris.* Habitat destruction and the ever-increasing need for economic development are major challenges for the survival of this species just like any other wild species. Other conservation threats we perceived in all the sites is the presence of stray dogs chasing shorebirds. In Sites1 & 2, children used to pick up eggs of ground nesting birds in general out of ignorance and for fun which must be overcome by creating awareness in the breeding areas. Moreover, these breeding plovers have limited breeding and wintering range emphasizing the need of protection. From the literature search on breeding records, no recent nesting population observations are recorded from these coasts on Hanuman Plover breeding. Hence, the current study also highlights that this species might be breeding in other wetlands of Tamil Nadu. This also emphasizes the need of comprehensive exhaustive survey and monitoring to be undertaken throughout the state to establish understanding of the breeding sites of Hanuman Plovers for future conservation and evaluation of the species status. The description of *C. seebohmi* as a regional endemic could make this species a flagship species in conservation prioritization in the Central Asian Flyway in Sri Lanka (Abeyrama & Seneviratne 2018) and south India.

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SHORT COMMUNICATION

A study on the breeding habits of Red-wattled Lapwing *Vanellus indicus* Boddaert, 1783 (Aves: Charadriformes: Charadridae) in the agricultural landscape of Muzaffarnagar District, Uttar Pradesh, India

Ashish Kumar Arya [1], Kamal Kant Joshi [2], Deepak Kumar [3] & Archana Bachheti [4]

[1,4] Department of Environmental Science, Graphic Era (Deemed to be University), Dehradun, Uttarakhand 248002, India.
[2] Department of Environmental Science, Graphic Era Hill University, Dehradun, Uttarakhand 248002, India.
[3] Department of Geology, DBS (PG) College, Dehradun, Uttarakhand 248002 India.
[1] ashishtyagi.gkv@gmail.com (corresponding author), [2] kamal_josi@yahoo.com, [3] deepakgeo72@gmail.com, [4] bachheti.archana@gmail.com

Abstract: This study investigated the breeding biology of Red-wattled Lapwing *Vanellus indicus* in the agricultural landscape of district Muzaffarnagar, Uttar Pradesh, India, during three consecutive breeding sessions (2019–2021). A maximum of 25 nests and average clutch sizes of 3.64 ± 0.49 were recorded in 2021. Hatching success estimated using the Mayfield method was 55% in 2019, 64% in 2020, and 65% in 2021; values obtained using the traditional method were 42%, 58%, and 53%, respectively. During 2019 and 2021, 3.8% and 3.3% (respectively) of eggs did not successfully develop, while no hatching failures were recorded in 2020. In total, 32% of eggs were destroyed during the study period by predators (cats, dogs, and foxes), and an average of 15% of eggs were destroyed due to anthropogenic activities such as agricultural practices. Red-wattled Lapwings displayed cryptic behavior and active defense against predators making them a successful open nesting species.

Keywords: Breeding season, clutch size, incubation period, hatching success.

Birds are good indicators of a healthy ecosystem (Gregory et al. 2003). Red-wattled Lapwings *Vanellus indicus* belong to the Charadriidae family and are recognized via a unique red wattle in front of the eye. This bird is widely distributed throughout the Indian subcontinent (Ali & Ripley 2002; BirdLife International 2017) and a loud alarm call is an important characteristics of this species (Anil & Sharma 2011). Lapwings are open field nesters, mostly living in small flocks near wetlands, agricultural fields, and human settlements and feed on vegetable waste, beetles, & snails (Ali & Ripley 2002; Grimmett et al. 2016), and commonly breed from March to June, with male lapwings choosing nest sites. The females lay eggs in open areas or on the ground, and nests are difficult to find since the eggs are cryptically colored, usually matching the ground pattern. The eggs are laid in a ground scrape or depression, sometimes fringed with pebbles and goat or hare pellets, which help to camouflage the eggs from predators (Saxena & Saxena 2013). Some studies (Saxena 1974; Koshy 1989; Anil & Sharma 2011; Sethi et al. 2011) have reported lapwings nesting on roof sites to protect their eggs from predators.

The Red-wattled Lapwing is considered a ‘Least Concern’ species according to the IUCN Red List of Threatened Species (IUCN 2021), with strong populations throughout the world. Few studies (Sethi et

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al. 2011; Khalil et al. 2018; Mishra & Kumar 2020) have been conducted on their breeding behavior. This study's primary aim is to document the lapwing's breeding biology, especially on rural agricultural ground, and to assess breeding parameters throughout the study period.

Material and Methods

Study area

The present study was carried out in the agricultural landscape in three villages of Muzaffarnagar District, Uttar Pradesh, India: Ghisukhera (29.5795°N, 77.6035°E), Chokra (29.5875°N, 77.5820°E), and Charthawal (29.5440°N, 77.5920°E) (Table 1; Image 1). About 60% of the area of these villages is occupied by agricultural land where seasonal commercial crops such as sugarcane, wheat, rice, and fodder grasses are cultivated. The temperature varies from 35°C in summer to 14°C in winter, with an annual average temperature of about 25 °C. The area receives about 120 mm rainfall annually (in monsoon).

Table 1. Geographical information about the agricultural landscape of district Muzaffarnagar, Uttar Pradesh.

	Name of study site	Geo-coordinates of sites	Elevation (m)
1	Ghisukhera Village	29.5795^{0}N, 77.6035^{0}E	246
2	Dahchand Village	29.5875^{0}N, 77.5820^{0}E	240
3	Charthawal Village	29.5440^{0}N, 77.5920^{0}E	252

Methods

The study was carried out in three agriculture fields during the lapwing breeding session (March–June). To assess breeding parameters (Sethi et al. 2011), key parameters including pairing, nesting, egg laying, incubation, and hatching were studied in 2019, 2020, and 2021. Data were collected in the morning (0700–1100 h) and evening (0400–0600 h) at two day intervals. In total, 10 visits were made to each study site, and observations were recorded using a Nikon Coolpix P1000 camera.

Data Analysis

Data were analyzed using one-way ANOVA (Analysis of Variance) and t-test as described by Clark (2007). MS

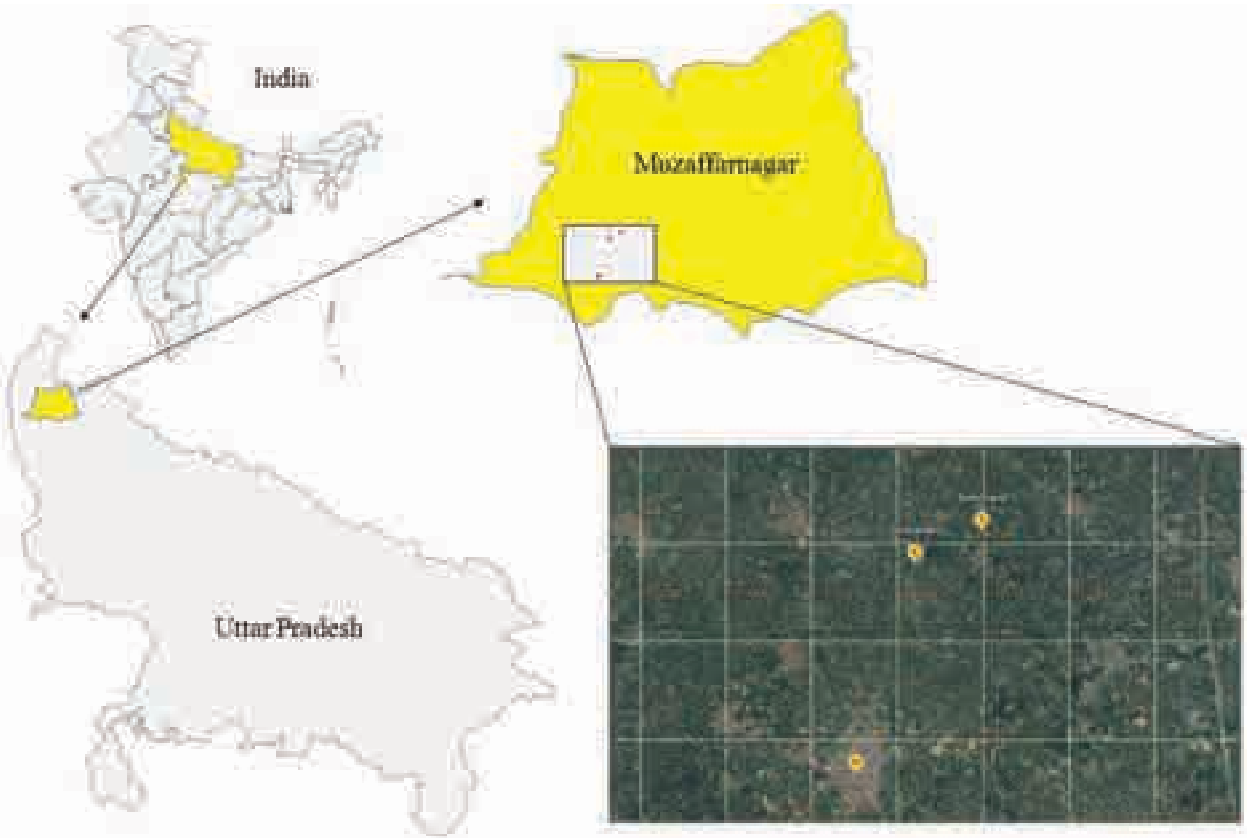

Image 1. The study area of the agricultural landscape in Muzaffarnagar District, Uttar Pradesh. Source: Google Maps.

Office Excel (version 10) was used for the data analysis. We used Mayfield's method to reduce error and biases in the determination of egg hatching success (Mayfield 1975; Johnson1979) according to the formula:

Hatching success = 1 – (total number of failed nests ÷ total number of exposure days) ×100

Lapwing egg hatching success was also calculated using the traditional method formula:

Hatching success = (No. of Eggs hatched/Total No. of eggs laid) X 100

Results

The results showed that the Red-wattled Lapwings started breeding in April in the study area and continued until June. We observed that when female lapwings incubate the eggs, males protect the nest, and vice versa. After hatching, both parents participate in parental duties, as reported in previous studies (Ali & Ripley 1998; Ali & Sharma 2011; Khalil et al. 2019). A total of 22, 18, and 25 nests were recorded in 2019, 2020, and 2021, respectively. During those years the average clutch sizes were 3.59±0.50, 3.67±0.49, and 3.64±0.49; and the mean number of eggs hatched successfully per clutch was 1.5±1.77, 2.11±1.97, and 1.92±1.80 (Table 2).

The hatching success during the period with the Mayfield method was found to be 55.10% in 2019, 63.90% in 2020, and 64.5% in 2021. The hatching success rates with the traditional method for the eggs hatched were 41.77%in 2019, 57.58% in 2020, and 52.75% in 2021. Un-hatched eggs or hatching failure was also reported during the study; hatching failure was 3.80% in 2019 and 3.30% in 2021. However, no hatching failures were recorded in 2020 (Table 3). The results indicated that an average of 32.11 % of lapwing eggs were destroyed during the study period (2019, 2020, and 2021) by predators (cats, dogs, foxes). Similarly, 14.82% of eggs were destroyed due to anthropogenic activities such as agricultural practices during the study period (Table3).

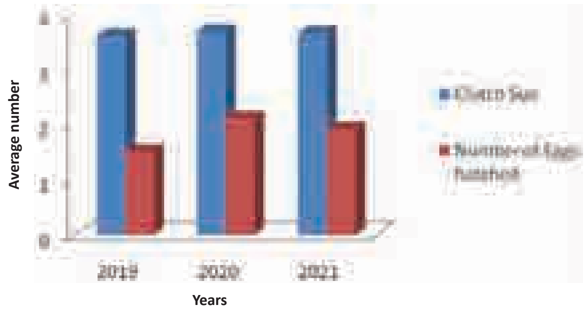

Figure 1. The average clutch size and hatched eggs during the study period.

Table 2. Breeding parameters studies in agricultural landscape (Ghisukhera, Dahchand, and Charthawal Villages) from 2019 to 2021.

Parameters	Years		
	2019	2020	2021
Incubation period	28 ± 0.10	25 ± 1.58	29 ± 0.40
Nest formation in months	April	March	March
No. of nests (n)	22	18	25
Clutch size (Mean ± SD)	3.59 ± 0.50	3.67 ± 0.49	3.64 ± 0.49
Number of eggs hatched (Mean ± SD)	1.5 ± 1.77	2.11 ± 1.97	1.92 ± 1.80

Discussion

In the present study, we found that the breeding period of Red-wattled Lapwing ranged from April to June, with a peak in April. Some previous studies (Kumar et al. 2011; Sethi et al. 2011) were conducted in the plain areas of Haridwar, and our results on breeding season support their findings. The breeding parameters of Lapwing species, clutch size (3–4 eggs), the average number of eggs hatched (2–3 eggs), and the incubation period (25–30 days) recorded in the present study are very close to those reported by previous studies (Desai & Malhotra 1976; Ali & Ripley 1998; Sethi et al. 2011) conducted in different regions of India.

In our study, we found that the agricultural landscape is very suitable for the lapwing breeding success; maybe the open harvested ground is not attractive to livestock, and the harvested land soil serves as an effective camouflage against the predators. However, in some cases, cattle reportedly crushed the eggs of ground-

Table 3. Nesting and breeding parameters of Red-wattled Lapwing *Vanellus indicus* in the agriculture landscape of Muzaffarnagar, Uttar Pradesh.

Year	Number of nests observed	Eggs laid	Eggs hatched	Hatching success calculated by Mayfield method (%)	Hatching success calculated by traditional method (%)	Eggs destroyed due to predation (%)	Eggs destroyed due to anthropogenic activities (%)	Hatching failure (%)
2019	22	79	33	55.10	41.77	40.51	13.92	3.80
2020	18	66	48	63.5	57.58	27.27	15.15	0
2021	25	91	38	64.9	52.75	28.57	15.38	3.30

nesting Lapwing (Hart et al. 2002). Lapwings, both males and females, often aggressively attack predators like dogs, cats, cattle, or humans who approach their nests. Some previous studies (Beintema & Muskens 1987; Khali et al. 2019) have also reported lapwing camouflage behavior and attack on predators. Lapwing have used different types of nest protection mechanism for successful breeding.

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Erratum

In the article describing the Rajendran's Shieldtail *Uropeltis rajendrani* by Ganesh & Achyuthan (2020), inadvertently, the details of the scientist in whose honour the new species was named, Dr. M.V. Rajendran were unfortunately miswritten. It is here clarified that Dr. M.V. Rajendran was a professor of Zoology in St. Xavier's College Palayamkottai and was a Founder Trustee with the Madras Snake Park Trust (now Chennai Snake Park Trust). This inadvertent handslip in furnishing his details and whereabouts is regretted.

Ganesh, S.R. & N.S. Achyuthan (2020). A new species of shieldtail snake (Reptlia: Squamata: Uropeltidae) from Kolli Hill complex, southern Eastern Ghats, peninsular India. *Journal of Threatened Taxa* 12(4): 15436–15442. https://doi.org/10.11609/jott.5680.12.4.15436-15442

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OPEN ACCESS

SHORT COMMUNICATION

Rediscovery and redescription of *Urolabida nilgirica* Yang (Hemiptera: Heteroptera: Urostylididae) from India

Pratik Pansare [1], H. Sankararaman [2] & Hemant V. Ghate [3]

[1,3] Post-Graduate Research Centre, Department of Zoology, Modern College of Arts, Science and Commerce (Autonomous), Shivajinagar, Pune, Maharashtra 411005, India.
[2] Department of Crop Protection (Entomology), Vanavarayar Institute of Agriculture, Manakkadavu, Pollachi, Tamil Nadu 642103, India.
[1] pansareptk101@gmail.com, [2] sankararaman05@gmail.com (corresponding author), [3] hemantghate@gmail.com

Abstract: *Urolabida nilgirica* Yang, 1938 is rediscovered and redescribed from India after 85 years since its original description. A brief redescription of this species along with the images of live habitus, various diagnostic characters, and genitalia are provided.

Keywords: Pentatomoidea, true bugs, Urolabidini, Western Ghats.

A pair of dark green bugs were collected from the lower Palani Hills at the Horticultural Research Station (HRS), Thadiyankudisai, Tamil Nadu. Dark black marking on overall dark green colouration were noticeable contrasting colour features in these bugs (Image 1A,B).

Examination under microscope revealed that the bugs belong to the family Urostylididae and the genus *Urolabida*, as the ocelli are absent; however, the specimens did not match with any species described by Distant (1902). The species appeared very close to *Urolabida tenera* Westwood, 1837 in some features of colouration but lacked some important features, such as angulate process on either side of genital segment, mentioned by Distant and as shown in the images of the type by Roca-Cusachs et al. (2021).

Search of literature for the other species of *Urolabida* indicated that the species in question is *Urolabida nilgirica* Yang, 1938, which was then described as a new species on the basis of two females collected from an unspecified location in the Nilgiri Hills. Although described in 1938, the specimens were collected much earlier: one specimen was collected by Lindsay (on 25.vi.1889) and the second specimen was collected by Andrews (in 1909); both these specimens are preserved in the The Natural History Museum, London (BMNH). That means over a century has passed since the last time this species was collected. Male genitalia of this species were illustrated and described by Kumar (1971) based on a specimen that was (as per the author) 'sent by Prof. Slater from University of Connecticut, Storrs and determined by Dr. W.E. China' but the locality / date of collection of this particular specimen were not stated.

Although this species was adequately described originally by Yang (1938), only drawings of habitus (in dorsal view) and female terminalia (in ventral view) were presented. We are giving brief morphology but providing digital images of the various morphological

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features of this bug, including the male genitalia because the species was originally described on the basis of two females only. We are also providing the digital image of the female terminalia. Kumar (1971) gave only details of the phallus (aedeagus) of this species and shape of the parameres, without commenting on or illustrating the shape of pygophore while we are providing details of the structure of pygophore as well. Thus, we are adding significant new information about *U. nilgirica* than what is available to date.

Taxonomy (as per Rider 2006, 2015)
Urostylididae Dallas, 1851
Urostylidinae Dallas, 1851
Urolabidini Stål, 1875
***Urolabida* Westwood, 1837**
***Urolabida nigirica* Yang, 1938**

Material examined: 2 males, India, Tamil Nadu, Dindigul, Thadiyankudisai, HRS, 10.29514°N , 77.70878° E, 11.vi.2018, leg. H. Sankararaman, light trap; 1 female, with the same data as of male. One male and one female preserved at Modern College, Pune 5 (MCZ Uro1 and MCZ Uro2, respectively); one male preserved at Department of Entomology, Faculty of Agriculture, Annamalai University, Chidambaram, Tamil Nadu (EDAU Het 1). Image of the syntype preserved at BMNH, London, was compared.

Redescription

Size and colouration

Medium size bug, male about 12 mm long, female slightly larger, about 13.5 mm. In life the colour is bright green dorsally and pale greenish-yellow ventrally. The first antennomere is dark green and the II–V are brownish with pale basal region of antennomeres 4 and 5. The area of corium adjacent to clavus along its length and the apical margin of the corium is dark black. All femora are dark green and tibiae pale green; the apices of all femora, anteriorly and posteriorly, are marked with black spots. The posterior margin of pronotum and clavus are pale green and, except the black basal line, the membrane is translucent, such that in male it is easy to see contour of the pygophore (Images 1A, 2A, 5A).

After drying, the bug becomes dorsally mostly brownish-ochraceous with greenish tinge at places, especially on corium; black areas remain unchanged and the black punctures, especially on posterior part of pronotum and scutellum, appear pronounced. Ventrally the insect is almost uniformly reddish-ochraceous, only black spots on apex of femora are different (Images 2B, 4B).

Structure

i. Head

Head short, as in most urostylidids, broader than long; eyes large, width of head at eye level more than width at anterior angles of pronotum. Clypeus and mandibular plates are distinct. Antenniferous tubercles situated anterolaterally between eye and mandibular plate, visible from above. Antennae long, longer than body, first segment thick and slightly curved and as long as pronotum, remaining segments slender. Labium relatively stout, reaching about middle of mesosternum (Image 3B).

Image 1. *Urolabida nilgirica* Yang, 1938 from Thadiyankudisai, Dindugal, Tamil Nadu: A—Live, male | B—Live, female. © H. Sankararaman.

Image 2. Habitus of *Urolabida nilgirica* Yang (male): A—dorsal view | B—ventral view. © H.V. Ghate.

ii. Thorax

Pronotum trapezoidal, with finely reflexed margin anteriorly and laterally; black punctures all over the surface except for calli. Pronotal anterior margin nearly straight, sides slightly sinuate and posterior margin slightly convex. Pro-, meso-, and metasternum smooth; prosternum very narrow, medially sulcate; metasternum convex, with median depression in anterior one third; metathoracic scent-gland peritreme long, transverse across sternum (Image 4A), evaporatorium not well developed. Procoxae close together, meso- and metacoxae well separated (Images 2B, 3B).

Scutellum triangular, as long as broad, uniformly punctured with black except for narrow median, longitudinal smooth line. Hemelytra well developed, passing beyond apex of abdomen in both sexes. In hemelytra, clavus almost impunctate along with adjacent inner area of corium; outer part of corium beyond media vein finely but sparsely punctate, punctures black with their margins reddish brown. Membrane with many parallel, colourless veins, almost transparent, in male revealing outline of large pygophore; width of abdomen at pygophore slightly broader than width at apex of segment VII (Image 5A & B). All legs with femora and tibiae slightly flattened, tibiae slightly shorter and slender than respective femora; femora sparsely but tibiae and tarsi densely setose.

iii. Abdomen

Abdomen in male nearly parallel-sided for 3/4 of its length thence slightly narrowed and again the segment IX or pyrophore is slightly broader; median region broadly ridged between segments III–VII; sternum VIII capacious yet accommodating only 1/3 of basal portion of pygophore—whole structure looking like a fan (Images 2B, 5B).

Detached pygophore (before / after KOH treatment views) in dorsal view appears like a limpet (Image 6A,B). There are two spiny protrusions on the inner wall in posterior half, inner one of those is long and strong while outer is more or less like a tubercle. There are many long setae on this lateral inner wall of pygophore and also on outer rim. Dark black, strong parameres are situated in anterior half and in more dorsal position.

Image 3. Structures of *Urolabida nilgirica*: A—Head, pronotum and scutellum | B—Head and thoracic sterna. © H.V. Ghate

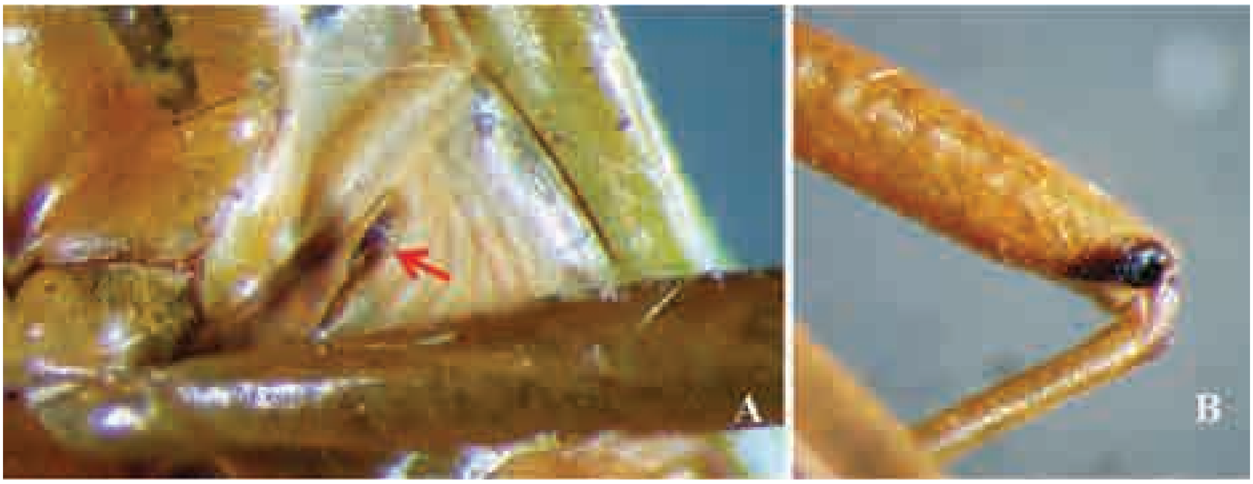

Image 4. Structures of *Urolabida nilgirica*: A—Metathoracic scent gland spout | B—Apex of femora black. © H.V. Ghate

Overall pygophore appears slightly longer than broad (Image 6A–F). In lateral view pygophore appears cup-shaped (Image 6C,D); in slightly oblique lateral view it is possible to see parameres and those spiny protrusions as well as sinuate and setose margin; position of phallus is also apparent due to KOH treatment. Ventral view of pygophore appears as in Image 6E; spiny protrusions and outline of phallus, which is situated in basal half, are visible through KOH treated, hence translucent, ventral wall (Image 6F).

Image 5. Abdomen of *Urolabida nilgirica*, male: A—Pygophore, dorsal | B—Pygophore, ventral. © H.V. Ghate.

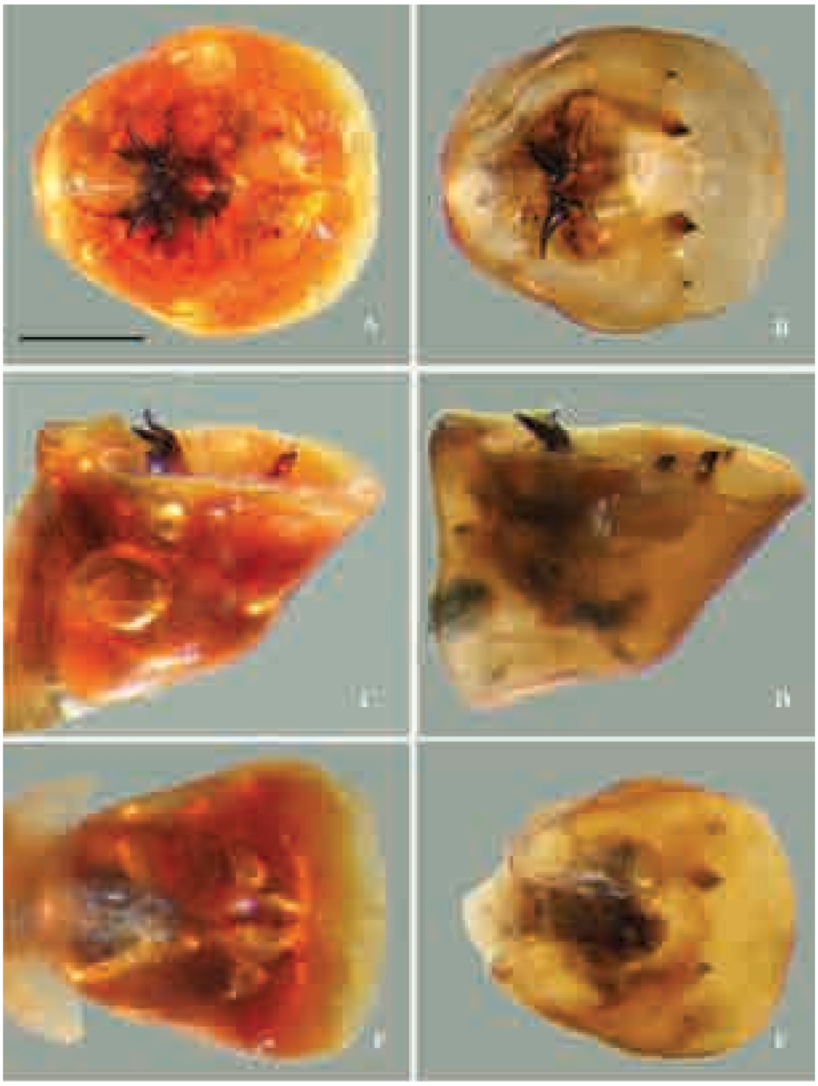

Image 6. Pygophore: A, B—dorsal | C, D—lateral | E,F. ventral. (Images 6A, 6C and 6E, pre KOH treatment; Images 6B, 6D and 6F post KOH treatment). (scale 1 mm). © H.V. Ghate.

Image 7. Phallus: A—dorsal | B—ventral | C—lateral (scale 1 mm). © H.V. Ghate.

Dorsal, ventral and lateral views of partly everted phallus are provided here (Image 7A–C). Phallus is symmetrical, uniformly cylindrical, dorsally as well as ventrally well sclerotized. Large, membranous dorsolateral proximal connexival (DLPC) lobes with lateral sclerotized lobes, ventromedian distal connexival processes (VMDC) are highly sclerotized and prominent, dark brown, elongate structures; dorsolateral distal connexival processes (DLDC) are also sclerotized but slender and brown (Image 8A). Due to rigid nature and single specimen further eversion of phallus was not successful to reveal details of vesica and other lobes. Parameres sclerotized, curved, with tooth like structure distally and also with a spiny projection in opposite direction, dark brown in distal half, pale brown in basal region (Image 8B).

Female

Identical to male in structure but broader and larger in size, with abdomen more parallel-sided and slightly narrowed only in genital region. Female with sternum VII very broad and long; female terminalia as shown in Image 8C. Paratergite VIII spatulate (labelled as 8pt in Image 8C), projecting distally but not meeting the opposite paratergite. Paratergite 9 (labelled as 9pt) short and narrow. Gonocoxite VIII (labelled as 8g) large but gonocoxite IX small and not clearly seen in ventral view here.

Measurements (mm): male: total body length, 12.0; head width at eyes, 1.75; interocular distance, 1.0; length of rostrum, 3.20; length of antennomeres, I, 3.0; II, 3.1; III, 1.5; IV, 3.0; V. 2.5; pronotum length, 2.25; pronotum width at humeral angles, 4.50; scutellar length, 2.75; scutellar width at base, 2.75; female: total body length, 12.7; head width at eyes, 2.0; interocular distance, 1.0; length of rostrum, 2.75; length of antennal segments, I, 3.0; II, 3.3; III, 1.75; IV & V, lost; pronotum length, 2.5; pronotum width at humeral angles, 5.2; scutellar length, 3.25; scutellar width at base, 3.25.

Discussion

The species *U. nilgirica* was described well by Yang and our specimens matches exactly with the original description given by Yang (1938). Further, the structure of the male genitalia (phallus as well as parameres) of our specimen match with the description and drawings given for this species by Kumar (1971); similarly female terminalia in our specimen match very well with the figure given in original description by Yang (1938). In addition, we have also compared dorsal habitus image of our female specimen with the identical image of the syntype preserved at the Natural History Museum (BMNH), London, and again found complete matching. Thus, there is no doubt that our specimens are *Urolabida nilgirica* and that this species has been rediscovered in Tamil Nadu, but from a different hill range, after a long gap of over 100 years.

Urostylididae are a small family with only eight genera, 173 extant species and a few fossil species (Roca-Cusachs et al. 2021; Duan et al. 2023). Rider et al. (2018) recently summarized essential features of this family and stated that the biological information on this group is still meagre. Chinese species have been relatively well worked and many of these works are cited by Roca-Cusachs et al. (2021) and hence need not be recited. Taiwanese Urostylididae were also reviewed by Ren & Lin (2003). Work on Indian species is wanting. We need more surveys to document / illustrate and redescribe such species but at present no specific efforts are made to understand Urostylididae fauna of India; a paper published on *Urolabida histrionica* (Westwood, 1837) (Ranade & Ghate 2023) may be the only recent paper on this family from India. Earlier, Ahmad et al.

Image 8. A—Phallus magnified, lateral | B—Parameres | C—Female terminalia, ventral. © H.V. Ghate.

(1992) reviewed and carried cladistic analysis of the various characters of Urostylididae (under earlier name Urostylidae), gave details of genitalia of some species, provided keys to all known 27 species of the Indian subregion at that time and discussed relationship of Urostylididae with some Pentatomoidea; however, their list did not include *Urolabida nilgirica.*

The taxonomy of this family is still problematic as the genera are not well defined and frequently the characters used to separate genera are not well-founded making identification difficult (Roca-Cusachs et al. 2021; Duan et al. 2023; Ranade & Ghate 2023). Even the molecular work involving nuclear 18S and 28S rRNA genes, along with total mitochondrial genome analysis, of seven genera and 51 species of Urostylididae by Duan et al. (2023) indicated that the three species-rich genera, *Urolabida* Westwood, 1837, *Urochela* Dallas, 1850 and *Urostylis* Westwood, 1837 are all polyphyletic groups; not only that but this analysis even does not support recognition of the two tribes (Urolabidini and Urostylidini) that are currently accepted in Urostylididae. It is clear that much work is required in this family, especially on species found in India as most Indian species are still poorly known. More knowledge about Indian as well as southeastern

Asian species will help revising the existing classification. We agree with Duan et al. (2023) who stated that "… the current classification of tribes and genera within this family needs to be thoroughly revised".

Finding this species near its own type locality, after a gap of a century, is really heartening as this indicates that the environs of this species are not still damaged beyond repair, in spite of ongoing deforestation in these areas.

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SHORT COMMUNICATION

The perception of bee and wasp fauna (Hymenoptera: Aculeata) by the inhabitants of Mangdi Valley, central Bhutan

Kinley Tenzin

Natural Resources Development Corporation Limited, Thimphu, Bhutan.
kintshen606@gmail.com, kinley.tenzin@nrdcl.bt

Abstract: This paper explores the perception, knowledge, and attitude of the inhabitants of Mangdi Valley in Trongsa District concerning bees and wasps (Hymenoptera). Prevailing conservation threats to these ecologically important insects were determined. Data were collected from June to September 2018 by means of open-ended interviews from 32 randomly selected individuals. Responses to questions regarding their perceptions were analyzed and comparisons were made among a variety of demographic groups distinguished by age group, gender, and education status. The results showed that the people were aware of 5–10 species of common bees and wasps, mostly found in the agriculture and forested areas. The main threats faced by these insects are developmental activities followed by hunting and consumption.

Keywords: Attitude, biodiversity, conservation threats, knowledge, Trongsa District.

Bhutan is one of the global biodiversity hotspots, straddling the Indomalayan (Oriental) region to the south and Palearctic realm to the north (Ohsawa 1987). The country is expected to have rich insect biodiversity, however, limited studies provide an incomplete picture for this country. Bees and wasps (order Hymenoptera: class Insecta) are good indicators of biodiversity (Westphal et al. 2008; Rubene et al. 2015) and play important ecological roles as pollinators, nutrient cyclers, scavengers, predators and parasitoids of insects and other arthropods, contributing to balancing and sustaining natural and agricultural ecosystems (Engel 2001; Jousselin et al. 2002; Loyola & Martins 2006; Moisset & Buchmann 2011; Spengler et al. 2011).

While many have vernacular names in particular regions, common names are given to few Hymenoptera species worldwide, and many small (usually less than 5 mm long) parasitic species go unnoticed even by entomologists (Foottit & Adler 2009). Human familiarity with insects typically arises through encounters, early childhood experiences, local knowledge, and education (Lemelin et al. 2016). Most bees and wasps are capable of stinging in self-defense, and incidental stings can lead to negative attitudes towards them (Foottit & Adler 2009).

The ecological importance of bees and wasps is not valued by the people in the study area and the conservation status is unknown. There is no information available in the literature about the perception of bees and wasps by humans in the region. Some larger social bees and wasps are familiar and are consumed

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as a source of protein and medicine, but most of them are unknown to the general public of the region. An understanding of local people's knowledge and ideas is a prerequisite for constructive collaboration between farmers and scientists towards conservation (Gurung 2003). Therefore, the objectives of this study were to: 1) Understand the perception and knowledge of communities from Mangdi valley about the bee and wasp fauna; 2) Identify potential conservation threats to bee and wasp fauna in central Bhutan.

Materials and Methods

Study Area

Trongsa District is located at 27.4465°N, 90.504°E in the heart of the country. It covers an area of about 1,807 km² with 87.15% of the total area under forest cover, and the elevation ranges 800–4,800 m (National Statistics Bureau 2012). The district experiences annual average temperatures ranges 8.9–19 0C, and average annual rainfall of 870 mm (National Statistics Bureau 2013). The district comprises of five blocks, and the study was conducted in Nubi and Tangsibji Block (Figure 1). These blocks feature broadleaved to blue pine and mixed conifer forest types. The district has a mixed climate of humid and warm temperate with sandy and clayey loam-based soil. The terrain is rough, with steep slopes in the south and deep canyons to the north. Alpine scrub, blue pine, chir pine, fir, mixed conifer, shrubs, meadows, broadleaved woods make up the majority of the vegetation type. The most dominant forest types in the district are broadleaved forests with more than 50%, followed by mixed conifer with over 26%. Various crops and vegetables are grown. The wide elevation range and the mountainous and complex terrain create complex climatic conditions, from wet sub-tropical in the south to cold temperate in the northern high elevation areas. The Tangsibji hydropower project and Mangdichu hydropower projects were underway.

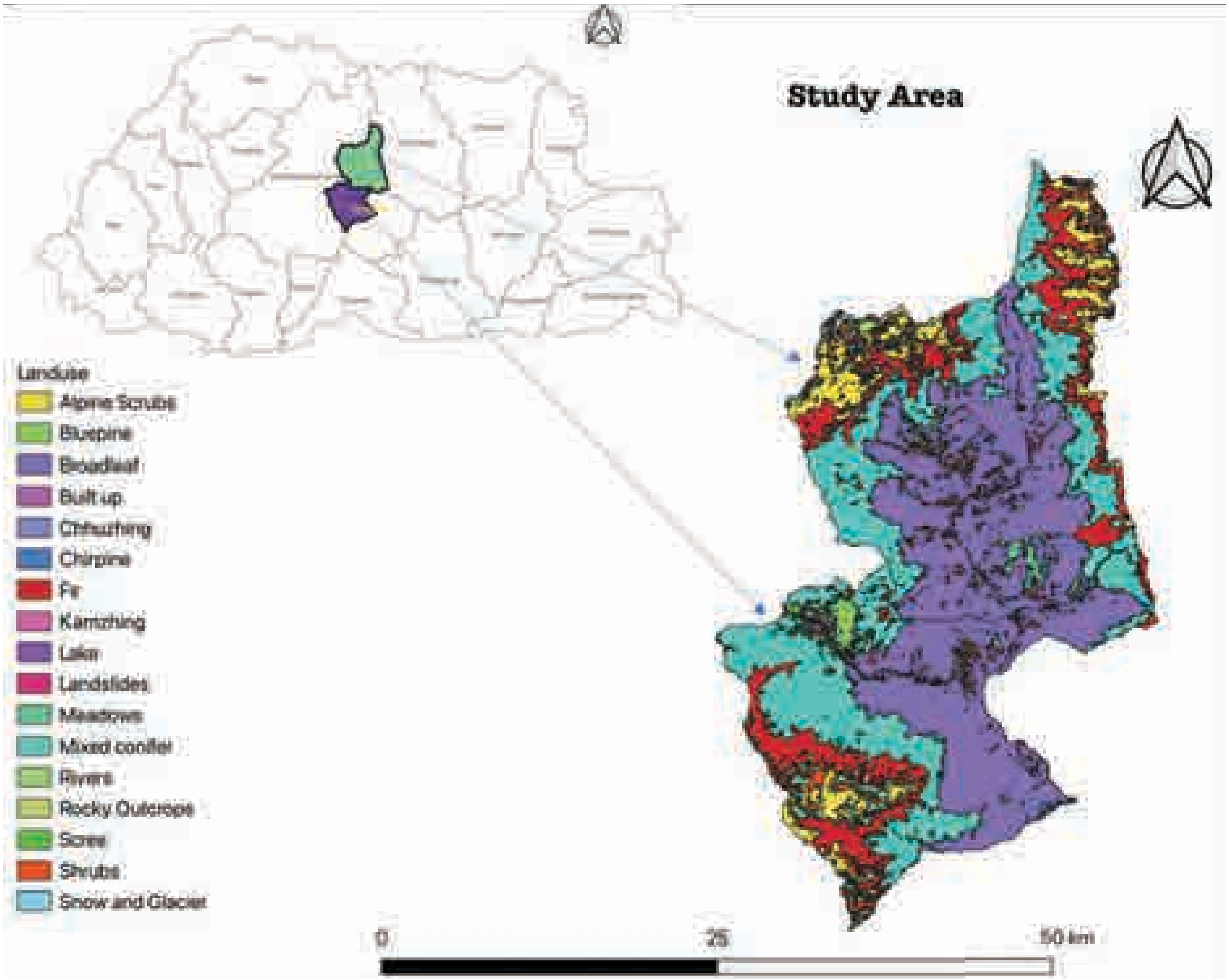

Figure 1. Map showing study area (Nubi and Tangsibji Block) concerning different land use area. Inset map show the 20 districts of Bhutan.

Data Collection and Analysis

Data were obtained from June to September 2018 by means of both close and open-ended structured questionnaires. People of both genders prioritizing the elderly villagers were interviewed. The respondents were selected based on stratified random selection, where the population was divided into strata or subgroups based on village wise with same ethnic group, and then individual samples and respondents are randomly selected from each stratum. The secondary data was gathered through various sources. Reports, journals, and various other research works, online sources and print media related to the context of this study. GPS handset was used to locate the site and record coordinates.

Descriptive statistics like frequency counts, percentages and tables were used in analyzing the data. Excel spreadsheet of office 2007 and pivot table was used for the data entry and segregation.

Result and Discussion

Perception of bees and wasps

The respondents represented a mixture of gender, age groups and education status. The social interview covered a total of 32 individuals from different areas and six education strata. One-hundred percent (n = 32) of the respondents were aware of bees and wasps, and 56% (n = 18) knew of 5–10 species of bees and wasps. This study found that 94% (n = 30) of respondents consumed bee and wasp products primarily for medicinal value (n = 13). The people usually collect bees and wasps during autumn and winter, collecting was once in a season. Through respondent interviews it was found that the authority restricting the collection of bee and wasp products was Department of forest and park services (Table 1).

According to respondents, bees and wasps usually begin to appear during April–June (n = 19), with wasps beginning to disappear during October–December while bees are seen throughout the year. A majority of respondents said aculeates are found in forested areas and agriculture land. The different types of bees and wasps found in different land use types in the study area are shown in Figure 2. Of the 32 respondents, 68% stated that bees and wasps were not harmful to human and agricultural crops. However, 32% of the interviewees stated that the bees and wasps are noxious.

Threats to bees and wasps in central Bhutan

The numbers of bees and wasps remain constant according to 14 respondents, while nine stated, numbers are decreasing compared to earlier days. Bees and wasps are important pollinators that play a crucial role in maintaining the biodiversity of ecosystems. However, their populations have been declining in recent years due to various factors, including habitat loss and fragmentation, pesticide use, climate change, and disease. As stated by Moron et al. (2008), one of the major contributors to the decline of bees and wasps are the loss of their natural habitats as a result of developmental activities such as deforestation, urbanization, and agriculture expansion. These activities often involved the destruction and fragmentation of natural habitats, including the removal of flowering plants that bees and wasps rely on for nectar and pollen.

Table 1. Regulatory authorities on hunting and consumption of bees and wasps.

	Regulatory/ Objecting Authority	Number of respondents
1	Department of Forest and Park Services	24
2	Block Administration	0
3	No objection	2
4	No idea	6
5	**Total**	**32**

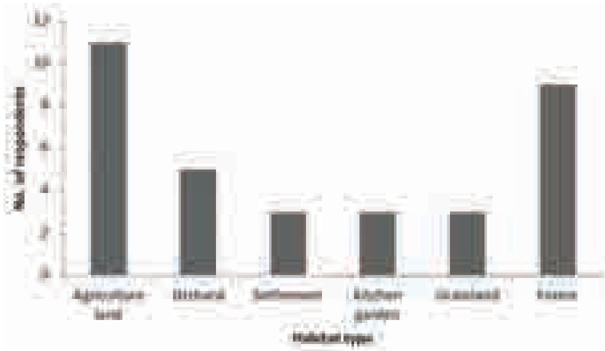

Figure 2. Occurrence of bees and wasps from different land use type as per respondents.

Table 2. Conservation threats faced by bees and wasps as per respondent perceptions.

	Conservation Threats	Number of respondents
1	Disease	5
2	Chemical fertilizer	4
3	Natural	1
4	Hunting and consumption	6
5	Developmental Activities	16
	Total	**32**

The current study found that the loss of natural habitats contributed to a reduction in the availability of nesting sites for bees and wasps, which further impacted their populations. Bees and wasps require different types of nesting sites depending on their species, but many rely on natural cavities in trees, shrubs, or the ground. Furthermore, the use of pesticides in agriculture and other activities adversely affected bees and wasps, leading to reduced populations and decreased biodiversity. According to respondents, the main threats faced by aculeates were developmental activities like construction of hydropower dams, road, and buildings, followed by hunting and consumption (Table 2) for example, when people burn down wasps to extract the larvae and pupae for consumption, in the study area. Bhutan is now in full swing of developmental activities such as hydropower, buildings, and roads, which results in habitat loss and fragmentation. Maximum numbers of respondents from both elevations suggested the Department of Forest and Park Services should frame effective rules and regulations to minimize threats to bees and wasps. Seven respondents did not have any suggestions for conserving aculeate fauna (a group of insects that have stingers or sharp pointed structures that can be used for defense or hunting).

Conclusion and Recommendation

This study provides baseline information on local peoples' perceptions of bees and wasps, their habitat types and conservation threats in central Bhutan. Feelings, knowledge, and behavior towards these insects are rationally coherent. Forty-three percent of the respondents said that numbers of bees and wasps remain constant, while 28% said they were decreasing. Major threats faced by bees and wasps include development activities, hunting, and consumption. Control measures for hunting and consumption of these valuable insects need to be taken. It is further suggested that this work may be extended to other parts of the country to assess perceptions of various groups of people concerning these valuable insect fauna and enhance conservation awareness.

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Appendix 1. Questionnaire for social survey.

Date............

Respondent's Name...
Gender: Male/ Female. Age...................................
Education level: 1. College 2. Secondary 3. Primary 4. Non Formal Education 5. Illiterate
Village.................................. ....
Gewog/block..Dzongkhag/District..............
Interviewer's Name...

Part I: People's knowledge and perception on Bees and Wasps

1. Do you know what a bee and wasp is?
   1. Yes 2. No
2. How many types of bees do you know?
   ....
3. How many types of wasps do you know?
   ....
4. Do you consume bee product?
   1. Yes 2. No
   If yes, 1. Annually 2. Monthly 3. Whenever available 4. No idea
5. Do you consume wasp product?
   1. Yes 2. No
   If yes, 1. Annualy 2. Monthly 3. Whenever available 4. No idea
6. Why do you consume?
   1. Medicinal value 2. As supplementary diet 3. Pleasure
7. How do you consume them?
   1. Raw 2. Boil 3.Fry 4. Dry
8. Do you collect them?
   1. Yes 2. No
9. Does any organization or authority object you from collecting them?
   1. Yes 2. No

Part II: Ecology and habitat preference of Bees and wasps as per people's knowledge

1. When do they appear, Month?
   ....
2. Which month do they disappear, month?
   ....
3. Where do they go?
   ....
4. In what type of habitat/land use are they found frequently, Rank them?
   1 Agriculture 2. Forest 3. Grass land 4. Orchard 5. Settlement 6. Kitchen garden
5. Are they harmful to any crops?
   1. Yes 2. No
   If yes, how?..
6. Are they harmful to human and livestock?
   1. Yes 2. No
   If yes, how?..
7. Do you know ecological importance of bees and wasps?
   1. Yes 2. No
   If yes, what are the importance...
8. Which weather does the bees and wasps appear mostly?
   1. Rainy day 2. Cloudy day 3. Sunny day 4. anytime
9. Did the number of bees and wasps increased or decreased from past ten years?
   1. Increased 2. Decreased 3. Constant/Same 4. No idea
   Why?...
10. What are the threats faced by the bees and wasps?
    1. Disease 2. Agriculture practice/Chemical fertilizers 3. Natural predators 4. Hunting and consumption 5. Developmental activities 6. No idea
11. What could you suggest to minimize the threats to bees and wasps?
    ....

NOTE: Please share any interesting social dynamics about bees and wasps which is not covered in the above questionnaire.
....
....

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NOTE

Breeding record of Little Ringed Plover *Charadrius dubius jerdoni* Legge, 1880 (Charadriidae: Charadriformes) from Tamil Nadu, India

H. Byju [1], Yoganathan Natarajan [2], N. Raveendran [3] & R. Kishore [4]

[1] Centre of Advanced Study in Marine Biology, Annamalai University, Parangipettai, Tamil Nadu 608502, India.
[2] 45 Kangeyam Road, Kodumudi, Tamil Nadu 638151, India.
[3] Iragukal Amritha Nature Trust, 61, Ramachandra Thadaga Street, Thirumangalam, Madurai, Tamil Nadu 625706, India.
[4] Sálim Ali Centre for Ornithology and Natural History, Anaikatty, Coimbatore, Tamil Nadu 641108, India.
[1] byjuhi@gmail.com (corresponding author), [2] yoganathan@gmail.com, [3] Iant.ravee@gmail.com, [4] kishorewfw@gmail.com

The Little Ringed Plover *Charadrius dubius* is a widely distributed small shorebird (body mass 26–53 g) (del Hoyo et al. 1996) of the family Charadriidae. The bird has been recognized as 'Least Concern' by the IUCN Red List and is represented by three sub species, viz.: *Charadrius dubius curonicus* (Gmelin, 1789), *Charadrius dubius dubius* (Scopoli, 1786), and *Charadrius dubius jerdoni* (Leggie, 1880). *C.d. jerdoni* is a resident species in the Indian subcontinent and southeastern Asia (Kirby & Scott 2009). A literature review about the breeding sites of the Little Ringed Plover in the Indian subcontinent from available published records are from Jhelum, Kashmir (Wilson 1899), Kashmir Valley (Phillips 1946), Sindh & Lidder rivers of Kashmir (Haq et al. 2021, 2022), Khyber Pakhtunkhwa, Pakistan (Whitehead 1911), Bajura, Himachal Pradesh (Whistler 1926), Brahmaputra sandbanks (Baker 1935), Faizabad, Uttar Pradesh (Eates 1937), Gadilam river, Attur, Tamil Nadu (Krebs 1956), Kavassery, Kudallor, Chittur & Palghat, Kerala (Neelakantan 1992) and Jawai dam, Tal Chappar & Phulera, Rajasthan (Sangha 2021). In Sri Lanka, the subspecies *C.d. jerdoni* is supplemented by *C.d. curonicus* as winter visitors (Harrison 1999).

During our regular shorebird monitoring on inland wetlands, we documented a breeding account of *C.d. jerdoni* from Uppar dam, Dharapuram, Tamil Nadu (10.7789 N, 77.4215 E) (Figure 1). Till now, many shorebird species have been recorded from this area by us. The species include Little Stint *Calidris minuta*, Grey Plover *Pluvialis squatarola*, Ruddy Turnstone *Arenaria interpres*, Curlew Sandpiper *Calidris ferruginea*, Terek Sandpiper *Xenus cinereus*, and Red-necked Phalarope *Phalaropus lobatus*. The study site also supports other large wading birds including cormorants, storks, egrets, and herons. The vegetation on the fringes, including the adjacent farmlands, support many land birds as well. The main plant species include *Acacia nilotica* and *Commiphora caudata*.

The Little Ringed Plover can generally be found on river banks, tidal mudflats, estuaries, and lake edges in small numbers. The species normally avoid rough or broken terrain, forest, cultivated land or pastures, and

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Figure 1. New breeding record of *Charadrius dubius jerdoni* from Tamil Nadu, India.

Image 1. Mating of Little Ringed Plover. © Yoganathan Natarajan.

Image 2. Incubating adult with eggs. © Yoganathan Natarajan.

Image 3. Little Ringed Plover chick. © Yoganathan Natarajan.

tall or dense vegetation including vegetated margins of inland waters (Cramp & Simmons 1983). During the breeding season, the Little Ringed Plovers show a preference for bare or sparsely vegetated sandy and pebbly shores of shallow standing freshwater pools, river islands, lakes or slow-flowing rivers, dry and stony riverbeds, and dune slacks (Johnsgard 1981; Cramp & Simmons 1983; del Hoyo et al. 1996; Grimmett et al. 1998).

The mating of the Little Ringed Plover (Image 1) was recorded from Uppar dam, Dharapuram, Tamil Nadu on 23 February 2022. The sexes are alike, but the male is a little larger than the female. On 17 October 2022, during our routine survey of birds in the area, after the brief wet period, we observed few plovers moved away as we approached them, except for one that continued sitting on the ground. We gently moved towards the bird after observing it for some time and found a nest with three eggs in it (Image 2). The dull-coloured eggs with black spots were small and shaped like peg tops. As we approached the nest, the bird moved away from the nesting area for a few minutes and came back to the nest. As we gradually moved away from the nesting area, the female started incubating the eggs again. We further observed that it preferred foraging in between and reached the water nearby, bathed and wet the eggs with its abdominal wet feathers, as if to cool the eggs or to maintain temperature. This was replicated several times on a sunny day. Though our study was not designed mainly to observe nest attendance, casual observations revealed that the female incubated while the male stood guard nearby. Whenever the female left for foraging, the male incubated the eggs. The nest we observed was a shallow scrape in the soil near the water. We also observed that due to continuous flight and roaming around wet soil, the tiny feathers over the abdomen portion about to fall were used as insulating material for the nest. When it causes depression with its abdomen on the moist soil of the bank, feathers of the nesting bird are shed inside the nest pit and become cushioning and insulating material for the eggs.

During breeding plumage, the Little Ringed Plover has a yellow circle that is visible around its eyes. The black ring around the neck becomes thicker. *C.d. jerdoni* can be differentiated from the other two subspecies by having an extensive white patch on the forehead and black on the forecrown. Also, a broader orbital ring (yolk-yellow) and pinkish-red (not yellow) are noted on the lower mandible (Hayman et al. 2011). As we observed the adults incubating, we confirmed the breeding record of the sub species. On 22 November2022, we further recorded the chicks from the same pair at the study site (Image 3). Furthermore, we observed that grasshoppers and worms were fed to the small chicks on hatching and parents attended and escorted the chicks till the second to third weeks.

The breeding record of the Little Ringed Plover *C.d. jerdoni* from Uppar dam, Dharapuram, Tamil Nadu is extremely significant as this inland wetland serves as a breeding ground for many shorebirds. Even though this area is not a protected area, it serves as an important habitat for many threatened waterbirds, during migration. Besides having rich bird diversity, the area is witnessing many changes as many landowners are converting barren land for real estate purposes leading to habitat destruction for birds and other small mammalian species like Madras Hedgehog *Paraechinus nudiventris*. Poaching of small mammals is also observed in this area. Additionally, these breeding species have varied breeding seasons with limited breeding ranges from different regions of the Indian subcontinent. As the habitat changes are happening at a rapid pace throughout the country due to various economic reasons, this breeding record further underlines the need for wide-ranging wetland surveys throughout peninsular India, to acquire more knowledge on the Little Ringed Plover nesting sites and the need for further conservation.

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