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**Caption: *Calomera lacrymosa* (Mindanao, Zamboanga). © A. Alexander Anichtchenko**

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# Diversity and distribution of snakes in Trashigang Territorial Forest Division, eastern Bhutan

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**Abstract:** This paper presents the results of a study conducted on the species composition of serpent fauna in Trashigang Territorial Forest Division (TTFD), Bhutan. The survey was conducted from August 2019 to September 2020. The study aimed to assess the diversity, conservation threats, and distribution of both venomous and non-venomous snakes in different habitat types using time constrained visual encounter survey technique. A total of 34 species of snakes belonging to five families and 23 genera were recorded. Of the total observed species, nine were identified as venomous species. These include four species of Elapidae, four species of Viperidae, and one Colubridae. Geographically, snakes occurred throughout the landscapes, although species composition and their geographical distribution differed notably amongst various localities. We documented survival threats to local snakes where deliberate killing and road mortality were found to be the most common cause of death. The increasing trend of diversity, species richness, and relative abundance of serpent fauna was noticed as the radial distance increased from urban residential areas towards less disturbed landscapes such as rural agricultural land and natural forests indicating that the habitat mosaic plays an important role in the structure and composition of the snake community. Considering the limited information currently available on diversity and geographical distribution of the serpent fauna of the region, the present study can be considered very significant.

**Keywords**: Elevation, relative abundance, serpent fauna, species richness, venomous snakes.

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For **Author details** and **Author contribution** see end of this article.

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## INTRODUCTION

Globally, living snakes (Reptilia: Squamata: Serpentes) as of December 2020 comprise of 3,889 recognized species belonging to 30 families distributed amongst 531 genera (Uetz et al. 2020). In southern Asia, India alone is abode to 310 species of snakes belonging to 16 families (Uetz et al. 2020), and 256 species distributed amongst 18 families and 73 genera are known to occur in China (Wang et al. 2020).

Until quite recently, in Bhutan, there has remained a long gap in the knowledge of serpent fauna, although many herpetological explorations already had gathered momentum in neighboring states of India. For example, in the year 1908, Wall (1909) examined 48 different species of snakes, which include a large part of his own collection and a few specimens he referred belonged to Darjeeling Museum and St. Joseph's College. The type locality of his collection comes from Darjeeling District, Indian state of West Bengal, which shares similar topographic complexity and climatic conditions of Himalayan region. The earliest record of serpent fauna of Bhutan that is within its political boundary, however, dates back to mid 1960s when a juvenile specimen of the King Cobra *Ophiophagus hannah* (Cantor, 1836) and Buff-striped Keelback *Amphiesma stolatum* (Linnaeus, 1758) were recorded in 1966 from Trashigang and Samdrup Jongkhar districts, respectively (Biswas 1976). After five years, a few more specimens of Bhutanese serpents were collected in an expedition by the Natural history Museum Basel in 1972, where 11 species of snakes belonging to four families were added as new country records for Bhutan (Bauer & Günther 1992). Since then, Bhutan had remained a herpetological terra incognita until 2000s, except for a few exclusive studies by Bustard (1979, 1980a,b) on the status of crocodiles in Bhutan.

Subsequent herpetological studies in Bhutan include Das & Palden (2000), Mitra (2009), Wangyal & Tenzin (2009), Wangyal (2011, 2012, 2013), and Mitra et al. (2012). These studies conducted at different times and spaces altogether resulted in up-to-date checklist of 49 species of snakes found in Bhutan. Koirala et al. (2016) reported 17 species of snakes from Jigme Dorji National Park, western Bhutan, but without any new country record. Das et al. (2016) in the Royal Manas national Park recorded 10 species of snakes, of which *Boiga siamensis* Nutaphand, 1971 was reported as new record for Bhutan. Subsequently, Wangyal & Gurung (2017) summarized all earlier herpetological reports and added new distribution information that raised the number to 67 species. The recent report of Assamese Cat Snake *Boiga quincunciata* (Wall, 1908) by Chaida et al. (2020), and addition of 15 new records by Wangyal et al. (2020) increased the snake checklist of Bhutan to 85 recognized species.

Snakes are of great conservation and ecological value (Mullin & Seigel 2009), and associated population declines has been suggested to have negative implications for the ecosystems in which snakes play significant roles (Reading et al. 2010). Despite snakes having occupied an important place in ecology and ethnozoology, venomous snakes in particular, also command medical attention owing to the propensity of their retaliatory bites on people and the ensuing medical emergencies. It is important, therefore, to be able to recognize local venomous snakes. Snakes are poorly studied in Bhutan and substantial proportion of prior studies on snakes in Bhutan exclude vital information on type locality, abundance, and classification based on their medical importance. The baseline information obtained from this current study would assist relevant authorities, conservationists, and Trashigang Territorial Forest Division (TTFD) to develop and implement conservation action plan so that species of concern and their critical habitats are protected. The aim of this study was to document the diversity, richness, distribution, and also to explore the venomous and non-venomous snakes in TTFD.

## MATERIALS AND METHODS

### Study site

Tashigang Territorial Forest Division (Figure 1) is located at 27.366 to 27.483 latitude and 91.366 to 92.116 longitude. It encompasses two districts (Tashigang and Trashiyantse) of eastern Bhutan and it shares its administrative border with Mongar and Pemagatshel, and towards the north and east it borders with India. Geographically the division covers an area of 2447.40km$^2$. The division spreads over 20 geogs (geog = sub-district) covering over 10,000 households under two districts. Majority of the people in these two districts sustain and generate their income through agricultural practices and depend heavily on natural resources.

Monsoons occur from May to September and annual rainfall ranges from 1,000mm to 2,000mm. The altitude ranges from 476–4,382m. The tropical and subtropical zone of the study area experience a hot summer with moderate rainfall, whereas in the warm temperate and cool temperate zones at higher altitudes, the climatic conditions are characterized by warm summers and cold winters.

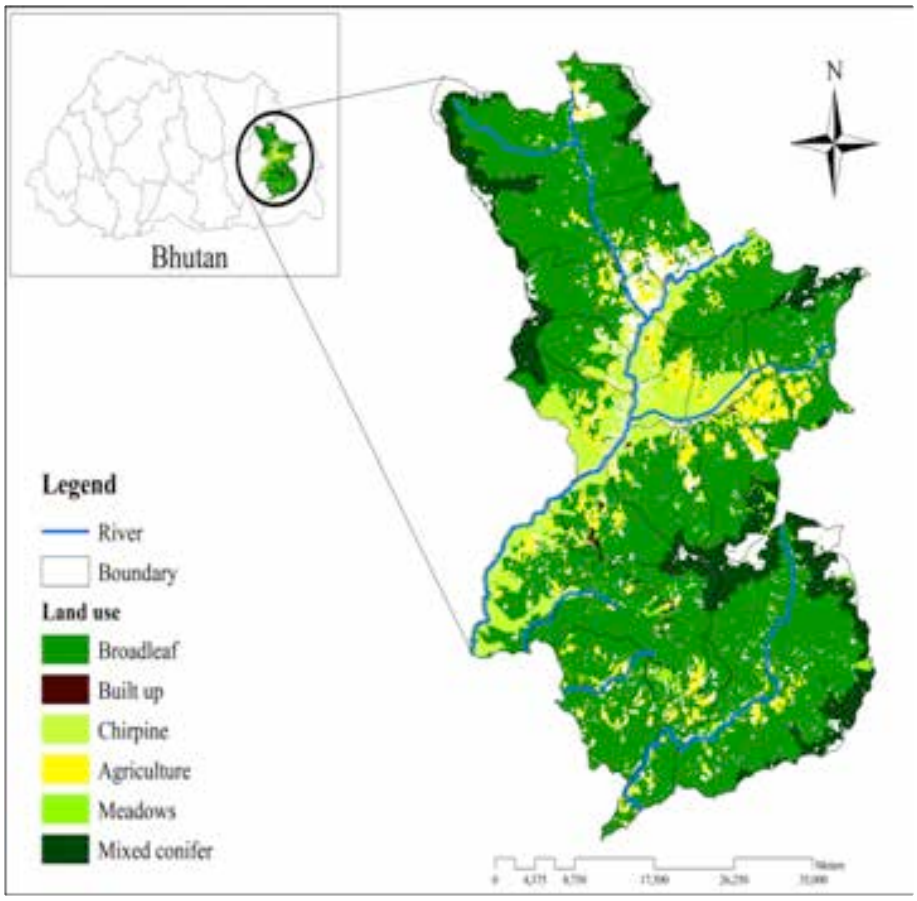


**Figure 1. Land use map of study site: Trashigang Territorial Forest Division.**

About 79 % and 70% of the total area of Trashigang and Trashiyangtse respectively is under forest cover (FRMD 2017). The corresponding vegetation types across the landscape are characterized by tropical and sub-tropical forests, warm and cool broadleaved forests, mixed conifer, and alpine meadows that harbour rich repositories of biodiversity. Drangmechuu River, one of the major rivers of Bhutan, with its tributaries spread across the landscape, flows through mountainous terrains towards south-west, and finally enters Mongar District. Scrub vegetation, sub-tropical forest belt, and rock outcrops are prominent geophysical features found along the rivers, which provides ideal habitats for various snake species.

## Methods

Taking into account the rugged terrain with steep slopes and vast elevation range of the study area, the sites were surveyed by following time constrained visual encounter method (Heyer et al. 1994; Rödel & Ernest 2004) along with active search covering all potential habitats in TTFD from August 2019 to September 2020. Agricultural lands, open forest, grass lands, roads, and river banks were searched using the standard visual encounter surveys (VES) method with three hours' time constrained (Doan 2003) by three observers in each survey bout. Areas accessible by roads were surveyed using a motor vehicle travelling at 10 to 20 km/h. Standardized road searches were conducted at 18.00–21.00 h thrice a month, covering all potential areas with the clearest ground visibility. In total, 120 man-hours were spent to cover the entire study area searching for nocturnal species.

Locality data along with habitat parameters were collected for all individual specimens encountered, irrespective of them being alive or dead. Wherever possible, the digital photographs were taken for specimens using Nikon COOLPIX P900 (83x optical zoom) digital camera, elevation and geo- location of each individual sighted was recorded using a GPS (global positioning system) Garmin eTrex. Species were identified using standard field guide books Daniel (2002), Vasudevan & Sondhi (2010), Ahmed et al. (2009), Whitaker & Captain (2004), and Das (2002, 2015).

## RESULTS

### Diversity

In total, 96-day field trips or 1,152 man-hours were spent searching for snakes in TTFD, of which 120 man-hours covering a total distance of 400km were dedicated to standardized road survey at night searching for nocturnal snakes.

A total of 34 species of snakes belonging to five families and 23 genera were recorded in different habitats and around the human habitations of TTFD (Table 1). The observations include eight singletons (species with only one observation) and five doubletons (species with two observations). Recorded families were Colubridae, Elapidae, Viperidae, Pareidae, and Typhlopidae. During the present survey, three species of snakes could not be confirmed at species level, hence conferred to closely related species (e.g., *Amphiesma* sp., *Trachischium* cf. *fuscum,* and *Trimeresurus* cf. *salazar*).

A total of 217 sightings were obtained during the entire study period. The family Colubridae was found to be the most diverse in terms of species richness, generic richness and abundance. The family Colubridae accounted for 14 genera and 24 species, followed by the Elapidae (four genera, four species). The third most speciose family was Viperidae (three genera, four species), and Paeridae & Typhlopidae were found to be the least diverse families, each being represented by one genus with a single species (Figure 2).

Of the total observed species, nine were identified as venomous. These include four species of elapids, viz., King Cobra *Ophiophagus hannah* (Cantor, 1836), Monocled Cobra *Naja kaouthia* (Lesson, 1831), MacClelland's Coral Snake *Sinomicrurus macclellandi* (Reinhardt, 1844), and Greater Black Krait *Bungarus niger* (Wall, 1908), four species of viperids, viz., Jerdon's Pitviper *Protobothrops jerdonii* (Günther, 1875), Kaulbacki's Pitviper *Protobothrops kaulbacki* (Smith, 1940), Mountain Pitviper *Ovophis monticola* (Günther, 1864), and Salazar's Pitviper *Trimeresurus* cf. *salazar* Mirza, Bhosale, Phansalkar, Sawant, Gowande & Patel, 2020, one species of dangerously venomous rear-fanged colubrid, viz., Red-necked Keelback *Rhabdophis subminiatus* (Schlegel, 1837).

### Relative abundance

A total of 217 sightings were recorded during the entire study period. Relative abundance data indicated that snakes belonging to Colubridae were found to be the most common (n=143, 65.89%), followed by Elapidae (n=53, 24.42%), Viperide (n=16, 7.37%), Pareidae (n=3, 1.38%), and species belonging to Typhlopidae were observed as least common (n=2, 0.92%) of the total individuals recorded (Figure 3). Colubrids were most dominant in the data because of their high richness and comprised 70.58% of total species recorded.

At species level, the abundance of snakes varied from 1–24 sightings. Analyses of species composition and relative abundance revealed that *N. kaouthia* (Image 1) was the most frequently encountered species with 24 sightings and made up 11.05% of the snake community at Trashigang Forest Division. This was followed by *O. hannah* (Image 2) with 18 sightings contributing 8.29%, *Orthriophis cantoris* (Boulenger, 1894) and *Pseudoxenodon macrops* (Blyth, 1855) (Image 3) with 14 individuals contributing 6.45% each. Other 17 commonly encountered species, altogether contributed 59.44%. Five doubletons species together accounted 4.60%, and remaining eight singletons species, viz., *Amphiesma* sp., *Hebius parallelum* (Boulenger, 1890), *Dendrelaphis proarchos* (Wall, 1909), *Dendrelaphis cyanochloris* (Wall, 1921), *Lycodon septentrionalis* (Günther,1875),

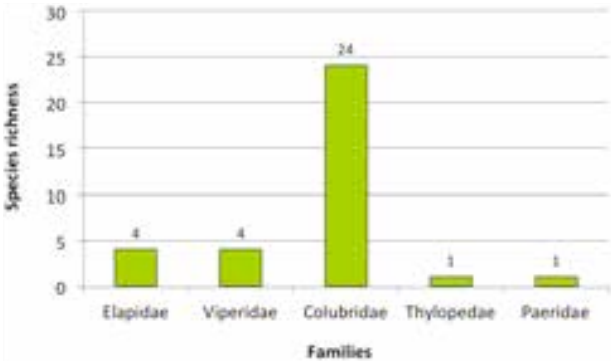


Figure 2. Species richness of snakes with respect to families recorded during the study period in TTFD.

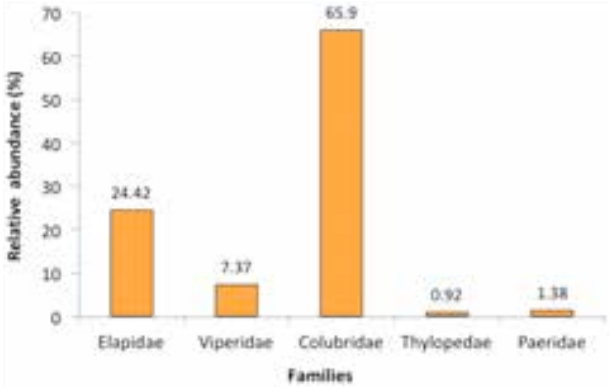


Figure 3. Relative abundance of snakes with respect to families in TTFD.

**Table 1. List of snake species documented in TTFD during August 2019–September 2020.**

| Families | Scientific name | Common name | IUCN status |
|---|---|---|---|
| Elapidae | *Bungarus niger* | Greater Black Krait | Not assessed |
| | *Naja kaouthia* | Monocled Cobra | Least Concern |
| | *Ophiphagus hannah* | King Cobra | Vulnerable |
| | *Sinomicrurus macclellandi* | Macclellandi's Coral Snake | Not assessed |
| Viperidae | *Ovophis monticola* | Mountain Pit Viper | Least Concern |
| | *Protobothrops jerdonii* | Jerdon's Pit Viper | Least Concern |
| | *Protobothrops kaulbacki* | *Kaulback's* Lance-headed Pit Viper | Data Deficient |
| | *Trimeresurus* cf. *salazar* | | |
| Colubridae | *Ahaetulla prasina* | Short-nosed Vine Snake | Least Concern |
| | *Amphiesma* sp. | | |
| | *Amphiesma platyceps* | Himalayan Keelback | Not assessed |
| | *Boiga ochracea* | Tawny Cat Snake | Not assessed |
| | *Boiga multifasciata* | Many-banded Cat Snake | Data Deficient |
| | *Coelognathus radiatus* | Copper-headed Trinket | Least Concern |
| | *Dendrelaphis proarchos* | Assam Bronzeback | Not assessed |
| | *Dendrelaphis cyanochloris* | Wall's Bronzeback | Least Concern |
| | *Hebius parallelum* | Yunnan Keelback | Not assessed |
| | *Lycodon septentrionalis* | Large-toothed Wolf Snake | Not assessed |
| | *Lycodon gammiei* | Gammiei's Wolf Snake | Not assessed |
| | *Oligodon albocinctus* | White-barred Kukri Snake | Not assessed |
| | *Oligodon taeniolatus* | Streaked Kukri Snake | Least Concern |
| | *Oreocryptophis porphyraceus* | Black-banded Trinket | Not assessed |
| | *Orthriophis cantoris* | Eastern Trinket | Not assessed |
| | *Pseudoxenodon macrops* | Large-eye False Cobra | Least Concern |
| | *Ptyas korros* | Indo-Chinese Rat Snake | Not assessed |
| | *Ptyas mocosa* | Indian Rat Snake | Not assessed |
| | *Ptyas nigromarginata* | Green Rat Snake | Not assessed |
| | *Rhadobphis himalayanus* | Orange-collared Keelback | Not assessed |
| | *Rhadobphis subminiatus* | Red-necked Keelback | Least Concern |
| | *Sibynophis collaris* | Collared Black Headed Snake | Least Concern |
| | *Trachischium tenuiceps* | Oriental Worm-eating Snake | Not assessed |
| | *Trachischium* cf. *fuscum* | | |
| Pareidae | *Pareas monticola* | Slug-eating Snake | Not assessed |
| Typhlopidae | *Indotyphlops braminus* | Common Blind Snake | Not assessed |

*Lycodon gammiei* (Blanford, 1878), *Ptyas mucosa* (Linnaeus, 1758), and *Rhabdophis subminiatus* were least common and collectively contributed to only 3.68% of the total abundance.

## Distribution

Geographically, snakes in study area occurred throughout the landscape up to 2,300m (Figure 4), although species composition and their geographical distribution differed notably amongst various localities (Figure 5). The study showed that snakes are sparsely distributed towards the higher elevation, however majority of them demonstrated uniform distribution pattern along the river valleys particularly below 1,800m. Among the observed snakes, species such as *O. hannah*, *S. collaris*, *N. kaouthia*, *O. albocinctus* (Image 4), *O. monticola*, *O. porphyraceus*, *A. prasina*, *P. korros* (Image 5), *Boiga ochracea* (Image 6), *O. cantoris*, and

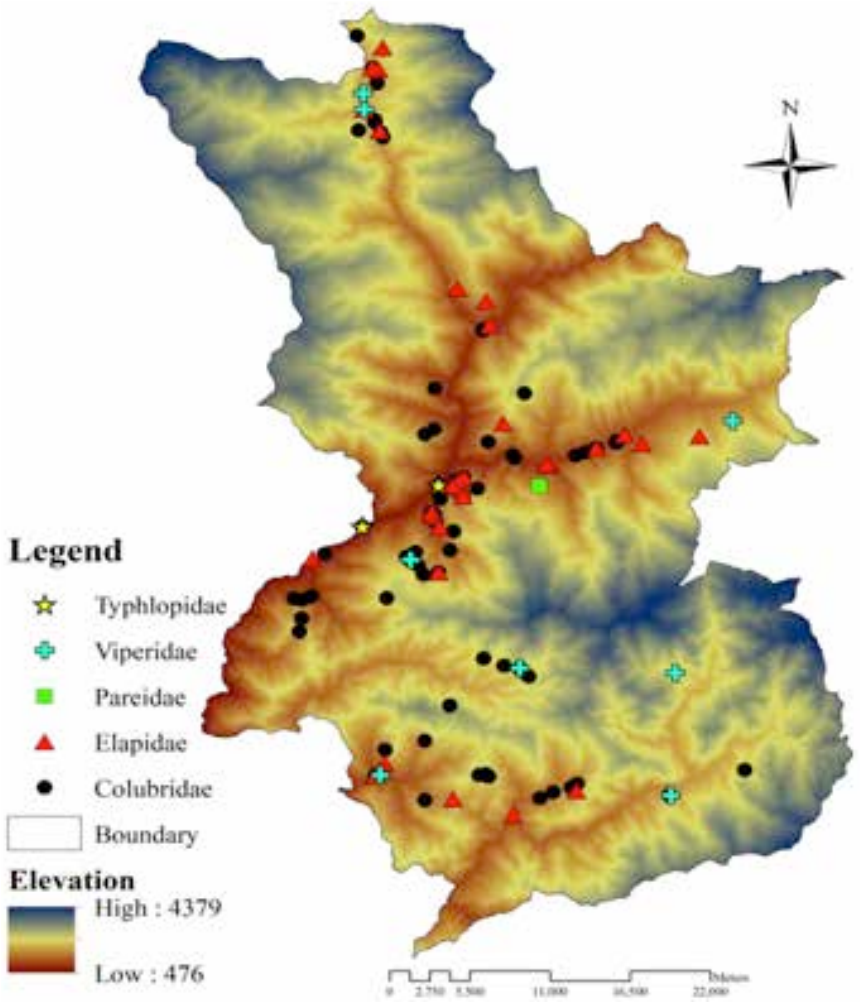


**Figure 4. Distribution of snakes along the elevation gradients in Trasigang Territorial Forest Division.**

*T. tenuiceps* were most widely sighted species across the landscape. Whereas, *P. kaulbacki*, *Trimeresurus* cf. *salazar*, *A. platyceps*, *Amphiesma* sp., *D. cyanochloris*, *L. gammiei*, *Trachischium* cf. *fuscum* (Image 7), and *P. mucosa* were recorded from a few specific localities. Range extension of these species, however, is not limited to present study locations because the type locality of observed species, shares similar climatic conditions and bio-geographic elements of eastern Himalayan locations from where most of the snakes in Bhutan have been reported.

The geo-physical features and biogeographic elements within the study area and adjoining landscapes are mainly forged by two major rivers. These rivers originate from China and flow through mountainous landscape of eastern Bhutan before entering the Indian state of Assam; Kurichu River flows through mountainous terrains of adjoining district of Mongar and meets with the Drangmechu River about 70km south-west of Trashigang. These two major rivers, with their tributaries create continuous stretch of biologically rich valleys across the landscape of eastern Bhutan. These climatically suitable warm valleys with habitat mosaic presumably support more ophidian faunal diversity and distribution than already recorded in the present study.

**Threats and conservation issues**

Among the total sightings (n=140 specimens; 64.51%) were recorded live and (n=77 specimens; 35.48%) were found dead. After close examination of all dead specimens, cause of deaths was estimated to be of anthropogenic origin, including road mortality and direct persecution. Virtually all kinds of snakes were killed instantly in first encounter, the most frequently killed species were *B. niger*, *N. kaouthia*, *O. hannah*, *A. prasina* (Image 8), *C. radiatus*, *P. korros*, *O. cantoris*, and *O. monticola*. We observed a few cases of human-caused death of forest dwelling species, although most of the dead snakes were recorded from rural agricultural lands and in close proximity to urban residential areas.

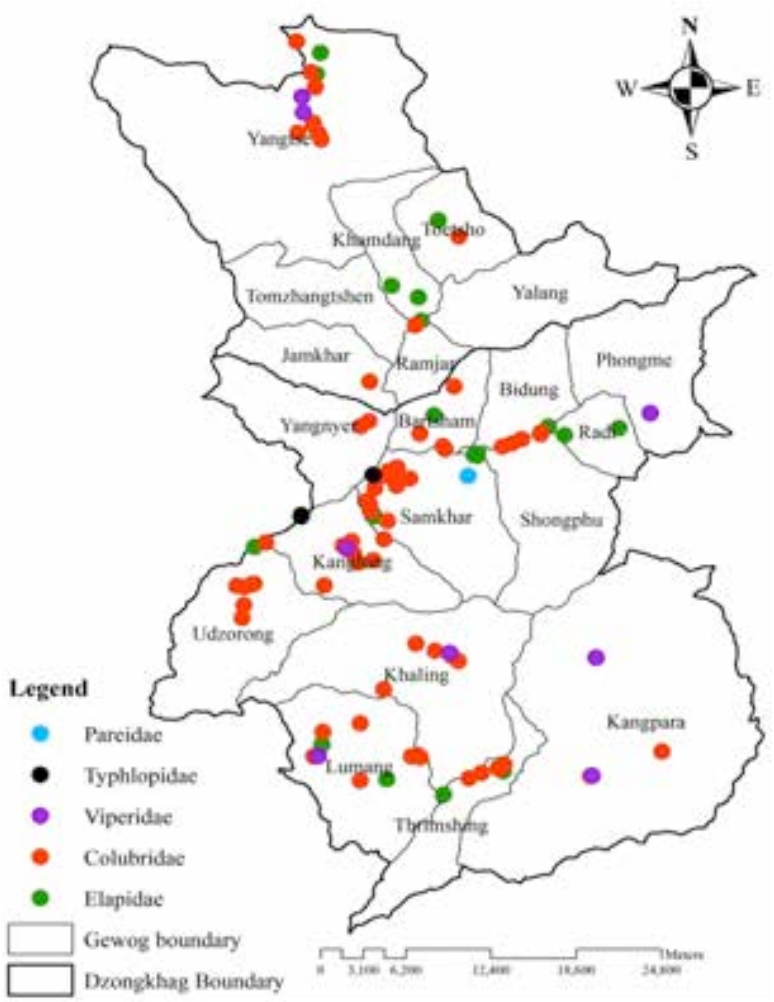


**Figure 5. Spatial distribution of snakes in TTFD. Circular coloured dots indicate the geo-locations where snakes were sighted.**

Species such as *O. hannah*, *P. korros*, *C. radiatus*, and *O. cantoris* were found to be most vulnerable to human killing as 33–60 % of total sightings encountered were recorded dead, wherein the cause of mortality was identified to be direct human persecution.

## DISCUSSION

Straddling the two major Indo-Malayan and Palaearctic biogeographic realms, Bhutan, a part of eastern Himalaya, is one of the biologically richest areas on earth and encompasses an incredible wealth of biodiversity. TTFD is one of the important conservation areas in eastern Himalaya which encompasses a wide range of habitats from sub-tropical to alpine ecosystems of Bhutan. Considering the limited information currently available on diversity, distribution and natural history of the serpent fauna of the region, the present study can be considered very significant.

As per IUCN Red List Category, 10 species belong to LC (Least Concern) category, two species DD (Data Deficient), one species VU (Vulnerable), 18 are not assessed, and three species could not be identified at species level thus its status is excluded. This indicates that for about 59% of the species there are not sufficient data available for evaluating their conservation status in this region.

Serpent fauna of Bhutan as of April 2020 was represented by 70 recognized species (Chaida et al.2020), and new records of 15 additional species by Wangyal et al. (2020) elevate the number of snakes species in Bhutan to 85. The number of snake species found in this research represented 40.47% of all snake species found in Bhutan. Of the eight families and 33 genera of snake fauna found in the country, five families and 23 genera were recorded in TTFD. This implies that TTFD is an important repository for serpent fauna conservation.

Three species of venomous snakes, viz., *O. hannah*,

**Table 2. Locality records of Snakes in Trashigang Forest Division. Localities data indicate geogs (geog = sub-district) within Trashigang Forest Division where species were sighted.**

| Species name | Localities | Latitude (°N) | Longitude (°E) | Altitude (m) |
|---|---|---|---|---|
| *Ophiophugus hannah* | Thrimshing | 27.111 | 91.590 | 650–2,057 |
| | Barsam | 27.373 | 91.587 | |
| | Radi | 27.363 | 91.723 | |
| | Samkhar | 27.325 | 91.558 | |
| | Kanglung | 27.283 | 91.522 | |
| | Lumang | 27.138 | 91.495 | |
| | Yangte | 27.612 | 91.499 | |
| *Naja kaouthia* | Samkhar | 27.331 | 91.552 | 670–1,471 |
| | Shongphu | 27.359 | 91.644 | |
| | Toetsho | 27.481 | 91.605 | |
| | Khamdang | 27.436 | 91.574 | |
| | Thrimshing | 27.122 | 91.609 | |
| | Udzorong | 27.258 | 91.451 | |
| *Bugarus niger* | Lumang | 27.147 | 91.501 | 700–1,400 |
| | Shongphu | 27.358 | 91.683 | |
| | Khamdang | 27.455 | 91.576 | |
| | Samkhar | 27.330 | 91.556 | |
| *Sinomicrurus macclellandi* | Lumang | 27.122 | 91.548 | 1,300–1,400 |
| | Thrimshing | 27.127 | 91.634 | |
| *Ovophis monticola* | Khaling | 27.209 | 91.596 | 1,700–2,300 |
| | Yangtse | 27.595 | 91.493 | |
| | Udzorong | 27.235 | 91.444 | |
| | Phogmey | 27.443 | 91.798 | |
| | Kanglung | 27.282 | 91.521 | |
| *Protobothrops kaulbacki* | Kangpara | 27.123 | 91.699 | 1,642 |
| *Protobothrops jerdonii* | Khaling | 27.205 | 91.703 | 1,800–2,000 |
| | Yangtse | 27.634 | 91.490 | |
| *Trimeresurus* cf. *salazar* | Lumang | 27.138 | 91.496 | 995 |
| *Ahaetulla prasina* | Samkhar | 27.335 | 91.555 | 700–1,300 |
| | Shongphu | 27.360 | 91.665 | |
| | Khamdang | 27.436 | 91.574 | |
| | Udzorong | 27.258 | 91.451 | |
| *Amphiesma platyceps* | Yangtse | 27.565 | 91.506 | 1,805 |
| *Amphiesma* sp. | Yangtse | 27.570 | 91.489 | 1,800 |
| *Boiga ochracea* | Jamkhar | 27.397 | 91.540 | 800–1,834 |
| | Yangyeer | 27.366 | 91.533 | |
| | Samkhar | 27.332 | 91.541 | |
| | Lumang | 27.138 | 91.495 | |
| | Yangtse | 27.603 | 91.493 | |
| *Boiga multifasciata* | Yangtse | 27.612 | 91.499 | 1,400–1,821 |
| | Kanglung | 27.274 | 91.541 | |
| *Coelognathus radiatus* | Samkhar | 27.333 | 91.556 | 800–1,300 |
| | Udzorong | 27.258 | 91.451 | |
| | Shongphu | 27.360 | 91.665 | |
| *Dendrelaphis proarchus* | Samkhar | 27.337 | 91.559 | 1,000–1,200 |
| | Udzorong | 27.244 | 91.445 | |
| *Dendrelaphis cyanochloris* | Bartsham | 27.361 | 91.576 | 1,400 |
| *Hebius parallelum* | Yangtse | 27.633 | 91.489 | 1,890 |

| Species name | Localities | Latitude (°N) | Longitude (°E) | Altitude (m) |
|---|---|---|---|---|
| *Lycodon septentrionalis* | Kanglung | 27.273 | 91.537 | 1,700–1,900 |
| | Yangtse | 27.585 | 91.494 | |
| *Lycodon gammiei* | Khaling | 27.585 | 91.494 | 2,100 |
| *Oligodon albocinctus* | Kangpara | 27.207 | 91.597 | 700–1,821 |
| | Kanglung | 27.139 | 91.751 | |
| | Khamgang | 27.273 | 91.537 | |
| | Samkhar | 27.436 | 91.574 | |
| | Yangtse | 27.351 | 91.593 | |
| *Oligodon taeniolatus* | Khamdang | 27.576 | 91.501 | 750–1,800 |
| | Yangtse | 27.436 | 91.574 | |
| | Yangtse | 27.612 | 91.499 | |
| *Oreocryptophis porphyraceus* | Kanglung | 27.612 | 91.499 | 1,200–1,800 |
| | Thrishing | 27.282 | 91.522 | |
| | Udzorong | 27.131 | 91.635 | |
| | Yangtse | 27.259 | 91.453 | |
| | Lumang | 27.576 | 91.501 | |
| *Orthriophis cantoris* | Lumang | 27.138 | 91.576 | 1,300–2,205 |
| | Phogmey | 27.138 | 91.576 | |
| | Samkhar | 27.443 | 91.798 | |
| | Udzorong | 27.329 | 91.568 | |
| *Pseudoxenodon macrops* | Khaling | 27.244 | 91.445 | 1,800–2,100 |
| | Kanglung | 27.209 | 91.596 | |
| | Lumang | 27.272 | 91.530 | |
| *Ptyas korros* | Udzorong | 27.138 | 91.572 | 750–1,800 |
| | Samkhar | 27.258 | 91.451 | |
| | Kanglung | 27.314 | 91.537 | |
| | Shongphu | 27.283 | 91.522 | |
| *Ptyas mocosa* | Udzorong | 27.359 | 91.665 | 2,000 |
| *Ptyas nigromarginata* | Kanglung | 27.235 | 91.444 | 1,400–2,300 |
| | Yangtse | 27.287 | 91.525 | |
| | Khaling | 27.577 | 91.501 | |
| | Lumang | 27.211 | 91.585 | |
| *Rhadobphis himalayanus* | Lumang | 27.121 | 91.529 | 1,500–1,700 |
| | Kanglung | 27.126 | 91.618 | |
| *Rhadobphis subminiatus* | Thrimshing | 27.278 | 91.527 | 1,600 |
| *Sibynophis collaris* | Thrimshing | 27.129 | 91.630 | 650–1,870 |
| | Samkhar | 27.128 | 91.631 | |
| | Kanglung | 27.312 | 91.538 | |
| | Yangtse | 27.283 | 91.522 | |
| *Trachischium tenuiceps* | Khaling | 27.602 | 91.503 | 900–2,300 |
| | Shongphu | 27.209 | 91.596 | |
| | Yangtse | 27.356 | 91.651 | |
| | Kanglung | 27.576 | 91.501 | |
| *Trachischium* cf. *fuscum* | Lumang | 27.283 | 91.522 | 1,800–2,300 |
| *Pareas monticola* | Samkhar | 27.131 | 91.567 | 1,200–1,400 |
| | Lumang | 27.331 | 91.611 | |
| *Indotyphlops braminus* | Samkhar | 27.100 | 91.466 | 700–900 |


Image 1. *Naja kaouthia*

Image 2. *Ophiphagus hannah*


Image 3. *Pseudoxenodon macrops*


Image 4. *Oligodon albocinctus*

Image 5. *Ptyas korros*

Image 6. *Boiga ochracea*

*O. monticola* (Image 9), and *N. kaouthia*, were previously reported by Biswas (1976) and Mitra (2009) from Trashigang District, which are also recorded in present study. Nonetheless, our records of five more species of venomous snakes, viz., *P. jerdonii* (Image 10), *P. kaulbacki* (Image 11), *Trimeresurus* cf. *salazar* (Image 12), B. niger (Image 13), and *S. macclellandi* (Image 14) are recorded for the first time from TTFD. This population was previously called as *T. albolabris* till the species *Trimeresurus salazar* got described (Mirza et al. 2020). Discovery of higher diversity of venomous snakes which is more than (52%) of total venomous snakes found in Bhutan warrants better medical attention to this problem.

Our records of 10 additional species, viz., *Pareas monticola* (Cantor, 1839) (Image 15) *Trachischium* cf. *fuscum* (Blyth, 1854), *P. kaulbacki, D. cyanochloris*, *D. proarchos* (see Vogel & van Rooijen 2007, 2011), (Image 16), *P. mucosa*, *R. subminiatus*, *L. gammiei, Indotyphlops braminus* (Daudin, 1803), and *A. platyceps* are the first records of these species for TTFD. Although Mitra (2009) mentioned two species of Kukri snakes viz., *Oligodon juglandifer* (Wall, 1909) and *Oligodon cyclurus* (Cantor, 1939), and *Boiga multifasciata* (Blyth, 1861) (Image 17) from present area but we did not detect former two species in this present study but later were found around 78km away from the previously recorded locality. Our records of *Trachischium tenuiceps* (Blyth, 1854) (Image 18), *L. septentrionalis*, *Oreocryptophis porphyraceus* (Cantor, 1839) (Image 19), and *Boiga ochracea* (Theobald, 1868) extends the distribution range of these species by 74km from the previously recorded locality, Kanglung, Trashigang District (Mitra 2009) to Yangtse, Trashigangtse District in the north. The occurrence of *L. gammiei* and D. cyanochloris in Bhutan (Wangyal, 2014) was reported without locality data. We, however, confirmed the presence of these two species from TTFD based on dead specimens recorded from Khaling and Bartsham, respectively. We could not find Pope's Pitviper Trimeresurus popeiorum (Smith, 1937) in TTFD. Our record of *T. popeiorum* (Image 20) from adjoining locality (Pemagatshel District), however, suggests that the species probably also occurs in TTFD.

Information on habitats used by snakes can be an important tool for conservation efforts (Seigel & Mullin 2009). Our study revealed that snakes in Bhutan use a wide variety of habitats which forest habitat, grasslands, rural agricultural farm land, and urban residential areas. Modifications in each landscape showed different levels of disturbance. The study showed that as the distance from residential area increased, the abundance, richness, and diversity of snakes also increased. This result concurred with similar phenomenon reported by Janiawati et al. (2015). The monotonic increase in richness and diversity of snakes with the increase in redial distance from urban residential area could be due to majority of snakes responding to disturbance levels, availability of resources, vegetation cover, varied habitats, and increased space. A more varied habitat can accommodate more species because more resources can be utilized (Janiawati et al. 2015). Reptiles use vegetation cover to protect themselves from environmental changes or predators (Botejue & Wattavidanage 2012). Highly modified landscapes contain few remnant vegetation (McIntyre & Hobbs 1999), thus provide limited resources. In contrary, increased abundance of some of the Elapid species, viz., *N. kaouthia* and *B. niger* in urban residential area could be due to availability of preferred microhabitat and their ability to withstand high degree of environmental changes resulted from landscape modifications.

Overall, these data suggest that species richness and diversity in of TTFD is relatively high, and that small geographic localities can sustain a large number and diverse group of snakes species. We suggest more comprehensive surveys and intensive research, particularly in ecologically vulnerable areas containing high biodiversity to facilitate snake monitoring efforts, assess threats to snakes, foresee potential threats to vulnerable snake species (e.g., *O. hannah*), better understand the distribution and ecology of medically significant species of snakes, rare and data-deficient species, and to ultimately formulate effective conservation strategy for conservation of serpent fauna of eastern Bhutan.

Human-caused mortality of snakes was the most severe among the threats that we observed. Although there have been no records of live snakes or their parts being traded in Bhutan, there are sufficient evidences that they are killed indiscriminately because of fear of snakebite. People in Bhutan have very little knowledge about snakes; as a result, many harmless species get victimized mainly due to belief that all snakes are venomous. Road mortality and direct human persecution are primary threats to snakes in the region. Frequent forest fires may also contribute to overall snake mortality in TTFD. The recorded evidences of high mortality (35.48%) within short span of time due to human persecution highlights how precarious human-dominated landscapes are for snakes.

Historically, due to the rugged terrains, cold climatic condition, and largely inaccessible landscape,


Image 7. *Trachischium* cf. *fuscum*


Image 8. *Ahaetulla prasina*


Image 9. *Ovophis monticola*


Image 10. *Protobothrops jerdonii*


Image 11. *Protobothrops kaulbackii*


Image 12. *Trimeresurus* cf. *salazar*

biological diversity of Eastern Himalaya remained largely unexplored. Tremendous effort, however, had been made in recent decades and *frequent addition of new records in the eastern Himalayas demonstrates a serious need for further exploration in the region*. Our results are based on surveys constrained by time, and presumably do not represent actual diversity as there are still some potential areas which remained unexplored. Majority of conservation efforts in Bhutan are focused on conservation of biodiversity in protected areas, however, many areas outside protected areas are biologically rich and thus offers great opportunities to conserve at least a portion of its diversity. We hope that our findings may serve as a foundation for further studies in this and other regions of Bhutan. Furthermore, we also emphasize on more holistic, education-focused conservation strategy combined with ecological research to address the snake-human negative interaction in the region.

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Image 13. *Bungarus niger*


Image 14. *Sinomicrurus macclellandi*


Image 15. *Pareas monticola*


Image 16. *Dendrelaphis proarchos*


Image 17. *Boiga multifasciata*


Image 18. *Trachischium tenuiceps*


Image 19. *Oreocryptophis porphyraceus*


Image 20.*Trimeresurus popeiorum*

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**Author contribution:** BKK prepared the review design, proof reading and editing. SP contributed literature review, paper drafting, review, and developed GIS maps. TN contributed in the literature review collection, paper editing, and proof reading. All authors contributed in the manuscript revision.

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# Freshwater fishes of Cauvery Wildlife Sanctuary, Western Ghats of Karnataka, India

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**Abstract:** The ichthyofauna of Cauvery Wildlife Sanctuary is comprised of 58 species belonging to 18 families and 44 genera of which close to 25% are endemic to the Western Ghats region, and eight are endemic to the Cauvery River system namely, *Dawkinsia arulius*, *Dawkinsia rubrotinctus*, *Hypselobarbus dubius*, *H. micropogon*, *Kantaka brevidorsalis*, *Labeo kontius*, *Tor remadevii* and *Hemibagrus punctatus*. Eight species found in Cauvery Wildlife Sanctuary are threatened, including two (*Tor remadevii* and *Hemibagrus punctatus*) listed as 'Critically Endangered', four species (*Dawkinsia arulius*, *Hypselobarbus dubius*, *H. micropogon*, and *Silonia childreni*) as 'Endangered' and two (*Hyporhamphus xanthopterus* and *Wallago attu*) as 'Vulnerable' on the IUCN Red List.

**Keywords:** Diversity, freshwater fish, mahseer, Western Ghats.

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**Author contribution:** NS—field work, fish identification, manuscript writing, proof reading, NM—field work, proof reading, images, RR—fish identification, literature review, manuscript writing, proof reading.

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## INTRODUCTION

The Cauvery River basin (81,155km$^2$) is India's fourth largest, and also the largest river system draining the southern part of peninsular India. The Cauvery River originates from the Brahmagiri Hills of the Western Ghats mountain ranges, and flows for a distance of 770km through the states of Karnataka (41%), Tamil Nadu (56%), and Kerala (3%) (Chidambaram et al. 2018), finally draining into the Bay of Bengal. Physiographically, the river is surrounded by the Western Ghats (in the west) and Eastern Ghats mountain ranges (in the east and south) and the Tungabhadra and Pennar River systems in the north (Chidambaram et al. 2018). Cauvery is one of the few rivers in the peninsular Indian region known to receive rain from both the north-east and south-west monsoons (Raj 1941), and also the most exploited river in the country in terms of water abstraction (95%) (Chidambaram et al. 2018).

Ichthyological studies in the Cauvery dates back to Jerdon (1849) who described several species from the main course of Cauvery River as well as various tributaries including Bhavani and Kabini. Subsequently, major exploratory studies (and subsequent compilations) on either the main river, or its tributaries were undertaken by Day (1867a,b), Hora (1942), Chacko et al. (1954), Rajan (1955), Jayaram (1981), Jayaram et al. (1982), and Raghunathan (1989). Though no recent studies have been carried out to understand the fish diversity of the entire river system, available estimates suggest that anywhere between 95 (Froese & Pauly 2019) and 142 species inhabit the Cauvery River basin (Jayaram 1981; Jayaram et al. 1982). This number could even be greater given the recent taxonomic and nomenclatural changes, as well as new species descriptions from the river system during the last 10 years.

The Cauvery Wildlife Sanctuary (1027.51km$^2$) (henceforth Cauvery WS) is an IUCN category IV protected area situated in the Chamarajanagara, Mandya, and Ramnagara districts of Karnataka State. River Cauvery, on which the sanctuary is named drains the protected area, and forms the interstate boundary between Tamil Nadu and Karnataka states. Two major tributaries, Arkavathi and Shimsha also join Cauvery inside the limits of the sanctuary. Apart from its mammal and bird diversity, Cauvery WS is also known to support diverse aquatic fauna including crocodiles, otters and freshwater fish as documented by the "Management of Cauvery Wildlife Sanctuary". Of particular importance is the Mahseer (*Tor* spp.), a group of large-bodied cyprinid fishes endemic to tropical Asia, that once attracted anglers from around the world to the famous Cauvery fishing camps, managed by the Wildlife Association of South India, and Jungle Lodges and Resorts (see Pinder & Raghavan 2013; Pinder et al. 2015).

Except for information on 22 species of large mammals, 10 species of reptiles, and 41 species of birds provided in official government documents (Management of Cauvery Wildlife Sanctuary), there are no organized checklists of the biodiversity of Cauvery WS. Recently, the Indian Grey Wolf (Kaggere 2020), and the Ratel/honey badger (Gubbi et al. 2014) were also recorded from the sanctuary. Recent interest in underwater photography led to the first report of the freshwater Jellyfish *Limnocnida indica* from the Cauvery WS (N. Sreenivasan, pers. comm. 5 August 2020), extending its known range within the river system, from previous records in Coorg and the Hemavathi reservoir (Manna et al. 2005). The biodiversity status of the Cauvery WS documented in government records is however considered an underestimate as anecdotal reports document the presence of 280 species of birds inside the sanctuary (Chandra 2014). Although Cauvery WS is mentioned in a number of papers relating to freshwater fish conservation (for e.g., Pinder & Raghavan 2013, Pinder et al. 2015, 2020), there is very little information available on the diversity of freshwater fish species inhabiting this protected area. Except for a study by Shenoy et al. (2003) who observed the occurrence of 18 species of fishes within a 5km stretch of the river Cauvery inside the sanctuary between Bheemeshwari (12.305°N & 77.285°E) and Muttatthi (12.306°N & 77.311°E), there have been no attempts to understand the fish fauna of this protected area.

As part of a larger project aimed at conservation and management of freshwater fishes of Cauvery WS, especially the Hump-backed Mahseer, we carried out a rapid survey of the ichthyofauna in February 2015, followed up by opportunistic visits until the end of 2019. This contribution provides the results of these surveys in the form of a preliminary checklist of the freshwater fish fauna of Cauvery WS with notes on their threats and conservation needs.

## METHODS

Initial part of the surveys were conducted from 3–14 February 2015. Follow-up visits were undertaken during different seasons as recently as December 2019 in the stretch of the Cauvery River between Shivanasamudram falls (11.294°N & 77.169°E) and Mekedattu (12.261°N

& 77.448°E) within Cauvery WS. A rapid assessment approach (Abd et al. 2009) with minor modifications as was carried out for other sites in the Western Ghats (see Baby et al. 2010) was used to maximize efforts and minimize costs. Three types of fishing gears were used. A bottom-weighted gill net (15m X 1.7m, 1-inch mesh size) was used to capture small fish, cast nets (3m diameter, 3-inch mesh size), and rod and line (plant-based bait and lures) were used to target fish larger than 30cm SL. All sampling was conducted between 06.00hr & 18.00hr. In the post-monsoon months, fish were caught opportunistically in river-side pools, formed as the water level receded. All fish caught were photographed live and released within the shortest possible time after their capture, adhering to the permissions provided by the Karnataka State Forest Department. Family level taxonomy primarily follow Nelson et al. (2016), while species level identification was carried out following Jayaram (1999) supported by relevant updated taxonomic papers on specific genera. Species that could not be identified accurately were mentioned as 'cf.' or 'sp.'. All species names adhere to the Catalog of Fishes (Fricke et al. 2020) unless otherwise mentioned. Personal interviews and focus group discussions were carried out with staff of the Karnataka Forest Department (KFD), Jungle Lodges and Resorts Private Limited (JLR), and members of the Wildlife Association of South India (WASI) to understand threats to freshwater fishes, and related conservation issues in the study area.

## RESULTS AND DISCUSSION

Fifty-eight species of freshwater fish belonging to 18 families and 44 genera were recorded from the 37km stretch between Shivanasamudram falls and Mekedattu inside Cauvery WS (Table 1). Order Cypriniformes dominated with 30 species (51.7%) under two families (Cyprinidae and Danionidae), followed by Siluriformes with 10 species (17.2%) under six families (Table 1). Close to 25% (15 species) of the fish species that occur within the study area are endemic to the Western Ghats region, of which eight are endemic to the Cauvery River system (including Bhavani, Moyar, and Kabini tributaries). Nine species of non-native fish including those that are exotic and introduced from other biogeographic regions of the country were also recorded (Table 1). Some of the species were found only in specific areas in the Cauvery WS, *Silonia childreni* was once reported from throughout the study area but is now only restricted to the Mekedattu gorge. *Tor* spp. are found in deep pools and rapids across the study area but were observed to migrate between pools and rapids in large schools either in response to time of day (09.00–10.00 hr and 17.00–18.00 hr), or change in water level (moving to deeper pools as water recedes). *Pterygoplichthys* sp. and *Clarias gariepinus* was only noticed close to the confluence of the Arkavathi River and the Shimsha River.

Although the waters of Cauvery WS (including the stretch of the river that was the focus of the present study) is world renowned for its mahseer populations (see Pinder & Raghavan 2013; Pinder et al. 2015), there remains several knowledge gaps. The mahseer population of this river is comprised of several distinct 'morphotypes' of which, the 'blue-fin', 'orange-fin' or the 'hump-backed' (see also Pinder et al. 2015) and a 'black-fin' are the most frequently encountered. While the humbacked mahseer is now known as *Tor remadevii* (see Pinder et al. 2018), there still remains ambiguities and confusions on the identity of the various morphotypes of mahseer present in the Cauvery, including the fact whether they constitute one, or more distinct species. Studies in this direction are ongoing.

Majority of the fish species that occur in the study area are assessed as 'Least Concern' on the IUCN Red List of Threatened Species (IUCN 2020), however, eight species found in the study area are threatened including two that has been assessed as 'Critically Endangered', four as 'Endangered' and two as 'Vulnerable'. Fifteen of these species are endemic to the Western Ghats region, of these 15 species, eight have a restricted range, and occur only in the Cauvery River system.

The actual fish diversity of the Cauvery WS is no doubt higher than what has been recorded in the present study, as there are additional species mentioned in Shenoy et al. (2003) as well as those recorded by recreational anglers (identified through social media and personal photographs). Over the last 10 years, several new species have been described from the tributaries of Cauvery (*Dario neela*, *Laubuka latens*, *L. trevori*, *Ompok karunkodu*, *Pethia nigripinna*) and so there are also possibilities of several undescribed species occurring in the waters of the Cauvery WS. Only a comprehensive exploratory survey of the freshwater habitats inside the protected area in various seasons could unravel the true diversity of fishes of this protected area.

The study area has been the site of a 40-year-old fishery initiated by WASI, and later carried forward by collaboration between KFD, JLR, and WASI. Consequently, the area was awarded forest department protection under the umbrella of the Cauvery WS. As a result, many direct threats to fishes such as

**Table 1. Freshwater fishes recorded from the Cauvery Wildlife Sanctuary, Karnataka.**

| Order/Family | Species | IUCN status |
|---|---|---|
| | | |
| **Beloniformes** | | |
| Adrianichthyidae | *Oryzias carnaticus* (Jerdon, 1849) | Least Concern |
| Belonidae | *Hyporhamphus xanthopterus* (Valenciennes, 1847) | Vulnerable |
| | *Xenentodon cancila* (Hamilton, 1822) | Least Concern |
| **Cypriniformes** | | |
| Cyprinidae | *Barbodes carnaticus* (Jerdon, 1849) | Least Concern |
| | *Gibelion catla* (Hamilton, 1822) † | |
| | *Cirrhinus mrigala* (Hamilton, 1822) † | |
| | *Ctenopharyngodon idella* (Valenciennes, 1844) † | |
| | *Cyprinus carpio* Linnaeus, 1758 † | |
| | *Dawkinsia arulius* (Jerdon, 1849) CWE | Endangered |
| | *Dawkinsia rubrotinctus* (Jerdon, 1849) CWE | Status not assessed |
| | *Garra mullya* (Sykes, 1839) | Least Concern |
| | *Garra stenorhynchus* (Jerdon, 1849) WGE | Least Concern |
| | *Hypselobarbus dubius* (Day, 1867) CWE | Endangered |
| | *Hypselobarbus micropogon* (Valenciennes, 1842) CWE | Endangered |
| | *Kantaka brevidorsalis* (Day, 1873) CWE | Least Concern |
| | *Labeo dyocheilus* (McClelland, 1839) | Least Concern |
| | *Labeo kontius* (Jerdon, 1849) CWE | Least Concern |
| | *Labeo nigriscens* (Day, 1870) WGE | Least Concern |
| | *Labeo rohita* (Hamilton, 1822) † | |
| | *Osteochilichthys nashii* (Day, 1869) | Least Concern |
| | *Pethia conchonius* (Hamilton, 1822) | Least Concern |
| | *Puntius sophore* (Hamilton, 1822) | Least Concern |
| | *Systomus sarana* (Hamilton, 1822) | Least Concern |
| | *Tor remadevii* Kurup & Radhakrishnan, 2011 CWE | Critically Endangered |
| | *Tor* sp. | --- |
| Danionidae | *Amblypharyngodon microlepis* (Bleeker, 1853) | Least Concern |
| | *Devario malabaricus* (Jerdon, 1849) | Least Concern |
| | *Esomus thermoicos* (Valenciennes, 1842) | Least Concern |
| | *Opsarius bendelisis* (Hamiilton, 1807) | Least Concern |
| | *Opsarius gatensis* (Valenciennes, 1844) WGE | Least Concern |
| | *Rasbora caverii* (Jerdon, 1849) WGE | Least Concern |
| | *Rasbora dandia* (Valenciennes, 1844) | Status not assessed |
| | *Salmostoma boopis* (Day, 1874) | Least Concern |
| **Mugiliformes** | | |
| Mugilidae | *Rhinomugil corsula* (Hamilton, 1822) | Least Concern |
| **Osteoglossiformes** | | |
| Notopteridae | *Notopterus synura* (Bloch & Schneider, 1801) | Status not assessed |
| **Incertae sedis under Ovalenteria** | | |
| Ambassidae | *Chanda nama* Hamilton, 1822 | Least Concern |
| | *Parambassis ranga* (Hamilton, 1822) | Least Concern |
| **Anabantiformes** | | |
| Badidae | *Badis badis* (Hamilton, 1822) | Least Concern |
| Channidae | *Channa gachua* (Hamilton, 1822) | Least Concern |
| | *Channa marulius* (Hamilton, 1822) | Least Concern |
| | *Channa pseudomarulius* (Günther, 1861) WGE | Status not assessed |
| | *Channa striata* (Bloch, 1793) | Least Concern |
| **Cichliformes** | | |
| Cichlidae | *Etroplus suratensis* (Bloch, 1790) | Least Concern |
| | *Oreochromis mossambicus* (Peters, 1852) † | |
| | *Oreochromis niloticus* (Linnaeus, 1758) † | |
| **Gobiiformes** | | |
| Gobiidae | *Awaous* sp. | |
| | *Glossogobius giuris* (Hamilton, 1822) | Least Concern |
| **Siluriformes** | | |
| Bagridae | *Hemibagrus punctatus* (Jerdon, 1849) CWE | Critically Endangered |
| | *Mystus seengtee* (Sykes, 1839) | Least Concern |
| | *Mystus vittatus* (Bloch, 1794) | Least Concern |
| | *Sperata seenghala* (Sykes, 1839) WGE | Least Concern |
| Clariidae | *Clarias gariepinus* (Burchell, 1822) † | |
| Loricariidae | *Pterygoplichthys* sp. † | |
| Pangasiidae | *Pangasius* sp. | |
| Siluridae | *Ompok bimaculatus* (Bloch, 1794) | Least Concern |
| | *Wallago attu* (Bloch & Schneider, 1801) | Vulnerable |
| Schilbeidae | *Silonia childreni* (Sykes, 1839) | Endangered |
| **Synbranchiformes** | | |
| Mastacembelidae | *Mastacembelus malabaricus* Jerdon, 1849 WGE | Status not assessed |

†—Non-native (transplanted or introduced) | WGE—endemic to Western Ghats | CWE—endemic to Cauvery River.


**Image 1. List of endemic and high conservation value species found in the Cauvery Wildlife Sanctuary.**
a— Red-tipped Halfbeak *Hyporhamphus xanthopterus* © Rahul Kumar | b—Humpback Mahseer *Tor remadevii* © WASI | c— Nilgiri Barb *Hypselobarbus dubius* © Naren Sreenivasan | d—Malabar Baril *Opsarius gatensis* © Shayan Subbaiah | e— Pink Carp *Hypselobarbus micropogon* © Naren Sreenivasan | f— False Giant Snakehead *Channa pseuomarulius* © Derek D'souza | g— Kantaka Barb *Kantaka brevidorsalis* © Naren Sreenivasan | h—Nilgiri Mystus *Hemibagrus punctatus* © Naren Sreenivasan | i—Fringe-lipped Carp *Labeo dyocheilus* © Naren Sreenivasan | j—Mulley *Wallago attu* © Sheik Imran | k— Pig-mouth Carp *Labeo kontius* © Salik khan | l— Silund *Silonia childreni* © Ajith Sreenivasan | m—Black Fringe-lipped Carp *Labeo nigriscens* © Naren Sreenivasan | n—Malabar Spiny Eel *Mastacembelus malabaricus* © Naren Sreenivasan.

indiscriminate and often destructive fishing practices (using dynamites) and sand mining have effectively been kept under control along most river stretches in the study site. The possible presence of a large number of African Catfish (as indicated in the focus group discussions with anglers) in the Shimsha tributary, however, is a cause for concern. It is currently not known how and when this predatory fish entered the waters of the protected area. Life history traits including an opportunistic feeding strategy and ability to establish large and persistent populations (Roshni et al. 2020) make the African Catfish an imminent threat to the native fishes of the Cauvery WS especially native catfishes with which they directly compete. The Silund *Silonia childreni* a threatened species of peninsular Indian catfish that was reported from within the study site during the 1970–80s (also see Shenoy et al. 2003) is now known to occur only in a limited stretch of the river in the Mekedattu Gorge, and close to the Karnataka-Tamil Nadu border (WASI Anglers pers. comm.). Whether the three large-bodied catfish species, viz, *Wallago attu, Pangassius* sp. and *S. childreni* which were known to occur in the study area until two decades ago has been potentially extirpated requires focused investigation. During the course of this study, only one specimen each of these three species was recorded, although local fishers report isolated populations in deep gorges in south-east of the Sanctuary.

The biggest threat to freshwater fishes in the area is the anthropogenic impacts to the riparian habitat that supports this large aquatic diversity. Development projects proposed in and around the study site threaten to change the dynamics of the river and its riparian vegetation, not only affecting breeding and feeding habits of many fish species, but also force key species in the sanctuary such as the Grizzled Giant Squirrel *Ratufa macroura*, Indian Marsh Crocodile *Crocodylus palustris*, and the Smooth-coated Otter *Lutrogale perspicillata* to drastically change their habitat use patterns. A comprehensive multi-year study on the diversity, distribution and threats to fishes and other aquatic wildlife in the Cauvery Wildlife Sanctuary is urgently required to strengthen future conservation action. Such an effort is currently being developed by WASI in collaboration with the State Forest Department and other relevant stakeholders.

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# Fish communities and associated habitat variables in the upper Subansiri River of Arunachal Pradesh, eastern Himalaya, India

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**Abstract:** Ecological information on the rivers of eastern Himalaya, specifically the state of Arunachal Pradesh is not studied well. The present study describes fish assemblage patterns and deriving relationships between local habitat variables in the upper reaches of Subansiri River, Arunachal Pradesh. This study was carried out during October to November 2014 and February to March 2015. A total of 26 fish species belonging to eight families were recorded, in which eight species are endemic to the eastern Himalayan region. Fish species richness varied from two to 18 species in the upper reaches of Subansiri River and high species diversity was recorded in Sigin Stream (H'=2.76). Based on the seven habitat variables (water velocity, depth, channel width, percentage of substrate composition, percentage of riparian vegetation, altitude, and water temperature) then streams were categorized into lower-order and higher-order streams using principal component analysis (PCA). The site-wise fish abundance data along with habitat variable information was then subjected to the canonical correspondence analysis (CCA) for testing the association of habitat variables on fish abundance. The CCA results revealed that the abundance of large-size barbs, *Neolissochilus hexagonolepis*, *N. nigrovittatus*, *Schizothorax progastus*, and *S. richardsonii* were strongly associated with high altitude, water velocity, rich dissolved oxygen, and good riparian vegetation. On the other hand, *Channa gachua*, *Botia rostrata*, *Danio rerio*, *Devario aequipinnatus*, and *Garra nasuta* showed strong association with warm water streams with more conductivity.

**Keywords**: Diversity, fish assemblage, fish ecology, northeastern Himalaya, Subansiri River.

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**Author contribution:** SS—involved in field sampling, data collection, data analysis and manuscript drafting; KS—involved in filed sampling, supervision and manuscript editing. JAJ—involved in filed sampling, supervision, data validation, image preparation and manuscript editing

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## INTRODUCTION

The questions addressed within the scope of community ecology are several; of them, one crucial objective is studying the differing species communities through changing environmental characters. Such an analysis leads us to identify the environmental factors that shape the species communities of a region (Angermeier & Karr 1983). Stream ecosystems have complex local processes occurring amongst abiotic, and biotic entities. This complexity renders a buffering capacity and stability to the system. Understanding these interrelationships with respect to stream ecosystems is challenging but critical, if one is to comprehend and conserve riverscapes. In the context of rivers, it has been repeatedly shown that fish communities change as one moves downstream from the headwaters (Platts 1979; Vannote et al. 1980) primarily because of an increase in diversity and quantity of habitats (Lowe-McConnell 1975; Gorrman & Karr 1978). Physico-chemical parameters such as dissolved oxygen and pH are also powerful drivers of fish diversity (Mathews 1986). Several other studies, showcasing the role of discharge (Horwitz 1978), substrate quality (Ambrosio et al. 2009), hydrological variability (Poff et al. 1995), and stream order (Platts 1979), have been well documented.

Multivariate statistical analyses used for understanding relationships between communities and habitat variables include regression (Angermeier & Winston 1998); principal components analysis (PCA) (Bistoni & Hued 2002); canonical correspondence analysis (CCA) (Ferreira et al. 2007; Li et al. 2012); detrended correspondence analysis (DCA) (May & Brown 2000), and non metric multi-dimensional scaling (NMDS) (Li et al. 2012; Mercado-silva et al. 2012) among many other statistical models developed over the years. Many studies correlating fish assemblages to habitat variables have been conducted in temperate as well as tropical regions across the world (Anderson et al. 1995; Fausch & Bestgen 1997; Winston 1998; Guisan & Zimmermann 2000; May & Brown 2000; Horig & Fauscch 2002; Oakes et al. 2005). In India, these studies have been done in the Western Ghats rivers (Saravanan et al. 2003; Bhat 2004; Johnson & Arunachalam 2010), central Indian rivers (Johnson et al. 2012; Shukla & Bhat 2017; Mondal & Bhat 2020), economically important fishes of the Ganga River (Lakra et al. 2010), and rivers of the western Himalaya (Johal 2002; Sivakumar 2008; Atkore et al. 2011; Johnson et al. 2020).

Fish assemblage studies in the eastern Himalayan streams in the Indo-Burma biodiversity region have not been conducted. Northeastern India's remote regions especially, Arunachal Pradesh, has many networks of flowing freshwater and associated resources. Studies on the rivers of Arunachal Pradesh are scanty (Nath & Dey 1997; Bagra et al. 2009) and literature addressing habitat-fauna correlations are missing. The high diversity in the region is attributed to the region's tectonic and consequently zoogeographical history (Kottelat 1989). The absence of information on the ecology of the rivers of the region and especially the Subansiri is glaring. In fact, with the controversies that the Lower Subansiri Hydro-Electric Project (LSHEP) has been embroiled in, this study gains even more importance as probably the only source of ecological information on the river.

With the above background, the present study was conducted to address the following questions: i) what type of fish fauna are associated with upper Subansiri River basin? and ii) which habitat variables are crucial drivers in the formation of fish assemblages in the streams of the upper Subansiri River basin?

## METHODS

### Study Area

This research effort was carried out in the upper Subansiri River basin of Arunachal Pradesh, eastern Himalaya. This river is one of the largest tributaries of the Brahmaputra River. It originates from the Tibetan Plateau and enters India through Taksing in the upper Subansiri District, of Arunachal Pradesh. It then courses through the entirety of the Upper and Lower Subansiri districts, covering a distance of 442km, and finally confluences with the Brahmaputra River at Lakhimpur, Assam. Twenty-one streams were sampled along the altitudinal gradient ranging from 200m in Daporijo, to 3,000m in Taksing (Figure 1) for fish and habitat characters in the seasons: post-monsoon (October–November 2014) and pre-monsoon (February–March 2015). The landscape is dominated with wild bananas and bamboo which give way to oak forests and finally alpine vegetation at two higher reaches. The region experiences heavy rains from the months of April to September. Winters are cold, and peak in the months of December and January. Sampling time is thereby limited to October, November, February, and March.

The fauna and flora of the region have affinities to southern China and the Malayan Peninsula because the river basin lies in the region where two biodiversity hotspots, viz., the Himalaya and the Indo-Burma, coalesce. There are innumerable rivulets flowing into the

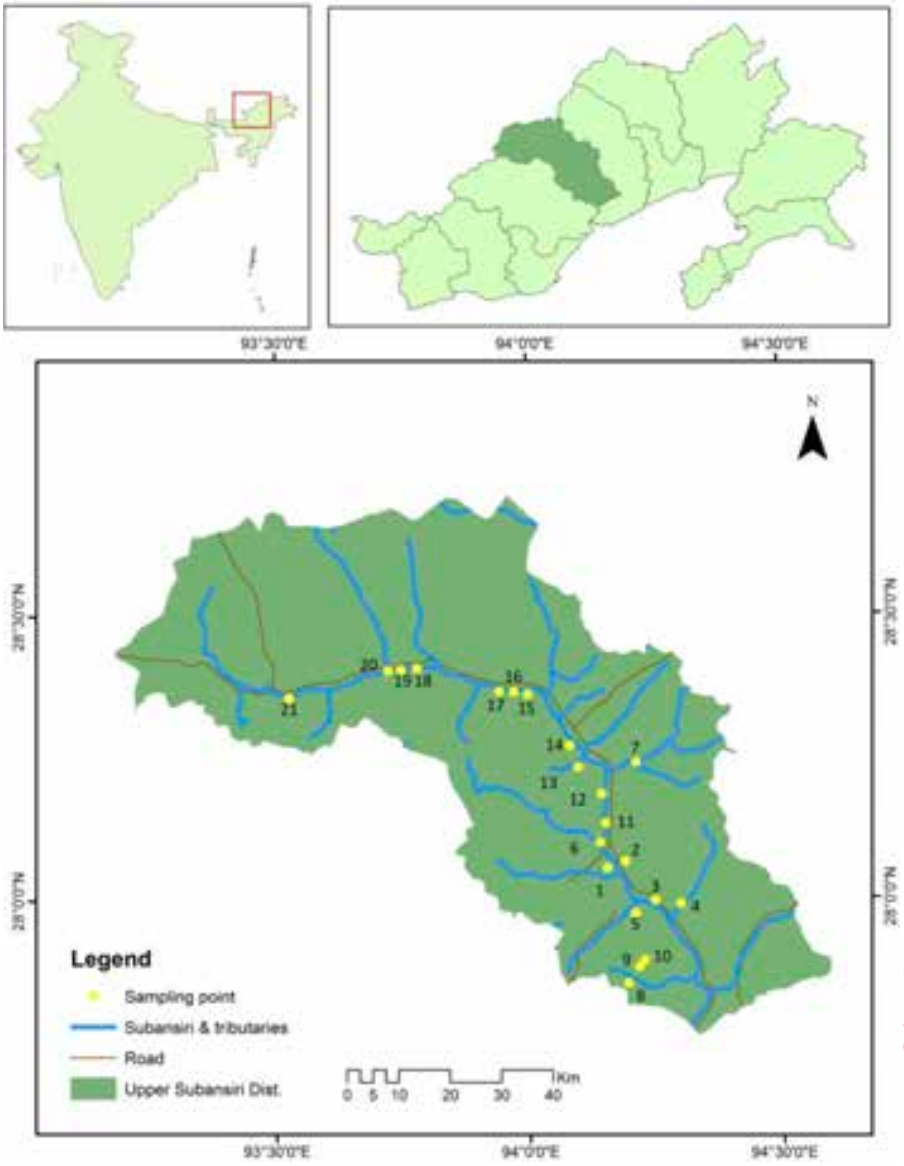


**Figure 1. The sampling locations in the upper Subansiri River basin, Arunachal Pradesh, India: 1—Sippi | 2—Sakro | 3—Sigin | 4—Singyum | 5—Menga | 6—Bui | 7—Silin | 8—Godak | 9—Wuon | 10—Mara | 11—Ryo | 12—Lingram | 13—Lingde | 14—Aying | 15—Gamte | 16—Mede | 17—Ginyo | 18—Digbhak | 19—Dasi | 20—Kete | 21—Kudok.**

Subansiri through either bank. The major tributaries of the Subansiri River are Sigin in Daporijo, Sippi in Chetam, Menga in Giba, Silin and Sichi in Taliha, Sikin Kro and Singyum in Dumporijo. A few small towns of the district, such as Daporijo, Dumporijo, and Taliha; are located close to major river confluences involving the river Subansiri. A lot of the stream channels have been altered for the purpose of irrigation or road constructions. Among other land-use activities of the region, slash and burn (*Jhum*) cultivation is prevalent throughout the landscape and is one of the important occupations. Fishing activities are only for purposes of subsistence and not commercial. Fishing techniques include both traditional and modern methods. Traditional fishing involves angling, basket traps, and use of river-bed substrates to construct seasonal fish breeding spots within the river channel. Modern methods are mostly destructive and include cast netting, gill netting, dynamite use, and some cases of poisoning and electro-fishing.

**Habitat Inventory**

At each sampling site, a 100m reach was selected for quantifying stream habitat variables such as depth, velocity and substrates. Before starting the inventory, altitude and GPS coordinates of sampling location were recorded. After that, 8–10 transects were drawn across the channel, using a rope calibrated at every meter. At each of those calibrations, depth, flow and substrate type were recorded at every 1m interval. Depth was recorded using a measuring rod and velocity was recorded using

a flow probe hand-held digital flow meter. In the case of substrate, percentage composition of different substrates categories (bedrock - >512mm; boulder 128–512 mm; cobbles 64–128 mm; pebbles 16–64 mm; gravel 8–16 mm; sand/silt/leaf-litter) were recorded for each transect. Based on the depth and velocity profile, mean depth and mean width were calculated for each site. Methods for recording habitat variables were followed the methods of Pusey et al. (1995) and Johnson & Arunachalam (2010). In addition to that the percentage of riparian cover along the stream, bank stability, water clarity and land use patterns were recorded for each sampling location. Riparian cover was recorded using a spatial densitometer. Bank stability, land-use pattern and water clarity were given score values through 1–4 ranging from pristine to heavily modified.

**Table 1. Scoring criteria of habitat variables with nominal data for CCA (Mercado-silva et al. 2012).**

| Variable | Scores | Criteria |
|---|---|---|
| Water Clarity | 1 | Turbid |
| | 2 | Moderately Turbid |
| | 3 | Transparent |
| Habitat Diversity | 1 | Single habitat type for 90% |
| | 2 | Two habitat types |
| | 3 | Three or more habitat types |
| Land-use Pattern | 1 | Urban/Pasture/Agricultural |
| | 2 | Modified natural |
| | 3 | Natural |
| Substrate Diversity | 1 | Soft sediments >90% |
| | 2 | Mix of > 3 substrates |
| | 3 | Rocky Substrates >90% |
| Riparian Cover | 1 | No riparian cover |
| | 2 | Modified riparian cover |
| | 3 | Natural |

### Fish Sampling

Fish sampling was carried out using different fishing gear such as cast nets and gill nets of varying mesh sizes from 0.5 to 5cm. Gill nets were deployed in pool habitats for four hours. Run and riffle habitats were sampled using a cast net. In addition, drag nets and locally made contraptions were used to acquire small fish. Fish sampling protocol was adopted from Johnson et al. (2012). After collection, fishes were examined and photographed. A few fishes were preserved in 10% buffered formalin for species confirmation and other laboratory analyses. The rest were released back into the stream after noting their length and weight. Fish species were confirmed using latest taxonomic literature (Jayaram 2010) and current nomenclature was followed according to the catalogue of fishes (Fricke et al. 2020).

### Data Analysis

Fish abundance data was subjected to different univariate indices, namely Shannon index, evenness index and Margalief's species richness for investigating species diversity patterns. The Shannon index of diversity was obtained by the following equation $H' = \sum pi \ln pi$, where $pi = ni/N$; where ni is the number of individuals of 'i'th species and $N = \sum ni$. Evenness index was calculated by $E = H'/\ln S$, where S is the number of species. Margalief's species richness was calculated using the equation $R = (S-1)/\ln N$, where S is the number of species, N is the total number of individuals. The 95% confidence intervals (95% CI) for Shannon and evenness indices were estimated using bootstrap methods with 9999 permutations using PAST programme (Hammer et al. 2001). In order to identify major categories of stream classes, the PCA was performed. In PCA analysis, correlation matrix of seven variables, viz., flow, depth, width, percentage composition of substrate, percentage of riparian cover, altitude, and temperature were considered. Whereas, the bank stability, land-use pattern, habitat diversity, and water clarity were not used for PCA, as these were nominal data and did not have any numerical qualities. Further, the CCA analysis was performed using 13 variables, including the ones not considered for PCA, to test the null hypothesis that the habitat variables do not influence species composition. In order to do this, a permutations test (n=999) was run and p-values for each canonical axis was considered (Legendre & Legendre 1998). Before using the data in CCA, the habitat variables with nominal data were converted into scores (see Table1) on the basis of Mercado-silva et al. (2012). The PCA and CCA were performed using PAST programme (Hammer et al. 2001).

## RESULTS

### Fish Diversity and Assemblages

A total of 26 species of primary freshwater fishes belonging to 16 genera, eight families and three orders were recorded from the upper Subansiri River (Table 2). Maximum species richness was found in Sigin stream (18 species), which is a low land stream located near Daporijo town, followed by Sippi with 12 species of fishes, which is located near the confluence of Sippi stream and the

Subansiri. Among all the species, *Garra gotyla* had the highest local dominance (recorded in 11 streams) followed by *Neolissochilus hexagonolepis*, *Schizothorax richarsonii* and *Schistura devdevi* (recorded each from 10 streams each). Among the species, eight species (*Aborichthys garoensis*, *A. kempi*, *A. tikaderi*, *Exostoma labiatum*, *Neolissochilus nigrovittatus*, *Psilorhynchus arunachalensis*, *Schistura nagaensis*, *S. tirapensis*) are endemic to the northeastern Himalaya. Images of some of the rare and endemic fishes recorded from upper Subansiri River are given in Image 1.

The site-wise information on species diversity, richness, evenness and fish assemblages are presented in Table 3. Of all the streams sampled, the Sigin Stream had the highest species diversity (H'=2.76, 95% CI 2.09-2.57) and richness (R=4.37) followed by Sippi (H'=2.34, 95% CI 2.68–2.95; R=3.56) whereas the headwater stream Dasi had low species diversity and richness (H'=0.43, 95% CI 0.23–0.63; R=0.39). The high value of evenness index observed in Aying stream (E=0.98, 95% CI 0.86–1.11) revealed that the species were distributed evenly in the community.

**Stream Categories and their Characteristics**

The first two components of the PCA explained 57.72% of the total variation in the data. The PCA of the sites categorized into headwaters (lower order streams) and downstream (higher-order streams). The bi-plot of site scores with habitat variables is displayed in Figure 2. Sites with low principal component 1 loadings (Sippi, Sakro, Sigin) had high water temperature and conductivity whereas sites with high component 1 scores (Kete, Mede, Bhagdik, Lingde) had good quality of riparian vegetation, high level of dissolved oxygen, swift flowing habitat and positioned in higher altitude (qualified as headwater streams). On the other hand, sites with high component two scores have greater width and depth, i.e., characters of higher order streams.


**Image 1. Rare and endemic fishes recorded from the upper Subansiri River, Arunachal Pradesh. a—*Aborichthys kempi* | b—*Aborichthys tikaderi* | c—*Exostoma labiatum* | d—*Neolissochilus nigrovittatus* | e—*Psilorhynchus arunachalensis* | f—*Schistura nagaensis*. © J.A. Johnson.**

**Table 2. List of fish species and abundance recorded from the upper Subansiri River, Arunachal Pradesh.**

| Species name | Sippi | Sakro | Sigin | Singyum | Menga | Bui | Silin | Godak | Wuon | Mara | Ryo | Lingram | Lingde | Aying | Gamte | Mede | Ginyo | Bhagdik | Dasi | Kete | Kudok |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Cypriniformes**<br>**Daniodinidae**<br>*Devario aequipinnatus* | 4 | 2 | - | - | - | - | - | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Devario devario* | 2 | 1 | 2 | 2 | 2 | 3 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Danio rerio* | 1 | 3 | 2 | 1 | 3 | 2 | 1 | 2 | - | - | - | - | - | - | - | - | - | - | - | 1 | - |
| *Opsarius bendelisis* | 4 | 3 | 3 | - | 2 | 1 | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **Cyprinidae**<br>*Garra gotyla* | - | - | 7 | - | 6 | 2 | 3 | 4 | 5 | 4 | - | 2 | - | - | - | 4 | - | - | 2 | 1 | - |
| *Garra lamta* | - | 2 | - | - | 3 | 5 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Garra nasuta* | - | - | 3 | - | - | 1 | - | - | 4 | - | - | - | - | 2 | - | - | - | - | - | - | - |
| *Neolissochilus hexagonolepis* | 1 | - | 1 | - | 4 | 6 | - | - | - | - | - | - | 3 | 3 | 1 | 3 | 2 | 2 | - | - | - |
| *Neolissochilus nigrovittatus* | - | - | - | - | 2 | - | - | - | - | - | - | - | 1 | - | - | 1 | - | - | - | - | - |
| *Schizothorax progastus* | - | - | - | - | - | - | - | - | - | - | 5 | - | 2 | - | 1 | 2 | 1 | - | - | - | 5 |
| *Schizothorax richardsonii* | - | - | - | - | - | - | - | - | - | 7 | 4 | - | 3 | 2 | 4 | 3 | 2 | 1 | - | 7 | 4 |
| *Tariqilabeo latius* | 2 | - | 1 | - | - | - | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **Psiloehynchidae**<br>*Psilorhynchus arunachalensis* | 1 | - | 3 | 4 | - | - | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **Nemachilidae**<br>*Aborichthys garoensis* | - | 2 | 5 | 1 | - | - | - | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Aborichthys tikaderi* | 1 | - | 3 | 1 | - | - | - | 5 | 1 | - | - | - | - | - | - | - | - | - | 11 | - | - |
| *Aborichthys kempi* | - | - | 2 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Paracanthocobitis botia* | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Schistura devdevi* | 1 | - | 3 | - | - | - | - | 5 | - | 3 | 2 | 1 | 3 | 2 | 1 | 2 | - | - | - | - | - |
| *Schistura nagaensis* | - | 3 | 2 | 1 | 4 | - | - | 2 | - | 2 | - | - | - | - | - | 2 | - | - | - | - | - |
| *Schistura tirapensis* | - | 1 | 4 | 1 | 1 | 1 | 3 | 1 | 2 | - | 1 | - | - | - | - | - | - | - | - | - | 1 |
| **Bottidae**<br>*Botia rostrata* | 1 | - | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **Siluriformes**<br>**Siluridae**<br>*Amblyceps mangois* | - | - | 1 | 1 | - | - | - | 1 | - | 3 | - | 1 | - | 2 | 2 | - | - | - | - | - | - |
| **Sissoridae**<br>*Exostoma labiatum* | - | - | - | - | - | - | - | 2 | 3 | - | - | 1 | - | - | - | - | - | - | - | - | - |
| *Glyptothorax cavia* | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **Perciformes**<br>**Channidae**<br>*Channa gachua* | - | - | 3 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Channa stewartii* | - | - | 2 | - | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |

## Fish species and habitat variable associations

The results of CCA revealed that there is no strong association observed between habitat variables and species abundance (Permutations=999, trace=2.061, p=0.204). Among the variables, the conductivity had very strong association with fish abundance data (p=0.01). On further inspection, it found that the first two axes explained 54.32% of the inertia (31.53% and 22.79% for axis 1 and axis 2 respectively) in the data matrix. There was a significant association between habitat variables and species abundance on the first canonical axis (P=0.02) and second canonical axis (P=0.01).

The triplot depicting associations of sites and species to habitat variables is given in Figure 3. The CCA plot revealed that the stream Kete, Mede, Bhagdik, Lingde, Ryo, Ginyo, and Gamte had good quality of riparian vegetation, high level of dissolved oxygen, swift flowing habitat and positioned in higher altitude, which were in turn strongly associated with fish species *Neolissochilus hexagonolepis*, *N. nigrovittatus*, *Schizothorax progastus*, *S. richardsonii*, and *Schistura tirapensis*. In the plot, the stream Silin segregated itself as an outlier among all site,

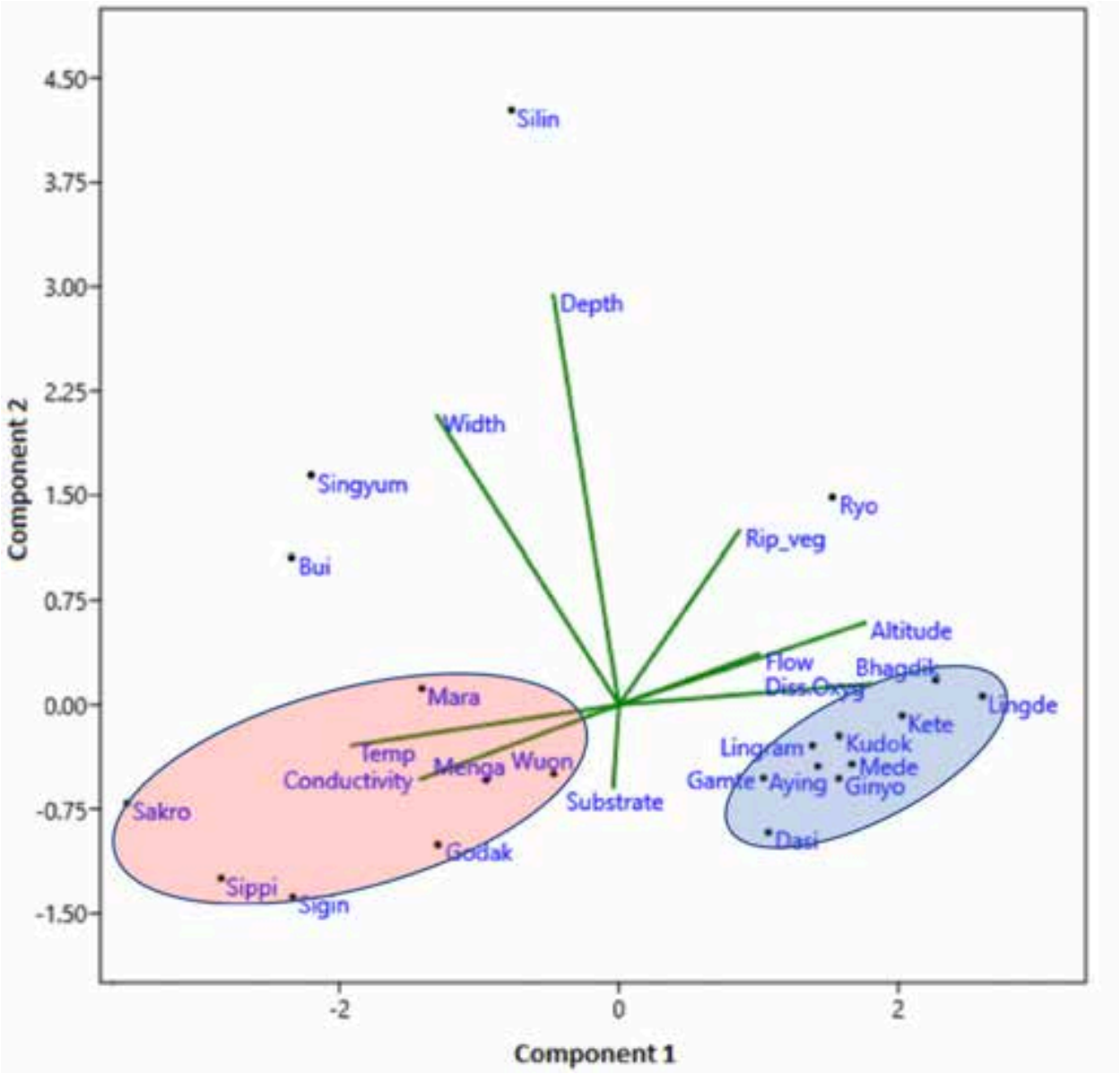


**Figure 2. PCA bi-plot of sites with habitat variable vectors (Blue: headwater streams; Red: lowland rivers).**

however, it was strongly associated with more number of *Aborichthys garoensis* and *Garra lamta*. The species, *Botia rostrata*, *Channa gachua*, *Danio rerio*, *Devario aequipinnatus*, *Garra nasuta*, *Glyptothorax cavia*, and *Psilorhynchus arunachalensis* formed a cluster near Sippi site and showed preferences to streams with relatively greater stream volumes, conductivity and warm temperature. The high altitude streams, Wuon, Lingram, and Godak located in south of Daporijo Town formed a separate group in terms of fish community.

## DISCUSSION

Assessing the species richness and habitat variables influencing their distribution are central to the subject of conservation science. Species composition in streams within a river basin is determined by large- and small-scale processes. The large-scale factors refer to biogeographic history, tectonic movements and latitude of given landscape. In the present study, the fish composition recorded from upper Subansiri River is a true representation of eastern Himalayan elements and most of the species occur in other sub-basins of Brahmaputra (Tamang et al. 2007; Bagra et al. 2009;

**Table 3. Species diversity and assemblages in the upper Subansiri River, Arunachal Pradesh.**

| Site | Number of species | Number of individuals | Shannon diversity (H') | Evenness index (E) | Species richness index (R) |
|---|---|---|---|---|---|
| Sippi | 12 | 22 | 2.34 | 0.86 | 3.56 |
| Sakro | 8 | 17 | 2.01 | 0.93 | 2.47 |
| Sigin | 18 | 49 | 2.76 | 0.88 | 4.37 |
| Singyum | 9 | 13 | 2.03 | 0.85 | 3.12 |
| Menga | 10 | 29 | 2.20 | 0.90 | 2.67 |
| Bui | 8 | 21 | 1.86 | 0.80 | 2.30 |
| Silin | 6 | 13 | 1.74 | 0.95 | 1.95 |
| Godak | 10 | 26 | 2.16 | 0.87 | 2.76 |
| Wuon | 5 | 15 | 1.49 | 0.89 | 1.48 |
| Mara | 5 | 19 | 1.52 | 0.91 | 1.36 |
| Ryo | 4 | 12 | 1.24 | 0.86 | 1.21 |
| Lingram | 4 | 5 | 1.33 | 0.95 | 1.86 |
| Lingde | 5 | 12 | 1.55 | 0.94 | 1.61 |
| Aying | 5 | 11 | 1.59 | 0.98 | 1.67 |
| Gamte | 5 | 9 | 1.43 | 0.83 | 1.82 |
| Mede | 7 | 17 | 1.88 | 0.93 | 2.12 |
| Ginyo | 3 | 5 | 1.06 | 0.96 | 1.24 |
| Bhagdik | 2 | 3 | 0.64 | 0.94 | 0.91 |
| Dasi | 2 | 13 | 0.43 | 0.77 | 0.39 |
| Kete | 3 | 9 | 0.68 | 0.66 | 0.91 |
| Kudok | 3 | 10 | 0.94 | 0.86 | 0.87 |

Kansal & Arora 2012). Further, the fish fauna recorded in the upper Subansiri River is similar to that of fishes reported from downstream of Subansiri in Assam. Eight species (*Aborichthys tikaderi*, *Exostoma labiatum*, *Neolissochilus nigrovittatus*, *Schistura devdevi*, *Schistura nagaensis*, *Schistura tirapensis*, and *Schizothorax progastus*) recorded from the upper Subansiri region are a new addition to Subansiri River fish list (Bakalial et al. 2014). The presence of recently described species *Psilorhynchus arunachalensis* in this region revealed that further inventory of remote areas is necessary.

At smaller scales, the habitat variables such as flow, riparian vegetation, water temperature and so on would determine the species composition in streams (Ricklefs 1987). The first step towards understanding the role of habitat variables on fish assemblages is categorizing streams into headwater and lowland streams on the basis of local factors in multivariate space. The results of PCA revealed that the streams of upper Subansiri River are categorized into headwater streams (with high altitude, low water temperature, good riparian cover, greater flow and rich dissolved oxygen) and lowland streams (with greater depth, width and high conductivity). The CCA results inferred that the distribution of few species such as *Schizothorax* sp., *Neolissochilus* sp., and *Exostoma labiatum* are strongly associated with pristine riparian vegetation, greater flows, and higher altitudes. Further, we observed that that species richness improved with an increasing order of stream volume or order as demonstrated by Platts (1979).

One could elaborate here that the PCA results and inferences drawn from the CCA are coinciding and are highly suggestive in that fish distribution in the upper Subansiri basin is primarily differentiated by the types of streams: smaller headwaters at high altitudes and rivers with larger volumes of water at comparatively lower heights. Stream volume was shown to be influencing species diversity by Gorman & Karr (1978); hydrological force, i.e., flow velocity selects species morphologically suited to such conditions (Suarez et al. 2011). Even in our study, the number of species increased with an increase in depth and to some extent with the increase of width. Loaches (*Aborichthys kempi*, *Schistura nagaensis*, and *Psilorhynchus arunachalensis*), snakeheads (*Channa* sp.), small barbs *Opsarius bendelisis* and *Danio rerio*) associated themselves with the depth and width vectors

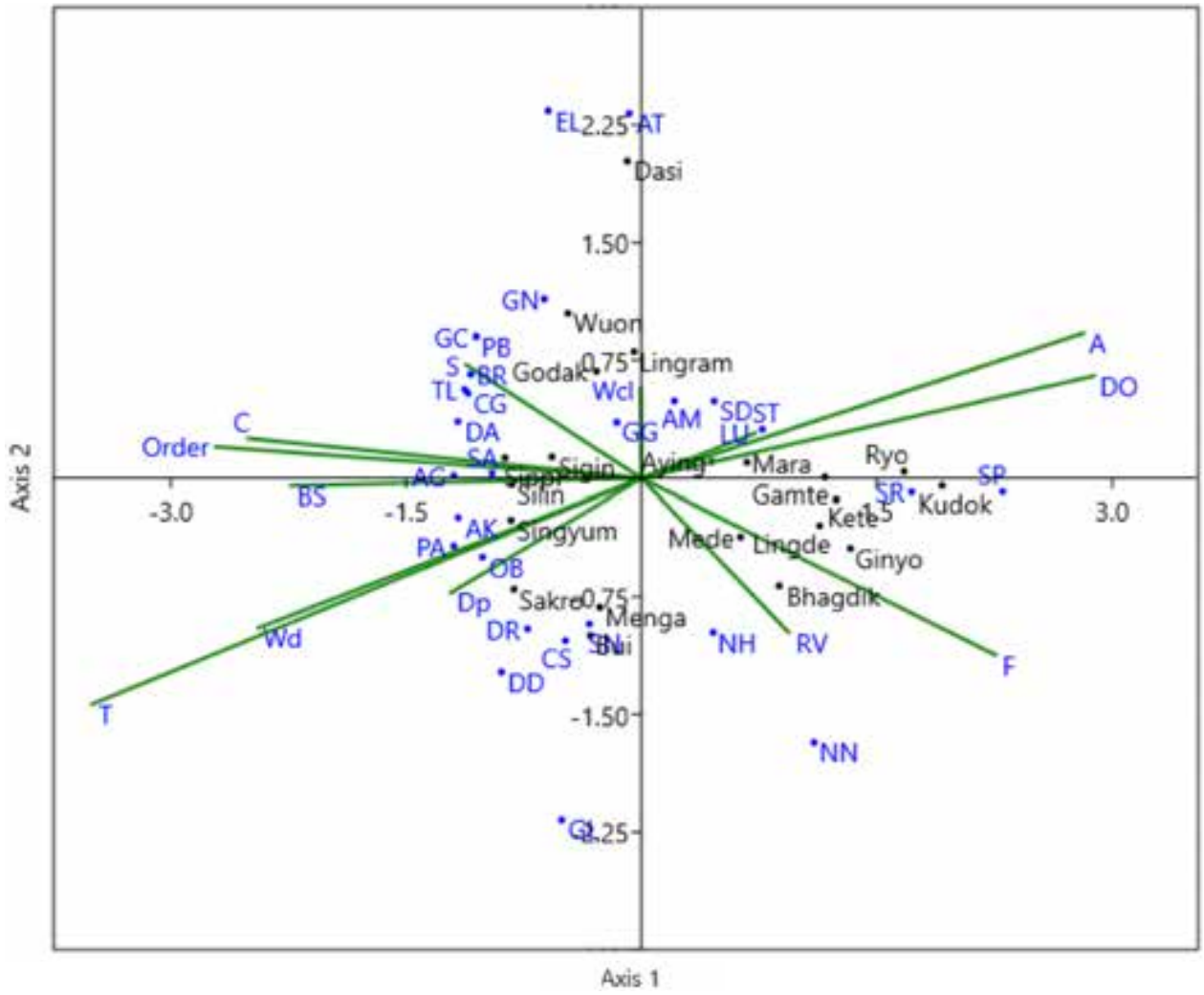


**Figure 3. CCA tri-plot depicting the associations of streams and species to habitat variables: AK—*Aborichthys kempi* | AG—*Aborichthys garoensis* | AT—*Aborichthys tikaderi* | AM—*Amblyceps mangois* | BR- *Botia rostrata* | CG—*Channa gachua* | CS—*Channa stewartii* | DA—*Devario aequipinnatus* | DD—*Devario devario* | DR—*Danio rerio* | EL—*Exostoma labiatum* | GG—*Garra gotyla* | GL—*Garra lamta* | GN—*Garra nasuta* | GC—*Glyptothorax cavia* | NH—*Neolissochilus hexagonolepis* | NN—*Neolissochilus nigrovittatus* | OB—*Opsarius bendelisis* | PA—*Psilorhynchus arunachalensis* | PB—*Paracanthocobitis botia* | SD—*Schistura devdevi* | SN—*Schistura nagaensis* | ST—*Schistura tirapensis* | SP—*Schizothorax progastus* | SR—*Schizothorax richardsonii* | TL—*Tariqilabeo latius*.**

of the CCA. Sites and species associated with depth, width, conductivity, temperature automatically had lower loadings on altitude, dissolved oxygen, land-use and flow velocity variable vectors.

The drainage of the river is unique regarding minimal human induced perturbations, landscape, biodiversity and habitat. People of the region are dependent majorly on the natural resources. Some basic advancement in the form of hospitals and roads can be seen, but with a poor quality of schools and very little awareness; one can expect a population surge soon. Along with these, the proposed hydropower plants in the upper region of the river basin are also going to irreversibly alter the riverine habitats and associated fish communities.

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**COMMUNICATION**

# Diversity and distribution of odonates in Rani Reserve Forest, Assam, India

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**Abstract:** Odonata are the bioindicators of freshwater ecosystem health and is recognised as an excellent 'flagship' group among insects. Baseline knowledge on the diversity and distribution of odonates over spatiotemporal scale is the key to biodiversity conservation. Rani Reserve Forest of Assam is a mosaic of all the habitat types suitable for odonates. The present work aims at studying the diversity and distribution of Odonates in Rani Reserve Forest. The study was carried out from December 2014 to November 2017 by categorising the study area into three major habitat types: 1. lentic system, 2. lotic system and 3. terrestrial woodland. A total of 67 species belonging to 44 genera, representing 11 families were recorded. First published records of three species, *Onychothemis testacea* (Libellulidae), *Philoganga montana* (Philogangidae) and *Indocnemis orang* (Platycnemididae) from the state are also provided herewith. Species richness was the highest in lentic system whereas recorded the lowest in running waters of larger forested streams. Shannon diversity index also indicated that the lentic system is relatively diverse (2.95) and smaller streams of the lotic system showed the highest species evenness (0.87). Libellulidae (43%) was found to be the most dominant family belonging to suborder Anisoptera followed by Coenagrionidae (22%) of suborder Zygoptera. Philogangidae (1%) recorded the lowest number of species. Taxonomically related species showed distinct ecological segregation within these different habitat types occupying different microhabitats therein.

**Keywords:** Biodiversity, conservation, dragonfly, generalist, Odonata, specialist, species composition.

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**Author details:** Dipti Thakuria is a working as a PhD research scholar in Department of Zoology, Gauhati University, Assam. Her specific field of interest is on diversity, taxonomy and ecology of odonates. Prof. Jatin Kalita is a retired Professor from Department of Zoology, Gauhati University. His special field of interest is in entomology.

**Author contribution:** First author have worked on the field surveys and preparation of the manuscript under the complete guidance of second author.

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## INTRODUCTION

Odonate abundance and diversity provides useful measures of habitat quality in both the aquatic and terrestrial environments (Clark & Samways 1996; Corbet 1999). This group of insects is very diverse, containing individuals with habitat specificities (Corbet 1999). The species assemblage of odonates is influenced by aquatic and terrestrial vegetation (Subramanian et al. 2008) along with channel width of streams (Dijkstra & Lempert 2003). They are found in a wide array of freshwater systems depending on biotic and abiotic constraints. Lentic and lotic systems ranging in physical habitat structure from seasonal to permanent is the habitat of many odonate species (Córdoba-Aguilar 2008). Some of the stenotypic species with low dispersal ability are specific to forest whereas more generalist species with high dispersal ability remain in disturbed open habitats (Clark & Samways 1996). Odonata shows strong response to change in the habitat because of their sensitivity to physical habitat quality (Clark & Samways 1996; Rith-Najarian 1998; Samways & Steytler 1996; Stewart & Samways 1998). The good physical condition of the forest is indicated by the presence of diverse forest species specially stenotypic species (Samways 1989; Corbet 1999).

Information on the species diversity and distribution of extant species of odonates is a prerequisite for an effective conservation strategy. Globally 6307 species of odonates have been reported (Schorr and Paulson, 2020), of which 493 species and 27 subspecies represented in 154 genera and 18 families exists in India (Subramanian and Babu, 2019). Studies on odonate fauna have been reported from various parts of northeastern India. Ninety species were reported from Nagaland (Joshi & Kunte 2014), 64 species from Mizoram (Prasad 2007), 68 species from Manipur (Srivastava & Sinha 2004), 65 species from Sikkim (Mitra 2003), 53 species from Tripura (Majumder et al. 2014), 92 species were recorded from Arunachal Pradesh (Mitra 2006) and 151 species from Meghalaya (Srivastava & Sinha 1995). Odonata fauna from many parts of northeastern India are still undocumented. The state Assam is a part of the eastern Himalayan biodiversity region, rich in rare endemic plant and animal species. Considering the remoteness, the odonate diversity of Assam has been understudied. Previous reports by Laidlaw (1914) described 20 species of dragonflies and damselflies from Assam and Burma. Borah et al. (2012) recorded seven species of damselflies from Gauhati University Campus, Assam; Baruah (2018) recorded 48 species of odonates from Barpeta. Again, very recent studies by Boruah et al. (2016) reported 82 species under 51 genera belonging to 10 families from Kaziranga, Assam. The present study aims at providing a list of species and document habitat and seasonal distribution of Odonata fauna in the Rani Reserve Forest of Assam.

## MATERIALS AND METHODS

### Study area

The study was conducted in Rani Reserve Forest situated at 26.091–26.021 $^0$N & 91.588–91.707 $^0$E with an altitude ranging from 60–670 m in Kamrup District, Assam, northeastern India (Devi et al. 2012) (Figure 1). The study area is a mixed moist deciduous forest bordered by hills of Meghalaya on the southern side and Deepor Beel on the northern side which is a Ramsar site of northeastern India, covering an area of 45km$^2$. It is considered to be an ecotone between montane subtropical moist broadleaf forest of Meghalaya Plateau and sub Himalayan moist mixed deciduous forest of Assam Valley (Champion & Seth 1968). The unique geological and physiographical makeup of the area forms a special habitat mosaic of hilly terrain and supports habitat like streams, marshes, ponds, puddles suitable for Odonata fauna. The area has a sub-tropical climate with hot humid summer and cool dry winter. Annual rainfall ranges between 1,500–2,600 mm, relative humidity ranges from 47–98 %. The maximum temperature is between 37–39 $^0$C and minimum temperature ranges from 6–7 $^0$C. The climate of the region is divided into four seasons (Barthakur 1986): pre-monsoon (March–May), monsoon (June–September), post-monsoon (October–November) and winter (December–February).

### Survey and Sampling

The study was conducted for three consecutive years from December 2014 to November 2017. Rani Reserve Forest (RRF) was categorised according to the habitat and ecological characteristics with which the organism's density is likely to be correlated (Sutherland 1996). Three distinct habitat types were selected for the study of odonates by random stratified sampling method**:** a) lentic water body b) lotic water body and c) terrestrial zone. Lentic system includes forested wetland like marshes; lotic system includes forested streams. Streams were further categorized into large streams and narrow streams whereas terrestrial zone includes the woodland along with the fringe areas of forest (Table 1).

The sampling was done twice a day, in the morning

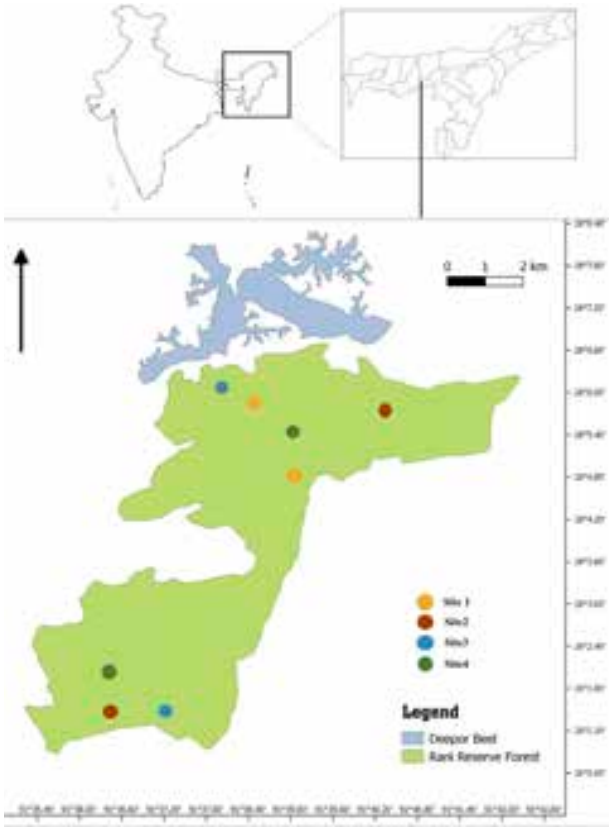


Figure 1. Study area at Rani Reserve Forest, Assam.

between 0700–1300 hrs and in the afternoon between 1400–1700 hrs. Sampling of odonates was done by the permanent belt transects method with fixed width (250x10m) and random forest trail. A total of four transects were laid on each site (with similar habitat type). In the case of lentic and lotic habitat, transects were laid along the edges of each waterbody. Thus, altogether a total of 16 transects were laid in the study area. Data were collected by direct search technique at the potential microhabitat of odonates. All the surveys and samplings were limited to sunny days when dragonflies are most active at the water bodies (Loiola & De Marco 2011). The photographs of the species were taken using a Canon 700D with a 90mm lens and those that could not be identified in the field were collected and carried to the laboratory for further identification.

### Collection and preservation

The specimens were collected using a sweeping net and were stored in 70% ethyl alcohol following the method employed by Subramanian et al. (2008). A few were dried on pins for further identification. All the odonates were identified following the standard literature of Fraser (1933, 1934, 1936), Mitra (2002a), Subramanian (2009), and Nair (2011). Web forums (Odonata of India, DragonflySouthAsia) were also used for finding the data records of species. All the examination, dissection and measurements were carried out under a Leica EZ4 E stereo zoom microscope.

### Data analysis

Biodiversity indices were used for the determination of species diversity at different sites. Shannon Wiener diversity index ($H^{/}$), Peilou's evenness index ($J^{/}$) were calculated using PAST ver. 3. Relative frequency and relative abundance of species were calculated. Species accumulation curves were created and Bray-Curtis cluster analysis (single link) was performed using Biodiversity Pro software version 2. The Odonata community structure of the study sites was compared.

Table 1. Selected sites in Rani Reserve Forest, Assam.

| Habitat type | Study sites | Co- ordinates | Number of transects | Habitat characteristics |
|---|---|---|---|---|
| Lentic water body (H1) | Site 1 (marshes) | 26.102°N 91.646°E 26.089°N 91.651°E | 4 | Bottom substrate is composed of clay and mud, rich in organic matter, surrounded by vegetation, high intensity of light penetration. |
| Lotic water body (Stream) (H2) | Site 2 (large streams) | 26.023°N 91.611°E 26.099°N 91.668°E | 4 | Sandy substrate at the bottom, open and wide, include streams in hilly terrains with rocks and boulders, deeper with many sunny patches. |
| | Site3 (small streams) | 26.109°N 91.642°E 26.023°N 91.627°E | 4 | Sandy substrate at the bottom, relatively closed and narrow, runs through dense vegetation, rarely wider than 2 meters, shallow with very less sunny patches, loaded with detritus |
| Terrestrial zone (H3) | Site 4 (woodland) | 26.097°N 91.650°E 26.097°N 91.650°E | 4 | Forest fringes covered with woody vegetation, less canopy cover |

## RESULTS

A total of 67 species belonging to 44 genera and 11 families represented by 5,197 individuals (Tables 2,3) were recorded from the study area including three species, *Onychothemis testacea* Laidlaw, 1902, *Philoganga montana* (Hagen in Selys, 1859), and *Indocnemis orang* (Förster in Laidlaw, 1907), which is the first published record from the state of Assam. Out of the total recorded species, the suborder Anisoptera was represented by four families 27 genera and 38 species whereas seven families 17 genera and 29 species were represented in the suborder Zygoptera.

The family-wise composition of odonates showed that out of the 11 families recorded, the highest number of species was from Libellulidae (43%) followed by Coenagrionidae (22%), whereas Philogangidae (1%) recorded the lowest number of species (Figure 2; Table 2). Based on the relative abundance (Table 2), it was found that *Brachythemis contaminata* (Fabricius, 1793) (14%) was the most dominant species followed by *Crocothemis servilia* (Drury, 1770) (8%). The greatest number of individuals of *B. contaminata* and *C. servilia* occurred in Site 4 (terrestrial woodland) of the study area with 415 individuals and 308 individuals, respectively. Species diversity and composition changes with respect to change in the microhabitat. Species richness, however, was the highest in Site 1 of RRF (32 species) and declined gradually in Site 4 (30 species), Site 2 (27 species), and lowest in Site 3 (22species) (Table 3, Figure 3). Out of the 11 families recorded, all of them were sighted in Site 2 of the forested streams (Figure 3), which is characterised by open canopy and high light intensity. The Shannon diversity index also indicated that odonate diversity in lentic water body (Site 1) is relatively diverse (2.95) followed by terrestrial woodland zone (Site 4) (2.86) and narrow stream of lotic system (Site 3) (2.64). The lowest diversity was observed at Site 2 (2.35) of the lotic water body which is characterised by a large stream with open area. The Simpson indices, however, also showed that Site 1 (0.92) and Site 4 (0.92) are relatively more diverse than all other sites (Table 3) whereas species evenness was highest in Site 3.

Species abundance varied across seasons in different habitat of the Rani Reserve Forest. In Site 1 of the study area, the highest number of individuals of odonates was recorded during pre-monsoon in March 2015 (116 individuals) while the lowest was recorded during the post-monsoon in November 2016 (8 individuals) (Figure 4). In Site 2 on the other hand, species abundance peaked during the monsoon season which recorded the highest individual in September 2017 (49 individuals) whereas declined sharply during winter (Figure 5). In Site 3, the highest number of individuals of odonates were recorded during the pre-monsoon season in May 2016, (27 individuals) and showed a sharp decline during winter (Figure 6). In Site 4, the species abundance showed a sharp peak during pre-monsoon with the highest individuals in May 2016 (142 individuals) and gradually decline towards post monsoon (Figure 7).

The species accumulation curve when plotted for each sampling site reached its stability (asymptote) at 67 species after 140 sampling replicates (Figure 8). Cluster analysis dendogram (Figure 9) based on Bray-Curtis' similarity of Odonata assemblage in different habitats showed two major branches within 0–50 % similarity distance. Species harboured in the stream had species assemblage most dissimilar to other habitat types and appeared as a separate group. Meanwhile species of lentic and terrestrial woodland zone had similar species assemblages and are clustered accordingly. Stream dwelling odonates showed analogous segregation to different types of streams. Species like *Euphaea ochracea* Selys, 1859 and *Aristocypha quadrimaculata* Selys, 1853 were predominantly found in the larger streams (Figure 11). These species were observed to occur in forest cover with plenty of sunny patches. Other species like *Coeliccia bimaculata* Laidlaw, 1914, *Coeliccia didyma* (Selys, 1863) were also found to share similar closed habitat and prefer shady places nearby smaller streams (Figure 12). Species like *Brachythemis contaminata*, *Crocothemis servilia*, and *Palpopleura sexmaculata* (Fabricius, 1787), however, were observed to prefer open habitat and were usually found to occur in standing water and perching in forest fringes, terrestrial woodland (Figures 10, 13). Other than this, habitat requirements were found to be seen overlapping in many species like *Euphaea ochracea* which occur predominantly in both shady and open forested streams.

Five species belonging to the genus *Macromia* Rambur, 1842 (Image C), *Zygonyx* Hagen, 1867 (Image A), *Calicnemia* Strand, 1928 (Image M) *and Protosticta* Selys, 1885 (Image P) could not be identified. Field notes of first published records of the species from Assam are also provided herewith. All the three species are rare and scarcely reported, known only from handful of records.

***Onychothemis testacea* Ris, 1912 (Libellulidae) (Image B).**

This species was found predominantly in the larger streams of the study area (Figure 11) during the pre-

**Table 2. Checklist of Odonata fauna recorded in the study area with their relative abundance. (species marked in asterisk * are recorded less than 3 individual each)**

| | Family | Species | IUCN Category | Relative abundance |
|---|---|---|---|---|
| 1 | **Aeshnidae** | *Gynacantha khasiaca* MacLachlan, 1896 | DD | 0.002 |
| 2 | | *Gynacantha dravida* Lieftinck, 1960 | DD | 0.002 |
| 3 | | *Gynacatha bayadera* Selys, 1891 | Unknown | 0.002 |
| 4 | **Gomphidae** | *Burmagomphus sp.* Williamson, 1907 | Unknown | 0.002 |
| 5 | | *Heliogomphus spirillus* (Fraser, 1922) | DD | 0.008 |
| 6 | | *Ictinogomphus rapax* (Rambur, 1842) | LC | 0.060 |
| 7 | | *Paragomphus lineatus* (Selys, 1850) | LC | 0.029 |
| 8 | | *Macrogomphus annulatus* (Selys, 1854) | DD | 0.004 |
| 9 | **Macromidae** | *Macromia sp.* Rambur,1842 | Unknown | 0.014 |
| 10 | **Libellulidae** | *Brachythemis contaminata* (Fabricius, 1793) | LC | 0.145 |
| 11 | | *Rhodothemis rufa* (Rambur, 1842) * | LC | 0.000 |
| 12 | | *Rhyothemis variegata* (Linnaeus, 1763) | LC | 0.026 |
| 13 | | *Neurothemis intermedia* (Rambur, 1842) | LC | 0.022 |
| 14 | | *Neurothemis tullia* (Drury, 1773) | LC | 0.007 |
| 15 | | *Neurothemis fulvia* (Drury, 1773) | LC | 0.038 |
| 16 | | *Brachydiplax sobrina* (Rambur, 1842) | LC | 0.010 |
| 17 | | *Palpopleura sexmaculata* (Fabricius, 1787) | LC | 0.029 |
| 18 | | *Potamarcha congener* (Rambur, 1842) | LC | 0.022 |
| 19 | | *Orthetrum pruinosum* (Burmeister, 1839) | LC | 0.032 |
| 20 | | *Orthetrum luzonicum* (Brauer, 1868) | LC | 0.031 |
| 21 | | *Orthetrum sabina* (Drury, 1770) | LC | 0.061 |
| 22 | | *Orthetrum triangulare* (Selys, 1878) | LC | 0.005 |
| 23 | | *Orthetrum glaucum* (Brauer, 1865) | LC | 0.016 |
| 24 | | *Orthetrum chrysis* (Selys, 1891) | LC | 0.009 |
| 25 | | *Crocothemis servilia* (Drury, 1770) | LC | 0.085 |
| 26 | | *Tholymis tillarga* (Fabricius 1798) | LC | 0.021 |
| 27 | | *Urothemis signata* (Rambur, 1842) | LC | 0.008 |
| 28 | | *Trithemis festiva* (Rambur, 1842) | LC | 0.003 |
| 29 | | *Trithemis pallidinervis* (Kirby, 1889) | LC | 0.016 |
| 30 | | *Trithemis aurora,* (Burmeister, 1839) | LC | 0.001 |
| 31 | | *Diplacodes trivialis* (Rambur, 1842) | LC | 0.025 |
| 32 | | *Brachydiplax chalybea* Brauer, 1868 | LC | 0.026 |
| 33 | | *Pantala flavescens* (Fabricius, 1798) | LC | 0.026 |
| 34 | | *Acisoma panorpoides* Rambur, 1842 | LC | 0.005 |
| 35 | | *Onychothemis testaceae* Laidlaw, 1902 | LC | 0.011 |
| 36 | | *Zygonyx sp.* Hagen, 1867 | Unknown | 0.008 |
| 37 | | *Aethriamanta brevipennis* (Rambur, 1842) | LC | 0.002 |
| 38 | | *Camacinia gigantea* (Brauer, 1867) * | LC | 0.000 |
| 39 | **Coenagrionidae** | *Ceriagrion cerinorubellum* (Brauer, 1865) | LC | 0.029 |
| 40 | | *Ceriagrion rubaie* Laidlaw, 1916 | Unknown | 0.001 |
| 41 | | *Ceriagrion olivaceum* Laidlaw, 1914 | LC | 0.006 |
| 42 | | *Ceriagrion coromandelianum* (Fabricius, 1798) | LC | 0.044 |
| 43 | | *Agriocnemis pygmaea* (Rambur, 1842) | LC | 0.016 |

| | Family | Species | IUCN Category | Relative abundance |
|---|---|---|---|---|
| 44 | | *Agriocnemis clauseni* Fraser, 1922 | LC | 0.006 |
| 45 | | *Agriocnemis pieris* Laidlaw, 1919 | LC | 0.009 |
| 46 | | *Agrocnemis lacteola* Selys, 1877 | LC | 0.007 |
| 47 | | *Agriocnemis femina* (Brauer, 1868) | LC | 0.021 |
| 48 | | *Ischnura aurora* (Brauer, 1865) | LC | 0.005 |
| 49 | | *Onychargia atrocyana* (Selys, 1865) | LC | 0.005 |
| 50 | | *Pseudagrion microcephalum* (Rambur, 1842) | LC | 0.004 |
| 51 | | *Pseudagrion decorum* (Rambur, 1842) | LC | 0.001 |
| 52 | | *Aciagrion pallidum* Selys, 1891 * | LC | 0.000 |
| 53 | | *Mortonagrion aborense* (Laidlaw, 1914) | LC | 0.011 |
| 54 | **Chlorocyphidae** | *Libellago lineata* (Burmeister, 1839) | LC | 0.013 |
| 55 | | *Aristocypha quadrimaculata* Selys, 1853 | LC | 0.012 |
| 56 | **Platycnemididae** | *Calicemia miles* (Laidlaw, 1917) | LC | 0.005 |
| 57 | | *Calicnemia sp*. Strand, 1928 | Unknown | 0.004 |
| 58 | | *Copera marginepes* (Rambur, 1842) | LC | 0.001 |
| 59 | | *Copera vittata* Selys, 1863 | LC | 0.002 |
| 60 | | *Indocnemis orang* (Förster in Laidlaw, 1907) * | LC | 0.000 |
| 61 | | *Coeliccia bimaculata* Laidlaw, 1914 | LC | 0.001 |
| 62 | | *Coeliccia didyma* (Selys, 1863) | LC | 0.001 |
| 63 | | *Coeliccia schmiditi* Asahina, 1984 | DD | 0.003 |
| 64 | **Euphaeidae** | *Euphaea ochracea* Selys, 1859 | LC | 0.064 |
| 65 | **Platistictidae** | *Protosticta sp.* Selys, 1855 * | Unknown | 0.000 |
| 66 | **Calopterygidae** | *Neurobasis chinensis* (Linnaeus, 1758) | LC | 0.010 |
| 67 | **Philogangidae** | *Philoganga montana* (Hagen in Selys, 1859) * | LC | 0.000 |

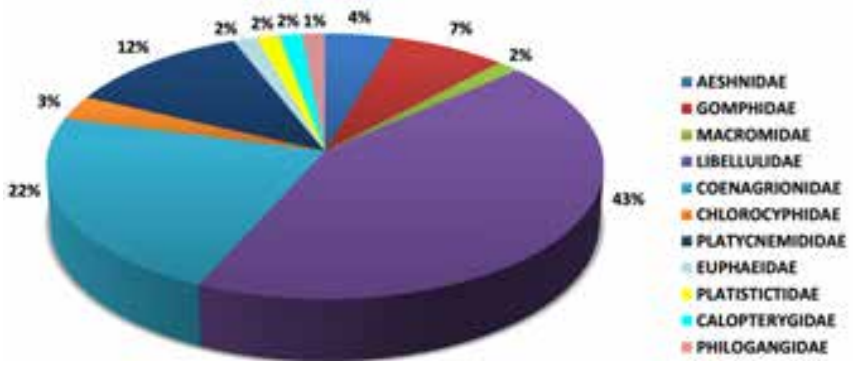


**Figure 2. Percentage composition of odonates (family wise) in Rani Reserve Forest.**

monsoon season in May and June. Altogether, four individuals of these species were observed to occur in forest cover with plenty of sunny patches. The males were usually found perching on the dry twigs over forested streams and were aggressively chasing other dragonflies in its territory. The male is black coloured with metallic lustre and easily identified by its prominent yellow bands along the abdomen and synthorax. Eyes are green in colour. Wings hyaline with brown in the apices.

***Philoganga montana* Selys, 1859 (Philogangidae) (Image F).**

The species was observed in the month of July and is found to be associated with freshwater habitat. Only a single individual was sighted in a belt transect of 250x10

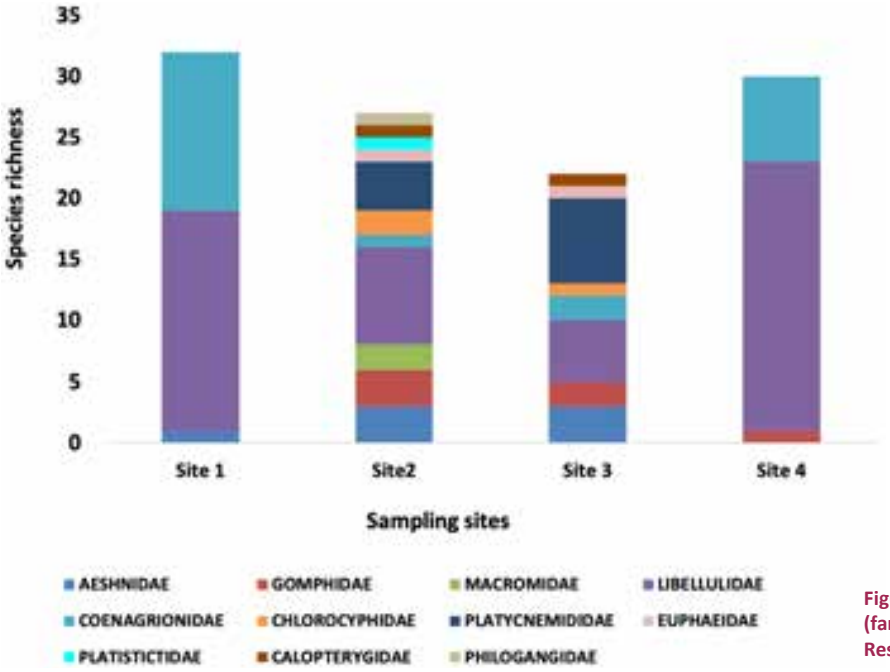


**Figure 3. Species composition of odonates (family wise) at different sites of Rani Reserve Forest.**

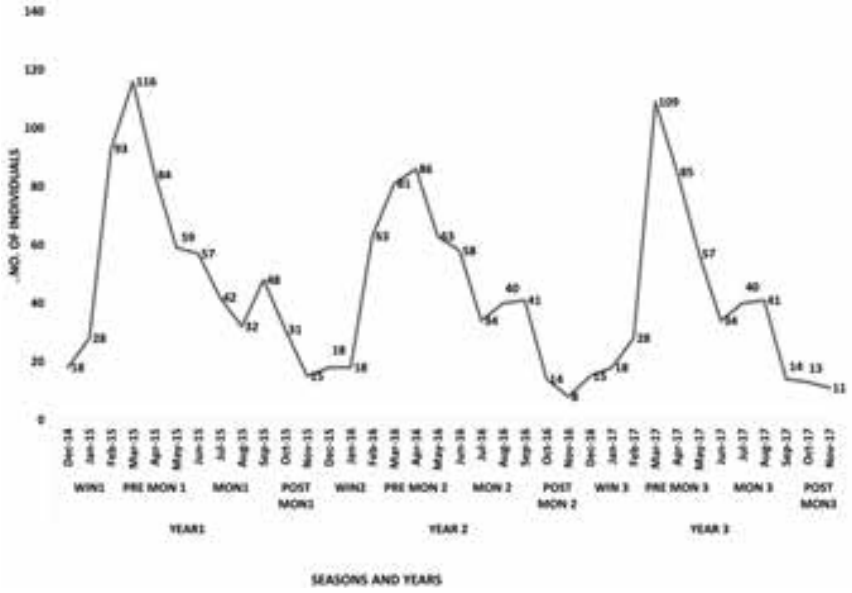


**Figure 4. Seasonal variation of odonates in Site 1 (Marshes).**

m in sunny patches of larger stream (144m) with sandy substrate. It was observed that *P. montana* does not appear to be active and prefers to perch on overhanging branching twigs of trees 1–2 m above the water surface. While perching in the hanging position, the wings were spread horizontally. The female is known to oviposit in the bark of the tree. Flight of the species is relatively low. This species is facing serious threat of habitat loss due to deforestation. The species of this genera are quite robust in size with large head and rounded eyes. The male is predominantly matte black coloured on dorsum with blue markings in thorax extending towards segment 1 and segment 2. Abdomen distinctly longer than wings or extending at least to wing tips. Wings hyaline. Anal appendages black. Superiors longer than segment 10. Legs black.

***Indocnemis orang* (Förster in Laidlaw, 1907) forma *orang* (Platycnemididae) (Image G,H).**

Two individuals were sighted during the survey. *I.*

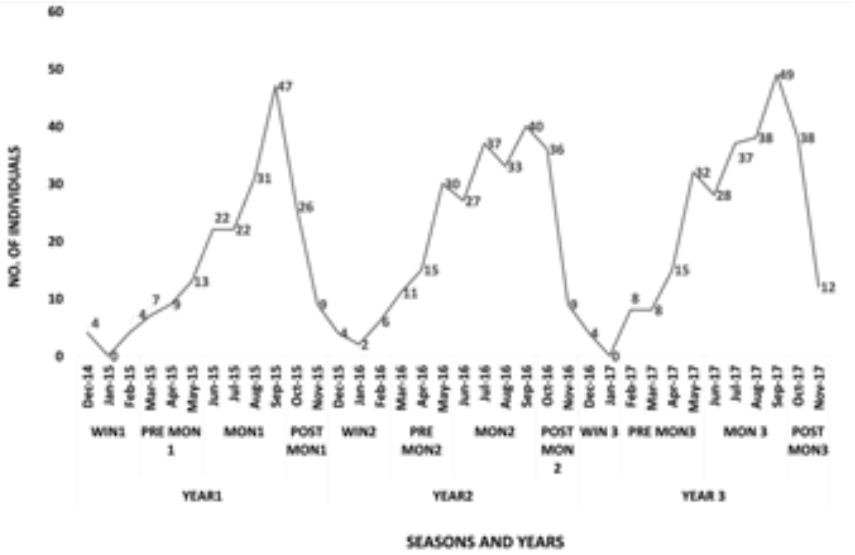


Figure 5. Seasonal variation of odonates in Site 2 (larger stream).

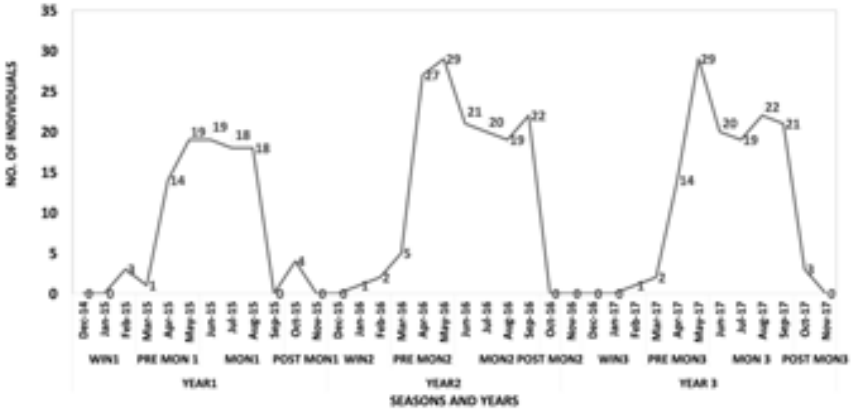


Figure 6. Seasonal variation of odonates in Site 3 (narrower stream).

*orang* was found perching on overhanging vegetation in the sun flecked patches near the stream with the sandy bottom. The matured male species is steely black coloured with light blue and citron coloured thoracic markings. Segments 9 and 10 of abdomen is light blue coloured dorsally. Wings hyaline, pterostigma black. Legs black. The species can be identified by a large shield-shaped stripe on synthorax which is light blue coloured in matured male. Cerci black with blue marking dorsally. Immature male species is similar except the thoracic shield is citron coloured.

## DISCUSSION

The Odonata occupies almost all kinds of habitats along the permanent gradient ranging from running waters and lakes to small temporary rain pools (Corbet 1999). Habitat structures are known to affect the suitability of an area for odonates (Hawking & New 1999). Our study demonstrates that Odonata diversity and distribution vary across different sites of the Rani Reserve Forest. This variation is probably determined by the interaction between intrinsic habitat and extrinsic environmental parameters. Odonata fauna of RRF is primarily dominated by Libellulidae that comprises 43% of the total species richness. Novelo-Gutiérrez & Gómez-Anaya (2009) also reported that Libellulidae gathers most of the Odonata species with wider distribution and richness. This follows a general trend which is also widely represented in surveys locally and globally (Rashid et al. 2001; Salmah 1996; Salmah & Afzan 2004). The larger body size of the species in this family may be the cause of greater dispersion and distribution (Dalzochio et al. 2011).

Of the total families which were recorded in the study area, all were found to occur in the larger stream of the lotic system. This is probably because of the open

**Table 3. Diversity of odonates at different sites of study area.**

| Landuse type | No. of species | No. of individuals | Diversity Index (H') | Evenness (J') | Simpsons (1-D) |
|---|---|---|---|---|---|
| Site1 | 32 | 1665 | 2.95 | 0.59 | 0.92 |
| Site2 | 27 | 645 | 2.35 | 0.39 | 0.81 |
| Site3 | 22 | 414 | 2.64 | 0.63 | 0.90 |
| Site4 | 30 | 2473 | 2.86 | 0.58 | 0.92 |

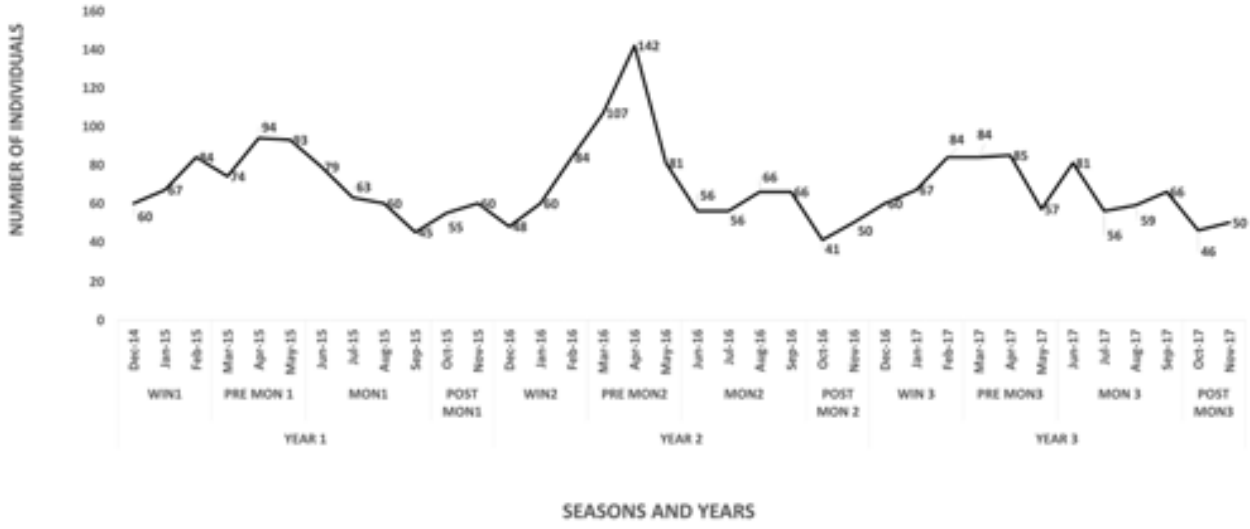


**Figure 7. Seasonal variation of odonates in Site 4 (terrestrial zone).**

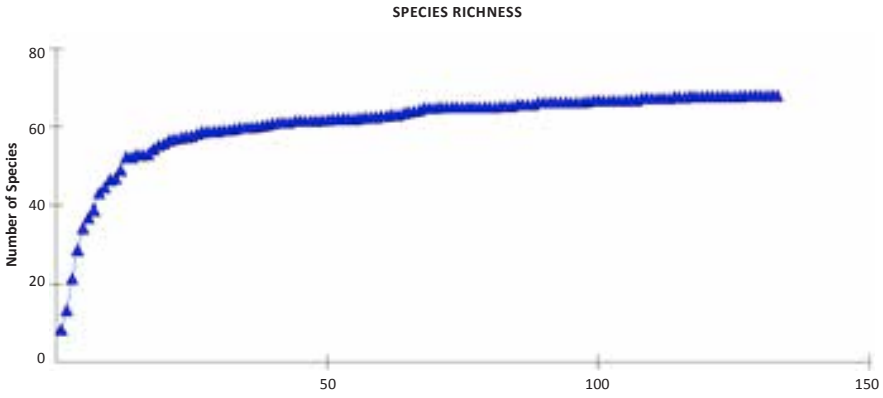


**Figure 8. Species accumulation curve.**

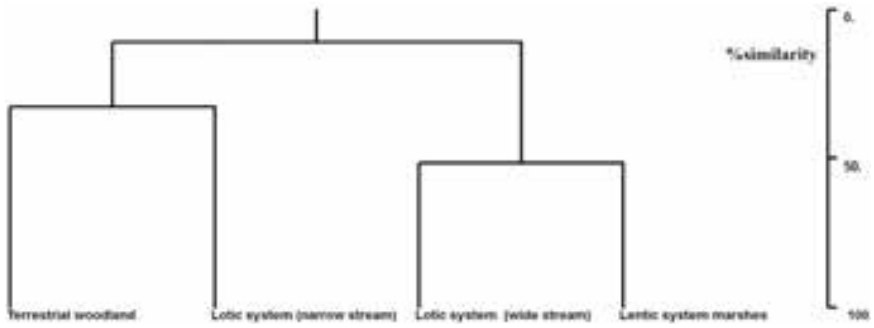


**Figure 9. Cluster analysis of Bray-Curtis similarity indices in different sites of Rani Reserve Forest.**

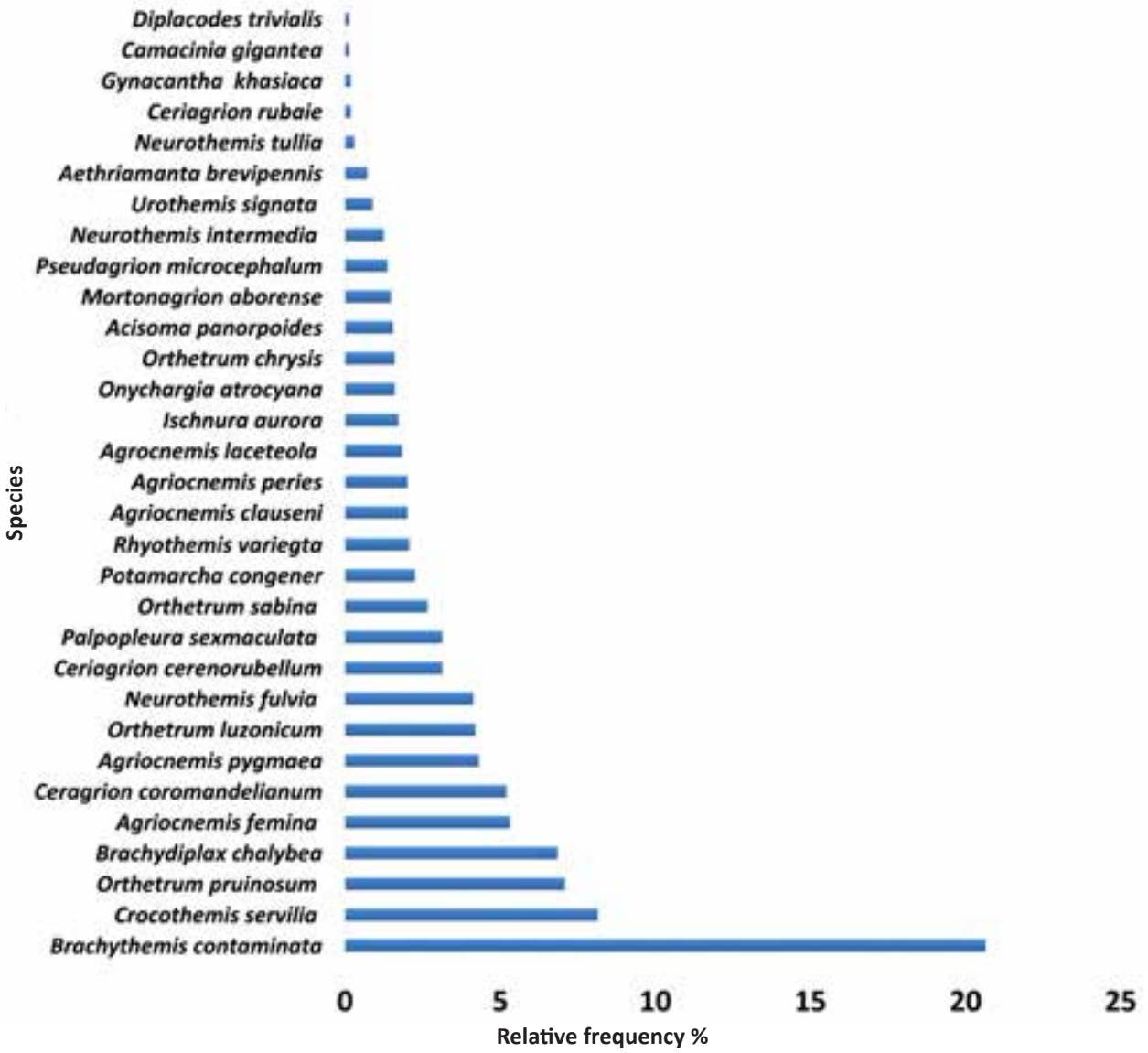


**Figure 10. Frequency distribution of odonates in Site 1 (lentic system).**

canopy cover and the presence of riparian vegetation nearby. The surrounding riparian vegetation plays a great role in supporting numerous life activities of odonates like foraging, perching structures for thermoregulation, nocturnal roosting, mate attraction, copulation, protection from unfavourable weather conditions and emergence (Buchwald 1992, Wildermuth 1993, McKinnon and May 1994, Rouquette and Thompson 2007). Moreover, the balance of sun and shade caused from the nearby vegetation is also an important factor resulting in the habitat selection (Dijkstra & Lempert 2003).

Highest species richness and species diversity was recorded in the lentic system (Site 1) relative to lotic (Site2, Site3) and terrestrial woodland habitat (Site 4). Higher number of species in lentic system can be linked to higher colonisation rate of widespread generalist species such as libellulids (Subramanian et al. 2008). However, heterogeneity in vegetation, availability of resources and openness of water bodies might provide good breeding sites for many odonate species (Bond et al. 2006). Moreover, the declination of odonate species diversity and abundance during the post monsoon and winter season are probably associated with habitat dryness and differences in microhabitat conditions compared to the monsoon and pre-monsoon seasons. Field observations suggested that the physical attributes of a particular habitat changes with the change in season, resulting in the seasonal variation of species. But different species may respond differently to habitat

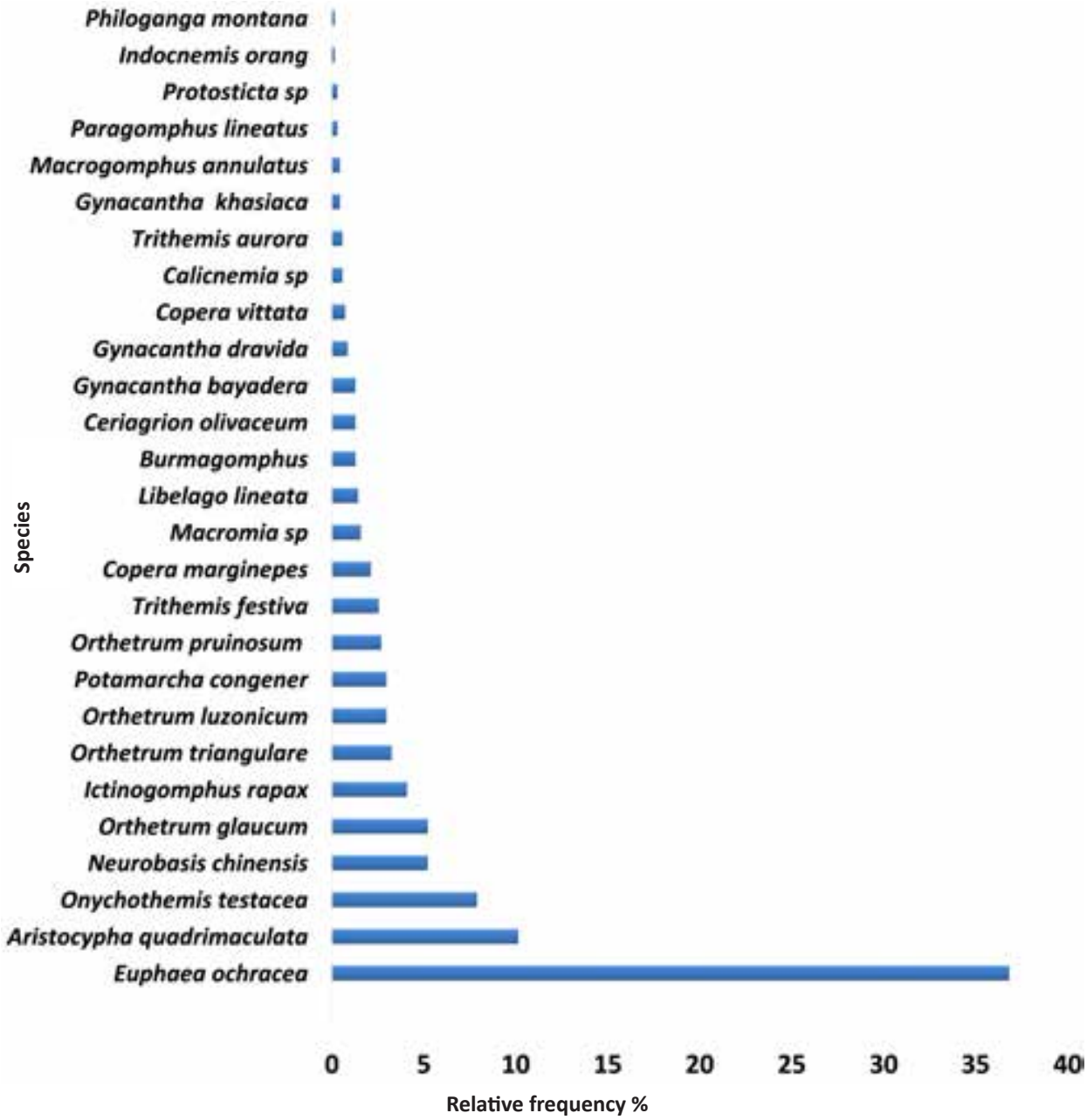


**Figure 11. Frequency distribution of odonates in Site 2 (lotic system).**

factors and environmental parameters affecting diversity. Hence summarising them without due consideration of habitat variability and other factors will not give the conclusion. Our current data do not reveal this pattern of seasonality affecting the diversity with abiotic factors.

The present study also revealed that communities of forest streams, however, segregate from other habitat types and supports many unique species. Similar were the findings of Dijkstra & Lampert (2003) which reported that odonates of running water are strongly selected by their habitat. Subramanian et al. (2011) also reported in their findings that stenotypic Odonata are mostly found in the streams. Species belonging to the family Platystictidae, Platycnemididae, and Euphaeidae usually remain restricted to closed canopy forested streams, dense riparian vegetation forested landscape which was similar to the findings of Koparde et al. (2014). In the present study *Euphaea ochracea* was found to occur predominantly in both larger streams and smaller streams. Overlapping of habitat requirements may

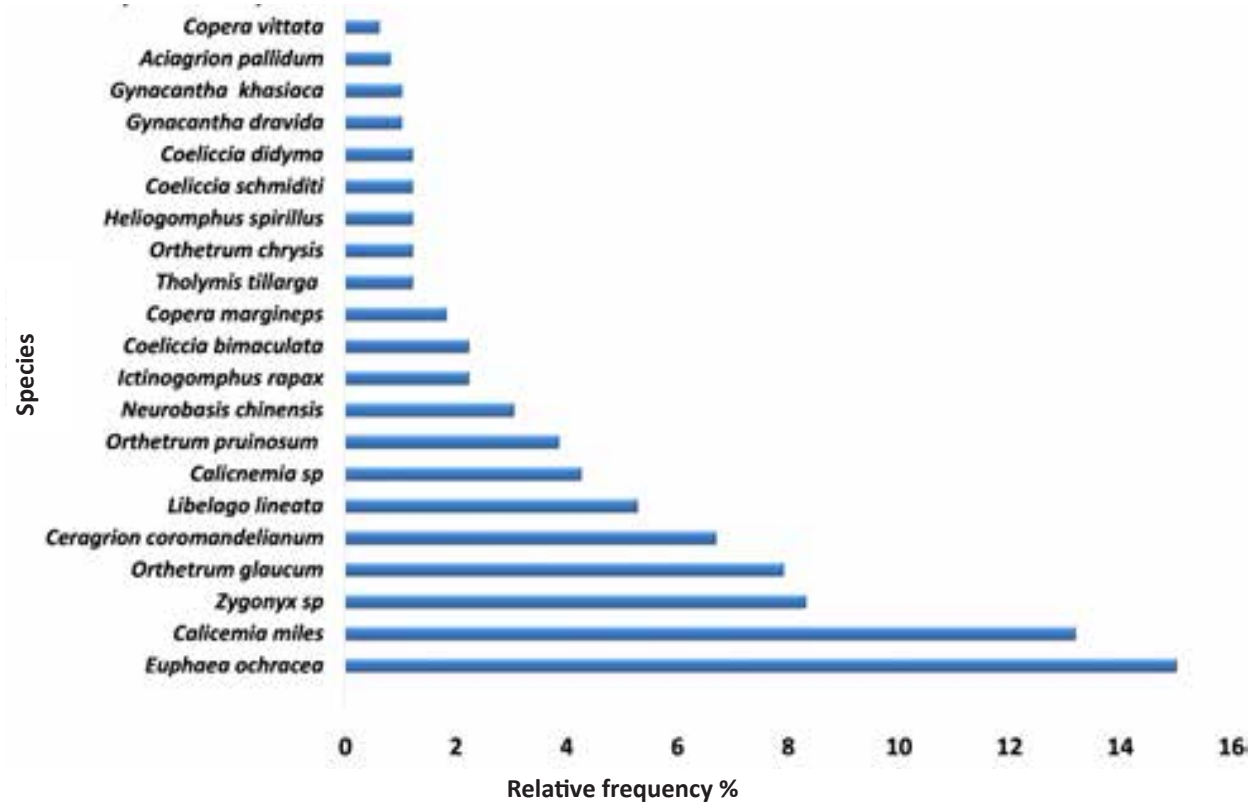


**Figure 12. Frequency distribution of odonates in Site 3 (lotic system).**

be the reason for the occurrence of species such as *Euphaea ochracea* in both larger and narrower streams. Spatial distribution of lotic species can be attributed due to differences in current velocity of water and respiratory physiology of the respective species (Zahner 1959, 1960).

The odonate fauna assemblage also showed clear distinction in the transition from smaller streams towards larger forested wetland systems. The dominance of Zygoptera like *Calicnemia miles* and species belonging to genus *Coeliccia* in the lotic systems (narrow streams) may be attributed due the heterogeneity of dense riparian vegetation which reduces the light input but also generates a more stable thermal environment (Dijkstra & Lempert 2003).

Many stenotypic species are narrowly distributed and occur only in small patches of suitable habitats (Koparde et al. 2014). Streams in high canopy forests have very low similarity in species composition compared to other forest wetlands (Koparde et al. 2015) which corresponds to our study as well. In the present study, *Onychothemis testacea* were found to prefer open sunny patches in rapidly flowing stream. Nair (2011) also reported that *O. testacea* inhabits fast flowing streams, waterfalls and areas surrounded by dense forest. Rangnekar & Naik (2014) on the other hand, reported this species from Goa and were found to occur in shady places. The preference of openness and shade may probably be because of the habitat requirements of the species. Previous records of *O. testacea* from Maharashtra is by Prasad (1996) and Koparde et al. (2014, 2015). Other spatial records of this species are also retrieved across the south to various localities of northeastern India including Assam in public domain www. indianodonata.org (Anonymous 2020a) which signifies the range extension of species.

*Philoganga montana* was previously reported from Bangladesh, Myanmar (Mitra 2002b) and is commonly found around Phewa Tal lake in Pokhara Valley in central Nepal (Kemp & Butler 2001). Very little information is available about this species. The species is also known to occur from West Bengal (Lahiri 1987; DragonflySouthAsia 2020) and was recorded from Bhutan very recently by Gyeltshen (2017). Previously *P.montana* has been reported in northeastern India from Shillong, Khasi Hills of Meghalaya at two localities bordered by montane stream (Fraser 1934). Lahiri (1987) again reported it from Shillong, Umran, Urmoi, Garampani of Meghalaya. Distributions of this species is also known from Arunachal Pradesh (Anonymous 2020b) (media code: br805), however, it has not been formally recoded from Assam.

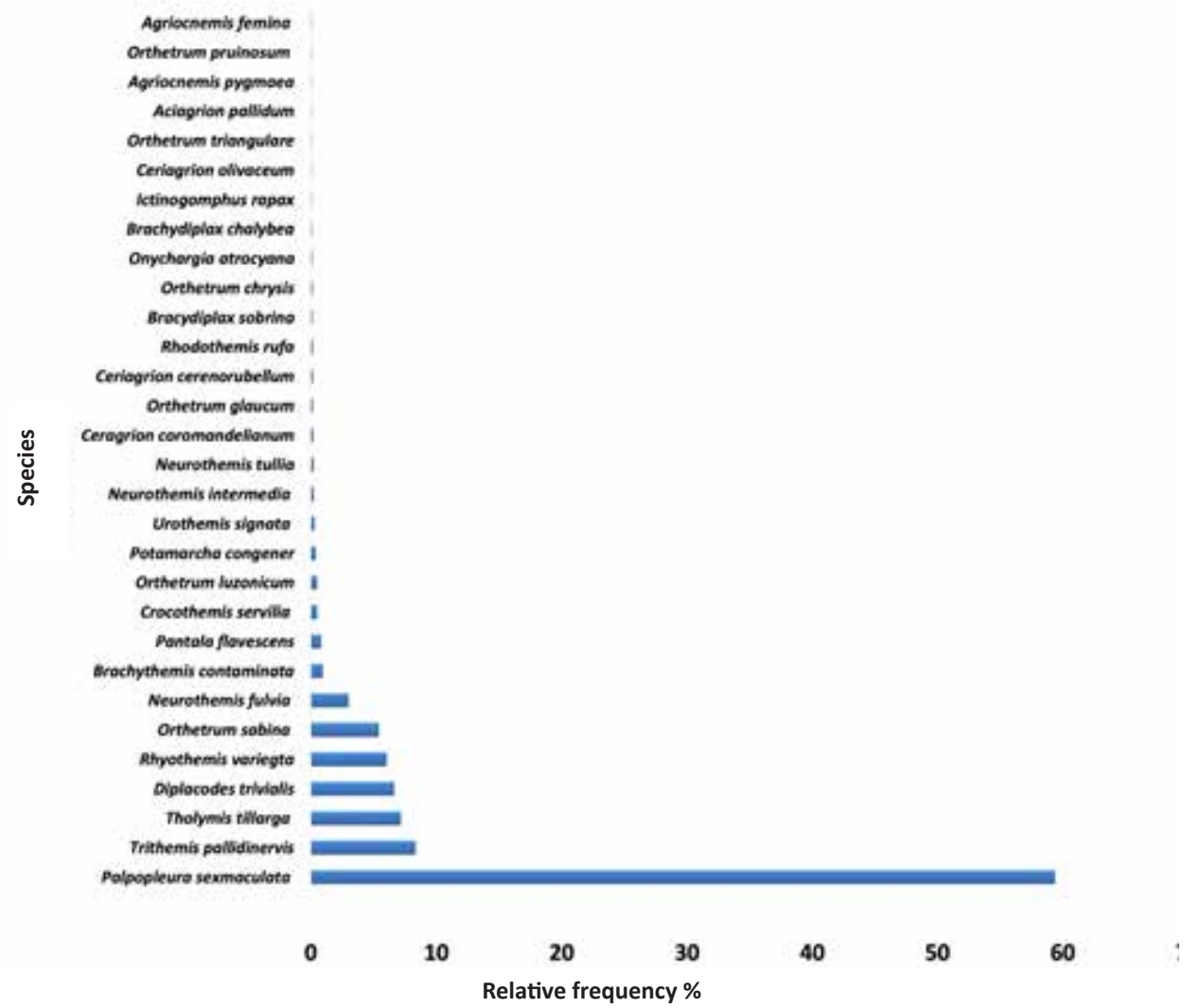


**Figure 13. Frequency distribution of odonates in Site 4 (terrestrial zone).**

*P. montana* inhabit montane stream at relatively high altitude. But the present study revealed the occurrence of this species from Assam at low altitudes (144m), which indicates the range extension of this species southwards Assam towards plains.

The genus *Indocnemis* on the other hand consists of only one species Asahina (1997). However, *I. orang* has two forms differing in size: *I. orang* originally described from Malaysia is slightly smaller than the second form *I. kempi* from Assam (Asahina 1997). Norma Rashid (2003) stated that this species is common in cleared forested streams which also corresponded to our study as well. *I. orang* in this paper are similar to the description of Toan (2018) in respect of the large dorsal shield on the synthorax and dark cerci which are entirely black or with blue mark dorsally. Records from public domain (Anonymous 2020c) also shows the occurrence of this species in Arunachal Pradesh (media code: am354). The present record from Assam, however, reveals the range extension of this species southwards and also from higher altitude to lower altitude.

Thus, the presence of lentic and lotic freshwater systems of the area along with the heterogeneity in forest vegetation supports a diverse community of odonates in RRF. These numbers of Odonata species demonstrate the need for more intensive surveys to document the complete fauna of Odonata in this area and hence its conservation is directly linked to the conservation of ecosystem health. The stenotypic species are strongly specific to a narrow range of habitat and the grave and accelerating destruction of habitats may cause serious threats to such habitat specific group of odonate species. Therefore, to ensure the conservation of such species, the protection of their microhabitat is highly


Image 1. Photographic records of species sighted: A—*Zygonyx* sp. | B—*Onychothemis testacea* | C—*Macromia* sp. | D—*Heliogomphus spirillus* | E—*Burmagopmphus* sp. | F—*Philoganga montana* | © Dipti Thakuria


Image 2. Photographic records of species sighted: G—*Indocnemis orang* (mature male) | H—*Indocnemis orang* (immature male) | I—*Aristocypha quadrimaculata* | J—*Calicnemia miles* (male) | K—*Calicnemia miles* (female) | L—*Ceriagrion rubiae* | M—*Calicnemia* sp. | N—*Agriocnemis pieris*. © Dipti Thakuria


**Image 2. Photographic records of species sighted: O—*Coeliccia didyma* | P—*Protosticta* sp. © Dipti Thakuria**

important. This study provides baseline data on local habitat association of Odonata. The information can be used as evidence in formulating conservation measures in RRF where cutting and felling of trees is continued illegally.

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# An assessment of the population status of the threatened medicinal plant *Illicium griffithii* Hook.f. & Thomson in West Kameng District of Arunachal Pradesh, India

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**Abstract:** *Illicium griffithii* Hook.f. & Thomson, a medicinal plant of the family Schisandraceae, is an Endangered species listed by the IUCN. A decline in population of this plant due to climate change as well as increasing human influences on the natural resources has been a matter of great concern among the researchers. In order to estimate the existing population of this plant, a field-based study employing linear transect method was conducted in four phases, May–June 2017, May–June 2018, April–May 2019, October–November 2019 covering an area of 700km² (approx.) in West Kameng District of Arunachal Pradesh that lies within the Himalayan biodiversity hotspot. The study recorded 3,044 live individuals of *I. griffithii* including 1,372 seedlings, 1,358 saplings, and only 314 mature trees. Additionally, 126 dead trees were also recorded. The study confirmed that the plant has a good regeneration rate but with a poor survival rate of saplings. Besides, large-scale collection of its fruits for trade and anthropogenic disturbances in the study area appears to be the major threat to its existing population. Therefore, proper training of the local people on large-scale cultivation of this plant together with awareness towards judicious harvesting of fruits from the wild may be the significant approach to conservation.

**Keywords:** Endangered species, regeneration, survival, risk assessment.

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**Author contribution:** Both the authors have contributed to the conception and design of the study. Tashi Dorjee Bapu collected, tabulated, and analyzed the field data and wrote the first draft of the manuscript. Dr. Gibji Nimasow helped in data analysis, interpretation of the results and commented on the first draft, then endorsed the final manuscript.

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## INTRODUCTION

People largely depend on plants for food security and a multitude of plant products, from medicine to fibre. In short, plants are vital to our existence, which enhances our lives in innumerable ways. Medicinal plants are an important source of raw material for traditional medicines and a large number of people derive employment and income from collection, processing and trade of these plants (Sarma & Sharma 2014; Bapu & Nimasow 2019). Today biodiversity and ecosystems (home to medicinal plants and other raw materials) are facing threat from over exploitation, habitat loss and fragmentation (Bapu & Nimasow 2018), climate change, pollution and invasion of alien species (IUCN 2003) and disturbance of community structure (Novacek & Cleland 2001).

The present population and regeneration status largely determines the existence of the species and is significant in conservation management. The regeneration status of a species is usually assessed from the population dynamics of seedlings and saplings in a forest community (Duchok et al. 2005). The age and diameter of a plant have been the basis for the prediction of regeneration status of tree species according to several researchers (Pritts & Hancock 1983; Khan et al. 1987; Bhuyan et al. 2003; Duchok et al. 2005). The presence of sufficient seedlings, saplings and young trees and the ability of the seedlings and saplings to survive and grow largely portray the successful regeneration of the species (Good & Good 1972; Saxena & Singh 1984). Although the species habitat changes over time naturally, the exposure to human interference and other causative factors largely influence the species structure and regeneration. The number of seedlings and saplings in an area allows assessing the regeneration potential of a species (Saxena & Singh 1984).

*Illicium griffithii* Hook.f. & Thomson belongs to the family Schisandraceae (Kew Science 2019). It is distributed sporadically in Bhutan, Hongkong, Vietnam, and India (Dung et al. 1995; Mukhia 2006). In Arunachal Pradesh, it occurs mostly in subtropical and temperate broad-leaved forests of West Kameng, Tawang, Lohit, and Lower Subansiri districts (Paul et al. 2013) and in very small numbers in Pakke Tiger Reserve of East Kameng District (Tag et al. 2012). It is an important medicinal plant of the temperate broad-leaved forests of northeastern India (Saha & Sundriyal 2010) with an average life span of 25–30 years (IUCN). This species is observed to be present in the second and third storey in the forest stratification in Arunachal Pradesh (Kaul & Haridasan 1987). It is known by different names in different places, most commonly as 'Lishi' / 'Lissi'. It is called "Domburshing" and "Munsheng" by Monpas of West Kameng and Tawang, "Taihelang" by Apatanis, Loshsing/Loshu by Membas (Paul et al. 2013) and "Anasphal" in Hindi. The fruits are star-shaped, consisting of 7–13 follicles / carpels, containing one seed each. These seeds in the fruits contains shikimic acid which is used for manufacturing antiviral / anti influenza drug Tami flu (Ghosh et al. 2012; Cui et al. 2014; Candeias et al. 2018). About 41 constituents of essential oils have been identified from the fruits and seeds that consists mainly of 4-methyl-6-(2-propenyl)-1,3-benzodioxole, linalool, p-methoxy phenyl acetone, terpinen-4-ol, limonene and safrole (Dutta et al. 1997; Saraswathy et al. 2010), for which it has high demand in the spice and perfumery industries. Recently, scientists have also found cancer fighting properties especially against lung cancer cells (Vijayakumar et al. 2012). Traditionally, the carpels of fruits are used for flavouring butter-salted tea (Inchaa-Jhaa/Tsaajhaa) and to increase the potency of 'Ara' (local wine) by 'Monpas' of West Kameng and Tawang districts of Arunachal Pradesh (Bapu & Nimasow 2017). It is also used as medicine to cure cough, toothache, abdominal pain and food poisoning by the local people and is considered carminative, stomachic, and galactagogic (Hung et al. 2016). *Illicium* flowers from January to April and fruiting occurs by the end of April (Saha & Sundriyal 2010) and it matures by September end.

International Union for Conservation of Nature and Natural Resources (IUCN) reported a decline in the habitat of *I. griffithii* due to land use changes and unregulated collection of seeds, fruits and tree felling. Further, the experts in Conservation Assessment and Management Plan (CAMP) workshop, 2003 reported a decline of more than 60% of its population over 84 years (three generations length). Hence, the species has been enlisted as Endangered in IUCN Red Data Book (Saha et al. 2015). It is reported to be Critically Endangered in Meghalaya and Near Threatened in Arunachal Pradesh (Ved et al. 2003, 2005). Paul et al. (2013) reported that the plant is found growing abundantly in the natural forests of Arunachal Pradesh, but raised concern about its endangerment due to localized distribution, occurrence in unprotected areas with high anthropogenic disturbances and adverse impact of climate change. Further, the local people used to collect its fruits from the forests for their nominal source of income (Duchok et al. 2005; Bapu & Nimasow 2019) and fell the trees for fuel wood and other purposes (Bapu & Nimasow 2017). Therefore, in the present study, an attempt has

been made to examine the current population structure and regeneration status of *I. griffithii* in the wild so as to understand the future prospects of its regeneration.

## STUDY AREA

The study was carried out in West Kameng District of Arunachal Pradesh (Figure 1) covering an area of about 700km² out of the total 5,013km². The study area is located in between 27.083–27.833°N & 92.083–92.416°E. The district shares an international boundary with Bhutan in the west and is bordered by Sonitpur and Darrang districts of Assam in the south, East Kameng District in the east and Tawang District in the north. The topography of the district is mostly mountainous and its greater part falls within the higher mountain zone, consisting of tangled peaks and valley. The study area was selected on the basis of the reports of large-scale exploitation of *I. griffithii* (Image 1) for medicinal purposes from the district in the past decades (Kalita & Khan 2013).

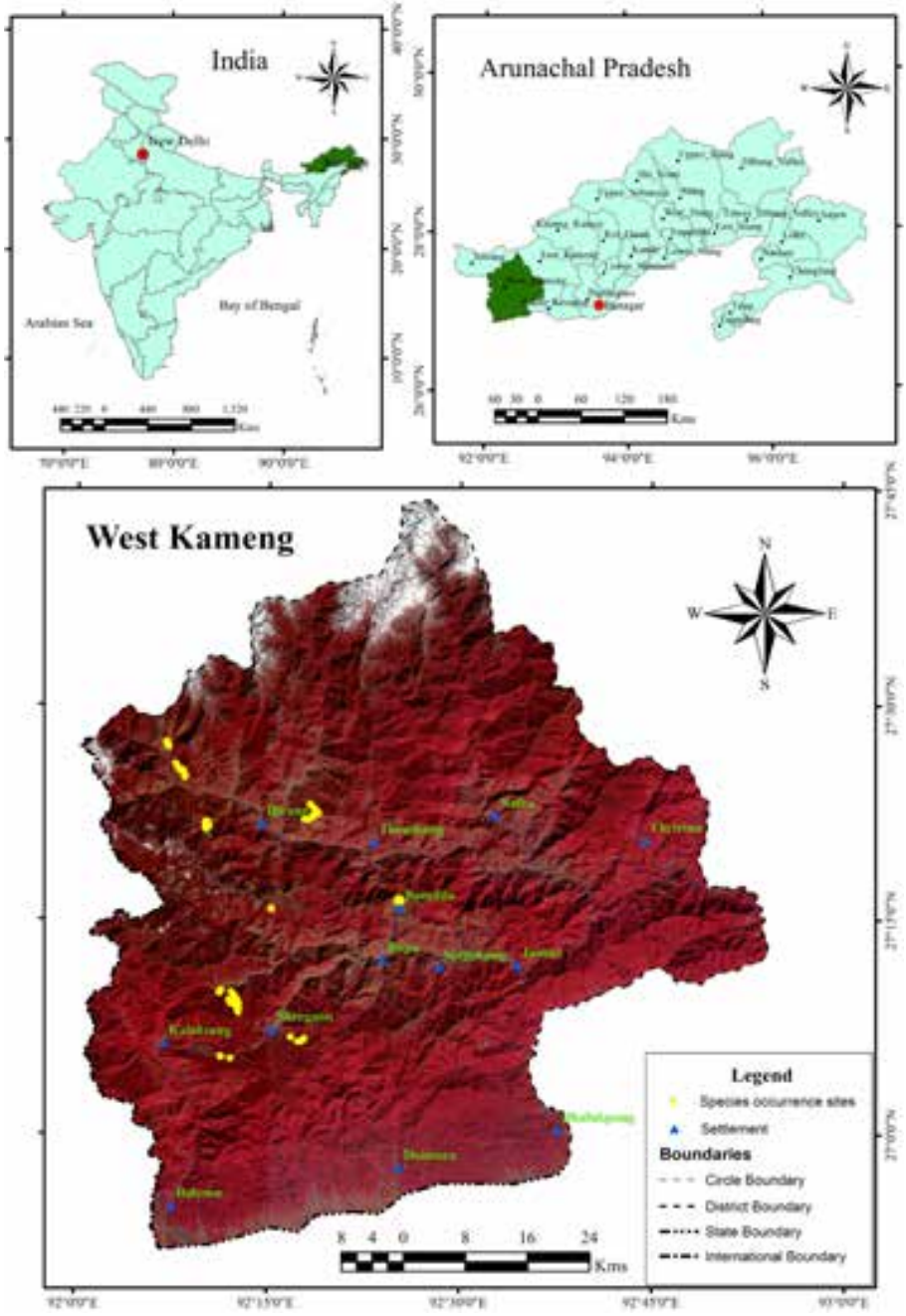


**Figure 1. Study area (ArcGIS 10.3)**


Image 1. *Illicium griffithii* Hook.f. & Thomson: A,B—tree | C—fruits | D—fruits and seeds. © Tashi Dorjee Bapu.

**Database and Methodology**

**Database**

1. Toposheets of survey of India for delineation of study area.
2. Shuttle Radar Topographic Mission Digital Elevation Model (SRTM DEM) for selection of study sites based on altitude.
3. Garmin Global Positioning System (GPS) for locating the species occurrence.
4. Camera to substantiate the field study.

## METHODS

**Field method and data collection**

Since the population size of *I. griffithii* is not known, non-probability sampling technique was used. Based on previous site history on availability of *I. griffithii,*

proximity of camping and other human settlements, human use, closeness to nearby forest area and reports from the local people on occurrence, a purposive sampling technique was applied to select the sites. The site selection, however, was primarily based on altitude viz. below 1,000m, 1,000–1,500 m, 1,500–2,000 m, 2,000–2,500 m, 2,500–3,000 m and above 3,000m. In total 10 sites, namely, Morshing, Sanglem, Bomdila, Namshu-Chander, Lubrang, Nyukmadung, Senge, Mandala Phudung, Shergaon, and Tenzingaon, were selected from various altitude categories and linear transect survey was carried out. The plants along the line transect were recorded in GPS in three categories based on girth (circumference) at breast height (gbh), i.e., seedlings (<5cm), saplings (5–10 cm), and tree (>10cm). The distance covered in a line transect was purely based on the natural barrier and distance covered in a specific period of time in each site with an average distance of 6.42km. The minimum and the maximum distances covered were 2km and 64.2km, respectively. The distance covered was classified into three classes for better analysis and representation, viz., <5 km, 5–10 km and >10 km (Table 1). Further, the plants located in the study sites were categorised into various altitudinal zones (Table 2). The population status was studied by observing and recording the number of individuals of the species during 2017–2019 in four different time periods, viz., May–June, 2017, May–June 2018, April–May 2019, October–November 2019 based on phenological cycle of the fruit. Further, the information on medicinal plants extraction and trade were collected through open-ended participatory discussion with the local informants (Joshi & Edingtong 2010; Bapu & Nimasow 2017). The collected data was represented with suitable tables and graphs.

## RESULTS AND DISCUSSION

Linear transact survey carried out at 10 sites recorded 3,170 individuals of *I. griffithii*, out of which 1,372 were seedlings, 1,358 saplings, 314 mature trees, and 126 were dead plants. The population structures of the live plants found in these sites along the line transect have been presented in Table 1. The number of plants recorded in 10 sites varies from 38 to 852 individuals. Out of the total 3,044 live plants, the mature trees were only 314. The Namshu-Chander site recorded the highest with 105 individuals whereas Tenzingaon recorded the lowest with only two mature trees. Out of the total number of 1,358 saplings, Namshu-Chander had the highest number of individuals (319) whereas Tenzingaon had the lowest number of individuals (11). Out of the total 1,372 seedlings, the highest number of individuals was recorded in Morshing (518) followed by Namshu-Chander (259), Lubrang (157) and the lowest in Shergaon (21). Overall, the number of live plants was highest in Namshu-Chander as the area is located relatively away from the settlements. Further, the Namshu Village Council has imposed a ban on the felling of *Illicium* for the last 30 to 35 years which is also a contributing factor for the abundance of the species in the wild. Morshing area recorded higher numbers of seedlings and saplings which may be attributed to the decline in fruit collection thereby allowing regeneration of the species. Moreover, recently the village council has also imposed certain restrictions on the felling of trees. Among the mature trees, the largest girth was recorded in Namshu-Chander site (1.80m gbh) followed by Morshing (1.55m gbh). The plant was found scattered and isolated in Tenzingaon and Shergaon areas. In the Tenzingaon area, large-scale land fragmentation and land conversion is taking place for agriculture and horticulture purposes leading to loss of species or habitat. The respective village councils of Senge and Lubrang have also banned the felling of *Illicium* recently. During the field survey frequent occurrence of stump sprouting was observed which reflects the coppicing ability of the species.

The distribution of various girth classes, i.e., seedlings (<5 cm), saplings (5-10 cm) and trees (>10 cm) of the species showed significant difference among the sites (Figure 2). The individual girth class followed the trend: seedlings > saplings > trees in the >10km distance category. The trend in <5 km and 5–10 km distance categories, however, were: seedlings < saplings > trees (Table 1 & Figure 2). The overall trend in terms of number of individuals in different category of growth was: seedlings (1,372) > saplings (1,358) > trees (314). So, the regeneration status of *Illicium* appears to be satisfactory in contrast to the poor regeneration of the species as reported by Duckhok et al. (2005). The difference in findings may be attributed to the declining trend of fruit collections compared to the late 1990s and early 2000s period. Because large-scale collection of *Illicium* fruits was reported from Arunachal Pradesh during 1990 till early 2000 which restricted the natural growth of the plant (Paul et al. 2013). The potential of species regeneration can be understood by the presence of seedlings and saplings in an area (Saxena & Singh 1984). The survival rate of the seedlings was found to be high in the study area which is in agreement with Paul et al. (2013) but in contrast to the findings of

**Table 1. Population structure of live *Illicium griffithii* and distance covered in 10 sites.**

| Distance category | Site | No. of seedlings (<5cm gbh) | No. of saplings (5cm-10cm gbh) | No. of trees (>10cm gbh) | Total | Distance covered in a transect (km) |
|---|---|---|---|---|---|---|
| >5 km | Mandala Phudung | 67 | 53 | 21 | **141** | 2 |
| | Tenzingaon | 25 | 11 | 2 | **38** | 2.9 |
| | Sanglem | 50 | 12 | 3 | **65** | 2.3 |
| | Senge | 124 | 238 | 9 | **371** | 2.9 |
| 5–10 km | Shergaon | 21 | 29 | 11 | **61** | 5.8 |
| | Bomdila | 116 | 149 | 18 | **283** | 5.3 |
| | Lubrang | 157 | 251 | 17 | **425** | 5.1 |
| <10 km | Nyukmadung | 35 | 70 | 20 | **125** | 12.8 |
| | Namshu-Chander | 259 | 319 | 105 | **683** | 11.9 |
| | Morshing | 518 | 276 | 58 | **852** | 13.2 |
| **Total** | | **1372** | **1408** | **264** | **3044** | **64.2** |

(Source: Field survey, 2017-19)

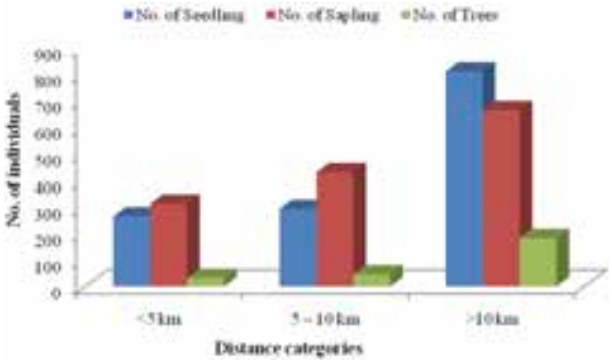


**Figure 2. Population structure of *Illicium griffithii* (distance surveyed).**

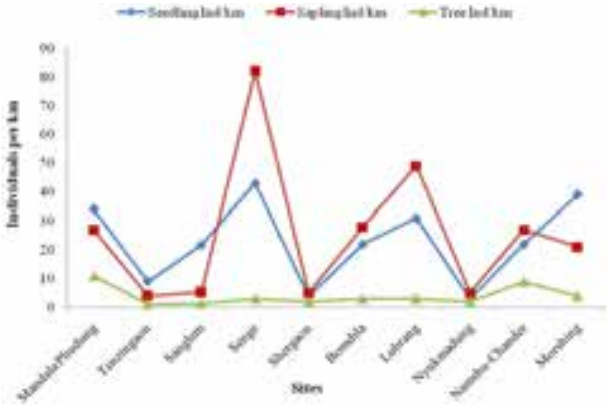


**Figure 3. Number of individuals per km in the study sites. Source: Field survey 2017–2019.**

Duchok et al. (2005). This might be due to a decline in the collection of *Illicium* fruits, thus contributing to its natural regeneration since 2010. Nevertheless, the establishment of saplings in comparison to number of trees present was very poor (trees < saplings) due to selective felling of larger girth trees for creating fields of plantation crops and other agricultural purposes, construction related activities, and for fences and fuel wood which are the underlying factors hindering the survival rate of saplings. Thus, the variations in number of individuals among different classes may be ascribed to the prevailing environmental factors and degree of disturbances (Duchok et al. 2005). The villagers informed that *Illicium* bears fruit in alternate annual cycles resulting in good production in a particular year but poor production in the next year. Similar finding has also been reported by others (Ved et al. 2003). People of Nyukmadung and nearby areas also informed that a huge forest area, mostly dominated by *I. griffithii* was gradually converted to pasture land in Nyukmadung after the establishment of a Yak Farm in 1989.

The survey revealed that the maximum occurrence of *I. griffithii* (1442 individuals or 47.37%) was observed in the altitudinal range of 2,600–2,800 m followed by 2,400–2,600 m (741 individuals), 2,800–3,000 m (636 individuals), 2,200–2,400 m (209 individuals), and 2,000–2,200 m (16 individuals) (Table 2). It was further observed that the species was growing abundantly in the altitudinal range of 2,500–2,750 m. Although, the present study found that the species was growing between 2,000–3,000 m (± 20 m), some earlier studies found it to be growing between 1,600–2,500 m (Hussain & Hore 2008), 1,700–3,000 m (Paul et al. 2013), 2,000–2,800 m (Gajurel et al. 2015). Such variation might be due to the tolerance level of the species or to a bio-climatic zone which is favourable for its growth.

It is reported that the price of the fruits ranged

**Table 2. Altitude-wise population structure of live *Illicium griffithii*.**

| Altitude range (in m) | No. of seedling | No. of sapling | No. of trees | Total |
|---|---|---|---|---|
| 2,000–2,200 | 10 | 6 | 0 | **16** |
| 2,200–2,400 | 107 | 78 | 24 | **209** |
| 2,400–2,600 | 330 | 339 | 72 | **741** |
| 2,600–2,800 | 652 | 650 | 140 | **1442** |
| 2,800–3,000 | 273 | 335 | 28 | **636** |
| **Total** | **1372** | **1408** | **264** | **3044** |

(Source: Field survey, 2017-19)

**Table 3. Proximity, altitude, habits and threats to *Illicium griffithii*.**

| Site | Proximity to settlement | Altitude range (m) (+ - 20m) | Parts Used | Types of threats |
|---|---|---|---|---|
| Mandala Phudung | Nb | 2,890–2,910 | fr, lv, st | Tr, HoP, Df, Tp |
| Tenzingaon | Nb | 2,230–2,280 | St | HoP, Df |
| Sanglem | Nb | 2,650–2,680 | fr, st | Tr, HoP, Tp |
| Senge | Nb | 2,810–2,910 | fr, lv | Tr, Tp |
| Shergaon | F | 2,120–2,760 | fr, st | Tr, HoP |
| Bomdila | Nb | 2,620–2,800 | St | HoP |
| Lubrang | Nb | 2,490–2,730 | fr, lv, st | Tr, HoP, Tp |
| Nyukmadung | MF | 2,380–2,730 | fr, lv, st | Tr, HoP, Df |
| Namshu-Chander | VF | 2,460–2,740 | fr, st | Tr, HoP |
| Morshing | F | 2,240–2,880 | fr, st | Tr, HoP, Tp |

**Proximity to settlement**: Nb—nearby (<1 km from settlement) | MF—moderately far (1–3 km from settlement) | F—far (3–5 km from settlement) | VF—very far (>5 km from settlement). **Parts used:** fr—fruits | lv—leaves | st—stems. **Types of threats:** Tr—trade | HoP—harvested for other purposes (e.g., fence, pole, construction) | Df—deforestation | Tp—trampling.

from Indian Rupees (INR) 120–150 per kg (Paul et al. 2013) and INR 100–200 during the early 2000 (Bapu & Nimasow 2017), which went down to INR 50 per kg during 2010, leading to less interest in fruits collection (Bapu & Nimasow 2019). *Illicium* fruits are mainly marketed through middlemen from the district which are sold at nearby markets at higher prices (Paul et al. 2013; Bapu & Nimasow 2017, 2019). Further, the local people informed us that the demand for fruits of *Illicium* was high during 2002–2007 (Bapu & Nimasow 2017) and fetched around INR 10,000–15,000 annually to a household (Bapu & Nimasow 2019). They also informed that the demand in the market has gone down, and therefore the price of the *Illicium* fruits is as low as INR 40 at present, however, interactions with the Range Forest Officer, Bomdila revealed that the low market demand is mainly due to the monopoly in the market. The actual rate in international market is as high as INR 700–800 per kg and around INR 400 in Mumbai, Maharashtra (Tsering Dorjee Megeji pers. comm., Range Forest Officer, Bomdila). The collection and trade of *Illicium* fruits in the district is regulated by issuing permit to the traders by the forest department. Some years back, however, the officials of Bomdila Forest Division reportedly seized *Illicium* products owing to improper documents for trade.

Many studies on population and regeneration status of a specific species have focused mostly on the number of individuals in a unit area (Dhar et al. 1997; Duchok et al. 2005; Paul et al. 2019) and number of individuals along linear transects (Nimachow et al. 2010). On an average, 32 individuals of *I. griffithii* in 1.0km linear transect was recorded in West Kameng District. The average number of seedlings, saplings and trees in the linear transect were 23, 24, and 5 individuals per km, respectively. The total number of seedlings (per km) ranged from 3–43, saplings 4–82 and trees 1–11. The maximum number of seedlings (per km) were recorded in Senge (43 individuals), followed by Morshing (39), Mandala Phudung (34), Lubrang (31) and lowest in Nyukmadung (3). The highest saplings (per km) was also reported in Senge (82) followed by Lubrang (49),

Mandala Phudung and Namshu (27) and lowest in Tenzingaon (4). The number of mature trees (per km) was recorded highest in Mandala Phudung (11) followed by Namshu-Chander (9) and the lowest in Tenzingaon and Sanglem (1 each). The sites located far away from the human settlements recorded a higher number of plants whereas the sites located near the settlements had a lesser number of plants owing to the higher rate of anthropogenic influences, as presented in Table 3. The local communities use *Illicium* mostly for pole, fences and others. Currently, the major threats to the species were deforestation, harvest of trees for various purposes including construction work and erection of fences, etc. and trampling of plants by bovines. Looking at the multiple uses of the plant, plantation and other conservation measures are essential for sustainability of the plant. The Bomdila Forest Division had ventured and planted *I. griffithii* in around one hectare of land at one mile area near Bomdila during 1990–1991 which was found to flourish during the field survey. Hence, more such efforts by the governmental and non-governmental organizations with community participation might be helpful in regeneration and conservation of the plant.

## CONCLUSION

A comprehensive study to understand the existing population status of a species is considered to be the most important in order to effectively protect the species from extinction (Vischi et al. 2004). The present study provides comprehensive information on population structure, regeneration status and distribution of *Illicium griffithii* Hook.f. & Thomson in West Kameng District of Arunachal Pradesh (India). The plant was found growing between altitudinal range of 2,100–2,930 m but showing its abundance between 2,500–2,750m. The study found a good number of *I. griffithii* in natural stand but only in a limited area. The dominance of saplings and seedlings over trees at all the sites was recorded which indicates its good regeneration potential. Adding to this, the localized distribution of the species, excessive extraction of large trees for various purposes and changing global climate has put a pressure on the population of the species. Although, the collection of fruits has declined in recent years, the silent illegal trade from deep inside of the forest cannot be ruled out. Cultivation and awareness on the value of such species can play an important role in the livelihood strategies of the local people in the study area. Therefore, proper awareness with regards to importance and market value of the species in particular and maintenance of the ecosystem as a whole is the need of the hour. The government and other organizations should encourage cultivation of *Illicium* and other important medicinal plants as a part of agroforestry, which in turn will help in conservation of these plants. Further, imparting proper training to the villagers on scientific way of fruits collection could ensure the sustainable utilization of the plant and its products. Finally, the present study opens up scope for further research on habitat suitability and impact of climate change of this endangered medicinal plant.

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PLATINUM OPEN ACCESS
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# The discovery of a melanistic Leopard *Panthera pardus delacouri* (Linnaeus, 1758) (Mammalia: Carnivora: Felidae) at Bukit Kudung in Jeli, Kelantan, Peninsular Malaysia: conservation and ecotourism

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**Abstract:** Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. During a study near an ecotourism site, we recorded a melanistic Leopard *Panthera pardus delacouri* on top of Bukit Kudung in Jeli District. This finding is considered important because the Indochinese Leopard *P.p. delacouri* is classified as Critically Endangered in the Red List of Threatened Species by the International Union for Conservation of Nature (IUCN). We hope that this record will foster conservation efforts in the area.

**Keywords:** Camera trapping, felid conservation, Indochinese Leopard, melanism.

The melanistic Leopard has been recorded throughout Peninsular Malaysia (Azlan 2006; Hedges et al. 2015). During camera trapping studies conducted between 1996 and 2009 in southern Thailand and Peninsular Malaysia, melanistic Leopards were recorded only south of the Isthmus of Kra, indicating a near fixation of melanism in Leopards in this region (Kawanishi et al. 2010). Nine Leopards recorded in a wildlife corridor in central Peninsular Malaysia were also melanistic (Hedges et al. 2015). Latter authors assumed that Peninsular Malaysia is the only region in the world where the entire Leopard population consists of melanistic morphs. Medway (1983), however, also reported spotted Leopards in the region. Kawanishi et al. (2010) referred to the presence of spotted Leopards in Endau Rompin National Park in the southern part of Peninsular Malaysia. Tan et al. (2015) recorded two spotted Leopards in Ulu Muda Forest Reserve in the northern state of Kedah. Melanistic Leopards are most common in tropical and subtropical moist broadleaf forests (da Silva et al. 2017).

From India, while reporting about melanistic and other range of over 12 colour variations in *Panthera tigris*, Singh (1999) also mentioned about the black panthers, whom nature has possibly given the way to favourable selection. Melanistic leopards were captured in camera trap from the eastern state of Odisha in India

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during June 2014 (Anonymous 2015a) and 2018 (Palei et al. 2018). Mahabal et al. (2019) have tabulated 45 instances of black or melanistic Leopard from India starting with Buckland (1889) to Anonymous (2015b) and Sayyed & Mahabal (2015).

Melanism in the Leopard *Panthera pardus delacouri* is caused by a non-synonymous mutation in the coding region of a gene that regulates the production of melanin, while keeping black rosettes visible (Schneider et al. 2012). According to da Silva et al. (2017), they demonstrate that this distribution is non-random across the subspecies' range, with the observed spatial patterns significantly supporting an association with moist forests and a decrease in frequency in open/dry habitats. It has been suggested that melanism is an evolutionary response to dipterocarp forest with a close canopy and low light levels (Kawanishi et al. 2010). While these results support classical adaptive hypotheses, implying that melanism in Leopards is influenced by natural selection related to habitat type and moisture, several questions remain unanswered, such as the exact selective mechanism in different areas.

In this article, we report a melanistic Leopard near an ecotourism attraction in Jeli District, Kelantan, Peninsular Malaysia. It was recorded by camera traps employed in autumn 2019. This finding is expected to promote conservation efforts for the Leopard in Malaysia and to enhance ecotourism in the area. An education centre in the area may provide exposure and awareness for tourists about the subspecies and the importance of conserving them in their natural habitat.

## Study Area

Our research focused on collecting terrestrial vertebrate data in Bukit Kudung, Jeli District, Kelantan, Peninsular Malaysia from October 2019 to December 2019 (Figure 1). The study area is a hill dipterocarp forest with streams and rivers at an elevation of 90–500 m. During the camera trapping survey, there was no evidence of snares and human footprints that indicated the presence of illegal hunting.

## Material and Methods

In this study, five camera traps units [Bushnell Natureview HD Model 119436 and Browning Spec Ops Advantage Trail Camera] were installed and left in selected areas where wildlife were expected to be present. The distance between any two camera traps was about 257m. The camera traps were set to one second interval between three consecutive images and were fitted with 8GB SD secure digital card storage and 12 double AA batteries to ensure that they were able to cope with this study period. The strap of camera was properly tied with appropriate angle, and checked before setting the feature. Possible stealing away of cameras or their damage by wildlife were the risks in this study. The GPS location of each point had been taken by using the Military Navigation application.

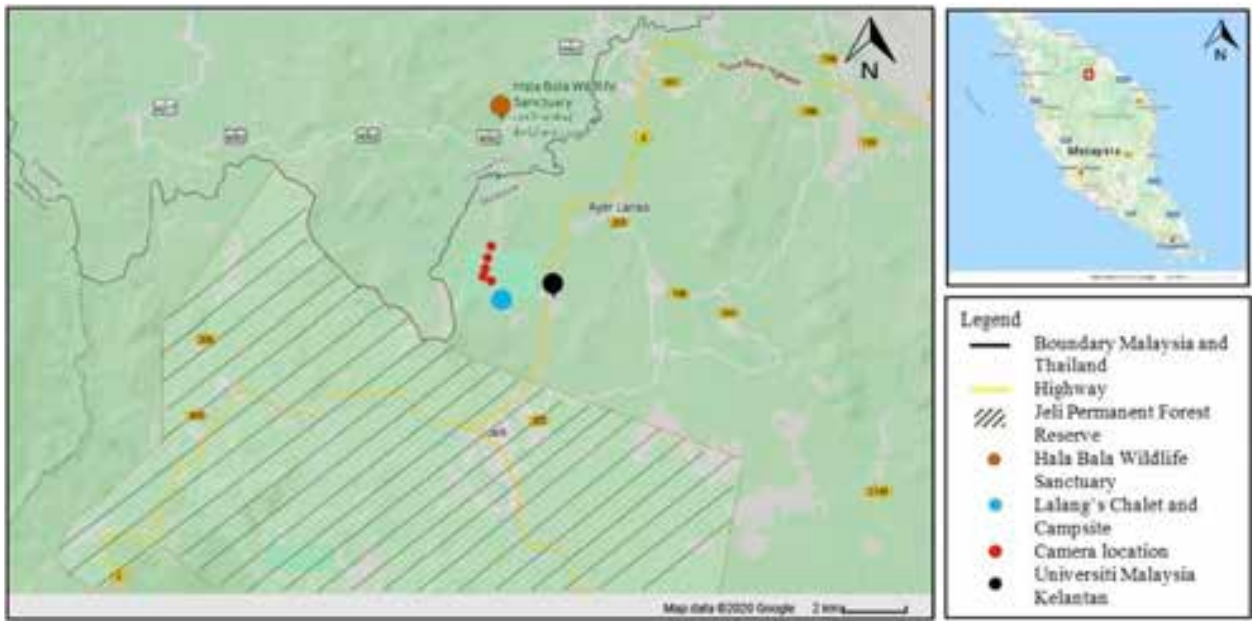


**Figure 1. Overview of the study area and its location in Peninsular Malaysia (Google Map 2020).**

## Results

From this study, 57 days of data from the entire camera traps were collected and 1,254 images obtained. A melanistic Leopard was recorded by two camera traps. One image was taken on 27 October 2019 at 07.04h (Image 1). Three consecutive images show a melanistic Leopard on 11 November 2019 at 04.42h (Image 2). The coordinates of the findings are kept confidential to ensure the safety of the Leopard.

## Discussion

The Indochinese Leopard has been recorded in primary and secondary forests, tropical dry and moist deciduous forests, evergreen and semi-evergreen forests, and also plantations (Rostro-García et al. 2019). As such, melanism has been proposed as an evolutionary reaction to acclimatize to specific environments where pigment genes can allow melanistic types to better adapt to green dipterocarp forest with a closed canopy and low light levels, whereas spotted Leopards are ideally adapted for disguising in open field environments (da Silva et al. 2017).

A geographical gradation is seen with spotted, melanistic and black leopard in the distributional range of the extant subspecies of *Panthera pardus* in their global distribution range. In India, it is possible that nature has already given way to favourable selection of black panthers (Singh 1999: page 52–53), and that the normal-spotted and black leopards have biologically settled for togetherness, and genetically settled with comparable body features except for the colour. Photographs of black and melanistic leopards are time and again have been posted in social media during 2020. As pointed out by Singh (1999) preponderance of black or melanistic large cats is an indication that the gene pool for normal spotted or striped forms is changing fast.

The Indochinese Leopard is listed as Critically Endangered (Rostro-García et al. 2019). The population trend of the Leopard is decreasing in Peninsular Malaysia because of high threats to its survival and habitat (Chew 2019). Dead Leopards have been seized from poachers and wildlife traders (Lai 2013; Traffic 2013, 2014). In addition, habitat destruction caused by development of infrastructure especially in rural areas also plays a role in the decline of the population.

The discovery of a melanistic Leopard in Bukit Kudung emphasizes the importance of this location as a conservation area. Today, Bukit Kudung, has been developed into an ecotourism destination known as Lalang's Chalet and Campsite. Governmental and non-governmental organizations need to cooperate in ensuring the safety of the Leopard population in


**Image 1. A melanistic Leopard photographed at 07.04h on 27 October 2019.**


**Image 2. A melanistic Leopard at 04.42h on 11 November 2019.**

the area. Among the forms of recommendations and joint measures that can be highlighted is establishing an area learning centre and also gazette the area as a wildlife protected area. The location of this study area has the potential to act as an important wildlife corridor connecting the forests of Thailand (Hala-Bala Wildlife Santuary) and Jeli Permanent Forest Reserve. Members of the near-by Faculty of Earth Sciences of Universiti Malaysia Kelantan should play a vital role in raising the awareness of visitors about the necessity of normal gene pool and biodiversity conservation.

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# On the epidemiology of helminth parasites in Hangul Deer *Cervus hanglu hanglu* (Mammalia: Artiodactyla: Cervidae) of Dachigam National Park, India

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**Abstract:** A one-year study conducted to ascertain the prevalence and risk factors associated with helminth infection in Hangul Deer *Cervus hanglu hanglu* at Dachigam National Park revealed that 40.45% (89 of 220 samples) were infected with four helminth species including *Heamonchus contortus*, *Trichuris ovis*, *Dictyocaulus viviparus*, and *Moneizia expansa*. The study signified that the infection was more prevalent during the dry season (summer and autumn) as compared to the wet season (winter and spring). The overall prevalence of *Heamonchus contortus* was the highest (23.18%) followed by *Trichuris ovis* (8.18%), followed by *Dictyocaulus viviparus* (5.45%), and *Moneizia expansa* (3.63%). The present study should be of importance in conserving the erstwhile state animal, listed as Critically Engendered in 2017 by IUCN.

**Keywords:** Conservation, Hangul, helminth infection.

Parasites are important natural components of ecosystems because they actively arbitrate in the ecological, demographic and life history processes of their hosts, impelling the structure and organization of free-living organism communities (Poulin & Morand 2000). The study of parasites provides information not only on the host's health but also on the evolutionary history and historical biogeography of the host-parasite relationships as well as the health of the ecosystem (Brook & McLennan 1993). Helminth's incursion of ruminants is one of the major problems worldwide. These infections are responsible a for large number of economic losses in the form of lower fertility, reduced capacity, involuntary culling and mortality in heavily parasitized animals (Carmicheal 1972; Akerejola et al. 1979). Gastrointestinal parasites especially the helminth infections are the main causal proxies of intestinal and extra-intestinal infections, however, the parasites in wildlife vertebrates are challenging to study. These parasites are the common cause of significant morbidity and mortality in wild animals especially the endangered ones. Hence, early detection and discrepancy of these parasites is important in the clinical management of wild animals. This, however, has been a major limitation in studying parasites of rare and endangered species like Hangul in Dachigam National Park.

Hangul, being the erstwhile State animal is a subspecies of the European Red Deer. Although more than 150 species of deer are recognized globally, Hangul is the only surviving race of the Red Deer family of Europe

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in the sub-continent. Before 1947, the number of Hangul Deer in Jammu & Kashmir was in thousands but due to poaching, parasitic infections, and lack of management, there has been a drastic waning in their number (Ahmad & Nigam 2014). In 2015, the total population size was estimated to be 110–130 individuals in Dachigam National Park with overall 150–200 individuals (the number of mature individuals presumably significantly smaller), thus declared as a Critically Endangered deer (Brook et al. 2017).

Parasitic infections are common in nature, but low intensity infections are often asymptomatic and intensify with anthropogenic changes, which may result in loss of stability associated with altered transmission rates, host range, and virulence (Anderson & May 1979). The prevalence of these parasitic infections in the Red Deer *Cervus elaphus* is widespread across the world (Watson & Charleston 1985). The proper identification of the helminth infection is vital to address this issue. The data concerning the gastrointestinal infection of Hangul Deer in Dachigam National Park is scarce and fragmentary. Therefore, the study will add to the existing knowledge and will help to devise appropriate control and prophylactic strategies for helminthiasis of the last surviving species of European Red Deer.

## Material and Methods

A total of 220 fresh faecal samples were collected from various feeding sites of Hangul Deer at Dachigam National Park. The samples were stored in sterile vials containing 10% formalin solution in order to avoid contamination and to preserve the parasites. The preserved samples were examined at Microbiology Research Laboratory, CORD, University of Kashmir using various qualitative and quantitative techniques. Simple flotation technique was used for the separation of nematode and cestode eggs by concentrating them by means of flotation fluid with appropriate specific gravity. Sedimentation technique was used to detect trematode eggs as this technique concentrates them in a sediment (Sloss et al. 1994; Urquhart et al. 1996). Many nematodes eggs are alike and species like *Heamonchus*, *Oesophagostomum*, *Ostertagia*, and *Cooperia* cannot be differentiated. Therefore, for proper identification, faecal culture was done for hatching and development of these helminth eggs into infective stage (L3). The larvae were then recovered by using Bearmann's technique. Identification of eggs and larvae was done on the basis of various morphological and morphometric characters (Sahai & Deo 1964; Soulsby 1982; van Wyk et al. 2004).

## Results

Out of the total 220 samples, 89 (40.45%) samples were found infected with one or more helminth species -- *Heamonchus contortus* (Image 1A), *Trichuris ovis* (Image 1B), *Dictyocaulus viviparus* (Image 1C), and *Moneizia expansa,* however, no acanthocephalan was detected during the study. Table 1 indicates the overall prevalence of helminthiasis in Hangul Deer: *Heamonchus contortus* (23.18%) followed by *Trichuris ovis* (8.18%) and *Dictyocaulus viviparus* (5.45%). *Moneizia expansa* was seen least (3.63%). There were significant differences in the prevalence of parasitic infestation with respect to the season. Table 2 and Figure 2 clearly depicts that the infection was higher in dry season as compared to the wet.

## Discussion

The current epidemiological study of helminth parasite infection in Hangul Deer revealed that the bulk of work has been done on gastrointestinal parasitic infestation of ruminants of Kashmir region (Dhar et al.

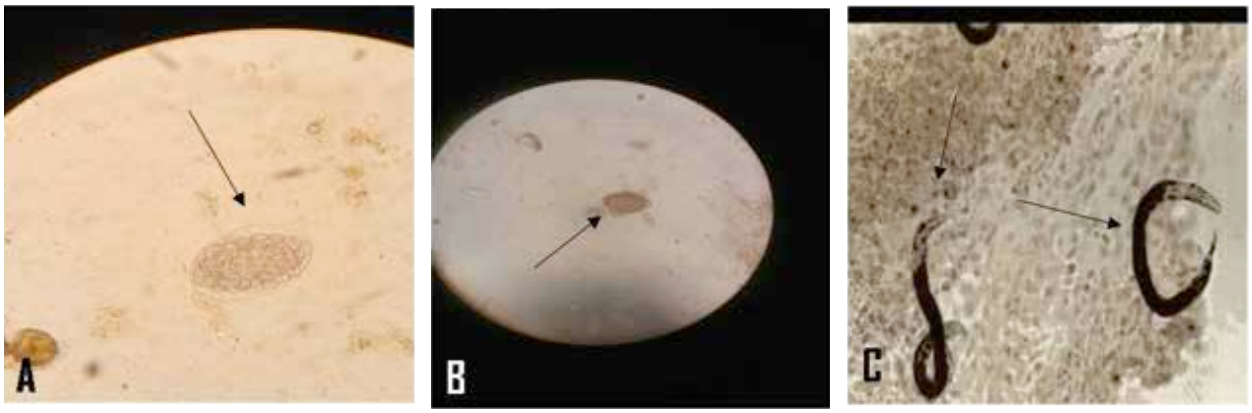


**Image 1. A—*Heamonchus contortus* | B—*Trichuris ovis* | C—*Dictyocaulus viviparus.* © Naziya Khurshid.**

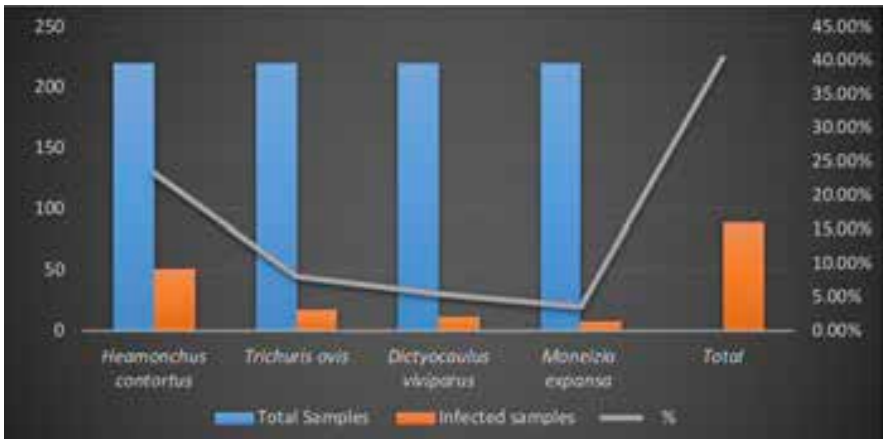


**Figure 1. Overall prevalence of helminth infection in Hangul Deer.**

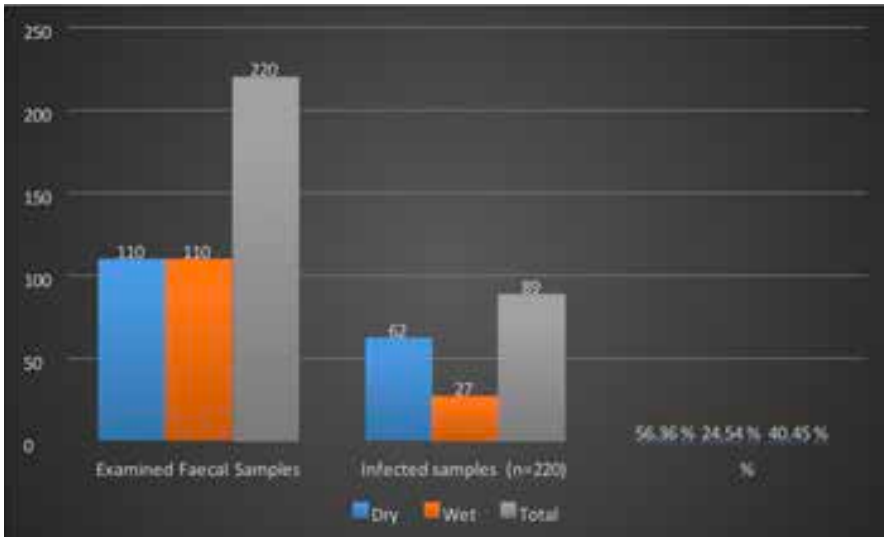


**Figure 2. Prevalence of helminth infection across seasons.**

**Table 1. Overall prevalence of helminth infection in Hangul Deer.**

| Parasite Species | Infected samples (Total 220) | Percentage (%) |
|---|---|---|
| *Heamonchus contortus* | 51 | 23.18% |
| *Trichuris ovis* | 18 | 8.18% |
| *Dictyocaulus viviparus* | 12 | 5.45% |
| *Moneizia expansa* | 8 | 3.63% |
| **Total** | 89 | 40.45% |

1982; Tariq et al. 2008a,b,c; Lone et al. 2012) but other wildlife of the region remains poorly studied. The current examination revealed four different helminth species in the faecal samples of Hangul deer. Of these three were nematodes, viz., *Heamonchus contortus* (23.18%) followed by *Trichuris ovis* (8.18%) and *Dictyocaulus viviparous* (5.45%). *Heamonchus contortus*, a tropical and sub-tropical parasite already prevalent in Kashmir Valley was found in the highest numbers. The increase in temperature due to global climate alterations can be one of the possible reasons for the occurrence of this parasite in the temperate climate zone. One cestode species *Moneizia expansa* was seen in least count (3.63%). Out of 220 samples (Table 1 and Fig. 1), 89 (40.45%) samples were found infected. The prevalence of infection was found higher in dry season which included summer and autumn (56.36%) than the wet season which included winter and spring (24.54%) (Table 2, Figure 2). The reason of this reduction could be the hypobiosis of nematodes in host and unavailability of hosts (Ogunsuri & Eysker 1979; Gibbs 1986) during the wet season. The data however, presents overall low intensity of infection possibly due to grazing break during winter season and also the relocation of sheep breeding farm outside the park in 2017, may have contributed to the lower infestation. The incidence of infection in this study was

**Table 2. Prevalence of helminth infection across seasons.**

| Season(s) | | Examined faecal samples | Infected samples | Percentage (%) |
|---|---|---|---|---|
| Dry season | Summer | 55 | 49 | 89.09% |
| | Autumn | 55 | 13 | 23.64% |
| | **Total** | **110** | **62** | **56.36%** |
| Wet season | Winter | 55 | 11 | 20% |
| | Spring | 55 | 16 | 29.09% |
| | **Total** | **110** | **27** | **24.54%** |
| **Overall** | | **220** | **89** | **40.45%** |

lower as compared to earlier studies (Nashiruddullah et al. 2005, 2007; Lone et al. 2014).

## Conclusion

The present study has revealed that the Hangul deer is infested with helminth infection and infection is influenced by seasonality, however, more information is required about these parasites and their transmission to effectively control helminthiasis in the Hangul Deer. We believe that the present study would provide baseline data for further studies.

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SHORT COMMUNICATION

# Histopathological findings of infections caused by canine distemper virus, *Trypanosoma cruzi*, and other parasites in two free-ranging White-nosed Coatis *Nasua narica* (Carnivora: Procyonidae) from Costa Rica

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**Abstract:** Canine distemper virus (CDV) causes systemic infections and immunosuppression in carnivores, which subsequently makes animals highly susceptible to opportunistic infections. Although *Trypanosoma cruzi* infects procyonids, chagasic myocarditis in Coatis has not been reported in Central America. The aim of this study was to report the histopathological findings caused by canine distemper virus, *T. cruzi*, and other parasites in two free-ranging White-nosed Coatis *Nasua narica* found dead in a national park on the Pacific coast of Costa Rica. Heart, lung, tongue, liver, brain and spleen samples were subjected to macroscopic and microscopic examination. A mononuclear meningoencephalitis associated with intra-nuclear eosinophilic inclusion bodies consistent with canine distemper virus was observed in nervous tissue. Myocarditis and associated nests of amastigotes of *T. cruzi* were observed during microscopic examination in cardiac tissue, and in muscle from the tongue of both animals. Molecular analysis confirmed *T. cruzi* in formalin-fixed paraffin embedded cardiac tissues. The myocardial damage caused by the opportunistic infection due to *T. cruzi* in these individuals could be the result of a severe compromised immunological status associated to the CDV infection, and subsequent opportunistic polyparasitism described herein. To the authors knowledge this is the first report of chagasic myocarditis in free-ranging coatis from Central America.

**Keywords**: CDV, myocarditis, *Nasua narica*, PCR, polyparasitism, *Trypanosoma cruzi.*

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**Competing interests:** The authors declare no competing interests.

**Ethical approval:** The procedure was performed under the approval of the National Environment Ministry (MINAE), and the National System of Conservation Areas (SINAC), Área de Conservación Pacífico Central (ACOPAC) (No permits found due to poor records). No animals were specifically harmed for the purpose of this study but were part of a mortality investigation; in addition, the necropsy protocols were performed at the Pathology Service of the School of Veterinary Medicine of the National University of Heredia, Costa Rica, (EMV-UNA), within the cases identification ND 107-2010 (female) and ND 112-2010 (male), respectively.

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In Latin America, *Nasua* spp. host for several zoonotic parasites including *Trypanosoma cruzi*, and viruses such as canine distemper virus (Chinchilla 1966; Herrera 2010; Santoro et al. 2016; Duarte Moraes et al. 2017; Michelazzo et al. 2020). In Costa Rica, the White-nosed Coati *Nasua narica* is a procyonid that is widely distributed in protected areas and is a frequent inhabitant of semi-urban or peridomiciliary zones (Wainwright 2007; Cuarón et al. 2016). An epidemic of sudden death in coatis with previous neurological signs occurred in a conservation area in the southern Pacific coast of Costa Rica in 2010. This report provides details on the diagnostic investigation of two individuals.

In 2010, a troop of 15–20 White-nosed Coatis from the Bahia Ballena Marine National Park (BBMNP) in Uvita, Dominical, Puntarenas (9.157N, -83.746W) presented with neurological signs and incoordination followed by sudden death. Due to decomposition and limited logistics, only two adult coatis (one male and one female) were collected and transported to a local small animal veterinary clinic by local authorities from the National System of Conservation Areas, Costa Rica (SINAC). In addition, the outbreak occurred only once and no more events of this type have been reported subsequently in the region (Dr. Fernando Riera pers. comm. January 2020). The veterinarian in charge submitted the carcasses to the Pathology Service of the School of Veterinary Medicine of the National University of Heredia, Costa Rica, (EMV-UNA) for necropsy and diagnostic evaluation. Selected tissues from heart, lung, tongue, liver, brain, and spleen were routinely processed, embedded in paraffin, and 4–5 mm thick sections were stained with hematoxylin and eosin (H & E), toluidine blue or Giemsa for light microscopy.

For detection of *T. cruzi* DNA, a conventional PCR using formalin-fixed paraffin-embedded (FFPE) tissues was performed on selected tissues from heart, lung, tongue, liver, brain and spleen. About 25mg sections were cut from each block and placed in a 1.5ml sterile microcentrifuge tube. The microtome and blade were cleaned with xylene between each block. The sections were de-waxed by cutting off paraffin edges and then mixed with 500µl xylene for eight minutes followed by washing with 95% ethanol and with 70% ethanol for five minutes each. Pellets were dried at 80°C for eight minutes on a heat block. As positive controls, FFPE cardiac tissue sections of mice experimentally infected with *T. cruzi* were used. The *T. cruzi* strain used in the mice experimentally infected corresponded to *T. cruzi* I (TcI) and was isolated from a naturally infected dog from Costa Rica (Mena-Marín et al. 2012). FFPE cardiac tissue sections of healthy mice were used as negative controls. Total DNA extraction from the paraffin material was performed using a commercial kit (QIAmp DNA Mini Kit ® QIAGEN). The primers used for PCR were S35 (5'AAATAATGTACGGGTGGAGATGCATGA-3') and S36 (5'-GGGTTCGATTGGGGTTGGTGT-3') (Ferrer 2015). This set of primers amplifies a 330bp fragment derived from the variable region of *T. cruzi* minicircles (Ferrer 2015). Although this set of primers amplifies the majority of strains of *T. cruzi,* and it is considered specific to *T. cruzi*, two fragments of *Trypanosoma rangeli* (300bp and 450bp) can be also amplified with this set (Vallejo et al. 1999). This is, however, a non-pathogenic parasite and it is not observed in mammalian tissue (Vallejo et al. 2015). PCR reaction conditions were carried out as previously described with the S35–S36 set with some modifications (Barrera et al. 2008). Briefly, PCR was carried out using a DNA thermal cycler (Gene Amp PCR System. Perkin Elmer), the amplification reaction was performed in a final volume of 20µl with 10µl of 2X Dream Taq™ PCR Master Mix (Thermo Fisher Scientific™, Whatman, MA), 4µl of nuclease free water (Thermo Fisher Scientific™ Whatman, MA), 1.5µl of 99.99% DMSO, 2µl of sample DNA, 1µl of each of the primers at 10µM and 0.5µl of bovine serum albumin (BSA) at a concentration of 20mg/ml, one cycle of initial denaturation for 5min at 95°C followed by 35 cycles of denaturation for 20sec at 95°C, alignment for 30sec at 63°C, elongation for 30sec at 72°C, and a final cycle of elongation for 10min at 72°C. The amplified DNA was visualized with 2% agarose gel using a UV transilluminator.

At gross examination, both coatis were in poor body condition, with dermatological lesions including alopecia, exudative dermatitis, abscesses, scabs, and pustules. Other significant findings were conjunctivitis and mass muscle atrophy of limbs. Both individuals had enlarged spleens. The female coati had several nematodes compatible with *Dirofilaria* sp. in the right ventricle and pulmonary artery (Image 1a). The lungs were congested, edematous, had multifocal hemorrhages, and a 0.5cm hemorrhagic nodule with eosinophilic infiltrate associated with the migration of immature trematodes compatible with *Paragonimus* spp. and microfilariae were in the right diaphragmatic lobule. Small numbers of cestodes, acanthocephalans and nematodes were found in the small intestine. In the male coati, the lungs were congested and edematous. Additionally, the male coati had a dilated esophagus and small numbers of acanthocephalans and nematodes were present.

Histologic evaluation revealed a mixed exudative

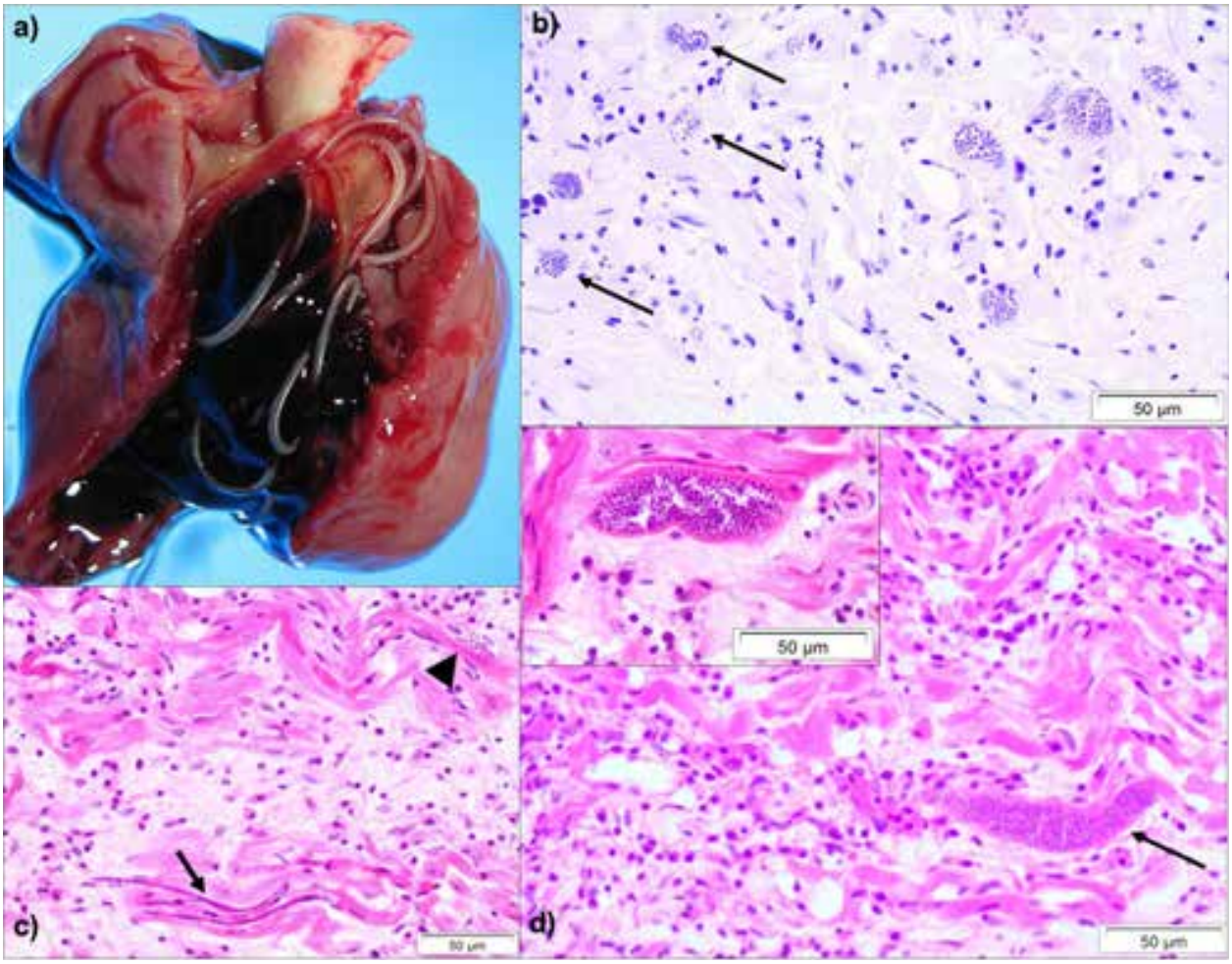


**Image 1. a—Nematodes morphologically similar to *Dirofilaria* spp. in the heart of a White-nosed Coati *Nasua narica* | b—mononuclear inflammatory infiltrate associated with *Trypanosoma cruzi* amastigote nests in cardiac tissue (arrows). Giemsa stain. 40X | c—microfilaria (arrow) and mononuclear inflammatory infiltrate associated with *T. cruzi* amastigote nests in cardiac tissue (arrowhead). Hematoxylin-eosin stain. 40X | d—*T. cruzi* amastigote nest in cardiac tissue (arrow). Hematoxylin-eosin stain. 40X. © Morales-Acuña & Departamento de Patología, Escuela de Medicina Veterinaria, Universidad Nacional de Costa Rica.**

dermatitis consistent with *Dermatophilus congolensis* and unidentified mites in both animals. In cardiac tissue of both coatis, a mild mononuclear infiltrate with lymphocytes, plasma cells, histiocytes, and few eosinophils were observed in both the myocardium and pericardium, from mainly the left ventricle and the atria. In addition, myocardial muscle fibers were edematous and exhibiting degeneration and necrosis. The inflammation was associated with multifocal amastigote nests in myocardial muscle fibers, and nematode larvae morphologically similar to *Dirofilaria* spp. (Images 1b, 1c, 1d). Moreover, cardiac tissue from both animals was positive for the expected 330bp amplicon product for *Trypanosoma cruzi*.

Both individuals had eosinophilic infiltrates in the lungs associated with the migration of immature trematodes compatible with *Paragonimus* sp. and microfilariae compatible with *Dirofilaria* sp. (Images 2a, 2b). In muscle tissue from the tongue of both coatis, an infiltrate with lymphocytic cells, macrophages and giant cells were observed in the muscle fibers. This inflammation was associated with protozoal cysts consistent with *Sarcocystis* sp. and with amastigote nests of *T. cruzi* (Image 2c). A multifocal mild infiltrate of neutrophils, eosinophils and macrophages was observed in the mucosa and submucosa of the ileum and colon. This inflammation was associated with acanthocephalans. In addition, unidentified adult nematodes consistent with spirurids were detected in the pancreatic ducts from both animals (Image 2d). In nervous tissue of both animals, the medulla oblongata and pons were edematous and congested, with gliosis, satellite glial cells, demyelination, and multifocal areas of encephalomalacia. Moreover, the meninges were

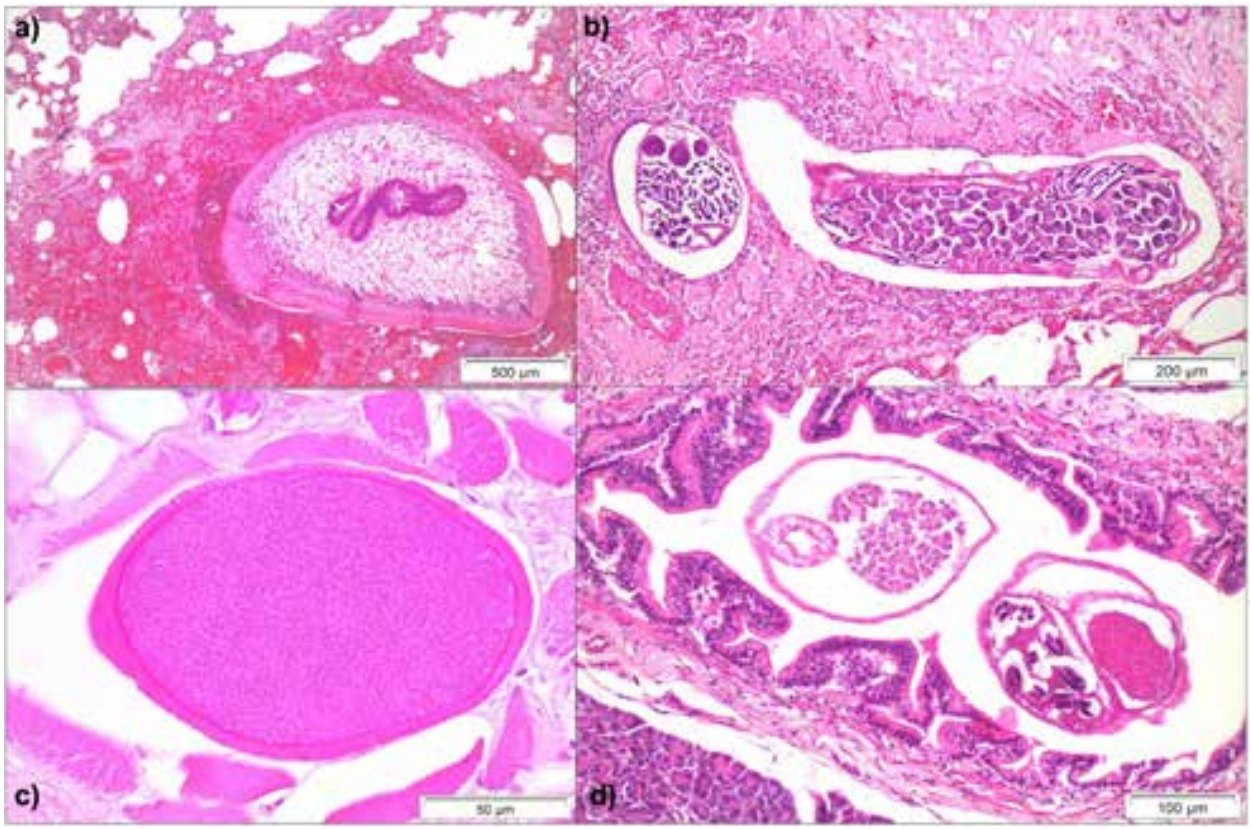


**Image 2. a—Eosinophilic inflammatory infiltrate associated to *Paragonimus* spp. in lung tissue. Hematoxylin-eosin stain. 4X | b—unidentified nematodes in lung tissue (arrow). Hematoxylin-eosin stain. 10X | c—*Sarcocystis* sp. cyst in skeletal muscle tissue of the tongue. Hematoxylin-eosin stain. 60X | d—unidentified spirurid nematodes in excretory ducts in pancreatic tissue. Hematoxilin-eosin stain. 20X. © Morales-Acuña & Departamento de Patología, Escuela de Medicina Veterinaria, Universidad Nacional de Costa Rica.**

edematous and congested, and a mild perivascular mononuclear infiltrate with neuronal necrosis, and syncytial cells containing intranuclear eosinophilic inclusions consistent with canine distemper virus (CDV) were observed in the hippocampus (Images 3a, 3b). Also, unidentified microfilaria were found in blood vessels of the cerebral cortex and nervous tissue.

White-nosed Coatis are widespread in Central America and Mexico and occur in parts of the southwestern United States. Their conservation status is Least Concern (Cuarón et al. 2016) and they do not have any protection in Costa Rica. They are distributed throughout the country including the mangrove and the beach of the BBMNP where this mortality event occurred (Wainwright 2007). This species is exposed to a great diversity of pathogens due to its diverse diet, long life expectancy, ability to disperse over long distances, and the use of both arboreal and terrestrial habits (de Lima et al. 2015; Alves et al. 2016). Moreover, living in social groups may increase the probability of transmission of parasites and other pathogens (Hass & Valenzuela 2002).

The interaction between several parasites and other infectious agents should be further investigated in order to explain the immune response in coatis. For example, the finding of mononuclear meningoencephalitis and intranuclear eosinophilic inclusions as seen in CDV deserves more study. CDV is one of the most important infectious agents of carnivores worldwide including procyonids (Deem et al. 2000). To date, the only published study on CDV in Costa Rican wildlife was on wild cats in the Osa Peninsula region which is located ~145km from the BBMNP (Avendaño et al. 2016). There are only a few previous published reports of CDV in coatis (Martinez-Gutierrez & Ruiz-Saenz 2016), and some studies have failed to detect CDV antibodies in wild or captive coatis (Furtado et al. 2016; Taques et al. 2018). The social nature of coatis likely makes them particularly at risk as this virus can quickly spread among different individuals belonging to the same troop, as has been reported in raccoons (Hass & Valenzuela 2002; Kapil & Yeary 2011; Rentería-Solís et al. 2014; Dr. Catao-Dias pers. comm. July 2019). In addition, due to the mass mortality event we suggest that CDV was the primary cause of death, with polyparasitism likely contributing to an impaired

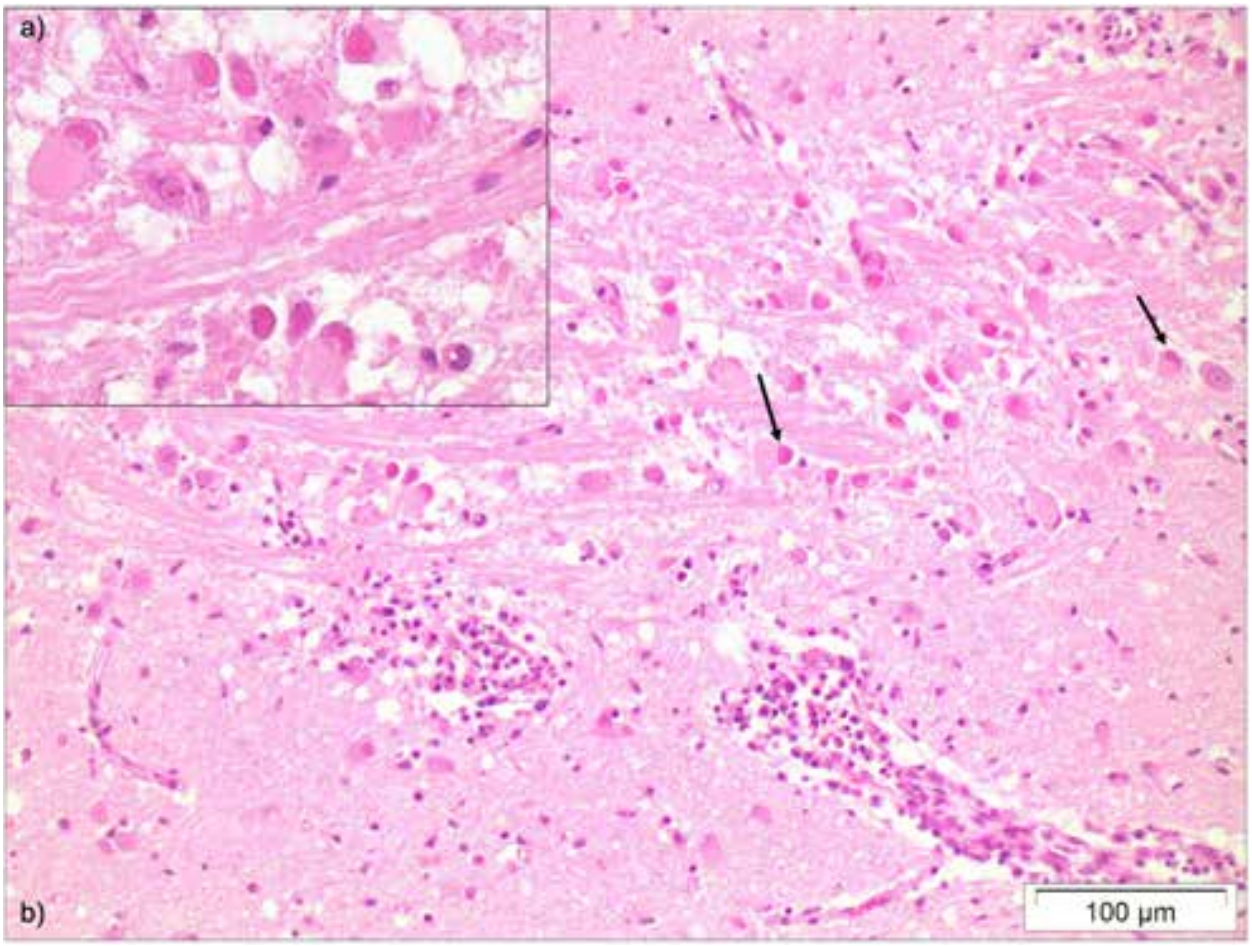


**Image 3. a—Mild peri-vascular mononuclear infiltrate associated with intra-nuclear eosinophilic inclusion bodies consistent with canine distemper virus in syncytial cells from the hippocampus. Hematoxilin-eosin stain. 40X | b—intra-nuclear eosinophilic inclusion bodies compatible with canine distemper virus (arrows). Hematoxilin-eosin stain. 20X. © Morales-Acuña & Departamento de Patología, Escuela de Medicina Veterinaria, Universidad Nacional de Costa Rica.**

immune status (Origgi et al. 2012; Kubiski et al. 2016). An initial differential diagnosis for CDV considered by local authorities was rabies, which is present in the region (Hutter et al. 2016). Compatible clinical signs, however, were not observed in the animals and Negri bodies were not detected in nervous tissue. Other differential diagnoses such as feline panleukopenia, toxoplasmosis and canine parvovirus were considered (Deem et al. 2000). Due to diagnostic limitations it was not possible to definitively rule these out, but the inclusion bodies observed were supportive of our diagnosis of CDV.

There have been numerous reports of *T. cruzi* infecting several species of coatis, including White-nosed Coatis in Costa Rica (Mehrkens et al. 2013), Mexico (Martínez-Hernández et al. 2016), and Honduras (Lainson 1965), and Ring-tailed Coati or Southern Coati *N. nasua* in Brazil and Peru (e.g., Alves et al. 2016; Morales et al. 2017). Coatis use of arboreal nests increases the risk of exposure to triatomine vectors, and these nests may be shared among multiple members of the social group (de Lima et al. 2015; Alves et al. 2016). Generally, the prevalence of *T. cruzi* can be high in coatis and they appear to have long-lasting parasitemias (Alves et al. 2011). Also, the attenuated pathogenicity of *T. cruzi* in neotropical mammals could be explained by its long co-evolution with this parasite (Schofield 2000). Moreover, experimental infection of another procyonid (i.e., *Procyon lotor*) with a strain of *T. cruzi* that normally does not infect that host led to severe clinical disease (hind limb paralysis and labored breathing) and severe myocarditis, suggesting that this corresponded to an acute phase of infection in these raccoons (Roellig et al. 2009). Alternatively, as reported in dogs by Barr et al. (1991) and also in raccoons by Curtis-Robles et al. (2016), the animals did not present cardiac lesions. In the latter, the authors mentioned that the high infection prevalence of *T. cruzi* detected in raccoons, could be explained since these animals were able to host infections

without serious chronic pathological implications (i.e., no cardiac lesions observed) (Curtis-Robles et al. 2016). Nonetheless, more research is needed to better understand the role of *T. cruzi* in co-infections with other agents in wild hosts, both experimentally and in wild conditions (Roellig et al. 2009; Curtis-Robles et al. 2016). In our case study, the myocardial damage caused by the opportunistic infection due to *T. cruzi* could be the result of a severe compromised immunological status associated to the CDV infection, and subsequent opportunistic polyparasitism described herein (Araujo Carreira et al. 1996; Herrera 2010; Origgi et al. 2012; Kubiski et al. 2016). The exact mechanisms underlying CDV infections and circulation of the virus among susceptible wild mesocarnivores, however, are relatively unknown, that is, several authors suggested that this could be related to CDV genotypes with different virulence and cell tropism (Origgi et al. 2012; Rentería-Solís et al. 2014; Kubiski et al. 2016). As for the discrete typing unit (DTU), TcI is the most common in Central America, and has been reported in coatis in Mexico, but unfortunately the DTU in these animals was not determined (Herrera 2010; Rocha et al. 2013; Martínez-Hernández et al. 2016; Dorn et al. 2017). More studies are necessary to elucidate if coatis may be competent reservoirs of *T. cruzi* and a source of infection for the triatomine bugs in the region (Roellig et al. 2009; Curtis-Robles et al. 2016).

Several other parasites were detected in these two individuals and though the worms found in the heart of the coatis were not saved so could not be identified, they were morphologically similar to *Dirofilaria* sp. These parasites are likely *Dirofilaria immitis* (i.e., canine heartworm), a parasite which is common in domestic dogs from coastal areas in Costa Rica (Montenegro et al. 2017). Additionally, *D. immitis* has been reported in Ring-tailed Coatis from Argentina and Brazil; however, infections in Brazil were based on morphology of microfilaria alone, and the parasites from Argentina were originally described as *D. nasuae* (now considered a synonym of *D. immitis*) (Vezzani et al. 2006; Duarte Moraes et al. 2017). Thus, given the extreme rarity of confirmed *D. immitis* infections in procyonids, careful morphologic and molecular characterization of heart-dwelling *Dirofilaria* species in coatis is warranted. Also, human and animal health authorities should draw attention to this parasite due to its potential for zoonotic transmission.

*Paragonimus* spp. have been reported in coatis previously (Calvopiña et al. 2014) and the parasites we detected could be *P. mexicanus* or *P. caliensis*, both of which have been reported in freshwater crabs in the same province (Hernández-Chea et al. 2017). Molecular and/or careful morphologic characterization are needed to determine the species. Similarly, the *Sarcosystis* sp. in these coatis is unknown but could be acquired from numerous carnivores or didelphid species in the region, the latter of which have a wide distribution in Costa Rica, including the Pacific coast (Wainwright 2007), and are known definitive hosts of several *Sarcocystis* spp. (Dubey et al. 2008). The unidentified spirurid nematodes in the pancreatic ducts may be related to the Thelazioidea which contains several interesting genera that inhabit the pancreatic ducts of non-human primates and rodents (*Trichospirura*), skates and sharks (*Pancreatonema*), marine teleosts (*Johnstonmawsonia*) and freshwater teleosts (*Prosungulonema*) (Anderson et al. 2009). Finally, the similarities in the histopathological findings in the two individuals included in this study may reflect life histories that lead to similar contact rates with vectors and parasites, since the animals apparently belonged to the same troop (Curtis-Robles et al. 2016).

To our knowledge this is the first report of chagasic myocarditis in free-ranging coatis from Central America. In addition, we recognize the diagnostic and logistic limitations of this report; however, we strongly consider the histopathological findings relevant because of the limited information on zoonotic infectious diseases that currently exists in wildlife populations such as coatis, in Costa Rica. Therefore, these findings may help local authorities to improve surveillance and conservation management strategies in protected areas such as keeping a safe distance from wild animals and discouraging supplemental feeding. Furthermore, we encourage local researchers and local authorities to carry out epidemiological surveys to assess the ecology of infectious diseases on coatis, and to better understand the current health status of *N. narica* populations that frequent protected areas and other regions of the country. A multidisciplinary approach, including education of local residents, park visitors and park rangers, is necessary to minimize cross-infections between wildlife, domestic animals and humans.

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SHORT COMMUNICATION

# On a new species of *Macrobrachium* Spence Bate (Decapoda: Palaemonidae) from Ayeyarwady River, Myanmnar

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**Abstract:** *Macrobrachium myanmarum* sp. nov. was found from near Min Kun (local name Min Gon) at Mandalay, Ayeyarwady (Irrawaddy) River (22.043N & 96.043E), Myanmar. It is a small-sized prawn showing close relation with *Arachnochium kulsiense* (Jayachandran et al. 2007) and *A. mirabile* (Kemp 1917). This species can at once be identified from both the species by the characters: medium-sized and highly-elevated and arched rostrum, extending as far as distal segment of antennular peduncle or behind, upper margin with 11–15 teeth of which three (rarely 4) teeth post-orbital; ventral margin without teeth (rarely one); second chelate legs unequal, right leg larger (sometimes left); major leg in which carpus with proximal part narrow and distal end broadened, subequal to merus, palm and fingers; propodus slightly more than the combined length of merus and carpus; fingers very slender, almost equal to palm, fixed finger a bit shorter than movable finger, cutting edges with 2–6 weak denticles at proximal cutting edges, distal denticle situated at about 1/3rd distance from base; ischium, merus, carpus, propodus, palm and dactylus in the ratio 9.62 : 19.25 : 24.06: 47.06 : 23.53 : 23.53, respectively (related to the total length of pereopod); minor leg with minute tubercles in larger specimens; ischium, merus, carpus, propodus, palm and fingers in the ratio 13.1 : 23.68 : 22.37 : 40.8 : 15.8 : 25.0, respectively (related to total length of pereopod); palm slightly swollen and shorter than fingers, fingers slender and curved with a wide gap when closed. Maximum size recorded for the species is 56mm male and 44mm female.

**Keywords:** Identification, *Macrobrachium myanmarum* sp. nov., Min Kun, palaemonid prawn.

Taxonomic studies on palaemonid prawns of Myanmar were carried out by De Man (1888), Henderson (1893), Schenkel (1902), De Man (1905, 1906), Rathbun (1910), De Man (1911), Kemp (1917, 1918, 1925), Tiwari (1949), Holthuis (1950), Tiwari (1952, 1958), Holthuis (1980), Naiyanetr (1980), Jayachandran (2001), Cai & Ng (2002), Cai et al. (2004), Hla Phone & Suzuki (2004), Short (2004), Mie et al. (2009), Wowor & Ng (2010), Mar & Myint (2014), Khin et al. (2018), and Mar et al. (2018) have reported 40 species, namely, *Arachnochium mirabile* (Kemp), *Exopalaemon styliferus* (Kemp), *Leptocarpus fluminicola* (Kemp), *Macrobrachium aemulum* (Nobili), *M. assamense* (Tiwari), *M. australiense* *M. birmanicum* (Schenkel), *M. cavernicola* (Kemp), *M. clymene* (De Man), *M. dayanum* (Henderson), *M. hendersoni* (De Man), *M. hildebrandti* (H.M.Edwards), *M. idella* (Hilgendorf), *M. johnsoni* Ravindranath, *M. joppae* Holthuis, *M. josephi* Jayachandran, *M. lamarrei* (H.M.Edwards), *M. lanatum* Cai & Ng, *M. lanceifrons* (Dana), *M. lanchesteri* (DeMan), *M. lar* (Fabricius), *M. latidactylus* (Thallawitz), *M. latimanus* (von Martens),

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**Competing interests:** The authors declare no competing interests.

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*M. malcolmsonii* (H.M. Edwards), *M. minutum* (J. Roux), *M. naso* (Kemp), *M. neglectum* (De Man), *M. nipponense* (De Haan), *M. palaemonoides* Holthuis, *M. pethienense* Hla Phone &Suzuki, *M. peguense* (Tiwari), *M. platyrostris* (Tiwari), *M. rogersi* (Tiwari), *M. rosenbergii* (DeMan), *M. villosimanus* (Tiwari), *M. yui* Holthuis, *Nematopalaemon tenuipes* (Henderson), *Palaemon serrifer* (Stimpson), *P. sewelli* (Kemp), and *Palaemonetes sinensis* (Sollaud). The studies revealed that the fauna of the region is rich and more studies are necessary to arrive at the exact status of biodiversity. Recently, a new species has been collected from near Min Gon at Mandalay region of Ayeyarwady (Irrawaddy) River and is described herein.

## Materials and Methods

Seventeen specimens (eight males and nine females) were collected from Min Kun at Mandalay, Ayeyarwady River (22°.2'.37"N & 96°.2'.37"E), Myanmar, on 29 July 2018 and 10 June 2020 (Image 1). Holotype deposited at referral center of Central Marine Fisheries Research Institute (ICAR CMFRI), Kochi, Kerala, India (CMFRI DNR No. ED.2.2.1.6); 4 females deposited at Regional Centre of ICAR NBFGR, Kochi, Kerala, India.

The specimens were identified based on the relevant literature on Palaemonid prawns (De Man 1888; Henderson 1893; Schenkel 1902; De Man 1905,1906; Rathbun 1910; De Man 1911; Kemp 1917, 1918, 1925; Tiwari 1949; Holthuis 1950, Tiwari 1952; 1958; Holthuis 1980; Naiyanetr 1980; Liu et al. 1990; Jayachandran 2001; Cai & Ng 2002; Cai et al. 2004; Short 2004; Hla Phone & Suzuki 2004; Komai & Fugita 2005; Jayachandran et al. 2007; Liu et al. 2007; Mie et al. 2009; Wowor & Ng 2010; Khin et al. 2018).


**Image 1. Collection station - Min Kun from Ayeyarwady (Irrawaddy) River, Myanmar**

**Infraorder: Caridea Dana, 1852**
**Superfamily: Palaemonoidea Rafinesque, 1815**
**Family: Palaemonidae Rafinesque, 1815**
**Subfamily: Palaemoninae Rafinesque, 1815**
**Genus: *Macrobrachium* Spence Bate, 1868**

***Macrobrachium myanmarum* sp. nov.**

(Figures 1–3; Image 3)

urn:lsid:zoobank.org:act:7D600155-7A10-4151-A22A-9330AE13AEAD

Synonym: non *Macrobrachium kulsiense* Khin et al., 2018.

### Materials examined

Holotype: Deposited at ICAR CMFRI referral museum, Kochi, Kerala, India with registration number - CMFRI DNR No. ED.2.2.1.6, male, Collected by Dr.H.H.S. Myo & Dr.K.L.Khin from Min Kun at Mandalay, Ayeyarwady River, Myanmar (22°2'.37"N & 96°2'.37"E) on 29.07.2018

Paratypes: 4 females, Collected from Min Kun by Dr. H.H.S.Myo & Dr. K.L.Khin on 29.07.2018 at Mandalay, Ayeyarwady River (22°2'.37"N & 96°2'.37"E), Myanmar has been utilized for molecular studies at Regional Centre of ICAR NBFGR, Kochi, Kerala, India. Remaining paratypes (males and females) collected from same locality on 29.07.2018 and 10.06.2020 in the personal collection of Dr. H.H.S. Myo at Department of Zoology.

Measurements (mm): Holotype (male): 56.0 TL, 24.0 CL; Paratypes: males 37.0 TL, 15.0 CL; 40.0 TL, 15.0 CL; 41.0 TL, 16.0 CL; 42.0 TL, 16.0 CL; 48.0 TL, 19.0 CL; 50.0 TL, 21.0 CL; 52.0 TL 21.5, CL; 56.0 TL, 24.0 CL; (females): 34.0 TL, 15.0 CL; 37.0 TL, 13.0 CL; 37.0 TL, 13.0 CL; 38.0 TL, 16.0 CL; 39.0 TL, 16.5 CL; 41.0 TL, 18.0 CL; 42.0 TL, 16.0 CL; 42 TL, 17.0 CL; 44.0 TL, 18.0 CL

Etymology: The species name is in honour of the country from where this new species has been collected and documented.

### Diagnosis

*Macrobrachium* having the medium-sized, highly-elevated and arched rostrum, extending as far as distal segment of antennular peduncle or behind, upper margin

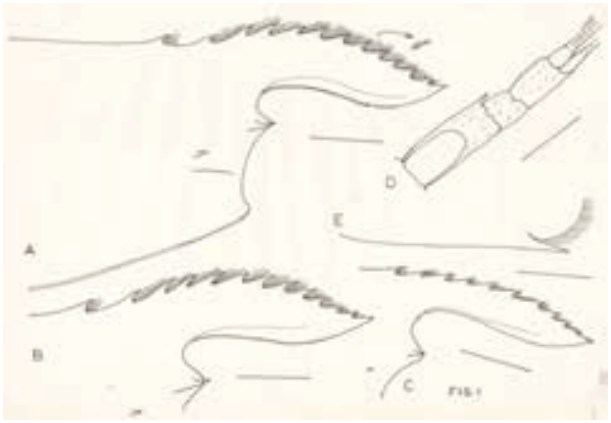

Figure 1. *Macrobrachium myanmarum* sp. nov.: A—anterior carapace of male | B—anterior carapace of female | C—anterior carapace of juvenile | D—antennular peduncle of male | E—outer disto-lateral region of antennal scale of male. scale 2mm

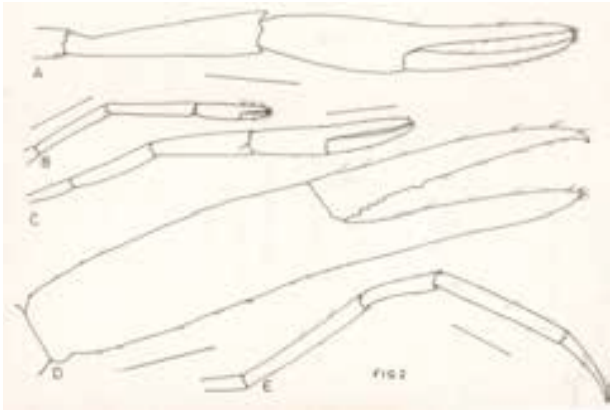

Figure 2. *Macrobrachium myanmarum* sp. nov.; A—2nd chelate leg of female | B—1st chelate leg of male | C—minor 2nd cheliped of male | D—Major 2nd cheliped of male | E—3rd non-chelate leg of male. Scale 2mm.

Figure 3. *Macrobrachium myanmarum* sp. nov. male: A—diaeresis | B—telson; scale 2mm

with 11–15 of which three (rarely 4) teeth post-orbital; ventral margin generally without teeth (rarely with one); second chelate legs unequal, right leg larger (sometimes left leg); major leg in which carpus with proximal part narrow and distal end broadened, subequal to merus, palm and fingers; propodus slightly more than the combined length of merus and carpus; fingers very slender, almost equal to palm, fixed finger a bit shorter than movable finger, cutting edges with 2–6 weak denticles at proximal cutting edges, distal denticles at about 1/3rd distance from base; ischium, merus, carpus, propodus, palm and dactylus in the ratio: 9.62: 19.25: 24.06: 47.06: 23.53: 23.53 respectively (related to total length of pereopod); minor leg with tubercles in large specimens; ischium, merus, carpus, propodus, palm and fingers in the ratio 13.1: 23.68: 22.37: 40.8: 15.8: 25.0, respectively (related to total length of pereopod); palm swollen and slightly shorter than fingers

**Description**

Rostrum medium-sized, extending as far as distal segment of antennular peduncle or behind, highly elevated and arched and tip directed forwards (in younger specimens rostrum less elevated), upper margin with 11–15 teeth of which three teeth (rarely 4) behind the orbit, proximal most and second teeth more widely separated than the remaining series teeth of uniform distance between them, proximal six teeth anteriorly directed and remaining teeth directed upwards, thick and long bunches of setae present in between teeth; ventral margin curved upwards, one minute tooth in holotype at the level of 10th dorsal tooth (generally absent); setae longer and closely set in both upper and lower margins (Figs. 1 A,B Image 2,4)

Carapace generally smooth but with small tubercles on antero-lateral side, about 43.0 per cent of total length, orbit sunken, antennal spine sharp, not placed at edge; hepatic spine sharp; a distinct groove present below hepatic spine, pterygostomian region not sharp (Figs. 1A,B Image 2,4)

Eyes developed. Telson slender, distal end sharply pointed and extends as far as or beyond the level of the outer spine of uropodal exopod; upper margin with two pairs of feeble spines, proximal pair situated at about 53 per cent and not in a line and distal pair closer to proximal pair (76 per cent), distal end with two pairs of spines, outer pair smaller and inner pair slender, longer and sharp, eight long plumose setae present in between the inner pair of spines (Fig. 3B).

Antennular peduncle three segmented, extends as far as 1/3rd of merus of major second cheliped and beyond merus of minor second legs, middle segment shortest, antero-lateral spine of basal segment reaches beyond middle but not to tip of 2nd segment of antennular peduncle (Fig. 1 D); disto-lateral spine of antennal scale

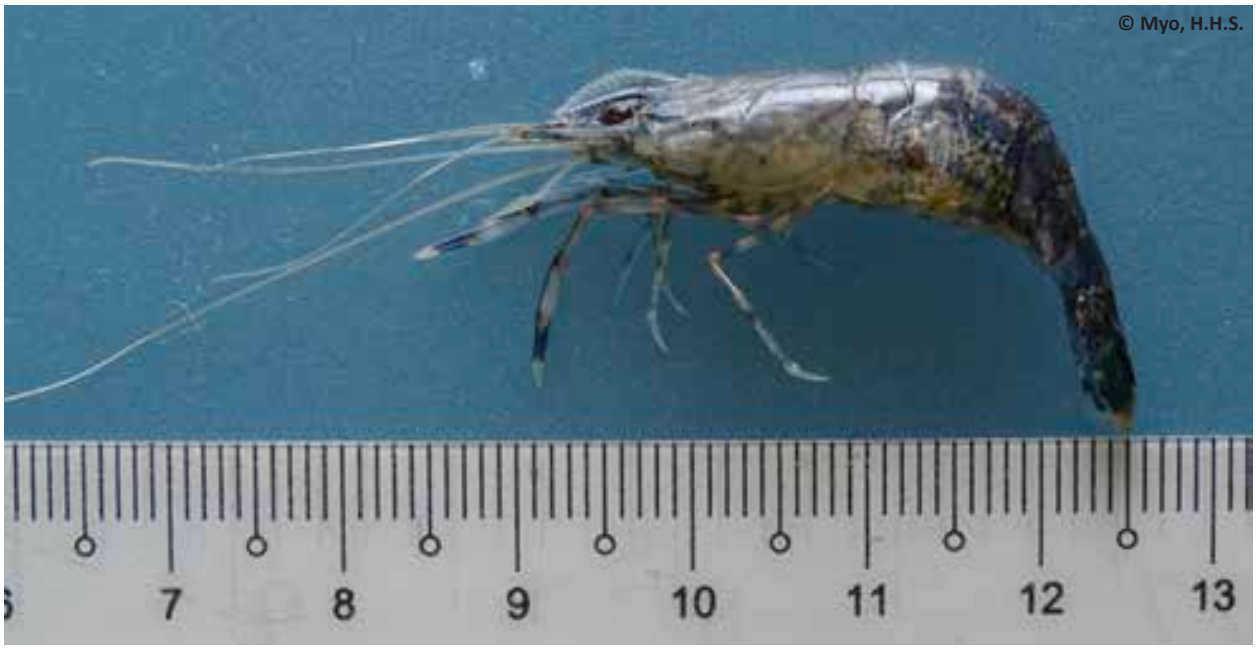


Image 2. *Macrobrachium myanmarum* sp. nov. (female) from Ayeyarwady (Irrawaddy) River, Myanmar.


Image 3. *Macrobrachium myanmarum* sp. nov. (male holotype) from Ayeyarwady (Irrawaddy) River, Myanmar showing nature of second pereiopods.


Image 4. Growth variations in *Macrobrachium myanmarum* sp. nov. from Mandalay, Myanmar; the smaller two specimens are females.

sharply pointed, subdistal in position and extends just in front of distal end of merus of 2nd cheliped (Fig. 1E).

First chelate legs slender, extends up to tip of antennal scale; ischium slightly broader; merus slender; carpus 1.60 times longer than propodus; palm cylindrical, 1.3 times longer than fingers; fingers slender, equal sized with tufts of setae on outer margin (Fig. 2B).

Second chelate legs with tubercles in bigger specimens, unequal, right leg larger (sometimes left); major leg 1.7 times the size of total length and 2.4 times the size of minor leg; ischium flat; merus cylindrical; carpus with proximal part narrow and distal end broadened, subequal to merus, palm and fingers;

**Table 1. Morphometric measurements (mm and ratio) of specimens of *Macrobrachium myanmarum* sp. nov. from Ayeyarwady (Irrawaddy) River, Myanmar.**

| Sex | TL | CL | CTL | LR | LT | Major second chelate leg | | | | | | Third non-chelate legs | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | I | M | C | P | Pa | D | I | M | C | P | D |
| ***Macrobrachium myanmarum* sp. nov.** | | | | | | | | | | | | | | | | |
| M* | 56.0 | 24.0 | 17.0 | 7.0 | 7.0. | 9.0 | 18.0 | 22.5 | 44.0 | 22.0 | 22.0 | 3.0 | 7.5 | 3.0 | 8.5 | 2.5 |
| Ratio → | | | | | | 9.62 | 19.25 | 24.06 | 47.06 | 23.53 | 23.53 | 13.9 | 34.9 | 13.9 | 37.2 | 11.6 |
| | | | | | | **Minor second chelate leg** | | | | | | | | | | |
| | | | | | | 5.0 | 9.0 | 8.5 | 15.5 | 6.0 | 9.5 | | | | | |
| Ratio → | | | | | | 13.1 | 23.68 | 22.37 | 40.80 | 15.8 | 25.0 | | | | | |
| F | 41.0 | 18.0 | 12.0 | 7.0 | 06.5 | 4.0 | 5.5 | 4.25 | 7.0 | 3.5 | 3.5 | 3.0 | 5.5 | 3.0 | 6.0 | 3.0 |
| F | 39.0 | 16.5 | 12.0 | 6.0 | 07.0 | 3.5 | 5.0 | 4.0 | 7.0 | 3.0 | 3.75 | 2.25 | 5.5 | 2.25 | 5.0 | 3.0 |
| F | 38.0 | 16.0 | 11.0 | 6.0 | 06.5 | 3.25 | 6.0 | 5.0 | 8.5 | 4.0 | 4.5 | 2.5 | 4.5 | 2.5 | 5.0 | 3.0 |
| F | 34.0 | 15.0 | 09.0 | 5.0 | 06.0 | 3.0 | 5.0 | 4.5 | 7.0 | 3.5 | 3.5 | 2.0 | 4.0 | 2.0 | 4.25 | 2.5 |
| Ratio → | | | | | | 16.8 | 26.0 | 21.6 | 35.7 | 17.9 | 18.4 | 13.8 | 27.5 | 13.8 | 28.6 | 16.3 |

(M*—male (Holotype) | F—female | TL—total length | CL—carapace length | CTL—post-orbital carapace length | LR—length of rostrum | LT—length of telson | I—ischium | M—merus | C—carpus | P—propodus | Pa—palm | D—dactylus)

propodus with maximum width at distal palm and slightly more than the combined length of merus and carpus; fingers very slender almost equal to palm, fixed finger a bit shorter than movable finger, movable finger curved, cutting edges with 2–6 weak denticles at proximal cutting edges, distal denticle at about 1/3rd distance from base; ischium, merus, carpus, propodus, palm and dactylus in the ratio 9.62: 19.25: 24.06: 47.06: 23.53: 23.53, respectively (related to total length of pereopod) (Fig. 2D, Image 3). Minor leg with tubercles in larger specimens; ischium, merus, carpus, propodus, palm and fingers in the ratio 13.1: 23.68: 22.37: 40.8: 15.8: 25.0, respectively (related to total length of pereopod); palm swollen and slightly shorter than fingers; fingers slender with a wide gap when closed (Fig. 2C, Image 3).

Three pairs of non-chelate legs nearly equal sized, slender, smooth, not reaching beyond antennular scale when extended, propodus subequal to merus, carpus subequal to dactylus; dactylus slender sharply pointed, curved distally; ischium, merus, carpus, propodus and dactylus of third pair in the ratio 13.9: 34.9: 13.9: 37.2: 11.6, respectively (Fig. 2E).

Fifth pleura of the abdomen unilobed at postero-lateral region as in the genus. Pleopods comparatively shorter than in other species of the genus; second pleopod with basis and rami almost same sized; appendix masculina long, folded structure with very stiff setae along its border and extends up to 2/3 distance of endopod. Uropodal exopod bears an accessory spine almost the length of major one and free borders with long setae (Fig. 3A).

Females: Carapace smooth, about 43 per cent to total length (average) (Fig. 1 B). Second pereopods slender, smooth, equal sized with ischium, merus, carpus, propodus, palm and dactylus in the average ratio 16.8: 26.0: 21.6: 35.7: 17.9: 18.4, respectively; palm subequal to fingers and without even traces of denticles on cutting edges (Fig. 2A). The non-chelate legs slender, segments in the average ratio 13.8: 27.5: 13.8: 28.6: 16.3, respectively. Fecundity 120 eggs (42 mm in total length).

Variation in growth: Young specimens: rostrum not much elevated as in adult, second chelipeds slender, without tubercles below the size of total length up to 48mm (Fig. 1 C). Male (big sized 56.0mm sized – recently collected): second pereopods unequal, major leg 2.4 times longer than minor leg; ischium, merus, carpus, palm and dactylus in the ratio 9.62: 19.25: 24.07: 23.52: 23.52, respectively; palm broader, fingers subequal and very slender, movable finger longer and slightly curved and with six small denticles of which distal one roughly 1/3rd distance from the base; minor leg with ischium, merus, carpus, palm and fingers in the ratio 14.10: 23.08 ; 21.79: 15.38: 25.64, respectively; palm swollen; fingers slender and curved with a wide gap when closed; palm and fingers possess stiff long setae (Image 3). Variations in the growth is shown in image 4.

Table 1 provides detailed morphometric measurements of the specimens.

Colouration: Body generally bluish coloured with red

**Table 2. A comparison of characters of *Macrobrachium myanmarum* sp. nov. with related species.**

| Characters | *A. kulsiense* | *A. mirabile* | *M. myanmarum* |
|---|---|---|---|
| Nature of rostrum | Long, reaches as far as the tip of antennal scale | Short, not reaching the tip of antennular peduncle | Medium sized reaching as far as distal segment of antennular peduncle or behind |
| Elevation of the upper margin of rostrum | Upper margin elevated, tip directed forwards | Upper margin highly elevated, tip directed forwards, | Upper margin highly elevated, tip directed forwards (small specimens not much elevated) |
| Nature of carapace | Smooth | Smooth | Generally smooth, antero-ventral region with tubercles |
| Rostral formula | 9–12 / 1 (2–3 post-orbital teeth) | 13–16/1 (3–5 post-orbital) | 11–15 / 0–1 (3–4 post-orbital) |
| Dorsal spines of telson | Placed at about 60 and 70 per cent, respectively | Placed at about 60 and 80 per cent, respectively | Placed at about 53 and 76 per cent, respectively |
| Ratio of segments of antennular peduncle | 3.0: 0.9: 1.75 | 3.3: 1.3: 2.3 | 3.3: 1: 1.4 |
| Nature of palm and fingers of first chelate legs | Palm and fingers equal sized | Palm shorter than fingers | Palm slightly longer than fingers |
| Nature and ratio of second chelate legs - ischium, merus, carpus, propodus, palm and fingers | Equal sized<br>21.43: 25.00: 21.43: 32.14: 14.28: 17.86<br><br>Fingers slender and equal sized | Equal sized and slender<br>21.15: 24.62: 20.38: 33.85: 14.62: 19.23<br><br>Fingers slender, equal in length | unequal in length (with spinules adult male). Large male in which major leg 2.4 times that of minor leg<br>Major leg –<br>9.62: 19.25: 24.06: 47.06: 23.53: 23.53<br>Fingers slender, fixed finger a bit shorter than movable finger<br>Minor leg –<br>13.1: 23.68: 22.37: 40.8: 15.8: 25.0<br>Fingers slender, curved with a wide gap when closed |
| Denticles on second chelate legs | Without denticles | Without denticles | 2 to 6 small denticles on the proximal part of fingers of major leg; distal one at 1/3$^{rd}$ distance from base |
| Details on appendix masculina | Normal sized and with 6 lateral and 2 distal stiff setae | Normal sized | Long, extends up to 2/3 length of endopod and with numerous stiff setae |
| Eggs | Very few large 15-20 eggs | small sized over 1000 eggs | Over 120 eggs |
| Colouration | Whole body with spots | Creamy white | Whole body is Dark-bluish in colour, a dark band on the lateral side of the body |

streak on lateral side of rostrum

Distribution: Ayeyarwady River at Mandalay, Myanmar.

## Remarks

The new species is closely related to *Arachnochium kulsiense* (Jayachandran, Lal Mohan & Raji, 2007) and *A. mirabile* (Kemp, 1917). *M. myanmarum* sp. nov. is characterized by the presence of a medium sized highly elevated rostrum which extends as far as the distal segment of antennular peduncle or behind. The dorsal margin is curved with 11–15 of which 3 (rarely 4) post-orbital in position. Branchiostegal groove extending slightly behind hepatic spine. The second pereopods are unequal. The major legs 1.7 times longer than the total length and 2.4 times the total length of minor leg. The fingers of major leg are slender and almost equal to palm and bear two to six minute denticles at proximal cutting edges of which the distal denticles situated at about 1/3$^{rd}$ distance from base whereas in the minor leg the palm is swollen and subequal to fingers and carpus. In large males the fixed finger is a bit smaller than movable finger and movable finger curved. It possesses large number of eggs. In *A. kulsiense* rostrum is long which extends as far as the tip of antennal scale and the upper margin highly elevated with 9–12 teeth of which two or three are post-orbital in position. The second cheliped in which palm is shorter than fingers and carpus. It possesses a few large eggs (up to 20). *A. mirabile* is characterized by a highly elevated short rostrum with a formula of 13–16 of which 4–6 teeth post-orbital in position and 1–2 ventral teeth. Dorsal teeth not uniformly spaced. Branchiostegal suture not extending behind hepatic spines. Second pereopods subequal in length and similar in form with palm subcylindrical, fingers slender and much longer than palm and without denticles on the cutting edges, chela 1 ¾ times as long as carpus, palm swollen, smooth and less than ¾ as

long as carpus. The present new species can at once be identified on the basis of its highly elevated curved rostrum with specific rostral formula and also nature, proportion of segments, ratio between carpus, palm and fingers of major leg and denticles on cutting edges. Fifth pleura of abdomen is unilobed as in the genus. A comparison of characters of related species is given in Table 2. Morphological variations during growth are shown in image 4.

The very slender fingers of the major second chelate leg of the present species shows some resemblance with that of *M*. *lar* (Fabricius, 1798). The rostral formula and general shape of the rostrum of the two species differ considerably. In *M*. *lar* chela is 3.5 times as long as carpus and palm of uniform thickness and longer than to twice as long as carpus. Carpus is shorter than merus. In the present new species chela is about 2.0 times as long as carpus and palm shorter than carpus and distal region with maximum thickness. Carpus longer than merus (Chace & Bruce 1993).

Wowor & Ng (2010) have created a new genus, namely, *Arachnochium*, to accommodate *M*. *mirabile* and *M*. *kulsiense*. This new genus is characterized by the presence of elongated fourth and fifth pereiopods, large blunt tip triangular median process on T4, without transverse plate in T5, without wide median process in T8, bilobed nature of postero-lateral region of fifth abdominal pleura and longer inner spine on exopod of uropod. The present new species does not possess any of the above characters and hence it is appropriate to retain it in the genus *Macrobrachium* Bate, 1868

Khin et al. (2018) have reported *M. kulsiense* Jayachandran, Lal Mohan & Raji (= *A. kulsiense)* from Myanmar and is a misidentification.

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SHORT COMMUNICATION

# Review of the tiger beetle genus *Calomera* Motschulsky, 1862 (Coleoptera: Cicindelidae) of the Philippines

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**Abstract:** The genus *Calomera* Motschulsky, 1862 from the Philippines is reviewed. Five species *C. angulata* Fabricuis, 1798, *C. cabigasi* Cassola, 2011, *C. despectata* (Horn, 1892), *C. lacrymosa* (Dejean, 1825), and *C. mindanaoensis* (Cassola, 2000) are described with diagnoses, illustrations, notes on their ecology, and distribution remarks. Status of the taxa *C. insularis* (Blanchard, 1853) is discussed. Images of endophallus structures of *C. lacrymosa* and *C. mindanaoensis* are given for the first time. A key to the Philippine *Calomera* species is provided.

**Keywords**: Asia, endemic, ground beetle, widespread.

The epithet convention used in this review followed the established priority of *Calomera* over *Lophyridia* (Lorenz 1998, 2005; Cassola 2000). These two genera were often interchanged until Cassola finally resolved the taxonomic ambiguity and established *Calomera* as the valid genus by the rule of priori (Cassola 2000, 2011).

The genus is distinct from the other genera of Indo-Malayan Cicindelidae by the following features: elytral maculation not restricted to the lateral margin only; pubescens of underside not felted; labrum with more than 10 marginal setae and, in the inner sac of the aedeagus a flagellum is present and complexly coiled on both sides of the inner sac. In the Philippines, the genus is represented by five species: *C. angulata* (Fabricius, 1798), *C. cabigasi* Cassola, 2011, *C. despectata* (W.Horn, 1892), *C. lacrymosa* (Dejean, 1825), and *C. mindanaoensis* (Cassola, 2000). This paper provides accurate literature for aspiring coleopterists and hobbyists in southeastern Asia, particularly in the Philippines, a megadiverse country (Heaney & Regalado 1998; Cassola & Pearson 2000; Catibog-Sinha & Heaney 2006), where there are numerous areas not previously explored and its tiger beetle fauna is still understudied (Medina et al. 2019, 2020b).

## Material and Methods

The material from the following institutional and private collections have been examined: DUBC –

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Daugavpils University Beetles Collection (Latvia); UMCRC – University of Mindanao Coleoptera Research Center (The Philippines); JWGC collection of Jürgen Wiesner, Wolfsburg, Germany.

High-resolution habitus images of *Calomera* species are available at Carabidae of the World web-project http://carabidae.org

## Results

***Calomera angulata angulata* (Fabricius, 1798)** (Image 1)

**Materials examined**: Luzon: Pola, Ifugao, N Luzon, August 2014 (1 male, DUBC); Isabela, Sierra Madre, N Luzon, August 2013 (1 male, DUBC). Negros: Negros Oriental, Dumaguete, XI.2014 (1 male, 3 females; DUBC); Don Salvador Benedicto, Negros Occidental, XI.2014 (2 males, DUBC).

**Diagnosis:** Body color bronze to dark copper or occasionally green. Elytra of male slender and female expanded at mid-body. Elytral pattern complete, ivory-coloured; medial band with "C"-shaped extension along suture toward the apice of elytron. Similar to *C. despectata*, but its elytra pattern of markings and expanded elytra of female distinguish it.

**Ecology:** This species can be found mostly in lowland ecosystems both in reservoirs and riverine habitats characterized by sandy and non-saline soil.

**Remarks:** First record from Negros Island. Previously known from Luzon.

**Distribution:** Nominative subspecies widely distributed in southern and southeastern Asia. Known from Afghanistan, Cambodia, China, India, Indonesia (Borneo, Sumatra), Laos, Nepal, Myanmar, Malaysia, Pakistan, The Philippines, Sri Lanka, Thailand, and Vietnam.

***Calomera despectata* (Horn, 1892)** (Image 2)

**Materials examined**: Luzon: Zambales (1 male, Paratype, at Museum fur Tierkunde Dresden, Germany). Mindanao: Davao City, Catigan, Toril, sandy river with secondary dipterocarp forest at the bank, 1,000m, 7.004°N & 125.241°E, 24.iv.2019, M. Medina leg (2 males; UMCRC); Agusan del Norte, Esperanza, 11.2014 (5 males, 3 females; DUBC).

**Diagnosis:** Body color bronze to dark copper or occasionally green. Elytra of male slender and female expanded at mid-body. Elytral pattern complete, white or ivory-coloured; medial band with "5"-shaped extensions along suture toward the apice of elytron.

**Ecology:** The species was collected at a much higher elevation as compared to the other two *Calomera* predominantly presented in Mindanao, *C. mindanaoensis* and *C. lacrymosa*. Biotype mark with rocky river bank, 1,000m, secondary forest, partially shaded.

**Remarks:** Larval morphology was described by Trautner & Schawaller (1996).

**Distribution:** Philippines: Luzon; Visayas, Leyte (Cabras et al. 2016b) with a new distribution record in Mindanao, Davao City, Catigan Toril.

***Calomera cabigasi* Cassola, 2011** (Image 3)

**Material.** Mindanao: Compostela Valley, New Bataan, Cagan, near stream, 949m, 7.291°N & 126.103°E, 23.iv.2013, M. Medina leg. (1 female; UMCRC); Bukidnon, Cabanglasan, October 2014 (1 male, 1 female; DUBC).

**Diagnosis:** Species with dark blue, sometimes almost black, dull elytra; elytral punctation not visible through. The two discal dots showing a tendency to almost coalesce with each other through a narrow lineole in between, which is sometimes poorly visible or almost effaced. Labrum structure (Images 10a-b).

**Ecology:** Unlike with the other two *Calomera* in Mindanao (*C. mindanaoensis* and *C. lacrymosa*) this species is found in relatively higher altitudes between 800–1,300 m, near secondary to primary forest approximately 5–10 m from the fluvial systems.

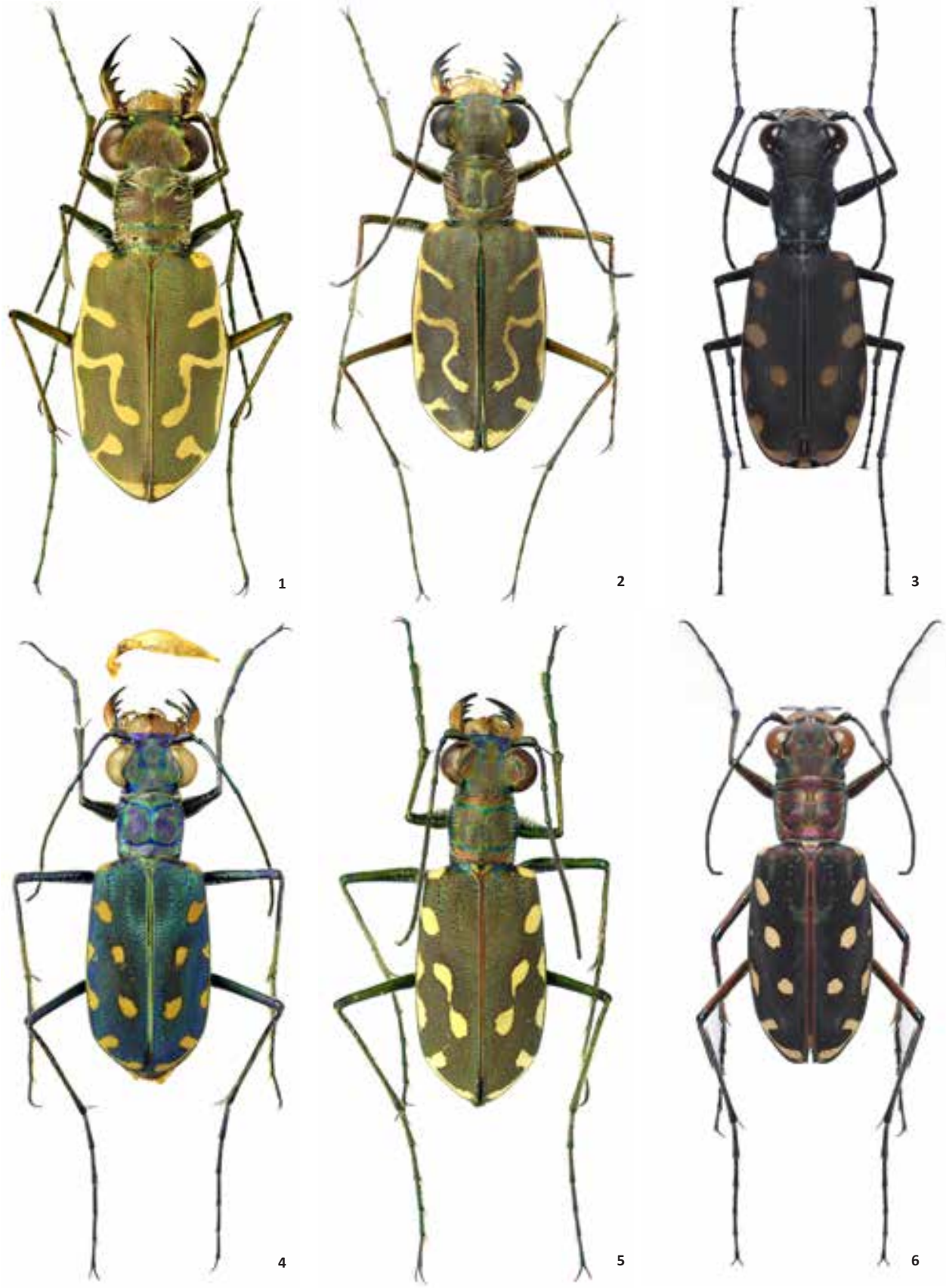
**Remarks:** Among the three *Calomera* species in Mindanao, this one is considered the rarest to find. The specimen at the CRC was collected through light trapping between 18.00h and 20.00h.

**Distribution:** Endemic to Mindanao, Misamis Oriental, Gingoog; Bukidnon, Impasug-ong; New Bataan, Cagan – new distribution record (Type locality: "Misamis Oriental, Gingoog").

***Calomera lacrymosa* (Dejean, 1825)** (Images 4–5)

**Materials examined**: Luzon: Apayao, Calanasan, rocky and sandy river, 80–150 m, 18.125°N & 120.593°E, 24.xi.2017, RJT. Villanueva leg (1 male, UMCRC); Aurora, Dingalan, Aug. 2013 (4 males, 1 female; DUBC); Sierra Madre, Aurora, E Luzon, XII.2014 (1 female; DUBC); Cagayan, Baggao X.2014 (1 female, DUBC). Mindanao: Davao City, Tawan-tawan, rocky and sandy river, 330m, 7.105°N & 125.202°E, 12.ii.2019, M. Medina leg (10 males, 6 females, UMCRC); Zamboanga del Norte, Gutalac, XII.2014 (3 males; 3 females, DUBC); idem but X.2014 (4 males; 2 females, DUBC); Bukidnon, Mt. Kalatungan, XI.2014 (2 males, DUBC). Palawan: Bordeus, X.2018 (1 male, DUBC). Tablas: San Agustin, October 2018 (2 males, DUBC).

**Diagnosis:** *C. lacrymosa* (Dejean, 1825) is a rather small *Calomera* species, having cupreous, greenish,




Images 1–6. Habitus of *Calomera* species from the Philippines: 1—*C. angulata* | 2—*C. despectata* | 3—*C. cabigasi* | 4—*C. lacrymosa* (Luzon) | 5—*C. lacrymosa* (Mindanao, Zamboanga) | 6—*C. mindanaoensis*. © 1,2,4,5—A. Alexander Anichtchenko | 3,6—Chrestine Torrejos.

or sometimes bluish elytra; slightly blackened on disc, with the blue-green punctuation mostly well apparent through especially in front part. Elytral markings normally include an anterior lateral dot, and in many specimens, on one elytron at least, there is an evident narrow lineole tending to connect the two discal dots. Labrum structure (Images 8–9).

**Ecology:** *C. lacrymosa* is one of the most adaptive species that thrives in almost all lowland river systems compared to the other four species of *Calomera* in the Philippines. In Mindanao, *C. lacrymosa* seem to occur sympatrically with *C. mindanaoensis* where it co-inhabited in the same river at different microhabitat (Medina 2020). The minimum requirement for *C. lacrymosa* to thrive includes lowland open area with direct sunlight and sandy river. Moreover, unlike *C. lacrymosa*, *C. mindanaoensis* was not observed thriving in a fluvial system with poor water quality.

**Remarks:** Population from peninsular Zamboanga (Mindanao) was described under the name *insularis* by Blanchard (1853). This taxon is considered a synonym of *C. lacrymosa*. Specimens from Zamboanga has slight but constant differences, i.e. smaller body size, always cupreous body colour (Image 5), the teeth of labrum of males are less distant from each other than in specimens from Luzon (Images 9a,b), and apice of aedeagus slightly blunt (Image 12). Probably this population deserve status of subspecies.

**Distribution:** *C. lacrymosa* is widespread in the Philippine Islands, from Luzon to Mindanao. It was known in Mindoro, Palawan, Romblom, Samar in Visayas, and Balabac (Wiesner 1992a).

***Calomera mindanaoensis* Cassola, 2000** (Image 5)

**Materials examined**: Mindanao: Davao de Oro, New Bataan, Cagan, 1,300m, rocky and sandy river, [7.242°N & 126.124°E], 23.iv.2013, MND. Medina leg (17 males, 19 females UMCRC); Davao de Oro, Montevista, Mayaon, rocky and sandy river, 150m, [7.433°N & 125.555°E], 12–14.iv.2012, MND. Medina leg (4 males, 1 female, UMCRC); Davao de Oro, Nabunturan, MHSPL, rocky and sandy river, 300m, [7.284°N & 126.014°E], 07–15.i.2012, MND. Medina leg (17 males, 19 females, UMCRC); South Cotabato, Mt. Parker, Lake Holon, 1,200m, [6.055°N & 124.525°E], 07–15.i.2012, A.A. Cabras leg (1 female, UMCRC); idem but 5–10.X.2019, Anichtchenko A. leg. (2 females, DUBC); Davao de Oro, Nabunturan, Cabalinan, rocky and sandy river, 80m, [7.284°N & 126.014°E], 21.iv.2012, K. Jumawan leg. (1 male, 2 females, UMCRC); Mount Hamiguitan Range Wildlife Sanctuary, 6.738°N & 126.145°E, 500m, 30.iii–2.iv.2018, Anichtchenko A. leg. (1 male, 1 female; DUBC); Sebu Lake, 28.ix.2014, K. Kolesnichenko leg. (1 female, DUBC); Araibo, Pantukan, Candalaga Mts, 15–20.x.2019 Anichtchenko A. leg. (2 males, 2 females, DUBC).

**Diagnosis:** Species is very similar to *C. lacrymosa*, however slightly larger in size on average, with darker, nearly velvety dark blue elytra; elytra punctuation nearly extinct (Cassola 2000). Anterior lateral spot very small, sometimes lacking, the two discal dots not connected each other by a narrow lineole. Labrum structure (Images 7a–b).

**Ecology**: Similar with its closest counterpart *C. lacrymosa*, *C. mindanaoensis* is also an adaptive species as it can tolerate severely disturbed habitats, even within banana plantations near fluvial systems just in the case in Maragusan in Davao de Oro. Common in lowland up to middle upland areas between 100–800 m, mostly thrives in sandy and rocky soil near the river or creek. It is active from 08.00–11.00 h on hot sunny days.

**Remarks:** Most of the materials are collected during their feeding time between 08.00–11.00 h Philippine Standard Time through hand netting. After this period, they are expected to have absorbed ample heat energy making them more agile and harder to catch. After this, most species are becoming harder to find as they started to rest and hide in shrubs and understory.

**Distribution:** At present, the known distribution of *C. mindanaoensis* is within Greater Mindanao. Materials were collected from the provinces of Davao de Oro, Bukidnon, Tagum City, Lake Sebu in South Cotabato (Cabras et al. 2016a), additional records are from Davao City in Tamugan and Matina Pangi, Mt. Hamiguitan Range Wildlife Sanctuary in Davao Oriental, Davao del Sur in Sta. Cruz, and Island Garden City of Samal (Medina et al. 2020b).

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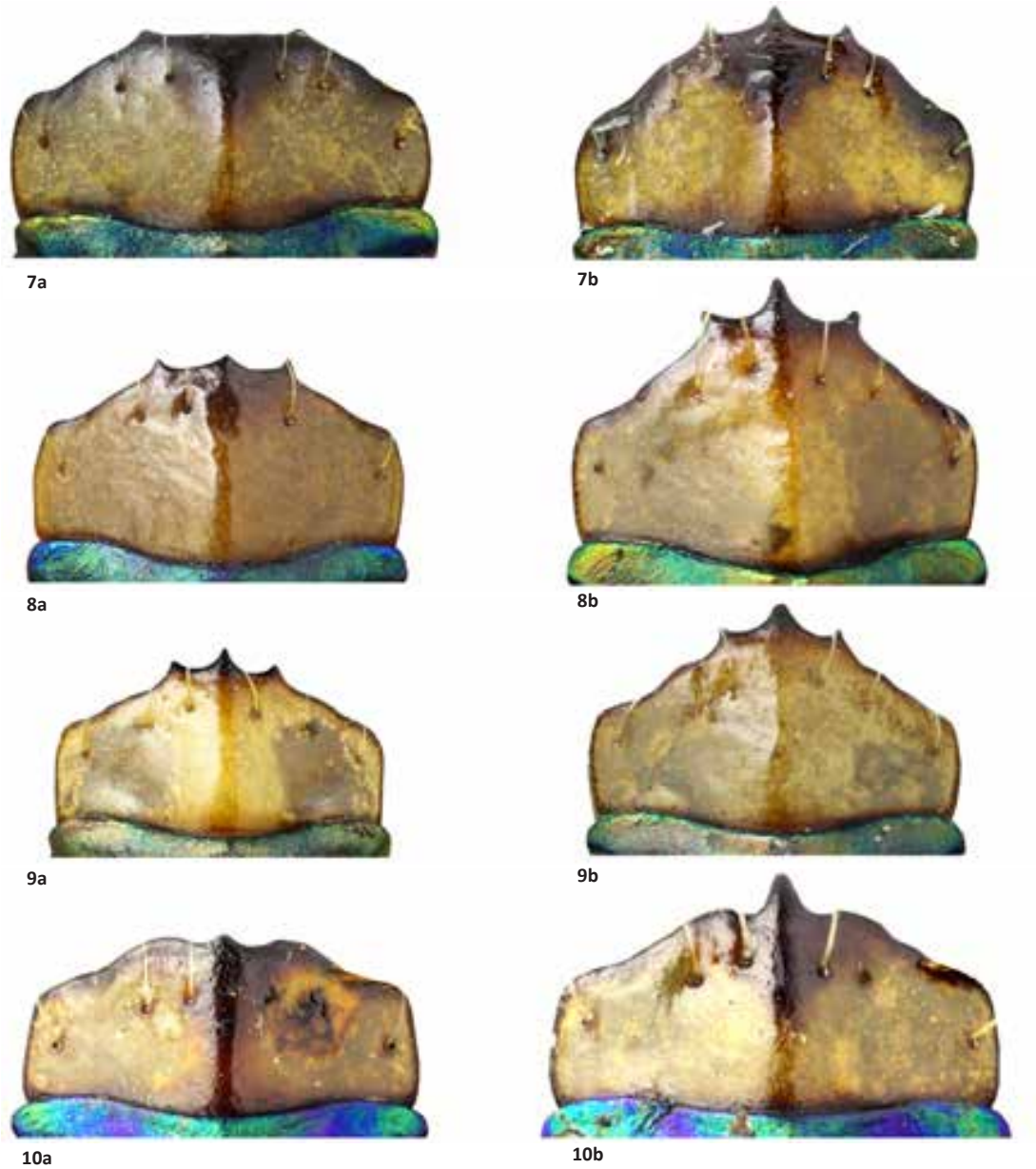


**Images 7–10. Labrum: a—male | b—female of: 7—*C. mindanaoensis* | 8—*C. lacrymosa* (Luzon) | 9—*C. lacrymosa* (Mindanao, Zamboanga) | 10—*C. cabigasi*. © A. Alexander Anichtchenko.**

**Key to species of *Calomera* Motschulsky, 1862 from Philippines**

| | | |
|---|---|---|
| 1 | Median elytral band interrupted, consist of three rounded spots (Images 3–6) | 2 |
| - | Median elytral band continuous (Images 1–2) | 4 |
| 2 | Sides of pronotum with white setae (Images 4–6) | 3 |
| - | Sides of pronotum without white setae (Image 3) | *C. cabigasi* |
| 3 | Head, pronotum and elytra concolor. Labrum of males tridentate, with central tooth (Images 8–10) | *C. lacrymosa* |
| - | Head and pronotum metallic cupreous red, elytra dark blue. Labrum of males bidentate, without central tooth (Image 9a) | *C. mindanaoensis* |
| 4 | Humeral macula of elytra inclined in respect to lateral margin of elytra (Image 2). Elytra of females not dilated in the middle | *C. despectata* |
| - | Humeral macula of elytra less inclined, almost perpendicular to lateral margin of elytra (Image 1). Elytra of females strongly dilated in the middle | *C. angulata* |


**Images 11–12. Endophallus structure: 11—*C. mindanaoensis* | 12—*C. lacrymosa* (Mindanao, Zamboanga). © A. Alexander Anichtchenko.**

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# Rediscovery of Martin's Duskhawker *Anaciaeschna martini* (Selys, 1897) (Odonata: Aeshnidae) from Western Ghats, peninsular India, with notes on its current distribution and oviposition behavior

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**Abstract:** Rediscovery and recent distribution records of *Anaciaeschna martini* (Selys, 1897) (Odonata: Aeshnidae) from Western Ghats of peninsular India is discussed with notes on oviposition behavior. Although mentioned in odonate checklists of the region, there are no recent records or photographic evidence of the species from Western Ghats since its last report and collection by F.C. Fraser from Annamalai Hills in 1933.

**Keywords:** Anamalais, Checklist, Check-dam, Coonoor, Kerala, Munnar, Nilgiris, Pampadum Shola National Park, rediscovery.

The family Aeshnidae Leach, 1815 consists of large dragonflies known for their fast majestic flight. They are found in diverse wetland habitats from the coast to high altitude montane lakes. Most are diurnal, though some are crepuscular species and distributed globally. They breed in large ponds, tanks or in small side-pools of fast-flowing streams; preferably with vegetation fringing it (Fraser 1936). Aeshnidae in Kerala State has representatives of three genera, namely, *Anaciaeschna* Selys, *Anax* Leach, and *Gynacantha* Rambur (Subramanian & Babu 2017). *Anaciaeschna* Selys has two species in the Western Ghats, *A. martini* (Selys, 1897) and *A. jaspidea* (Burmeister, 1839) (Fraser 1936). Fraser (1922) described *Anaciaeschna donaldi* from Kodaikanal (Palni hills) and recent studies demonstrate that *A. donaldi* is a junior synonymn of *A. martini* Selys, 1897 (Conniff et al. 2019). Though there are many records of *A. jaspidea* from peninsular India, there are no recent records of *A. martini*. The last record of the species was by F.C. Fraser in 1933 from Annamalai Hills (Conniff et al. 2019). The current distribution range for the species is Sri Lanka, Nepal, and peninsular India to Japan (Subramanian et al. 2018; Conniff et al. 2019). Here, we report recent sightings *A. martini* (Selys, 1897) from Western Ghats of peninsular India, with descriptive notes on its oviposition behavior.

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## Materials and Methods

This paper is based on three sightings of the females of *A. martini* (Selys, 1897). The first was from Nilgiris in September 2014 and later two sightings were from Munnar region in Anamalais landscape of Western Ghats in June 2019 (Figure 1). Photographs of the specimens were taken with Nikon D90 DSLR 90mm lens and Canon EOS 70D DSLR and 180mm macro lens. The current odonate checklist for Kerala follows Subramanian & Babu (2017). The present distribution of the odonates of the Western Ghats region is based on Subramanian et al. (2018). Weather conditions were documented in the 2019 sightings using Kestrel 5500 (Neilsen-Kelleran, USA). Initials of the names of the authors are used in text below in details of observation.

## Results

***Anaciaeschna martini* (Selys, 1897)**

(Images 1 & 2)

**Material Examined:** (1) *Anaciaeschna martini* (Selys, 1897): Female, dead specimen found by Kalesh Sadasivan (KS); Munnar River (10.085N, 77.061E), Munnar Town, Idukky District, Kerala, India; 15 June 2019; 1387m; photographed by KS; 1,387m. (Image 1). (2) *Anaciaeschna martini* (Selys, 1897): Female ovipositing observed by KS and Baiju Kochunarayan (BK); in a montane lake at Bander in Pampadum Shola National Park, near Top-station in Munnar; observed, not photographed or collected; 16 June 2019; 2,250m. (3) *Anaciaeschna martini* (Selys, 1897): Female ovipositing observed by Manoj Sethumadavan (MS) and Jeevith.S (JS); photographs of ovipositing female was taken at a Ralliah Dam in Coonoor (11.401N, 76.799E), Nilgiris District by MS; 9 September 2014; 2,100m (Image 2).

### Field Observations

All observations are of females of the species from the stagnant montane waterbodies of southern Western Ghats above 1,300m.

Anamalais sightings (Image 1, Figure 1): A fresh dead female was observed by KS by a roadside near Munnar River, Munnar Town, Idukky District, Kerala, India at 10.15h on 15 June 2019. This was probably a roadkill and the weather parameters at the site was 27.5$^0$C, 79.30% relative humidity, and non-windy. The nearby lake had a water depth of >2m and was undergoing renovation of its banks (Image 1).

A female of the species was sighted by KS & BK, ovipositing in a montane pond, amidst grassland and wattle plantation on 16 June 2019, at 2,250m at Pampadum Shola National Park, near Top-station in Munnar. It was a bright sunny day, and the activity was observed from 10.00 to 11.30 h and the weather parameters was as follows: wind speed was 0.7m/s,


**Figure 1. Study sites in Western Ghats of southern India.**

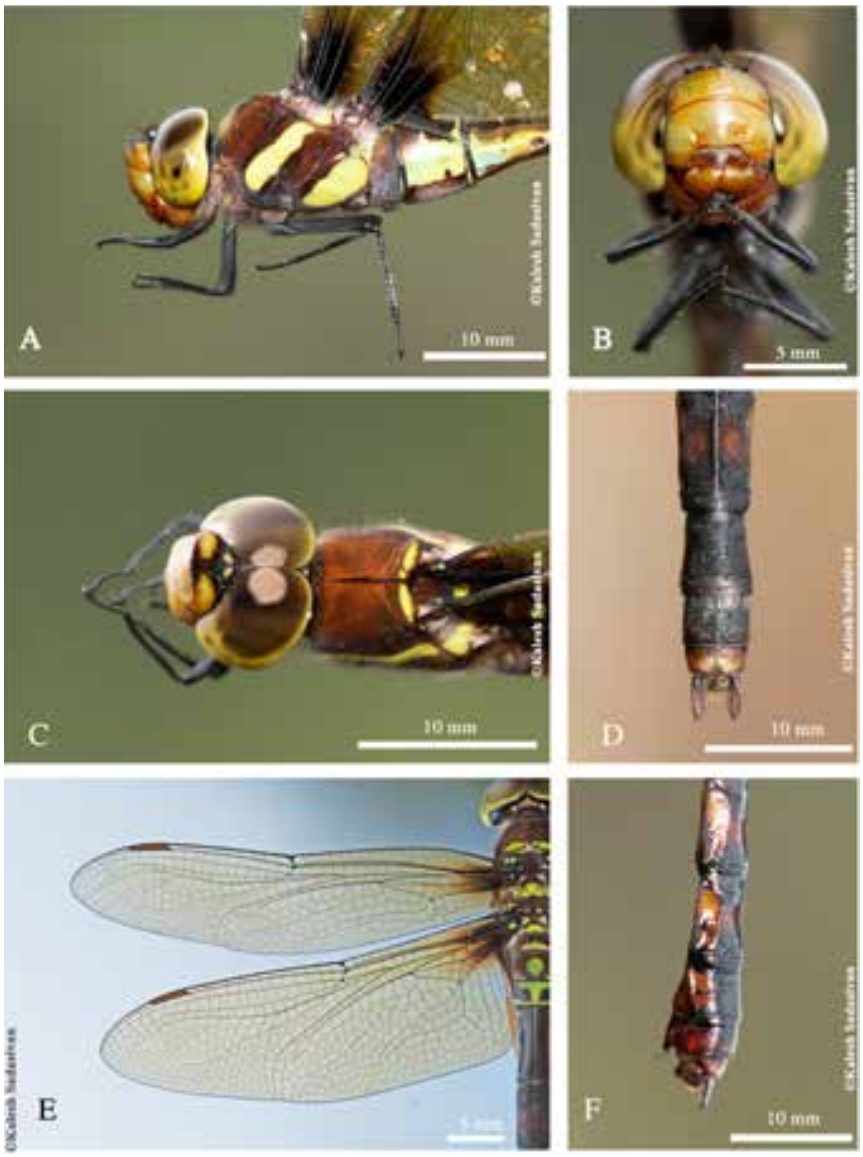


**Image 1. *Anaciaeschna martini* (Selys, 1897) Female from Munnar, 15 June 2019: A—lateral view of thorax | B—view of Labium, labrum and frons | C—dorsal view of frons with the 'H' shaped mark and thorax | D—dorsal view of last four abdominal segments and anal appendages | E—venation | F—lateral view of the last four abdominal segments and anal appendages. © Kalesh Sadasivan.**

temperature was 19.9$^0$C, and the relative humidity was 54%. The pond was formed by a small check dam on a small montane stream and had a perennial supply of water. The depth of the water was about 1.5m at the deepest part of its sloping floor, which was partially formed by a large rock, though predominantly formed of clay and mud. Water was relatively clear and the edges of pond had good vegetation. Dominant vegetation around the pond was of emergent reeds *Juncus inflexus* L. (Juncaceae) and *Viola pilosa* Blume (Violaceae), the latter forming the ground vegetation at edges. The female would visit the pond once every 30min or so after a patrol, disappear into the emergent fringing vegetation and circle to and forth for a few minutes just above the water level. It would then suddenly fly off downstream, only to reappear after a while. Flight was swift and straight. It later settled on the emergent reed leaf and was ovipositing with its abdomen on the submerged part of the reed. No males were seen on guard. Other species that were seen in the same habitat *were Orthetrum triangulare* (Selys, 1878), *O. pruinosum* (Burmeister, 1839), *Sympetrum fonscolombi* (Selys, 1840), *Pantala flavescens* (Fabricius, 1798), and *Aciagrion approximans krishna* Fraser, 1921.

Nilgiri sightings (Figure 1, Image 2): Ovipositing behaviour was photographed in bright sun, at about 11.00h on 09 September 2014, at a check-dam near Ralliah Dam in Nilgiris at an elevation of 2,100m by MS & JS. The check dam was situated 500m off the outlet of the dam and the source of water was from the


**Image 2. *Anaciaeschna martini* (Selys, 1897) female from Coonoor Nilgiris, 9 September 2014: A—female landed on the *Nymphea* leaf on its margin | B—curving the abdomen and probing for oviposition.**

overflow of the dam as well as the inherent seepages at the location. At its origin the stagnation is of a metre in width and hardly a foot in depth on swampy terrain the check dam extends in width to its farthest with 1.828m in depth and 4.572m in width. It has a radius of 25m to its banks from its deepest and has a width of 50m. It had a luxuriant growth of Waterlilly *Nymphaea nouchali* Burm.f. (Nymphaeaceae) and *Schoenoplectus mucronatus* (L.) Palla in Engl. (Cyperaceae) as emergent vegetation. On its left side it was edged with native bushes and on the right with grassland enclosed all along with *Schoenoplectus* reeds. The female landed on an exposed *Nymphaea* leaf on its edge (Image 2A) and then searched down for water by curving down its abdomen and probing (Image 2B). It sometimes walked on from one leaf to another. It was also seen landing amidst the *Schoenoplectus* reeds, then move down to water and oviposit underneath on the submerged part of it. No males were seen guarding or in the female's vicinity. In the same pond *Pseudagrion microcephalum* (Rambur, 1872) and *Aciagrion approximans krishna* Fraser, 1921 were breeding.

### Habitat and Distribution

*Anaciaeschna martini* (Selys, 1897) is a high elevation species restricted to the montane lakes and waterbodies in southern montane wet temperate forests and southern montane wet grasslands in the Western Ghats above 1,300m (Image 3). The current known distribution is Nilgiri, Palni, and Anamalais hills in peninsular India. It is otherwise seen from montane regions of Sri Lanka, Himalaya (Nepal and Bhutan) and further eastwards till Japan (Conniff et al. 2019).

## Discussion

The previous records of the species in Western Ghats and southern India are from Fraser only from Varatapari, Annaimalai (Anamalais) Hills in 1933; Ooty, Nilgiris in 1921, Yercaud in 1921, and Kodaikanal in Palani Hills in 1908 (Conniff et al. 2019). Thereafter, this species had escaped notice in the Western Ghats until now. As far as it is known, this species is restricted to the shola-grasslands of the region. The recent records confirm that the species is still found in the montane habitats (1,500–2,250 m), on both sides of the Palghat Gap and is breeding there. The species breeds in montane marshes, large stagnant ponds, and small lakes. The males are virtually never encountered in the field, while the females are seen ovipositing on emergent aquatic vegetation. The breeding season observed was from May to September, based on our observation, and may be reasonably presumed to be extended from May to November tallying with the monsoon rains in the region. The species is a strong flyer and hence may be expected to be found across similar mountainous locations with suitable habitats in peninsular India as commented by Conniff et al. (2019). The status of the species is possibly locally 'not uncommon' but may be rare altogether in the Western Ghats. Further studies may be done to elucidate the status and distribution of the species along with those odonates occupying the montane lakes of Western Ghats, as an indicator of the rapidly changing environmental conditions of this threatened mountain ecosystem.

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**Image 3. *Anaciaeschna martini* (Selys, 1897) habitat: Montane lake at Coonoor, Nilgiris District, Tamil Nadu.**

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# A note on the current distribution of reedtail damselfly *Protosticta rufostigma* Kimmins, 1958 (Odonata: Zygoptera: Platystictidae) from Western Ghats, and its addition to the odonate checklist of Kerala

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**Abstract:** The genus *Protosticta* (Odonata, Zygoptera, Platystictidae) is represented by nine species in the Western Ghats of peninsular India, of which seven are reported for the state of Kerala. Our recent records of *Protosticta rufostigma* Kimmins, 1958 from the Western Ghats of Kerala State is discussed, and despite a thorough literature search no collection records or photographs of the species has been found after the original description from Tamil Nadu. The species is, thus, added to the checklist of odonates of Kerala State. The description of the live insect, its ecology, status and distribution is discussed.

**Keywords:** Agasthyamalai, broad-leaved evergreen forests, Kakkayam, Malabar Wildlife Sanctuary, *Myristica* swamps, Ponmudi, *Ochlandra* reed brakes, rediscovery, western coast evergreen forest.

The genus *Protosticta* Selys, 1885 consists of zygopterous damselflies of small size and slender built commonly called Reed-tails or Shadow-damsels, inhabiting hill streams of tropical, subtropical and southern montane wet temperate sholas of southern India and forests of south east Asia. In India, they are distributed in the Western Ghats of peninsular India, parts of north-eastern India and Burma (Fraser 1933; Emiliyamma & Palot 2016). The genus has 49 extant species (Schorr & Paulson 2020), distributed from Pakistan, through Indian subcontinent to Indo-China and southeastern Asian Islands (van Tol 2000). There are 12 species of *Protosticta* in India and of them nine inhabit Western Ghats of peninsular India. These are *Protosticta gravelyi* Laidlaw, 1915, *P. hearseyi* Fraser, 1922, *P. sanguinostigma* Fraser, 1922, *P. antelopoides* Fraser, 1924, *P. mortoni* Fraser, 1924, *P. davenporti* Fraser, 1931, *P. rufostigma* Kimmins, 1958, *P. ponmudiensis* Kiran, Kalesh & Kunte, 2015, and *P. monticola* Emiliyamma & Palot, 2016 (Subramanian et al. 2018). Other species recorded within Indian limits are *P. himalaica* Laidlaw, 1917, *P. fraseri* Kennedy, 1936, and *P. damacornu* Terzani & Carletti, 1998 (Fraser 1933; Kennedy 1936; Terzani, & Carletti 1998; Subramanian, 2014; Kiran et al. 2015; Emiliyamma & Palot 2016). Of these, all except *P. mortoni* and *P. rufostigma* had been recorded from Kerala (Subramanian et al. 2018). *P. rufostigma* was only known from its type locality in

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**Image 1. Type locality and recent spot records of *Protosticta rufostigma* Kimmins, 1958 in Kerala.**

Tinnevelly, Tamil Nadu (Kimmins 1958); and was likely to occur in the hill streams with good riparian forest cover in Agasthyamalai Hills (Subramanian et al. 2018). No records of the species, however, had been found after a search of peer-reviewed literature and the first confirmed records for state of Kerala is provided here based on field records of the authors since 2006.

## Materials and Methods

The field data on odonates of the authors since 2000 from expeditions to Western Ghats of Kerala State was analysed for this work (full work will be published later). Whenever possible the species photographs were taken with special emphasis on the structure of prothorax and anal appendages of the insects. The morphological descriptions follow Fraser (1933) and Garrison et al. (2006). The central depression in the middle lobe of the prothorax is referred to as the sulcus in the description below. Measurements of specimens were taken using a vernier caliper. Morphometrics of species are based on specimens in NCBS (National Centre for Biological Sciences, Bengaluru, India) collections. Images of the holotype (NHMUK 01332477) and allotype (NHMUK 013324264) from Naraikadu, 2500–3000 ft, Tinnevelly Dt, S.India, 3-8-X-1938, were referred from online portals of the Natural History Museum London https://data.nhm.ac.uk/, accessible at Natural History Museum (2014). Dataset: Collection specimens. Resource: Specimens. Natural History Museum Data Portal (data.nhm.ac.uk). https://doi.org/10.5519/0002965, Retrieved: 06.15 23 July 2020 (GMT). Current distribution is based on personal records and published literature. Unless specified, all the results including locality records are of the authors. Photographs of the specimens were taken with Canon (Canon Inc., Japan) EOS 70D DSLR and 180mm macro lens. Taxonomy of the group follows Fraser (1933). The current taxonomic checklist for Kerala follows scientific names in Subramanian & Babu (2017). The current distribution of the odonates of the Western Ghats region is based on Subramanian et al. (2018). Weather conditions were documented for the Agasthyamalai sightings of 2019 using Kestrel 5500 (Neilsen-Kelleran, USA). Initials of the names of the authors are used in text below in describing the details of field observation.

## Results

***Protosticta rufostigma* Kimmins, 1958**

(Image 2&3)

**Material examined**

NCBS-BH878, male, vii.2014, brook in a private estate, Ponmudi, Thiruvananthapuram, Kerala, India; 800m, coll. Kalesh Sadasivan; NCBS-BH879, male, vii.2014, stream side in a private estate, Ponmudi, Thiruvananthapuram, Kerala, India; 700m, coll. Kalesh Sadasivan.

**Measurements**

NHMUK 01332477 holotype male abdomen 46mm, hindwing 23mm (Kimmins, 1958).

NHMUK 013324264 allotype female abdomen 36mm, hindwing 22mm (Kimmins, 1958).

NCBS-BH878 male abdomen 49mm, hindwing 22mm.

NCBS-BH879 male abdomen 52mm, hindwing 23mm.

**Historical distribution**

The type locality is 'Naraikadu in Tinnelvely (Thirunelveli) District Tamil Nadu 2500–3000 ft, September 1938' (Kimmins 1958). No other distribution records of the species are available.

**Recently observed field records of *Protosticta rufostigma* Kimmins, 1958 (not collected) and its current distribution:**

All observation are from the montane seepages and brooks of low to mid-elevation evergreen forests of Western Ghats above 200m (Image 1).

1. Male; 1 January 2006; Kakkayam, Malabar Wildlife Sanctuary, Kozhikode District, Kerala State, 709m (KS & MJP).
2. Female; 22 April 2012; Pandipathu, Peppara Wildlife Sanctuary, Thiruvananthapuram District, Kerala State, 702m (KS) (Image 2C).
3. Male; 31 May 2013; Ponmudi-Kallar Valley, Thiruvananthapuram District, Kerala State, 898m (KS). (Image 2D).
4. Male; 6 June 2013; Pandipathu, Peppara


**Image 2. *Protosticta rufostigma* Kimmins, 1958: A—male, 8 June 2013 Pandimotta in Shendurney in Kollam District | B—male, 6 June 2013, Pandipathu, Peppara Wildlife Sanctuary, Thiruvananthapuram District | C—female, 22 April 2012, Pandipathu, Peppara Wildlife Sanctuary | D—male, 31 May 2013, Ponmudi-Kallar Valley, Thiruvananthapuram District.**

Wildlife Sanctuary, ThiruvananthapuramDistrict, Kerala State, 695m (KS) (Image 2C). (Image 2B).

5. Male; 8 June 2013 Pandimotta in Shendurney in Kollam District, Kerala State, 898m (KS) 900m Ochlandra reed brake (KS) (Image 2A).

6. Male June 2, 2019; Ponmudi-Kallar Valley, Thiruvananthapuram District, Kerala State, 196m (KS).

7. Male; June 2, 2019; Ponmudi-Kallar Valley, Thiruvananthapuram District, Kerala State, 198m (KS).

Thus, all our records are from Kerala part of the Western Ghats from Kakkayam in Kozhikode District and Agasthyamalais of Thiruvananthapuram District.

**Description and field identification of males**

The features that are consistent, as per the original description of Kimmins (1958) are as follows. The variations observed in the species is mentioned separately below.

Head: labium is brownish-black; labrum is light blue broadly bordered with brownish-black; clypeus is pale blue. Frons: glossy blue-black; vertex and occiput are dull black. Prothorax: greenish white, posterior lobe blackish, this colour extending into the middle lobe. Synthorax: dark metallic green, with bluish-white oblique stripe on lateral thorax to mid legs and similar one to the hindlegs behind it. Legs: brownish-white. Abdomen: black-brown, marked with yellow and blue; S1 and S3 laterally yellowish-white; S3 narrow basal annulus yellowish-white, divided dorsally with black; S4-7 broader yellowish-white annuli, slightly widened laterally; S8 with basal half blue, not extending apically at sides; 9 and 10 black. Anal Appendages: black, similar to *P. davenporti* in general, but the cerci with basal tooth less acute and the thumb-like process more slender; paraprocts in dorsal aspect a little stouter. Wings hyaline, faintly smoky; pterostigma reddish-brown; 14 post nodals in FW, 13 in HW; Riv+v arising well distal to node. Female is similar to male, legs paler, knees and dorsal carinae brown; abdomen marked in bluish-white instead of yellowish-white; S7 annulus occupying the basal fourth.

**Additional morphological and taxonomic notes based on NCBS-BH878 and NCBS-BH879**

Head*:* eyes in the live insect are turquoise greenish-blue, capped dark brownish-black on the posterosuperior aspect, pale blue below and more or less whitish behind. Vertex is dark metallic green with golden shine; occiput and post ocular region black; Antennae are dark blackish-brown (Image 3D). Prothorax: unarmed with no spines or ornamentations to lobes, posterior lobe fully metallic black with dark green reflux, middle lobe is pale bluish-white with lateral borders dirty yellow; anterior lobe is pale brown with a central transverse triangular black streak and a lateral bluish suffusion. Sulcus of middle lobe of prothorax dark blackish-brown and this colour is confluent with the black of the posterior lobe (Image 3B). Thorax: the ground colour is dark metallic green with scattered golden sheen. The dorsal carina black; lateral stripes may be very pale blush white to almost white. Coxae pale bluish. Trochanters white. Femora all dirty pale ashy brown with black thick stripe on the extensor aspect. Knees and extensor keels are black; tibia is brown and tarsus dark brown. Claws are dark brown (Image 3B&C). Wings: venation with 1A reaching the posterior wing margin after 5–6 cells in FW and 5–6 in HW; Post-nodals 13–14 in FW and 12–13 in HW; FW $IR_3$ origin near origin of $Px_6$ in FW and Px5 in HW (Image 3A). Abdomen: S8 with a complete basal annulus occupying just a little lesser than half of the segment. The black of the dorsal carina on S8 encroaches into the band as a small convex intrusion from either side on the dorsal midline. Length of S9 is a little more than half of that of S8. Anal appendages (Image 3E&F). The external deviation of the cerci at the tip seen in *P. davenporti* is not appreciable in *P. rufostigma,* where the outer border is uniformly converging. Cerci with a basal tooth pointing inwards; tip of the finger process is thickened; outer border of cerci gradually converging and not sinuous, the thumb with a medial angulation, a small tubercle before this angle and the tip tapering and spine like (Image 4). The paraprocts bears a basal spine pointing inwards.

**Females**

Females were not collected, but were observed in field and photographed. The female from Agasthyamalai had darker brownish legs, yellowish annuli, and lateral thoracic stripes (Image 2C).

**Ecological notes**

The species generally flies during May–July, 200–1,200 m elevation in the Agasthyamalai Hills in small brooks and seepages in evergreen forests, broad-leaved evergreen forests, *Myristica* swamps, and *Ochlandra* reed brakes. It was also seen at elevation of 700m as observed at Kakakyam in Malabar Wildlife Sanctuary on 01 January 2006, in the dry winter. It always keeps to cooler and darker shady jungles and perches on overhanging vegetation, branches of *Ochlandra* reeds, and *Schumannianthus* plants (Marantaceae) in these marshes. The weather conditions observed at the Agasthyamalai site was as follows: temperature

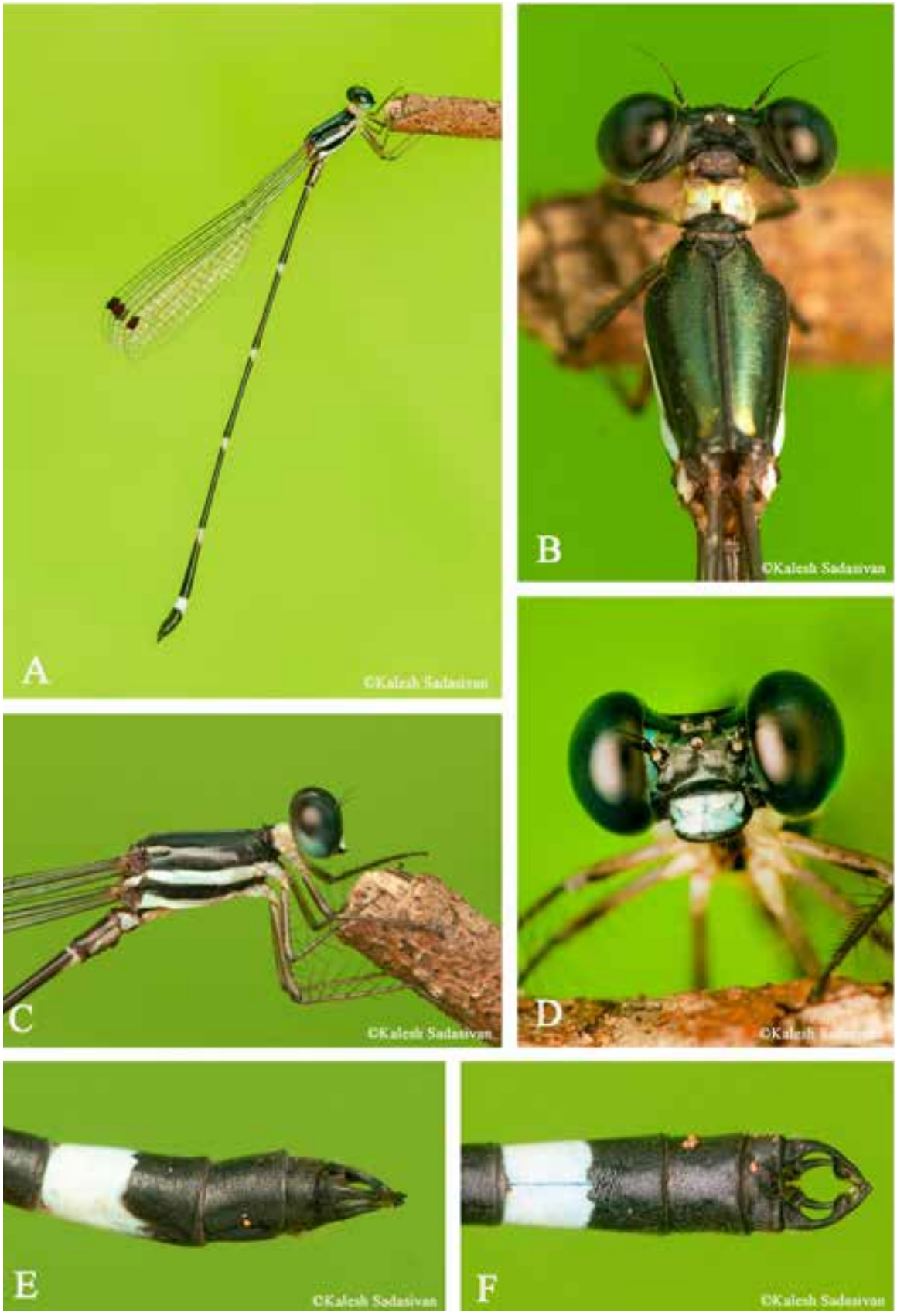


**Image 3.** ***Protosticta rufostigma*** **Kimmins, 1958: A—male | B—dorsum of prothorax and thorax | C—lateral view of head and thorax | D—close-up of head | E—anal appendages lateral view | F—anal appendages dorsal view.**

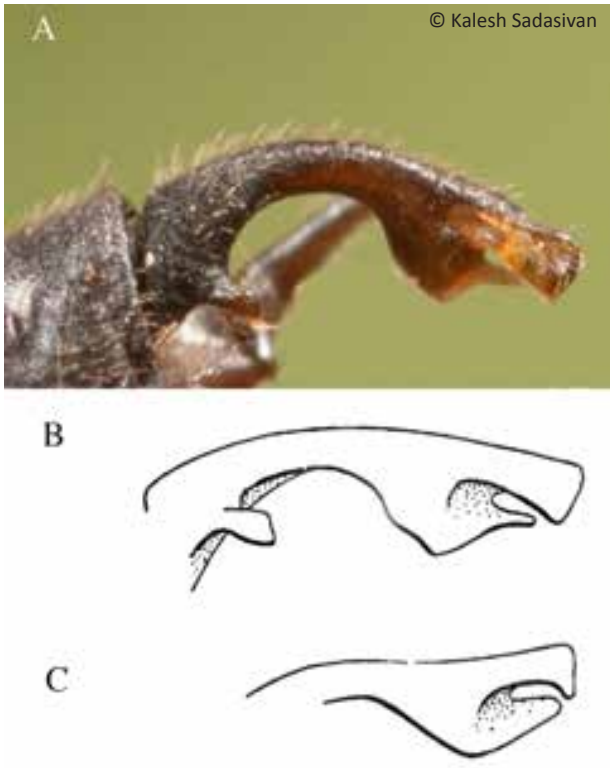


**Image 4. Anal appendages: A—*Protosticta rufostigma* Kimmins, 1958, male cerci dorsal view of NCBS-BH878 | B—*P. rufostigma* Kimmins, 1958, male cerci (adapted from Kimmins, 1958) | C—*P. davenporti* Fraser, 1931 male cerci (adapted from Kimmins 1958).**

26–28$^0$C, relative humidity 86–96% and no wind. The species shares it habitat with other odonates like *Heliogomphus promelas* (Selys, 1873), *Hylaeothemis indica* Fraser, 1946, *Idionyx travancorensis* Fraser, 1931, *Vestalis submontana* Fraser, 1934, *Euphaea cardinalis* (Fraser, 1924), *E. fraseri* (Laidlaw, 1920), *Caconeura ramburi* (Fraser, 1922), *C. risi* (Fraser, 1931), *Esme mudiensis* Fraser, 1931, *Melanoneura bilineata* Fraser, 1922, *Indosticta deccanensis* (Laidlaw, 1915), *Protosticta gravelyi* Laidlaw, 1915, and *P. ponmudiensis* Kiran et al., 2015.

## Discussion

This paper confirms the presence of *Protosticta rufostigma* Kimmins, 1958, from the Western Ghats of Kerala, thus adding it to the checklist of odonates of Kerala. The species is similar to *P. davenporti* Fraser, 1931, but may be distinguished by the larger pterostigma, pattern of prothorax, S8 and the structure of the male cerci. Though the pterostigma is similar to that of *P. sanguinostigma* Fraser, 1922, the anal appendages are very different from it, as the latter has a prominent dorsal spine on the cerci. The original description of the species was based on specimens deposited in the Natural History Museum, London. So the colours on the live insect were not mentioned in the description by Kimmins (1958). Here an additional description of the insect is provided based on live individuals. The dark bottle green colour of the eyes are diagnostic of the species, along with the characteristic anal appendages of males. As per our field experience the species is not uncommon in the Agasthyamalais in suitable habitats. Given the similarities of the species in morphology and ecology, it can be considered closely related to *P. davenporti* of Anamalais, in the Agasthyamalais. It is to be also noted that despite best efforts *P. davenporti* has not been recorded by us until now in the Agasthyamalais, though recorded in Kerala from the Anamalais (Fraser 1933; Subramanian et al. 2018).

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SHORT COMMUNICATION

# Assessment of threat status of the holly fern *Cyrtomium micropterum* (Kunze) Ching (Polypodiopsida: Dryopteridaceae) in India using IUCN Regional guidelines

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**Abstract:** During the field survey in central Western Ghats of India, an interesting dryopteridoid fern species was collected from Nellikathrupodu Range of Billigiri Rangaswamy Temple (BRT) Tiger Reserve of Karnataka. After a critical study of literature, the specimen was identified as *Cyrtomium micropterum* (Kunze) Ching. In India, this species is known only from its type locality Nilgiri and Palani hills of Tamil Nadu. The present collection from the BRT Tiger Reserve shows its extended distribution and forms the first report for the state of Karnataka. The present paper deals with the assessment and conservation status of *Cyrtomium micropterum* (Kunze) Ching in India in accordance with IUCN guidelines for the application of Red List Criteria at regional and national Levels, 2012, Version 4.0. Detailed descriptions, photographs, microphotographs are provided for easy identification of this species.

**Keywords:** Categorization, GeoCAT, Nilgiris, threatened pteridophytes, Western Ghats.

The seed-free vascular plants of pteridophytes, which include ferns (10,578 species) and lycophytes (1,338 species) are the second most species-rich group of vascular plants composing of ca. 11,916 species globally (PPG I, 2016). It has, however, received little conservation effort than other plant groups and most species of ferns have not yet been evaluated for their conservation status (IUCN 2017). A huge number of ferns and lycophytes have become threatened (Arcand & Ranker 2008) and the decline is probably due to habitat destruction and loss of mature individuals (IUCN 2019). In India, about 1,107 species of ferns and lycophytes were reported (Fraser-Jenkins et al. 2017) of which nearly about one-third of total Indian populations (337 taxa) are considered to be threatened (Fraser-Jenkins 2012). The Western Ghats, one of the global hotspots of the world, harbors 349 species of ferns and lycophytes (Benniamin & Sundari 2020) among which 38 species are assessed as threatened (Benniamin et al. 2008). The previous assessments, however, could not meet the guidelines of IUCN Red List Categories and Criteria neither at the regional nor national Level (IUCN 2012). Hence, the threatened status of most

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**Competing interests:** The authors declare no competing interests.

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ferns and lycophyte species in India remains under-evaluated. The present study is an attempt to assess the threat status of *Cyrtomium micropterum* (Kunze) Ching. (Dryopteridaceae) in India, in accordance with the IUCN Guidelines for application of Red List Criteria at regional and national Levels, 2012, Version 4.0.

During the field survey (2017–2020) the first author collected an interesting dryopteridoid fern species from Nellikathrupodu Range of Billigiri Rangaswamy Temple (BRT) Tiger Reserve, Karnataka (11.91180°N & 77.20776°E). After making detailed studies on morphological characters along with consultation of relevant literature (Manickam & Irudayaraj 1992, 2003; Rajagopal & Bhat 2016; Benniamin & Sundari 2020) and herbarium (BSI, RHT, JCB, MPU), this species was identified as *Cyrtomium micropterum* (Kunze) Ching. On perusal of literature surveys and herbarium consultation, it became apparent that this genus has not been reported in Karnataka. Hence the genus *Cyrtomium* forms a new addition to the pteridophytic flora of Karnataka State, with the single species *C. micropterum* (Kunze) Ching. The paleotropical species *C. micropterum* (Kunze) Ching is distributed in eastern and southern Africa, Madagascar, and southern India. In India this species is known only from its type locality in Nilgiri Hills and from Palani Hills of Tamil Nadu (Figure 1).

The present record with previous studies shows that the habitats of this species, somewhat high altitude on the eastward offshoots of the Western Ghats like Palni Hills, Nilgiri Hills, and BRT Hills are more suitable for this species when compared to Munnar Hills and Tirunelveli Hills on the main tract of the Western Ghats. As far as the Dryopteridaceae members are concerned, most of the species are altitude specific, i.e., 1,300–1,800m. Since the altitude of northern Western Ghats is less than 1,300 m (Maharashtra, Goa, and Gujarat), it is not possible for this species to grow there. This may be due to the requirement of a highly specific ecological niche for this species, which prefers ever-green or partially-exposed semi-evergreen forests at high altitudes. It has also been confirmed that no such specific habitat has been observed on the roadsides of Palni Hills, Nilgiris, and Nellikathuru Podu in the BRT Tiger Reserve, Karnataka. Apart from the altitudinal and physiographic characteristics mentioned above, other climatic factors, in particular the proportion of maritime and land

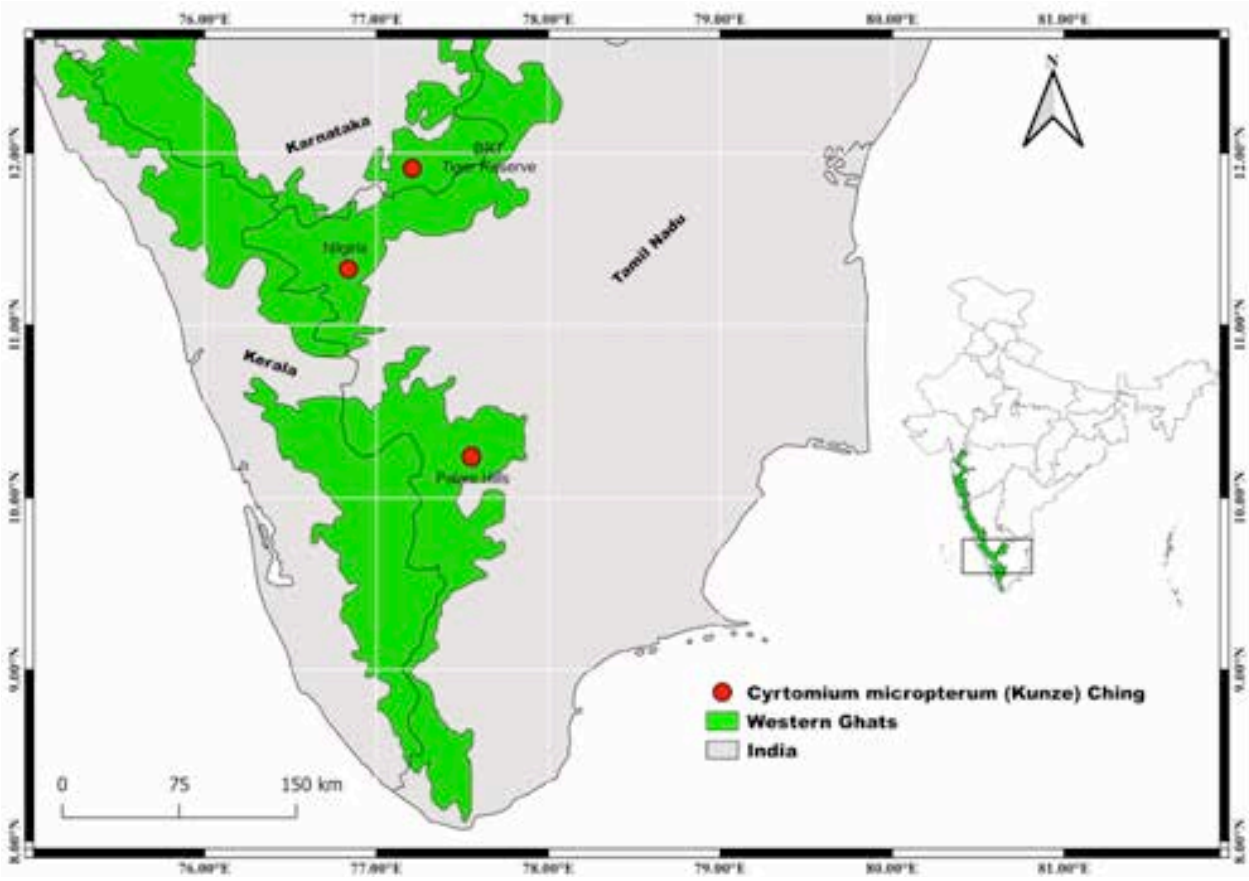


**Figure 1. Distribution of *Cyrtomium micropterum* (Kunze) Ching in India.**

moisture and temperature, also play an important role in the distribution of this threatened fern as shown in the distribution map (Map 1). In general, all the populations are present on the eastern side of the Western Ghats to get more continental air mass and less maritime air mass as in Africa (Bostock et al. 1998). From the distribution pattern of this species, it is well understood that this species prefers high altitude locations along the eastern border of the main tract of Western Ghats, as opposed to unfavorable regions/localities on both the eastern and western slopes. It is expected to be present in Meghamalai, adjacent to Palni Hills, but due to lack of high altitude, it does not grow there (Mr. Amirtham, pers.comm. 15.11.2020).

All the 31 species of *Cyrtomium* are maritime-moisture-loving ferns common in Japan to Africa where all the species are strictly restricted to the easternmost coastal border. But the Indian diploid and triploid apogamous species of *Cyrtomium* shows the difference in the requirements of maritime and land moistures. Thus the triploid *C. caryotideum* requires more moisture with the coolest climate in contrast to the diploid apogamous *C. micropterum* which requires a cooler climate with comparatively less moisture. With the above details on the global distribution of the genus *Crytomium*, the present gatherings of *Cyrtomium micropterum* from BRT Tiger Reserve is a very important record for its complete distribution range in India.

## Materials and Methods

Extensive field exploration was carried out between 2017 and 2020 in different seasons of the year and geographical coordinates were recorded using geographical positioning system (GPS). Plant identification was done by consulting relevant literature (Manickam & Irudayaraj 1992, 2003; Benniamin & Sundari 2020) and herbaria consultation (BSI, RHT, JCB, MPU). Photomicrographs were taken using an Olympus stereo microscope SZ61. Herbarium specimens were deposited at the Botanical Survey of India, Western Regional Centre Herbarium (BSI). A distribution map was constructed using open-source software QGIS Ver. 3.12.0. Assessment of threat status was carried out according to the IUCN Red List Criteria at Regional and National Levels, 2012 (version 4.0). Mature individuals were also counted as per the guidelines of IUCN 2010. The area of occupancy (AOO) and extent of occurrence (EOO) were calculated using the open-source online software GeoCAT (Geospatial Conservation Assessment Tool, Bachman, et al. 2011), available at http://geocat.kew.org/

## Results

***Cyrtomium micropterum* (Kunze) Ching**

Icon. Fil. Sin. 3: t. 127. 1935. Image 1. Benniamin & Sundari, Pteridophytes of Western Ghats-A Pictorial guide: 41. f. 113. 2020; Fraser-Jenk. et al., Annot. Checkl. Indian. Pterid. 2: 215. 2018. *Aspidium anomophyllum* f. *micropterum* Kunze, Linnaea 24: 278–279. 1851. *Phanerophlebia caryotidea* var. *micropteris* (Kunze) C.chr., Manickam, Fern Fl. Palani Hills, 132. 1986; Manickam & Irudayaraj, Pterid. Fl. West. Ghats, S. India: 272. *t*. 209. 1992; Manickam & Irudayaraj, Pterid. Fl. Nilgiris S. India: 157. 2003.

**Isosyntype:** India, Tamil Nadu, Nilgiris, Hohenacker #913 (MPU image!).

Herbs perennial; rhizome erect, densely covered with persistent leaf base and scales; scales lanceolate, fimbriate at margins, long acuminate at apex, brownish-black; stipes tufted, 15–18 cm long, brown at base, green towards above, densely scaly at base, grooved above. Leaves unipinnate; lamina oblong with trilobed terminal pinna, 50–60 cm long, dark green; pinnae 10–12 pairs, slightly ascending, subopposite, ovate to lanceolate, c. 7 × 2.5 cm, auriculate at acroscopic end, blunt auricle, serrate at margin, acute at apex, petiolate, widely spaced, brown unicellular hairs on both surfaces; veins anastomosing with included veinlets; rachis as for stipe; sori indusiate, indusium fimbriate at margins, reniform, orbicular, scattered, seated on free veinlet, 32 spores per sporangium; spores bilateral, monolete, laesura long, exine thick, perine highly folded to form tubercle like structues all over the spore, darkish brown, 18–20 µm long.

**Specimen examined:** 205936 (BSI), 29.xi.2018, India, Karnataka state, BRT Tiger reserve, Nellikathurupodu range, 11.91180°N, 077.20776°E, 1,370m, coll. C. Bagathsingh (Image 4). 17687 (RHT!), 03.v.1981, India, Tamil Nadu State, Palani Hills, on the slopes of Perumal Peak, 1,800m, coll. V.S.Manickam.

**Phenology:** Fertile from August to January.

**Habitat & Ecology:** This species was found growing in a terrestrial habitat as small colonies on fully shaded evergreen forest floors, between 1,600 and 1,800 m.

**Global distribution:** Ethiopia, Kenya, Lesotho, Malawi, Madagascar, South Africa, Tanzania, Uganda, and India; **India:** Nilgiris and Palani Hills of Tamil Nadu and BRT Tiger Reserve of Karnataka (present report).

**Threat status assigned:** Endangered (B2ab(iii,v)).

*Cyrtomium micropterum* (Kunze) Ching is placed under the Endangered (ER) category in the present assessment as the species is restricted to only three locations in India. The extent of occurrence is 7,152.25

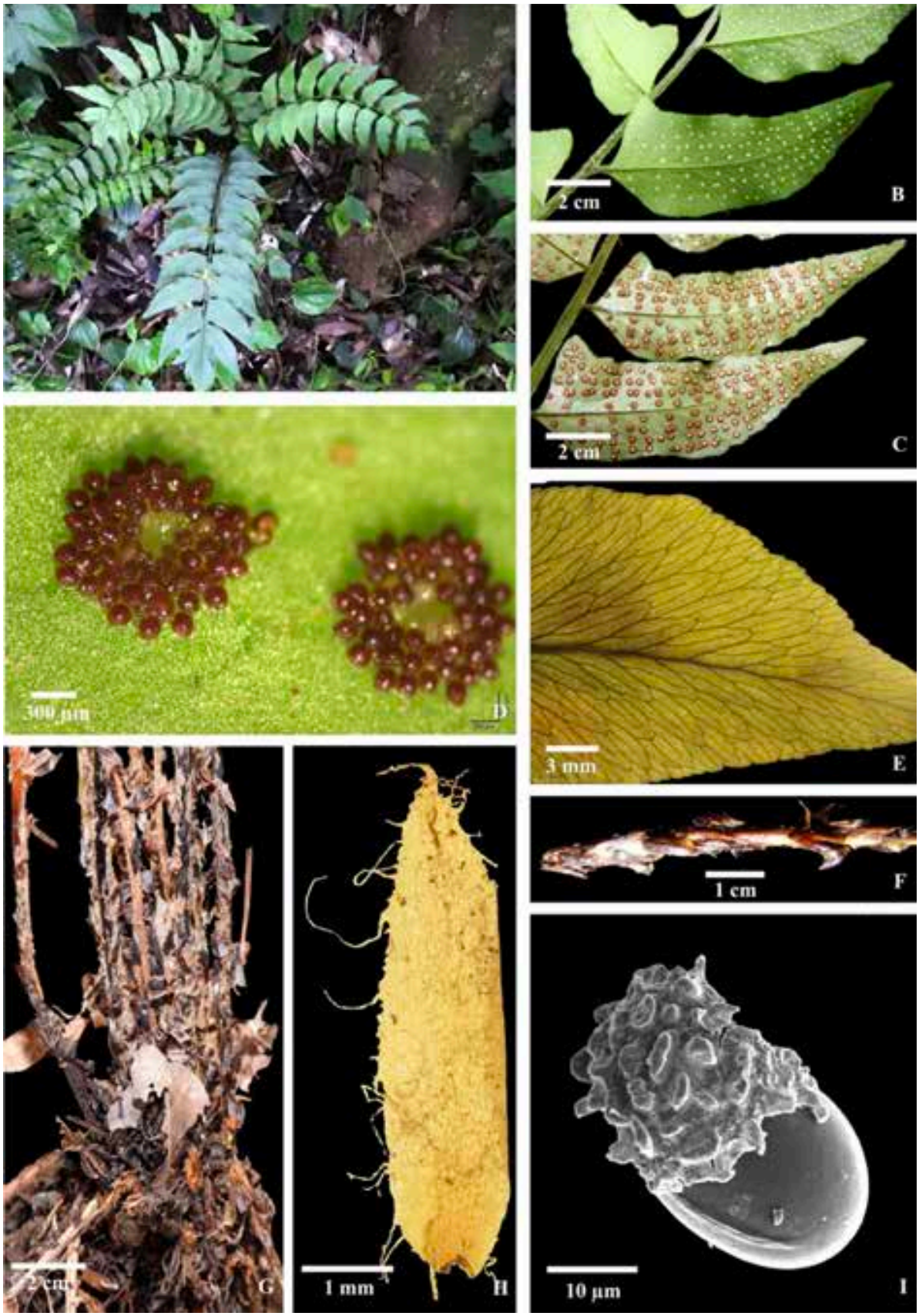


**Image 1.** ***Cyrtomium micropterum*** **(Kunze) Ching: A—habitat | B&C—fertile fronds | D—close view of sporangia | E—anastomosing veins with included veinlets | F—stipe base | G—rhizome | H—scale | I—spore morphology under scanning electron microscope. © C. Bagathsingh.**


**Image 2. Evaluation of area of occupancy and extent of occurrence of *Cyrtomium micropterum* (Kunze) Ching in India using GeoCAT.**


**Image 3. *Cyrtomium micropterum* (Kunze) Ching introduced at Botanical Survey of India, Pune.**

km$^2$ which is more than threshold value for Endangered category, so it's not applicable for category assignment and the area of occupancy is estimated to be about 12.00km$^2$, which meets criterion B2 for Endangered category. The continuous decline in the quality of habitat (an increase of temperature, and a decrease of air humidity) and the number of mature individuals was observed due to extension of patrol roads, invasions of weeds, poor spore viability & germination rate, increased transport inside the reserve, and other anthropogenic activities which qualify for the Endangered category under sub-criteria B2a,b(iii,v). Due to the lack of adequate information on the number of mature individuals in localities and estimation & reduction in the size of the population, we couldn't able to apply Criteria A, C, D, and E. Since the distribution of these species is restricted only to the southern Western Ghats of India, the influences of colonization from African countries is not possible. It is still unpredictable for the reason for its diminished capacity for colonization of new habitats in the Western Ghats, though the species is apogamic (development of sporophyte without fertilization). So the threat status of these species will get upgraded if the same trends continue (Detailed justification for this assessment is given in Appendix I)

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**Image 4. Herbarium specimen of *Cyrtomium micropterum* (Kunze) Ching.**

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**Appendix I**

**Extent of Occurrence (EOO):** EOO for the species was estimated to be 7,152.25km$^2$, calculated by using GeoCAT software (Bachman et al. 2011).

**Area of Occupancy (AOO):** AOO was calculated based on the cell width (2km × 2km) recommended by IUCN and it is estimated to be 12 km$^2$ by using GeoCAT software (Bachman et al. 2011).

**Number of locations and its information:** Based on the field experience by the second author for the last 20 years (1999–2020) in different seasons in India, the species is reported from only three localities, i.e., Perumal Peak of Palani Hills (Manickam 1981; Pounraj 2020), Nilgiris Guliar Reserve, Pachaikadu Shola, Kodanadu Valley in Tamil Nadu (Manickam 1991, 1992), Nellikathuru Podu range in BRT Tiger Reserve, Karnataka (2020, present report). As this species grows nearby roadsides, due to the widening of roads and tourist activities, the locations are severely fragmented. This is also one of the reasons for the rarity of the species. Active searches for the species from additional localities in the Western Ghats have been unsuccessful.

**Population numbers and its trends:** As far as the population numbers are concerned there are no early reports on mature individuals in any locality (Manickam & Irudayaraj 1992, 2002; Manickam 1994). Dr. V. Irudayaraj and Pounraj (pers. comm. 10.09.2020) have collected this species recently (2020) in Palani Hills and they have found only three mature individuals. While studying the fern diversity of Western Ghats (2004), the senior author (AB) could not relocate this species in Nilgiris and Palni hills in Tamil Nadu except in Kodanadu Valley. Continuous field survey, during the last five years (2016–2020) in different parts of Western Ghats, by the senior author (AB), has resulted in the observation of 25 individuals in the year 2016 and they were reduced to 10 mature individuals in 2019 and recently on 2020 they have been further reduced to only five individuals. Due to the widening of road and tourist activities, the number of individuals is gradually declining. A quite high number of mature individuals (25) were encountered in BRT Tiger Reserve, Karnataka (in 2018) and now it has reduced to 11 individuals. Nearly 70% and 45% population got decreased on the Nilgiris and in the BRT Tiger Reserve, respectively.

**Threats:** In general, all the populations in all the three localities are growing along shaded roadsides with an easy approach to human beings with periodic roadside cleanings by the local government. In the BRT Tiger Reserve, increased transport activities to the coffee estates within the reserve pose a serious threat to the population and impedes the growth of mature individuals, and most of the matured individuals were uprooted last year, during the expansion of patrol roads in the Reserve. Apart from the anthropogenic pressure, the habitat of *C. micropterum* in the Reserve has been invaded by notorious weeds such as *Chromolaena odorata* (L.) R.M.King & H.Rob., *Ageratina riparia* (Regel) R.M.King & H.Rob. The vigorous growth of these weeds often interrupt the growth of individuals by covering them all over.

Moreover, when compared to the common triploid apomictic *Cyrtomium caryotideum* (Chromosome count database), this diploid apomictic species does not require a humid atmosphere and it prefers to grow at high altitude on the eastward side (Nilgiris, Palni Hills, BRT), more or less on the same longitude of the Western Ghats, with the presence of more continental air masses with less humidity. With the climate change and increase of atmospheric temperature, this species struggles for survival in the existing locations without being able to spread to other localities.

Through this assessment, we strongly recommend conserving this species by both in vivo and in vitro (biotechnological) methods, since it has a high ornamental valve. These species have been introduced in the botanical garden of Botanical Survey of India (BSI) Western Regional Centre, Pune as a part of ex situ conservation (Image 3).

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NOTE

# First report of the Asiatic Brush-tailed Porcupine *Atherurus macrourus* (Linnaeus, 1758) (Mammalia: Rodentia: Hystricidae) from West Bengal, India

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The Asiatic Brush-tailed Porcupine *Atherurus macrourus* is considered to be one of the lesser-known rodent species of southern Asia distributed throughout the northeastern part from central China to Malaysia including countries such as India, Bhutan, Bangladesh, Myanmar, Laos, Vietnam, Thailand, and Cambodia (Molur 2016; Dhendup & Dorji 2017). Although it has such a wide distribution range it is still considered a rare species (Choudhury 2006; Talukdar et al. 2019). It occurs in the subtropical and tropical montane forests at 100–4,571 m (Eisenberg et al. 2015; Talukdar et al. 2019). It is listed as Least Concern by the IUCN Red List of Threatened Species (Molur 2016) and in India it is protected under Schedule II of the Wildlife (Protection) Act, 1972.

Here we report this species for the first time from the state of West Bengal. Prior to this, the species has been reported only from the northeastern states of India: Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, and Tripura (Agrawal 2000; Gupta 2000; Choudhury 2006; Datta et al. 2008; Srinivasulu & Srinivasulu 2012; Choudhury 2013; Choudhury 2016; Talukdar & Choudhury 2017; Talukdar et al. 2019). The present record can be considered the western-most distribution range of the Asiatic Brush-tailed Porcupine as the earlier report mentions the Gedu region of Bhutan as the western-most distribution limit (Dhendup & Dorji 2017) which is ca. 125km away in the east.

As part of our research investigation on the human-leopard interactions in northern Bengal, we deployed camera traps to monitor the Leopard population in Mahananda Wildlife Sanctuary in November 2018–February 2019. On 28 January 2019, at 21.09h a single individual of Asiatic Brush-tailed Porcupine was photo captured in a camera trap deployed in upper Ghoramara Block (26.887N & 88.417E, 640m) of the Latpanchor

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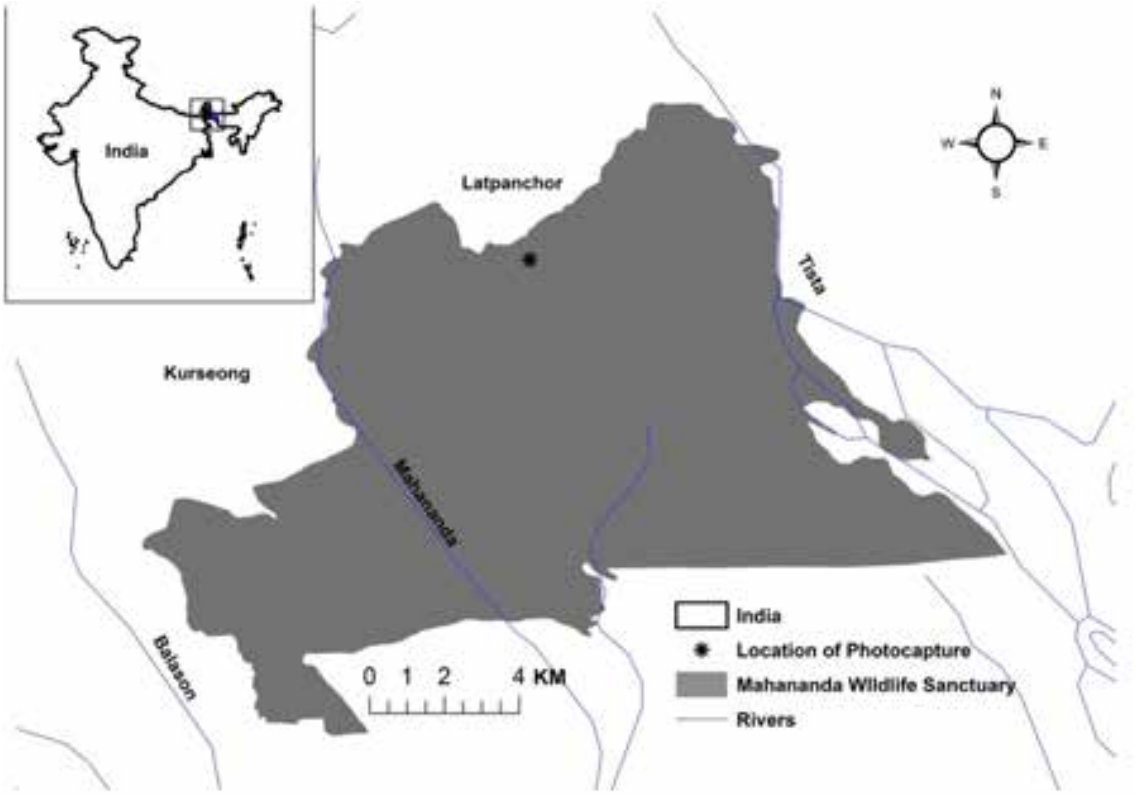


**Figure 1. Location where the photo of *Atherurus macrourus* in Mahananda Wildlife Sanctuary, northern West Bengal, India, was captured.**

**Image 1A & B. Asiatic Brush-tailed Porcupine photo captured in Mahananda Wildlife Sanctuary, West Bengal, 28 January 2019.**

Beat, North Range, Mahananda Wildlife Sanctuary (Image 1A,B). The photo capture site was characterized by dense vegetation of plant species such as *Baccaurea sapida*, *Bauhinia vahlii*, *Betula cylindrostachya*, *Castanopsis tribuloides*, *Cinnamomum obtusifolium*, *Duabanga grandiflora*, *Evodia fraxinifolia*, *Ostodes paniculata*, *Saurauia nepalensis*, *Schima wallichii*, *Semecarpus anacardium*, *Terminalia myriocarpa*, and *Terminalia crenulata*. The present observation on the habitat and nocturnal activity are similar to earlier reports (Agrawal 2000; Choudhury, 2006; Talukdar et al. 2019).

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# Record of the world's biggest pangolin? New observations of bodyweight and total body length of the Indian Pangolin *Manis crassicaudata* Gray, 1827 (Mammalia: Pholidota: Manidae) from Mannar District, Sri Lanka

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The Indian Pangolin *Manis crassicaudata* is one of the four extant pangolin species in Asia and, has a wide distribution across southern Asia, including eastern Pakistan, Sri Lanka, and India from the foothills of the Himalaya up to southern India (Mahmood et al. 2020). *M. crassicaudata* is a predominantly nocturnal and fossorial, medium-sized mammal (Mahmood et al. 2019). The global population of *M. crassicaudata* has been identified as Endangered (EN) by the IUCN, and the species has been further included in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES; Mahmood et al. 2019). According to the National Red List of Sri Lanka, the Indian Pangolin is listed as 'Near Threatened' (NT) (Weerakoon 2012). It is also included in the schedule II of the Flora and Fauna Protection Ordinance (Amendment) Act No. 22 of 2009 of Sri Lanka (Perera et al. 2017).

The Indian Pangolin is the only pangolin species occurring in Sri Lanka, and the species is distributed throughout the lowlands, from coastal habitats up to 1,850m (Perera & Karawita 2020). The Indian Pangolin population in Sri Lanka may be of special interest as it is a geographically isolated population in the Indian subcontinent (Perera et al. 2020). The population size of *M. crassicaudata* in Sri Lanka is mostly unknown (Pabasara et al. 2015; Perera et al. 2017), and their distribution appears to coincide with the range of ants and termites (Philips 1926; Karawita et al. 2020). Recent studies suggest that their abundance tend to vary across the island with a few known locations such as Kurunegala, Puttalam, Anuradhapura, Monaragala, Hambantota, Polonnaruwa, Galle, Matara, and Kalutara districts having comparatively frequent records of occurrence (Karawita & Perera 2020; Perera & Karawita 2020). In Sri Lanka, the species has been recorded from a variety of natural, semi-natural, and human-modified habitats, including tropical lowland rain forests, dry-mixed evergreen forests, sub-montane to montane forests scrublands, croplands/ agricultural lands and rural home gardens (Karawita & Perera 2020).

The literature suggests that there are intra-specific variations in Indian Pangolin's morphometrics across

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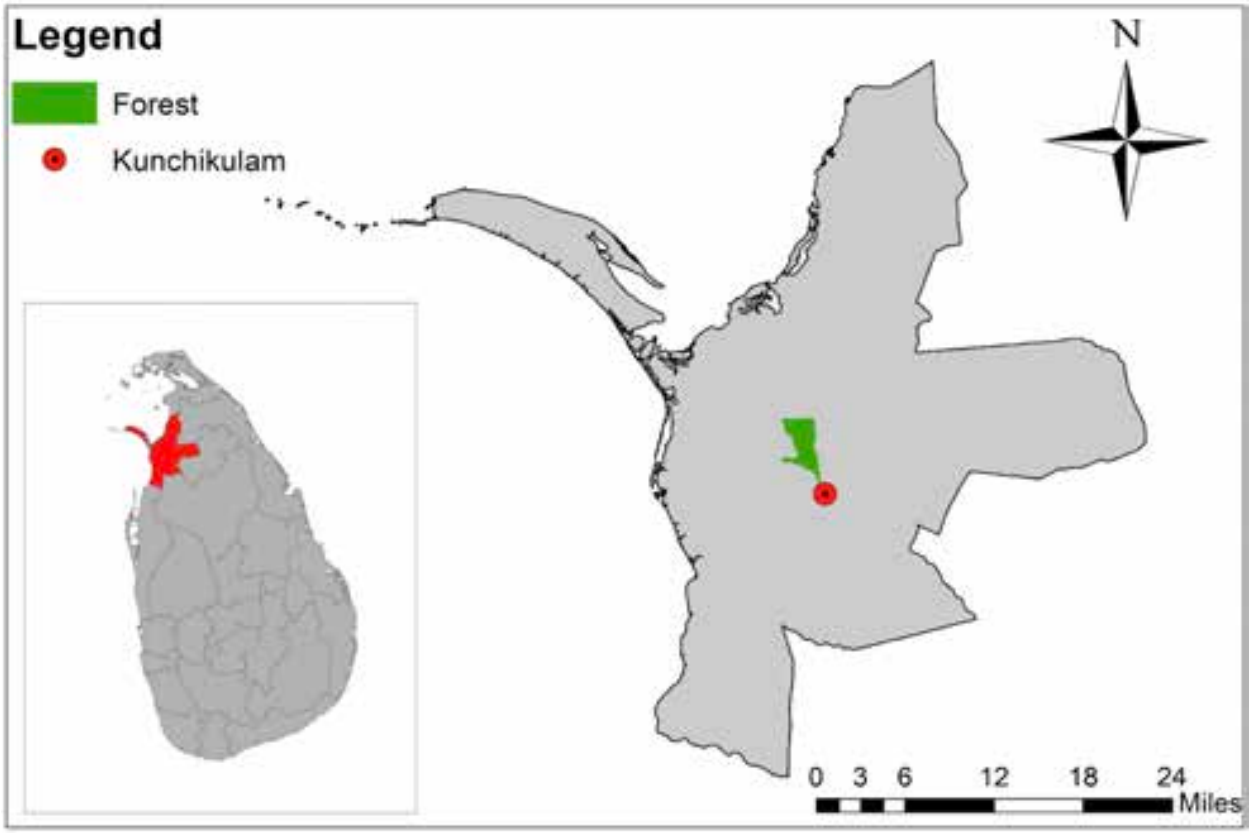



**Figure 1. The Kunchikulam Forest in Mannar District, Sri Lanka where the two largest Indian Pangolin specimens were recorded.**

its range (Mohapatra et al. 2015; Irshad et al. 2016; Ullmann et al. 2019). Such variations, however, remain poorly understood. Commonly reported morphometric measurements include bodyweight, total body length (length from snout to the tip of the tail), tail length, lengths of forelimbs and hindlimbs and scale frequencies (Irshad et al. 2016; Mahmood et al. 2020). Such morphometric measurements are used to define age classes and describe the sexual dimorphism of the species. For instance, Irshad et al. (2016) categorized Indian Pangolin into three age classes based on bodyweight (B) and total body length (TBL); Juveniles (≤2.5 kg, 40–65 cm), sub-adults (2.51–8 kg, 66–120 cm) and adults (≥8kg, ≥120cm). Algewatta et al. (2021) defined age classes for Indian Pangolin occurring in Sri Lanka based on bodyweight and total body length as juvenile (B: <4.3kg TBL: <56.0cm), subadult (B: 4.3–7.3kg TBL: 56–101 cm), and adult (B >7.3kg TBL: >101cm). Adult male Indian Pangolins are heavier and larger than females of the same age group (Mahmood et al. 2020).

During a study to understand the morphometric variations of *M. crassicaudata* occurring in Sri Lanka, we recorded two well-grown male pangolins killed by poachers at the Kunchikulam Forest Reserve in Mannar District, Sri Lanka (08.75332N, 80.16419E) on 08 December 2019 (Figure 1). The two poachers were taken into custody on the same day by the Police Special Task Force, Sri Lanka, while the poached animals were

**Table 1. Body measurements of the two Indian Pangolin specimens.**

| Specimen | | KL 1 | KL 2 |
|---|---|---|---|
| Sex | | Male | Male |
| Body weight(kg) | | 48.76 | 34.15 |
| Total Length (cm) | | 176.8 | 157.5 |
| Head Length (cm) | | 26.6 | 20.4 |
| Snout Length (cm) | | 12.4 | 9.6 |
| Body Length (cm) | | 58.8 | 61.50 |
| Tail Length (cm) | | 91.5 | 75.6 |
| Hind Foot Diameter (cm) | | 8.25 | 6. |
| Ear Length (cm) | | 14.00 | 10.20 |
| Limb Lengths (cm) | Forelimb | 16.5 | 12.7 |
| | Hind-limb | 14.0 | 10.2 |
| Circumference (cm) | Shoulder | 80.8 | 72.0 |
| | Body | 103.5 | 90.7 |
| | Neck | 42.0 | 37.2 |

**Table 2. Number of scales on each specimen by body regions.**

| Specimen | Trunk | Head & Neck | Fore Limbs | | Hind Limbs | | Tail | | Total |
|---|---|---|---|---|---|---|---|---|---|
| | | | Right | Left | Right | Left | Dorsal | Ventral | |
| KL1 | 145 | 90 | 48 | 45 | 38 | 38 | 78 | 56 | 538 |
| KL2 | 138 | 87 | 45 | 45 | 39 | 41 | 73 | 52 | 520 |

**Table 3. Largest specimens recorded for the eight pangolin species recorded in the literature.**

| Species | Largest Specimen Recorded | | Reference |
|---|---|---|---|
| | Bodyweight (kg) | Total length (cm) | |
| Chinese Pangolin *Manis pentadactyla* | 8.5kg | 8.9cm | Shibao et al. (2004) |
| Indian Pangolin *Manis crassicaudata* | 32.2kg | 170.0cm | Sharma (2002) |
| Sunda Pangolin *Manis javanica* | 9.1kg | 137.5cm | Sulaiman et al. (2017), Save Vietnam's Wildlife (unpub. data) |
| Philippine Pangolin *Manis culionensis* | 7.3kg | 133.0cm | S. Schoppe, unpub. data |
| Black-bellied Pangolin *Phataginus tetradactyla* | 3.6kg | 93.7cm | Kingdon & Hoffmann (2013), Hatt et al. (1934) |
| White-bellied Pangolin *Phataginus tricuspis* | 2.9kg | 102.7cm | Kingdon & Hoffmann (2013), Hatt et al. (1934) |
| Giant Pangolin *Smutsia gigantea* | 33.0kg<br>38.0kg | 179.8cm<br>172.0cm | Kingdon (1971), Hatt et al. (1934), S. Nixon & N. Matthews (unpub. data), Newton et al. (2019) |
| Temminck's Pangolin *Smutsia temminckii* | 16.1 kg | 124.0cm | Coulson (1989), D.W. Pietersen (unpub. data) |

being transported out of the forest on a motorbike. The animals have been photographed at the location (Images 1–4) and transferred to the veterinarian office of the Department of Wildlife Conservation at Kilinochchi for the postmortem and subsequent legal procedures. The cause of death of both pangolins was assault on the head with a sharp object.

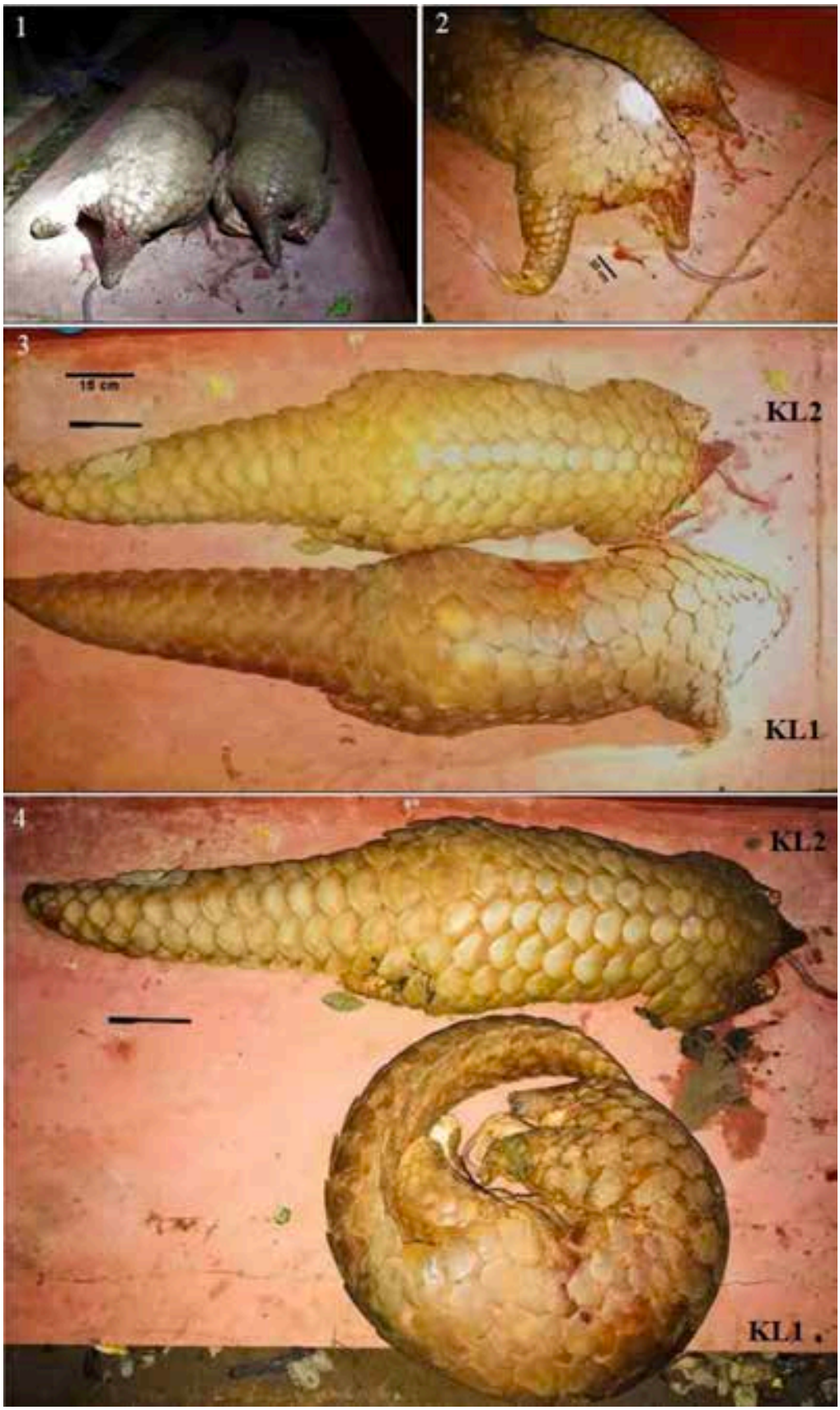
We recorded the morphometric measurements of the two fresh carcasses following the protocols described in Perera et al. (2020). The specimens were coded as KL1 and KL2 (Images 1–4). All measurements were taken at the veterinarian's office of the Department of Wildlife Conservation at Kilinochchi under the supervision and observation of the chief veterinary surgeon. The morphometric measurements recorded from the two specimens are summarized in Table 1.

Following the protocols and guidelines specified in Perera et al. (2020) for body scale counting and scale type identification, body scale counts were performed. The number of scales observed in each specimen is reported by body regions in Table 2. The specimen KL1 had 538 body scales (436 broad rhombic scales, 70 elongated kite-shape scales, and 32 folded-shape scales in the tail) while the specimen KL2 had 520 body scales (418 broad rhombic scales, 72 elongated kite-shape scales and 30 folded-shape scales in the tail).

After taking the body measurements and scale counts, the two pangolin carcasses were destroyed by the Veterinary Division Kilinochchi as per the court order issued by the Magistrate Court. Hence, further studies on the two specimens were not possible.

On average, adult Indian Pangolins can weigh between 8 and 16kg and measure about 148cm in total body length (Mahmood et al. 2020; Roberts & Bernhard 1977). The largest Indian Pangolin specimen has been recorded from Rajasthan, India, an adult male weighing 32.2kg and measuring 170cm in total body length (Sharma 2002). The largest Indian Pangolin recorded from Pakistan weighed 20kg and measured 147.3cm in total body length (Irshad et al. 2016). In this study, we recorded two male Indian Pangolin specimens from Mannar District of Sri Lanka, weighing 48.76kg and 34.15kg with the total body length measuring 176.8cm and 157.5cm, respectively. Both these new records exceed the maximum bodyweight reported for an Indian Pangolin in the literature. These two new records and observations from other range countries (India and Pakistan) provide novel insights into the maximum growth of the male Indian Pangolins.

There are eight extant species of pangolins in the world. The largest specimen recorded so far in literature for each species is summarized in Table 3. The Giant Pangolin *Smutsia gigantea* is considered the largest of all pangolin species, with the body weight of an adult exceeding 30kg and total body length measuring between 140 and 180 cm (Hoffmann et al. 2020). The




**Images 1–4. Photographs of the two Indian Pangolins (coded as KL2 and KL2) taken at the DWC Assistant Director Office at Madu, Mannar District, Sri Lanka. © Buddhika Vidanage.**

largest specimen of Giant Pangolin recorded so far is an adult male weighing 38kg with a total body length of 172cm from Gabon (Newton et al. 2019).

Compared to the published information, the male Indian Pangolin (KL1) recorded from Mannar District of Sri Lanka exceeded the maximum body weight and total body length recorded so far in the literature for any of the pangolin species. Hence, this individual could be considered as the largest pangolin documented so far. Such "extreme" observations highlight the dearth of knowledge we have on the morphometric variations of Indian Pangolins and call for further studies on the species.

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NOTE

# First record of *Touit melanonotus* (Wied, 1820) (Aves: Psittaciformes: Psittacidae) in Cantareira State Park, Brazil: new colonization or simply unnoticed?

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A avifauna do Parque Estadual da Cantareira (PEC, São Paulo, Brazil) apresenta 120 anos de estudos, mas inexistiam registros do apuim-de-costas-pretas *Touit melanonotus*. Aqui, apresentamos seu primeiro registro e item alimentar (frutos de *Ocotea* sp.) no PEC, discutindo o seu potencial de cruzar paisagens urbanas ou ter passado despercebido por longo período.

Palavras-chave: Mata Atlântica; Extensão de distribuição; Endemismo; Urbanização; Ameaçada de extinção.

*Touit* is a genus of Psittacidae comprising small (14–18 cm) parrotlets (Straube et al. 2010) with eight species restricted to the Neotropical region (del Hoyo et al. 2019). The Brown-backed Parrotlet *Touit melanonotus* is a rare psittacid endemic of the Brazilian Atlantic Forest (Parker III et al. 1996; Sick 1997) and restricted to the Serra do Mar endemism center (Cracraft 1985), whose distribution is from southern Bahia to Santa Catarina (Vallejos et al. 2013; Leal et al 2018). The Brown-backed Parrotlet is recorded mostly between 500 and 1,000 m altitude, although there are records from sea level to 1,700m (Leal et al. 2018). It is 15cm in length and 66.5g in weight, a forest specialist that feeds mainly on fruits and forages on varied forest strata (Parker III et al. 1996; Sick 1997; Wilman et al. 2014). Historically, human activities associated with agricultural and livestock, and recently with urbanization, however, have resulted in serious habitat loss and degradation in the Atlantic Forest (Ribeiro et al. 2009). Nowadays, this biome presents a highly fragmented landscape with few forest patches larger than 100ha, mostly confined to the Serra do Mar mountains (Ribeiro et al. 2009). Consequently, *T. melanonotus* populations are declining and are actually classified as Vulnerable in regional and global red lists of threatened species (Brasil 2014; São Paulo 2018; IUCN 2019).

The forests of Serra do Mar continuum are responsible for the maintenance and conservation of all known *T. melanonotus* populations (Leal et al. 2018). Its absence is noticeable as distance increases from the Serra do Mar continuum (see map in Schunck 2009) even in the largest forest remnants (> 5,000ha)

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in the Atlantic Plateau of São Paulo such as Morro Grande Forest Reserve (Develey & Martensen 2006) and Cantareira State Park (São Paulo 2009; Tonetti et al. 2017). This context has supported the inference about the high sensitivity of this parrotlet and it restriction for crossing the non-forest habitat matrix (Leal et al. 2018) which would make it impossible for it to pass through a highly fragmented landscape influenced by more than 40km of the urbanized area of the São Paulo "megacity".

Frequently, low bird sampling efforts are inefficient to detect rare species of birds. There are few bird studies conducted in Morro Grande Forest Reserve (Develey & Martensen 2006; Boscolo et al. 2006) compared with Cantareira State Park (CSP) for which there is a large amount of ornithological knowledge (Tonetti et al. 2017). From the end of the 19th century to the 1960's, several collectors sampled birds in CSP (Pinto 1938, 1944; Graham 1992). Graham performed the first avian community study (Graham 1992) and other studies were carried out between 2000 and 2017 (Antunes & Eston 2008; Antunes et al. 2009; São Paulo 2009; Tonetti & Pizo 2016; Tonetti et al. 2017). Moreover, many researchers and birdwatchers have visited CSP and have made contributions to the knowledge of the bird richness in the park. The last compilation demonstrated a total of 326 bird species confirmed in CSP (Tonetti et al. 2017), however, even after more than 120 years, *T. melanonotus* had not been recorded.

The present study has shown a first record of *T. melanonotus* in the CSP, the largest urban forest of the world (Ayres 2008). In the morning (08:18h) of 18 October 2019, we heard and observed 10 individuals of *T. melanonotus* at Pedra Grande, an administrative CSP zone (-23.438920 & -46.631539, 945m), in the municipality of São Paulo, SP, Brazil. The flock was perched in the canopy (~15m high) and feeding on fruits of *Ocotea* sp. Aubl. (Lauraceae). We saw just two birds eating fruits attached to the stalks, and they remained upside down to reach the fruits. The call was recorded and deposited in the xeno-canto library (XC521608). After six minutes of observation, the flock flew above the canopy and was not relocated. To the best understanding of this parrotlet distribution in São Paulo metropolitan region, we present other previous records made by us, together with other localities cited in literature (Table 1; Figure 1). The present record of *T. melanonotus* for CSP reinforces its classification as an important bird area for conservation (Bencke et al. 2006). This record is the closest yet to the São Paulo urban fringe (1km) (Figure 1b). Our record is 109km removed from the nearest two known populations in Capivari-Monos Environmental Protection Area (EPA) and Curucutu administrative zone of Serra do Mar State Park (Melo et al. 2016; Schunck et al. 2019), 90km from a private area (Solo Sagrado de Guarapiranga property) (Melo et al. 2011), and 89km from Serra da Mantiqueira (Wege & Long 1995) (Figure 1).

There is little information on diet items and feeding behavior of *T. melanonotus*. Fruits of *Maytenus* sp. (Schunck et al. 2008), *Clusia criuva* (Simpson & Simpson 2012), *Rapanea acuminata* (Juniper & Parr 1998), and *Struthanthus vulgaris* (Vallejos et al. 2013) are the food items recorded for this rare parrotlet. To our knowledge, this is the first time that fruits of *Ocotea* sp. (Lauracea) have been recorded in their diet. We observed two birds hanging upside down to reach the fruits, which adopted non-plucker behavior; although the plucker strategy has been observed for the majority of birds when eating fruits of *C. criuva* (Simpson & Simpson 2012).

The presence of these birds in CSP calls attention to two questions: (i) is it possible this species has been unnoticed in CSP for more than a century? and (ii) is it evidence that *T. melanonotus* could cross altered human landscapes between CSP and other large Atlantic Forest fragments? To respond to these questions, we suspect the vocal similarity of *T. melanonotus* to other birds could be a reason for it being misidentified in the past if only heard and not seen. In the São Paulo state, voices of syntopic birds (e.g., *Megarhynchus pitangua* and *Pionopsitta pileata*) have not been a strong source of identification errors as observed in other regions (Vallejos et al. 2013). On the other hand, *T. surdus,* a species without documentation in this state of São Paulo (Silveira & Uezu 2011), has been confounded with *T. melanonotus* by researchers in the past (Bencke et al. 2006). The rarity and difficulty of voice identification of *T. melanonotus* explains its apparent long absence from Santa Catarina state, even in a well-studied region (Vallejos et al. 2013). Although this parrotlet is recorded more in São Paulo state than in southernmost region of its geographic distribution (Simpson & Simpson 2012; Vallejos et al. 2013; Leal et al. 2018; Schunck et al. 2019), and several birdwatchers and ornithologists that visited the CSP already recorded it in other regions (Willis & Oniki 2003; Minns et al. 2009; Schunck 2009), however, its absence in CSP making us rule out the possibility that *T. melanonotus* couldn't have been missed there for 120 years. It is strong evidence that *T. melanonotus* might be newly arrived in CSP. But only new records will conclude if CSP is functioning as a stepping-stone or provide habitat year-round for *T. melanonotus*, as a result of recent colonization.

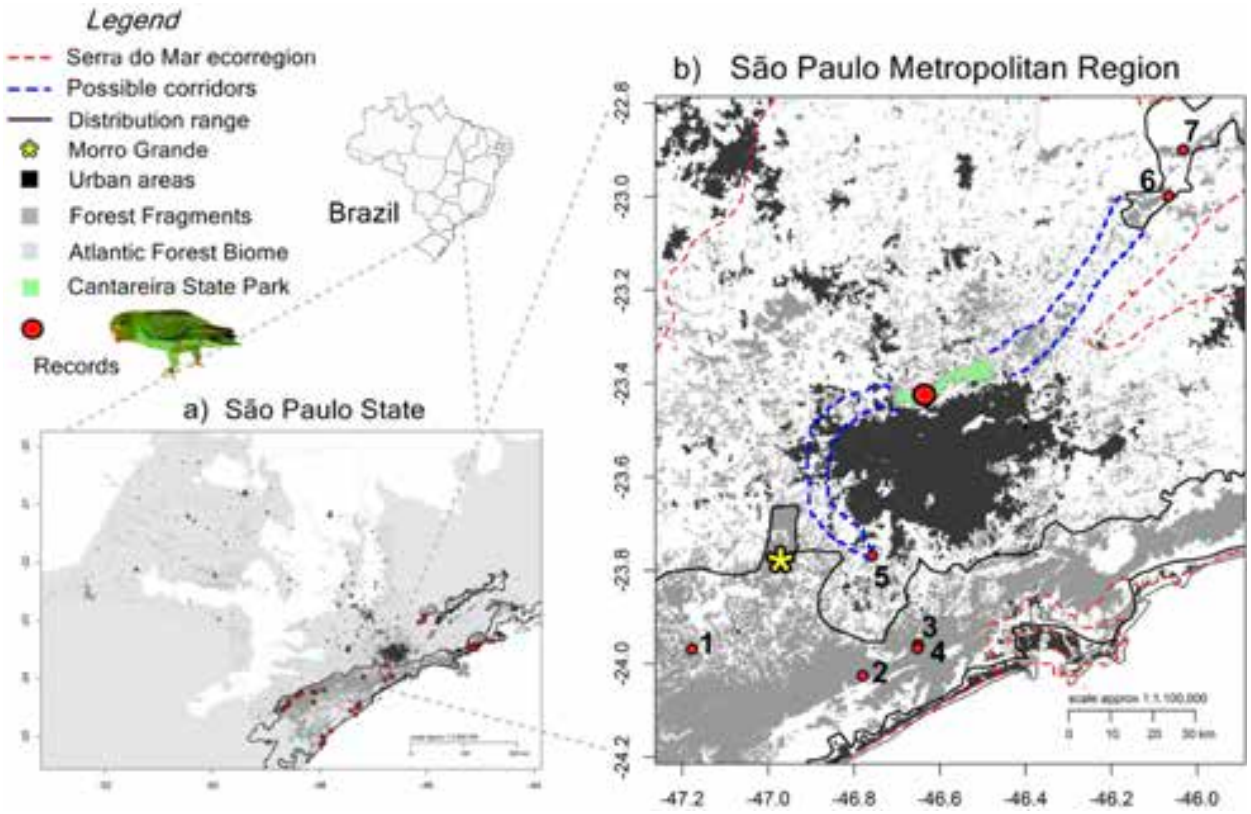


**Figure 1. Distribution map of Brown-backed Parrotlet *Touit melanonotus* in a—São Paulo state and | b—São Paulo Metropolitan region. Distribution range limits update from Birdlife International (2019). Big red circle, the first record in Cantareira State Park (green patch); little red circles, other records across São Paulo metropolitan region: 1—Serra do Mar Environmental Protected Area (EPA) / Jurupará State Park | 2—Curucutu administrative zone of Serra do Mar State Park | 3–4—Capivari-Monos EPA/Serra do Mar State Park | 5—private area (Solo Sagrado de Guarapiranga property | 6–7—records from Serra da Mantiqueira mountains; yellow asterisk, Morro Grande Forest Reserve – a large forest fragment still without records of *T. melanonotus*; blue dashed lines, possible ways of displacement of *T. melanonotus* to arrive in Cantareira State Park; red dashed lines, Serra do Mar coastal forest limits (The Nature Conservancy 2019). More details of each one of the records in Table 1.**

**Table 1. Records of *Touit melanonotus* surrounding the São Paulo metropolitan region and Serra da Mantiqueira, São Paulo state, Brazil.**

| Date | Municipality | Sites | References | Coordinates | Alt(m) | Rec | Doc | Ind |
|---|---|---|---|---|---|---|---|---|
| 18.x.2019 | São Paulo | Cantareira State Park (Pedra Grande) | Present study | -23.438 & -46.631 | 985 | A/V | Y | 10 |
| 04.i.2012 | São Paulo | Capivari-Monos Environmental Protected Area/ Serra do Mar State Park (Curucutu) | Present study | -23.967 & -46.652 | 790 | A | N | 6 |
| 05.ix.2010 | São Paulo | Private area – Solo Sagrado de Guarapiranga property (non-protected) | Present study | -23.769 & -46.757 | 740 | A | Y | 4 |
| 20.xii.2009 | Juquitiba | Jurupará State Park | Present study | -23.969 & -47.178 | 650 | A/V | N | 26 |
| 24.iii.2009 | São Paulo | Capivari-Monos Environmental Protected Area (EPA)/ Serra do Mar State Park: Curucutu | Melo et al. 2016 | -23.967 & -46.652 | 780 | A | N | 4 |
| 05.xi.2009 | São Paulo | Capivari-Monos Environmental Protected Area (EPA)/ Serra do Mar State Park Curucutu | Melo et al. 2016 | -23.959 & -46.650 | 780 | A/V | Y | 8 |
| 01.xii.2007 | Itanhaém | Serra do Mar State Park: Curucutu | Schunck et al. 2008, 2019 | -24.025 & -46.779 | 400 | A/V | Y | 6 |
| 29.v.1994 | São José dos Campos | Serra dos Poncianos/ Mantiqueira | Wege & Long 1995 | -22.878 & -45.969# | 1476 | A/V | N | ? |

Alt(m)—altitude in meters | Rec—record type | A—aural | V—visual | Doc—documentation: Y—yes or N—no | Ind—number of individuals seen [?, not informed] | #, data collected in www.ebird.org.

Although lacking evidence that this bird could cross long distances across rural and urban matrices, it is commonly observed flying over forest canopies (Leal et al. 2018), indicating a higher capability of displacement than previously believed. Other forest psittacids, e.g., *Pionopsitta*, are already observed crossing long distances between the Serra do Mar and countryside forest fragments (Pinto 1944). In this sense, there are possibilities for the source population having originated from Serra da Mantiqueira or the Serra do Mar mountains, both localities with confirmed records (Wege & Long 1995; Schunck 2009). Nonetheless, as *T. melanonotus* has been more frequently recorded in the Serra do Mar than in Serra da Mantiqueira (Schunck 2009), provides additional evidence that these birds may have come from the first region. This record could bring to light an inference that *T. melanonotus* is able to cross though anthropic landscapes surrounding the São Paulo megacity.

To elucidate the actual means of displacement of this species, studies using geolocators would be required (Jahn et al. 2016). In September 2010, another record of *T. melanonotus* came from a private area (Solo Sagrado de Guarapiranga property) (-23.771 & -46.754; 760m; XC76242) (Melo et al. 2011), 23km from a narrow strip of the Serra do Mar and 2.9km from an urbanized area, which was recently fragmented by the construction of Rodoanel roads (Catharino & Aragaki 2008). These records in the north (CSP) and southwestern (Guarapiranga dam) of the São Paulo metropolitan region open another opportunity for application of conservation strategies in peri-urban habitats of the São Paulo megacity, a type of habitat until now without evidence of use by this species. Our records highlight that peri-urban habitat use by *T. melanonotus* demonstrates the importance of public policies that provide effective forest protection in the Green Belt of São Paulo City, which has been constantly threatened by urban sprawl and infrastructures (Bencke et al. 2006; Melo et al. 2016; Schunck & Rodrigues 2016; Tonetti et al. 2017). Habitat loss seems to be the main threat for this emblematic psittacid of the Atlantic Forest, and urban sprawl and its associated infrastructures directly and indirectly contribute to habitat loss (Leal et al. 2018). The creation of new protected areas has been recommended (Schunck 2009). We highlight the importance of creating new protected areas in the Green Belt of São Paulo City, as well as the execution of forest restoration projects in regions situated between Mantiqueira and Cantareira, and Serra do Mar and Serra da Cantareira. This measure might be fundamental to improve habitat connectivity for many Atlantic Forest endemic birds (Uezu & Metzger 2016), and likely a corridor for *T. melanonotus*. Thereafter, such measures will help in the preservation of bird's ecosystem functions in the peri-urban forest fragments belonging to one of the main biodiversity hotspots of the world.

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NOTE

# Is *Bombus pomorum* (Panzer, 1805) (Hymenoptera: Apidae) a new bumblebee for Siberia or an indigenous species?

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The bumblebee fauna of Siberia has not been well studied historically, but great progress has been made in the last two decades (Konusova & Yanushkin 2000; Byvaltsev 2008, 2013; Knyazev et al. 2010; Kupianskaya et al. 2014; Byvaltsev et al. 2013, 2015, 2016). These and other data are summarized in the Annotated Catalogue of the Hymenoptera of Russia (Levchenko et al. 2017). There are 55 species in Siberia, with 52 in each of the western and eastern parts. There is information about one species newly recorded for Western Siberia – *Bombus pomorum* (Panzer, 1805) previously known only from Europe, Anatolia, the Caucasus and the Ural region.

*B. pomorum* is one of three species of the *pomorum*-group (formerly *Rhodobombus*) subgenus *Thoracobombus* Dalla Torre, 1840 (Williams 1998). The species can be distinguished from the other members of the group by its predominately brightly red coloured metasoma. There are some colour patterns of *B. mesomelas* Gerstaecker, 1869, with red hair, although in most cases the last tergum of *B. pomorum* has red hairs, whereas it has black hairs in *B. mesomelas*. There are three main colour patterns of *B. pomorum* females, which have been regarded as a subspecies by some authors (Özbek 2002; Rasmont et al. 2015b), but are considered here to all be *B. pomorum s. l.*: thorax and two first metosomal terga black (nominative taxon in Western and Central Europe, western Anatolia); thorax and first metasomal tergum yellow banded (*B. uralensis* Morawitz, 1881 in the territory of European Russia to Chelyabinsk); thorax and first metasomal tergum with the pale bands (*B. pomorum* var. *canus* Schmiedeknecht, 1883 in eastern Anatolia and the Caucasus region). Males everywhere are usually paler than females, and the variation is not so distinct.

The previous known distribution of *B. pomorum* is from Denmark, southern Switzerland (58°N) (Løken 1973), and France (Rasmont et al. 1995), to Sverdlovsk and Chelyabinsk regions in the east (Popov 1923), and to Greece (Olympus) (Anagnostopoulos 2005), northern Anatolia (Rasmont & Flagothier 1996), and Transcaucasia (Skhirtladze 1981; Kirkitadze & Japoshvili 2015) in the south. Only five specimens were recorded from Britain (Kent) between 1834 and 1864 (Jeffers 2017). These could be cases of rare migration (Alford 1975) or they

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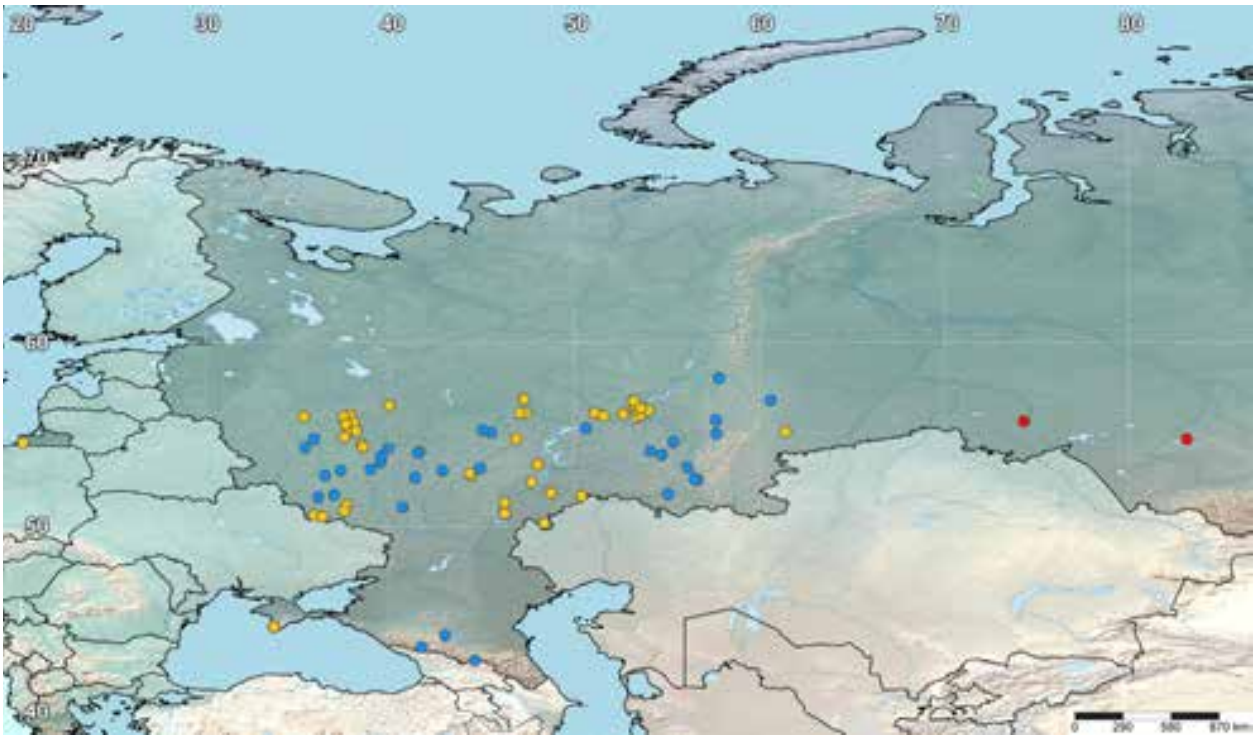

**Figure 1. Distribution of *Bombus pomorum* in Russia: yellow dots—literature data | blue—material examined | red—new records. There are no detailed data for Ulyanovsk region, thus there are no dots on the map in this territory. The map was compiled using the online mapping software SimpleMappr (Shorthouse 2010).**

could have arrived as queens hibernating in flower pots transported from garden-plant nurseries (Williams et al. 2018). *B. pomorum* is a meadow species in the steppe and forest–steppe zones and in the mountains, with a broad range of feeding plants. Nests are underground, frequently in small rodent holes (Skorikov 1923; Efremova 1991).

Two specimens (a queen and a worker) of *B. pomorum* were collected in the forest-steppe of the West Siberian Plain by S. Knyazev and A. Afinogenov in 2017 and 2019 respectively. Label data: queen – Russia, Omsk region, Gorkovsky District, Serebryanoe vill. [village] vic. [vicinity], 55°43'0.29"N & 74°20'21.88"E [55.717°N & 74.339°E] , 03.vi.2017, S.A. Knyazev leg. [Knyazev private collection, Omsk, Russia]; worker – Russia, Novosibirsk region, Agroles, 54.756°N & 83.146°E, flowerbed with *Tagetes* sp., 1– 10.ix.2019, A. Afinogenov [Novosibirsk State University, Novosibirsk, Russia – NSU].

The queen of *B. pomorum* was sent to A. Byvaltsev by S. Knyazev with other bumblebees for determination in the winter of 2018, but we decided not to publish this information until supported by rediscovery of more specimens. A new worker was sent for determination by A. Afinogenov, so we now have no doubt about the presence of this species in Western Siberia.

Comparative material from Europe, the Caucasus, and the Ural regions including several types of related taxa, considered here to be part of *B. pomorum* s. l., were examined in Zoological Institute RAS (St. Petersburg, Russia – ZISP) by A. Byvaltsev: *B. uralensis* Morawitz, 1881 (replacement name for *B. rufescens* Eversmann, 1852), *Fervidobombus oreas* Skorikov, 1926, *F. pomorum flavotestaceus* Skorikov, 1926. Other members of *pomorum*–group have also been studied – several specimens of *B. mesomelas* from Spain and Italy and numerous specimens of *B. armeniacus* Radoszkowski, 1877 from different parts of its range. The queen (Image 1a) agrees closely in colour pattern with *B. uralensis*: metasomal terga 2–6 reddish, thorax and first segment of metasoma yellow, head, legs, and the band on the thorax between wings black. The worker specimen is paler (Image 1b) but agrees well with some workers from the European part of Russia in the ZISP collection, including having tergum sixth black.

The queen was collected on the high right bank of the Irtysh river, on the southern slope of a clay cliff with steppe meadow, where the bee was in flight (Image 2). The worker was collected visiting *Tagetes* sp. in the Agroles settlement near Novosibirsk.

*B. pomorum* is a new record for Siberia, and


**Image 1. Specimens of *Bombus pomorum* collected in Western Siberia: a—queen (© S. Knyazev) | b—worker (© A. Byvaltsev).**

**Image 2. The locality where the queen specimen of *Bombus pomorum* was collected, description in the text (© S. Knyazev).**

for the Omsk and Novosibirsk regions. Thus, the bumblebee fauna of Siberia includes 56 species, with 53 species recorded for Western Siberia. *B. wurflenii* Radoszkowski, 1859 and *B. lapidarius* (Linnaeus, 1758) were listed as "possible inhabitants" based on literature records that are probably erroneous (Byvaltsev 2008) and unconfirmed for the present for this territory, so they are not part of the fauna of Siberia. There are 39 species in the Novosibirsk region and 28 in the Omsk region. *Bombus hypnorum* (Linnaeus, 1758), *B. lucorum* (Linnaeus, 1761), *B. semenoviellus* Skorikov, 1910 are absent for the Omsk region in the catalogue (Levchenko et al. 2017), but are well known to occur there (Knyazev et al. 2010).

The new finds expand the range of *B. pomorum* eastwards by approximately on 1,400km. Thus, the distribution of *B. pomorum* in Russia (Figure 1) includes the following regions from specimens examined: Kursk, Orel, Kaluga, Voronezh, Lipetsk, Tambov, Ryazan, Nizhny Novgorod, Penza, Orenburg, Tatarstan, Bashkortostan, Perm, Sverdlovsk, Chelyabinsk, North Ossetia, Karachay–Cherkessia, Stavropol, Omsk, Novosibirsk; with additional literature records – Kaliningrad (Alfken, 1912), Moscow (Panfilov 1957; Levchenko 2012), Chuvashia (Sysoletina 1967), Ulyanovsk, Samara (Efremova 1991), Belgorod (Prisnyi 2005), Saratov (Anikin & Kondratiev 2006), Ivanovo (Tikhomirov 2007), Udmurtia (Adakhovskiy 2012), Kirov (Yuferev & Levchenko 2014), Crimea (Rasmont et al. 2015a), Penza (Dobrolubova 2015), and Bryansk (Goloshchapova & Prokofiev 2016). The map with distribution in Europe and Western Asia was published by Rasmont et al. (2015a).

*B. pomorum* was assessed as being vulnerable in Europe using the IUCN Red List Criteria (Rasmont et al. 2015b) because of a population decline, estimated to be more than 30% over the last 10 years so that it is

considered to be facing a high risk of extinction in the wild. The bee was in the Red Book of the USSR (Panfilov et al. 1984), but excluded from the main list of threatened taxa of the Red Book of the Russian Federation (2001) and moved to the "Appendix 3" as a species in needs of monitoring. Federal protection is weak at present. In many regions of Russia, *B. pomorum* is in the regional Red Books – Kursk (Bausov 2002), Belgorod (Prisnyi 2005), Saratov (Anikin & Kondratiev 2006), Ivanovo (Tikhomirov 2007), Sverdlovsk (Olshvang 2008), Moscow City (Berezin 2011), Ryazan (Ananieva & Nikolaeva 2011), Tambov (Ganzha & Ishin 2012), Udmurtia (Adakhovskiy 2012), Nizhny Novgorod (Zryanin 2014), Kirov (Yuferev & Levchenko 2014), Bryansk (Goloshchapova & Prokofiev 2016), Chelyabinsk (Lagunov & Gorbunov 2017), and Moscow (Levchenko 2018). In some regions, however, this species is included only in the appendix as a species in needs of monitoring – Orenburg (Belov 2019), Lipetsk (Aleksandrov et al. 2014), Ulyanovsk (Artemieva et al. 2015) or moved from the main list to the appendix – Kaluga (Antokhina 2017), or completely excluded – Rostov (Arzanov 2014), Tatarstan (Nazirov 2016). Reliable data for a significant decline in this species are available only for the Moscow region (Panfilov 1957; Berezin et al. 1996; Levchenko 2012, 2018). Based on the collection in the ZISP, *B. pomorum* was abundant in the beginning of the 20th century in the Orel and Ryazan regions. There are 995 among the 1,314 pinned specimens of *B. pomorum* in the ZISP collected between 1910 and 1924 from the Orel region and 984 of these specimens are from near the Mohovoe settlement (53.05°N & 37.35°E), 257 specimens are from the Ryazan region collected between 1899 and 1927, and most (248) are from near the Gremyachka Village (53.48°N & 39.51°E ) collected by Andrey Petrovich Semyonov–Tyan–Shansky. This does not mean that the bee was rare in other regions, but only that there were no regular observations. It is likely that *B. pomorum*, however, is not an abundant species at present in many parts of its range, but special studies are required.

There is a question whether *B. pomorum* is a recent invader of the forest–steppe of Western Siberia or whether it has always lived there. There are several examples of expansion of bumblebees to the west – *B. hypnorum* (Goulson & Williams 2001; Prŷs-Jones 2019), *B. semenoviellus* (Smissen & Rasmont 2000; Šima & Smetana 2012), *B. schrencki* Morawitz, 1881 (Levchenko 2012). There is no doubt about these cases, because there is a long history of bumblebee studies in Europe. The first comprehensive faunistic review of bumblebees in the forest-steppe and steppe zones of the West Siberian Plain was done only at the end of the first decade of the current century (Byvaltsev 2008). For example, among the species listed in that paper *B. sylvarum* Linnaeus, 1761 was recorded for the first time for Siberia with the easternmost observation in the Kurgan region (55.11°N & 66.95°E). Later the recorded range was extended to 54.10°N & 75.02°E in the Omsk region based on two specimens collected in 1996 and 2008 (Byvaltsev 2010; Knyazev et al. 2010). After the species was found in Altai Territory in 2011 and in the Novosibirsk region in 2014, so the range was extended to 83°E (Levchenko et al. 2017). Thus, it is possible that *B. sylvarum* is an indigenous species for the south of Western Siberia but was not discovered until regular observations were made. Nevertheless, there is a chance that our study coincided in time with a range expansion of this species which was able to begin in the end of 20th century.

The second case is likely, because there are no specimens of *B. sylvarum* from Western Siberia in the collections of the Institute of Systematics and Ecology of Animals SB RAS (Novosibirsk, Russia) and NSU. The species was never collected previously in the Omsk region by S. Knyazev, although his observations in localities of known records have been annual since 2005, so the species must be very rare. There were no records of this bee during regular studies in the Altai Territory between 2005 and 2008 (Byvaltsev 2013) or in Novosibrsk and its environs between 2001 and 2006 (Byvaltsev 2009). Although the increasing of percentage of specimens of *B. sylvarum* during studies in 2011–2012 in the south of the Omsk region has been documented (Byvaltsev et al. 2013). The first record of this bee in Altai Territory was in near the Klepechikha Village in 2011 (Levchenko et al. 2017), but the species was not collected there in either 2005 or 2008 (Byvaltsev 2013). *B. sylvarum* is regularly seen near Novosibirsk since the first record in 2014.

*B. pomorum* is not a commercially-reared bee like *B. terrestris* (Linnaeus, 1758), and most probably the observation is not a result of delivery of goods by people, as it has been for many pest species. The spread eastwards of European species into Siberia is documented for butterflies (Knyazev & Kosterin 2003; Knyazev et al. 2017, 2019). Thus, the discovery of *B. pomorum* in Western Siberia looks more likely to be a result of the natural expansion of this European and West Asian species. Further research of this question is required, including the application of modern molecular techniques of population ecology for studying the relationship between populations in Siberia and those in Europe.

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# Some new records of scarab beetles of the genus *Onthophagus* Latreille, 1802 (Coleoptera: Scarabaeidae) from northern Western Ghats, Maharashtra, with a checklist

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Latreille in 1802 established the genus *Onthophagus*. It belongs to the tribe Onthophagini of the subfamily Scarabaeinae, and family Scarabaeidae. It is comprised of nearly 2,200 described species (Schoolmeesters 2016) from the world, making it a very diverse genus in the subfamily representing almost 38% of the Scarabaeinae beetles (Rossini et al. 2018) with cosmopolitan distribution (Tarasov & Kabakov 2010). Approximately, 182 species have been reported from Indian mainland (Arrow 1931; Balthasar 1963; Löbl & Smetana 2006; Sathiandran & Sabu 2012). From Maharashtra, nearly 25 species are reported by Arrow (1931) and Jadhav & Sharma (2012).

Beetles from Scarabaeinae are being considered as important biological indicators due to their higher sensitivity to the changing climatic conditions (Rossini et al. 2018). Beetles of the genus *Onthophagus* are coprophagous and some are scavengers (carrion feeders). The main food source of these beetles is the faeces of animals, which they partially decompose (Fischer 2006), and helps in increasing the nutrient content, texture and structure of soil. They are paracoprid nesters (tunnelers) with biparental care, an important phenomenon of the genus *Onthophagus*, wherein the female digs branched tunnel with a brood chamber under the dung pat and males move the portion of dung to the entrance of these tunnels and then, female makes pieces, put it in the brood chamber and lay one egg in each chamber (Sowig 1996).

The Western Ghats is one of the important biodiversity hotspots of the world (Myers 2003), with high level of endemism and species richness. The northern Western Ghats ecoregion is dominated with drier dipterocarp (Sabu et al. 2011), harbouring a vast diverse fauna along with endemic species. The Oriental *Onthophagus* fauna is inadequately studied (Tarasov & Kabakov 2010). Also, Tarasov & Kabakov (2010) and Sathiandran & Sabu (2012) stated that the taxonomic

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errors from the Indian subcontinent are high for this genus. Moreover, the major documents like Arrow (1931) and Balthasar (1963) reporting this genus from this region are outdated (Sathiandran & Sabu 2012). Therefore, documenting diversity of this highly diverse genus will play an important role in removing the confusions and errors.

The dung beetle fauna of southern Western Ghats is very well documented (Arrow 1931; Balthasar 1963, 1974; Vinod & Sabu 2007, Sabu et al. 2011; Sathiandran & Sabu 2012; Sathiandran et al. 2015; Latha and Sabu, 2018). Sabu et al. (2011) recorded about 78 species of *Onthophagus* from moist southern Western Ghats. Of these recorded species, 19 are endemic to the entire Western Ghats, 12 are regional endemics to southern Western Ghats and a single species is a local endemic to the tropical montane cloud forest. On the contrary, very few or scattered publications are available on the diversity of dung beetle fauna from northern Western Ghats, Maharashtra (Arrow 1931; Balthasar 1963, 1974; Jadhav & Sharma 2012; Kalawate 2018). Hence, in the present study, an attempt has been made to prepare an updated checklist of the genus *Onthophagus* based on the collections from recent surveys, unidentified collections present at ZSI, WRC, Pune and also from the literature (Arrow 1931; Balthasar 1963, 1974; Jadhav & Sharma 2012; Kalawate 2018).

Specimens were collected from different parts of the northern Western Ghats, Maharashtra. They were collected by installing light traps using 160-Watt mercury bulb as a light source as they are attracted to the light in night. Some of the beetles were hand-picked from the dung pats present in the field in day during the field surveys in the northern Western Ghats, Maharashtra. The collected beetles were euthanized by ethyl acetate vapours and brought to the laboratory for further studies. The specimens were relaxed, pinned and stored in the fumigated entomological boxes for further examination. They were examined under Leica EZ4E® with in-built photographic facility. The male genitalia were dissected wherever necessary by carefully removing it from the abdomen. After removal, it was further boiled in 10% KOH for 5–10 minutes to remove the adhered tissues and soft muscles and then rinsed in distilled water. The genitalia were stored in separate vials containing 70% ethanol with same catalogue number as the specimen. The map of the collection locality has been prepared using QGIS software. The beetles were determined as per the available literature viz., Arrow (1931) and Balthasar (1963) and the classification followed is as per Arrow (1931) and Balthasar (1963) with modifications as per Lobl & Smetana (2006). The distribution of the species provided here are taken from Arrow (1931), Balthasar (1963), Chandra & Gupta (2011, 2013), Sabu et al. (2011), and Sathiandran et al. (2015). The checklist of the genus *Onthophagus* from Maharashtra including northern Western Ghats (Maharashtra) based on the collections from the recent surveys, unidentified collections from ZSI, WRC, Pune and also from the literature, with the record of endemic beetles has been provided.

A total of 36 species in eight subgenera of *Onthophagus* have been reported based on the recent collection (*) and reports from available literature. Of the recorded species, *O.* (*Onthophagus*) *madoqua* Arrow, 1931 and *O*. (*Gibbonthophagus*) *duporti* Boucomont, 1914 are new records for Maharashtra and northern Western Ghats. The details of new recorded species like material examined, distribution, description, genitalial features, images of adult habitus and genitalia are also given in this paper. Among the studied species, two endemic species namely *O*. (*O*) *madoqua* Arrow, 1931 and *O*. *coeruleicollis* Arrow, 1907 are recorded. A checklist of the species from Maharashtra is presented in Table 1. Image 1 represents the new recorded species along with their genitalial figures. The map of collection locality of the recorded species and the new reported species are given in Figures 1 and 2.

As stated earlier, a few literatures are available on this genus from Maharashtra; 21 and 25 species of *Onthophagus* have been reported from Vidarbha region of Maharashtra by Khadakkar et al. (2018) and entire Maharashtra by Arrow (1931) and Jadhav & Sharma (2012), respectively. Chandra & Gupta (2012) enlisted 34 species under six subgenera of Onthophagus from Madhya Pradesh. This study resulted into enumeration of 36 species under eight subgenera from the genus *Onthophagus* from the studied area (Table 2).

**Genus *Onthophagus* Latreille, 1802**

*Onthophagus* Latreille, 1802; Hist. Nat. Crust. Et. Ins. 3: 141.

*Onthophagus*, Arrow, 1931; Fauna of British India including Ceylon and Burma (Coleoptera: Lamellicornia: Coprinae) 3: 159–162.

Type species: *Scarabaeus taurus* Schreber, 1759

**1. *Onthophagus* (*Onthophagus*) *madoqua*** Arrow, 1931 (Image 1 A–B)

*Onthophagus madoqua* Arrow, 1931; Fauna of British India including Ceylon and Burma (Coleoptera: Lamellicornia: Coprinae), 3 : 258–259.


**Figure 1. Collection locality of *Onthophagus* from northern Western Ghats, Maharashtra.**

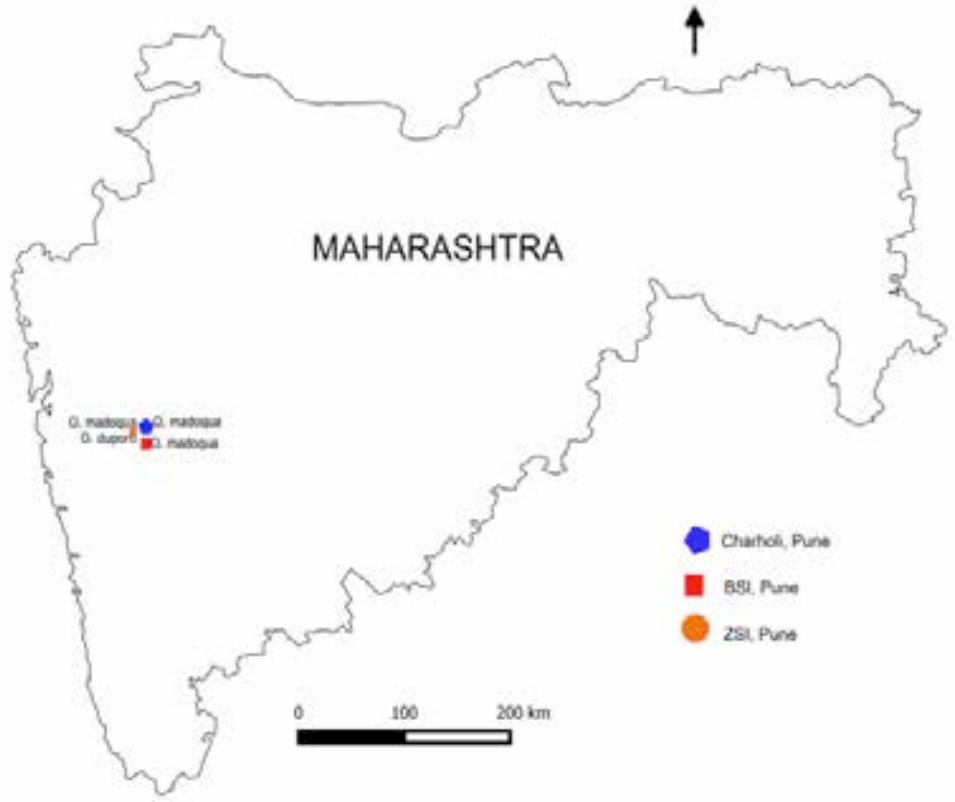


**Figure 2. Collection locality of *O. madoqua* and *O. duporti*.**

**Table 1. The checklist of the genus *Onthophagus* Latreille, 1802 from Maharashtra including northern Western Ghats, with distribution and endemic record.**

| Order **COLEOPTERA** Linnaeus, 1758<br>Suborder **POLYPHAGA** Emery, 1886<br>Superfamily **SCARABAEOIDEA** Latreille, 1802<br>Family **SCARABAEIDAE** Latreille, 1802<br>Subfamily: **SCARABAEINAE** Latreille, 1802<br>Tribe **ONTHOPHAGINI** Burmeister, 1846 | **Location** | **Reference** | **Remark** |
|---|---|---|---|
| **Genus *Onthophagus*** Latreille, 1802 | | | |
| **Subgenus *Onthophagus*** Latreille, 1802 | | | |
| *O. unifasciatus* (Schaller, 1783) * | BSI, Pune; Gaganbawda | | Responsible for Scarabiasis in young children |
| *O. abreui* Arrow, 1931 | | Thakare et al. 2012 | |
| *O. fasciatus* Boucomont, 1914 | | Jadhav & Sharma 2012 | |
| *O. madoqua* Arrow, 1931* | BSI, ZSI, Charholi, Pune | | New record for Northern Western Ghats, Maharashtra. Endemic to India. |
| *O. cervus* (Fabricius, 1798) * | ZSI, BSI, Tamhini Ghat, Pune | | |
| *O. ludio* Boucomont, 1914* | ZSI, BSI, Pune | | |
| *O. quadridentatus* (Fabricius, 1798) * | ZSI, Pune | | |
| *O. turbatus* Walker, 1858* | Tamhini Ghat | | |
| *O. orientalis* Harold, 1868 | | Jadhav & Sharma 2012 | |
| *O. spinifex* (Fabricius, 1781) | | Jadhav & Sharma 2012 | |
| *O. tritinctus* Boucomont. 1914 | | Jadhav & Sharma 2012 | |
| *O. centricornis* (Fabricius, 1798) | | Jadhav & Sharma 2012 | |
| *O. griseosetosus* Arrow, 1931 | | Jadhav & Sharma 2012 | |
| *O. abacus* Boucomont, 1921 | | Kalawate 2019 | |
| *O. malabarensis* Boucomont, 1919 | | Arrow 1931 | |
| **Subgenus *Trichonthophagus*** Zunino, 1979 | | | |
| *O. tarandus* Fabricius, 1792 | | Jadhav & Sharma 2012 | |
| **Subgenus *Colobonthophagus*** Balthasar, 1935 | | | |
| *O. dama* (Fabricius, 1798) * | Satara; Karjat; Gaganbawda; BSI, Tamhini Ghat, Pune | | |
| *O. hindu* Arrow, 1931* | Charoli, BSI, ZSI, Pune; Palghar; Satara; Dhule | | |
| *O. agnus* Gillet, 1925* | BSI, ZSI, Pune; Satara | Kalawate 2018 | |
| *O. armatus* Blanchard, 1853* | Tamhini Ghat | | |
| *O. aenescens* (Wiedemann, 1823) * | | Kalawate 2019 | Reported first time from Maharashtra (Kalawate 2019). |
| *O. ramosus* (Wiedemann, 1823) * | Tamhini Ghat | | |
| *O. ramosellus* (Bates, 1891) | | Jadhav & Sharma 2012 | |
| **Subgenus *Micronthophagus*** Balthasar, 1963 | | | |
| *O. gulo* Arrow, 1931 | | Jadhav & Sharma 2012 | |
| *O. hystrix* Boucomont, 1914 | | Jadhav & Sharma 2012 | |
| **Subgenus *Gibbonthophagus*** Balthasar, 1963 | | | |
| *O. duporti* Boucomont, 1914* | BSI, ZSI, Pune | | New record for Northern Western Ghats, Maharashtra. |
| **Subgenus *Eremonthophagus*** Zunino, 1979 | | | |
| *O. semicinctus* Dorbigny, 1897 | | Arrow 1931 | |
| **Subgenus *Proagoderus*** van Lansberge, 1883 | | | |
| *O. pactolus* (Fabricius, 1787) | | Jadhav & Sharma 2012 | |
| **Species incertae sedis** | | | |
| *O. coeruleicollis* Arrow, 1907 | | Kalawate 2019 | Endemic to India |

| | | | |
|---|---|---|---|
| *O. zebra* Arrow, 1931 | | Kalawate & Sharma 2019 | |
| *O. laborans* Arrow, 1931 | | Kalawate & Sharma 2019 | |
| *O. vultur* Arrow, 1931 | | Kalawate & Sharma 2019 | |
| *O. turbatus* Walker, 1858 | | Sathiandran et al. 2015 | |
| *O. lilliputanus* Lansberg, 1883 | | Arrow 1931 | |
| *O. circulifer* Arrow, 1931 | | Arrow 1931 | |
| **Subgenus *Parascatonomus*** Paulian, 1932 | | | |
| *O. quaestus* Sharp, 1875 | | Kalawate & Sharma 2019 | |

* species collected and studied.

*Onthophagus* (*Onthophagus*) *madoqua*. Balthasar, 1963; Monographie der Scarabaeidae und Aphodiidae der Palaearktischen and Orientalischen Region (Coleoptera: Lamellicornia), 2: 426.

Specimen examined: ZSI-WRC, ENT-1/3234, 06.xi.2017, 07 ex., Charholi, Pune, Maharashtra, (18.653°N, 73.907°E), coll. A.S. Kalawate; ZSI-WRC, ENT-1/3240, 23.viii.2018, 06 ex., ZSI, WRC, Pune, Maharashtra (18.6482$^0$N & 73.760$^0$E, 580m), coll. B. Mukhopadhyay; ZSI-WRC, ENT-1/3251, 27.viii.2018, 02 ex., BSI, WRC, Pune, Maharashtra (18.540$^0$N & 73.885$^0$E, elevation 556m), coll. B. Mukhopadhyay; ZSI-WRC, ENT-1/3257, 27.viii.2018, 11 ex., ZSI, WRC, Pune, Maharashtra (18.6482$^0$N & 73.760$^0$E, 580m), coll. B. Mukhopadhyay; ZSI-WRC, ENT-1/3265, 28.viii.2018, 12 ex., ZSI, WRC, Pune, Maharashtra (18.648$^0$N & 73.760$^0$E, 580m), coll. B. Mukhopadhyay; ZSI-WRC, ENT-1/3271, 28.viii.2018, 07 ex., BSI, WRC, Pune, Maharashtra (18.540$^0$N & 73.885$^0$E, 556m), coll. B. Mukhopadhyay.

Description (Image 1A): Length, 4–5 mm., breadth, 3mm. Black, shining, oval and convex. Head coppery, short and broad; clypeus smooth in front, with its margin strongly reflexed; forehead separated by curved carina; a pair of quite separate, straight, erect and parallel horns at vertex. Pronotum deep golden-green, smooth in front, slopes steeply but not abruptly. Elytra decorated, red patch on each elytron at shoulder and hind margin. Upper surface clothed with erect pale setae.

Male genitalia (Image 1B): Phallobase is almost same in length as parameres, gently curved in lateral view. Parameres funnel shaped, broad at base, minutely constricted in the middle, strongly bent downward, acuminating, tips rounded. Maximum Length, about 1.39mm; maximum width, about 0.504mm.

Known distribution until this study: India (Gujarat, Karnataka, Rajasthan, Tamil Nadu).

**Table 2. Details of the surveyed localities.**

| Location | Coordinates |
|---|---|
| Tamhini Ghat | 18.494$^0$N & 73.425$^0$E, elevation 631m |
| BSI,WRC, Pune | 18.540$^0$N & 73.885$^0$E, elevation 556m |
| ZSI, WRC, Pune | 18.648$^0$N & 73.760$^0$E, elevation 580m |
| Satara | 17.229$^0$N & 73.952$^0$E, elevation 731m |
| Karjat | 18.932$^0$N & 73.325$^0$E, elevation 49m |
| Law College Hill | 18.514$^0$N & 73.828$^0$E, elevation 580m |
| Dhule | 21.039$^0$N & 74.207$^0$E, elevation 497m |
| Gaganbawda | 16.552$^0$N & 73.846$^0$E, elevation 601m |
| Palghar | 19.758$^0$N & 73.347$^0$E, elevation 518m |
| Charholi, Pune | 18.653$^0$N & 73.907$^0$E |

**2. *Onthophagus* (*Gibbonthophagus*) *duporti*** Boucomont, 1914 (Image 1 C–D)

*Onthophagus duporti* Boucomont, 1914; Annali del Museo civico di storia naturale di Genova, XLVI: 228.

*Onthophagus* (*Gibbonthophagus*) *duporti*; Sathiandran et al. 2015; Journal of Threatened Taxa 7(15): 8250–8258.

Specimen examined: ZSI-WRC, ENT-1/3264, 27.viii.2018, 01 ex., ZSI, WRC, Pune, Maharashtra (18.648$^0$N & 73.760$^0$E, 580m), coll. B. Mukhopadhyay.

Description (Image 1 C): Length, 7mm., width, 4mm. Dark brown, smooth and shining, oval and convex. Clypeus feebly produced, front margin rounded and strongly reflexed, separated from forehead by a short transverse carina. Near inner margin of each eye, a short, erect, blunt, conical horn present. Pronotum with three small tubercle, one just behind the front margin in the middle and a pair positioned between the front and hind margins, the space between these tubercles slightly depressed but not smooth. Elytra testaceous-yellow, with brown-black bands at the inner and outer margins, which usually more or less fused together in the middle line. The pygidium and the femora are yellow,


**Image 1. *Onthophagus* (*Onthophagus*) *madoqua* Arrow, 1931: A—adult | B—genitalia | *Onthophagus* (*Gibbonthophagus*) *duporti* Boucomont, 1914: C—adult | D—genitalia. Scale bar = 2mm (A & C); 0.5mm (B & D).**

with minute setae.

Male genitalia (Image 1 D): Phallobase larger than the parameres, broader and tubular. Parameres roughly triangular, broad at the base, acuminating towards the tip, rounded tip, curved ventrally. Maximum length, about 2.01 mm; maximum width, about 0.967mm.

Known distribution until this study: India (Arunachal Pradesh, Bihar, Karnataka, Tamil Nadu (Nilgiri Hills), Kerala, West Bengal), China, Indo-China, Laos, Myanmar, Thailand, Tonkin, Vietnam.

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NOTE

# Ecological importance of two large heritage trees in Moyar River valley, southern India

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Large old trees are considered as 'keystone structures' because of their humungous size and disproportionately high production of resources for multiple species in an ecosystem (Manning et al. 2006). They play a significant role in providing ecological services and maintaining the ecosystem function in various ecosystems (Lindenmayer et al. 2013; Lindenmayer & Laurance 2017). Large old trees are often called heritage trees for their natural and cultural significance as they function as critical habitat for a wide array of species in large landscapes (Dean et al. 1999; Jim 2017). The decline of large old trees would negatively influence the environment, and the species that depend on them may even face the risk of local extinction, thus affecting the ecological integrity (Manning et al. 2006; Lindenmayer et al. 2013; Lindenmayer & Laurance 2017).

Numerous animals, including insects, reptiles, birds, herbivores, carnivores, and other species immensely depend on large trees for shelter, shade, and food, especially in tropical dry forests that usually support large populations of emblematic species like tigers, leopards, and elephants. The large old trees are also the major contributors to the high heterogeneity and biomass of forest landscapes across the globe (Das et al. 2018). Most importantly, they occur at low stem densities, yet influence spatial patterns over long inter-tree distances (Lutz et al. 2018). Despite their significant role in maintaining the ecological flows, the importance of large trees is often understudied and overlooked in habitat conservation programs (Lutz et al. 2018).

The Moyar River valley landscape (henceforth MRVL) at the juncture of the Western Ghats and the Eastern Ghats is one among the dry tropical landscape, which supports rich flora, fauna, and act as a habitat for many endangered and heritage species. Especially, the riverine forest along the Moyar River (a major perennial river in the landscape) is one of the remaining contiguous forests in the Nilgiri Biosphere Reserve. The large

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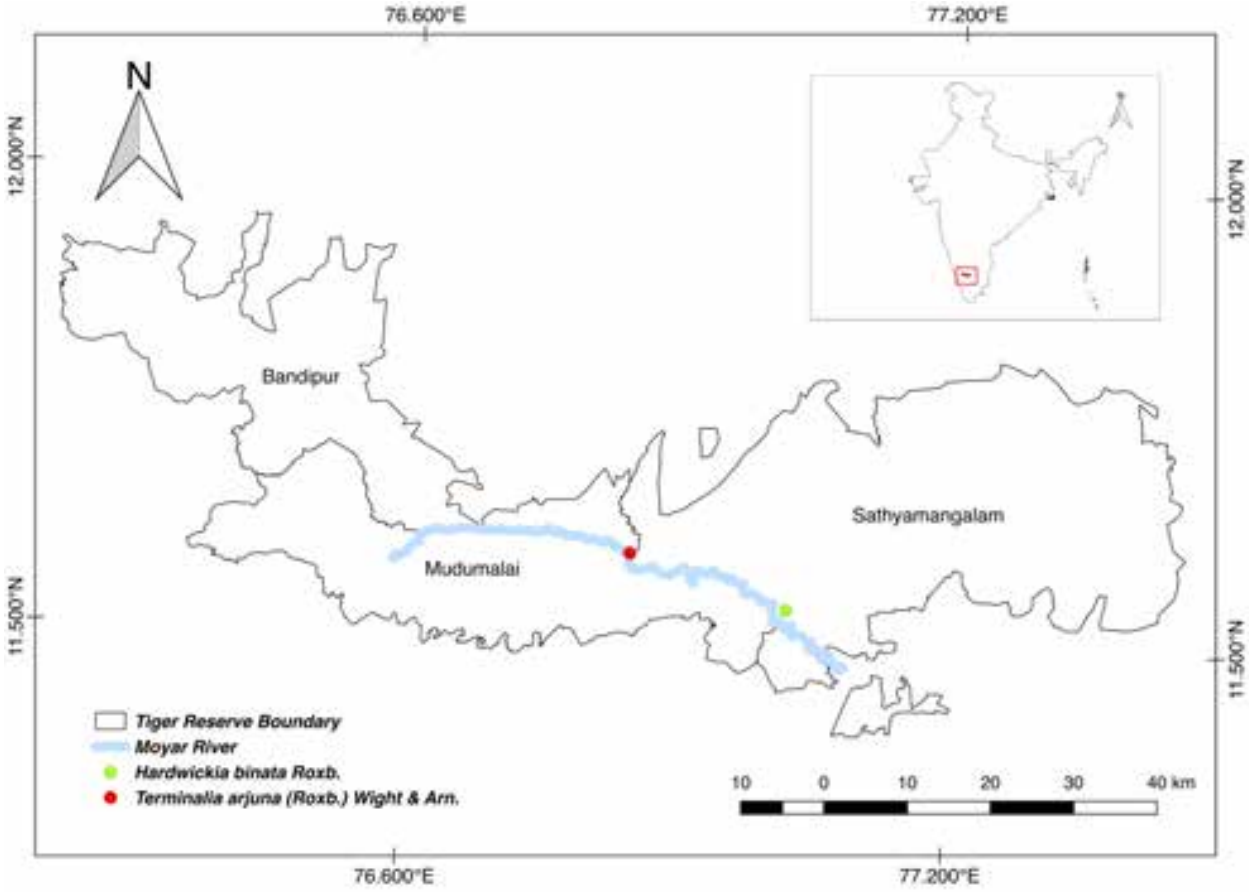


**Figure 1. The location of two large trees *Hardwickia binata* Roxb. & *Terminalia arjuna* (Roxb ex DC.) Wight & Arn. in Moyar River valley landscape, Tamil Nadu, India.**

trees in landscapes like MRVL have special ecological significance as they provide microhabitat for numerous species that have high conservation significance. During the two years (November 2017–January 2020) of vegetation survey that included 500 plots (10m x 10m) established across five major forest types in the MRVL, we came across two large old trees one each of *Terminalia arjuna* (Roxb.) Wight. & Arn. and *Hardwickia binata* Roxb. This article is an attempt to exemplify the ecological significance of these two large old trees in the Moyar River valley landscape (Figure 1).

We recorded an enormous tree of *Terminalia arjuna* (Combretaceae) measuring 32m height and 8.45m girth at breast height (GBH; above buttress) at 11.594$^0$N & 76.846$^0$E, 398m (Image 1). This individual tree occurs in the riparian forest along the Moyar River, where the average canopy height reaches around 25m. This particular tree is a unique landscape feature that marks the tri-junction boundary of three tiger reserves (TR), namely Sathyamangalam TR, Mudumalai TR, and Bandipur TR. Likewise, the large individual tree of *Hardwickia binata* (Fabaceae) measuring 21m in height and 4.24m in GBH was observed at 11.537$^0$N & 77.021$^0$E, 324m (Image 2). This individual tree is located in the scrub forest, where the average canopy height is around 5m – four-fold lesser than the observed large old tree.

*Terminalia arjuna* is a large deciduous tree (local name: 'Neermathi') usually found along the river, dry watercourse, and streams of tropical dry and moist forests in India and Sri Lanka (Kundu & Schmidt 2015). The ecological significance of *T. arjuna* in MRVL includes providing habitat for many species, stabilizing the riverbanks, and trapping the sediments as buttress roots act as an excellent soil binder. Also, the large crown, tall stature of *T. arjuna* is often used by major faunal species such as Elephants, Muggers, Leopards, Sloth Bears, Chital, Grey Langur, and Malabar Giant Squirrel for various purposes. Hence, it is considered a keystone species of the riparian forest in southern India (Sunil et al. 2019).

The largest tree of *T. arjuna* with 14m GBH and an estimated age of 550 years was reported from Javvadhu


**Image 1. a—The largest tree of *Terminalia arjuna* recorded at Moyar River valley landscape | b—nesting of White-rumped Vulture in the observed tree | c—the claw marks of Sloth Bear seen in this tree indicating the high use of *T. arjuna* by the animal | d—Spot-bellied Eagle-owl, new record to the checklist of Sathyamangalam Tiger Reserve.**

Hills of Tamil Nadu by Vijayasankar et al. (2012). Though the tree that we observed is not the largest ever reported, it has a high ecological value. For example, this individual tree is highly used as a roosting site by four species of vultures, of which three are Critically Endangered namely White-rumped Vulture *Gyps bengalensis* (J.F. Gmelin, 1788), Red-headed Vulture *Sarcogyps calvus* (Scopoli, 1786), and Long-billed Vulture *Gyps indicus* (Scopoli, 1786); and one is endangered Egyptian Vulture *Vulture percnopterus* (Linnaeus, 1758) as per the IUCN Red List data. We have recorded seven nests of White-rumped Vulture on this tree during December 2019. Also many raptors, namely, the Brown Fish-owl *Ketupa zeylonensis* (Gmelin, 1788), Spot-bellied Eagle-owl *Bubo nipalensis* (Hodgson, 1836), Oriental Honey-buzzard *Pernis ptilorhynchus* (Temminck, 1821), Changeable Hawk-eagle *Nisaetus cirrhatus* (Gmelin, 1788), and Shikra *Accipiter badius* (Gmelin, 1788) are observed roosting on this tree. Interestingly, the Spot-bellied Eagle-owl is a new record to the faunal checklist of Sathyamangalam Tiger Reserve. These observations signify the conservation importance of large old trees in general and the observed tree in particular.

*Hardwickia binata* is native to southern and southeastern Asia (Arunkumar & Joshi 2018) representing the only species under the genus *Hardwickia* (Kumar &

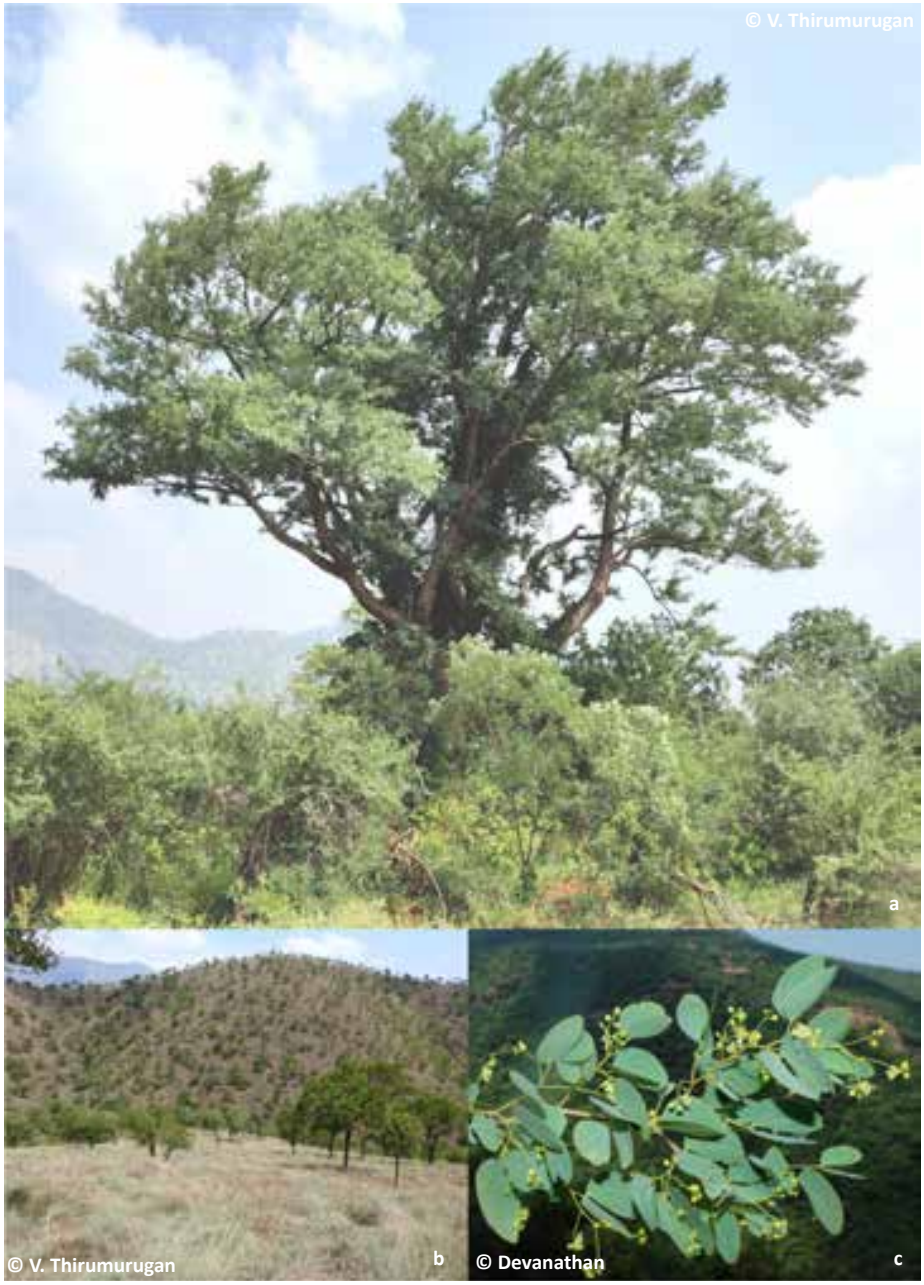


**Image 2. a—The largest tree of *Hardwickia binata* recorded at Moyar River valley landscape | b—Woodland savannah dominated by *Hardwickia binata* | c—a flowering twig of the tree.**

Sane 2003; Sanjappa 2010; Kundu & Schmidt 2011). The records suggest that this species can grow up to 36m tall and 4m GBH (Arunkumar & Joshi 2018). The tree that we observed has the largest GBH as per the available reports. *H. binata* is one of the dominant tree species in the tropical dry deciduous forest of southern India (Meher-Homji 2008). It also commonly occurs in the southern tropical thorn forest, scrub forest, deciduous forest, and woodland savannah of the MRVL (Champion & Seth 1968). In MRVL, *H. binata* (locally called 'Aacha', 'Aachamaram' or 'Karachi') are commonly found along the ridges, furrows, and hillocks.

In MRVL, *H. binata* remains as one of the essential foraging trees for the herbivores where mammals generally prefer the leaves, twigs, and bark. The Asian Elephant *Elephas maximus* intemperately feeds on its bark, leaves, and act as a primary seed-dispersing agent (Sukumar 1992; Baskaran et al. 2010). The Irula's (indigenous community in this landscape) also use this tree species for multiple purposes (timber, firewood

and to make ropes during local festivals) indicating the cultural ethos associated with this species.

The growing evidence suggests that the large old trees are globally on the decline due to various environmental and anthropogenic drivers (Lindenmayer et al. 2013). Experts particularly urge that the conservation of large old trees require site-specific unique conservation approaches (inclusive of social and cultural aspects) that span over unprecedented spatio-temporal scales (Lindenmayer et al. 2013; Blicharska & Mikusiński 2014; Lindenmayer et al. 2014; Lindenmayer & Laurance 2016). In India, the conservation mechanism adapted to the large Kannimara teak (*Tectona grandis* L.f.) that occur in Parambikulam Tiger Reserve could serve as a model system for large old trees; where the cultural heritage along with designating a special status (i.e., tree of national importance) made an effective conservation tool for awareness building (Nagarajan et al. 2010). Therefore, implementing new policies to register and recognize the large old trees and mapping their distributions will immensely help in their protection and conservation of associated biodiversity. Besides, future scientific studies focusing on the role that large old trees play in biodiversity conservation and regulating the ecosystem process could provide much-needed insights on the conservation significance of large old trees; which is particularly crucial for the management of highly important wildlife landscapes such as the Moyar River valley landscape. Moreover, such initiatives can play a vital role in the conservation awareness programs designed for local stakeholders.

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NOTE

# *Bulbophyllum spathulatum* (Orchidaceae), a new record for Bhutan

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*Bulbophyllum* Thouars (1822) is one of the largest genera in family Orchidaceae comprising approximately 2,200 species, distributed in the tropical and subtropical regions of the world with the richest diversity in the tropics of Africa and Asia (Pearce & Cribb 2002; Chen & Vermeulen 2009; Chase et al. 2015; Gyeltshen et al. 2020). In Bhutan, the genus is represented by 57 species from 13 sections distributed mostly in eastern, western, and southern parts of Bhutan (Gurung 2006; Dalstrom et al. 2017; Gyeltshen et al. 2020).

During a recent floristic exploration in the Subrang and Pantang under Zhemgang District in 2019, the first author encountered a small population of an unfamiliar orchid growing on a tree. For initial examination sufficient photographs were taken. After critical examination of morphological parts, careful scrutiny of herbarium materials and literatures (Reichenbach 1970; Seidenfaden 1970, 1973; Garay et al. 1994; Pearce & Cribb 2002; Chen & Vermeulen 2009; Averyanov 2016), this species was identified as *Bulbophyllum spathulatum* (Rolfe ex E.Cooper) Seidenf. and this is a new record for Bhutan (Figure 1).

Originally described as *Cirrhopetalum spathulatum* Rolfe ex E.W.Cooper, this species was circumscribed under the genus *Bulbophyllum* by Seidenfaden (1970) as *Bulbophyllum spathulatum*. Alternatively, Garay et al. (1994) described a new genus as *Rhytionanthos* where based on fusion of lateral sepals to form a synsepal by inward twisting and connation of their edges and included *Bulbophyllum spathulatum* as *Rhytionanthos spathulata*, however, this concept has changed. The genus *Rhytionanthos* has now been merged under *Bulbophyllum* (Pridgeon et al. 2014) and accordingly followed thereafter (Govaerts et al. 2020).

*Bulbophyllum spathulatum* had been included in the Orchids of Bhutan by Pearce & Cribb (2002) based on its occurrence in adjacent areas in India, however, it was never collected from within the political boundaries of Bhutan. Hence, the present collection of the species from Zhemgang District, Bhutan stands as a new record for Bhutan. Later, plants were also discovered at one more area in Zhemgang District followed by two sites in Wangduephodrang District, however, no voucher specimens were collected due to the rarity of the species. Detailed morphological descriptions, updated distribution, phenology, and ecology along with distribution map and colour photographs are provided based on the collected specimens.

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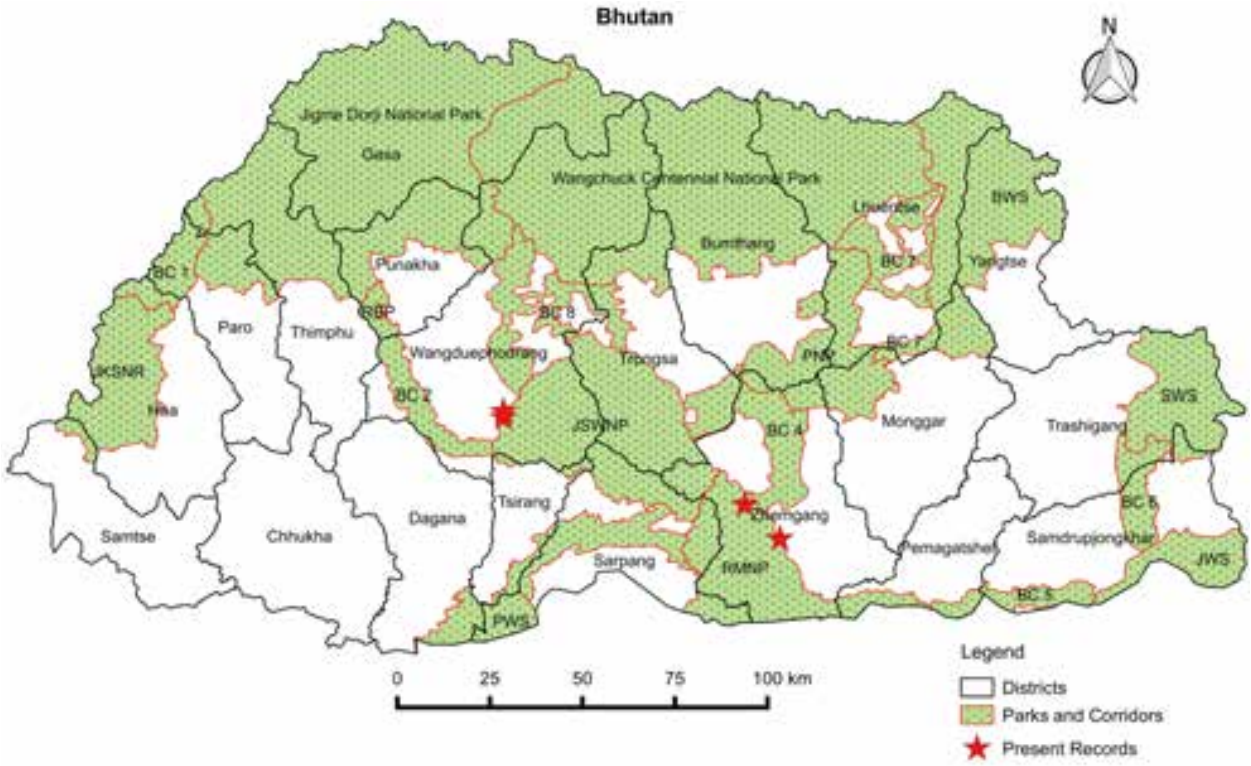


**Figure 1. Distribution of *Bulbophyllum spathulatum* at Pangkhar block in Zhemgang District in Bhutan.**

***Bulbophyllum spathulatum*** (Rolfe ex. Cooper) Seidenf. Bot. Tidsskr. 65: 347 (1970); *Cirrhopetalum spathulatum* Rolfe ex. Cooper in Orchid Rev. 37: 106 (1929)*; Rhytionanthos spathulatum* (Rolfe ex Cooper) Garay, Hemer & Siegerist in Nordic J. Bot. 14(6): 639 (1994).

Type: Thailand, Bangkok, Roebelen 292-12 (K000829943) (K!-Holotype).

Epiphytic herb. Roots terete, ca. 1mm thick, caespitose. Rhizome creeping, terete, 2.5–9.3 cm long, 1.5–3.0 mm wide, covered with membranous sheaths, old sheaths brownish, new sheaths greenish-yellow with purplish-mauve spotted, 1.0–1.5 cm long, 1.0–1.2 cm wide, persistent, internodes of rhizome 1.0–1.4 cm long. Pseudobulbs cylindrical-ovoid, narrowly-ovoid, 1.5–4.0 cm x 0.6–1.5 cm wide, 2.5–9.3 cm apart from each other on the rhizome, glabrous, greenish-yellow, brownish-pale yellow with the age, longitudinal ridges present, bearing a solitary leaf at the apex. Leaf blade green, linear-oblong to oblong-elliptic, 3.5–15.0 cm long, 1.3–2.5 cm wide, entire, apex sub-acute or obtuse, base attenuate, adaxially glabrous, abaxially whitish-brown spotted and occasionally purple coloured, fleshy, coriaceous to leathery. Petiole yellowish-green, 0.4–1.0 cm long, ca. 0.2 cm wide, longitudinally channeled, glabrous, obliquely notched on the pseudobulb, conduplicate. Inflorescences arising from the base of the pseudobulbs, sub-umbellate, ca. 6.5–7.0 cm long, 4–10 flowers, erect; peduncle with 4–5 sheaths, 1.5–2.5 cm long, pale yellow with mauve streaks and spotted towards apex, sheathing bracts broadly ovoid to oblong-ovoid, 0.8–1.2 cm x 0.7–0.9 cm wide, thin, glabrous, basal bracts turning brownish with the age. Flowers, 4.2–5.0 cm long including pedicel and ovary, resupinate, golden-yellow with reddish-brown spotted. Floral bracts oblong–lanceolate, 10–14 × 4–5 mm, thin, margin entire, apex acute, base truncate, glabrous, whitish-pink, three-veined. Pedicel and ovary pale yellow with reddish-maroon spots, 1.5–2.5 cm long, 1.5–2.0 mm wide. Dorsal sepals obovate, 7.5–9.0 × 4.0–4.5 mm when flattened, yellowish-green with reddish-brown spots mostly in the middle, two prominent reddish spots at the base, margin entire, apex obtuse and slightly mucronate, base truncate, abaxially glabrous, adaxially papillose, concave, three-veined. Lateral sepals fused to form slipper-shape, 1.6–2.2 cm long, 5.5–6.5 mm wide, upper and lower edges connate to forming a synsepal; synsepal 10–11 mm wide, golden-yellow with reddish-brown, outer surface minutely warty with white papillae including margins, apex rounded and slightly incurved,

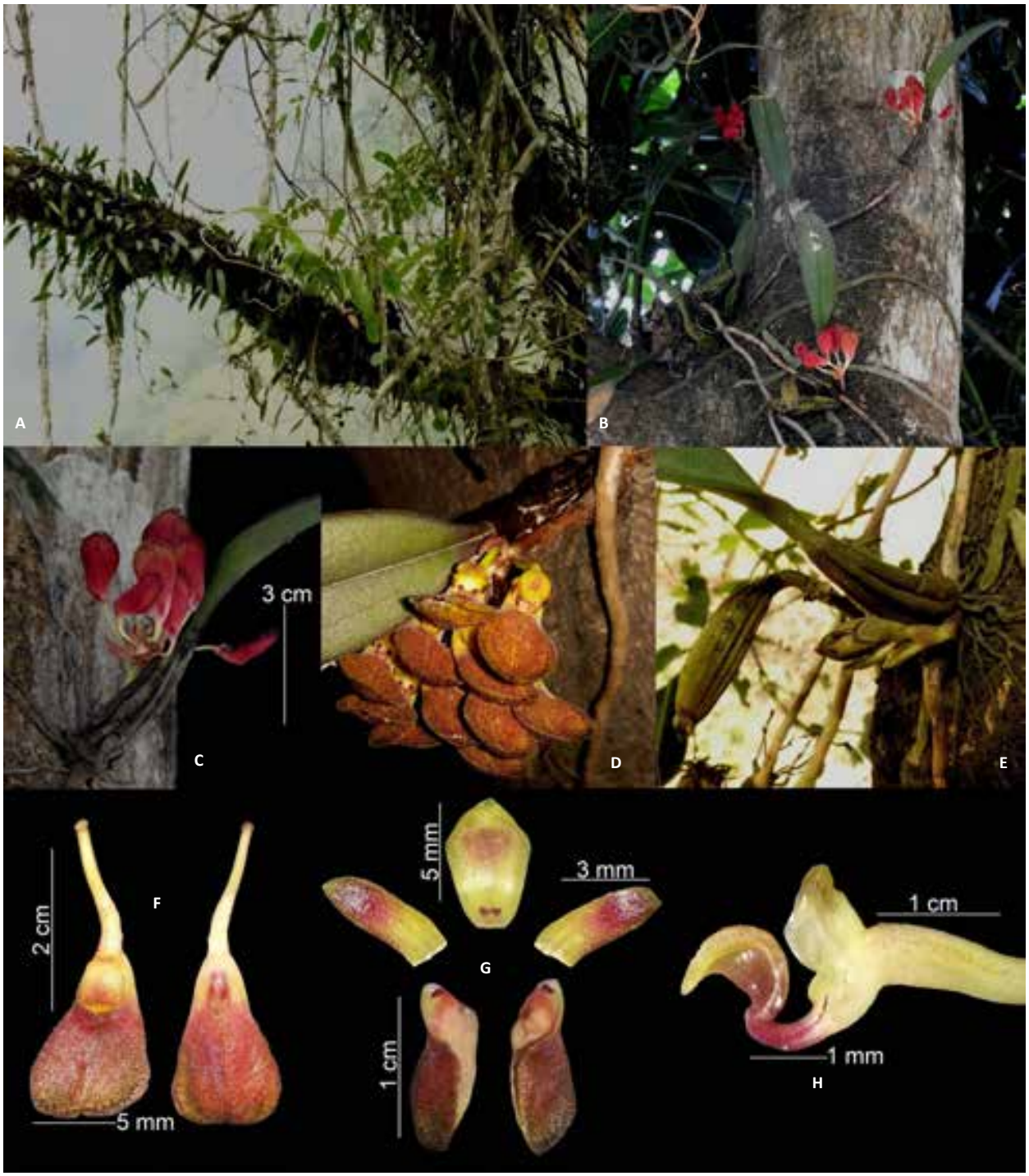


**Image 1.** ***Bulbophyllum spathulatum*** **(Rolfe ex E.W.Cooper) Seidenf.: A & B—Plant in habitat | C—inflorescence | D—top view of flowers | E—fruit and flower shoot | F—flowers (adaxial and abaxial surface view) | G—dorsal sepal, petals and lateral sepals (adaxial view) | H—column and lip attached to ovary (lateral view). © A–E - Pema Zangpo; F–H - Phub Gyeltshen.**

base obliquely truncate to rounded when dissected, two prominent reddish-maroon spots at base. Petals oblong to oblong-lanceolate, 4.0–5.0 × 1.2–2.0 mm, yellow with deep maroon-purplish, falcate towards left, slightly incurved, margin entire, revolute, apex obtuse, base obliquely truncate, surface glaucous, left petal slightly longer than the right petal. Lip thick and fleshy, ovate–lanceolate, 4–4.2 mm long, 1.5–2.0 mm wide, glabrous, side ridges present, margin entire, mobile, recurved, base with reddish-brown and yellow towards

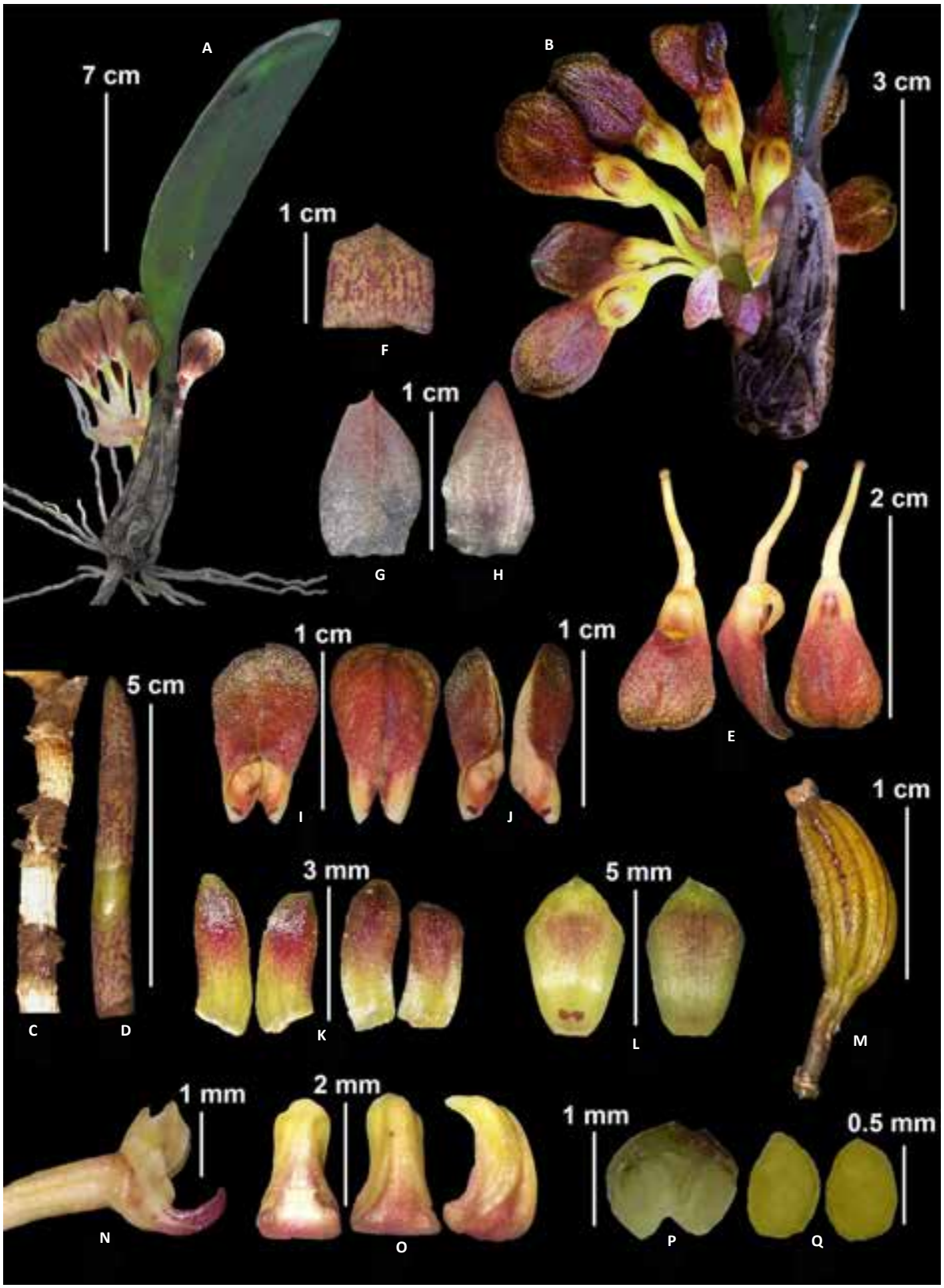


Image 2. *Bulbophyllum spathulatum* (Rolfe ex E.W.Cooper) Seidenf.: A—plant in habit | B—inflorescence | C & D—rhizomes (mature (C) and young (D)) | E—flowers (adaxial, lateral and abaxial view) | F—rhizome sheath (adaxial surface) | G—inflorescence bract (adaxial surface) | H—flower bract (adaxial surface) | I & J—lateral sepals (adaxial, abaxial and dissected view) | K—petals (abaxial and adaxial surface view) | L—dorsal sepals (abaxial and adaxial surface view) | M—fruit | N—column (lip and operculum removed) | O—lip (abaxial, adaxial and lateral view) | P—operculum | Q—pollinia. © A–B - Pema Zangpo; C–Q - Phub Gyeltshen.

the apex, apex obtuse, base broad, truncate to slightly auriculate. Column yellow, quadrangular, 1.8–2.0 mm long, 2mm wide, forwarded and incurved foot; foot rectangular, 2.0–2.5 mm long, 1.5mm wide, purplish-maroon, minutely wing margins with maroon lining, margin entire, prominent triangular shape at abaxial surface, column wall with prominent deep-maroon lines one on each sides separating the column wing, a swollen protruding structure at the inter-connecting inner column and column foot bases. Stelidia deltoid, ca. 1mm long 1.5mm wide, yellow. Operculum sub-spherical, cucullate, ca. 1.4–1.6 mm long, 1.0–1.2 mm wide, white towards the base from middle and yellowish-green towards the apex. Pollinia four in two pairs, ovoid, ca. 1.2 × 1.0 mm, glaucous, slightly flat and slightly curved towards apex from the middle. Fruits yellowish–green, clavate, 2.5–2.7 cm long, 1.5–1.7 cm wide, straight or slightly curved, longitudinally grooved (Figures 1; Image 1, 2).

Phenology: Flowers from mid-February to end of March, fruits mature from May to September.

Habitat: *Bulbophyllum spathulatum* was found growing as epiphyte on the tree trunks of *Canarium strictum* in the subtropical forest at around 350m along the river bank. Other associated trees and shrubs in its habitat comprises of *Tetrameles nudiflora* R.Br., *Ficus auriculata* Lour., *Maesa chisia* Buch.-Ham. ex D.Don., *Terminalia grandiflora* Benth., *Alangium alpinum* (C.BClarke) Smith. & Cave, *Alstonia neriifolia* D.Don., *Celastrus paniculatus* Willd and *Boemeria* sp. The associated orchids sharing the same habitat are *Dendrolirium lasiopetalum* (Willd.) Chen & Wood and *Vanda ampullacea* (Roxb.) L.M. Gardiner.

Updated Global distribution: Bhutan, China, India, Myanmar, Laos, Thailand, and Vietnam.

Specimens examined: Vietnam: 2 (P00355148) (P!), 01.i.1954, Annam, Dalat, Vietnam, C.R.S.T. 274; (P00355149) (P!), 01.i.1957, Annam, Dalat, Vietnam, Grillet s.n.; (P00355150) (MNHN-P!), 1,000m, Region de Dalat, Pougour, Vietnam, P. Tixier s.n.. Thailand: 0916 (K000597358) (K!), 23.ii.1931, 1,000m, Pu Kio, Chaiyapum, Thailand, A.F.G. Kerr 292; (K000829943) (K!), 10.i.1973, Thailand, C. Roebelen s.n. India: 131 (BM000516930) (NHMUK!), northern Sikkim, Sikkim, India, 01.iii.1891, R. Pantling 131; (P00355147) (P!), 01.iii.1891, tropical valleys, India, R. Pantling s.n.; (L1488962) (NBC!), Sikkim, India, R. Pantling s.n. Bhutan: 015–016 (THIM), Subrang, Trong, Zhemgang District, 20.ii.2020, 1,130m, P. Zangpo & P. Gyeltshen 017.

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NOTE

# On the occurrence and distribution of the narrowly endemic Andaman Lantern Flower *Ceropegia andamanica* (Apocynaceae: Ceropegieae)

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The genus *Ceropegia* L. (Apocynaceae, Asclepiadoideae) is the largest of the tribe Ceropegieae, represented by 190–200 taxa (Meve 2002; Mabberley 2017). The genus is distributed mainly in tropical and subtropical regions of the old world from the Canary Islands in the west through Africa, Madagascar, Arabia, India, southeastern Asia, New Guinea, and northern Australia in the east (Kidyoo & Paliyavuth 2017). Karthikeyan et al. (2009) recorded 56 species, two subspecies and three varieties for India, and according to more recent estimates the genus is represented by 56 species, two varieties and one forma (Kambale 2015; Kambale & Gnanasekaran 2016). A total of 40 species and three varieties are endemic to India (Singh et al. 2015; Kambale & Gnanasekaran 2016) of which *C. andamanica* Sreek., Veenak. & Prashanth is the only species known to occur in Andaman & Nicobar Islands.

*Ceropegia* are considered very attractive owing to the intricate ornamental nature of their "fly trap" flowers and their ecological adaptations. Flowers of distinctive color, pattern, and shape are unique to this genus. The Andaman & Nicobar Islands, with a total geographical area of 8,249km$^2$, stretch from Myanmar in the north to Sumatra in the south. This is one of the major phytogeographical regions of India, well known for tropical lowland rainforests (Nayar 1997). The floral components of these islands show many similarities with Malaysia, Myanmar, Thailand, and Sri Lanka. Most of the species found on these islands are also found outside India (Balakrishnan & Rao 1983).

While studying and identifying old specimens collected from Andaman & Nicobar Islands deposited at CAL, the authors found a specimen of *Ceropegia* sp. collected from South Andaman Island in 1890. On further examination of the specimen and scrutiny of literature, it was found to be *Ceropegia andamanica* Sreek., Veenak. & Prashanth.

It is interesting to note that Dr. King's collection from Goplakabang, South Andamans in 1890, came almost 108 years before the species was described in 1998 from the collections made from Mount Harriet in South Andaman Islands. The 1890 collection was from a different locality, from where this species was not reported until now. The species was also collected in the recent past from different localities by N.G. Nair in 1975, from Herbertabad in South Andaman almost 23 years

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before the type collection, and by Sam K. Mathew from Mount Harriet in 1989, but remained unrecognized. Sreekumar & Veenakumari collected this species from Mount Harriet (1995) and identified it to be a new species and published it as *Ceropegia andamanica* in 1998. The purpose of this article is to update the distribution data of the species and provide a detailed description, image of the oldest herbarium specimen collected 108 years before the type collection, and to map its distribution to aid the conservation of this rare and narrow endemic species (Figure 1). A color photograph is also provided for easy identification. The species is also critically evaluated as per the recent IUCN category.

***Ceropegia andamanica*** Sreek., Veenak. & Prashanth

Blumea 43(1): 215. 1998; Karthik et al., Fl. Pl. India 1: 160. 2009. (Figure 1 & Image 1).

Type: India, Andaman & Nicobar Islands, South Andaman: Mt. Harriet National Park, 14.xii.1995. Sreekumar & Veenakumari 15493 (holotype CAL0000018036!; isotypes PBL, L).

Perennial herb with watery latex. Leaves simple, opposite-decussate, lanceolate, 5–15 x 1–5 cm, chartaceous, base shallowly cordate, margins entire, apex acute to acuminate, dark green above, glaucous beneath, glabrous, lateral veins 2–8 pairs, more or less prominent on both surfaces, tertiary veins prominent on both surfaces. Petiole 0.5–2 cm long, slender, glabrous. Inflorescence axillary, pedunculate, in 3–8-flowered cymes; peduncle slender, 1–2.5 cm long, glabrous. Flowers purple, 4–12 cm long; bracts 3–4 mm long, glabrous; pedicel slender, 0.5–2 cm long, glabrous. Calyx 5-lobed; sepals 5, subulate, 0.5–1 cm long, glabrous. Corolla 5–12 cm long; corolla tube 1.5–2 cm long, dilated at base, sub-cylindrical, funnel shaped at throat; corolla lobes 3–7 cm long, connate at the tip, twisted, whip like, purplish, hairy. Corona biseriate; outer corona c. 3x2 mm, with 5 ovate-retuse bifid lobes, ciliate along margin and inside; inner corona with 5 erect, club shaped lobes, c. 2x1 mm, glabrous. Fruits not seen.

Flowering: November–December.

Distribution: India: Andaman Islands; South Andaman (known only from three localities).

Habitat: Along the edges of inland evergreen forests in association with *Mallotus resinosus* (Blanco) Merr. and *Phaulopsis imbricata* Sweet.

Additional specimens examined: India: Andaman Islands, South Andaman, Goplakabang, 1890, Dr. King's collector s.n. (CAL0000031581!) (Image 2); Herbertabad, 29.xi.1975, N.G. Nair 3169 (PBL!); Mount Harriet, 7.xii.1989, Sam P. Mathew 20416 (PBL!).

**Conservation status**

The species is endemic and reported so far only from three locations in Andaman Islands, India. The extent of occurrence (EOO) of the species is estimated as c. 33km$^2$ (severely fragmented and with a projected decline in area of occupancy, number of locations, and number of mature individuals) and the area of occupancy (AOO) of the species is estimated as c. 12km$^2$. The AOO is measured against the grid size of 4km$^2$ for each of the three locations. The number of mature individual of this


**Image 1. *Ceropegia andamanica* Sreek., Veenak. & Prashanth - a flowering twig.**

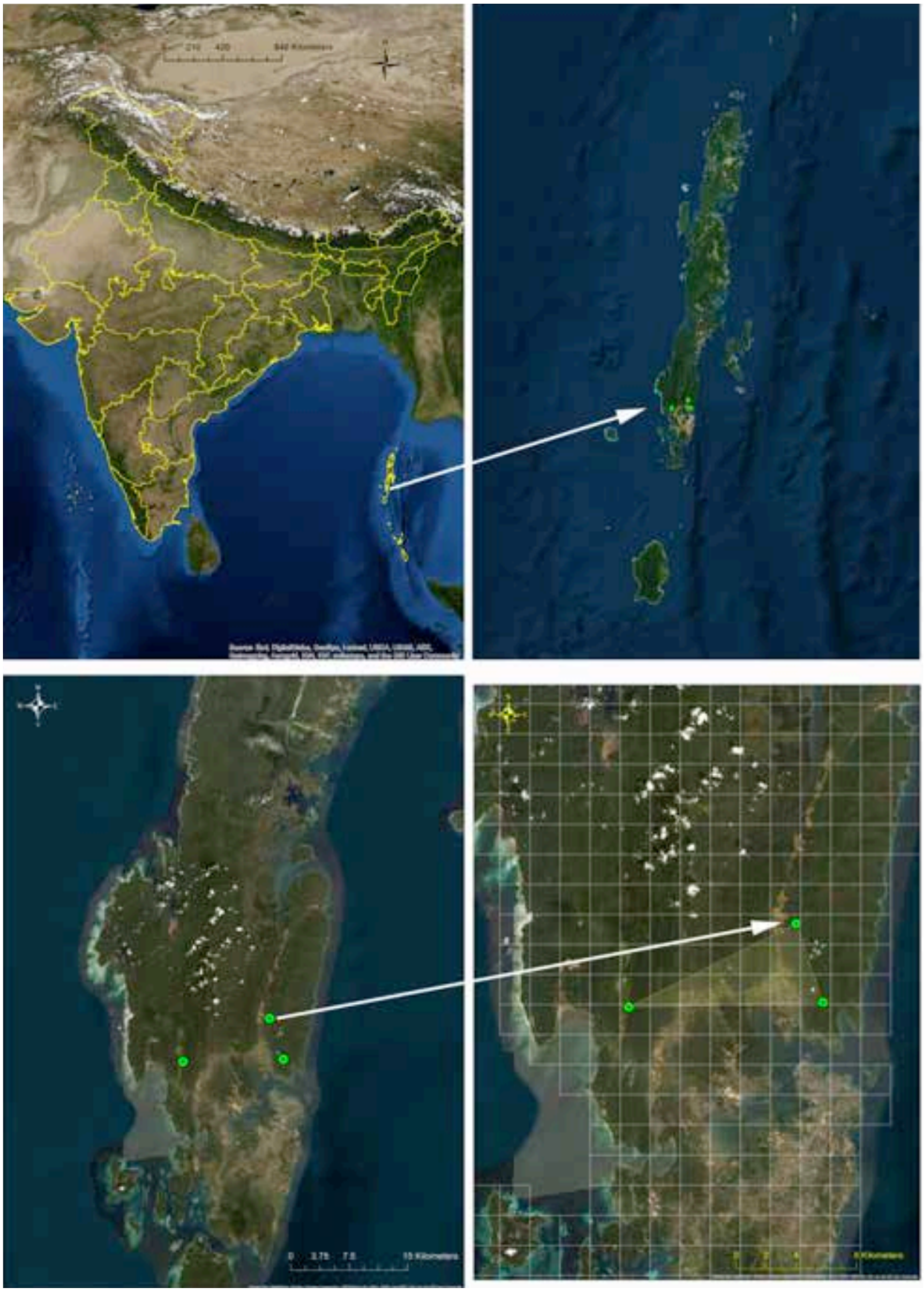

**Figure 1. Distribution of *Ceropegia andamanica* Sreek., Veenak. & Prashanth in Andaman Islands.**

**Image 2. The oldest collection of *Ceropegia andamanica* collected by King's collector in 1890.**

species is <50.

The threat perception on the species is assessed here as Critically Endangered [CR B1 b(ii,iii,iv,v); D] globally.

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NOTE

# The oat-like grass *Trisetopsis aspera* (Munro ex Thwaites) Röser & A.Wölk (Poaceae): a new record for the flora of central Western Ghats of Karnataka, India

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During the survey of grasses of Baba Budangiri Hills, Western Ghats of Chikkamagaluru District, Karnataka (13.431$^0$N & 75.758$^0$E), some interesting grass specimens were collected from the montane highlands associated with *Chrysopogon zeylanicus* (Steud.) Thwaites, *Arundinella pumila* (Hochst.) Steud. and *Agrostris pilosula* Trin. Initially, these were identified as *Helictotrichon aspera* by referring to Flora of the Presidency of Madras (Fischer 1934–36) and The Grasses of Burma, Ceylon, India and Pakistan (Bor 1960). The identity of this grass was later confirmed by matching our sample with photograph of the type specimen. A scrutiny of literature revealed that this species has now been transferred to the genus *Trisetopsis* by M. Röser and A. Wölk (Wölk & Röser 2013) as the morphological and phylogenetic studies by them revealed that *Helictotrichon* s.l. is polyphyletic and heterogeneous (Wölk & Röser 2017). The genus *Trisetopsis* is characterized by its apical, bifid lemma. This species, *Trisetopsis aspera* (Munro ex Thwaites) Röser & A.Wölk, was hitherto known only from Kerala and Tamil Nadu (Sreekumar & Nair 1991; Kabeer & Nair 2009). Sreekumar & Nair (1991) reported this species as *H. virescens* (Nees ex Steud.) Henrard. They followed Henrard (1940) and Sevenstert & Veldkamp (1983) to treat *H. aspera* as a synonym of *H. virescens*; however, in this work by following Kellogg et al. (2020), it is considered as *Trisetopsis aspera* and reported here as an addition to the grass flora of Karnataka. A brief description along with photographs is provided to facilitate easy recognition of this grass. The herbarium specimens are deposited in Herbarium of Department of Applied Botany, Kuvempu University, Shankaraghatta, Shivamogga, Karnataka.

***Trisetopsis aspera*** (Munro ex Thwaites) Röser & A. Wölk in Taxon 66(1): 38. 2017 *Avena aspera* Munro ex Thwaites, Enum. Pl. Zeyl. 372. 1864. *Helictotrichon asperum* (Munro ex Thwaites ) Bor in Indian Forest Rec., Bot. n.s., 1: 68. 1938; Bor, Grasses Burma, Ceylon, India & Pakistan: 438. 1960. *Avenastrum asperum* (Munro ex Thwaites) Vierh. in Verh. Ges. Deutsch. Naturf. 85(2;1): 672. 1914; Fischer in Gamble, Fl. Madras: 1802. 1934. *Helictotrichon virescens* sensu Sreek. & V.J. Nair Fl. Kerala: Grasses: 351. 1991,

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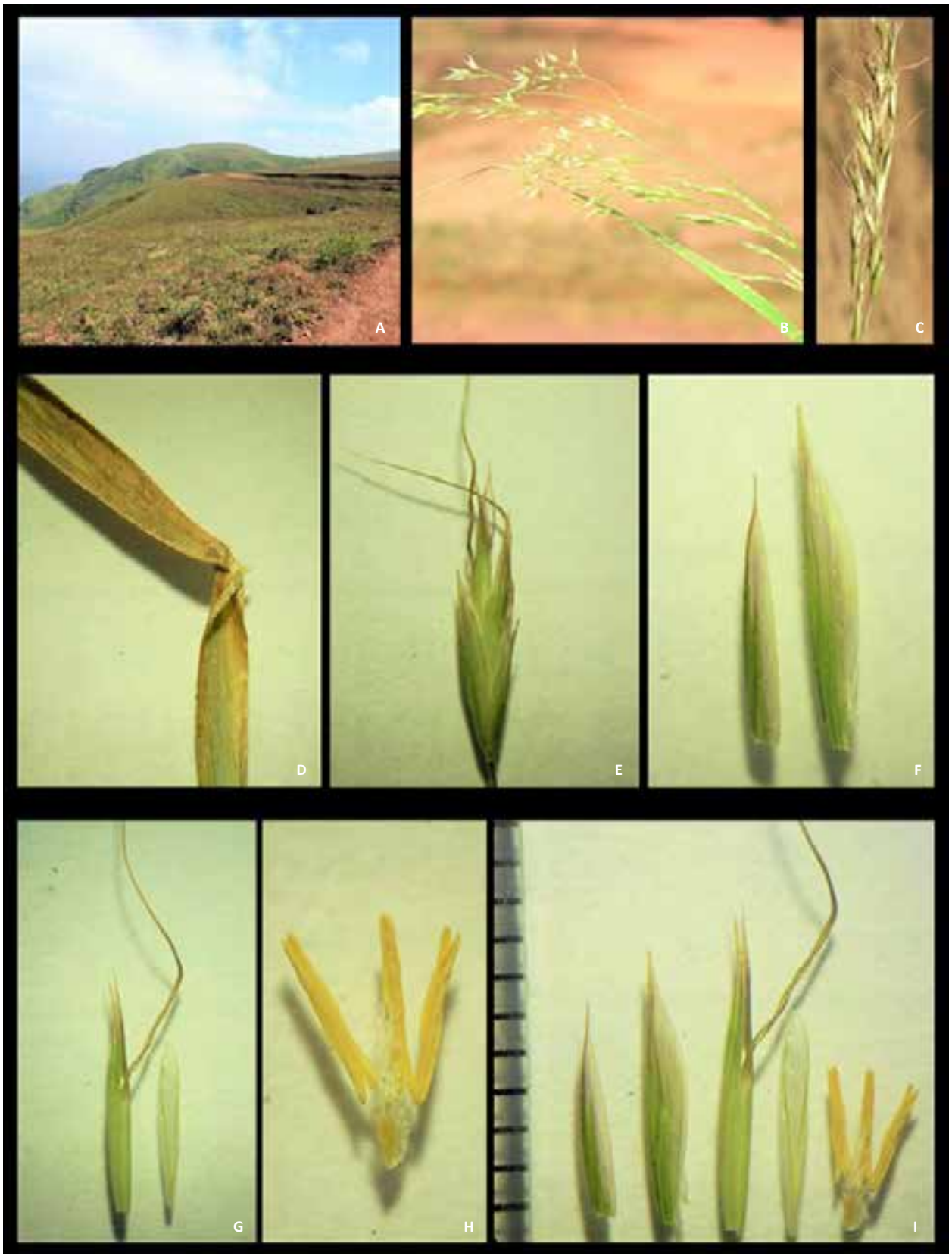


**Image 1.** ***Trisetopsis aspera*** **(Munro ex Thwaites) Röser & A.Wölk. A—Habitat | B—habit | C—raceme | D—leaf | E—spikelet | F—lower & upper glume | G—lemma & palea | H—stamens | I—dissected spikelet. © H.U. Abhijit.**


**Image 2. Herbarium of *Trisetopsis aspera* (Munro ex Thwaites) Röser & A.Wölk.**

p.p. quoad syn. *H. asperum*, non (Nees ex Steud.) Henrard.

Tufted perennials; culms up to 120cm high. Leaf blades up to 40 × 0.5 cm, glabrous or pubescent; sheaths glabrous or pubescent; ligule membranous, up to 4mm long. Panicles up to 30cm long, effuse, nodding. Spikelets 10–14 mm long (excluding awns); florets 3–5, uppermost floret rudimentary and sometimes reduced to awn. Glumes unequal, lanceolate-oblong, herbaceous, 3-nerved, acute to acuminate; lower 5–7 mm long; upper 8–10 mm long. Lemmas lanceolate, scabrous, 7–9-nerved, lowest 8.5–10.5 mm long, bidentate at tip and awned from back near middle; awn geniculate, 10–13 mm long, scabrous. Palea 6–6.8 mm long, ciliate on keels. Stamens 3; anthers 2.5–2.8 mm long. Styles 2; stigmas plumose. Caryopsis linear-elliptic, 3.5–3.8 mm long, pubescent. (Image 1B- I)

Flowering and fruiting: September–December

Habitat and Ecology: Grasslands of high altitude about 1,200m (Image 1A).

Distribution: India: Kerala, Tamil Nadu and in the present work from Karnataka. Endemic.

Specimens examined: KUAB455, 03.i.2019, India, Karnataka, Chikkamagaluru District, Baba Budangiri Hills, 13.431$^0$E & 75.758$^0$N, coll. H.U. Abhijit.

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NOTE

# Star Grass Lily *Iphigenia stellata* Blatter (Colchicaceae) – a new addition to the flora of Gujarat, India

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patelmeet15@gmail.com

The genus *Iphigenia* Kunth (Colchicaceae) comprises 12 species distributed from tropical Africa, over Madagascar and India to Australia (Govaerts & Persson 2014). In India, it is represented by seven species, viz., *I. indica* (L.) Kunth, *I. magnifica* Ansari & R.S.Rao, *I. mysorensis* Arekal & S.N.Ramaswamy, *I. pallida* Baker, *I. sahyadrica* Ansari & R.S.Rao, *I. stellata* Blatter, and *I. ratnagirica* S.M.Almeida & M.R.Almeida (Lekhak et al. 2015). Out of these, only one species (*I. indica*) has been reported so far from the state of Gujarat, India (Shah 1978; GEC 1996).

A recent botanical expedition in southern Gujarat resulted in the collection of an interesting specimen of *Iphigenia* whose characters were found to be different from hitherto reported species (*I. indica*). Critical studies of the type description and other relavant literature revealed it to be *I. stellata*, a species hitherto not reported from Gujarat State of India (Blatter & McCann 1928). A detailed description and photographs of the species is provided here to facilitate easy identification.

### *Iphigenia stellata* Blatter

in J. Bombay Nat. Hist. Soc. 32: 734. 1928 emend. Ansari & R.S.Rao in Bull. Bot. Surv. India 15: 120, f. 1–7b. 1972; Karthik. et al., Fl. Ind. Enum. Monocot. 96. 1989 (Liliaceae) (Image 1).

Common name: Star Grass Lily, Gulabi Bhuichakra (Marathi).

Perennial herbs, 8–14 cm in hight; corms ovate-subglobose 0.8–1.4 cm in diameter, tunicate with light brown sheaths, gradually narrowing to a neck above. Stem up to 10cm, high, rigid to flexuous. Leaves 4–6, 8–14 × 0.9–1.0 cm, grass like, sessile, linear to linear-lanceolate, apex acute or mucronate, base long-sheathing. Flowers 3–7 in a short terminal raceme, white-bright pink, pedicellate. Bracts up to 5cm long, linear-lanceolate. Pedicels 1.0–1.6 cm long, stout, grooved, supporting a petal. Perianth segments 6, 0.5–1.2 × 0.2–0.4 cm, oblong-ovate, broad in the middle, acuminate at apex. Stamens up to 0.5cm long, light purple; filaments straight, rigid, slightly flattened at inner side; anthers 0.8–1.2 cm long, purple; pollen yellow. Ovary green, obovoid, shorter than the styles; style 3, purple, recurved; ovules ovoid-oblong. Capsules 0.8–1.0 cm long, subglobose or obovoid, loculicidal, deeply grooved. Seeds 18–26, brownish-black, subglobose-ovoid, 0.2cm long, irregular, flattened on one side.

Habitat: Growing on moist gravelly soil in most open area.

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**Competing interests:** The author declares no competing interests.

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**Image 1. *Iphigenia stellata* in habitat.**

Flowering and fruiting: June–September

Specimen examined: BVBRC136, viii.2018, India, Gujarat State, Dang District, Ahwa, Don Hill station (20.733$^0$N, 73.863$^0$E, 967m) coll. Mitesh Patel. Herbarium deposited at Bapalal Vaidya Botanical Research Centre (BVBRC), Department of Biosciences, VNSGU, Surat, Gujarat, India (Image 2).

Distribution: Maharashtra (Kolhapur, Satara, and Sindhudurg districts), Karnataka, and Gujarat (present study).

Conservation status: In Gujarat, the plant has so far been reported from only Don Hill station of Ahwa Taluka, Dang District. About six individuals were seen in this area, however, futuristic surveys are recommended to assess its status in different regions in Gujarat.

Note: *I. stellata* is easily distinguished from *I. indica* by its much larger flower and by the shape of the clawless petals. As per the IUCN threat criteria, it falls within the Endangered category. It is endemic to the Western Ghats of India and common to a few parts of Maharashtra. A few individuals were also collected from the Mookambika Wildlife Sanctuary of Karnataka (Singh 2015). The present collection of this taxon from Dang District in the state of Gujarat is also a terminus of Western Ghats which warrants further explorations in the remote localities of Western Ghats so as to update its distribution and threat status.

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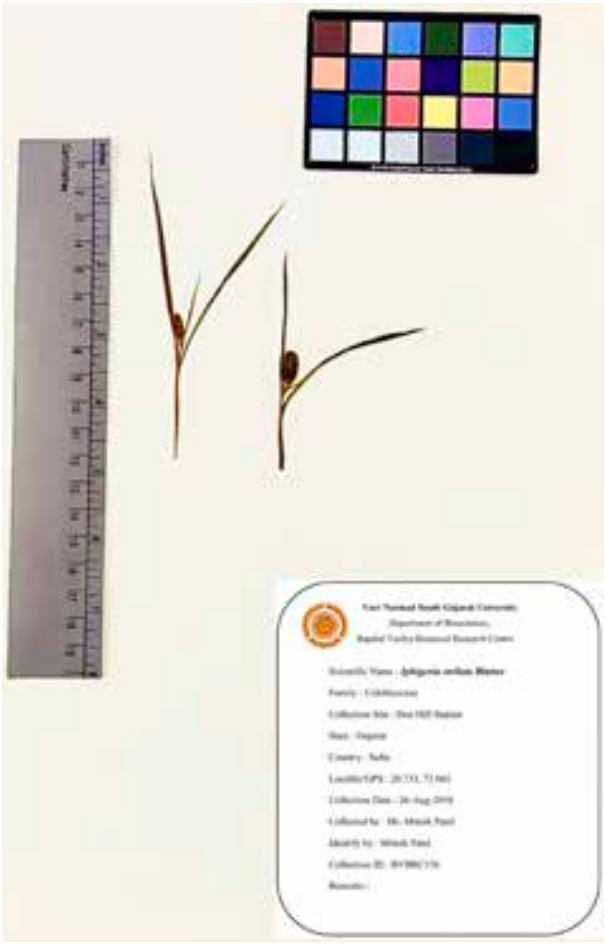

**Image 2. Herbarium sheet of *Iphigenia stellata*.**

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NOTE

# A new record of pyrenocarpous lichen to the Indian biota

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India has a rich diversity of lichens, including the pyrenocarpous lichens, which is a group of lichens that have flask-shaped ascocarps (fruiting bodies) called perithecia. Pyrenocarpous taxa commonly grow on the bark of a number of trees or sometimes on rocks, soil, or leaves in moist tropical and temperate regions of the world. The Western Ghats and eastern Himalayan regions hold the highest number of cryptogams together with lichens (Sinha et al. 2018). Both regions are rich in biodiversity so far and lichenologically were investigated by various workers for doing revisionary and floristic studies of the states. Aptroot (2012) revised the genus *Anthracothecium* and *Pyrenula* and listed 155 species of *Anthracothecium* and 745 species of *Pyrenula* from different parts of the world including India. India is represented by the occurrence of the 350 species of 44 genera and 11 families of pyrenocarpous lichens (Singh & Sinha 2010).

Upreti (1990) described 10 species of *Pyrenula*, exhibiting *Pyrenula subducta* (Nyl.) Müll. Arg., spore type of which seven species were new records to the Indian lichen biota. Awasthi (1991) consolidated the information of different lichen genera in a key to the microlichens India, Nepal & Sri Lanka and enumerated 229 species of pyrenocarpous lichens. Upreti (1991a,b, 1992, 1993a,b) studied the *Pyrenula* genus of pyrenocarpous lichens from India and reported several new records for Indian lichen biota. Jagadeesh et al. (2005) revised the genus *Pyrenula* and reported *Pyrenula subcylindrica* Jagadeesh & Upreti new to science from India. Recently, Ingle et al. (2018) listed *Pyrenula* taxa from India and reported 77 species including 10 new records from the country. Based on a revisionary study of *Pyrenula,* the aim of the present study is to provide a new record for lichen biota.

## Materials and Methods

The present study is based on freshly collected specimens from Iravangallaru located at Megamalai Wildlife Sanctuary, Tamil Nadu (Figure 1) and previously collected sample from Arunchal Pradesh's specimens

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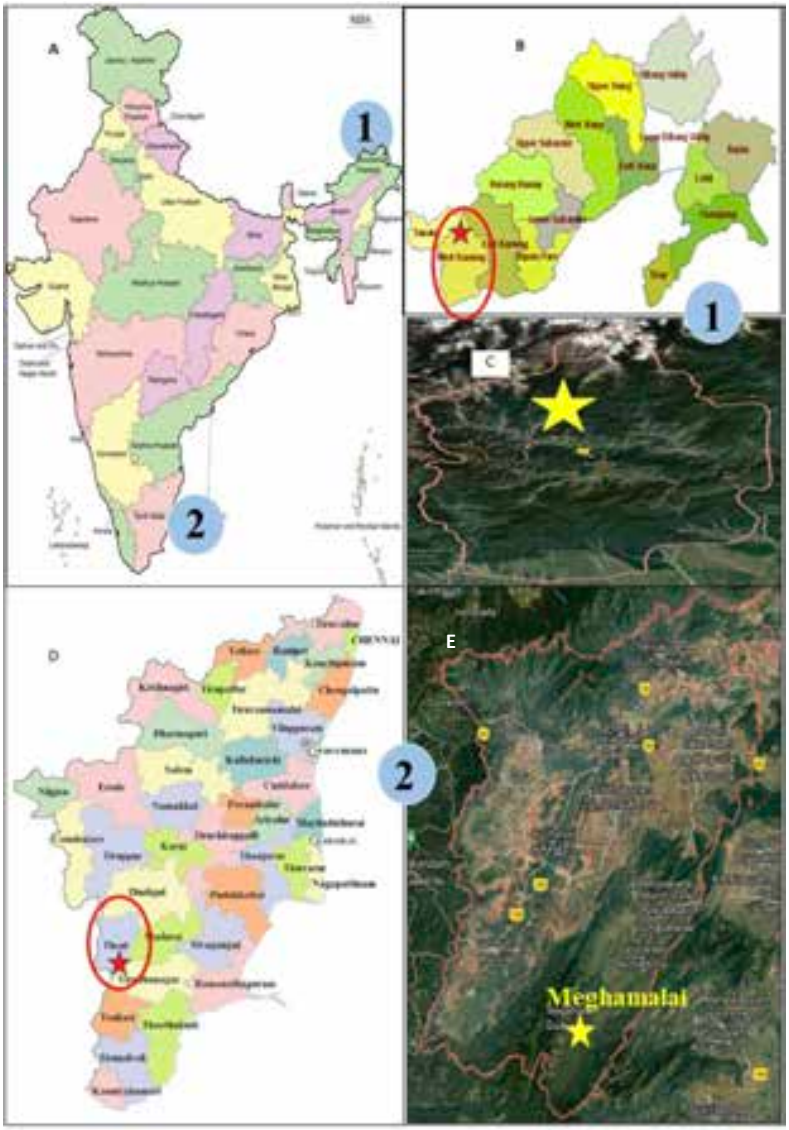


**Figure 1. The distribution of *Pyrenula subglabrata* from Arunachal Pradesh from northeastern India and southern Western Ghats in Tamil Nadu. A—India (1–2 AP & TN States geographic borders) | B—Arunachal Pradesh ( C—West Kameng District) | D—Tamil Nadu | E—Theni District - Megamalai Wildlife Sanctuary.**

deposited in the herbarium CSIR-National Botanical Research Institute, Lucknow (LWG). Morphological and anatomical characters were examined using stereo zoom Leica S8APO and light DM2500 microscopes attached with camera. Thin sections of perithecia were cut using a razor blade under the stereoscope zoom microscope. All anatomical measurements were recorded in plain water, while 10% KOH was used for detailed study of asci and ascospores. For spot tests the usual reagents of K, C, and P were used and for identification of lichens substance by thin layer chromatography (TLC) was performed in solvent system C following Orange et al. (2001). The specimens were identified up to species level with the help of keys of Awasthi (1991), and Aptroot (2006, 2012). The identified specimens were deposited in the herbarium of CSIR-National Botanical Research Institute, Lucknow.

***Pyrenula subglabrata*** (Nyl.) Müll. Arg.

Bot. Jb. 6: 410 (1885).

= *Verrucaria subglabrata* Nyl., in Nylander & Crombie 1883.

Thallus corticolous, corticate, smooth, continuous, thin, up to 10cm across, pale yellow to yellowish-brown, without pseudocyphellae; prothallus indistinct; photobiont trentepohlia. Ascomata perithecioid, simple, dispersed, conical, emergent, 0.3–0.5 mm diam., black, edges without thallus covering; ostioles eccentric to lateral, red-brown, pointing in various directions; hamathecium hyaline, densely inspersed with oil droplets; asci cylindrical to clavate, 4–8 spored, 40–48 × 10–12.5 µm; ascospores brown, 3–septate, 16–22

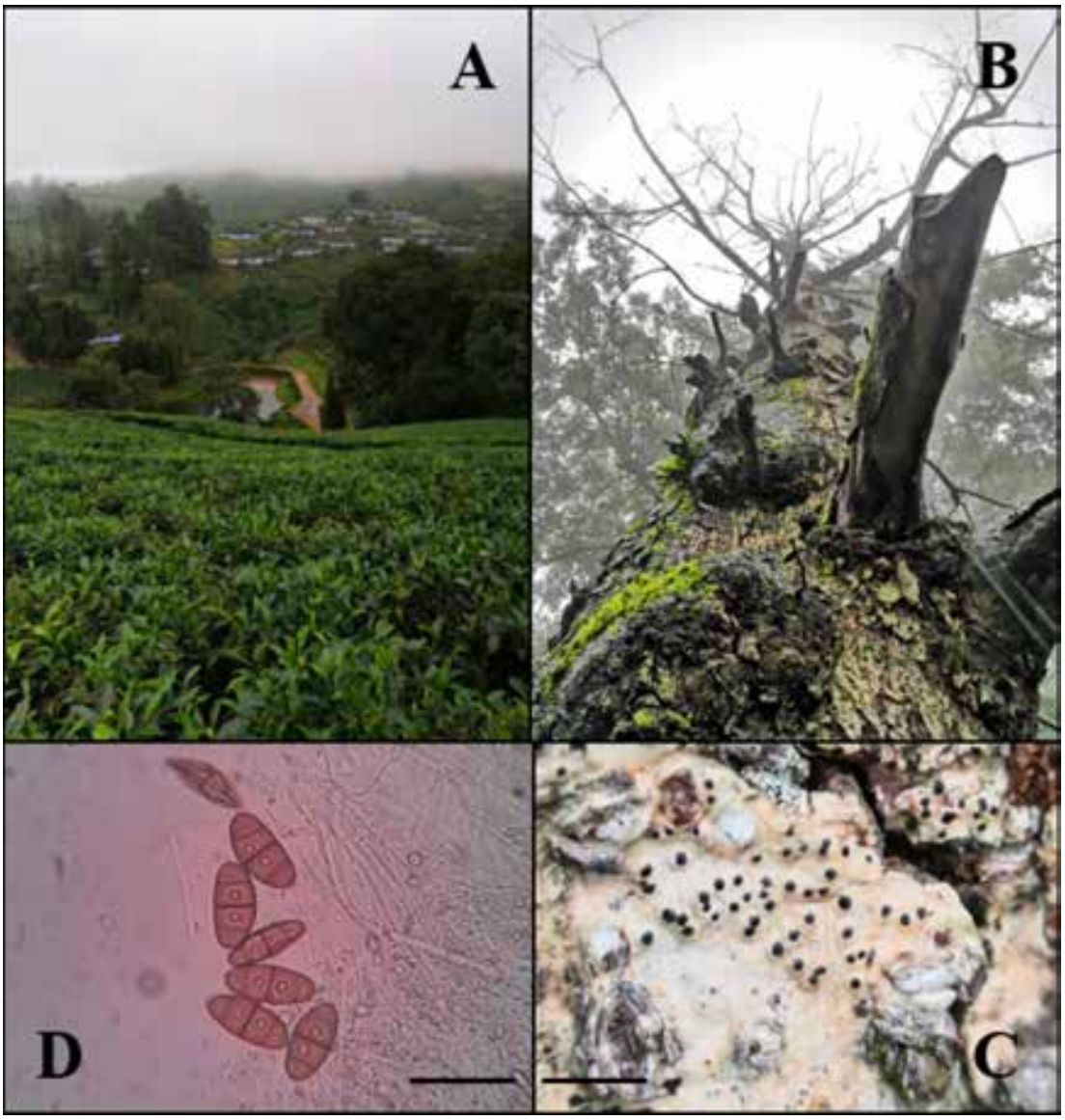


Image 1. Specimen analysis: A—The collection point -Iravangallaru (© N. Rajaprabu) | B—gigantic dead wood tree, habitat (© N Rajaprabu) | C—pale yellowish crustose lichen thallus with Perithecia (© N Rajaprabu) | D—triseptate ascospores (© N Rajaprabu & G.K. Mishra). Scale: C = 1cm, D = 20µm.

× 8–11 µm, central lumina not strongly elongated, terminal lumina mostly separated from the exposere wall by endospore layer. Pycnidia not seen (Image 2).

**Chemistry:** Thallus K–, C–, KC–, PD–, UV–; no lichen substance present in TLC.

**Discussion**: *Pyrenula subglabrata* closely resembles *Pyrenula oculata* A. Singh & Upreti in that they have similar ascomata and not constricted ascospores but the *P. subglabrata* differs in smaller ascospores 18–20 × 5–10 µm. *Pyrenula minarum* Vain is another species similar to *P. subglabrata* in having similar morphology and ascomata except the size and shape of ascospores of *P. subglabrata*. *Pyrenula occidentalis* (R.C. Harris) R.C. Harris also closely resembles *P. subglabrata* in having similar morphology and inspersed hemithecium but *P. subglabrata* lacking anthraquinone neither thallus nor ascomata (Aptroot 2012; Cáceres et al. 2013).

**Ecology and distribution:** The species is found growing on smooth bark of trees at altitudes of between 1,747–2,575 m in the Arunachal Pradesh and Tamil Nadu states of India. Previously, this species is known only from Singapore (Aptroot et al. 2012). This species is a new record for India.

**Specimens examined**: 08-009440/A (LWG), 12.xi.2008, India, Arunachal Pradesh, West Kameng District, Sela Pass, 27.503'N, 92.104'E, 2,575m, on bark, coll. D.K. Upreti, U. Dubey, R. Khare & G.K. Mishra. 19-36053 (LWG), 02.ix.2019, Tamil Nadu, Megamalai

Wildlife Sanctuary, Iravangallaaru, Behind Vinayakar Temple, 9.723'N, 77.456'E, 1,747m, coll. Rajaprabu, N. & G.K. Mishra.

## Results and Discussion

The pyrenocarpous lichens communities are a good indicator of young and regenerated forest type. The rich diversity of lichens clearly indicates that most of the forest within the eastern Himalayan region has good health of forest (Singh 1999; Rout et al. 2010). India is represented by the occurrence of 82 species of *Pyrenula* and maximum diversity was reported from the Western Ghats and the eastern Himalayan region (Mishra et al. 2020). While Tamil Nadu has semi-evergreen forests and smooth bark trees, so far 22 species of *Pyrenula* have been reported, while Arunachal Pradesh with evergreen dense moist forests have a maximum diversity of *Pyrenula* with 40 species reported (Awasthi 1991; Nayaka et al. 2001; Hariharan & Balaji 2007; Singh & Sinha 2010). In the present study *Pyrenula subglabrata* (Nyl.) Müll. Arg. is provided as a new record for Indian lichen biota.

## Conclusion

The evergreen forest in both the regions exhibit the maximum diversity of *Pyrenula* species. The smooth bark trees along the streams in moist shady habitat bear pyrenolichens mostly the species *Pyrenula* on bark, leaves and rocks. Due to dense virgin forests that cover tracts of land in moist regions of the states are suitable for growth of *Pyrenula* lichens. Therefore, occurrence of *Pyrenula* species indicates an evergreen forest with abundance of smooth barked trees. The present investigation is of a preliminary nature, a more intensive and extensive survey will definitely add additional *Pyrenula* taxa to the country.

**Key to the Taxa**

| | | |
|---|---|---|
| 1a | Spores oval | 2 |
| b | Spores ellipsoidal | 3 |
| 2a | Centrum I+ | 4 |
| b | Centrum I- | 5 |
| 3a | Perithecia < 1.0mm diam | 6 |
| b | Perithecia >1.0mm diam | *P. minarum* Vain |
| 4a | Centrum I+ blue, with oil globules | *P. cayennensis* Müll. Arg. |
| b | Centrum I+ wine red, without oil globules | *P. mastophora* (Nyl.) Müll. Arg. |
| 5a | Centrum I-, with oil globules | *P. kurzii* A.Singh & Upreti. |
| b | Centrum I- without oil globules | *P. introducta* (Stirton) Zahlbr. |
| 6a | Ascospores < 21µm long | 7 |
| b | Ascospores >21µm long | *P. oculata* A.Singh & Upreti |
| 7a | Ascomata with anthraquinone | *P. occidentalis* (R.C.Harris) R.C.Harris |
| b | Ascomata without anthraquinone | *P. subglabrata* (Nyl.) Müll. Arg. |

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