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Caption: Female *Hottentotta jabalpurensis* with newborn babies on her back. © Pratyush P. Mohapatra.

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COMMUNICATION

First record of Wroughton's Small Spiny Mouse *Mus phillipsi* Wroughton, 1912 (Rodentia: Muridae) from Odisha, India with notes on diversity and distribution of other rodents

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Abstract: We report the occurrence of Wroughton's Small Spiny Mouse *Mus phillipsi* Wroughton, 1912 based on a specimen collected from Gajapati District, Odisha. With this species, the diversity of order Rodentia in Odisha increases to 17 species under three families and 12 genera. An updated checklist of the rodents with distribution localities and threats to various species in Odisha is also presented.

Keywords: Eastern Ghats, Mahendragiri, natural history, new locality, threats.

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Author contribution: PPM, VS and SKD carried out fieldwork; SST identified the specimen; PPM & SST wrote the manuscript; SKD & VS helped in review and editing.

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INTRODUCTION

The order Rodentia is represented by 2,335 species worldwide, comprising nearly 41% of total mammalian species (Wilson & Reeder 2011), of which Pradhan & Talmale (2011) recorded 103 species and later Sharma et al. (2015) mentioned 101 species from India. This order is represented by three suborders in Odisha, namely Sciuromorpha, Myomorpha, and Hystricomorpha (Mohapatra et al. 2019, Debata & Palai 2020). Ball (1877), Thomas (1915), Wroughton (1915, 1919a,b, 1920), Robinson & Kloss (1918), Hinton & Lindsay (1926), Ellerman (1961), Behura & Guru (1969), Das & Agrawal (1973), Agrawal & Chakraborty (1979), Das et al. (1993), and Mishra et al. (1996) mentioned about rodents of Odisha. Das et al. (1993) listed 14 species under 10 genera based on collections housed in the Zoological Survey of India at Kolkata. Although Mishra et al. (1996) listed 14 species, they excluded *M. blanfordi* but included *R. norvegicus*. Later compilations on mammals of Odisha by Mohapatra et al. (2019) recorded 17 species in order Rodentia including the present species, citing this reference and that of by Debata & Palei (2020) reported 15 species. Rodent diversity from protected areas of the state is known from the works of Chadha & Kar (1999) from Bhitarkanika (six species), Tiwari et al. (1997, 2002) from Chandaka-Dampara Wildlife Sanctuary (nine species) and Ramakrishna et al. (2006) from Similipal Tiger Reserve (11 species). Apart from these works, other studies on the nesting behaviour of the Indian Giant Squirrel *Ratufa indica* (Erxleben, 1777) in Similipal, Karlapat, Kapilas, and Kuldiha wildlife sanctuaries are also available (Rout & Swain 2006; Pradhan et al. 2012, 2017; Nayak & Patra 2015; Palei et al. 2015, 2017).

Through this contribution, we report for the first time the occurrence of *Mus phillipsi* Wroughton, 1912 from Odisha based on a specimen collected from Mahendragiri Hill in Gajapati District. An updated checklist including distribution of the rodent species from Odisha is also provided based on published literature and the observation in the present study.

METHODS

Study area

Odisha, situated along the eastern coast of India, is an amalgamation of varied physiography. With a geographical area of 155,707km^2 and a coastline of nearly 480km, the state is bestowed with high to medium peak mountain ranges, plateaus and plains. As per the classification by Rodgers et al. (2002), most parts of Odisha is covered by Deccan Peninsula (6B and 6C biogeographic provinces), a small portion towards the extreme north-east represents the southern boundary of lower Gangetic plain (7B) and the eastern coast (8B). The river Mahanadi broadly dissects the state into northern and southern parts, the northern Odisha having isolated mountains and mid-elevation hillocks in the Chotanagpur Plateau, and towards the south are the chains of broken mountain ranges named as the Eastern Ghats. Some of the important and high peak mountain ranges of the Eastern Ghats ranges in Odisha are Deomali Parbat (1,673m), Sambari Konda near Gudem Village (1,670m), Turiakonda (1,598m), Singaraju Parbat (1,516m), Mahendragiri (1,501m), Hatimali (1,391m), Devagiri (1,382m), Dharakonda (1,365m), and Chandragiri (1,269m). Broadly four forest types—semi-evergreen forests, tropical moist deciduous forests, tropical dry deciduous forests, and littoral and tidal swamp forests—are seen in Odisha (Champion & Seth 1968, Panigrahi 1983). Forests are predominantly of the mixed deciduous type with pockets of semi-evergreen, scrub forest, and shola patches offering refuge for some unique biodiversity. The moist deciduous Sal forest dominates the northern part and mixed forests are seen in the southern and western parts. A well-protected mangrove patch (Bhitarkanika Wildlife Sanctuary) is present on the northeastern side, with sporadic patches of mangroves and mangrove-associates in the deltaic regions. The coastline is almost entirely planted with *Casuarina equisetifolia* to supposedly protect from the frequently occurring cyclonic storms. There are 19 wildlife sanctuaries (WS), one national park (NP), two tiger reserves (TR), and one biosphere reserve (BR) in Odisha. Varied geography and topography of Odisha offer potential habitat for many species of flora and fauna including rodents.

The Mahendragiri Hill range encompassing around 5,000km^2 is flanked between Vamsadhara River to the west and Bay of Bengal to the east in the Gajapati District of Odisha and Srikakulam District of Andhra Pradesh (Mahalik 2010). The forest types are tropical moist and dry deciduous with patches of shola forest at the pick (Champion & Seth 1968; Dash et al. 2015). The floral diversity is well studied in this landscape (679 species comprising three species of gymnosperms and 676 species of angiosperms, under 453 genera and 115 families), among the faunal groups more than 30 species of mammals, 200 species of birds, and 69 herpetofauna species have been documented from the area (Mohapatra et al. 2010; Dash et al. 2015).

Image 1. Wroughton's Small Spiny Mouse *Mus phillipsi* Wroughton, 1912 from Mahendragiri forest, Odisha, India.

Survey and identification

During biodiversity surveys in various localities of Odisha (conducted between 2010 and 2015) information on the status and distribution of rodents was collected by the authors. For the collection of rodents, stainless steel live catch rat traps with dry-fish or bread-peanut butter bait were deployed outside protected areas and in private lands. Rodents observed in fields were photographed using a DSLR camera (Nikon-D-5100). During the survey, two of us (PPM & VS) collected a female specimen of *Mus* sp. from Mahendragiri Forest of Gajapati District in Odisha on 20 July 2013 using the rodent trap. The animal was euthanized, and the specimen was fixed by injecting 4% formaldehyde solution into the body cavities and muscles and then preserved in the 70% alcohol for further study. It was deposited in the Zoological Survey of India, Central Zone Regional Centre, Jabalpur, Madhya Pradesh. Measurements were taken using Mitutoyo absolute digimatic digital caliper and characters were observed under Leica MZ 125 stereo zoom binocular microscope. Species identification was carried out by following the key provided by Marshall (1977) and Agrawal (2000). The literature on rodent species reported from Odisha was reviewed to present an updated checklist based on records and present observations.

RESULTS AND DISCUSSION

The present study reports occurrence of Wroughton's Small Spiny Mouse *M. phillipsi* in Odisha, which extends its distribution further eastwards. With the addition of this species, the rodent diversity of Odisha now comprises 17 species under 12 genera and three families. Data on past distribution records and observation by authors are summarized in Table 1.

Mus phillipsi **Wroughton, 1912 Wroughton's Small Spiny Mouse**

Specimen (Image 1)**:** ZSI-CZRC-V-6289, 20.vii.2013, one female, Mahendragiri Reserve Forest, in the Ashram premises (18.964^{0}N, 84.369^{0}E, 1,343m), coll. Pratyush P. Mohapatra & Vivek Sarkar.

Measurements: External—Head and body length: 77mm; tail: 72mm; hind foot: 16.3mm; ear: 8.6+ (cut); Cranial**—**Occipitonasal length: 24.1mm; condylobasal length: 23.9mm; nasal length: 8.6mm; length of palate: 13.1mm; maxillary tooth row: 3.7mm; tympanic bulla: 5mm; anterior palatal foramina: 5mm; length of diastema: 7.2mm; zygomatic width: 11.1mm; interorbital width: 3.8mm; cranial width: 10.2mm.

Description : A small spiny furred field mouse having the head and body length (HBL) in the range of 62.0–80.0 mm; tail bicoloured, dark above and pale below;

Table 1. Distribution and conservation status of rodent fauna of Odisha, India.

	Common & Scientific name	WL(P)A, 1972	IUCN	Distribution in Odisha	Important citations
Family: Sciuridae					
1	Five-striped Palm Squirrel *Funambulus pennantii* Wroughton, 1905	Schedule IV	LC	Throughout Odisha; distributed in forests, rural and urban areas	Das et al. 1993; Mishra et al. 1996; Mohapatra et al. 2019; Debata & Palei 2020
2	Three-striped Palm Squirrel *Funambulus palmarum* Linnaeus, 1766	Not listed	LC	Widely distributed in southern Odisha Distribution in PAs: Chandaka, Baisipalli, Satkosia, Lakhari Valley, Kotagarh, and Karlapat WS. Specific records are from Puri (Balugaon & Chilika), Ganjam (Tarasingi forest of Berhampur division, Chatrapur, Khallikote, Aska, Digapahandi, Sorada); Kalahandi (Madanpur-Rampur of Kalahani (N) division), Rayagada (Kashipur), Phulbani & Kandhamal (Daringbadi, Simonbadi, Phulbani, Kalingaghati, Baliguda and Raikia), Nayagarh (Daspalla, Banigocha, Nayagarh town, Charichaka), Khurdha (Barbara, Balugaon and Bhubaneswar) and Gajapati (Parelakhemundi, Gandahati, Mohana and Chandragiri) districts	Das et al. 1993; Mishra et al. 1996; Panda et al. 2012; Mohapatra et al. 2019; Debata & Palei 2020
3	Indian Giant Squirrel *Ratufa indica* Erxleben, 1777	Schedule II	LC	All the Protected areas except coastal PAs. Best seen at Similipal, Kuldiha, Kapilas, Satkosia, Debrigarh and Karlapat WS; also recorded from Balasore, Khurdha (Barbara and Dhuannali RF), Ganjam (Taptapani and Tarasingi forests of Berhampur division), Sundargarh (Bonai), Mayurbhanj (Rairangpur, Karanjia), Sambalpur, Nayagarh, Phulbani (Baliguda, Ghumsar North & South divisions), Rayagara (Niyamgiri, Muniguda), Koraput, Malkanagiri, and Kalahandi (North & South divisions) districts	Behura & Guru 1969; Das et al. 1993; Mishra et al. 1996; Mohapatra et al. 2019; Debata & Palei 2020
4	Giant Indian Gliding Squirrel *Petaurista philippensis* Elliot, 1839	Schedule II	LC	Mostly distributed in protected areas and primary forests. Specific records are from Similipal, Satkosia, Badrama, Karlapat, Lakhari Valley and Baisipali WS; also recorded from Sundargarh (Bonai division), Dhenkanal, Khariar, Mayurbhanj (Baripada,Thakurmunda and Karanjia divisions), Sambalpur (Rairakhol), Kalahandi (North & South divisions), Khurdha (Barbara RF) and Rayagada (Niyamgiri) districts	Ball 1877; Behura & Guru 1969; Das et al. 1993; Mishra et al. 1996; Mohapatra et al. 2019; Debata & Palei 2020
Family: Muridae					
5	Lesser Bandicoot *Bandicota bengalensis* Gray, 1835	Schedule V	LC	Throughout Odisha	Behura & Guru 1969; Das et al. 1993; Mishra et al. 1996; Mohapatra et al. 2019; Debata & Palei 2020
6	Large Bandicoot *Bandicota indica* (Bechstein, 1800)	Schedule V	LC	Throughout Odisha	Behura & Guru 1969; Das et al. 1993; Mishra et al. 1996; Mohapatra et al. 2019; Debata & Palei 2020
7	Blanford's Rat *Madromys blanfordi* (Thomas, 1881)	Schedule V	LC	Chandaka-Dampara Wildlife sanctuary, Satkosia, Baisipalli, Debrigarh WS; also recorded from Keonjhar, Mayurbhanj, Sundargarh (Khandadhar, Bonai division) and Dhenkanal (Kamakhya Nagar) districts	Tiwari et al. 1997, 2002; Agrawal 2000; Mohapatra et al. 2019; Debata & Palei 2020
8	Indian Bush Rat *Golunda ellioti* Gray, 1837	Schedule V	LC	Chandaka-Dampara Wildlife sanctuary; also recorded from Puri District; although recorded from a few areas, it might be occurring in a large distributional range in Odisha	Tiwari et al. 2002; Das et al. 1993; Agrawal 2000; Mohapatra et al. 2019; Debata & Palei 2020
9	Little Indian Field Mouse *Mus booduga* (Gray, 1837)	Schedule V	LC	Throughout Odisha	Behura & Guru 1969; Das et al. 1993; Mishra et al. 1996; Mohapatra et al. 2019; Debata & Palei 2020
10	House Mouse *Mus musculus* Linnaeus, 1758	Schedule V	LC	Throughout Odisha	Das et al. 1993; Mishra et al. 1996; Mohapatra et al. 2019; Debata & Palei 2020
11	Wroughton's Small Spiny Mouse *Mus phillipsi* Wroughton, 1912	Schedule V	LC	Gajapati (Mahendragiri hill) District	Present study

	Common & Scientific name	WL(P)A, 1972	IUCN	Distribution in Odisha	Important citations
12	Indian Gerbil *Tatera indica* (Hardwicke, 1807)	Schedule V	LC	Throughout Odisha; found near agricultural fields and scrub forests Specific records are from Chandaka-Dampara, Nandankanan, Satkosia, Baisipalli, Kapilas and Lakharivalley WS	Das et al. 1993; Mishra et al. 1996; Mohapatra et al. 2019; Debata & Palei 2020
13	Brown Rat *Rattus norvegicus* (Berkenhout, 1769)	Schedule V	LC	Throughout Odisha	Mishra et al. 1996; Mohapatra et al. 2019; Debata & Palei 2020
14	House Rat *Rattus rattus* (Linnaeus, 1758)	Schedule V	LC	Throughout Odisha	Das et al. 1993; Mishra et al. 1996; Mohapatra et al. 2019; Debata & Palei 2020
15	Indian Long-tailed Tree Mouse *Vandeleuria oleracea* (Bennett, 1832)	Schedule V	LC	Throughout Odisha in forested tracts	Mishra et al. 1996; Mohapatra et al. 2019; Debata & Palei 2020
16	Cutch Rat *Cremnomys cutchicus* Wroughton, 1912	Schedule V	LC	Khandadhar, Bonai forest division	Ellerman 1961; Alfred & Chakraborty 2002; Srinivasulu & Pradhan 2003; Mohapatra et al. 2019; present study
Family: Hystricidae					
17	Indian Crested Porcupine *Hystrix indica* Kerr, 1792	Schedule IV	LC	Throughout Odisha in suitable habitats, including mangrove forests	Das et al. 1993; Mishra et al. 1996; Chadha & Kar 1999; Mohapatra et al. 2019; Debata & Palei 2020

Abbreviations: WL(P)A, 1972—Indian Wild Life (Protection) Act, 1972 | IUCN—International Union for Conservation of Nature | LC—Lease Concern as per IUCN | PA—Protected Area.

tail shorter than HBL, about 80%; hind feet between 14.0–18.0 mm and are white; dorsal colour brown to buff and white below; mammae five pairs; occipitonasal length with an average of 22.2mm; skull with well-developed supraorbital ridges; anterior palatal foramina extending posteriorly between maxillary tooth row; upper incisors opisthodont; maxillary tooth row less than 4mm, averaging 3.7mm in length; first upper molar without an anterior accessory cusp; anterointernal cusp (t1) distorted inwards and in line with second; m^1 with eight cusps, m^2 with six cusps and m^3 very small (Agrawal 2000). Based on the morphological characters as well as cranial details, we identified the present specimen (ZSI-CZRC-V/6289) from Mahendragiri Hills as *Mus phillipsi.*

Distribution

This species is reported for the first time from Odisha from Mahendragiri Hill in Gajapati District under Parelakhemundi forest division. As it is difficult to diagnose *Mus phillipsi* from congeners such as *Mus saxicola* and *M. platythrix* in the field (the latter two species are not yet recorded from Odisha), similar-looking individuals sighted by us in Deomali (Koraput division), Gupteswar (Jeypore division) and Barbara Reserve forest (Khordha division) in Odisha are not reported. The Wroughton's Small Spiny Mouse is endemic to India and has been earlier reported from Madhya Pradesh (type locality Asirgarh, Burhanpur district, 1500 ft., Karnataka, Andhra Pradesh, Gujarat, Maharashtra, Rajasthan, and Tamil Nadu (Agrawal 2000; Molur et al. 2005; Pradhan & Talmale 2012). It is rarely encountered in its distribution range. It is terrestrial, fossorial, and nocturnal in habit and generally found in rocky outcrops, hillocks, and in forests (Agrawal 2000; Pradhan 2005). At Mt. Abu in Aravalli Hills, it was reported to be common in regions with Indian Spurge Tree *Euphorbia neriifolia* (Prakash et al. 1995).

Status: It is assessed as Least Concern by IUCN Red List (Molur & Nameer 2016) and is listed as a vermin under Schedule V of Indian Wildlife (Protection) Act, 1972.

Distribution, threats and conservation of rodents in Odisha

In Odisha, two species of palm squirrels are known to occur, of which the Five-striped Palm Squirrel *Funambulus pennantii* is widely distributed and the Three-striped Palm Squirrel *F. palmarum* is mostly distributed across southern Odisha and has patchy distribution towards northern parts. Palm squirrels are occasionally poached for bushmeat by Kela and Munda tribal communities in Odisha. During 1990s, groups of nomadic communities (Kalbeliyas and Pardhi) from central India were poaching palm squirrels on large scale to make trophies out of stuffed animals and the meat was consumed by them (SKD and PPM pers. obs. 1990).

Indian Giant Squirrel *Ratufa indica* is a canopy dwelling arboreal species, diurnal in habit and has been recorded from various protected and reserve forests of Odisha. Rout & Swain (2006) reported 24 species of plants from seven families being used as food and 14 species of trees used for nest building by the Indian Giant Squirrel in Similipal BR, which had an estimated population of 10,660 individuals in the tiger reserve. A similar study by Palei et al. (2015) reported and estimated population density of 25.6 ± 4.6 (SE) individuals per km^2 in Similipal TR and identified 23 plant species as the food resources of the species from 17 families. Palei et al. (2017) reported 53 species of fodder plants belonging to 27 families from Kapilas WS. From Kuldiha WS, Nayak & Patra (2015) reported 23 species of plants belonging to 15 families used as food and 15 species belonging to 14 families are used for nest building. In Karlapat WS, Pradhan et al. (2012, 2017) reported 37 tree species belonging to 21 family and 31 genera were used to build nest and 18 species of food plants with a maximum preference for *Xylia xylocarpa* and *Bauhinia vahlii* in the sanctuary. Threats to the species include habitat loss, illicit timber felling, forest fire, anthropogenic disturbances, poaching for bushmeat, and use of body parts in traditional medicine (magico-religious belief) by some tribal communities. This species was occasionally found in captivity in Odisha.

The Giant Indian Gliding Squirrel *Petaurista philippensis* is a nocturnal species found in dry and moist deciduous forests, orchards, and groves. Although it has a wider range in Odisha, it is an uncommon species. Because of its nocturnal and cryptic habit, this species remains unnoticed, even if it is very much present in the village outskirts. In Baisipalli WS, three babies were seen during May 2009 near Gochhabari village (20.465^{0}N, 84.818^{0}E, 131m) inside a tree hole of *Madhuca longifolia* (Mahua tree) at a height of nearly three meters from the ground. In 2004, one animal was found incarcerated by a person in Kamakhyanagar, Dhenkanal, which died after three months in captivity.

Among the Murid rodents, species such as Large Bandicoot *Bandicota indica*, Lesser Bandicoot *B. bengalensis*, little Indian Field Mouse *Mus booduga*, House Mouse *Mus musculus*, Long-tailed Tree Mouse *Vendeleuria oleracea*, Common House Rat *Rattus rattus*, Brown Rat *R. norvegicus*, and Indian Gerbil *Tatera indica* are widely distributed in the state (Das et al. 1993; Mishra et al. 1996). The Blanford's Rat *Madromys blanfordi* and Indian Bush Rat *Golunda ellioti* are known only from a few localities in Odisha. Among these rats and mice, the Brown Rat *Rattus norvegicus* and the House Mouse *Mus musculus* are non-native/introduced species (Nameer 2000). Additionally, the Cutch Rat *Cremnomys cutchicus* is added to the checklist based on distribution locality provided by Ellerman (1961), Alfred & Chakraborty (2002), and Srinivasulu & Pradhan (2003). Although this species was earlier mentioned to be distributed in Odisha, in the subsequent literature (Das et al. 1993; Mishra et al. 1996; Molur et al. 2005; Srinivasulu & Srinivasulu 2012) the authors remained silent regarding its distribution in Odisha. The Cutch Rat was sighted by two of us (VS and PPM) from Khandadhar area of Bonai Forest Division and this locality is considered as provisional distribution locality for the species till any specimen is obtained in future.

The Indian Crested Porcupine *Hystrix indica* is the sole representative of family Hystricidae in peninsular India including Odisha. This species is found throughout Odisha including mangrove forests and lives in colonies, making their warrens by digging tunnels. They feed on roots, tubers, and barks of trees and occasionally damage crops. During the study period, a case of largescale depredation of Coconut *Cocos nucifera* L. plantation by porcupine was observed in Dakhinapur Village (19.336^{0}N, 84.740^{0}E), 10km from Berhampur Town, in Ganjam District. Within 12 days (between 4 and 15 September 2014), a total of 123 out of 132 coconut trees of 3–4 years old were damaged by the porcupines. The extent of damage was visually estimated and by the end of 12th day 46 saplings (37%) were completely damaged due to debarking and bole feeding and the rest of the trees were partially damaged at the base (debarking). The average rate of damage was 9–11 trees per day. A random survey conducted in the nearby hillock revealed the presence of a healthy population of porcupines based on secondary evidence such as droppings and quills. Similar reports of damage to the coconut plantation by porcupines have been reported elsewhere in India, with most prevailing situations in southern India (Chakravarthy & Girish 2007; Govind & Jayson 2018). In Odisha, where crop depredation by porcupine is more causing large scale damage they are poached. Porcupines are poached for bush-meat, use of quills for religious rituals, and use of intestine and bezoar in traditional medicine. It is poached by using dogs, snares and by beating the animal with a stick when sighted. The Kondh tribe in southern Odisha use to smoke the dens by sealing the entrances from all sides except one and after fanning the smoke into the den the last entrance is closed for 6–8 hours. The animals die due to suffocation and the carcasses are collected by the poachers for further use.

Out of 17 species of rodents recorded from Odisha, two species are listed under Schedule II, two under Schedule IV, 12 in Schedule V, and one species (*Funambulus palmarum*) is not listed under any schedule of Wildlife (Protection) Act, 1972. Although all the species are assessed as Least Concern as per the assessment of International Union for Conservation of Nature (IUCN), the Indian Giant Squirrel and Giant Indian Gliding Squirrel population are declining due to poaching and habitat destruction, despite being protected under Schedule II. Hence, strict enforcement of law and awareness education may prevent these species from local extinction.

Rodents play a major role in the food chain and some species are regarded as ecological indicators. Most of them are considered as major pests for agriculture while all species are poached either for bushmeat or for use of their body parts in traditional medicine. Hence it is imperative to update knowledge on their status and distribution, which will help in developing an action plan for the species for their conservation and management. As already stated, some species of the rodents are known only from few localities, there is a need for systematic surveys to understand their distribution range, ecology, and to document additional species that are not yet recorded from this landscape. Species such as *Mus saxicola*, *M. platythrix*, *M. terricolor*, and *Rattus tanezumi* which are known from the southern and northern peninsular India (Sharma et al. 2015) are yet to be recorded from Odisha.

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COMMUNICATION

Small mammals in the human-dominated landscape in the northern Western Ghats of India

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Abstract: The Western Ghats biodiversity hotspot is under huge anthropogenic pressure, with unique flora and fauna facing severe threats from habitat fragmentation, loss, and degradation. The northern Western Ghats has been poorly studied for its small mammal fauna, hence we examined small mammals near Pune from 2014 to 2017. Live trapping was carried out in irrigated and rainfed agriculture fields, forests, and grasslands at low, mid, and high elevations. A total of 538 individuals were trapped, representing 17 species of rodents and one shrew. Most abundantly captured species were *Millardia kondana* (23%), *Mus saxicola* (19%), *Suncus murinus* (17%), and *Mus booduga* (13%). Species richness and abundance of small mammals varied across the habitats. High elevation grasslands were species-rich relative to low elevation grasslands and forests. Our observations indicate that human disturbances play a role in determining the richness and abundance of small mammals in the area, where populations are under threat from urbanization, tourism, agriculture, grazing, and fire. Habitat and species specific conservation measures need to be taken, coupled with in-depth species–habitat relationship studies, for the conservation of small mammal diversity of the northern Western Ghats.

Keywords: Conservation, forts, high-elevation grasslands, *Millardia kondana,* rocky outcrops, small mammals, threats.

सारांश: जगात जैवविविधतेने समृद्ध असणाऱ्या क्षेत्रांत भारतातील पश्चिमी घाटांचा समावेश होतो जे अलीकडील काळात वाढत्या मानवी हस्तक्षेपांमुळे बाधित होत आहेत. अधिवासांचं विखंडन, नाश आणि त्यात उत्तरोत्तर होणारी अधोगती यामुळे धोक्यात असणाऱ्या उत्तर-पश्चिमी घाटांतील वैशिष्ट्यपूर्ण प्राणी आणि वनस्पतींच्या प्रजातींचे संवर्धन होणे आवश्यक आहे, परंतु विशेषकरुन तिथे आढळणाऱ्या लहान सस्तन प्राण्यांचा फारच कमी अभ्यास झाला आहे. त्या अनुषंगाने सन २०१४-२०१७ च्या दरम्यान पुणे शहराजवळील पश्चिम घाटात आम्ही लहान सस्तन प्राण्यांचा अभ्यास केला. यात आम्ही मनुष्यवस्तीलगतच्या बागायती- जिरायती शेते, वने तसेच समुद्रसपाटीपासून कमी-मध्यम-अतिउंचीच्या गवताळ अशा विविध अधिवासांतून रात्रीच्या वेळी लहान सस्तन प्राणी जिवंत पकडले. या अभ्यासाअंती एकूण ५००० प्रयत्नांतून १७ प्रजातींचे ५३८ कृदन्त व एक चिचुंद्री नमुन्यादाखल जिवंत पकडले. पकडलेल्या एकूण सस्तन प्राण्यांपैकी मिलार्डिया कोंडाणा (२३.०५%), मस सॅक्सिकोला (१८.९६%), संकस मुरिनस (१६.९१%) आणि मस बुडुगा (१३.०१%) या चार प्रजातींचे प्रमाण सर्वात जास्त आढळले. विविध अधिवासांत लहान सस्तन प्राण्यांची समृद्धता आणि मुबलकतेच्या अनुषंगाने कमीअधिक फरक दिसून आला. समुद्रसपाटीपासून अतिउंचीवरील गवताळ क्षेत्रातील प्रजातींचे वैविध्यपूर्ण प्रमाण हे समुद्रसपाटीपासून तुलनेने कमी उंचीवर असणाऱ्या गवताळ तसेच झाडीच्या वनक्षेत्रांत आढळलेल्या प्रजातींपेक्षा जास्त दिसून आले. निरीक्षणाअंती मानवी घडामोडींमुळे होणाऱ्या त्रासाचा अभ्यासक्षेत्रातील लहान सस्तन प्राण्यांच्या समृद्धतेवर परिणाम झालेला दिसून आला. नागरीकरण, पर्यटन, शेतीपद्धतीतील आधुनिकीकरण, चराई व वणवे या बाबींमुळे सदर अभ्यासक्षेत्र धोक्यात आले आहे. त्यामुळे अधिवास आणि प्रजातीकेंद्रित संवर्धन होण्यासाठी योग्य ते उपाय योजले जाणे आवश्यक आहे. त्याला जोडून उत्तर-पश्चिमी घाटातील लहान सस्तन प्राण्यांच्या विविधतेचे संवर्धन करण्यासाठी प्रजाती व त्यांचा अधिवास यांतील परस्परसंबंधाचा सखोल अभ्यास करणे गरजेचे आहे.

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INTRODUCTION

The Western Ghats (along with Sri Lanka) is a global biodiversity hotspot (Myers et al. 2000) with remarkable variations in the distribution of plant and animal communities ranging from flowering plants (7,402 species, 38% endemic) to mammals (121 species, 12% endemics) (Nayar et al. 2014; Nameer 2020). Based on the composition of the flowering plants, the Western Ghats is divided into four zones: northern, central, southern, and Nilgiri Mountains (Subramanyam & Nayar 1974). The northern Western Ghats have characteristic rocky (lateritic/basaltic) outcrops on the summit of the mountains, and sustain highly seasonal and endemic herbaceous plant communities that survive only for 2–3 months of the monsoon (Watve 2013).

Small mammals of the Western Ghats include bats (50 species) and rodents (31 species; Nameer 2020). Studies on the small mammals of India began in the early 20th century in the form of primarily descriptive and natural history surveys. Ecological and quantitative investigations were initiated in the 1970s, and became more systematic and numerous towards the end of the 20th century (Shanker 2003). Most of these studies were carried out in the southern Western Ghats and Nilgiri Mountains (Chandrasekar–Rao & Sunquist 1996; Prabhakar 1998; Shanker & Sukumar 1998, 1999; Mudappa et al. 2001; Kumar et al. 2002; Shanker 2003; Venkataraman et al. 2005; Molur & Singh 2009; Ramchandran 2013).

The Western Ghats has experienced substantial loss and degradation of natural vegetation due to changes in land-use patterns (Jha et al. 2000; Reddy et al. 2013). It is forecast that the Western Ghats will be one of the most densely populated biodiversity hotspots in the world by 2030 (Seto et al. 2012). The northern Western Ghats is the most degraded and fragmented zone in the entire region (Roy et al. 2012). Little is known about its small mammal fauna except for a few quantitative ecological studies conducted in the urban areas of Mumbai (Deoras & Gokhale 1958; Brosset 1961; Deoras et al. 1975; Pradhan 1975), and some short-term surveys and species occurrence records (Wroughton 1916; Ranade 1989; Singh & Pradhan 1992; Yazdani et al. 1992; Pradhan 1993; Pradhan & Talmale 2004, 2012; Talmale et al. 2013). Habitat loss and disturbances are taking place at an alarming rate in the Western Ghats (Gadgil 2011). It is essential to study and conserve the small mammals of this region, especially Critically Endangered and endemic species like Kondana Soft–furred Rat *Millardia kondana*. We undertook this study to examine the species richness, abundance, and natural history of small mammals in the northern Western Ghats.

MATERIALS AND METHODS

Study area

The study area is located in the mountain ranges of the northern Western Ghats (Figure 1 and Table 1) near Pune in Maharashtra State. The terrain is hilly and rugged with characteristic basaltic and lateritic rocky outcrops on summits of mountains; elevation 600–1,400 m. Climate is tropical monsoon with an average temperature range of 9.6–36.7°C and average annual rainfall of 2,500mm. The eastern slopes are less rugged with low rainfall and covered with dry deciduous forests, while the western slopes are highly rugged, receive high rainfall, and covered with moist–deciduous and semi-evergreen forests. The area is under tremendous anthropogenic pressure, especially from grazing, burning, wood extraction, agriculture, and more recently, from housing and infrastructure development as a part of expanding suburban areas of Pune metropolitan city. The urban area cover of Pune metropolis has almost doubled from 2001 to 2013 (Kantakumar et al. 2015). As a result, the natural forests are being transformed into settlements, grasslands, and agricultural fields over most of the area.

This area has a relatively large number of reservoirs. Irrigated agriculture is practiced in areas below 700m, while rain-fed agriculture is predominant at the base of hills and on gentle to moderate slopes. A large proportion of the study area is covered with grasslands and they can be categorized as low, mid- and high-elevation grasslands. Low-elevation grasslands (<900m) are situated close to human settlements and are intensively modified by burning, grazing, and fodder extraction. Mid-elevation grasslands (900–1,200 m) are less accessible and mostly found on ridges and steep slopes of the hills, and are comparatively less disturbed. High elevation grasslands (>1,200m) are relatively less disturbed due to their remoteness and also as they come under the protection of forest and archaeological departments. They, however, face threats from fire and developing/uncontrolled tourism. Forests are generally confined to the high elevation areas, gorges, and areas that are difficult to access.

Small mammal sampling

We selected 31 sites for sampling small mammals, comprising five forest sites, 12 agriculture sites, and 14 grassland sites (Figure 1, Table 1). We carried out

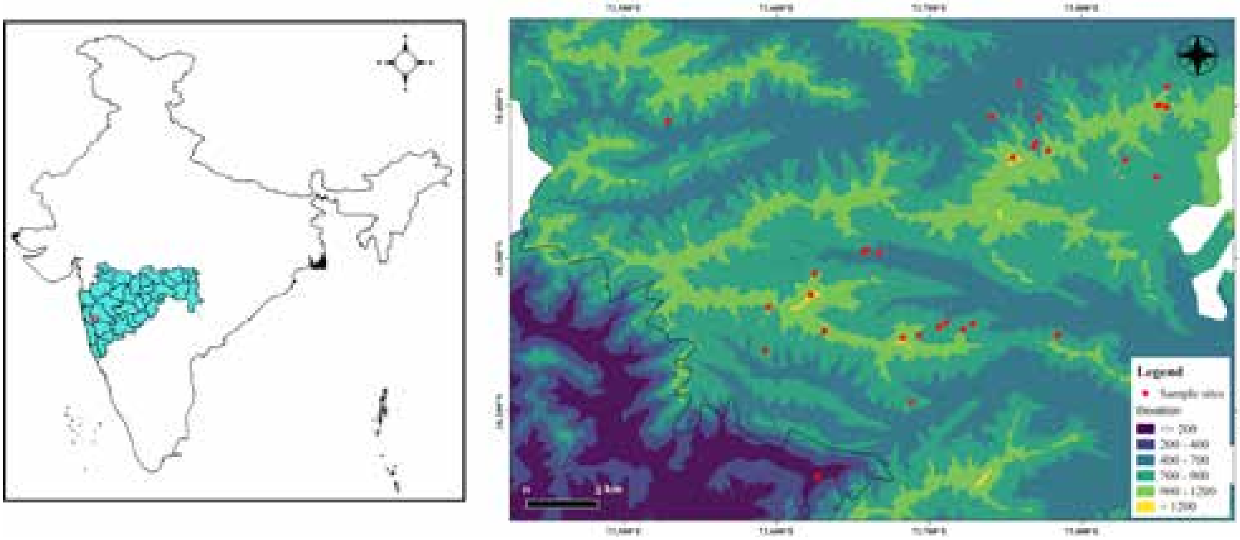

Figure 1. Study area showing elevation and sampling sites.

Table 1. Details of the trapping sites.

Locality	GPS coordinates	Elev. (m)	Habitat
Padalghar	18.389930°N, 73.528665°E	648	Rainfed agriculture field
Sambrewadi	18.392691°N, 73.741062°E	684	Rainfed agriculture field
Hirpodi_1	18.305603°N, 73.659056°E	686	Rainfed agriculture field
Hirpodi_2	18.30459441°N,73.65693911°E	685	Rainfed agriculture field
Atkarwadi_agriculture	18.37549478°N,73.76999058°E	730	Rainfed agriculture field
Kasabe-Shivtar	18.157087°N, 73.626977°E	128	Rainfed agriculture field
Gauddara	18.3646018°N,73.82818624°E	818	Rainfed agriculture field
Gunjavane_1	18.25537584°N,73.70641709°E	707	Rainfed agriculture field
Girinagar	18.41468886°N,73.75884102°E	610	Irrigated agriculture field
Khed Shivapur	18.353207°N,73.84908601°E	773	Irrigated agriculture field
Hirpodi_3	18.30318151°N,73.6672126°E	677	Irrigated agriculture field
Gunjavane_2	18.25837147°N,73.71070131°E	694	Irrigated agriculture field
Katraj Ghat_grassland_2	18.39920702°N,73.85563861°E	970	Low-elevation grassland
Kolambi_grassland	18.23974364°N,73.59274876°E	813	Low-elevation grassland
Manjai Asani_1	18.25728995°N,73.72846273°E	830	Low-elevation grassland
Sonde-Mathana	18.249864°N, 73.784194°E	747	Low-elevation grassland
Atkarwadi_grassland	18.39191865°N,73.77172104°E	734	Low-elevation grassland
Manjai Asani_2	18.2532695°N,73.72219777°E	928	Mid-elevation grassland
Katraj Ghat_grassland_3	18.40036272°N,73.85156276°E	1,083	Mid-elevation grassland
Velhe	18.28995131°N,73.62497345°E	960	Mid-elevation grassland
Katraj Ghat_grassland_1	18.399918°N, 73.849462°E	1,120	Mid-elevation grassland
Metpilaware	18.252577°N, 73.631384°E	995	Mid-elevation grassland
Avasarewadi	18.37065422°N,73.77788407°E	1,057	Mid-elevation grassland
Rajgad Fort	18.24814956°N,73.68249373°E	1,251	High-elevation grassland
Sinhgad Fort	18.36604523°N,73.75451226°E	1,312	High-elevation grassland
Torna Fort	18.27623015°N,73.62228899°E	1,376	High-elevation grassland
Gunjavane_forest	18.24949456°N,73.69378517°E	825	Forest
Bhandravali	18.205975°N, 73.687931°E	790	Forest
Kolambi_forest	18.26824283°N,73.594925°E	960	Forest
Katraj Ghat_forest	18.41256705°N,73.85606534°E	857	Forest
Atkarwadi_forest	18.37301657°N,73.76873061°E	775	Forest

trapping of small mammals during two phases: March–December 2014 and December 2016–February 2017.

In the first phase, our focus was documentation of the small mammals of the study area. Hence, we carried out trapping over a large area to cover various habitats. In each habitat, we searched for the signs of presence of small mammals such as burrows, runways, pellets and, feeding marks, and placed Sherman live traps (4”x4.5”x12”). The traps were baited with a mixture of ‘pakoda’ (deep-fried gram flour batter with onions) and peanut butter. We laid 40 traps in each habitat and ran for a night.

In the second phase, we undertook intensive trapping to study the abundance and habitat association of small mammals. At each site we laid five trap lines 100m in length within a buffer of radius 200m from the center of the site. We maintained a minimum distance of 50m between traplines and habitat the edges to avoid edge effects. Traps were placed at intervals of 10m in each trap line (10 trapping stations). A trap was placed within 1m of the trapping station, close to grass clumps, shrubs, trees, rocks or litter covered areas. Traps were checked once a day between 06.00 and 11.00 hours, then closed and re-opened at dusk. Each habitat was trapped for four consecutive nights between 19 December 2016–5 February 2017. Trapped individuals were measured, sexed, weighed, marked (by fur clipping), and released at the captured locations. We strictly followed animal care and use guidelines recommended by the American Society of Mammalogists (Sikes et al. 2011) during trapping and handling of the small mammals.

We calculated the abundance of species using capture rate (number of individuals trapped per 100 trap nights) and proportion (number of individuals of species/total number of individuals of all species x 100). Species richness and Shannon’s diversity index were computed for each habitat using the R package ‘BiodiversityR’ (Kindt 2019).

RESULTS

Five-hundred-and-thirty-eight individuals of 17 species of rodents and a shrew were trapped in the 5,000 trap night effort. The overall capture rate was 10.8 individuals per 100 trap nights. The capture rate varied considerably among species; for instance, *Millardia kondana* (2.48 individuals/100 trap nights), *Mus saxicola* (2.04), *Suncus murinus* (1.82) and *Mus booduga* (1.40) had high capture rates, whereas *Funambulus palmarum* (0.02), *Vandeleuria oleracea* (0.02), *Rattus rattus* (0.04), and *Tatera indica* (0.06) had low capture rates.

Table 2. Species richness and diversity of small mammals in various habitats. Mean, standard deviation, and, minimum & maximum in parentheses.

Habitat	Richness	Diversity
Low-elevation grassland	1.80±1.30 (0–3)	0.85±0.49
Mid-elevation grassland	3.00±1.26 (1–4)	0.95±0.34
High-elevation grassland	7.00±1.00 (6–8)	1.31±0.31
Rainfed agriculture	2.75±1.75 (1–6)	1.05±0.49
Irrigated agriculture	2.75±1.25 (1–4)	1.23±0.10
Forest	1.80±1.09 (1–3)	0.72±0.55

M. kondana (23% of all animals captured), *M. saxicola* (19%), *S. murinus* (17%), and *M. booduga* (13.01%) were the most abundant species. *F. palmarum*, *V. oleracea*, *R. rattus*, *T. indica*, *Bandicota bengalensis*, and *Rattus satarae* were uncommon or rare, collectively constituting less than 4% of total animals captured (Figure 2).

Species richness was greatest in high-elevation grasslands (seven species) and lowest in low-elevation grasslands (1.80) and forests (1.80; Table 2). Shannon’s diversity index was highest for high–elevation grasslands (1.31±0.31), followed by irrigated agriculture fields (1.23±0.10) and rainfed (1.05±0.49) agriculture fields, and was lowest for forests (0.72±0.55; Table 2).

DISCUSSION

The trapping success (10.8%) of small mammals recorded in our study area was higher than that reported in other sites in the Western Ghats, which ranged from 2.6% to 5.7% (Chandrasekar–Rao & Sunquist 1996; Prabhakar 1998; Venkataraman et al. 2005; Molur & Singh 2009), except for the capture success rate of 10.6% recorded by Shanker (2003) in the Nilgiris. Unlike these sites in the Western Ghats, our study area had been modified to a high degree by humans, with natural vegetation being transformed into a grassland–agriculture dominated landscape, which could be a reason for the high trapping success. It is, however, usually difficult to disentangle the influence of particular factors on trapping success, especially in short duration and small–scale studies (Venkataraman et al. 2005; Himsworth et al. 2014). Trapping success is also dependent on factors such as geographic variations in densities of small mammals (Emmons 1984; Rose 2008; Wood 2008), trapping season (Prabhakar 1998; Shanker & Sukumar 1998; Prakash & Singh 2005), habitat (Chandrasekar–Rao & Sunquist 1996; Venkataraman et

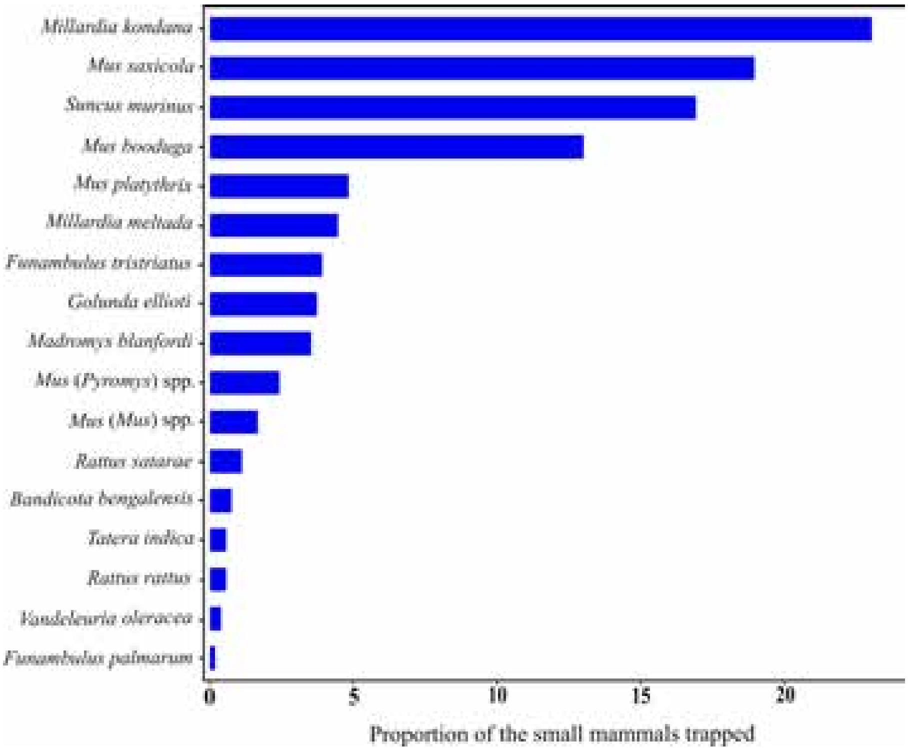

Figure 2. Proportions of the small mammals trapped in this study.

al. 2005; Prakash & Singh 2005), human disturbance (Rickart et al. 2011; Bajaru 2015) and the type of bait and trap (Patric 1970; Woodman et al. 1996).

Several studies in the Western Ghats found *Rattus rattus wroughtoni* and *Madromys blanfordii* to be dominant species (Chandrasekar–Rao & Sunquist 1996; Prabhakar 1998; Shanker 2003; Venkataraman et al. 2005; Shenoy & Madhusudan 2006; Ramchandran 2013). These species, however, had low abundance in our study area. Both these species prefer forested habitat: *R.r. wroughtoni* favors undisturbed evergreen forest, while *M. blanfordii* prefers deciduous and degraded forests. Hence their low abundance was not surprising in our study area, which primarily comprised of agriculture and grassland.

Millardia meltada, *M. booduga*, *M. platythrix*, and *S. murinus* were recorded to be the most abundant species in other sites (Prabhakar 1998; Shanker 2003; Venkataraman et al. 2005; Shenoy & Madhusudan 2006). In our study area, *M. kondana*, *M. saxicola*, *M. booduga*, and *S. murinus* were the species with high abundance. We anticipated their high abundance, as the first two species are reported to prefer grassland while the other two favor agriculture (Bajaru et al. 2019), and both habitat types were dominant in the study area. Though *S. murinus* is a generalist species (Prakash & Singh 2005), it was trapped mainly in agricultural fields in our study area.

Species richness (17 species) of small mammals was high compared to those reported in other sites in the Western Ghats, 5–9 species (Prabhakar 1998; Shanker & Sukumar 1998; Mudappa et al. 2001; Venkataraman et al. 2005; Ramchandran 2013), but was comparable with 14 species recorded from Kodagu, Karnataka (Molur & Singh 2009). The numbers of species trapped in the agriculture area in our study were comparable with that recorded by Molur & Singh (2009) in Kodagu (nine species). The species richness recorded in forests was lower (three species) than reported in other sites of the Western Ghats, i.e., 5–9 species (Shanker 2003; Venkataraman et al. 2005; Molur & Singh 2009; Ramchandran 2013). We anticipated that species richness would be poor in the forest habitat as our study area was covered with highly degraded and secondary forests, which would have impacted forest specialist species. Moreover, the northern Western Ghats is known to be poor in mammalian species richness compared to the other parts of the Western Ghats (Nameer 2020). Interestingly, we found high-elevation grasslands to be the most species-rich: the maximum richness of a site was eight species, whereas pooled richness was 13 species. The only other study on small mammals of high-

Table 3. Summary of external characters (in cm) and weights (in g) of small mammals measured in this study. Mean, standard deviation, and sample size in parentheses.

Species	HB	TL	HF	EL	Weight
Millardia kondana	13.74±1.79 (121)	14.59±1.58 (114)	3.02±0.18 (124)	2.06±0.15 (124)	85.95±29.98 (124)
Millardia meltada	12.07±1.07 (24)	11.13±1.92 (21)	2.50±0.21 (23)	1.91±0.19 (24)	56.41±16.21 (24)
Mus saxicola	8.72±1.17 (100)	6.98±0.60 (90)	1.77±0.09 (99)	1.33±0.09 (95)	20.62±7.57 (95)
Mus platythrix	8.86±1.07 (25)	7.38±0.49 (16)	1.75±0.15 (25)	1.35±0.11 (24)	23.00±7.89 (24)
Mus booduga	6.66±1.05 (62)	6.78±0.70 (61)	1.44±0.10 (64)	1.10±0.11 (64)	8.76±2.74 (63)
Golunda ellioti	11.34±1.25 (18)	10.61±1.13 (17)	2.40±0.18 (18)	1.58±0.16 (18)	50.88±13.89 (18)
Madromys blanfordii	13.72±2.29 (17)	18.71±2.87 (18)	3.38±0.20 (18)	2.30±0.20 (18)	83.88±35.65 (18)
Rattus satarae	14.58±1.11 (6)	22.70±1.52 (5)	3.20±0.08 (6)	2.21±0.11 (6)	79.33±19.21 (6)
Rattus rattus	11.95±0.07 (2)	15.35±1.20 (2)	2.95±0.07 (2)	2.00±0.00 (2)	47.00±4.24 (2)
Suncus murinus	11.61± 0.81 (17)	7.58±0.42 (18)	1.96±0.08 (18)	1.29±0.17 (18)	35.00±5.65 (16)
Bandicota bengalensis	14.62±2.20 (4)	15.17±4.96 (4)	3.25±0.23 (4)	2.12±0.05 (4)	100.00±43.81 (4)
Tatera indica	12.86±2.91 (3)	17.10±3.98 (3)	4.00±0.10 (3)	2.30±0.10 (3)	129.00±12.72 (2)
Vandeleuria oleracea	7.20±0.56 (2)	11.55±0.63 (2)	1.75±0.07 (2)	1.40±0.14 (2)	14.00±0.00 (1)
Funambulus tristriatus	14.00±0.96 (3)	14.05±0.84 (4)	3.85±0.19 (4)	1.50±0.00 (4)	82.00±55.46 (3)

elevation grassland in the Western Ghats reported three species (Shanker 2003).

The high species richness in high-elevation grasslands may be related to the low to moderate human disturbance at these sites. Disturbances such as fire, grazing, grass cutting, cultivation, and human habitation are under control in these sites (forts) because they come under the jurisdiction of Archaeological and Forest Departments of Maharashtra. This finding is consistent with the intermediate disturbance hypothesis (Connell 1978), which predicts that species diversity is highest in moderately disturbed habitats (Rickart et al. 2011). Other sites in the study area are under high human disturbances, viz., urbanization, tourism, agriculture, wood-extraction, grazing, and fire. Hence species and habitat-specific conservation actions need to be taken up without delay to conserve these habitats and species. Moreover, further investigations on species-habitat relationships of the small mammals using robust sampling and statistical analyses are needed for their effective conservation and management.

The species accounts of the small mammal trapped in this study are as follows:

Kondana Soft-furred Rat *Millardia kondana*

This species is endemic to the northern Western Ghats and only known from four forts, viz., Sinhgad, Torna, Rajgad, and Raireshwar. *M. kondana* is a large rodent (Table 3; Image 1) with reddish or grayish-brown above and grayish-white below. The tail is bicolored, sparsely haired and equal to or slightly longer than head and body length. Though *M. kondana* is superficially similar to *M. meltada,* it differs by larger body size, comparatively small ears and hind feet, and six distinct planter pads on the hind feet (Mishra & Dhanda 1975). We, however, found that some individuals of *M. meltada* had six plantar pads, and an individual had five plantar pads on one foot and six on the other foot. Hence uniqueness of the number of plantar pads as a character in differentiating the species from others is questionable.

M. kondana is much heavier than *M. meltada*. It is restricted to high-elevation grasslands (>1,200m) and not trapped in other habitats or low elevations (<1,200m). Though restricted in distribution, *M. kondana* was the most frequently trapped species (23% of total catches). We found that it favors the patches of perennial herbs and scattered shrubs in high-elevation grasslands. It mainly breeds in monsoon and post-monsoon (July–November), but a few breeding individuals were also trapped in winter (December–January). It digs burrows near trees, shrubs or perennial herbs; active burrows were recognized by the presence of pellets or remnants of seeds and fruits at burrow openings.

Soft-furred Field Rat *Millardia meltada*

This sister species of *M. kondana* is found throughout India (Agrawal 2000). It resembles *M. kondana* externally but is smaller in size and lighter in weight (Table 3; Image 2). It was only trapped below 900m in agricultural fields and low-elevation grasslands in our

Image 1. *Millardia kondana*

Image 3. *Mus saxicola*

Image 2. *Millardia meltada*

Image 4. *Mus booduga*

study area. It showed a high preference for irrigated agriculture fields, which is also reported elsewhere (Prakash & Singh 2005). This species was relatively less abundant (4.5% of total catches) than *M. kondana*. We trapped it in December–January, and some individuals were reproductively active.

Elliot's Spiny Mouse *Mus saxicola*

It is a small rodent, easily distinguished by its pure white underparts, spiny hair, and a short tail (Table 3; Image 3). The body is grayish to grayish-brown above; some individuals had a faint orange line separating the dorsal and ventral sides. The species is almost indistinguishable from *M. platythrix* morphologically, except for having an anterior accessory cusp on the first lamina of first upper molar (Agrawal 2000). It was the second most abundant species in the study area (19% of total captures). Though it appeared to be a habitat generalist (trapped in all the habitats), it was more common in low- and mid-elevation grasslands. Unlike *M. kondana,* this species was trapped frequently in degraded and open grasslands lacking shrubs and trees. Some of the individuals trapped between December–February were reproductively active. Except for three individuals with 3+2 (thoracic+abdominal) mammae, the rest had 4+2 mammae.

Brown Spiny Mouse *Mus platythrix*

This species is morphologically similar to *M. saxicola* (Table 3) but lacks an anterior accessory cusp on the first lamina of first upper molar (Agrawal 2000). It seems to be a habitat generalist, but unlike *M. saxicola*, it was not trapped in irrigated agriculture fields. It was also not abundant (4.83% of total captures). Some individuals trapped between December–February were reproductively active. Except for an individual with 4+2 mammae, the rest of the rats had 3+2 mammae.

Little Indian Field Mouse *Mus booduga*

It is the smallest rodent that was trapped in this study (Table 3; Image 4). Unlike *M. platythrix* and *M. saxicola,* it has soft hair. The body is reddish-brown above and greyish-white underneath. The tail is bicolored, thin and its length is equal to head and body length. It showed a preference for agriculture fields, but it was also trapped in low- and mid-elevation grasslands. Interestingly, it was not captured in high-elevation grasslands. This was one of the most abundant species in the study area, constituting 13.01% of total captures. Some individuals trapped between December–February were reproductively active.

Indian Bush Rat *Golunda ellioti*

This species has spiny and coarse hair, covering almost half of the ears. It is yellowish-brown above and grayish underneath. The tail is thick, shorter than head and body length, and covered with black hair having a yellowish or golden-yellow tinge (Table 3; Image 5). Though this species was trapped in all habitats, it was most often captured in low-elevation grasslands, followed by mid-elevation grasslands. It was trapped in grazed grasslands and grass patches among agriculture fields. Its abundance was low (3.71% of total captures).

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Image 5. *Golunda ellioti*

Sahyadris Forest Rat *Rattus satarae*

This species is endemic to the Western Ghats. It is morphologically similar to *R. rattus* but has a very long tail (Table 3; Image 6). The body is covered with soft hair, which is reddish-brown above and white below. The species was recorded to be relatively less aggressive than that of *R. rattus* when captured. It was trapped in undisturbed semi-evergreen and moist–deciduous forest patches; similar results were found in another study (Molur & Singh 2009). Overall, its abundance was low (1.11% of total catches) in our study area. Some individuals trapped between December–February were reproductively active.

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Image 6. *Rattus satarae*

White-tailed Wood Rat *Madromys blanfordii*

A large arboreal rat with a long, white-tipped tail (Table 3; Image 7). Body covered with soft hair; grayish above and white below. It was trapped in forested habitats and was observed preferring ruined structures like forts, temples, and old houses for shelter. Its abundance was low (3.53% of total catches). Some individuals trapped between December–February were reproductively active.

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Image 7. *Madromys blanfordii*

Jungle Striped Squirrel *Funambulus tristriatus*

This species is endemic to the Western Ghats. It is similar in appearance to *F. palmarum* but is larger in size with a rufous forehead, flanks, and underside of the tail (Table 3). All specimens trapped were from the forested areas, and usually away from human settlements. Though we did not place traps above the ground for

Image 8. *Suncus murinus*

Image 9. *Tatera indica*

Image 10. *Vandeleuria oleracea*

Image 11. *Bandicota bengalensis*

trapping this highly arboreal species, the squirrels came for the bait put in the ground-laid traps. Its abundance was relatively higher (3.90% of total catches) than the other arboreal rodents, viz., *R. rattus* and *M. blanfordii*. The individuals trapped in February were found to be reproductively active.

House Shrew *Suncus murinus*

Suncus murinus, a widespread and generalist species (Prakash & Singh 2005), was the only shrew species recorded in the study area. It has a smooth, thick, and grey coat. The tail is shorter than head and body length and covered with thinly scattered, long, and white hair (Table 3; Image 8). It has a strong musky smell. It was trapped mainly in irrigated agriculture fields, followed by rainfed agriculture fields. It seems to prefer areas with moisture and the herbaceous cover as it was frequently trapped on bunds in agriculture fields covered with green grasses and forbs. It was a third-most abundant species (16.91% of total captures).

Other Species

In addition to frequently trapped species, some species were captured rarely (less than five individuals or less than 1% of total captures; Table 3). For instance, only three individuals of *Rattus rattus* were trapped near human settlements, and three individuals of *Tatera* *indica* (Image 9) were captured in high and mid-elevation grasslands. The absence of *T. indica* in agriculture fields is intriguing, as it is associated with agroecosystems and considered an important crop pest (Prakash & Singh 2005). We trapped two individuals of *V. oleracea* (Image 10)*;* one by hand from the ruined walls of the fort, the other in a rainfed agriculture field in a trap placed on a grass-covered bund under a *Ficus racemosa* tree. Four individuals of *B. bengalensis* (Image 11) were trapped from both rainfed and irrigated agriculture fields, and in a high-elevation grassland. All capture locations of *B. bengalensis* were close to the human settlements which was not surprising as this is a synanthropic species, thrives in human habitation areas. We also captured a squirrel, *F. palmarum,* in a rainfed agriculture field. This study was not particularly focused on squirrels, hence trapping time and trap placement was not ideal for capturing squirrel, which would explain the low capture rate of this otherwise common Indian rodent species. *Ratufa indica*, an arboreal and large (too large for our trap size) squirrel species, was not captured during the study but was seen and heard in undisturbed semi-evergreen and moist deciduous forest patches.

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Threatened Taxa

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Faunal diversity of an insular crepuscular cave of Goa, India

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Abstract: This study is the first attempt to document troglofaunal diversity of crepuscular cave ecosystem from the state of Goa. Twelve faunal species (seven invertebrates and five vertebrates) have been documented from an insular crepuscular cave which measures 18.62m in floor length and shows a transition of light and hygrothermal profile between its entrance and dead end. Absence of primary producers, thermal constancy, high humidity, poor ventilation, and competitive exclusion due to limited food resources restricts the faunal diversity of this cave; though trophic linkages are interesting yet speculative, as is typical of subterranean ecosystem. Among the macro-invertebrates, cavernicolous Whip Spider is a significant species here; whereas the important vertebrates encountered are the Fungoid frog and the Indian Cricket frog, besides roosts of the Rufous Horseshoe bat. Eco-energetic subsidy, possibly offered by crickets and bats that regularly feed outside this oligotrophic cave ecosystem is discussed. The need to document the unique and vulnerable troglofauna of this sensitive ecosystem from the conservation perspective is highlighted.

Keywords: Crepuscular, eco-energetic subsidy, insular cave, troglofauna.

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INTRODUCTION

Caves are natural or man-made subterranean cavities that may also be formed in the face of a cliff or a hillside. Their speleogenesis is attributed to various geologic processes; inclusive of a combination of chemical processes, erosion by water, tectonic forces, microorganisms, pressure and atmospheric influences (Ford & Williams 2007).

Cave as an ecosystem has its unique features characterized by gradients of darkness, narrow range of temperature differences and high humidity with limited air currents as some of its abiotic factors. These features make the cave ecosystem unique and the study of its biota fascinating (Biswas 2009). Bio-speleology is a relatively nascent area of ecology in India; the dearth of bio-speleological data being on account of the relatively hostile and secluded nature of these ecosystems.

The cave environment creates an ecosystem, which the fauna living in epigean conditions find difficult to adapt to (Biswas 2010). Nonetheless, caves support and sustain a good faunal diversity within the limited geophysical parameters. Organisms attracted to live in caves show high degree of morphological, behavioral, and physiological adaptations necessary to endure and thrive in such an ecosystem (Vandel 1965; Barr 1968; Biswas 1992; Gunn 2004). Species colonise caves for various reasons for at least part of their life cycles for temporary shelter or due to low predation pressure and easy availability of prey (Biswas 2009).

This study is the first attempt at charting out the faunal diversity of crepuscular cave ecosystem of Goa's insular landscape. The term insular is used here to indicate the cave's presence on an island. Divar is the third largest of the seven islands of Goa; roughly triangular in shape and measures an average 5.80km long and about 3.00km wide, with an area of around 17.56km^2. A cursory mention of this cave ecosystem of Divar Island appears in the book "Island Biodiversity Goa" (Sawant & Jadhav 2014).

Present study is particularly intended to obtain data on the troglofaunal diversity inhabiting the cave. In the present case the crepuscular cave investigated is a relatively small subterranean ecosystem with a floor length of 18m and average roof height of 3.4m; as such the environmental variables typical of a classical cave resulting in distinct zonation as proposed by Vermeulen & Whitten (1999) cannot be applied here. Nonetheless, from the cave entrance towards the dead end it is possible to demarcate three zones using variation in hygrothermal profile and diminishing light intensity as zone boundaries. The organic carbon and phosphate content of the soil through the floor length of the cave have been analysed. The data gathered addresses an important gap in our state specific biodiversity of sensitive ecosystems.

MATERIALS AND METHODS

The cave investigated in this study is located at 15.535^{0}N & 73.924^{0}E on Divar Island towards the north of Old Goa, 9.50km from Panaji and surrounded by the Mandovi estuary and its network of tributaries (Image 1a,b). The island is dominated by agricultural landscape and a few aquaculture units (Image 1c).

The cave was physically measured for various speleometric dimensions and a schematic diagram was hand drawn by mapping the layout of the cave and later digitized to add details like measurements and sampling points. Physical parameters such as light (Luxmeter HTC Model LX-103), temperature and humidity (Digital Hygrometer-Thermometer HTC Model 103-CTH) were recorded throughout the cave.

Soil samples from various points within the cave were collected in pre-sterilized zipped plastic pouches using a spatula and analysed for organic carbon (Walkley & Black 1934) and phosphate content (Adelowo et al. 2016). Monthly visits were made for seven months from August 2018 to February 2019 for documentation of troglofauna in relation to three zones of the cave. Only direct evidences were considered to compile an inventory of troglofauna. Most observations were made between 09.00h and 17.00h, but occasional observations were made at night to account for any night cave visitors. Species were photo-documented and collection was avoided to uphold conservation ethics, unless absolutely necessary for taxonomy.

The various troglofaunal species observed and photo-documented in this cave were identified based on taxonomic guides, as also consultations with taxon experts (Chopard 1970; Bastawade 1995; Whitaker 2006; Srinivasulu et al. 2010; Gururaja 2012; Keswani et al. 2012; Baidya & Chindarkar 2015). Notwithstanding that much larger sample sizes instill confidence for detecting small changes between sampling times or sites, in this exercise semi-quantitative ACFOR scale was used for the rapid assessment of abundance of the cave fauna. The utility of ACFOR scale in coarse assessment of abundance, both accurately and quickly, has been proven (Hawkins & Jones 1992).

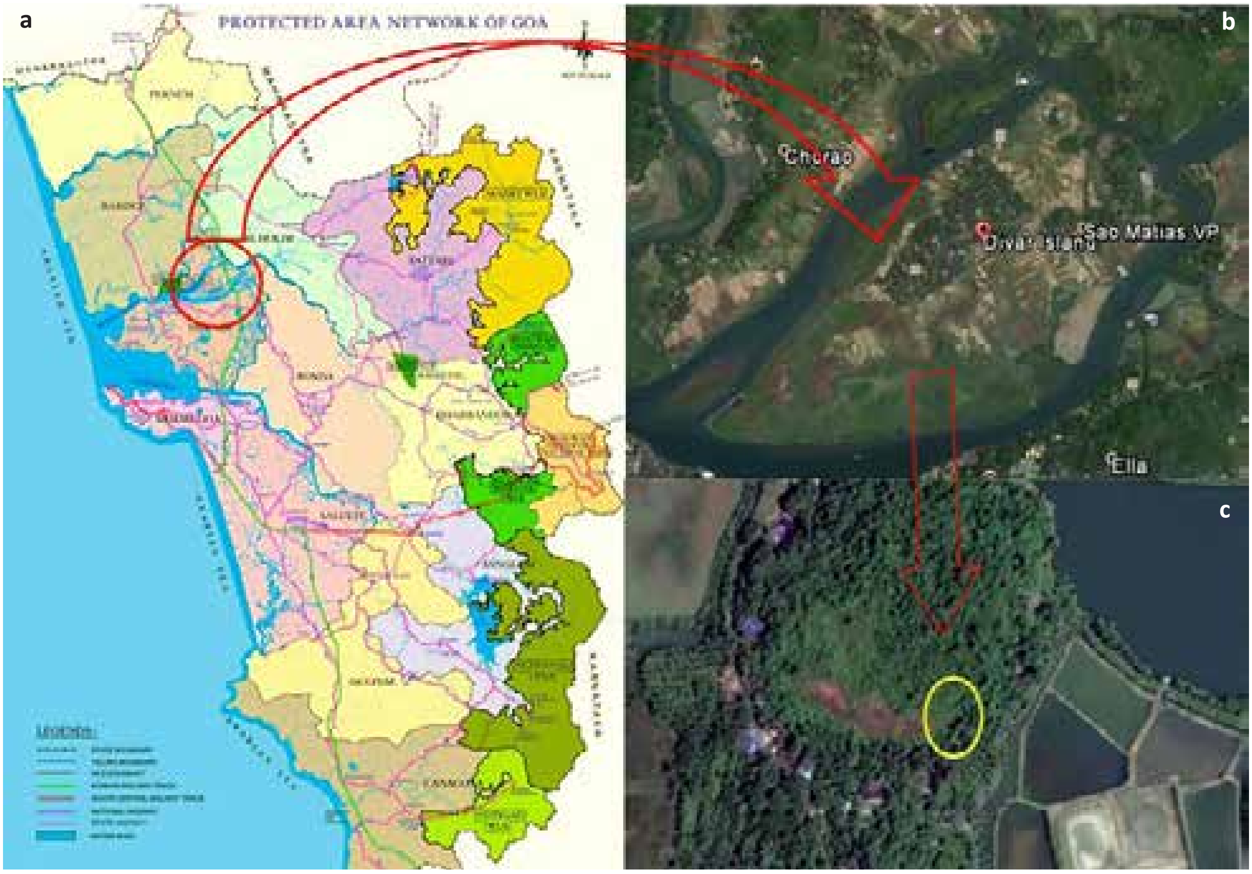

Image 1. Location of the cave on Divar Island of Goa, India.

RESULTS & OBSERVATIONS

The investigated cave on Divar Island in Goa is a natural subterranean vault at the base of a cliff (Image 1). This crepuscular cave is lateritic and damp with progressively diminishing light from the entrance to the end chamber, totaling a floor length of 18.62m (Image 2 & Fig. 2). Schematic diagrams (Fig. 1 & 2) depict the measurements of the cave. The cave entrance is 3.52m wide and opens up horizontally into a chamber typed as the zone A (proximate to the entrance), since it had less light and vegetation than outside and the temperature and humidity were found to be 30.5°C and 80%, respectively (Fig. 2 & 3, sampling point C). The next cave segment with light intensity decreasing further was considered to be the zone B (middle zone) with temperature of 30.4°C and humidity at 97% (Fig. 2 & 3, sampling point D). The zone C (end zone) is characterized by complete darkness with 99% humidity and temperature ranging between 29.1–30.1°C (Fig. 2 & 3, sampling points E & F). The intensity of light decreased with increasing distance from the cave entrance to the end zone, average light of 1782.13 lux and 0 lux being recorded respectively at the two extreme points. The organic carbon and phosphate content of the soil from sampling sites along the three cave zones is shown in Fig. 5 & 6 and correlates well with roost positions of the bats (Fig. 4), values being higher in the zone B and C as compared to zone A.

In the present investigation, 12 faunal species were recorded from various zones of the cave; (See Table 1 and Image 3). Two species of frogs have been encountered in the cave, namely, Fungoid Frog *Hydrophylax malabaricus* and Indian Cricket Frog *Fejervarya limnocharis*; the sightings of the former being more frequent after the rains extending in distribution from the zone A to Zone C, but the latter more confined to zone A. Often called the Paddy Frog, *Fejervarya limnocharis* is a common species of croplands here. Brooke's Gecko *Hemidactylus brookii* occurs from the entrance through the zone A of the cave co-inhabited by Scutigeromorph Centipede *Scutigera coleoptrata,* Woodlouse unidentified species, Daddy Longlegs *Puria dorsalis*, Humped Spider *Zosis geniculata* and Whip Spider *Phrynichus phipsoni*. The

Image 2. a—Cave Entrance | b—Zone A (proximate to the entrance) | c—Zone B (middle zone) | d—Zone C (end zone). © Manoj R. Borkar.

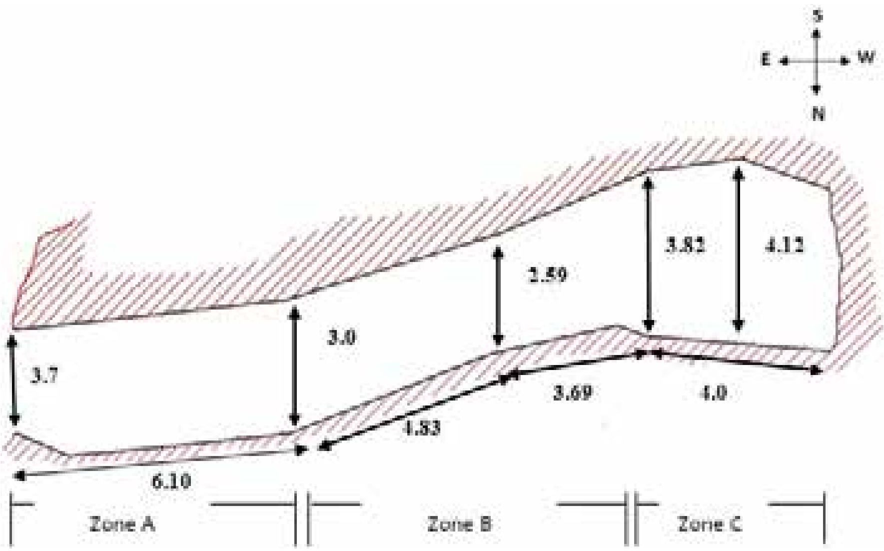

Figure 1. Speleometric data (in meters) in a schematic lateral section of the Divar Cave in Goa.

Cricket *Itaropsis parviceps* and Long-necked Sugar Ant *Camponotus angusticollis* were associated with zone B of the cave. The Whip Spider *Phrynichus phipsoni* population of this cave exhibits site fidelity, with individuals dispersing at night on the cave walls from their hideouts in crevices.

The Rufous Horseshoe Bat *Rhinolophus rouxii* is an important mammalian constituent of troglofauna in this cave, its population and distribution varying seasonally. In the wet months dense bat roosts occupied the zone B and C. In the zone A, five individuals of Rufous Horseshoe Bat were seen clustered on extreme right

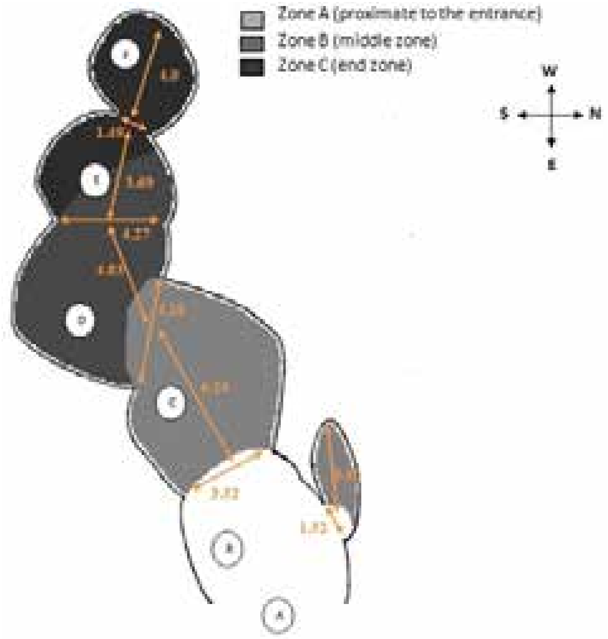

Figure 2 . Cave measurements and zones. (A to F are sampling points in different zones).

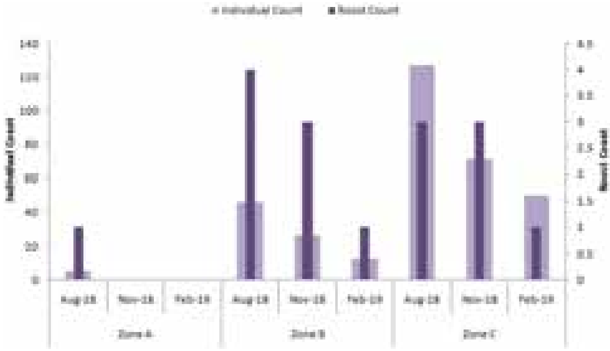

Figure 4. Roost and individual count of Rufous Horseshoe Bat *Rhinolophus rouxii* across cave zones.

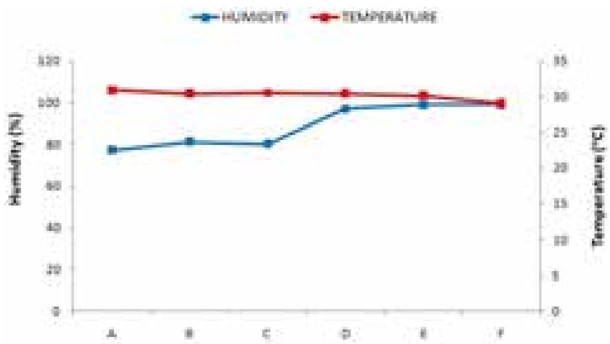

Figure 3. Hygrothermal data recorded at the sampling points of different cave zones as shown in Figure 2.

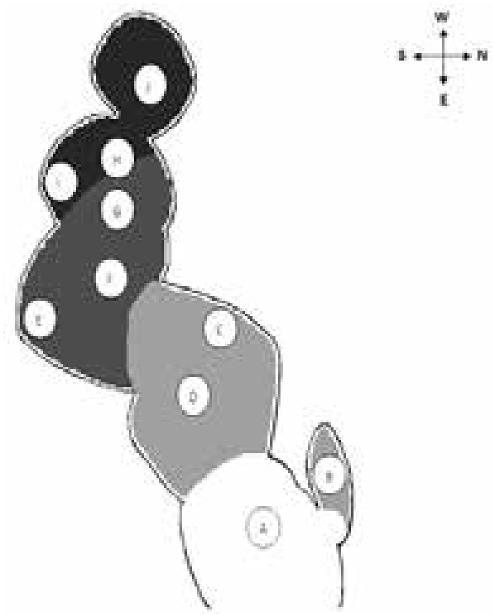

Figure 5. Sampling points for total organic Carbon and Phosphate content of soil in different cave zones.

wall, where light intensity was perceptibly less. Bats preferred to roost on the walls rather than the roof of the cave. In the month of November 2018, the bat density decreased and the roosts were restricted to zone B and C. By February 2019, the numbers dropped further; barring a small cluster of bats in the distal end of the zone B and a roost of predominantly sub-adults was confined to the end part of the cave. Such seasonal shifts in the distribution and number of the bat roosts within this cave (see Fig. 4) accounts for absence of a thick bulky guano deposit in this cave and the guano is loosely scattered on the cave floor.

A single individual of Common Krait *Bungarus caeruleus* documented from this cave during the night survey is most likely to have been a straggler or an opportunistic predator that had been attracted to the cave, after seeing concentrated food supply in form of roosting bats. Such opportunistic predations on cave roosting bats have also been recorded by Tanalgo et al. (2020).

All the species listed in this study are secondary consumers and saprotrophs. The smaller invertebrates help in remineralization of dead organic matter, as also constitute the prey base for lower rungs of secondary consumers such as daddy longlegs, Scutigeromorph Centipede, humped spider, and whip spider. The herpetofauna and bats operate at the next trophic level, whereas the Common Krait could either be a straggler or an opportunistic predator of frogs, lizards, and bats. From the troglofaunal inventory compiled in this study,

Table 1. Zone of occurrence and abundance of faunal diversity of the crepuscular cave in Divar, Goa.

	Common name	Species	Zone of occurrence	Abundance ratings
1	Scutigeromorph Centipede	*Scutigera coleoptrata* Linnaeus, 1758	A	F
2	Woodlouse	Unidentified Isopod	A	F
3	Cricket	*Itaropsis parviceps* Walker, 1869	B	C
4	Long-necked Sugar Ant	*Camponotus angusticollis* Jerdon, 1851	B	C
5	Daddy longlegs	*Puria dorsalis* Roewer, 1914	A	C
6	Humped spider	*Zosis geniculata* Olivier, 1789	A	O
7	Whip spider	*Phrynicus phipsoni* Pocock, 1900	A, B & C	F
8	Fungoid Frog	*Hydrophylax malabaricus* Tschudi, 1838	A, B & C	F
9	Indian Cricket Frog	*Fejervarya limnocharis* Gravenhorst, 1829	A	R
10	Brooke's Gecko	*Hemidactylus brookii* Gray, 1845	A	O
11	Common Krait	*Bungarus caeruleus* Schneider, 1801	A	R
12	Rufous Horseshoe Bat	*Rhinolophus rouxii* Temminck, 1835	B & C	A

Abundance rating are based on the semi-quantitative visual estimates: A—Abundant | C—Common | F—Frequent | O—Occasional | R—Rare.

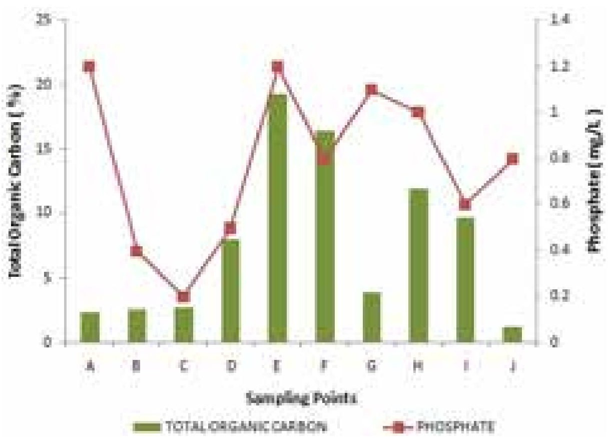

Figure 6. Total organic Carbon and Phosphates in soils from sampling points of different cave zones as in Figure 5.

it is evident that this cave has a truncated biodiversity typified by absence of phototrophic primary producers and presence of fewer apex predators in the food chains operating here.

DISCUSSION

Perusal of literature confirmed a glaring gap in documentation of troglofauna in the state of Goa. Deciphering the composition and dynamics of cave communities has been a key challenge for speleobiologists. The limited organization of a cave ecosystem has been attributed to permanent darkness and competitive exclusion due to resource scarcity (Fernandes et al. 2016). Despite a relatively hostile cavernous environment characterized by diffuse or complete absence of light, constant temperature and high humidity, poor air circulation and severely constrained food supplies; caves do support and sustain a unique assemblage of biota, whose density however is lower than epigean habitats (Mitchell et al. 1977; Parzefall 1983). The relatively poor faunal diversity of this cave ecosystem could also be attributed to the absence of phototrophs; resulting in scarcity of food, reducing the number of predators as well as the overall biodiversity of the cave ecosystem (Gibert & Deharveng 2002). Species might colonise cave environments for reasons such as the need for temporary shelter or in order to escape from persistent adverse environmental conditions on the surface, whereas others may be temporary visitors with limited reliance on the cave environment.

Several researchers have conclusively shown that phenology of species and in particular that of ectotherms, is influenced by air temperature and water availability (Kearny et al. 2013; Amarasekare & Coutinho 2014; Sheldon & Tewskbury 2014) and variations in these features in epigean environments often force animals to search for 'shelter microhabitats' of stable environments such as caves that offer the most suitable and stable conditions (Seebacher & Alfrod 2002; Papaioannou et al. 2015).

Expectedly, the variations in microclimatic attributes across the various cave zones create an environmental gradient, which influences distribution of various faunal elements. Such patterns of macro-invertebrate distribution in a cave ecosystem have also been

Image 3. Faunal diversity of the crepuscular cave in Divar, Goa, India: a—Scutigeromorph Centipede *Scutigera coleoptrata* | b—Woodlice, unidentified isopod | c—Cricket *Itaropsis parviceps* | d—Long-necked Sugar Ant *Camponotus angusticollis* | e—Daddy longlegs *Puria dorsalis* | f—Humped Spider *Zosis geniculata* | g—Whip Spider *Phrynichus phipsoni* | h—Fungoid Frog *Hydrophylax malabaricus* | i—Indian Cricket Frog *Fejervarya limnocharis* | j—Brooke's Gecko *Hemidactylus brookii* | k—Common Krait *Bungarus caeruleus* | l—Rufous Horseshoe Bat *Rhinolophus rouxii*. © Manoj R. Borkar & Andrea Sequeira.

confirmed by Mazebedi & Hesselberg (2020). The basic tenet of eco-energetics requires linkages between biodiversity and the abiotic components; and the species richness is limited by productivity (Ricklefs & Schluter 1993). As is also the case with the cave investigated here, macro-invertebrates usually play a critical role in cave ecosystem functions because of their relatively high diversity compared to the vertebrate biota. Such an opinion has also been corroborated by Lavoie et al. (2007) and Moseley (2009). Crickets and bats subsidise the consumer community dynamics of this oligotrophic cave ecosystem. The crickets are known to take regular nocturnal feeding sorties on vegetation outside the cave (Benoit et al. 2004) and the bats offer guano subsidy by feeding in epigean habitats (Iskali & Zhang 2015). In the present case too, both these species offer a definite trophic connect to the cavernicoles of this cave, with the epigean resources.

Epigean populations of *Phrynichus phipsoni* have been reported from Goa earlier by Borkar et al. (2006). As documented from this cave; whip spiders also inhabit the crevices and cracks in the subterranean ecosystems that commensurate well with their dorso-ventrally flattened body contour (Chapin 2015). Their site fidelity and homing behavior as has been observed in this investigation, has been well documented (Hebets 2002).

Herepetofaunal constituents of this cave are two species of frogs, one species of gekkonid lizard belonging to the *Hemidactylus* clade complex of *brookii* group (Bauer et al. 2010a,b) and the Common Krait. The association of the Fungoid Frog with subterranean caves of Western Ghats is well established (Chari 1962) and has also been observed in the caves of Kanger Valley National Park, Chattisgharh (Biswas 2010; Biswas & Shotriya 2011). Caves are known to accumulate heat and create a microclimate favouring macrofaunal poikilotherms such as the amphibians and reptiles, and the abundant invertebrate species here remove limitations of food for these opportunistic predators (Turbanov et al. 2019). A single observation of Common Krait in this cave presumably for opportunistic feeding is corroborated by Sinha (1999), who has also reported Banded Kraits preying on Bats from Siju caves in Meghalaya.

The presence and roosting habits of Rufous Horseshoe Bat in caves of the Western Ghats have been previously reported by Korad et al. (2007). The variations in numbers and size of the bat roosts observed in this study is speculated to be driven by the species-specific social structure and foraging behaviour (Kunz & Lumsden 2005). The relatively sparse and scattered guano in this cave correlates well with shifting positions and density of the bat roosts. Similar observations have also been reported by Biswas & Shrotriya (2011). Bat guano may support guanophile communities that in turn could attract predators of these guanophages to the cave (Encinares 2019). Perhaps in a small subterranean cave like the one investigated here the species diversity may seem small, because all micro crustaceans and cavernicolous guanophiles have not been included.

CONCLUSION

On Divar Island where this cave is located, locals have consciously resisted urbanization thus far; but the place is a popular location for Bollywood film shoots. Tourists have been steadily pouring in to relish the rustic countryside. Influx of tourists will open up the hitherto inviolate areas for exploration and exploitation. Ecological studies of cave ecosystems and charting out their troglofauna are a prerequisite for management and conservation of sensitive and fragile subterranean ecosystems (Schneider & Culver 2004). Conservation of cave ecosystems is vital not only because they shelter unique and vulnerable biodiversity (Mammola 2019), but more so because their stable environments provide natural laboratories for testing doctrinal evolutionary concepts of adaptation and speciation (Culver & Pipan 2019). Also, collection and collation of a standardised data for a long term referral purpose is crucial for species conservation assessment (Lunghi et al. 2020).

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COMMUNICATION

Potential remote drug delivery failures due to temperature-dependent viscosity and drug-loss of aqueous and emulsion-based fluids

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Abstract: The ability to inject wild animals from a distance using remote drug delivery systems (RDDS) is one of the most effective and humane practices in wildlife management. Several factors affect the successful administration of drugs using RDDS. For example, temperature-dependent viscosity change in aqueous (Newtonian) or water-in-oil emulsion (non-Newtonian) fluids, commonly used in tranquilizer and adjuvant-based vaccines, respectively, can potentially result in drug delivery failure. To better understand impacts due to viscosity changes, we investigated the fluid dynamics and ballistics involved in remote drug delivery. Our research was divided into two phases: we investigated the viscosimetric physics in the first phase to determine the fluid behavior under different temperature settings, simulating recommended storage temperature (7ºC), plus an ambient temperature (20ºC). In the second phase of our study, we assessed the drug delivery efficiency by specialized darts, using a precision CO_2 projector and a blowgun. Efficiency assessment was done by comparing the original drug volume with the actual volume injected after firing the dart into a fresh pork hide mounted on a ballistic gel. Before testing, we configured the required minimum impact velocity as our parameter for intramuscular injection (determined as > 40 m/sec). All executed dart-deployments performed satisfactorily, despite initial concerns of potential incomplete drug delivery, however, noteworthy drug loss was observed (>10%) associated with drug residues in syringe/dart dead space and within the transfer needle. This could potentially result in inaccurate dosing depending on the drug used. Furthermore, the use of a blowgun for remote drug delivery (>3m) is discouraged, especially when using specialized darts, as the required minimum dart velocity for adequate penetration is difficult to reach, in addition to a loss of precision during targeting.

Keywords: Ballistic, darts, inject, immunogenic, remote drug delivery system, tranquilizer, vaccines, wildlife.

Abbreviations: RH—Efficiency assessment of remote drug delivery systems.

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

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INTRODUCTION

The ability to inject wild animals from a distance without the need for physical restraint has many advantages, including logistics, safety, and improved animal welfare. Several factors, however, influence the success of drug delivery using a remote drug delivery system (RDDS), including the user's ability to accurately use RDDS (Cattet et al. 2006), ambient influences (weather/light), dart ballistics, and drug solution characteristics. The drug's specific fluid characteristics can potentially interfere with the delivery efficiency when used in a dart and can be easily overlooked, especially when it comes to temperature-dependent viscosity (Evans et al. 2015). This is an important issue for wildlife vaccines. Vaccines developed for wildlife applications have to be highly immunogenic, thus permitting a single dose application. The duration of immunity after vaccination should also last long. Water-in-oil emulsions and adjuvants provide such attributes, but depending on temperature, the emulsion's viscosity (fluid resistance) can be a hindrance if remote drug delivery is to be used for vaccine delivery.

RDDS technologies have progressed significantly in recent times, allowing for specific application needs. For example, a vaccine with the aforementioned characteristics has to be injected as a bolus (depot), subcutaneously or intramuscularly. This can be accomplished with a single-port cannula dart. On the other hand, a tranquilizer drug is delivered using a dart with a tri-port cannula that injects the drug over a large area in a dispersed fashion, facilitating quicker drug absorption for faster biological effects.

The work described in this paper was motivated by an experience during our immunocontraception project for wildlife population control. While administering the immunocontraceptive vaccine stored at 4–7 ºC intramuscularly by a hand syringe, a substantial manual force was required even with a large diameter cannula (18 gauge). We were, therefore, concerned about potential delivery failure or incomplete delivery with RDDS. A potential solution was to increase the temperature of the vaccine to ambient temperature before deployment. This study aimed to assess the impact of temperature on the delivery of a solution while using RDDS. Although there are several publications on the use of darts in wildlife (Kreeger 1997; Cattet et al. 2006; Cracknell 2013; Evans et al. 2015; Griffin 2015; McCaan et al. 2017; Rosenfield 2017), to our best knowledge, none addressed the fluid dynamics and efficiency of drug delivery. Furthermore, we investigated if specialized darts for vaccine delivery can be adequately deployed by blowguns.

Objectives

1) To assess temperature-dependent viscosity dynamics of aqueous and emulsion solution by comparing Newtonian (aqueous) and non-Newtonian (emulsion) fluid behavior under the influence of temperature variance on their viscosity dynamics.

2) To determine minimum impact velocity and dart delivery ballistics by classifying the minimum impact velocity (MIV) necessary for adequate dart penetration, to minimize potential tissue damage using:

a. CO_2 projector (20m)

b. Blowgun (3m)

3) To evaluate drug delivery efficiency of aqueous and emulsion-based solutions at two different temperature conditions (storage 7ºC; ambient 20ºC), by comparing weights of the syringe, transfer needle, dart, and dart cannula before and after use/deployment to identify any potential drug volume loss.

MATERIALS & METHODS

Experimental design for fluid behavior of emulsion and aqueous solution:

To determine the impact of temperature on the viscosity of aqueous and emulsion-based fluids, as typically found in injectable anesthetics and vaccines, we used the programmable Rheometer, Brookfield DV-III, a cone plate version viscometer, and the Waele's Ostwald equation:

$$\tau = K\left(\frac{\partial u}{\partial y}\right)^n$$

whereby:

• K (flow consistency index) expressed in (N/m ^ 2). (S^n)

• n (flow behavior index), dimensionless.

• du / dy (shear rate), expressed in 1/s.

Water-in-oil emulsion (non-Newtonian fluid)

We analyzed the temperature impact on the viscosity of an injectable, water-in-oil based emulsion. We used an original sham vaccine (USDA, NWRC, Fort Collins, USA) at two temperature settings. First, simulating the manufacturer's recommended storage temperature of 7ºC, and second, at an ambient temperature of 20ºC. The temperature of the tested fluid was maintained by using the Rheometer's temperature-controlled circulating bath. Subsequently, the viscosity was measured with different spindle sizes and rotation velocities. Each test was then repeated.

Aqueous solution (Newtonian fluid)

For comparison, we also tested an aqueous-based fluid, simulating a drug consistency commonly found in tranquilizer drugs by preparing a saline/ethylene glycol solution (90% v/v to 10% v/v). The viscosity tests were performed at 20ºC. Subsequently, the viscosity was measured with different spindle sizes and rotation velocities. Each test was then repeated.

Statistics

To evaluate the differences between the means for viscosity samples, a bi-caudal Welch's t-test was used considering unequal sample sizes. The data was analyzed using Stats Package (Version 3.6.2) in R (R Core Team 2020).

Dart-delivery assessment

Equipment

CO_2 Projector: Distance darting was performed using a high-precision CO_2 projector (X-Caliber, 50 cal. [12.3mm] Pneu-Dart, Inc., Williamsport, PA, USA) with a mounted scope.

Blowgun: For the blowgun tests, we used a 58.5cm length blowgun, with a 12.3mm diameter (Pneu-Dart, Inc.).

Darts (n=6): The employed dart specifications: Type P, cannula length 31,75mm, gel collar, single-port, and a tri-port, with an explosive charge.

Chronographer: Dart-velocity recording was performed by using a precision chronographer, recorded in m/sec (accuracy +/- 0.25%), along with external digital data recording (Ballistic Precision Speed Chronograph, Caldwell, USA). The chronographer was placed 30cm in front of the target field. The darts were fired in such a way, that they pass two screens, and the time it takes for the darts to travel the distance between the screens is measured electronically.

Target: The target was a 112mm thick piece of fresh pigskin with an intact layer of adipose tissue and some visible areas of connected muscular tissue, serving as an indicator for intramuscular (IM) injection (Image 1). The pigskin was mounted onto a block of 10% ballistic gel.

Basic set-up - Distance darting: The CO_2 projector was mounted on a rifle shooting rests (Caldwell, USA), with the scope zeroed-in at a distance of 20m.

Shooting execution: Using the manufacturer's guidelines for initial pressure settings on the CO_2 projector, we developed our own settings, designated as "minimum impact velocity" (MIV). Most common dart delivery-failures are due to inadequate pressure settings on the CO_2 projector. Too low of a pressure and the dart will not reach their intended targets or bounce off the animal. Too high of a pressure, and the dart may provoke extensive tissue injury or ricochet. MIV refers to the lowest functional pressure setting, allowing for the dart to reach its target with adequate intramuscular penetration, believed to minimize tissue damage. Optimal depth was considered when the dart's gel collar was positioned on the far side of the pork skin's adipose tissue, allowing for the cannula orifice to reach muscle tissue. This was accomplished by gradually increasing the gas pressure and recording the dart's velocity. The results were quantified by needle penetration depth:

* Full = gel collar past skin/fat layer
* ½ = gel collar stuck within the skin/fat layer
* F = failure of gel collar to penetrate the skin

The setting with the lowest pressure that resulted in full penetration was used as the new MIV.

Basic set-up - Blowgun

Darting via blowgun was performed from a distance of 3m, using the same chronograph setup to assess minimum impact velocity.

Assessment of Drug Delivery Efficiency

Before testing, all syringes, transfer needles, and darts were identified with permanent markers. The efficiency of drug delivery was determined by the weight-differences between:

1) original quantity (1mL) of the sham vaccine, prefilled in 3mL syringes (Henke-Sass, Wolf GmbH, Germany)

2) 18G x 76.2mm transfer needle (Pneu-Dart, Inc.), before and after use

3) Dart empty weight

4) Full-filled dart weight (dart + drug load) prior to deployment

5) Dart weight after deployment (drug injected into the target)

Weight differences were determined by using a digital precision top scale (500g x 0.01g).

The difference in weight between the original sham vaccine-loaded syringe and the weight of the vaccine-filled dart after deployment was considered the net drug weight deposited. Any weight difference not being equal to the 1mL sham vaccine weight was considered to be the amount of drug lost.

RESULTS

Fluid behavior

Water-in-oil emulsion (non-Newtonian fluid)

The rheological behavior of the sham vaccine, a water-in-oil emulsion, indicated that there is no linear relationship between tension and strain rate. It is, therefore, a liquid with non-Newtonian behavior. As for the temperature, it was observed that the increase in temperature implies a greater fluidity of the emulsion, a behavior that is typical of viscous liquids (Fig.1). The emulsion's viscosity was significantly different at two different temperatures, 7ºC vs. 20ºC (Bi-caudal Welch's t-test [p=0.04052;95% CI, 598.00–20160.65]).

Aqueous Solution (Newtonian fluid)

The aqueous solution presented a linear relationship between the stress and the rate of deformation, i.e. Newtonian behavior. Therefore, the viscosity of the aqueous solution can be defined as being constant at a temperatures of 7ºC, and constant at a temperature of 20ºC, however, significantly different when compared to one another, (viscosity cP 8 to cP 2, respectively), (Fig. 2) (Bi-caudal Welch's t-test [p=0.0000156; 95% CI,-7.634565/-5.850435]).

Minimum impact velocity

For our specific equipment, the pre-determined impact velocity necessary for adequate dart cannula penetration to reach intramuscular tissue was ≥ 40m/s. As demonstrated in Images 1 & 2, the identified MIV allowed all deployed darts to reach IM injection depth.

Overall drug delivery quality

Not considering drug volume loss due to cannula/ syringe/dart dead-space, the drug volume deposited of all deployed darts were satisfactorily (Image 3). Images 4 A and B demonstrate the different deposit characteristics with a single-port and a tri-port cannula, respectively.

Dart weight-differences

We identified a mean drug weight difference between original drug volume (1mL pre-deployment) and injected volume (0.886mL) post-deployment). The weight difference of 0.114gm was statistically significant (p<0.01; 95% CI, 0.076–0.123).

Weight Difference of deposited drug volume by temperature variations:

Differences in deposited drug volume due to temperature variant (7°C vs. 20°C) were considered statistically not significant (p=0.3194).

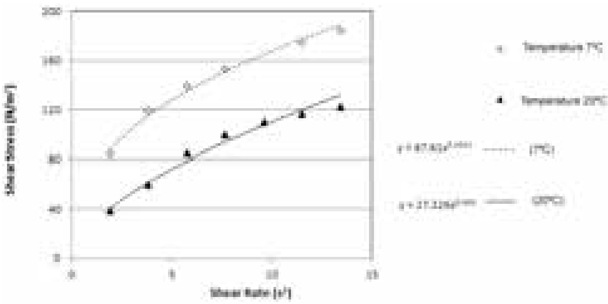

Figure 1. Shear stress test of the emulsion-based solution at different temperatures. The emulsion's viscosity was significantly different at two different temperatures, 7ºC vs. 20ºC (Bi-caudal Welch's t-test [p = 0.04052; 95% CI, 598.00 – 20160.65]).

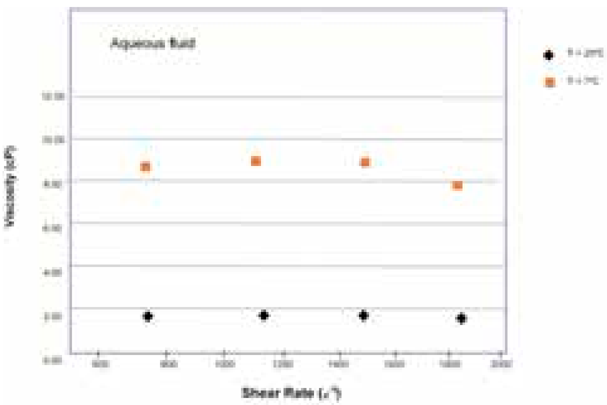

Figure 2. Shear stress test of the aqueous solution at different temperatures. The viscosity of the aqueous solution was also significantly different at two different temperatures, 7ºC vs. 20ºC (Bi-caudal Welch's t-test [p = 0.0000156; 95% CI, -7.634565 / -5.850435]).

Drug Volume Loss

The only significant drug loss identified was related to the residue in the transfer needle in addition to the residue in the syringe hub (dead space), (Image 5), a space between the syringe needle and barrel.

Hypothesized drug loss using dead space's volume calculations for transfer syringe/needle and dart/ canula

Formula: $V = \pi r^2 h$

Where the 18G syringe needle volume (dead space) = 0.84 mm ID x 76.2 mm length.

$V = 4.22mm^3 = 0.00422mL$

Where the 14G Dart cannula = 1.6mm ID x 31.75mm

$V = 67.06mm^3 = 0.06706mL$

Total syringe needle/dart canula residue volume: 0.07128mL

Image 1. Darting – Drug deposit evaluation. Pork hide mounted on a block of ballistic gel with two darts showing full penetration of the dart's cannula. © D. Rosenfield

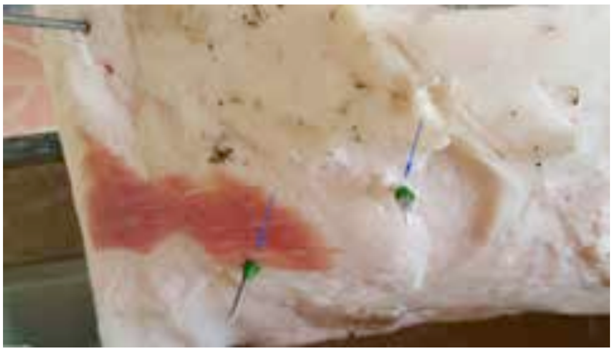

Image 2. Showing the backside of the pork hide, adequate penetration of the dart cannulas, with the single-port reaching muscle tissue, secured by the gel collar past the adipose tissue (blue arrows). © D. Rosenfield

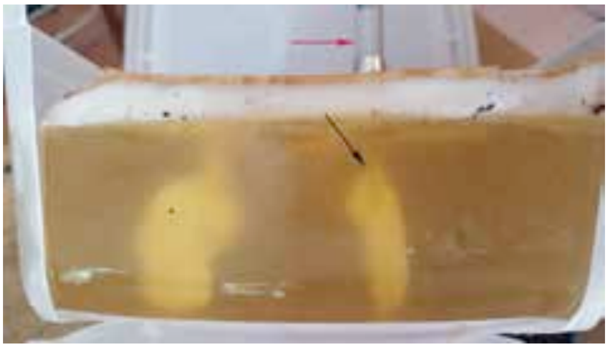

Image 3. Birdeye view of the ballistic gel with mounted pork hide. Depicting the deployed dart (red arrow), and the quality of the drug deposits in the form of clouds within the ballistic gel (black arrow). © D. Rosenfield

Also, prior identified dead space of conventional 1mL syringes (Küme et al. 2012; UC Davis 2016) of 0.066mL, including the same volume amount for the dart hub, the total hub volume projected is 0.132mL. Adding the calculated syringe/cannula and the hub dead space, the total residue volume could be as high as 0.203mL, a potential 20% drug loss.

DISCUSSION

The initial concern due to the potential increase in fluid resistance for an emulsion-based drug stored at 7ºC was corroborated during the viscosity assessment, where temperature-dependent rheological behavior was evident. Similar concerns were reported by Baker et al. (2005) and Kirkpatrick et al. (2011), when observing delivery failure, potentially linked to the viscosity issue of a polymer mixture. Our experiment results confirmed a significant temperature impact on emulsion-based fluids. Specifically, that a decrease in solution temperature increases fluid resistance (Palm et al. 2015).

Although drug delivery using darts was efficient for fluids at 7ºC as well as 20, as observed in our pork skin/ballistic gel setup, attention should be paid to other potential delivery failures when darting live animal, in particular, due to drug fluids traveling back the wound channel, as described by (Evans et al. 2015). The use of a blow-gun is discouraged as the indicated minimum impact velocity of specialized darts for adequate perforation would be difficult to achieve, leading to inadequate injection depth, failure to trigger propellent mechanism or bounce-backs.

Finally, drug loss due to accumulated residue in the syringe and dart dead spaces, dart cannula and transfer needle should be considered when using drugs sensitive to minute variations. To the best of our knowledge, scientific literature on potential drug loss due to dead-space in darts does not exist, however, similar corroborated information can be found in human medicine (Bobashev & Zule 2010; UC Davis, YSP, 2016).

CONCLUSION

Contrary to our initial concerns, the findings of this study demonstrated efficient drug deliveries, without the need to warm an emulsion-based vaccine to ambient temperatures. Nevertheless, the drug volume loss attributed to dead-space residues of the syringe, needle, dart during drug transfer from the syringe to dart, is noteworthy. Drug delivery with specialized darts, using any kind of propellant, will bring about tissue damages to a certain degree. But risks associated with physical restraint (nets, traps, etc.) are much greater.

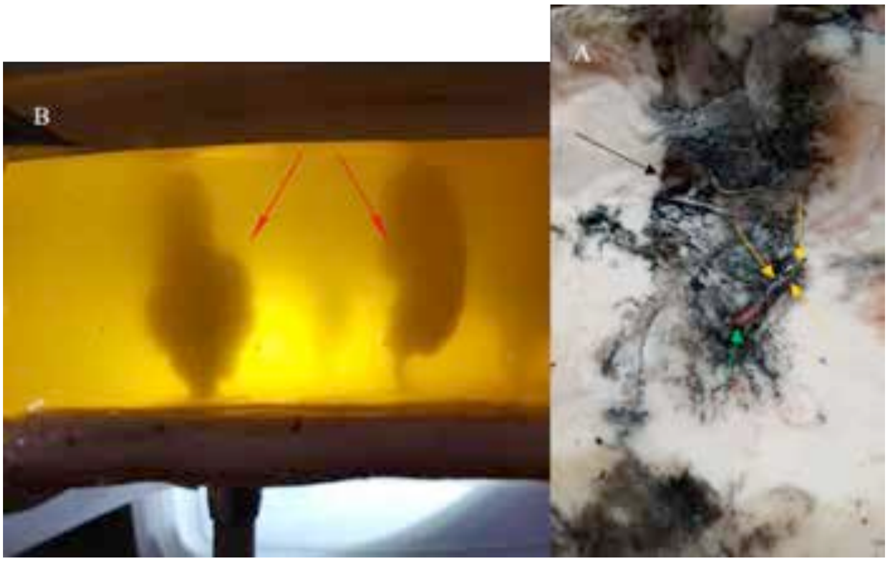

Image 4, A—Emulsion deposits (red arrows) by dart injection, using background-light to enhance contrast | B—For comparison, dispersed injection of a colored aqueous solution with a tri-port dart. Orange arrows: cannula's orifices, green arrow: cannula with gel collar, black arrow: injected colored aqueous solution. © D. Rosenfield

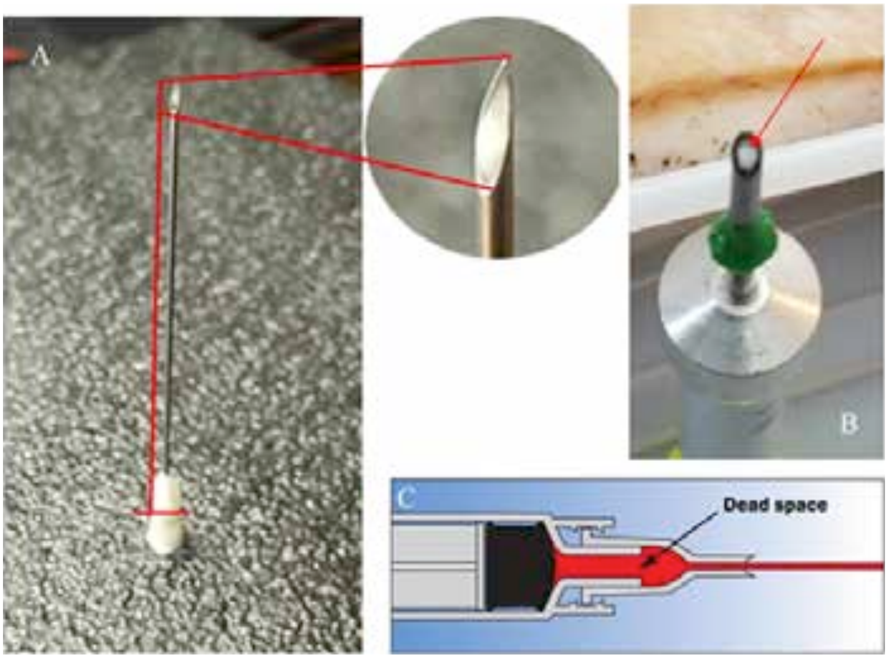

Image 5. Dead space evidence, post-application. A—red indicator, residue in a 76.2mm length transfer needle dead space | B—drug residue in the dart's 31.75mm cannula | C—illustrated dead space (UNC, 2018). © D. Rosenfield

Remote drug delivery systems, with their high precision, reliability of drug delivery, and safety for animals and personnel, may outweigh the potential adverse effects. Overall, our results suggest that RDDS can be used for emulsion-based drug delivery.

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Spanish Resumen: La habilidad para inyectar animales salvajes a distancia, utilizando sistemas de administración remota de medicamentos (RDDS), es una de las más efectivas y humanizadas prácticas en el manejo de la vida silvestre. Varios factores afectan la administración exitosa de medicamentos usando RDDS. Por ejemplo, el cambio de viscosidad, dependiente de la temperatura en fluidos acuosos (newtonianos) o las emulsiones de agua en aceite (no newtonianos), comúnmente usados en tranquilizantes y en vacunas con base de adyuvantes; estos cambios pueden potencialmente resultar en fallas en la administración de los fármacos. Para comprender mejor los impactos debidos a los cambios de viscosidad, investigamos la dinámica de fluidos y balística involucrados en la administración remota de fármacos. Nuestra investigación se dividió en dos fases: en la primera fase investigamos la física viscosimétrica para determinar el comportamiento del fluido a diferentes niveles de temperatura, simulando la temperatura de almacenamiento recomendada (7ºC), además de una temperatura ambiente (20ºC); en la segunda fase, evaluamos la eficacia de la administración de fármacos mediante dardos especializados utilizando un rifle de precisión de CO2 y una cerbatana. Se realizó una evaluación de la eficiencia comparando el volumen de fármaco original con el volumen real inyectado después de disparar el dardo en una piel de cerdo fresca montada en un gel balístico. Antes de la prueba, configuramos la velocidad de impacto mínima requerida para nuestros parámetros y la inyección intramuscular (determinada como > 40 m/s). Todos los despliegues de dardos se comportaron satisfactoriamente, a pesar de las preocupaciones iniciales de una posible entrega incompleta del fármaco. Sin embargo, se observó una pérdida de fármaco notable (~ 10%) asociada al residuo de fármaco en el espacio muerto de la jeringa / dardo y dentro de la aguja de transferencia. Esto podría potencialmente resultar en una dosificación inexacta dependiendo del medicamento utilizado. Por otra parte, el uso de la cerbatana para administración remota de medicamentos (> 3 m) es desaconsejada, especialmente cuando se utilizan dardos especializados, debido a que la velocidad mínima requerida para una penetración adecuada es difícil de alcanzar, además de la pérdida de precisión al apuntar.

Palabras clave: balístico, dardos, inyectable, inmunogénico, sistema de administración remota de fármacos, tranquilizante, vacunas, vida silvestre.

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PLATINUM OPEN ACCESS

COMMUNICATION

Foraging behavior and association with mixed flocks by the Critically Endangered Alagoas Tyrannulet *Phylloscartes ceciliae* (Aves: Passeriformes: Tyrannidae)

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Abstract: The Alagoas Tyrannulet *Phylloscartes ceciliae* is a Critically Endangered species with a restricted distribution to the Atlantic Forest of the Pernambuco Endemism Center. It seems to specialize in using the sally-strike maneuver (68.85%) to catch prey on green foliage (50.82%) and in the air (34.42%). We calculated a catch rate of 2.93 catches/minute, identified a new food item for this species (caterpillars), and included 12 species in the list of birds recorded in mixed flocks with the species. Our results show that majority of the prey capture events by Alagoas Tyrannulet occurred inside tree canopies, thus we can infer that this species needs a more advanced stage of forest sucession, with higher trees, emphasizing the urgency for restoration programs in the region.

Keywords: Atlantic forests, endemic bird, Serra do Urubu, threatened species.

Resumo: O cara-pintada (*Phylloscartes ceciliae*) é uma espécie criticamente ameaçada de extinção com distribuição restrita à Mata Atlântica do Centro de Endemismo Pernambuco. Utiliza preferencialmente a manobra investir-atingir (68,85%) para capturar presas em folhas verdes (50,82%) e no ar (34,42%). Captura em média 2,93 presas/minuto, incluindo lagartas de Lepidoptera (novo item alimentar registrado para a espécie). Registramos doze novas espécies na lista de aves presentes em bandos mistos com *P. ceciliae*. Nossos resultados mostraram que a espécie forrageia preferencialmente no interior das copas de árvores, necessitando de florestas em estágio sucessional avançado, com árvores altas, sendo urgentes ações de restauração em sua área de ocorrência.

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Competing interests: The authors declare no competing interests.

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Author contribution: COAG and TP collected the data in the field and wrote the article.

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INTRODUCTION

Alagoas Tyrannulet *Phylloscartes ceciliae* (Image 1) is a globally threatened species (Critically Endangered; BirdLife International 2020) with a restricted distribution to the Pernambuco Endemism Center (Roda et al. 2011). This bird is found in 13 municipalities in the states of Alagoas and Pernambuco, however within only five protected areas (Roda et al. 2003; BirdLife International 2020; GBIF 2020; WikiAves 2020). Data on this species biology are still scarce. There is only sparse information about the species (e.g., Teixeira 1987; Collar et al. 1992; Roda et al. 2011). Here, we provide the first detailed information about the foraging behavior of *P. ceciliae* and new information about association with mixed flocks.

MATERIALS AND METHODS

Study area. We collected field data mainly in 2009 in Frei Caneca, and Pedra D'Antas Private Reserves (RPPNs) which encompass 1,066ha of protected area, both located at Serra do Urubu Mountains (-8.717S, -35.840W), in Jaqueira and Lagoa dos Gatos municipalities, Pernambuco, northeastern Brazil. The Serra do Urubu Forest Complex is one of the largest remaining areas of montane forest in the state of Pernambuco. Located in a region known as Pernambuco Endemism Center, Serra do Urubu is classified by the Brazilian Ministry of Environment as an area of extreme biological importance and identified by BirdLife International and SAVE Brasil as an Important Bird and Biodiversity Area (IBA) of high priority action. The predominant vegetation is montane dense ombrophilous forest based on the types of vegetation proposed by Veloso (1992) and the altitude varies from 600 to 750 m. We also recorded some information about associations of *P. ceciliae* with mixed flocks between 2010 and 2015. This study is part of the bird monitoring program of Serra do Urubu, conducted annually since 2005.

We actively searched for individuals of *P. ceciliae* from 18–27 November 2009, mainly during 05.00–08.00 h and 16.00–18.00 h, to collect information about the species' foraging behavior. We used the focal-animal method (Altmann 1974; Martin & Bateson 1986)

Image 1. The Alagoas Tyrannulet *Phylloscartes ceciliae*.

following individuals as long as possible and observing their foraging strategies with 10x binoculars. The interval between each observation was five minutes long so that they could be considered as independent samples (according to Alves & Duarte 1996). Any attempt of capture was treated as a sample of foraging behavior, either it was a successful attempt or not, as proposed by Fitzpatrick (1980). We classified the maneuvers according to Remsen & Robinson (1990). Also, we recorded the following parameters for each capture: substrate type (tree, shrub, or herbaceous), substrate characteristics (the presence and type, simple or pinnate, of the green leaves, dry leaves and/or twigs), substrate height, bird position on the substrate (inside/outside the canopy), the site where capture began (features: branches with green/dry leaves or twigs; height; and slope: horizontal = any angle between 0 and 15°, tilt = between 16 ° and 70°, vertical = between 71° and 90°), the site where capture ended (features: branches with green/dry leaves or twigs; height, and slope), the substrate where the prey was captured (air, green foliage, dry foliage, branch, stem, inflorescence; height), the distance between the start and the return perches, the distance from the bird to the prey, the distance from the prey to the new resting place (estimated visually), the height of the site where the prey lay, prey identity (when possible), whether the bird returned or not to the perch of departure, and the maneuver performed to capture. In addition, for aerial maneuvers, we recorded flight slope and direction. Other information on the biology of the species was collected ad libitum (Altmann 1974). The total dataset consisted of 61 foraging samples.

RESULTS

Foraging behavior

The Alagoas Tyrannulet seems to specialize in using the sally-strike maneuver (68.85%; n= 61) to catch prey (n= 61) on green foliage (50.82%) and in the air (34.42%). *P. ceciliae* used mainly branches with green leaves as both starting (68.86%) and return perches (70.49%). The other maneuvers used to catch prey were: reach-up (4.92%), reach-out (13.11%), lunge (4.92%), sally-hover (6.56%), and glean (1.64%). Individuals also captured prey on dry leaves (6.56%), dry branches (4.92%), inflorescences (1.64%), and trunks (1.64%). Among the prey capture substrates, *P. ceciliae* preferred small pinnate leaves, which accounted for 32.72% of the catch substrates, while simple leaves corresponded to 24.59%. The main prey manipulation (n= 61) performed was engulfing (93.44%), followed by gulping (3.28%), beating prey against dry branches (1.64%), and deliverance to another individual (1.64%).

The species also foraged either alone or in pairs, mainly in trees with green leaves (81.97%) 18.10 ± 6.03m high (median= 18m; min.= 8m; max.= 30m), with most capture events occurring inside tree canopies (98.36%). Individuals preferentially used tilted branches as perches of departure (75.41%) and return (70.49%), with the perches of departure being 12 ± 5.36 m high (median= 13.95m; min.= 5m; max.= 25m) and return perches were at 12 ± 5.21 m above ground (median= 13.86m; min.= 5m; max.= 25m). Most flights were also slanted (58.33%), with 64.41% out of them being slanted up while 16.95% were slanted down. On the other hand, 16.95% of flights were horizontal flights, and 1.69% were vertical-up ones. In none of the aerial maneuvers observed did the birds return to the perch after catching the prey. The distance from the initial perch to the return one ranged from 0 to 3.3 m (median= 54.32cm; mean= 50 ± 54.39cm), the distance from the bird to the prey ranged from 2cm to 1m (median= 29.61cm; mean= 30 ± 20.53cm) and the distance from the prey to the new perch ranged from 0 to 3 m (median= 35.68cm; mean= 30 ± 45.09cm).

Phylloscartes ceciliae's successful catch rate was 2.93 catches/minute. In two capture events, it was possible to identify the prey: two caterpillars of approximately 5mm long each. One of them was captured by one individual and delivered to another one on the return perch (25 November 2009). In November 2009, we observed three individuals foraging together, possibly a family group.

Association with mixed flocks

We observed four events in which individuals of Alagoas Tyrannulet accompanied mixed flocks in July (n= 1), November (n= 2), and December (n= 1). The mixed flocks were composed of the following species (the number of flocks in which they are present are in brackets): *Myrmotherula axillaris* (n= 3), *Terenura sicki* (n= 2), *Dysithamnus mentalis* (n= 1), *Herpsilochmus atricapillus* (n= 1), *Ceratopipra rubrocapilla* (n= 1), *Tolmomyias flaviventris* (n= 1), *Cyclarhis gujanensis* (n= 1), *Basileuterus culicivorus* (n= 1), *Coereba flaveola* (n= 1), *Saltator maximus* (n= 1), *Tachyphonus rufus* (n= 1), *Tangara cayana* (n= 1), *Dacnis cayana* (n= 1), *Hemithraupis guira* (n= 2), and *Euphonia violacea* (n= 1). In November 2009, contacts with the other species in mixed flocks corresponded to only 4.54% of the sightings of *P. ceciliae* (n= 44), indicating that this species is not a frequent follower of these flocks.

DISCUSSION

Foraging behavior

The data obtained added new information about the foraging activity of *P. ceciliae*, allowing a more detailed description of the strategies used by this species to catch prey. According to Teixeira (1987), *P. ceciliae* forage on the surface of leaves and branches, where it catches small insects. Collar et al. (1992) reported that this species feeds 6–15 m above ground level, capturing its prey with rapid movements directed to the axial and abaxial leave surfaces.

The foraging height we observed in the current study agrees with other reports for species in the genus *Phylloscartes*, which forage from the lower stratum to the forest canopy where they inhabit (Narosky & Yzurieta 1987; Parker III 1992; Ridgely & Tudor 1994; Willis & Oniki 2003; Fitzpatrick et al. 2004; Sigrist 2005; Maldonado-Coelho 2009). As reported herein, several other species of the genus forage alone, in pairs or small groups, including family groups (Collar et al. 1992; Ridgely & Tudor 1994; Fitzpatrick et al. 2004; Birdlife International 2009). Many species of *Phylloscartes* often catch prey on leaves and/or in the air (see Fitzpatrick et al. 2004). Moreover, the Alagoas Tyrannulet seems to have a preference for capturing prey from small pinnate leaves, as reported by Maldonado-Coelho (2009) for *P. roquettei*.

Collar et al. (1992) recorded the capture of a tettigoniid (Orthoptera) by an individual of *P. ceciliae*, and Teixeira (1987) reports that this bird feeds on small insects. In this study, we report a new food item on *P. ceciliae*'s diet: caterpillars. This item is also present in the diet of other species such as *P. kronei* (Gussoni & Santos 2011), *P. ventralis* (Smith & Betuel 2006), *P. eximius* (Belton 1994), and *P. oustaleti* (Gonzaga et al. 2016). The catch rate is similar to that found for *P. kronei* that catches, on average, 2.12 prey/min (Gussoni & Santos 2011).

Association with mixed flocks

According to Fitzpatrick et al. (2004), all species of the genus *Phylloscartes* accompany mixed bird flocks, however, it is not clear which bird species are associated with *Phylloscartes* species in these groups. Literature reports the presence of species from at least 12 families within mixed flocks with *Phylloscartes* (Teixeira 1987; Collar et al. 1992; Parker III 1992; Gonzaga & Pacheco 1995; O'Neill et al. 2000; Willis & Oniki 2003; Fitzpatrick et al. 2004; Venturini et al. 2005; Bodrati & Cockle 2006; O'Shea et al. 2007; Santos et al. 2009). Teixeira (1987) and Roda et al. (2003) found 19 species in mixed bird flocks with *P. ceciliae*. The current study included 12 new species to the list, totaling 31 species recorded in flocks with the species. As described for *P. kronei* by Gussoni (2010), *P. ceciliae* is not a frequent follower of mixed bird flocks. Other species of *Phylloscartes*, however, may follow such aggregations more often. *P. ventralis*, for example, is regurlarly found among mixed bird flocks, being recorded in 13% of the flocks studied by Ghizoni-Jr. (2009) in Santa Catarina.

The natural history data presented here is valuable to support conservation efforts and possible management actions for this species. It is well known that other species are locally extinct in our study area and two of them are probably extinct in the wild, the Alagoas Foliage-gleaner *Philydor novaesi* and the Cryptic Treehunter *Cichlocolaptes mazarbarnetti*, and others are on the brink of extinction such as the Alagoas Antwren (*Myrmotherula snowi*; known mainly for one site, Murici Ecological Station, nowadays). Unfortunately, the Alagoas Tyrannulet is one of the next candidates to require a recovery plan and our findings are useful for the conservation practioners to design the best management strategies. Also, our results show that the majority of the prey capture events by Alagoas Tyrannulet occurred inside tree canopies, thus we can infer that this species needs a more advanced stage of forest sucession, with higher trees, emphasizing the urgency for restoration programs in the region. Fortunately, there are some actions led by the NGO SAVE Brasil to recover the habitat and bring some hope for these birds on the brink of extinction at Serra do Urubu.

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COMMUNICATION

Ichthyofaunal diversity in the upper-catchment of Kabini River in Wayanad part of Western Ghats, India

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Abstract: We present here a detailed account of the diversity, distribution, threats, and conservation of freshwater fishes in the upper-catchment of the Kabini River in the Wayanad part of the Western Ghats Biodiversity Hotspot. A total of 136 fish species belonging to 13 orders, 29 families, and 69 genera were recorded. Order Cypriniformes dominated with five families, 36 genera, and 84 species, and Cyprinidae was the dominant family represented by 51 species within 21 genera. The true diversity of ichthyofauna in this catchment, is still unclear and requires further exploration and taxonomic studies. At least 44 species recorded during the study are endemic to the Western Ghats, of which 16 are endemic to the Cauvery River System and two species endemic to the Kabini Catchment. A total of 20 non-native fish species were recorded from the study area, of which six species were inter-basin (within India) transplants and 14 species were exotic. Among the native species with confirmed identity, four are Critically Endangered (CR) and nine Endangered (EN) as per the IUCN Red List of Threatened Species. As a part of the study, we also extend the distribution ranges of *Opsarius malabaricus*, *Laubuka trevori*, *Opsarius bendelisis*, *Puntius cauveriensis*, *Oreichthys coorgensis*, *Mesonoemacheilus pambarensis*, *Hypselobarbus curmuca*, and *Pseudosphromenus cupanus* to the Kabini Catchment. The presence of four species, which were earlier considered to be endemic to the west flowing rivers of the Western Ghats, viz, *Laubuka fasciata*, *Hypselobarbus kurali*, *Sahyadria denisonii*, and *Puntius mahecola*, in an east flowing stream is reported and discussed. Deforestation and removal of riparian vegetation, pollution, stream channel modification, sand mining, destructive fishing practices, dams and other impoundments, monsoon fishing, and non-native species are the major threats to freshwater fishes in the region. Strategies for the conservation of aquatic ecosystems in the Kabini Catchment are discussed.

Keywords: Biodiversity hotspot, conservation, freshwater fish, species, taxonomy.

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INTRODUCTION

The Western Ghats of India, a global biodiversity hotspot (together with Sri Lanka) is also the principal watershed of peninsular India (Myers et al. 2000). Rivers and streams of the Western Ghats are exceptionally biodiverse with high levels of endemism (Kottelat & Whitten 1996; Dahanukar et al. 2011). Much of these critical ecosystems, however, are threatened by a range of anthropogenic stressors (Dahanukar et al. 2011; Kumar et al. 2019). Around 340 species of freshwater fishes are known from the Western Ghats till date, of which more than 60% are endemic (Dahanukar & Raghavan 2013).

Despite several studies on freshwater fish fauna of southern Western Ghats, most upstream tributaries of major river systems continue to remain underexplored. Kabini is one of the major tributaries of the east flowing Cauvery River, originating from the Wayanad region of the Western Ghats. Studies on freshwater fishes of Wayanad date back to Jerdon (1847, 1849) and Day (1867) who described several species from the region, but the first comprehensive list of freshwater fishes of Wayanad was compiled only in the 1990s (Shaji & Easa 1995). Three species, viz., *Pethia pookodensis* (Mercy & Jacob 2007), *Pethia nigripinnis* (Knight, Rema Devi, Indra & Arunachalam 2012), and *Dario neela* (Britz et al. 2018), were subsequently described from this region. Most upstream tributaries of Kabini, however, continue to be poorly studied and the diversity and distribution of fish species in the river system has not been investigated in a comprehensive manner over the past two decades. In this paper, we provide an overview of the diversity and distribution of fishes in the upper-catchment region of Kabini in Wayanad, identify threats to the river and its fish species, and suggest conservation plans.

MATERIALS AND METHODS

Study Area

Kabini, also known as river Kapila is an important tributary of Cauvery which waters almost the entire part of the Wayanad Plateau. Kabini is an east flowing eighth order stream with a total basin area of 7,060.362km^2 spread across the southern Indian states of Kerala, Karnataka, and Tamil Nadu. A major part of its catchment area is in Mysore and Chamarajnagar districts of Karnataka. The river flows for around 250km before joining the main Cauvery River at Thirumakudal in Karnataka; however, in Kerala, Kabini is a seventh order stream with a catchment area of only about 1,934.5km^2.

For the present study, the total catchment area of Kabini in Wayanad was further subdivided into six sub-catchments following Wakode et al. (2011). Sub-catchments were selected based on the sixth order tributaries, and the seventh order main stem of Kabini, viz., 1. Panamaram sub-catchment, 2. Mananthavady sub-catchment, 3. Karapuzha sub-catchment, 4. Bavali sub-catchment, 5. Nugu sub-catchment, and 6. Kabini sub-catchment.

Wayanad has a total forest cover area of 907km^2, divided into three major administrative divisions, viz., Wayanad Wildlife Sanctuary (344.44km^2), Wayanad North (214.94km^2), and Wayanad South forest divisions (347.66km^2). The forest patches in various sub-catchment regions of Kabini are represented by 118.9km^2 in the Panamaram sub-catchment, 167.8km^2 in the Mananthavady sub-catchment, 4.7km^2 in the Karapuzha Sub-catchment, 123.2km^2 in the Bavali sub-catchment, 147.1km^2 in the Nugu sub-catchment, and 138.9km^2 in the Kabini sub-catchment. Nagarhole and Bandipur tiger reserves of Karnataka, and Mudumalai Tiger Reserve of Tamil Nadu are the other important protected areas in the Kabini Basin.

Mapping

The drainage basin of Kabini River was digitized prior to the study. For the delineation of catchments and sub-catchments ArcGIS pro software and Arc Hydro tool was used. Cartosat V3.0 data was used for the delineation of the drainage basin. Streams were delineated using Arc Spatial analyst extension and hydrology tool. Drainage channels were ordered according to Strahler's (1957) classification.

Sampling sites and methods

Fish sampling was carried out from March 2014 to March 2020. A total of 89 different stream stretches were selected across various sub-catchments of the Kabini (Image 1), with sampling done at every 500m point of the total stream length (Image 2). GPS co-ordinates at each sampling location was recorded using standard digital GPS reader (Garmin eTrex 30x).

Fish were collected using monofilament gillnets, cast nets and scoop nets of varying mesh size, with the help of local fishers. Traditional fishing techniques like bund making, bamboo cage traps and sieving by cloth were also used in suitable areas. Only a minimum number of fish were collected for identification and the rest were released back into the stream, immediately after capture. Samples were fixed in 5% formaldehyde after

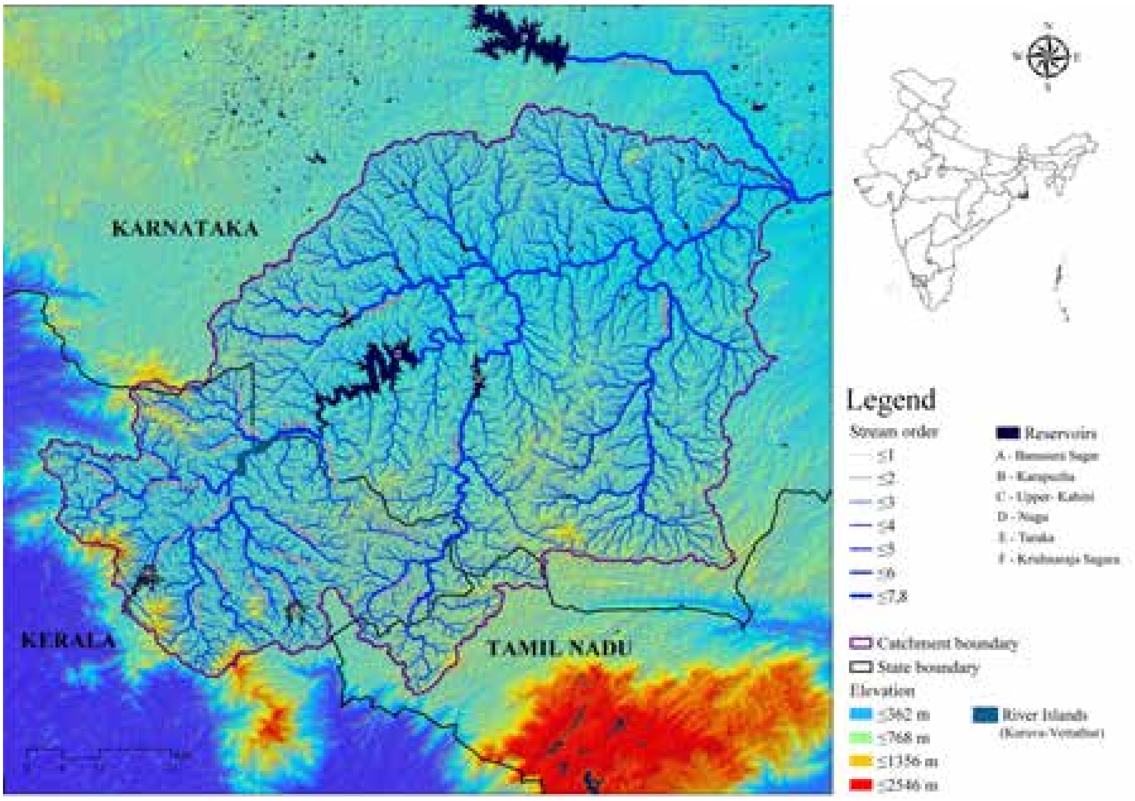

Image 1. The Kabini catchment showing major tributaries and reservoirs.

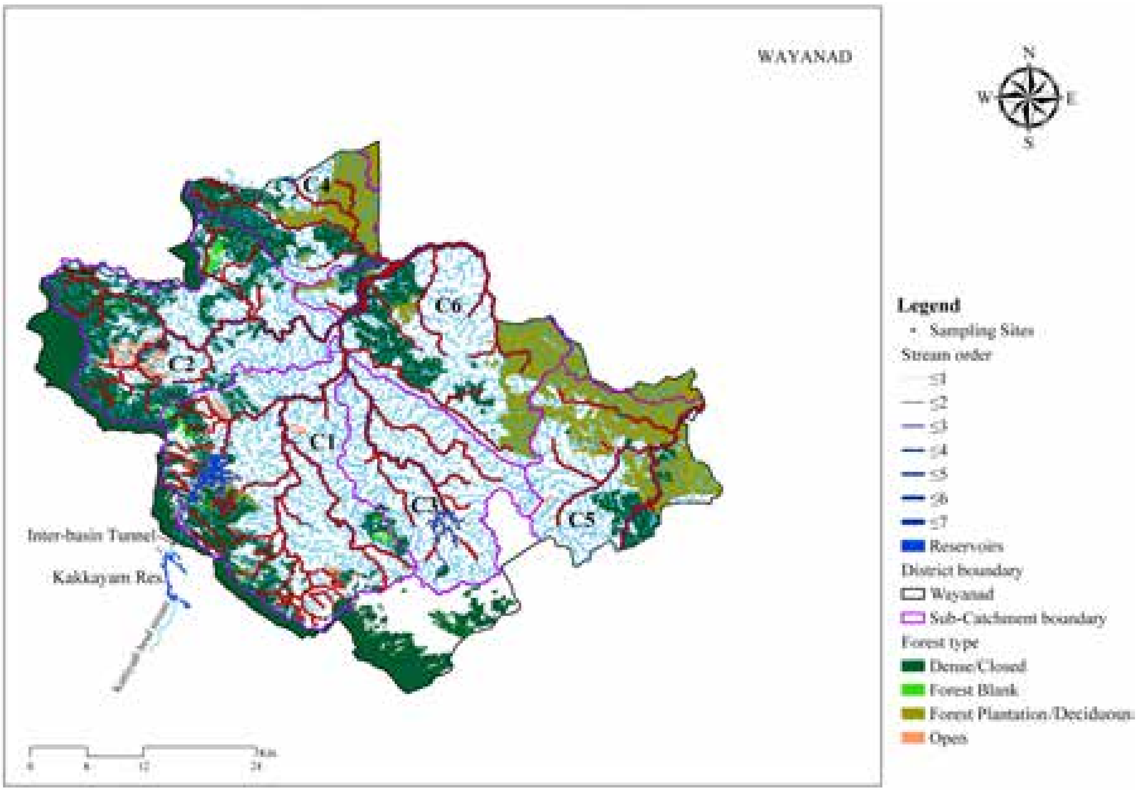

Image 2. Various sub-catchments of Kabini in Wayanad District showing sampling locations and forest cover: C1—Panamaram sub-catchment | C2—Mananthavady sub-catchment | C3—Karapuzha sub-catchment | C4—Bavali sub-catchment | C5—Nugu sub-catchment | C6—Kabini sub-catchment.

anaesthesia with clove oil and later preserved in 70% ethanol. Samples for molecular studies were directly fixed in 80–99 % ethanol. Under the same sampling effort, we categorize records of 10 or less than 10 individual specimens of a species as 'very rare', 10–50 as 'rare', 50–100 as 'moderate', and more than 100 as 'common'. This classification is not based on any standard methodology or literature.

Species identification and morphometry:

Measurements were made with point to point using a digital-callipers to the nearest 0.1mm. Fish were identified by comparing the measurements and counts with the type/type series and/or as mentioned in the original description. Fish identification was confirmed using the relevant taxonomic literature for each group. Collected fish specimens are deposited in the museum collection of the Zoological Survey of India Western Ghats Research Centre, Kozhikode (ZSI WGRC) and the Laboratory of Systematics and Germplasm Conservation, Kerala University of Fisheries and Ocean Studies, Kochi (KUFOS). A few species could be identified only up to the generic level, as they showed significant variations in morphology from the currently known species. Some species which closely resembled known species whose specific status could not be confirmed due to a few marked differences in morphology were labelled with cf. (confusion). Specimens which could not be identified up to species level and some species with confusing identity have not been deposited in the museum collection as further studies on them are in progress, while some other species including most of the non-native species could not be preserved due to different logistic reasons (e.g., large size). We follow Nelson et al. (2016); Tan & Armbruster (2018) for family status while overall taxonomy and nomenclature follows Fricke et al. (2020).

RESULTS AND DISCUSSIONS

Diversity and distribution

A total of 136 fish species belonging to 13 orders, 29 families and 69 genera were recorded from the study area (Table 1). Cypriniformes was the most dominant order with five families, 36 genera and 84 species, followed by Siluriformes with seven families, 11 genera and 21 species. Cyprinidae was the most dominant family represented by 51 species belonging to 21 genera, followed by Danionidae (19 species within eight genera) and Nemacheilidae (11 species within four genera). Lack of detailed taxonomic and systematic revisions have rendered the diversity of several groups of fishes in the Western Ghats to be obscure. The specific identity of 45 species collected during the present study could not be confirmed. We refrain from citing some recent publications in predatory journals following the journal policy (see Raghavan et al. 2015). Among the 91 species with confirmed specific identity, 44 are endemic to the Western Ghats, of which 16 are endemic to the Cauvery River System (Image 15a–d, Image 16e,g,i,k and Image 17a–h) and two species are currently known only from the Kabini Catchment (Image 15a, Image 17g). A total of 20 non-native fish species were also recorded from the study area, of which six species were inter-basin transplants within India, and 14 species were exotic to the country. Among the 74 native species with confirmed specific identity, four are Critically Endangered (CR) (Image 15a–d), nine Endangered (EN), three Vulnerable (VU), four Near Threatened (NT), 44 Least Concern (LC), and one species Data Deficient (DD). The conservation status of a further eight species have not yet been assessed.

Panamaram sub-catchment had the highest species richness (n= 98), followed by Kabini (n= 97) and Mananthavady (n= 90) sub-catchments. Number of threatened species was highest in the Bavali sub-catchment (n= 14), followed by Panamaram sub-catchment (n=13) (Figure 1).

Seventeen species (Table 2) which were earlier reported from Kabini could not be collected during the present study. Voucher specimens of these species are not available and based on the latest taxonomic literature, many are assumed to be misidentifications.

Kabini River Basin, identified as a freshwater Key Biodiversity Area (IUCN 2014) is among the regions of Western Ghats with the highest richness and endemism of freshwater faunal groups (Molur et al. 2011). The present study revealed that the river system is exceptionally rich in ichthyofaunal diversity. The total species richness of 136 is higher than many of the studied rivers in Kerala including the Bharathapuzha (117 species) (Bijukumar et al. 2013), and the Chalakkudy (98 species) (Raghavan et al. 2008). It is also important to note that the present study only surveyed the upper-catchment region of Kabini falling within the state boundary of Kerala and a detailed study in the lower reaches of the river and the tributaries in Karnataka may lead to more species being added into the list.

All six sub-catchment regions of Kabini support good numbers of endemic and threatened fish species, and have equal conservation value. Higher order streams running through forests (Images 6, 7 and 8) supported

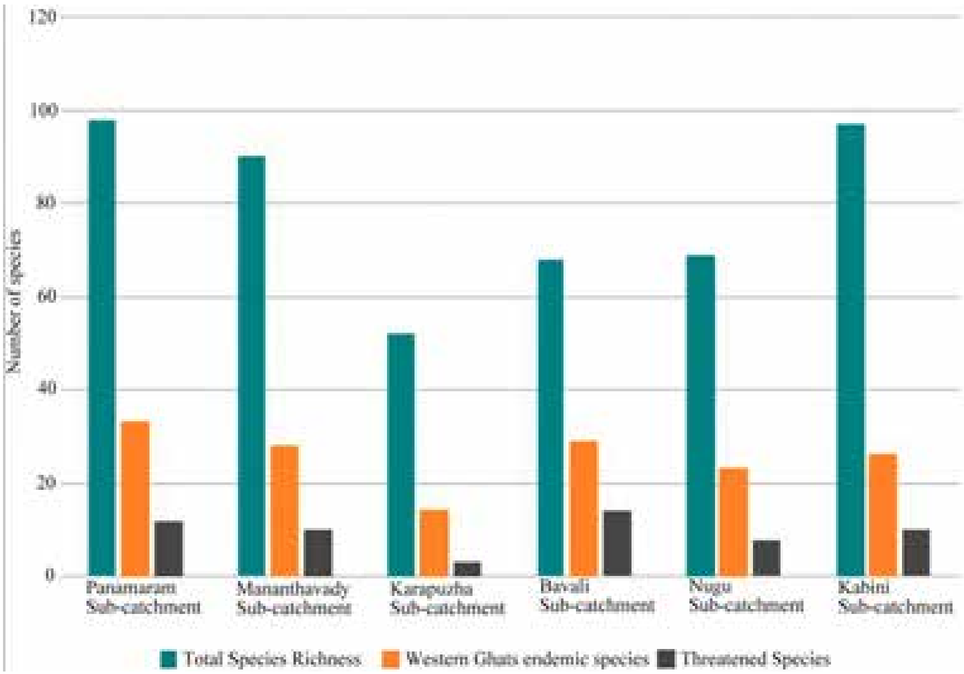

Figure 1. Fish species richness across various sub-catchments of Kabini in Wayanad.

the highest number of species, while several endemic species like *Neolissochilus wynaadensis*, *Pterocryptis wynaadensis*, *Dario neela,* loaches belonging to the family Nemacheilidae and Balitoridae and a few catfishes of the family Sisoridae could be recorded only from the lower order hill streams (Image 3,4 and 5) which are comparatively less disturbed.

Though we studied several streams in the region during the survey span of six years, records of more species are expected and further taxonomic studies are essential for calculating the true diversity of fishes in this region. It was noted that the assemblage and diversity of fishes are greatly dependent on the climatic conditions and vary between seasons, with several species available only during the monsoon.

Range extensions and first records

Our study revealed the presence of several species which were previously not recorded from Wayanad, and from the east flowing river systems. *Laubuka fasciata* (Image 16j), *Hypselobarbus kurali* (Image 16d), *Sahyadria denisonii* (Image 16f), and *Puntius mahecola* (Image 16h) are species considered endemic to the west flowing streams of Western Ghats (Abraham 2011a,b; Raghavan & Ali 2011; Ali et al. 2015). All four species mentioned above were recorded from various locations (Table 3) within the Banasura Sagar Reservoir and could not be collected from any other part of the Kabini catchment. This suggests that the four species could have either been introduced to the reservoir, or might be inter-basin migrants between Kuttiyadi and Kabini rivers, facilitated by a feeder canal which connects the Banasura Sagar Reservoir with the Kakkayam Reservoir built across the west flowing Kuttiyadi River (Image 2). It is currently not understood what the nature and population status of these species inside the reservoir are, as their presence is known only from a few specimens. Juvenile specimens of *H. kurali* and *S. denisonii*, however, were collected during the present study, which confirms that both species are breeding within the reservoir limits. *Sahyadria denisonii* is also one of the most traded ornamental fishes (Raghavan et al. 2018) and therefore the possibilities of introduction of this species into the Kabini Basin by aquarist and breeders needs to be considered. *Laubuka fasciata*, *H. kurali*, and *P. mahecola* are, however, rare native species which are not commonly found in the ornamental fish trade in Kerala, and there are less likely chances of the introduction of these species into the reservoir, further supporting the idea of inter-basin migration. A feeder canal is also suspected to facilitate the movement of fish species endemic to Cauvery River System into the Kuttiyadi Basin (Gopi 2006). There is, however, no conclusive evidence to prove these speculations, and until any further information becomes available, all four species are considered native to the study region.

Table 1. Details of fish species collected from the Upper Catchment region of Kabini River in Wayanad District from March 2014 to March 2020.

Order/Family/Species	[a]Red List Status	Native/ Introduced	Presence in Kabini River System	[b]Endemism	Distribution	Voucher code
Cypriniformes: Danionidae						
Opsarius gatensis (Valenciennes, 1844)	LC	Native	Common	WG	C1, C2, C3, C4, C5, C6	ZSI/WGRC/IR/VER: 3009
Opsarius malabaricus Jerdon, 1849	NA	Native	Very Rare	WG	C1	ZSI/WGRC/IR/VER: 3010
Opsarius bendelisis (Hamilton, 1807)	LC	Native	Very Rare		C5,C6	KUFOS.F.2019.2003
Salmostoma acinaces (Valenciennes, 1844)	LC	Native	Common	PI	C1,C2,C3,C4, C5, C6	KUFOS.F.2019.2004
Salmostoma boopis (Day, 1874)	LC	Native	Moderate	WG	C1,C2,C3,C4, C5, C6	ZSI/WGRC/IR/VER: 3011
Salmostoma balookee (Sykes, 1839)	LC	Native	Common	PI	C1, C2, C3, C4, C5, C6	ZSI/WGRC/IR/VER: 3012
Amblypharyngodon cf. *mola* (Hamilton, 1822)	-	Native	Common		C1,C2,C3,C4, C5,C6	KUFOS.F.2019.2005
Amblypharyngodon melettinus (Valenciennes, 1844)	LC	Native	Rare	PI, SL	C1,C2	ZSI/WGRC/IR/VER: 3013
Laubuka trevori Knight, 2015	NA	Native	Very Rare	WG-CY	C1, C2	KUFOS.F.2019.2006
Laubuka cf. *laubuca* (Hamilton, 1822)	-	Native	Common		C1,C2, C3, C4, C5, C6	KUFOS.F.2019.2007
Laubuka fasciata (Silas, 1958)	VU	Native	Very Rare	WG-KL	C1	ZSI/WGRC/IR/VER: 3015
Danio rerio (Hamilton, 1822)	LC	Native	Common		C1,C2, C3, C4, C5, C6	KUFOS.F.2019.2008
Devario cf. *malabaricus* (Jerdon, 1849)	-	Native	Very Rare		C1, C2	KUFOS.F.2019.2009
Devario sp. 1 ***	-	Native	Rare		C1, C2, C4	
Devario neilgherriensis (Day, 1867)	EN	Native	Very Rare	WG-CY	C5	ZSI/WGRC/IR/VER: 3016
Devario sp.2***	-	Native	Common		C1,C2, C3, C4, C5, C6	
Esomus cf. *thermoicos* (Valenciennes, 1842)	-	Native	Rare		C1, C2, C3, C4, C5	KUFOS.F.2019.2012
Rasbora dandia (Valenciennes, 1844)	LC	Native	Common	PI, SL	C1,C2, C3, C4, C5, C6	ZSI/WGRC/IR/VER: 3017
Rasbora neilgherriensis (Day, 1867) (Thampy et al. 2020)	NA	Native	Very Rare	WG-CY	C5, C6	ZSI/WGRC/IR/VER.3140
Cyprinidae						
Tor khudree (Sykes, 1839)*	-	Transplanted	Rare		C1, C2, C4, C6	
Tor remadevii Kurup & Radhakrishnan, 2011*	CR	Native	Very Rare	WG-CY	C4, C5, C6	
Neolissochilus wynaadensis (Day, 1873)	CR	Native	Rare	WG- CY	C1, C2, C3, C4	ZSI/WGRC/IR/VER: 3018
Neolissochilus sp. ***	-	Native	Very Rare		C6	
Systomus sarana (Hamilton, 1822)	LC	Native	Rare	PI	C6	ZSI/WGRC/IR/VER: 3019
Barbodes carnaticus (Jerdon, 1849)	LC	Native	Moderate	WG	C1,C2, C3, C4, C5, C6	ZSI/WGRC/IR/VER: 3020
Hypselobarbus dubius (Day, 1867)	EN	Native	Very Rare	WG-CY	C4, C5,C6	ZSI/WGRC/IR/VER: 3021
Hypselobarbus micropogon (Valenciennes, 1842)	EN	Native	Very Rare	WG-CY	C1, C2, C4, C5, C6	ZSI/WGRC/IR/VER: 3022
Hypselobarbus kurali Menon & Rema Devi, 1995	LC	Native	Very Rare	WG	C1	ZSI/WGRC/IR/VER: 3023
Hypselobarbus curmuca (Hamilton, 1807)	EN	Native	Very Rare	WG	C4, C6	KUFOS.F.2019.2015
Hypselobarbus sp.***	-	Native	Very Rare		C6	
Dawkinsia rubrotincta (Jerdon, 1849)	NA	Native	Rare	WG-CY	C1,C2, C3, C4, C5, C6	KUFOS.F.2019.2016
Dawkinsia filamentosa (Valenciennes, 1844)	LC	Native	Very Rare		C1,C6	ZSI/WGRC/IR/VER: 3024
Sahyadria denisonii (Day, 1865)	EN	Possibly transplanted	Very Rare	WG	C1	ZSI/WGRC/IR/VER: 3025
Puntius cf. *chola* (Hamilton, 1822)	-	Native	Common		C1,C2, C3, C4, C5, C6	ZSI/WGRC/IR/VER: 3026
Puntius cf. *sophore* (Hamilton, 1822)	-	Native	Common		C1,C2, C3, C4, C5, C6	KUFOS.F.2019.2017
Puntius cauveriensis (Hora, 1937)	EN	Native	Rare	WG-CY	C2, C4, C6	KUFOS.F.2019.2018

Order/Family/Species	[a]Red List Status	Native/ Introduced	Presence in Kabini River System	[b]Endemism	Distribution	Voucher code
Puntius dorsalis (Jerdon, 1849)*	LC	Native	Rare		C6	
Puntius cf. *parrah* Day, 1865	-	Native	Common		C1,C2, C3, C4, C5, C6	KUFOS.F.2019.2019
Puntius mahecola (Valenciennes, 1844)	DD	Native	Very Rare	WG-KL	C1	ZSI/WGRC/IR/VER: 3027
Puntius vittatus Day, 1865	LC	Native	Rare		C1, C2, C4, C6	ZSI-WGRC: 3028
Puntius cf. *bimaculatus* (Bleeker, 1863)	-	Native	Common		C1,C2, C3, C4, C5, C6	KUFOS.F.2019.2020
Puntius cf. *melanostigma* (Day, 1878)***	-	Native	Rare		C1, C2, C6	
Puntius sp. 1***	-	Native	Very Rare		C5	
Waikhomia cf. *sahyadriensis* (Silas, 1953)***	-	Native	Very Rare		C2	
Oreichthys coorgensis (Jayaram, 1982) ***	NA	Native	Very Rare	WG-CY	C6	
Haludaria fasciata (Jerdon, 1849)	LC	Native	Common	WG	C1,C2, C3, C4, C5, C6	ZSI/WGRC/IR/VER: 3029
Pethia pookodensis (Mercy & Jacob, 2007)	CR	Native	Rare	WG-KB	C1,C2, C3, C4, C5, C6	KUFOS.F.2019.2024
*Pethia sp.****	-	Native	Very Rare		C6	
Pethia punctata (Day, 1865)	LC	Native	Rare	WG	C1	ZSI/WGRC/IR/VER: 3030
Pethia conchonius (Hamilton, 1822)	LC	Native	Common		C1,C2, C3, C4, C5, C6	ZSI/WGRC/IR/VER: 3031
Pethia nigripinnis (Knight, Rema Devi, Indra & Arunachalam, 2012)	NA	Native	Common	WG	C1, C2, C4	ZSI/WGRC/IR/VER: 3032
Pethia cf. *sharmai* (Menon & Rema Devi, 1993)***	-	Native	Rare		C6	
Osteochilichthys nashii (Day, 1869)	LC	Native	Rare	WG	C1, C2, C4, C5, C6	ZSI/WGRC/IR/VER: 3033
Kantaka brevidorsalis (Day, 1873)	LC	Native	Rare	WG-CY	C5	ZSI/WGRC/IR/VER: 3034
Cirrhinus mrigala (Hamilton, 1822)*	-	Transplanted	Common		C1,C2, C3, C6	
Gymnostomus ariza (Hamilton, 1807)	NA	Native	Common		C1,C2, C3, C5, C6	ZSI/WGRC/IR/VER: 3035
Bangana cf. *dero* (Hamilton, 1822)	-	Unknown	Common		C1, C2, C6	KUFOS.F.2019.2027
Labeo kontius (Jerdon, 1849)	LC	Native	Very Rare	WG-CY	C6	ZSI/WGRC/IR/VER: 3036
Labeo cf. *potail* (Sykes, 1839)***	-	Native	Very Rare		C5	
Labeo cf. *nigrescens* Day, 1870***	-	Native	Very Rare		C5, C6	
Labeo calbasu (Hamilton, 1822)*	-	Transplanted	Very Rare		C6	
Labeo cf. *boga* (Hamilton, 1822)	-	Unknown	Rare		C1, C2, C6	KUFOS.F.2019.2028
Labeo cf. *porcellus* (Heckel, 1844)	-	Unknown	Rare		C2, C6	KUFOS.F.2019.2029
Labeo rohita (Hamilton, 1822)*	-	Transplanted	Common		C1,C2, C3, C5, C6	
Labeo catla (Hamilton, 1822)*	-	Transplanted	Common		C1,C2, C3, C5 C6	
Cyprinus carpio Linnaeus, 1758*	-	Exotic	Common		C1,C2, C3, C4, C5, C6	
Ctenopharyngodon idella (Valenciennes, 1844)*	-	Exotic	Rare		C3, C6	
Garra stenorhynchus (Jerdon, 1849)	LC	Native	Moderate	WG	C1,C2, C3, C4, C5, C6	KUFOS.F.2019.2030
Garra cf. *mullya* (Sykes, 1839)	-	Native	Common		C1,C2, C3, C4, C5, C6	ZSI/WGRC/IR/VER: 3037
Garra mcclellandi (Jerdon, 1849)*	LC	Native	Rare	WG-CY	C1, C2, C4, C6	
Balitoridae						
Balitora mysorensis Hora, 1941***	VU	Native	Very Rare	WG	C1, C2, C4	
Bhavania australis (Jerdon, 1849)	LC	Native	Common	WG	C1, C2, C4, C5	ZSI/WGRC/IR/VER: 3038
Nemacheilidae						
Paracanthocobitis cf. *mooreh* (Sykes, 1839)	-	Native	Common		C1,C2, C3, C4, C5, C6	KUFOS.F.2019.2031
Schistura cf. *denisoni* (Day, 1867)	-	Native	Rare		C1, C2, C4, C5, C6	KUFOS.F.2019.2032

Order/Family/Species	[a]Red List Status	Native/ Introduced	Presence in Kabini River System	[b]Endemism	Distribution	Voucher code
Schistura cf. *nilgiriensis* (Menon, 1987)	-	Native	Moderate		C1, C2	KUFOS.F.2019.2033
Schistura semiarmata (Day, 1867)	LC	Native	Common	WG	C1,C2, C3, C4, C5, C6	KUFOS.F.2019.2034
Schistura sp. 1***	-	Native	Rare		C1, C2	
Schistura sp. 2***	-	Native	Rare		C2, C4	
Schistura striata (Day, 1867)	EN	Native	Moderate	WG-CY	C1, C2, C4, C5	KUFOS.F.2019.2037
Mesonoemacheilus pambarensis (Rema Devi & Indra, 1994)	VU	Native	Rare	WG-CY	C1, C4	KUFOS.F.2019.2038
Mesonoemacheilus guentheri (Day, 1867)	LC	Native	Common	WG	C1,C2, C3, C4, C5, C6	KUFOS.F.2019.2039
Mesonoemacheilus sp.***	-	Native	Very Rare		C5, C1	
Nemacheilus monilis Hora, 1921	LC	Native	Rare	WG	C1, C2, C4, C5, C6	KUFOS.F.2019.2041
Cobitidae						
Lepidocephalichthys thermalis (Valenciennes, 1846)	LC	Native	Common	PI, SL	C1,C2, C3, C4, C5, C6	ZSI/WGRC/IR/VER: 3038
Siluriformes: Bagridae						
Mystus seengtee (Sykes, 1839)	LC	Native	Common	PI	C1,C2, C3, C4, C5, C6	ZSI/WGRC/IR/VER: 3040
Mystus malabaricus (Jerdon, 1849)	NT	Native	Rare	WG	C2, C6	KUFOS.F.2019.2042
Mystus montanus (Jerdon, 1849)	LC	Native	Common	WG	C1,C2, C3, C4, C5, C6	KUFOS.F.2019.2043
Mystus cf. *armatus* (Day, 1865)***	LC	Native	Very Rare		C5	
Mystus cf. *vittatus* (Bloch, 1794)	-	Native	Common		C1,C2, C3, C5 C6	ZSI/WGRC/IR/VER: 3041
Mystus cf. *bleekeri* (Day, 1877)***	-	Native	Very Rare		C1	
Hemibagrus punctatus (Jerdon, 1849)	CR	Native	Very Rare	WG-CY	C1,C2, C4, C5, C6	ZSI/WGRC/IR/VER: 3042
Batasio sp.***	-	Native	Very Rare		C2	
Siluridae						
Pterocryptis wynaadensis (Day, 1873)	EN	Native	Rare	WG	C1,C2, C4	ZSI/WGRC/IR/VER: 3043
Ompok bimaculatus (Bloch, 1794)	NT	Native	Common		C1,C2, C3, C4, C5, C6	ZSI/WGRC/IR/VER: 3044
Ompok malabaricus (Valenciennes, 1840)	LC	Native	Rare	WG	C5, C6	KUFOS.F.2019.2045
Wallago attu (Bloch & Schneider, 1801)*	NT	Native	Very Rare		C1, C5, C6	
Sisoridae						
Glyptothorax cf. *annandalei* Hora, 1923	-	Native	Moderate		C1,C2, C4, C5	ZSI/WGRC/IR/VER: 3045
Glyptothorax madraspatanus (Day, 1873)***	EN	Native	Very Rare	WG	C4, C5, C6	
Glyptothorax sp. 1***	-	Native	Very Rare		C1, C2, C4	
Glyptothorax sp. 2***	-	Native	Very Rare		C2, C4	
Clariidae						
Clarias gariepinus (Burchell, 1822)*	-	Exotic	Common		C1,C2, C3, C4, C5, C6	
Clarias cf. *dussumieri* Valenciennes, 1840	-	Native	Very Rare		C1, C5	KUFOS.F.2019.2048
Heteropneustidae						
Heteropneustes fossilis (Bloch, 1794)	LC	Native	Moderate		C1,C2, C3, C5, C6	ZSI/WGRC/IR/VER: 3046
Pangasiidae						
Pangasius sp.*	-	Exotic	Rare		C1, C6	
Loricariidae						
Pterygoplichthys sp.*	-	Exotic	Rare		C6	
Cyprinodontiformes: Aplocheilidae						
Aplocheilus lineatus (Valenciennes, 1846)	LC	Native	Common	PI	C1,C2, C3, C4, C5, C6	ZSI/WGRC/IR/VER: 3047

Order/Family/Species	[a]Red List Status	Native/ Introduced	Presence in Kabini River System	[b]Endemism	Distribution	Voucher code
Aplocheilus sp.***	-	Native	Common		C1,C2, C4, C6	
Poecilidae						
Poecilia reticulata Peters, 1859*	-	Exotic	Common		C1, C2, C3, C6	
Xiphophorus maculatus (Günther, 1866)*	-	Exotic	Rare		C6	
Xiphophorus helleri Heckel, 1848*	-	Exotic	Rare		C1	
Synbranchiformes: Mastacembelidae						
Mastacembelus armatus (Lacepède, 1800)	LC	Native	Common		C1,C2, C3, C4, C5, C6	ZSI/WGRC/IR/VER: 3048
Ovalentaria (incertae sedis) : Ambassidae						
Parambassis thomassi (Day, 1870)	LC	Native	Rare	WG	C1,C2, C6	ZSI/WGRC/IR/VER: 3049
Parambassis cf. *ranga* (Hamilton, 1822)	-	Native	Common		C1,C2, C3, C4, C5, C6	ZSI/WGRC/IR/VER: 3050
*Parambassis sp.****	-	Native	Very Rare		C6	
Chanda nama Hamilton, 1822	LC	Native	Common		C1,C2, C3, C4, C5, C6	ZSI/WGRC/IR/VER: 3051
Cichliformes: Cichlidae						
Oreochromis mossambicus (Peters, 1852)*	-	Exotic	Common		C1,C2, C3, C5, C6	
Oreochromis niloticus (Linnaeus, 1758)*	-	Exotic	Common		C1,C2, C3, C4, C5, C6	
Pseudetroplus maculatus (Bloch, 1795)	LC	Native	Common	PI,SL	C1,C2, C6	ZSI/WGRC/IR/VER: 3058
Anabantiformes: Anabantidae						
Anabas cobojius (Hamilton, 1822)*	-	Transplanted	Very Rare		C6	
Pristolepididae						
Pristolepis marginata Jerdon, 1849	-	Native	Rare	WG	C1,C2, C3, C4, C5, C6	ZSI/WGRC/IR/VER: 3052
Pristolepis sp.***	-	Native	Rare		C1, C2, C6	
Channidae						
Channa gachua (Hamilton, 1822)	LC	Native	Common		C1,C2, C3, C4, C5, C6	KUFOS.F.2019.2052
Channa marulius (Hamilton, 1822)	LC	Native	Common		C1,C2, C3, C4, C5, C6	KUFOS.F.2019.2053
Channa striata (Bloch, 1793)	LC	Native	Rare		C1,C2, C6	KUFOS.F.2019.2054
Channa punctata (Bloch, 1793)	LC	Native	Very Rare		C1,C2	KUFOS.F.2019.2055
Badidae						
Dario neela Britz, Anoop & Dahanukar, 2018	NA	Native	Rare	WG- KB	C1, C2	ZSI/WGRC/IR/VER : 2696
Osphronemidae						
Pseudosphromenus cupanus (Cuvier, 1831)	LC	Native	Common		C1,C2, C3, C4, C5, C6	ZSI/WGRC/IR/VER: 3054
Osphronemus goramy Lacepède, 1801*	-	Exotic	Very Rare		C3	
Trichopodus trichopterus (Pallas, 1770)	-	Exotic	Very Rare		C6	ZSI/WGRC/IR/VER: 3055
Gobiiformes: Gobiidae						
Glossogobius giuris (Hamilton, 1822)	LC	Native	Common		C1,C2, C3, C4, C5, C6	ZSI/WGRC/IR/VER: 3053
Osteoglossiformes: Notopteridae						
Notopterus notopterus (Pallas, 1769)	LC	Native	Common		C1,C2, C3, C4, C5, C6	ZSI/WGRC/IR/VER: 3056
Anguilliformes: Anguillidae						
Anguilla bengalensis (Gray, 1831)*	NT	Native	Very Rare		C6	
Beloniformes: Hemiramphidae						
Hyporhamphus cf. *limbatus* (Valenciennes, 1847)	-	Native	Common		C1,C2, C6	KUFOS.F.2019.2057

Order/Family/Species	[a]Red List Status	Native/ Introduced	Presence in Kabini River System	[b]Endemism	Distribution	Voucher code
Belonidae						
Xenentodon cancila (Hamilton, 1822)	LC	Native	Rare		C1, C6	ZSI/WGRC/IR/VER: 3057
Characiformes: Serrasalmidae						
Piaractus brachypomus (Cuvier, 1818)*	-	Exotic	Rare		C1, C2, C6	
Polypteriformes: Polypteridae						
Polypterus sp.	-	Exotic	Very Rare		C6	KUFOS.F.2019.2058

[a] Endemism: WG—Western Ghats | PI—Peninsular India | SL—Sri Lanka | KL—Kerala | CY—Cauvery River System | KB—Kabini Catchment.
[b] IUCN Red list Categories: CR—Critically Endangered | EN—Endangered | VU—Vulnerable | NT—Near Threatened | DD—Data Deficient | NA—Not Assessed
c—Catchments: C1—Panamaram Sub-catchment | C2—Mananthavady Sub-catchment | C3—Karapuzha Sub-catchment | C4—Bavali Sub-catchment | C5—Nugu Sub-catchment | C6—Kabini Sub-catchment.
*—specimens not preserved | ***—specimens not submitted as further studies are in progress.

Opsarius malabaricus (Image 16a), described from northern Malabar was considered as a synonym of *Opsarius bakeri* until Knight et al. (2015), cleared the identity of the two species, based on collections from west flowing Payaswini and Valapattanam rivers of Kasargod and Kannur districts. Ten specimens of this species were collected from two locations (Table 3), within the catchment area of Banasura Sagar Reservoir, where they are rarely seen.

Laubuka trevori (Image 16e), is a recently described species from the Cauvery Catchment in Coorg District of Karnataka. This species was recorded from four different locations (Table 3) within the Kabini Catchment, extending the range of this species to the Kerala part of the Western Ghats.

In Kerala, *Opsarius bendelisis* (Image 16c) is known only from Chinnar and Pambar rivers of Amaravati Catchment in Idukki District (Easa & Shaji 1996). Our study confirms the range extension of this species to northern Kerala and for the first time from the Kabini Catchment.

Puntius cauveriensis (Hora, 1937) (Image 16i) is an endangered barb, endemic to the Cauvery River System in Karnataka, with records from Ithipuzha and Malampuzha in west flowing Bharathapuzha requiring confirmation (Shaji 2011). In our study, we recorded *P. cauveriensis* from seven different locations (Table 3) within the Kabini Catchment extending the range of this species to the Kerala part of Western Ghats.

Oreichthys coorgensis (Image 16g) is a poorly known species of small barb known only from the upper reaches of the Cauvery River in Coorg District of Karnataka (Knight & Kumar 2015). We report the range extension of this species to the Kerala part of Western Ghats with specimens collected from a single location (Table 3) within Kabini Catchment.

Pethia pookodensis (Image 15a) is a Critically Endangered small-sized barb endemic to Wayanad, with confirmed records only from the Pookode Lake in Wayanad, the type locality (Ali & Raghavan 2015). During our study, the species was recorded from all the sub-catchments of Kabini, confirming their occurrence outside the type locality, and its wide distribution range. A reappraisal of the conservation status of the species is hence required.

Mesonoemacheilus pambarensis (Image 16k), currently known only from Chinnar and Pambar rivers of Amaravati Catchment in Kerala, and from the Bhavani River in Tamil Nadu (Anoop et al. 2018) was collected from four different locations (Table 3) in Wayanad, extending the range of this species to northern Kerala.

Hypselobarbus curmuca (Image 16b) and *Pseudosphromenus cupanus* (Image 16l), which were not recorded from Wayanad in previous ichthyofaunal studies were recorded in our study. *Hypselobarbus curmuca* was found be to be very rare in Kabini with records only from two locations (Table 3), while *Pseudosphromenus cupanus* is widely distributed in the basin with records from all the major tributaries of Kabini.

Major threats

Deforestation and removal of riparian vegetation (Image 9), pollution (Image 13), stream channel modification, sand mining, destructive fishing practices, dams & other impoundments, monsoon fishing, and non-native species are the major threats to freshwater fishes in the region. Riparian vegetation along Kabini and its major tributaries are severely disturbed, and in many cases totally destroyed. Over the past few decades, the natural vegetation across many of the streams has been cleared for agricultural plantations and construction.

Image 3. Upstream tributary of Periya River in Mananthavady sub-catchment. © Dencin Rons Thampy.

Image 4. Riparian vegetation across Lakkidipuzha, an upstream tributary of Venniyodupuzha in Panamaram sub-catchment. © Dencin Rons Thampy.

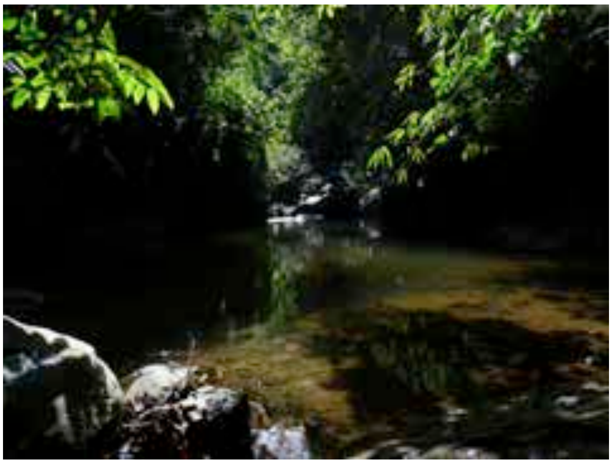

Image 5. Shade in stream habitat, riffle-pool ecosystem in Chathankunduthodu, an upstream tributary of Venniyodupuzha in Panamaram sub-catchment. © Dencin Rons Thampy.

Image 6. Nulpuzha tributary of Nugu sub-catchment in Wayanad Wildlife Sanctuary. © Dencin Rons Thampy.

Image 7. Deep pool ecosystem in a distributary of Kabini River in Kuruva-Vettathur River Islands, Kabini sub-catchment. © Dencin Rons Thampy.

Image 8. Shallow run ecosystem with boulder-bedrock substrates, distributary of Kabini at Kuruva-Vettathur River Islands, Kabini sub-catchment. © Dencin Rons Thampy.

Table 2. Details of fish species reported from Kabini Catchment in the literature, which were not recorded during the present study.

	Species name	Author	Remarks
1	*Sperata aor* (Hamilton, 1822)	Arunachalam et al. 2000a, 2000b	Not recorded during the present study
2	*Puntius amphibius* (Valenciennes, 1842)	Easa & Basha 1995; Shaji & Easa 1995; Easa & Shaji 1997; Shaji & Easa 1998, Arunachalam et al. 2000b & Kurup et al. 2004	Possible misidentification with *Puntius mahecola* or another *Puntius* sp., the specific identity of which could not be confirmed
3	*Parambassis baculis* (Hamilton, 1822)	Arunachalam et al. 2000a	Not recorded during the present study
4	*Opsarius bakeri* (Day, 1865)	Kurup et al. 2004	Likely to be *Opsarius malabaricus*
5	*Opsarius canarensis* (Jerdon, 1849)	Arunachalam & Manimekalan 2000b	Likely to be *Opsarius malabaricus*
6	*Tariqilabeo latius* (Hamilton, 1822).	Kurup et al. 2004	Not recorded during the present study
7	*Glyptothorax lonah* (Sykes, 1839)	Kurup et al. 2004	Possible miss misidentification with *Glyptothorax sp.* 2, the specific identity of which could not be confirmed
8	*Mystus oculatus* (Valenciennes, 1840)	Kurup et al. 2004	Not recorded during the present study
9	*Indoreonectes evezardi* (Day, 1872)	Kurup et al. 2004	Not recorded during the present study
10	*Mesonoemacheilus petrubanarescui* (Menon, 1984)	Easa & Basha 1995; Shaji & Easa 1995; Kurup et al. 2004	Possible misidentification with another similar looking species of *Mesonoemacheilus*, the specific identity of which could not be confirmed
11	*Tor putitora* (Hamilton, 1822)	Kurup et al. 2004	Likely to be *Tor remadeviae*
12	*Dawkinsia arulius* (Jerdon, 1849)	Easa & Basha 1995; Shaji & Easa 1995; Arunachalam & Manimekalan 2000a	Likely to be *Dawkinsia rubrotincta*
13	*Esomus danrica* (Hamilton, 1822)	Easa & Basha 1995; Shaji & Easa 1995b	Likely to be *Esomus* cf. *thermoicos*
14	*Pethia ticto* (Hamilton, 1822)	Easa & Basha 1995; Shaji & Easa 1995; Arunachalam & Manimekalan 2000b	Possible misidentification with *Pethia nigripinnis* or another *Pethia sp.*, the specific identity of which could not be confirmed
15	*Hypselobarbus thomassi* (Day, 1874)	Easa & Shaji 2003	Not recorded during the present study
16	*Hypselobarbus periyarensis* (Raj, 1941)	Arunachalam et al. 2000b	Possible misidentification, as the species is currently considered endemic to the Periyar River Basin (Ali & Raghavan, 2011)
17	*Batasio travancoria* Hora & Law, 1941	Arunachalam & Manimekalan 2000b	Mentioned as *Batasio* sp. in the present study

The Kuruva-Vettathur River Islands (Images 1,7 and 8) is the only region in the Kabini main stem where the riparian vegetation is currently intact. Similarly, the stream stretches running through reserved forests and protected area network are the only reaches with intact or less disturbed riparian buffer. Most of the stream stretches outside forests are severely disturbed, with riparian vegetation completely removed, particularly evident in Panamaram, Karapuzha, and Mananthavady sub-catchments. Loss of forest cover negatively impacts freshwater fish and several other faunal groups, since the nutrient cycle in stream ecosystems are regulated by a healthy riparian buffer (Vannote et al. 1980; Junk et al. 1989; Pusey & Arthington 2003). In addition, several freshwater fish species in the Western Ghats exploit allochthonous food resources and use the flooded riparian forests as spawning grounds (Arunachalam 2000). Canopy cover is also important in regulating stream water temperature which in turn plays an important role in the distribution of fish communities (Marsh-Matthews & Matthews 2000).

Indiscriminate sand and gravel mining poses irreparable damage to habitats in the Kabini. Even the smallest stream stretches in the region are exploited for sand. Large scale destruction of river beds due to sand mining for commercial purposes are evident in Panamaram River, Mananthavady River, and Kabini main stem (Image 12). Sand mining-related stream bank modifications resulted in mass failure of stream banks in several locations during the floods of 2018 and 2019.

Heavy siltation of streams due to deforestation and sand mining which modify the stream beds directly affects several endemic species as it degrades their breeding substrates (Dahanukar et al. 2011). Hill stream loaches of the families Balitoridae, Cobitidae, and Nemacheilidae, and several species of cyprinids including the Critically Endangered *Neolissochilus wynaadensis* and *Tor remadevii* are particularly vulnerable to siltation.

Indiscriminate fishing, often using destructive practices such as dynamiting and poison fishing is

Table 3. Details of sampling locations of the species recorded for the first time in Kabini Basin.

	Species	Details/ GPS co-ordinates of locations
1	*Laubuka fasciata*	11.597°N, 75.926°E to 11.670°N, 75.958°E
2	*Hypselobarbus kurali*	11.597°N, 75.926°E to 11.670°N, 75.958°E
3	*Sahyadria denisonii*	11.597°N, 75.926°E to 11.670°N, 75.958°E
4	*Puntius mahecola*	11.597°N, 75.926°E to 11.670°N, 75.958°E
5	*Opsarius malabaricus*	11.636°N, 75.926°E & 11.616°N, 75.929°E
6	*Laubuka trevori*	11.910°N, 75.984°E;11.845°N, 75.939°E; 11.827°N, 75.840°E &11.532°N, 76.025°E
7	*Opsarius bendelisis*	11.808°N, 76.095°E; 11.846°N, 76.120°E & 11.706°N, 76.396°E
8	*Puntius cauveriensis*	11.747°N, 76.128°E; 11.777°N, 75.925°E; 11.831°N, 76.093°E; 11.852°N, 76.128° E; 11.862°N, 76.098°E; 11.862°N, 76.204°E & 11.827°N, 76.209°E
9	*Oreichthys coorgensis*	11.829°N, 75.094°E
10	*Mesonoemacheilus pambarensis*	11.909°N, 75.985°E; 11.843°N, 76.113°E; 11.837°N, 75.817°E & 11.352°N, 76.025°E
11	*Hypselobarbus curmuca*	11.833°N, 76.095°E & 11.859°N, 76.101°E
12	*Pseudosphromenus cupanus*	Widely distributed: All the major tributaries and the main stem of Kabini in Wayanad.

Image 9. Main stem of the Kabini with severe disturbance to riparian vegetation. © Dencin Rons Thampy.

Image 10. "Vayals" or grassy swamp-lands are sites where many lower order streams originate, and are spawning grounds for several fish species. © Dencin Rons Thampy.

Image 11. Local tribal communities engaged in fishing using traditional method of bund making during the drought period, from Chekadi, Kabini sub-catchment. © Dencin Rons Thampy.

Image 12. Sand mining in Kolavally, Kabini sub-catchment during the drought period. © Dencin Rons Thampy.

observed in almost all the major sub-catchments of Kabini. Monsoon triggers the local migration of several fish species from large rivers into smaller streams, flooded marsh lands (Image 10), paddy fields and riparian forests, which serves as their spawning grounds. This mass movement of fishes is locally called 'ootha or ootha keattam" (Shaji & Laladhas 2013). Many of the migratory routes, mostly at the mouths of smaller seasonal streams are blocked and large numbers of spawning individuals are caught. Fishing during ootha, though banned by the Government of Kerala, is seldom

Image 13. Sewage disposal into river through underground tunnel. Kabini sub-catchment from Palvelicham. © Bibin Paul M.

Image 14. Flood in Kabini River; Photo taken from Chekadi, Kabini sub-catchment. © Dencin Rons Thampy.

Image 15 (a–d). Critically Endangered fish species from the Upper Kabini Catchment: a—*Pethia pookodensis* | b—*Neolissochilus wynaadensis* | c—*Tor remadevii* | d—*Hemibagrus punctatus*. © a,c—Dencin Rons Thampy | b—Abhijith T.V. | d—Rahul G. Kumar.

enforced, and is one of the major factors resulting in the decline and extirpation of several fish species.

Exotic fish species pose serious threats to the fish fauna of Kabini, especially to those having low population sizes and narrow distribution. *Cyprinus carpio*, *Ctenopharyngodon idella*, *Clarias gariepinus*, *Pterygoplichthys* sp., *Oreochromis mossambicus*, *O. niloticus*, *Poecilia reticulata*, and *Xiphophorus helleri* are invasive species as per the IUCN Global Invasive Species Database (2020). *Oreochromis niloticus*, *Clarias gariepinus*, *Poecilia reticulata*, and *Cyprinus carpio* are now well established, and widely distributed in the Kabini Basin. Occurrence of the bichir (*Polypterus* sp.) (Image 18) in the Kabini River system is known only from the collection of seven individuals during the 2018 monsoon. Similarly, species such as *Osphronemus goramy*, *Trichopodus trichopterus*, *Pterygoplichthys* sp., and *Xiphophorus helleri* were also collected only during the post flood period of 2018 and could be attributed to their escape from private aquaculture facilities during the flood. Flood-associated inundation of fish farms and other aquaculture facilities is identified as one of the major factors facilitating the introduction of several exotic species into rivers and other open water sources (Casimiro et al. 2018; Bijukumar et al. 2019).

Climate change is also accelerating the decline of fish diversity in the Kabini catchment. Kabini experienced severe shortage of water during the summers of 2017, 2018, and 2019 (Image 11), and also experienced massive floods during the monsoons of 2018 and

Image 16 (a to l). Fish species recorded for the first time from the Kabini Catchment: a—*Opsarius malabaricus* | b—*Hypselobarbus curmuca* | c—*Opsarius bendelisis* | d—*Hypselobarbus kurali* | e—*Laubuka trevori* | f—*Sahyadria denisonii* | g—*Oreichthys coorgensis* | h—*Puntius mahecola* | i—*Puntius cauveriensis* | j—*Laubuka fasciata* | k—*Mesonoemacheilus pambarensis* | l—*Pseudosphromenus cupanus*. © a—Anandu V | c,g—Rahul G. Kumar | b,d,e,f,h,i,j,k,l—Dencin Rons Thampy.

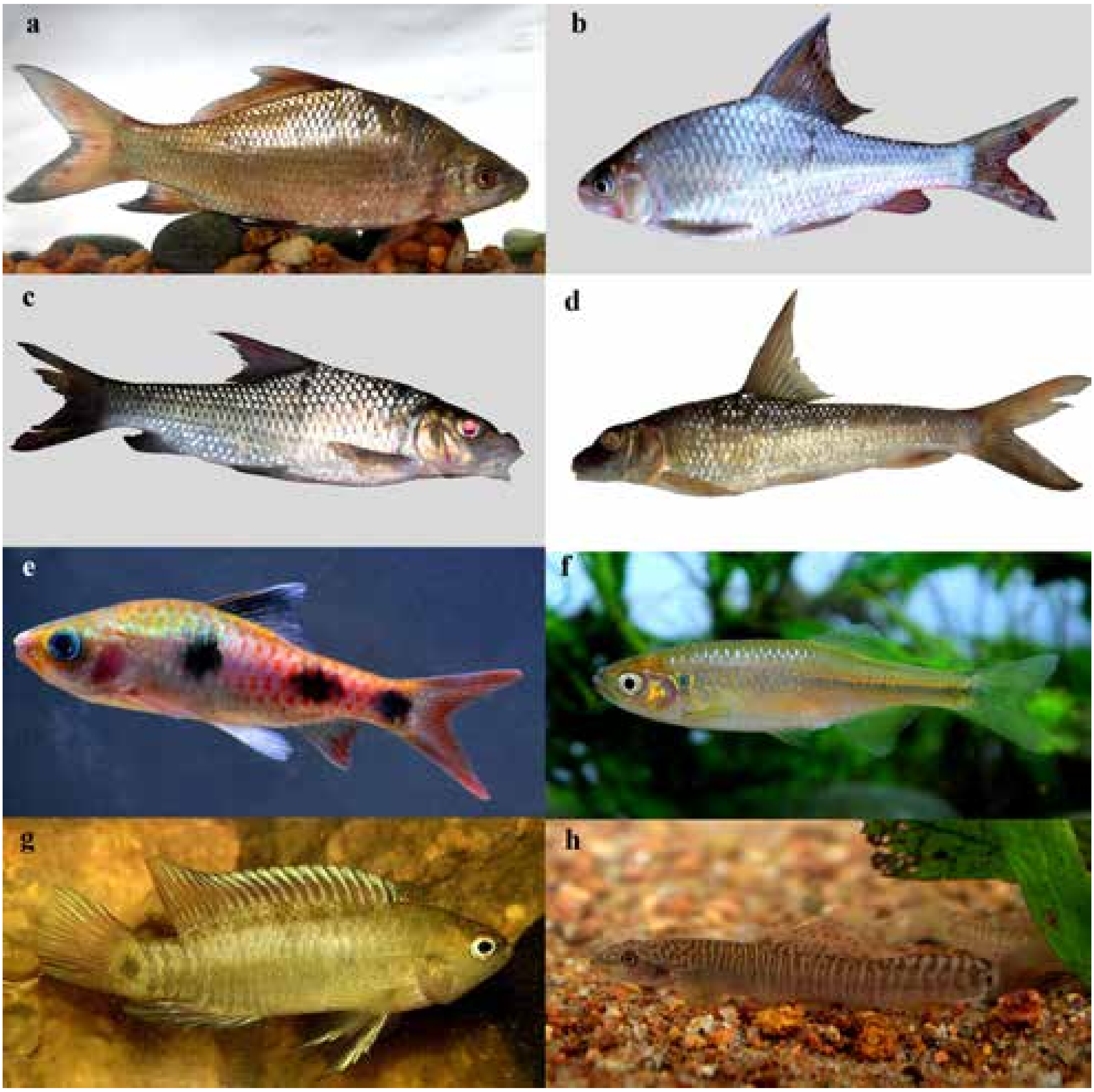

Image 17 (a–h). Endemic fish species of the Cauvery Basin: a—*Labeo kontius* | b—*Kantaka brevidorsalis* | c—*Hypselobarbus micropogon* | d—*Hypselobarbus dubius* | e—*Dawkinsia rubrotincta* | f—*Devario neilgherriensis* | g—*Dario neela* | h—*Schistura striata*. © a,b,f,g,h—Dencin Rons Thampy | c,d—Abhijith T.V. | e—Subin Yacob

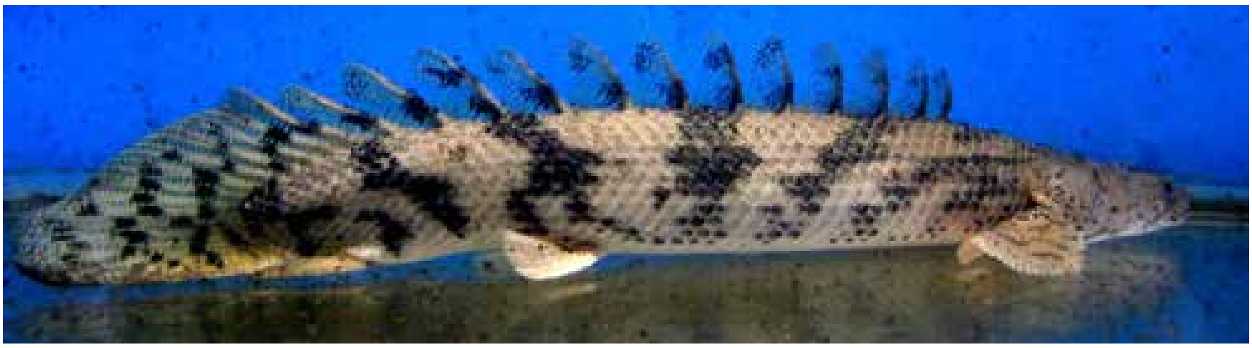

Image 18. *Polypterus* sp. from the Kabini catchment, an example for post-flood escapees. © Dencin Rons Thampy.

2019 (Image 14). Extreme climatic events increase the susceptibility of freshwater fishes to infections and disease outbreaks (Lopez et al. 2010), which was evident during the summer and post flood months of 2018 and 2019, when bacterial disease outbreaks resulted in widespread mortality of fishes at several locations in the Kabini catchment.

Conservation measures

Streams and rivers across the Kabini Catchment are severely threatened by a range of anthropogenic activities, leading to the fragmentation of available habitats. For the effective conservation of aquatic species in the river basin, a landscape-scale conservation strategy should be implemented, such that the complexity and diversity of the watershed is maintained. Longitudinal and lateral drainage network connections including lower order streams, head-water tributaries, upper-slope areas, wetlands and flood plains in the region should be maintained to provide un-obstructed corridors, to satisfy the life history requirements of several endemic species. River protection should be taken as a priority issue by the District Environmental Impact Assessment Authority (DEIAA) before giving clearances for activities such as mining, waste disposal plants and construction. To stop further ecological degradation of the river, we recommend that clearance should not be given to any large-scale constructional activities along the stream stretches, which includes dams, buildings and roads.

Structural diversity and species integrity of plant communities in wetland and riparian zones within the catchment should be conserved and the continuity of riparian forests can be maintained via restoration of degraded landscapes. Eco-restoration of the river can be initiated by the local self-governments by collaborating with non-governmental organizations, educational institutes and other public bodies like the Vana Samrakshana Samithi of the state forest and wildlife department.

It is also important to maintain the physical integrity of the ecosystems which include stream banks, shorelines and substrates. Regular monitoring of river sand extraction, recording the severity of extraction and periodic environmental auditing could prevent further degradation of river beds. Immediate actions are to be taken by the government to stop illegal sand mining in the region. Large scale conversion of floodplains and marshes for construction and unsustainable farming practices should be prohibited by strict implementation of the available laws. Actions should also be taken to stop the disposal of sewage water and domestic wastes into the river system.

Destructive fishing practices and indiscriminate harvest of fishes in Kabini, especially during the breeding seasons should be completely prohibited. The official ban on dynamiting and poisoning should be reinforced by the concerned authorities. Seasonal streams and marshes adjacent to the main river channels should be protected to secure the migratory corridors and spawning grounds of several native species.

Immediate actions are also to be taken to control the populations of exotic and invasive species in the river system and the introduction of new non-native species should be prevented. Farming and cultivation of non-native species in the regions adjacent to river channels should not be promoted, and parties associated with such activities have to be made aware of the issue.

Designation of river reaches in reserved forest areas as fish sanctuaries or river sanctuaries with elevated protection level will also help in conserving the habitat and the species. Kuruva-Vettathur River Island region (image 1) in the Kabini main stem is a potential site which can be declared a riverine sanctuary.

Conservation and management of aquatic environments in the Kabini Basin require research involving inter-disciplinary approaches aimed at understanding the various aspects of landscape evolution, biodiversity and socio-economic vulnerability. Awareness campaigns involving researchers, students, farmers, fishing communities and other stakeholders can be arranged at local levels to create a network of people who can be employed for long-term monitoring and restoration of ecosystems.

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Author contributions: DRT, conceived the idea; DRT, MBP and MRS conducted field surveys; DRT and CPS did taxonomic studies; DRT developed the manuscript with the inputs from MBP and CPS; MRS developed the maps for the study; CPS was in charge of overall direction and planning.

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COMMUNICATION

Herpetofaunal inventory of Van Province, eastern Anatolia, Turkey

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Abstract: In this study, amphibian and reptile diversity in the province of Van (eastern Anatolia, Turkey) was surveyed. For this purpose, four herpetological excursions (20 days in total) were conducted covering all the districts of the province in 2014. In this paper, up-to-date herpetofaunal inventory of Van Province, including two urodelian, four anuran, two chelonian, 15 saurian (lizards), and 14 ophidian (snakes) species (six amphibians and 31 reptiles in total) is presented. To the best of our knowledge, *Salamandra infraimmaculata*, *Heremites auratus, Dolichophis jugularis, Eirenis modestus,* and *Telescopus fallax* were recorded for the first time in the province of Van. Additionally, the first published print record of *Stellagama stellio* in Van Province is presented. The major threat to the herpetofaunal diversity in surveyed habitats was found as human-origin habitat degradation. With the georeference database obtained in this study, it will be possible to determine the actual distribution ranges of the species and to guide decision-makers. The results of the study will provide a useful basis for future monitoring studies and distribution information will contribute to the conservation of the species of interest.

Keywords: Amphibia, biodiversity, check-list, distribution, new record, Reptilia.

Abbreviations: CITES—The Convention on International Trade in Endangered Species of Wild Fauna and Flora | DD—Data Deficient | GPS—Geographical Positioning System | IUCN—The International Union for Conservation of Nature and Natural Resources | LC—Least Concern | NE—Not Evaluated | NT—Near Threatened | VU—Vulnerable | WGS84—World Geodetic System of 1984.

Turkish: Bu çalışmada, Van ilinin (Doğu Anadolu, Türkiye) kurbağa ve sürüngen biyoçeşitliliği araştırılmıştır. Bu amaçla, 2014 yılında tüm ilçeleri kapsayacak şekilde toplam 20 gün olmak üzere dört arazi çalışması gerçekleştirilmiştir. Bu yayında Van iline ait güncel herpetofauna envanteri sunulmaktadır. Elde edilen verilere göre güncel olarak Van ilinde iki kuyruklu kurbağa, dört kuyruksuz kurbağa, iki kaplumbağa, 15 kertenkele ve 14 yılan olmak üzere toplam altı amfibi ve 31 sürüngen türü bulunmaktadır. *Salamandra infraimmaculata*, *Heremites auratus, Dolichophis jugularis, Eirenis modestus* ve *Telescopus fallax* türleri bu çalışma ile Van'dan ilk defa kaydedilmiştir. Ayrıca daha önce Van ilinden fotoğraf ile kaydedilen *Stellagama stellio* ise basılı makale kaydı olarak ilk kez verilmiştir. Çalışma yapılan habitatlarda herpetofauna çeşitliliğini tehdit eden en önemli faktör insan kaynaklı habitat parçalanması olarak bulunmuştur. Bu çalışmada elde edilen coğrafi referans veri tabanı ile türlerin güncel dağılışlarının belirlenmesi mümkün olacaktır ve bu veriler karar-vericileri yönlendirecektir. Çalışmanın sonuçları gelecekte yapılacak izleme çalışmaları için temel oluşturacaktır ve dağılış verileri türlerin koruma planlarına katkı sağlayacaktır.

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Note: Preliminary results of this study was presented in 12th National Ecology and Environment Congress, held in Muğla, Turkey between the dates 14–17 September 2015.

INTRODUCTION

Amphibians and reptiles are important parts of various ecosystems and make up a considerable part of the global vertebrate diversity. Their central role is to maintain the energy flow and nutrient cycling between trophic levels (Valencia-Aguilar et al. 2013). Additionally, as they depend on the habitat microstructure, they are good indicators to monitor the ecosystem health (Budak & Göçmen 2008). Therefore, inventory and monitoring amphibian and reptile diversity are important to assess the species' population statuses and provide useful information for ecosystem management (Morrison et al. 2008). The identification and protection of any species are constrained by the lack of information regarding the abundance, distribution, and habitat requirements of the threatened species (Smith et al. 1997). The course of future management strategies for the threatened species depends on this type of baseline information (Blamford & Gaston 1999) that comes from the inventory and monitoring studies (Morrison et al. 2008). Short-term monitoring studies are more feasible and draw a general framework for a species or habitat, while long-term monitoring studies produce more valuable data allowing to assess the change in ecological communities over time. Both approaches are essential for developing evidence-based species conservation programs (Smith et al. 1997; Blamford & Gaston 1999; Morrison et al. 2008; Magurran et al. 2010).

Turkey has a very rich floral and faunal diversity due to its special biogeographical features which makes this region one of the important intersections of biodiversity hotspots (Ambarlı et al. 2016; Gür 2016). Herpetofauna surveys have been conducted in Turkey by many researchers (Venzmer 1922; Bird 1936; Bodenheimer 1944; Clark & Clark 1973; Başoğlu & Baran 1977, 1980; Başoğlu et al. 1994; Baran & Atatür 1998; Eksilmez et al. 2017; Avcı et al. 2018; Yıldız et al. 2019; Akman et al. 2020; Gidiş & Başkale 2020; Üçeş & Yıldız 2020). Many new findings, especially after 2000, provided the most recent information and revealed the rich herpetofauna diversity of Turkey (e.g., Sindaco et al. 2000; Baran et al. 2004; Göçmen et al. 2007; Yıldız et al. 2007; Hür et al. 2008; Göçmen et al. 2009; Afsar and Tok 2011; Akman et al. 2013; Göçmen et al. 2013a,b, 2014; Cihan & Tok 2014; Tok & Çiçek 2014; İğci et al. 2015; Yıldız & Iğci 2015; Akman et al. 2016; Kumlutaş et al. 2017; Sarıkaya et al. 2017; Akman et al. 2018; Avcı et al. 2018; Yıldız et al. 2018a,b; Mebert et al. 2020; Üçeş & Yıldız 2020; Yıldız 2020).

East Anatolian region is a transitional zone between the continents, and its high mountainous structure produces different types of habitats for the flora and fauna elements. These special features make the region one of the hotspots for biodiversity (Şekercioğlu et al. 2011; Ambarlı et al. 2016). Van Province is located in eastern Turkey and on the closed basin of Lake Van, the largest lake of the country. Van is surrounded by high mountains; 53% of the province consists of mountains, 33% of plateaus, and 14% of the plains, approximately. High mountains are mainly located on the south and north, and there are high plateaus in the eastern part of the province. The average altitude of Van Province is approximately 2,000 m (Baylan et al. 2013). The province has a continental climate with an average temperature ranging 3.3–11.7 °C and the main vegetation is the steppe (Baylan et al. 2013; Kalkan et al. 2019). Locality records of some amphibians and reptiles from Van Province were previously published in herpetofauna notes or species-oriented studies (e.g., Clark & Clark 1973; Franzen & Sigg 1989; Schmidtler & Lanza 1990; Schmidtler et al. 1994; Uğurtaş 2001; Ilgaz et al. 2007; Tayhan et al. 2011; Yıldız & İğci 2015; Akman et al. 2016) and books (Başoğlu & Baran 1977, 1980; Başoğlu et al. 1994; Budak & Göçmen 2008). The herpetofauna of the province, however, has not been studied in detail. Since inventory studies are important for developing species conservation plans, it is aimed in this study to determine the herpetofauna diversity of the province and provide an updated species list and distribution data.

MATERIALS AND METHODS

Four herpetological surveys between 25 May and 20 September (20 days in total) were conducted in the province of Van in 2014 (in May, June, August, and September). The area was divided into 150km^2 (1: 25.000) grids and at least one suitable site in each grid was surveyed for amphibians and reptiles. Field studies were conducted in various habitats (e.g., wetlands, forests, steppes, dune, high mountains, settlements, and agricultural areas). A total of 283 localities, ranging 1,252–2,990 m, were surveyed during these excursions. One-hundred-and-seven localities in which at least one amphibian and/or reptile species was observed are shown on a map (Figure 1). Different sites within the range of 5km^2 are shown as one point to obtain a comprehensible map. The geographical coordinates of the stations were recorded by using the geographical positioning system (GPS) device (Garmin Montana 650). Coordinates were recorded as latitude and longitude in

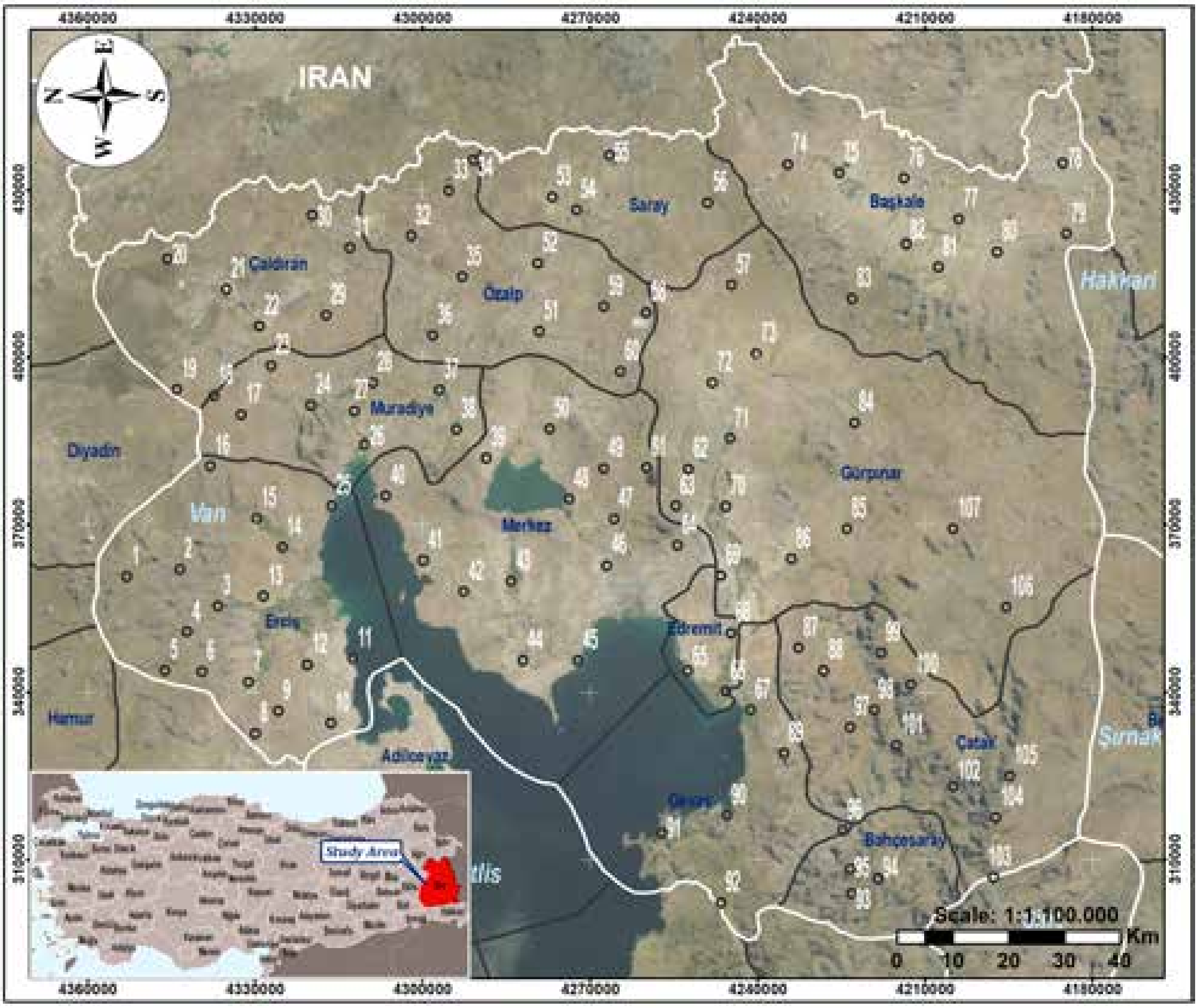

Figure 1. Localities of the species observed in the present study. The numbers correspond to the locality numbers in Table 1 and Appendix 1.

decimal degrees and referenced to the World Geodetic System of 1984 (WGS84) datum. The coordinates were deposited in The Noah's Ark Biodiversity Database (The Republic of Turkey, Ministry of Agriculture and Forestry, General Directorate of Nature Conservation and National Parks).

During the field studies, reptiles were identified by either visual encounter or caught by hand for detailed examination if needed. Amphibians were identified by the visual encounter and anuran calling surveys or caught. Sampling from lakes was done by using a scoop if needed. Opportunistic records (e.g., by the way) and road-kills were also obtained. Photographs of the live animals were taken on-site using digital cameras. After the examination and photographing, the animals were released at the same locality where they had been captured.

Identification of the common species was performed by referencing the literature (Başoğlu & Baran 1977, 1980; Leviton et al. 1992; Baran & Atatür 1998; Budak & Göçmen 2008). The species were grouped into chorotype categories as proposed by Vigna Taglianti et al. (1999). Species endemic to Anatolia were categorized as "Anatolian endemic", one species (*Parvilacerta parva* (Boulenger, 1887)) was assigned to "Armeno-E-Anatolian endemic" and main chorotypes were used for other species. Additionally, the conservation status of the amphibians and reptiles was noted according to the International Union for Conservation of Nature and Natural Resources (IUCN) Red List of Threatened Species, version 2020.2 (IUCN 2020), the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (CITES 2020), and the Convention on the Conservation of European Wildlife and Natural

Habitats (BERN Convention 2020).

RESULTS

As a result of the literature and field surveys, a total number of six species of amphibians and 31 species of reptiles belonging to 13 different families were recorded in the province of Van in this study. Species list with their locality numbers, conservation status, and related references is given in Table 1 and in situ photographs of the observed species are demonstrated in Images 1, 2, and 3. Briefly, six species of amphibians (Families: Salamandridae (two), Bufonidae (one), Pelobatidae (one) and Ranidae (two)), two species of chelonians (Families: Testudinidae (one) and Geomydidae (one)), 15 species of lizards (Families: Agamidae (two), Scincidae (three), Lacertidae (10)), and 14 species of snakes (Families: Typhlopidae (one), Natricidae (two), Colubridae (s.l.) (10), Viperidae (one)) were inventoried.

All three anurans that were observed during the field studies (*Bufotes sitibundus* (Pallas, 1771), *Pelophylax ridibundus* (Pallas, 1769), and *Rana macrocnemis* Boulenger, 1885) were common in the province, based on the number of the localities. As a salamander species, *Neurergus strauchii* (Steindachner, 1887) was recorded from two different localities and *Salamandra infraimmaculata* (Mertens, 1948) from only one locality. *Testudo graeca* Linnaeus, 1758 was found in 12 and *Mauremys caspica* (Gmelin, 1774) was recorded in three localities in different parts of the province of Van. Among lizards, *Ophisops elegans* Ménétries, 1832 and *Paralaudakia caucasia* (Eichwald, 1831) were the most common species with 31 and 19 localities, respectively. *Darevskia raddei* (Boettger, 1892) was observed as the most common rock lizard in the province of Van, with 15 localities. *Natrix tessellata* (Laurenti, 1768) was the most common snake species in the province of Van, with 25 different localities. *Dolichophis jugularis* (Linnaeus, 1758) and *D. schmidti* (Nikolsky, 1909) were also common with 11 and 10 locality records.

According to the IUCN Red List (IUCN 2020), one species (*Darevskia bendimahiensis* (Schmidtler, Eiselt & Darevsky 1994)) is categorized as Endangered (EN), two species (*S. infraimmaculata* and *Montivipera raddei* (Boettger, 1890)) are Near Threatened (NT), and two species (*N. strauchii* and *T. graeca*) are classified as Vulnerable (VU). The IUCN categories of other species (LC, DD, or NE) are listed in Table 1. All of the species are under protection according to the BERN convention appendices II and III; however, only one species (*T. graeca*) is regulated by CITES.

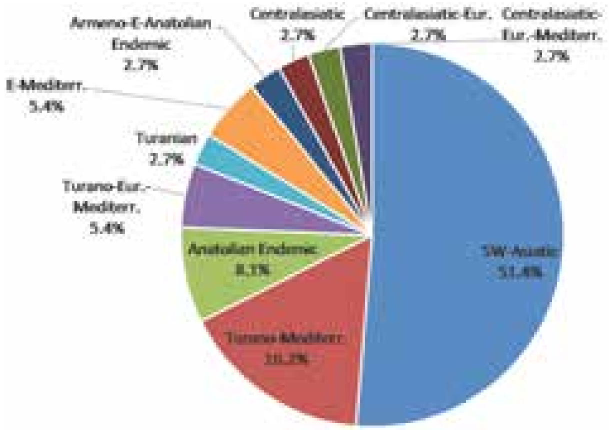

Figure 2. Chorotype distribution of amphibians and reptiles occurring in Van Province.

The species of amphibians and reptiles in the province of Van can be grouped into 10 chorotype categories (Table 1, Figure 2). SW-Asiatic is the main chorotype (51.4%), which is represented by 19 species. Chorotype with the second highest percentage (16.2%) is Turano-Mediterranean, which is represented by five species. Anatolian endemic chorotype includes three species (8.1%). A pie chart of all the chorotypes is presented in Figure 2.

DISCUSSION

Eastern and southeastern Anatolia is a hotspot region for amphibian and reptile biodiversity with many endemic species (Ilgaz 2019). This study presents the results of a detailed herpetofaunal survey in the province of Van (eastern Anatolia). It provides an updated herpetofaunal inventory of the province with five new provincial records and many new localities of some poorly known species. Among 37 species inventoried, three of them are endemic to Turkey (east Anatolia). Recent studies in east Anatolia recorded 27 species of amphibians and reptiles in the province of Iğdır (Tosunoğlu et al. 2010), 35 species in Ağrı (Yıldız et al. 2018a), and 36 species in Bitlis (Akman et al. 2018). Van Province is bordered by Bitlis Province on the west and Ağrı on the north. According to the results of the Jaccard similarity index (Jaccard 1912), it is not surprising that herpetofauna species of the province of Van is similar to Bitlis (Akman et al. 2018) and Ağrı (Yıldız et al. 2018) with percentages of 58.6% and 56.5%, respectively. With 37 species of amphibians and reptiles in total, it can be

Table 1. The list of the species of amphibians and reptiles occurring in Van Province based on this study and bibliographic data. The localities where the specimens were observed and identified, their status according to Bern Convention and IUCN criteria and their chorotypes are presented. Additionally, selected references reporting the occurrence in Van for each species are given. Appendices II and III of the Bern Convention refer to "strictly protected fauna species" and "protected fauna species", respectively. The abbreviations for IUCN criteria are explained in the Abbreviations section of the article.

Family	Species	BERN	IUCN	Chorotype	Localities (in this study)	Elevation range (m)	References
Salamandridae	*Neurergus strauchii* (Steindachner, 1887)	III	VU	Anatolian Endemic	93, 95	1,676–1,791	Olgun et al. 2015; Yıldız et al. 2018b
Salamandridae	*Salamandra infraimmaculata* (Mertens, 1948)	III	NT	SW-Asiatic	103	1,245	New record
Bufonidae	*Bufotes sitibundus* (Pallas, 1771)*	III	DD	Turano-Europeo-Mediterranean	2, 4, 5, 6, 10, 11, 13, 16, 20, 28, 29, 30, 31, 33, 34, 36, 37, 39, 40, 41, 42, 44, 45, 50, 53, 54, 55, 56, 58, 63, 68, 69, 70, 71, 72, 74, 75, 76, 77, 78, 79, 80, 81, 84, 85, 86, 87, 90, 91, 92, 94, 99, 100, 102, 104, 105, 106	1,454–2,897	Başoğlu et al. 1994; Mulder 1995; Baran & Atatür 1998; Budak & Göçmen 2008; Adızel et al. 2017
Ranidae	*Pelophylax ridibundus* (Pallas, 1769)	III	LC	Turano-Europeo-Mediterranean	4, 5, 6, 8, 9, 14, 15, 16, 18, 20, 21, 22, 23, 24, 25, 26, 29, 30, 31, 36, 38, 39, 42, 43, 45, 46, 47, 49, 50, 51, 52, 55, 57, 61, 62, 63, 64, 66, 67, 70, 78, 79, 80, 89, 90	1,652–2,575	Başoğlu et al. 1994; Mulder 1995; Baran & Atatür 1998; Budak & Göçmen 2008; Adızel et al. 2017
Ranidae	*Rana macrocnemis* Boulenger, 1885	III	LC	SW-Asiatic	1, 6, 12, 16, 18, 19, 20, 26, 27, 29, 30, 31, 39, 49, 56, 57, 58, 59, 62, 70, 72, 74, 75, 76, 80, 81, 83, 84, 85, 88, 93, 96, 97, 98, 99, 101, 102, 104, 105, 106, 107	1,782–2,972	Başoğlu et al. 1994; Mulder 1995; Baran & Atatür 1998; Budak & Göçmen 2008
Pelobatidae	*Pelobates syriacus* Boettger, 1889	II	LC	Turano-Mediterranean	Literature record, not observed in the present study.	–	Mertens 1953; Uğurtaş 2001; Adızel et al. 2017
Geoemydidae	*Mauremys caspica* (Gmelin, 1774)	II	NE	Turano-Mediterranean	26, 39, 102	1,574–1,803	Başoğlu & Baran 1977; Fritz & Freytag 1993; Sindaco et al. 2000; Budak & Göçmen 2008; Adızel et al. 2017
Testudinidae	*Testudo graeca* Linnaeus, 1758	II	VU	Turano-Mediterranean	4, 5, 11, 16, 25, 39, 87, 90, 92, 93, 99, 102	1,574–2,273	Başoğlu & Baran 1977; Sindaco et al. 2000; Türkozan et al. 2004a; Budak & Göçmen 2008; Adızel et al. 2017
Agamidae	*Stellagama stellio* (Linnaeus, 1758)	III	LC	E-Mediterranean	Web record, not observed in the present study	–	New print published record. (Previously published in www.turkherptil.org as a photographical record by Ufuk Karaca)
Agamidae	*Paralaudakia caucasia* (Eichwald, 1831)	III	LC	Turanian	14, 15, 16, 17, 24, 25, 37, 39, 50, 56, 57, 68, 70, 71, 74, 79, 81, 83, 102	1,574–2,741	Başoğlu & Baran 1977; Mulder 1995; Sindaco et al. 2000; Budak & Göçmen 2008
Scincidae	*Ablepharus bivittatus* (Ménétries, 1832)	III	LC	SW-Asiatic	35, 36, 56, 59, 61, 76, 82, 96	2,047–2,741	Sindaco et al. 2000; Ilgaz et al. 2007; Budak & Göçmen 2008
Scincidae	*Ablepharus chernovi* Darevsky, 1953	III	LC	SW-Asiatic	Literature record, not observed in the present study	–	Schmidtler 1997; Sindaco et al. 2000
Scincidae	*Heremites auratus* (Linnaeus, 1758)	III	LC	SW-Asiatic	4, 8, 101, 102	1,574–2,062	New record
Lacertidae	*Lacerta media* Lantz & Cyrén, 1920	III	LC	SW-Asiatic	1, 2, 3, 5, 8, 12, 16, 62, 92, 97, 99, 100, 101, 102, 106	1,574–2,504	Başoğlu & Baran 1977; Mulder 1995; Sindaco et al. 2000; Budak & Göçmen 2008; Adızel et al. 2017

Family	Species	BERN	IUCN	Chorotype	Localities (in this study)	Elevation range (m)	References
Lacertidae	*Apathya cappadocica* (Werner, 1902)	II	LC	SW-Asiatic	78, 79, 90, 93, 94, 95, 96, 99, 101, 102, 104	1,252–2,523	Başoğlu & Baran 1977; Eiselt 1979; Sindaco et al. 2000; Budak & Göçmen 2008
Lacertidae	*Darevskia bendimahiensis* (Schmidtler, Eiselt & Darevsky, 1994)	III	EN	Anatolian Endemic	23	2,002	Schmidtler et al. 1994; Budak & Göçmen 2008
Lacertidae	*Darevskia raddei* (Boettger, 1892)	III	LC	SW-Asiatic	18, 24, 37, 41, 50, 51, 55, 57, 58, 61, 71, 76, 77, 83, 85	1,663–2,575	Eiselt et al. 1993; Schmidtler et al. 1994; Sindaco et al. 2000; Arnold et al. 2007
Lacertidae	*Darevskia sapphirina* (Schmidtler, Eiselt & Darevsky, 1994)	III	LC	Anatolian Endemic	6, 8	1,887–2,345	Schmidtler et al. 1994; Sindaco et al. 2000; Arnold et al. 2007; Budak & Göçmen 2008; Akman et al. 2016
Lacertidae	*Darevskia valentini* (Boettger, 1892)	III	LC	SW-Asiatic	16, 20	2,155–2,239	Başoğlu & Baran 1977; Schmidtler et al. 1994; Mulder 1995; Sindaco et al. 2000; Arnold et al. 2007; Budak & Göçmen 2008
Lacertidae	*Eremias suphani* Başoğlu & Hellmich, 1968	III	LC	SW-Asiatic	30, 71, 82, 83	1,937–2,163	Başoğlu & Baran 1977; Mulder 1995; Sindaco et al. 2000; Budak & Göçmen 2008; Rastegar-Pouyani et al. 2013
Lacertidae	*Ophisops elegans* Ménétries, 1832	II	LC	E-Mediterranean	4, 7, 9, 10, 11, 18, 26, 43, 45, 47, 48, 50, 53, 57, 64, 65, 68, 69, 70, 71, 77, 79, 85, 87, 97, 98, 99, 100, 101, 102, 104	1,252–2,374	Başoğlu & Baran 1977; Sindaco et al. 2000; Budak & Göçmen 2008; Adızel et al. 2017
Lacertidae	*Parvilacerta parva* (Boulenger, 1887)	II	LC	Armeno-E-Anatolian Endemic	16, 17, 18, 20, 30, 33	2,049–2,422	Başoğlu & Baran 1977; Sindaco et al. 2000; Kumlutaş et al. 2004; Budak & Göçmen 2008
Lacertidae	*Iranolacerta brandtii* (De Filippi, 1863)	III	DD	SW-Asiatic	31, 52, 59, 72	2,041–2,309	Yıldız & İğci 2015; Avcı et al. 2015; Rato et al. 2015
Typhlopidae	*Xerotyphlops vermicularis* (Merrem, 1820)	III	LC	Turano-Mediterranean	90	1,868	Başoğlu & Baran 1980; Sindaco et al. 2000; Budak & Göçmen 2008
Colubridae	*Hemorrhois ravergieri* (Ménétries, 1832)	III	LC	Centralasiatic	5, 6, 23, 49, 70, 81, 102, 106	1,574–2,504	Başoğlu & Baran 1980; Sindaco et al. 2000
Colubridae	*Dolichophis schmidti* (Nikolsky, 1909)	III	LC	SW-Asiatic	16, 39, 44, 45, 81, 92, 97, 99, 102, 106	1,574–2,504	Clark & Clark 1973; Başoğlu & Baran 1980; Sindaco et al. 2000; Adızel et al. 2017
Colubridae	*Dolichophis jugularis* (Linnaeus, 1758)	II	LC	SW-Asiatic	47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57	1,574–2,441	New record
Colubridae	*Eirenis thospitis* Schmidtler & Lanza, 1990	III	DD	SW-Asiatic	47	1,903	Schmidtler & Lanza 1990; Sindaco et al. 2000; Nagy et al. 2003; Mahlow et al. 2013
Colubridae	*Eirenis eiselti* Schmidtler & Schmidtler, 1978	III	LC	SW-Asiatic	Literature record, not observed in the present study.	–	Sindaco et al. 2000; Budak & Göçmen 2008; Tayhan et al. 2011
Colubridae	*Eirenis punctatolineatus* (Boettger, 1892)	III	LC	SW-Asiatic	68	1,821	Başoğlu & Baran 1980; Sindaco et al. 2000; Budak & Göçmen 2008
Colubridae	*Eirenis modestus* (Martin, 1838)	III	LC	SW-Asiatic	4	1,969	New record
Colubridae	*Platyceps najadum* (Eichwald, 1831)	II	LC	Turano-Mediterranean	2, 8	1,887–1,961	Başoğlu & Baran 1980; Sindaco et al. 2000; Budak & Göçmen 2008
Colubridae	*Elaphe urartica* Jablonski et al. 2019	III	NE	SW-Asiatic	Literature record, not observed in the present study.	–	Jablonski et al. 2019
Colubridae	*Telescopus fallax* (Fleischmann, 1831)	II	LC	Turano-Mediterranean	4	1,893	New record

Family	Species	BERN	IUCN	Chorotype	Localities (in this study)	Elevation range (m)	References
Natricidae	*Natrix tessellata* (Laurenti, 1768)	II	LC	Centralasiatic-European	5, 7, 8, 16, 18, 21, 24, 26, 27, 38, 39, 43, 48, 49, 51, 71, 81, 85, 90, 92, 94, 95, 97, 99, 106	1,507–2,504	Başoğlu & Baran 1980; Sindaco et al. 2000; Budak & Göçmen 2008; Adızel et al. 2017
Natricidae	*Natrix natrix* (Linnaeus, 1758)	III	NE	Centralasiatic-Europeo-Mediterranean	21, 26, 55, 61, 63	1,665–2,575	Başoğlu & Baran 1980; Sindaco et al. 2000
Viperidae	*Montivipera raddei* (Boettger, 1890)	III	NT	SW-Asiatic	Literature record, not observed in the present study.	–	Franzen & Sigg 1989; Sindaco et al. 2000

* According to a recent phylogenetic study by Dufresnes et al. (2019), populations in the Anatolia (except Thrace and some parts of Bosphorus region) formerly identified as *Bufotes variabilis* are assigned to *Bufotes sitibundus*. It is not included in the IUCN Red List yet, so we used the data given for *B. variabilis*.

Image 1. Photographs of the observed amphibians and chelonians during the field studies in the province of Van (eastern Turkey): a—*Neurergus strauchii* | b—*Salamandra infraimmaculata* | c—*Salamandra infraimmaculata* | d—*Bufotes sitibundus* | e—*Pelophylax ridibundus* | f—*Rana macrocnemis* | g—*Mauremys caspica* | h—*Mauremys caspica* | i—*Testodo graeca*. © a,e,f,h—M. Z. YILDIZ; b,c—S. YILDIZ; d,g,i—N. İĞCİ.

stated that Van has a rich herpetofauna diversity and it is the only province in Turkey inhabited by *Iranolacerta brandtii* (De Filippi, 1863). The first observation of *I. brandtii* in Turkey was made in the province of Van, and results were published independently by two groups the same year (Avcı et al. 2015; Yıldız & İğci 2015).

Based on the results of the study, *Salamandra infraimmaculata*, *Heremites auratus* (Linnaeus, 1758), *Dolichophis jugularis, Eirenis modestus* (Martin, 1838), and *Telescopus fallax* (Fleischmann, 1831) were recorded for the first time in the province of Van. Additionally, *Stellagama stellio* was published from Van province as a photographic voucher and the first published print record is presented in this paper. Three species (*N. strauchii, D. bendimahiensis, Darevskia sapphirina* (Schmidtler, Eiselt & Darevsky, 1994)) covered in the present study are endemic to Anatolia, Turkey. *Eirenis eiselti* Schmidtler & Schmidtler, 1978 was known as an endemic species of Turkey until the paper by Mahlow et al. (2013), that reports the species from Syria. *Eirenis thospitis*

Image 2. Photographs of the observed lizards during the field studies in the province of Van (eastern Turkey): a—*Paralaudakia caucasia* | b—*Ablepharus bivittatus* | c—*Heremites auratus* | d—*Lacerta media* | e—*Apathya cappadocica* | f—*Darevskia raddei* | g—*Darevskia sapphirina* | h—*Darevskia valentini* | i—*Eremias suphani* | j—*Ophisops elegans* | k—*Parvilacerta parva* | l—*Iranolacerta brandtii*. © a–f,i,k,l—N. İĞCİ; g, h,j—M. Z. YILDIZ.

Schmidtler & Lanza, 1990 is a rare species with a limited number of vouchers. After its original description in 1990 (Schmidtler & Lanza 1990) based on the specimens from the province of Van, the first additional observation was made during the field excursions of the present study and presented before as a preliminary finding (Yıldız et al. 2015). Afterwards, *E. thospitis* was also recorded from Bitlis, a neighboring province of Van (Akman et al. 2018). Two recent papers by Mohamad & Afrasiab (2015) and Asadi et al. (2020) reported its occurrence in northern Iraq and Iran, respectively.

The taxonomy of the Anatolian mountain frogs belonging to the genus *Rana* is still controversial. Mountain frogs (*Rana* sp.) both with and without a vertebral stripe in the same locality at some of the stations were observed during the present study. In this paper, we considered *R. camerani* to be conspecific with *R. macrocnemis*, following Veith et al. (2003).

The occurrence of *Testudo perses* Perälä, 2002 in Turkey was reported by Türkozan et al. (2004b) based on the specimens collected in the province of Hakkari. One of the two localities presented in that paper is very close to the Van border (district Başkale), suggesting the occurrence of this species was also in Van Province. Although genetic analyses did not support the validity of *T. perses* as a separate species (Fritz et al. 2007), morphological assessments revealed this taxon was a distinct species (Türkozan et al. 2010). The same authors, however, considered this taxon a synonym of "*buxtoni*" clade after their comprehensive morphological and

Image 3. Photographs of the observed snakes during the field studies in the province of Van (eastern Turkey): a—*Xerotyphlops vermicularis* | b—*Hemorrhois ravergieri* | c—*Dolichophis schmidti* | d—*Dolichophis jugularis* | e—*Eirenis thospitis* | f—*Eirenis thospitis* | g—*Eirenis punctatolineatus* | h—*Eirenis modestus* | i—*Platyceps najadum* | j—*Telescopus fallax* | k—*Natrix tessellata* | l—*Natrix natrix*. © a,b,e,g,i–l—N. İĞCİ; c—M. GÜL; d,f,h—M.Z. YILDIZ.

genetic studies and they did not use the name *T. perses* in their map (Türkozan et al. 2018). We followed the most recent study by Türkozan et al. (2018) in this regard and omitted *T. perses* in the species list considering all the tortoise observations as *T. graeca*.

One *H. auratus* specimen collected from locality 101 (Akçabüyük, Çatak) during the field studies has the following morphological characteristics: third supraocular shields are separated from the frontal shield, the dorsal pattern consists of four longitudinal rows of small spots rather than bigger rectangular shaped markings and has a higher number of gular scales. These characters are in agreement with those in the literature given for *H. a. transcaucasicus* (Moravec et al. 2006; Durmuş et al. 2011). Longitidunal rows of small spots on the dorsum is also a colour-pattern characteristics of *Heremites septemtaeniatus* (Moravec et al. 2006); however, the reliability of the contact position of third supraocular and frontal as a distinctive character between *H. auratus* and *H. septemtaeniatus* and the occurrence of *H. septemtaeniatus* in Turkey was considered doubtful by Durmuş et al. (2011). Although taxonomic reorganization is still needed for the aforementioned taxa (Güçlü et al. 2014), it is considered that the sample in the present study resembles *H. a. transcaucasicus*, which is not mentioned from Turkey in the previous literature (Moravec et al. 2006; Durmuş et al. 2011; Güçlü et al. 2014). Since any additional specimens from the site could not be found, the morphological variation could not be assessed.

Ablepharus bivittatus (Ménétries, 1832) was known only from two localities in Turkey (both in the province of Van) previously (Ilgaz et al. 2007) until Yıldız et al. (2018a) reported this species in the province of Ağrı (eastern Anatolia). Recently, Bozkurt & Olgun (2020) combined the taxon with the genus *Asymblepharus* based on some shared characters, but we follow the former taxonomic arrangement in our species list. In the present study, eight new localities of this species from different districts in Van (Özalp, Saray, Başkale, İpekyolu, Gevaş) are added and it is shown that *A. bivitattus* can be found in different locations in the province of Van above 2,000m where the habitat is suitable.

Darevskia sapphirina, an Anatolian endemic species of rock lizards was firstly described from a locality close to Van-Ağrı border (Erciş), and no additional sites were reported until the publication by Akman et al. (2016). During the herpetological surveys, which were conducted in the provinces of Van and Ağrı, new sites of this species were discovered and published previously (Akman et al. 2016). We also reported some of the localities within the species' known range in Van province in the present paper.

Populations of *Elaphe sauromates* (Pallas, 1811) in eastern Anatolia were assigned to a new species, *Elaphe urartica* Jablonski et al. 2019, by a recent study. Its type locality is Kısıklı, a village nearby Süphan Mountain in Bitlis province (Jablonski et al. 2019). The province of Van also lies within the distribution area of *E. urartica*, according to the abovementioned study. Although no individuals were observed during the field surveys of this study, it was possible to confirm the occurrence of this species in the province based on the reliable questionnaire results obtained through conversation with the locals.

Based on their known distributions in adjacent provinces (Akman et al. 2018; Yıldız et al. 2018a) and the world, it is possible that some other species of amphibians and reptiles such as *Hyla savignyi* (Audouin, 1829), *Trapelus lessonae* (De Filippi, 1865), *Mediodactylus heterocercus* (Blanford, 1874), *Heremites vittatus* (Olivier, 1804), *Eryx jaculus* (Linnaeus, 1758), *Malpolon insignitus* (Geoffroy De St-Hilaire, 1809), and *Macrovipera lebetinus* (Linnaeus, 1758) may be found in Van Province.

The present study was carried out within the scope of the National Biodiversity Inventory and Monitoring Project in Turkey. This project was launched in 2013 under the coordination of the Republic of Turkey Ministry of Agriculture and Forestry (formerly Ministry of Forestry and Water Affairs), General Directorate of Nature Conservation and National Parks, and aims to obtain the most recent biodiversity information in all the provinces of Turkey as well as to determine the major threats. The project is almost completed now and has resulted in the production of invaluable new information regarding Turkey's flora and fauna. Most of the Van Province is rural and generally used as grassland (Kalkan et al. 2019). During the project, the major threat to herpetofaunal diversity in surveyed habitats in Van Province was found as human-origin habitat degradation generally caused by overgrazing, construction, and pollution. Human-caused habitat degradation is considered as the major threat for amphibians and reptiles worlwide (Gibbons et al. 2000; Gidiş & Başkale 2020).

The knowledge of the actual distribution range and the locality coordinates (as obtained in this study) is important and guides the species conservation action plans (Mebert et al. 2020). Once the georeference databases are created for every species of interest, it will be easier for authorities to make ecosystem master plans and to make their decisions while giving construction permissions. Moreover, more realistic distribution modeling studies can be carried out with this kind of data. In this regard, the results of this study provide a useful basis for future monitoring studies and distributional information will contribute to the conservation of the species of interest.

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Author contribution: MZY attended all the field studies, contributed to species identification, manuscript writing and preparation of the figures. NI attended all the field studies, contributed to species identification and drafted the manuscript. BA attended the field studies, contributed to species identification and figure preparation. All the authors contributed to manuscript revision.

Appendix 1. Village and district names of the localities shown on the map in Figure 1.

1. Gergili/Erciş, 20.09.2014, 2123m asl; **2.** Doğancı/Erciş, 20.09.2014, 1961m asl; **3**. Ağaçören/Erciş, 20.09.2014, 1852m asl; **4**. Köycük/Erciş, 20.09.2014, 1893m asl; **5.** Ağırkaya/Erciş, 20.09.2014, 2273m asl; **6**. Pınarlı/Erciş, 20.09.2014, 2334m asl; **7.** Kırkpınar/Erciş, 20.09.2014, 1934m asl; **8**. Duracak/Erciş, 16.09.2014, 1887m asl; **9.** Kayaboyun/Erciş, 16.09.2014, 2051m asl; **10**. Akçayuva/Erciş, 16.09.2014, 1948m asl; **11**. Bayramlı/Erciş, 16.09.2014, 1681m asl; **12.** Dinlence/Erciş, 16.09.2014, 1858m asl; **13.** Oyalı/Erciş, 20.09.2014, 1809m asl; **14**. Keklikova/Erciş, 16.08.2014, 1751m asl; **15**. Payköy/Erciş, 16.08.2014, 2038m asl; **16**. Yankıtepe/Erciş, 16.08.2014, 2422m asl; **17**. Güllüçimen/Muradiye, 16.08.2014, 2200m asl; **18**. Hıdırmenteş Gölü/Çaldıran, 21.08.2014, 2351m asl; **19**. Yukarıyanıktaş/Çaldıran, 21.08.2014, 2343m asl; **20**. Soğuksu/Çaldıran, 27.05.2014, 2155m asl; **21**.Oruçlu/Çaldıran, 27.05.2014, 2049m asl; **22.** Sellik/Çaldıran, 15.09.2014, 2041m asl; **23**. Gümüştepe/Muradiye, 27.05.2014, 2002m asl; **24**. Kemerköprü/Muradiye, 15.09.2014, 1736m asl; **25**. Aşağıkozluca/Erciş, 27.05.2014, 1666m asl; **26**. Karahan/Muradiye, 27.05.2014, 1665m asl; **27**. Balaklı/Muradiye, 25.06.2014, 1664m asl; **28**. Beydağı/Muradiye, 25.06.2014, 1717m asl; **29**. Yuvacık/Çaldıran, 15.09.2014, 2084m asl; **30**. Baydoğan/Çaldıran, 15.09.2014, 2368m asl; **31**. Gülyolu/Çaldıran, 15.09.2014, 2233m asl; **32**. Yumruklu/Özalp, 16.09.2017, 2060m asl; **33**. Eğribelen/Özalp, 16.09.2014, 2149m asl; **34**. Yukarıtulgalı/Özalp, 16.09.2014, 2147m asl; **35**. Çubuklu/Özalp, 16.09.2014, 2084m asl; **36**. Çırakköy/Özalp, 16.09.2014, 2047m asl; **37**. Çakmak/Muradiye, 16.09.2014, 2092m asl; **38**. Sarımemet/Muradiye, 16.09.2014, 1969m asl; **39**. Ilıkaynak/Merkez, 16.08.2014, 1974m asl; **40**. Çolpan/Merkez, 15.09.2014, 1733m asl; **41**. Gedikbulak/Merkez, 27.05.2014, 1764m asl; **42**. Tabanlı/Tuşba, 15.09.2014, 1843m asl; **43**. Otluca/Tuşba, 16.08.2014, 1690m asl; **44**. Alaköy/Tuşba, 15.09.2014, 1724m asl; **45**. Çitören/Tuşba, 25.06.2014, 1652m asl; **46**. Bostaniçi Göleti/Merkez, 26.05.2014, 1784m asl; **47**. Köşebaşı/İpekyolu, 21.06.2014, 1903m asl; **48**. Baklatepe/İpekyolu, 22.06.2014, 1904m asl; **49**. Gövelek Gölü/İpekyolu, 21.06.2014, 2242m asl; **50**. Kaymaklı/İpekyolu, 26.05.2014, 1952m asl; **51**. Aşağımollahasan/Özalp, 26.05.2014, 1949m asl; **52**. Tepedam/Özalp, 26.05.2014, 2026m asl; **53**. Kazımpaşa/Saray, 26.05.2014, 2125m asl; **54**. Değirmigöl/Saray, 22.06.2014, 2236m asl; **55**. Yamanyurt/Saray, 26.05.2014, 2248m asl; **56**. Karahisar/Saray, 22.06.2014, 2501m asl; **57**. Topsakal/Gürpınar, 22.06.2014, 2401m asl; **58**. Akgöl/Gürpınar, 23.06.2014, 2371m asl; **59**. Gültepe/Özalp, 23.06.2014, 2380m asl; **60**. Karlıyamaç/Özalp, 22.06.2014, 2275m asl; **61**. Ekece/İpekyolu, 25.05.2014, 2575m asl; **62**. Savacık/Gürpınar, 23.06.2014, 2156m asl; **63**. Gölardı/Gürpınar, 25.05.2014, 2317m asl; **64**. Bakraçlı/İpekyolu, 25.05.2014, 1836m asl; **65**. Kiyicak/Edremit, 25.05.2014, 1668m asl; **66**. Uğurveren/Gevaş, 25.05.2014, 1662m asl; **67**. Atalan/Gevaş, 24.06.2014, 1807m asl; **68**. Köprüler/Edremit, 25.05.2014, 1821m asl; **69**. Koyunyatağı/Gürpınar, 25.05.2014, 1917m asl; **70**. Erkaldı/Gürpınar, 22.06.2014, 1829m asl; **71**. Ortaköy/Gürpınar, 22.06.2014, 1955m asl; **72**. Çörekli/Gürpınar, 23.06.2014, 2122m asl; **73**. Sevindik/Gürpınar, 22.06.2014, 2090m asl; **74**. Yanal/Başkale, 18.09.2014, 2166m asl; **75**. Konuksayar/Başkale, 18.09.2014, 2432 m a.s.l: **76**. Güleçler/Başkale, 18.09.2014, 2322m asl; **77**. Açıkağıl/Başkale, 18.09.2014, 2026m asl; **78**. Esenyamaç/Başkale, 20.08.2014, 2047m asl; **79**. Çaldıran/Başkale, 20.08.2014, 1865m asl; **80**. Aşağıküme/Başkale, 19.09.2014, 2897m asl; **81**. Erek/Başkale, 20.08.2014, 2017m asl; **82**. Aşalan/Başkale, 20.08.2014, 2097m asl; **83**. Gedikbaşı/Başkale, 20.08.2014, 2370m asl; **84**. Yedisalkım/Gürpınar, 17.09.2014, 2314m asl; **85**. Merkez/Gürpınar, 19.08.2014, 2115m asl; **86**. Kuşdağı/Gürpınar, 19.08.2014, 1900m asl; **87**. Onağıl/Çatak, 17.08.2014, 1973m asl; **88**. Derebaşı/Çatak, 17.08.2014, 2171m asl; **89**. İliköy/Gevaş, 24.06.2014, 1781m asl; **90**. Göründü/Gevaş, 24.06.2014, 1686m asl; **91**. İnköy/Gevaş, 24.06.2014, 1683m asl; **92**. 700 m west of Söğütlü/Tatvan, 18.08.2014, 1856m asl; **93**. Çatbayır/Bahçesaray, 18.08.2014, 1774m asl; **94**. Elmayaka/Bahçesaray, 18.08.2014, 1562m asl; **95**. Bahçesaray, 21.08.2014, 1676m asl; **96**. Arpit/Gevaş, 18.08.2014, 2972m asl; **97**. Uzuntekne/Çatak, 17.08.2014, 2319m asl; **98**. Aşağınarlıca/Çatak, 17.08.2014, 2028m asl; **99**. Bilgi/Çatak, 17.08.2014, 1674m asl; **100**. Alacayar/Çatak, 17.08.2014, 1636m asl; **101**. Akçabüyük/Çatak, 17.08.2014, 1782m asl; **102**. Gökçedal/Çatak, 17.08.2014, 1454m asl; **103**. Dalbastı/Çatak, 17.08.2014, 2183m asl; **104**. Sugeldi/Çatak, 17.08.2014, 1702m asl; **105**. Beşbudak/Gürpınar, 19.08.2014, 2482m asl; **106**. Geziyurt/Gürpınar, 19.08.2014, 2379m asl.

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COMMUNICATION

Herpetofauna assemblage in two watershed areas of Kumoan Himalaya, Uttarakhand, India

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Abstract: We surveyed herpetofauna along the poorly-explored region of two watersheds of Kumoan Himalaya, Dabka and Khulgarh. Adaptive cluster method was used to collect forest floor reptiles, and stream transect was used for stream reptiles and amphibians. In total, 18 species of reptiles were recorded in two watersheds, with 15 and nine species recorded in Dabka and Khulgarh, respectively. Forest floor density of reptiles was 87.5/ha in Dabka and 77.7/ha in Khulgarh. In terms of species, *Asymblepharus ladacensis* and *Lygosoma punctatus* density were highest in Dabka and Khulgarh, respectively. Eight species of amphibians were recorded in Dabka with a density of 9.4/ha and four species in Khulgarh with density of 5.2/ha. In both watersheds, density of *Euphlyctis cyanophlyctis* was highest. Reptilian and amphibian diversity of Dabka was 1.52 and 1.23, respectively, and in Khulgarh 0.43 and 0.23, respectively. In both watersheds reptile density, diversity and richness decreased with increasing elevation. Reptile density showed a weak correlation with microhabitat features such as litter cover, litter depth, and soil moisture in both watersheds. Amphibian density was positively correlated with soil moisture, litter cover, and litter depth. Comparison showed that Dabka is richer and more diverse than Khulgarh, presumably because of the undisturbed habitat, broad and slow stream, and deeper forest litter of the former.

Keywords: Amphibians, Dabka, Khulgarh, microhabitat, reptiles, watersheds, western Himalaya.

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Author contribution: The data collection, analysis and writing was done by KA under the guidance of JAK. JAK is also the PI of the project under which the present study was conducted.

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INTRODUCTION

Amphibians and reptiles play integral roles in food webs as herbivores, predators and prey, and they also connect aquatic and terrestrial ecosystems (Schenider et al. 2001; Ahmed 2010). Unlike birds and mammals, herpetofauna in India have not been studied in detail (Vasudevan et al. 2001), with most studies restricted to the rainforests of the Western Ghats (Myers 1942; Inger et al. 1984; Vasudevan et al. 2006; Naniwadekar & Vasedevan 2007; Chandramouli & Ganesh 2010; Venugopal 2010; Murali & Raman 2012; Balaji et al. 2014; Bhupathy et al. 2016; Garg & Biju 2017; Chaitanya et al. 2018; Ganesh et al. 2018; Harikrishnan et al. 2018; Malik et al. 2019; Ganesh & Achyuthan 2020) and northeastern India (Ahmed et al. 2009; Das et al. 2009; Chhetri et al. 2010; Purkayastha et al. 2011; Pan et al. 2013; Vogel & Ganesh 2013; Roy et al. 2018). Sporadic studies have described or recorded new species for the western Himalaya (Murthy & Sharma 1976; Saikia et al. 2007; Negi & Banyal 2016; Santra et al. 2019).

Gibbons et al. (2000) enumerated six causes of global decline in herpetofauna: habitat loss and degradation, introduced invasive species, environmental pollution, disease and parasitism, unsustainable use, and global climate change. These causes are present in India where conservation strategies are mostly based on glamorous taxa such as birds and mammals, and thus may neglect smaller and less conspicuous vertebrates such as amphibians and reptiles (Vasudevan et al. 2006). The inclusion of smaller vertebrates in management plans for any particular region is necessary for the overall conservation of biodiversity at local as well as landscape-level (Pawar et al. 2007). Information on the herpetofauna species constellation appears to be largely neglected regionally. Moreover, the information available mostly restricted to some protected areas, and there is a need to study amphibians and reptiles, particularly at watersheds, which are ecological islands of these species.

In the present study, we present and discuss the species composition and abundance of the herpetofauna of the two watershed areas in northern India. The paper investigates species diversity and abundance of reptiles and amphibians in watersheds on mountains in northern India. For the first time ecological and distributional data are provided for the herpetofauna of Kumoan Himalaya, particularly the watersheds. Due to little or no herpetological information in this region, this work can be essential for understanding the ecosystem in this region. The data collected is valuable not only to assess current biodiversity and abundance scientifically, but also to estimate them in the future, which will aid efficient conservation.

STUDY AREA

The Khulgarh Watershed Area (KWA) lies between 29.575—29.683 ^{0}N and 79.537—79.616 ^{0}E in Almora District of Kumaon Himalaya, Uttarakhand, northern India (Fig. 1). The area spreads over 32km^2 and represents middle Shiwaliks. It is situated 15km west of Almora Town and encompasses 34 villages. There are three distinct seasons: summer, winter, and monsoon. The average annual temperature of the watershed is 20°C and the elevation of the area ranges 1,100–2,200 m. The most dominating tree species in the study area was *Pinus roxburghii* both in forested and outside forest areas. Other dominant tree species found in the area were *Quercus incana* and *Lyonia ovalifolia.*

Dabka Watershed Area (DWA) has an area of about 69.06km^2 and lies between 29.505–29.402 ^{0}N and 79.298–79.427 ^{0}E in the region of lesser Himalaya in the state of Uttarakhand (Ahmed 2010) (Fig. 1). The climate of the area is cold and temperate with temperate vegetation. The monsoon starts at the end of June and ceases by the middle of September. This area falls in different altitudinal ranges of 500–2,600 m. In the lower elevations of 600–900 m near Kotabagh, the mean annual temperature varies from 18.9°C to 21.1°C with a mean annual rainfall of 2,860.3mm. In the warm temperate zone of 900–1,800 m, the mean annual temperature varies from 13.9 to 18.9°C with mean annual rainfall of 3,623.33mm. In the cold temperate zone of 1,800–2,500 m, the mean annual temperature varies from 10.3 to 13.9°C with an annual rainfall of 1,750mm. DWA is a reserve forest, which is divided into forest ranges, Vinayak and Naina. Most of the study area was located under Vinayak forest range of Kumaon division with dominating *Quercus leucotricophora*, and a few patches of *Pinus roxburgii*, *Taxus baccata*, and *Cedrus deodara* trees are also present. *Rhododendron arborium* trees are common throughout the area because both KWA and DWA were present in similar ecological conditions and KWA has more disturbed habitat than DWA (Ahmed 2010), so, we compared them based on their elevation pattern and disturbance factor.

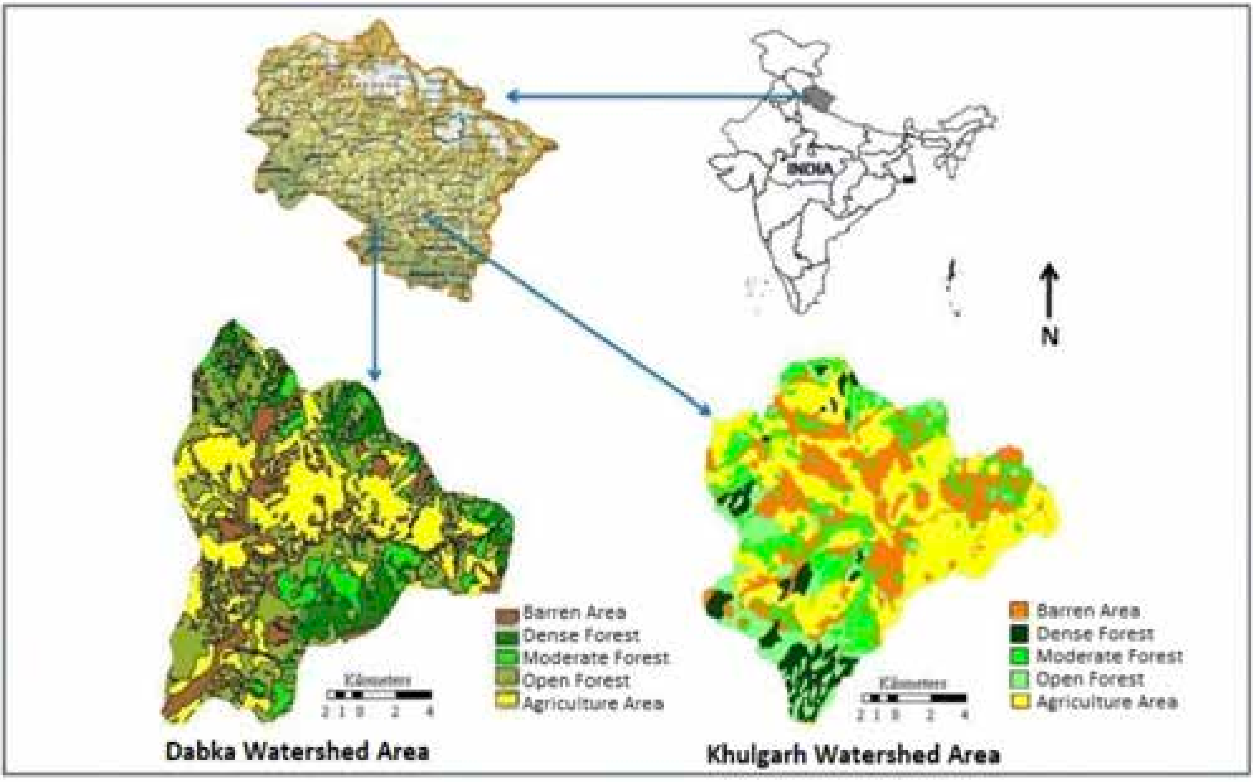

Figure. 1. The location of Dabka and Khulgarh watershed areas.

METHODS

Reptiles were sampled using the adaptive cluster sampling method (Ishwar et al. 2001). The basic sampling unit used was 5m x 5m randomly laid quadrats. If a reptile was sighted in one of these quadrats (hereafter referred to as primary quadrats), additional quadrats (secondary quadrats) of the same dimension were searched on the four sides of the primary quadrat. There was a gap of one meter between the primary and secondary quadrats. If any of these four quadrats had reptiles, further quadrats were laid around them until the quadrat with reptiles was surrounded by the quadrats without reptiles. The whole network of quadrats with reptiles then becomes a cluster. If the primary quadrat did not have any reptile, the sampling was carried out in the next, randomly selected quadrat. In order to minimize the chances of missing animals during search efforts, two observers searched the quadrat from opposite sides towards the center. We also searched study sites opportunistically to confirm the record of species that are rare and may not be recorded by the standard methods. We identified all species whenever possible and released them back into their natural habitats.

In addition to the adaptive cluster sampling method, three quadrats of 5m x 1,000m along the streams were established. Stream was considered as center of quadrat, and sampling was carried on both sides of the stream simultaneously. Loose rocks and leaf litter was carefully turned, and cavities were prodded for reptilian species. In DWA, 40 permanent quadrats were laid and monitored for two seasons (summer and winter), amounting to 300 quadrats (both primary and secondary). In KWA 30 permanent quadrats were laid amounting to 250 quadrats (both primary and secondary) in two seasons (summer and winter). Data were collected from September 2007 to June 2009 except monsoon for stream transects.

The amphibian community was sampled using the methods described by Vasudeven et al. (2001). Amphibians were sampled using a combination of the adaptive cluster sampling method and visual encounters. Opportunistic records were also maintained. The adaptive sampling was done along streams on the forest floor with the same procedure as reptiles. In DWA 4 streams and in KWA 3 streams transect were established and monitored (Table 3). During monsoon the stream became flooded, therefore, sampling was abandoned. Herpetofauna were surveyed during mid-day as mostly the species come out from their refuge for basking when the ambient temperature turns warmer (Hill et al. 2005).

Analysis

Data were summarized, and density was calculated for each species. Shannon-Weiner index (H') was used for measuring diversity, and Simpson's diversity index (D) was used for calculating evenness. Margalef's diversity index (RI) was used to measure richness of species on different transects and in different seasons. Pearson's product moment correlation coefficient was used to examine the correlation of reptile and amphibian density with different habitat variables.

RESULTS

Reptiles

Dabka Watershed Area: In DWA, 15 species of reptiles were recorded (Appendix I). Overall reptile density was 87.52 individuals/ha. Overall diversity, richness, and evenness of reptiles were 1.519, 0.932, and 0.759, respectively. Density of reptiles was higher in summer (127/ha) than in winter (50.4/ha). The diversity, richness, and evenness of reptiles were higher in summer than in winter (Table 1). In terms of species, *Asymblepharus ladacensis* density was highest (43.75/ha), followed by *Eutropis carinata* (27.22/ha), *Laudakia tuberculata* (25/ha), *Calotes versicolor* (12.5/ha), and *Eutropis macularia* (12.5/ha).

Khulgarh Watershed Area: In KWA, nine species of reptiles were recorded (Appendix I) with overall density of 77.71/ha. Overall diversity, richness and evenness of reptiles were 1.227, 0.733, and 0.659, respectively. *Lygosoma punctatus* density was highest (110.37/ha), followed by *Eutropis macularia* (35.57/ha), *Laudakia tuberculata* (30.76/ha), and *Calotes versicolor* (10.12/ha). Reptilian density, diversity, richness, and evenness were found to decrease with the increase of elevation in both watersheds (Figs. 2–5). Reptile density showed weak positive correlations with soil moisture in both watersheds (Table 2). Density was positively correlated with litter cover and litter depth weakly to moderately (Table 2).

Amphibians

Dabka Watershed Area: In DWA eight species of amphibians were recorded (Appendix II). Overall, amphibians density was 9.38/ha. Diversity, richness, and evenness were 0.426, 0.674, and 0.278, respectively. In total, 221 individuals were encountered in DWA. In Baghjala transect, 111 individuals contributing to six

Table 1. Diversity, richness, and evenness of reptiles in different seasons in Dabka and Khulgarh watershed areas.

Index	DWA		KWA	
	Winter	Summer	Winter	Summer
Diversity	0.413	0.981	0.213	0.589
Richness	1.325	2.513	1.542	1.653
Evenness	0.931	1.431	0.831	1.00

Table 2. Correlations of reptile density with nine microhabitat variables in Dabka and Khulgarh watershed areas (*p<0.01).

Microhabitat variables	DWA	KWA
Slope	-0.026	0.030
Soil moisture	0.122*	0.160*
Canopy cover	0.018	0.089
Shrub cover	0.085	0.068
Herb cover	0.020	-0.098
Presence of logs	0.414	-0.049
Presence of rocks	0.052	-0.147
Litter cover	0.216*	0.330*
Litter depth	0.318*	0.536*

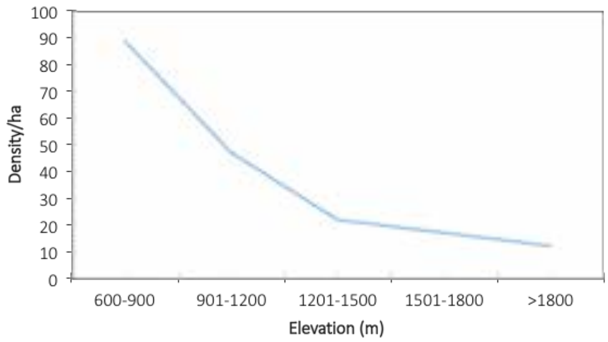

Figure 2. Reptile density along altitudinal gradients in Dabka Watershed Area.

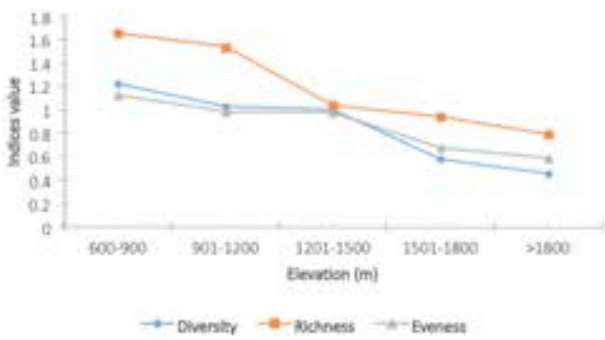

Figure 3. Reptile diversity, richness, and evenness along the altitudinal gradients in Dabka Watershed Area.

Table 3. Density of amphibians (individuals/ha) on different stream transects in Dabka and Khulgarh watershed areas.

DWA		KWA	
Stream Transect		Stream Transect	
Chand	1.21	Sayhedevi	2.43
Mahadav	4.12	Kosi	5.10
Baghjala	22.21	Kovodov	10.22
Gugukhan	3.11		

Table 4. Amphibian density (individuals/ha) in Dabka and Khulgarh watershed areas.

Species	DWA	KWA
Duttaphrynus melanostictus	2.22	0.023
Duttaphrynus himalayanus	1.11	1.04
Euphlyctis cyanophlyctis	23.34	11.23
Hoplobatrachus tigerinus	0.24	-
Hoplobatrachus crassus	1.21	-
Nanorana liebigii	2.23	0.87
Limnonectes limnocharis	0.91	-
Amolops marmoratus	10.22	-

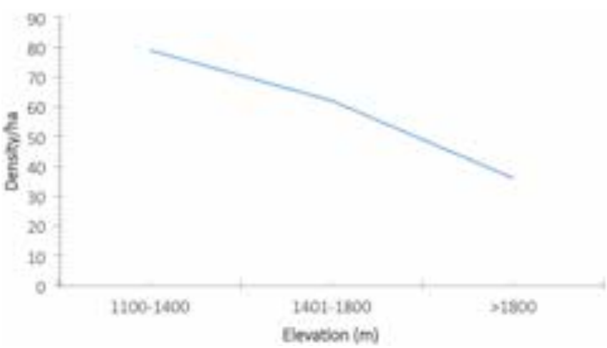

Figure 4. Reptiles density along altitudional gradients in Khulgarh Watershed Area.

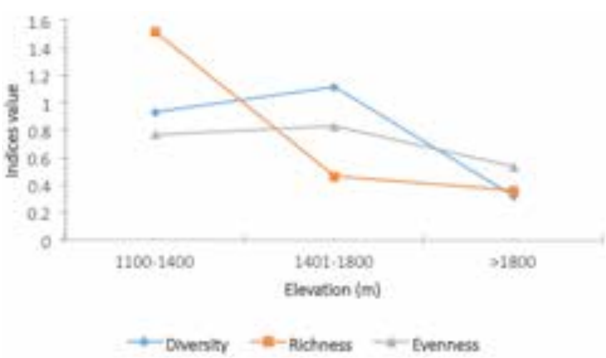

Figure 5. Reptiles diversity, richness, and evenness along altitudional gradients in Khulgarh Watershed Area.

Table 5. Correlations of amphibian density with nine microhabitat variables in Dabka and Khulgarh watershed areas (*p<0.01).

Habitat variables	DWA	KWA
Slope	0.019	-0.360
Soil moisture	0.621*	0.485*
Canopy cover	-0.077	-0.015
Shrub cover	0.175	0.149
Herb cover	-0.067	-0.044
Presence of logs	-0.061	0.061
Presence of rocks	0.017	0.061
Litter cover	0.170*	0.299*
Litter depth	0.202*	0.316*

species were encountered with a density of 22.21/ha, followed by 61 individuals of three species in Mahadev, 29 individuals of two species in Gugukhan, and 20 individuals of two species in Chand transect (Table 3). In terms of species, the density of *Euphlyctis cyanophlyctis* was found highest (23.34/ha), followed by *Amolops marmoratus* (10.22/ha) and *Duttaphrynus melanostictus* (2.22/ha) (Table 4).

Khulgarh Watershed Area: Four species of amphibians were recorded in KWA, which were also present in DWA. Overall amphibian density was 5.23/ha. Diversity, richness, and evenness were 0.234, 0.174, and 0.025, respectively. Density in Kovodov transect was found highest (10.22/ha), followed by Kosi (5.10/ha) (Table 3). In terms of species, overall density of *Euphlyctis cyanophlyctis* was found highest (11.23/ha), followed by *Duttaphrynus himalayanus* (1.04/ha) (Table 4).

A total of 151 individuals were encountered in KWA. Of these 84 individuals of three species were encountered in Kovodov transect, followed by 36 individuals of two species in Kosi transect and 31 individuals of two species in Sayhedevi transect.

Amphibian density showed weak positive correlations with litter cover and litter depth in both watersheds (Table 5). Amphibian density had moderate to relatively high positive correlations with soil moisture in both watersheds (Table 5).

DISCUSSION

Reptiles

The overall reptilian density in DWA and KWA was 87.5/ha and 77.7/ha, respectively, during the entire study period. These values are much lower than 154/ha recorded in Panama (Inger 1980) and 108/ha recorded in KMTR in Western Ghats (Kumar et al. 2001), but they are similar to the 66.5/ha recorded in the Garhwal Himalaya (Dar et al. 2008). The higher density recorded in Panama and the Western Ghats can be attributed to these studies being conducted in tropical rainforests, whereas the present study was conducted in subtropical areas of the Himalaya. Kumar et al. (2001) reported 54 species from KMTR, and Inger et al. (1984) and Dar et al. (2008) reported 33 and 10 species, respectively, in Garhwal Himalaya. In our study, 15 species were recorded. Fewer species in the two watersheds may be due to small study sites located in sub-tropical areas of Kumoan Himalayas (Dar et al. 2008)

In both DWA and KWA, the density of reptiles was higher in summer than in winter. Lower density in winter may be due to harsh climatic conditions in both sites, however, the high density in summer may be also due to high density of non-snake reptiles including geckos and agamids (Dar et al. 2008). There were some differences in abundance in both watersheds. Overall, a higher number of species was recorded in DWA with more diversity and richness than KWA. This may reflect the general topographical condition of DWA starting from 500 to 2,600 m, thus representing the species of both lower and higher altitudes. Skinks and agamids formed dominant groups in both watersheds. Snakes were more abundant in DWA than in KWA, but contributed to a small portion of forest floor reptiles in both sites. Low abundance of snakes could be due to their secretive nature, and thus they escape detection during sampling (Ahmed 2010).

Change in reptilian abundance along altitudinal gradients has been documented in previous studies (Fauth et al. 1989; Bhupathy & Kannan 1997; Dar et al. 2008; Chettri et al. 2010; Gautam et al. 2020). The results of both the study sites showed a decline in density with altitude. Porter (1972) believes that this might be primarily due to the decline in temperature. Atmospheric temperature is considered as dominant factor for the elevational zonation of life in Himalaya (Mani 1974) and terrestrial reptiles respond more strongly to temperature than moisture (Hofer et al. 1999). It seems logical because reptiles are ectothermic, and thus, temperature plays a vital role in their ecology.

Reptile density showed a positive correlation with leaf litter cover, litter depth, and soil moisture. This was particularly demonstrated by skinks and agamids. There was also a preference for certain structural diversity in the ground vegetation characters. This association of geckos, skinks has already been shown by Kumar et al. (2001) and Dar et al. (2008). Agamids, which were dominated by *Calotes,* preferred more rocky and open canopy than skinks. The specific habitat features are essential for leaf litter reptiles as they can meet the conflicting demands of thermoregulation, predator avoidance, and participation in other activities (Lima & Dill 1990). It might also be possible that a cool and humid environment below litter provides good microclimatic conditions for arthropods, which are major prey animals for the forest floor reptiles (Kumar et al. 2001). Because snakes are predatory in nature, their local distribution might be influenced by the distribution of their prey abundance such as lizards and frogs (Dar et al. 2008).

Amphibians

Amphibian density in both areas showed positive correlations with litter cover and litter depth. Deep litter may provide a wider range of microhabitat, allowing more individuals and species to coexist in the litter microhabitat (Fauth et al. 1989), or provide refuge from predation (Lieberman 1986). Lieberman & Dock (1982) argued that litter may sustain large arthropod prey population. Block & Morrison (1998) found that litter depth is an important factor in habitat selection in amphibians and reptiles. In addition, various biotic and abiotic factors are also reported to influence the distributions of amphibians. Anuran activity temperature can also be predicted accurately from environmental temperature; therefore, ambient temperature is a crucial factor that limits their distribution (Navas 2003). In the present study, amphibian density showed a positive correlation with soil moisture in both watersheds. Naniwadekar & Vasedevan (2007) also found that Increase in soil moisture and decrease in soil temperature were associated with increase in amphibian species richness. This correlation is reasonable because amphibians have soft skin and are sensitive to temperature and precipitation, and thus prefer moist habitat. Moreover, Khatiwada et al. (2019) found among all the environmental variables, elevation, surface area and humidity were the best predictors of species richness, abundance and composition of amphibians, and high elevations in the tropics are also characterized by greater soil moisture and abundant perennial running or stagnant water that provides suitable microhabitats for anurans (Navas 2003).

Baghjala in DWA and Sayadevi in KWA were found with the highest density of amphibians. It might be due to the presence of water till late winter, less rocky and width of the stream (Kaleem Ahmed personal observation). In addition to these, streams were wide as compared to others, as a result, slowing the flow and creating stagnant pools for species like *Euphlyctis cyanophlyctis* to flourish. The low density of amphibians was recorded in Kosi and Sayadevi streams in KWA and Gugukhan and Mahadav streams in DWA. These streams were perennial but quite deep, and amphibians like water seem to avoid deep water (Dar et al. 2008). Hecnar & M'Closkey (1998) also found a negative correlation of amphibian density with water depth. Low density in Chand stream may be due to the fast flow of the water; amphibians are known to avoid fast-flowing streams (Dar et al. 2008).

Higher density and diversity of amphibians in DWA than in KWA might be due to the general topography of the area starting from 550 to 2,600 m, representing the species of both Himalayan foothills as well as middle Himalaya. Another reason may be fewer disturbances and the larger area of DWA (69.06km$^{2)}$ compared to KWA (32km^2). Overall, it is concluded that DWA is more diverse and richer in reptiles and amphibians than KWA. This study indicates that watersheds of Kumoan Himalaya is rich in herpetofaunal diversity, which decreases along the elevation gradients. This is because they can provide suitable habitats for herpetofauna (i.e., more humidity and food). Moreover, unequal distribution of different habitat types (more forested area and less barren and agriculture area in DWA as compared to KWA) may provide herpetofauna suitable habitat to flourish more in DWA. Overall, our results could provide important baseline information to design effective conservation and management strategies in the future.

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Appendix I. List of reptile species recorded in Dabka and Khulgarh watershed areas (P—present | A—absent).

Taxa	DWA	KWA
Family: Gekkonidae Gray, 1825		
Hemidactylus flaviviridis Rüppell, 1835	P	A
Family: Agamidae Gray, 1827		
Calotes versicolor (Daudin, 1802)	P	P
Laudakia tuberculata (Gray, 1827)	P	P
Psammophilus dorsalis (Gray, 1831)	A	P
Family: Scincidae Gray, 1825		
Asymblepharus ladacensis (Günther, 1864)	P	A
Eutropis macularia (Blyth, 1853)	P	P
Eutropis carinata (Schneider, 1801)	P	A
Lygosoma punctata (Gmelin, 1799)	A	P
Family: Colubridae Oppel, 1811		
Ahaetulla nasuta (Lacépède, 1789))	P	A
Boiga trigonata (Schneider in Bechstein, 1802)	P	A
Coelognathus Helena (Daudin, 1803)	P	A
Ptyas mucosa (Linnaeus, 1758)	A	P
Family: Natricidae Bonaparte, 1838	P	A
Amphiesma stolatum (Linnaeus, 1758)		
Family: Elapidae Boie, 1827		
Naja naja (Linnaeus, 1758)	P	P
Bungarus caeruleus (Schneider, 1801)	P	P
Family: Pythonidae Fitzinger, 1826		
Python molurus (Linnaeus, 1758)	P	A
Family: Viperidae Oppel, 1811		
Daboia russelii (Shaw & Nodder, 1797)	P	P
Gloydius himalayanus (Günther, 1864)	P	A

Appendix II. List of amphibian species recorded in Dabka and Khulgarh watershed areas (P—present | A—absent)

Taxa	DWA	KWA
Family: Bufonidae Gray, 1825		
Duttaphrynus melanostictus (Schneider, 1799)	P	P
Duttaphrynus himalayanus (Günther, 1864)	P	P
Family: Dicroglossidae Anderson, 1871		
Euphlyctis cyanophlyctis (Schneider, 1799)	P	P
Limnonectes limnocharis (Gravenhorst, 1829)	P	A
Hoplobatrachus crassus (Jerdon, 1854)	P	A
Hoplobatrachus tigerinus (Daudin, 1802)	P	P
Nanorana liebigii (Günther, 1860)	P	A
Family: Ranidae Rafinesque, 1814		
Amolops marmoratus (Blyth, 1855)	P	A

Threatened Taxa

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COMMUNICATION

A checklist of earthworms (Annelida: Oligochaeta) in southeastern Vietnam

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Abstract: The earthworms of southeastern Vietnam are reported based on literature and samples collected during the period of 2012–2019. A total of 41 earthworm species of 12 genera in six families are recorded in the southeastern part of Vietnam. Of these, *Polypheretima elongata* and *Dichogaster affinis* are recorded for the first time in the region. The dominant family is Megascolecidae with 35 species of seven genera while each of the other families is represented by only one species, except for Octochaetidae which has one genus and two species. The comprehensive checklist also provides data of each species including examined specimens, distributions and remarks. An identification key to species is compiled for southeastern Vietnam.

Keywords: Identification key, survey, Ho Chi Minh, humid, subtropical, data

Abbreviation: A—Aclitellate specimens | C—Clitellate specimens | CTU—Can Tho Univesity | IEBR—Institute of Ecology and Biological Resources-Vietnam Academy of Science and Technology | SORC—Soil Organism Research Center – Hanoi National University of Education | NP—National Park | NR—Natural Reserve | Mts—Mountain | ag—accessory gland | amp—ampula | atr—atrium | cl—clitellum | dv—diverticulum | fp—female pore | gm—genital markings | mp—male pore | np—nephridial pore | sg—seminal groove | os—penial seta | sp—spermathecal pore | st—seta.

Khu hệ giun đất vùng Đông Nam Bộ Việt Nam được tổng kết dựa trên các tài liệu nghiên cứu trước đây và các mẫu vật thu thập trong giai đoạn 2012-2019. Tổng số có 41 loài đất thuộc 12 giống, 6 họ được ghi nhận cho khu vực này. Trong đó, hai loài *Polypheretima elongata* và *Dichogaster affinis* được ghi nhận lần đầu tiên ở khu vực Đông Nam Bộ. Họ Megascolecidae là họ chiếm ưu thế với 35 loài, 7 giống, trong khi các họ giun đất khác chỉ gặp 1 loài, 1 giống, và họ Octochaetidae gặp 2 loài, 1 giống. Các thông tin về số lượng cá thể phân tích, phân bố và nhận xét cho từng loài cũng được trình bày chi tiết. Khoá phân loại các loài giun đất cho khu vực cũng được xây dựng.

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INTRODUCTION

Southeastern Vietnam has an area of 23,607.8km^2, located between 10.316–12.283^{0}N & 105.800–107.583^{0}E. This region is the territory of six provinces and city: Ho Chi Minh, Ba Ria – Vung Tau, Dong Nai, Binh Duong, Binh Phuoc, and Tay Ninh. The terrain changes from mountainous areas and midlands to coastal deltas. The region is located in a humid subtropical climate zone featured by the rainy season, which starts in May and lasts till October (average rainfall counted for 90% of the whole year), and the dry season from November to April. The region has different soil types, but mainly dominated by ferralsols and acrisols (Sterling et al. 2008).

The earthworms of Vietnam in general and of the southeastern part in particular was first reported by Perrier (1872, 1875) with descriptions of four new species. There were no reports for the southeastern part of Vietnam until 1956 when Omodeo (1956) described six new species. After that, there were no reports on earthworms in the region for approximate 60 years. Recently, Nguyen (2014) and Nguyen et al. (2015) reported list of earthworms recorded in small parts of Binh Duong Province. Nguyen et al. (2015a,b) also described four new species from Dong Nai Province. All data were synthesized into a comprehensive checklist of earthworms in Vietnam by Nguyen et al. (2016). After 2016, the earthworms of southeastern Vietnam have been intensively studied, and 14 new species were described from this region (Nguyen & Lam 2017; Nguyen et al. 2018, 2019, 2020a,b). Together with discoveries of new species, taxonomic acts have also been undertaken. Nguyen et al. (2017) and Nguyen (2020) corrected *Metaphire magophila* (Nguyen, 2011) as a senior synonym of *M. easupana* (Thai & Huynh, 1993). Samples of *M. neoexilis* (Thai & Samphon, 1988) found in Binh Duong province were misidentified as *Amynthas modigliani* (Rosa, 1896).

This work aims to provide comprehensive information on the earthworms of southeastern Vietnam. An identification key is also provided to facilitate further studies on earthworms in this region.

MATERIAL AND METHODS

The species list was created based on literature, e.g., Perrier (1872, 1875), Omodeo (1956), Nguyen (2014), Nguyen et al. (2015), Nguyen et al. (2015a,b, 2016, 2017, 2018, 2020a,b), Nguyen & Lam (2017), and Nguyen et al. (2019, 2020). The species was also confirmed by identifying samples collected from 263 sites (Figure 1) during the rainy season (early September to late October) in 2012–2019.

Earthworms were collected by digging and hand-sorting method following Górny & Grum (1993). After collecting, specimens were cleaned by tap water, killed in 2% formalin, temporally fixed in formalin 4% for 12 hours, then transferred to new formalin 4% for long-term preservation. All specimens were deposited in the Laboratory of Zoology, Department of Biology, Can Tho University.

The specimens were examined under a motic digital microscope (Model: DM143-FBGG-C) and dissected from the dorsal side for internal observation. Colour images were taken using a camera attached directly to the microscope, then improved and grouped into plates using Photoshop CS6.

RESULTS

Until date, a total of 41 earthworm species of 12 genera in six families (Almidae, Megascolecidae, Moniligastridae, Octochaetidae, Ocnerodrilidae, and Rhinodrilidae) have been recorded in southeastern Vietnam. All information of each species is presented in the checklist. *Polypheretima elongata* and *Dichogaster affinis* are reported for the first time in the region. Megascolecidae was the dominant family in terms of the number of species and genera (35 species of seven genera). It also corresponded to the earthworm distribution in the Oriental region (Hendrix & Bohlen 2002). Other families had only one species each except Octochaetidae which had two species in one genus. Particularly, the genus *Metaphire* had 20 species while *Amynthas* was poorly known with only seven species. Thai (2000) also indicated that *Metaphire* was the most diverse genus in the south of Vietnam.

In addition, 16 species were described from the southeastern part of Vietnam since 2016. Therefore, the total earthworm species of Vietnam has increased to 240 in 25 genera and eight families.

Family ALMIDAE Duboscq, 1902

Genus *Glyphidrilus* Horst, 1889

***1. Glyphidrilus papillatus* (Rosa, 1890)**

(Image 1 a1, Table 1)

Examined material: 2C (CTU-EW.030.02) and 3C (CTU-EW.030.04); data for samples shown in Table 1.

Distribution: Ba Ria-Vung Tau (Dat Do); Binh Duong (Tan Uyen, Dau Tieng, Phu Giao); Ho Chi Minh City (Nha

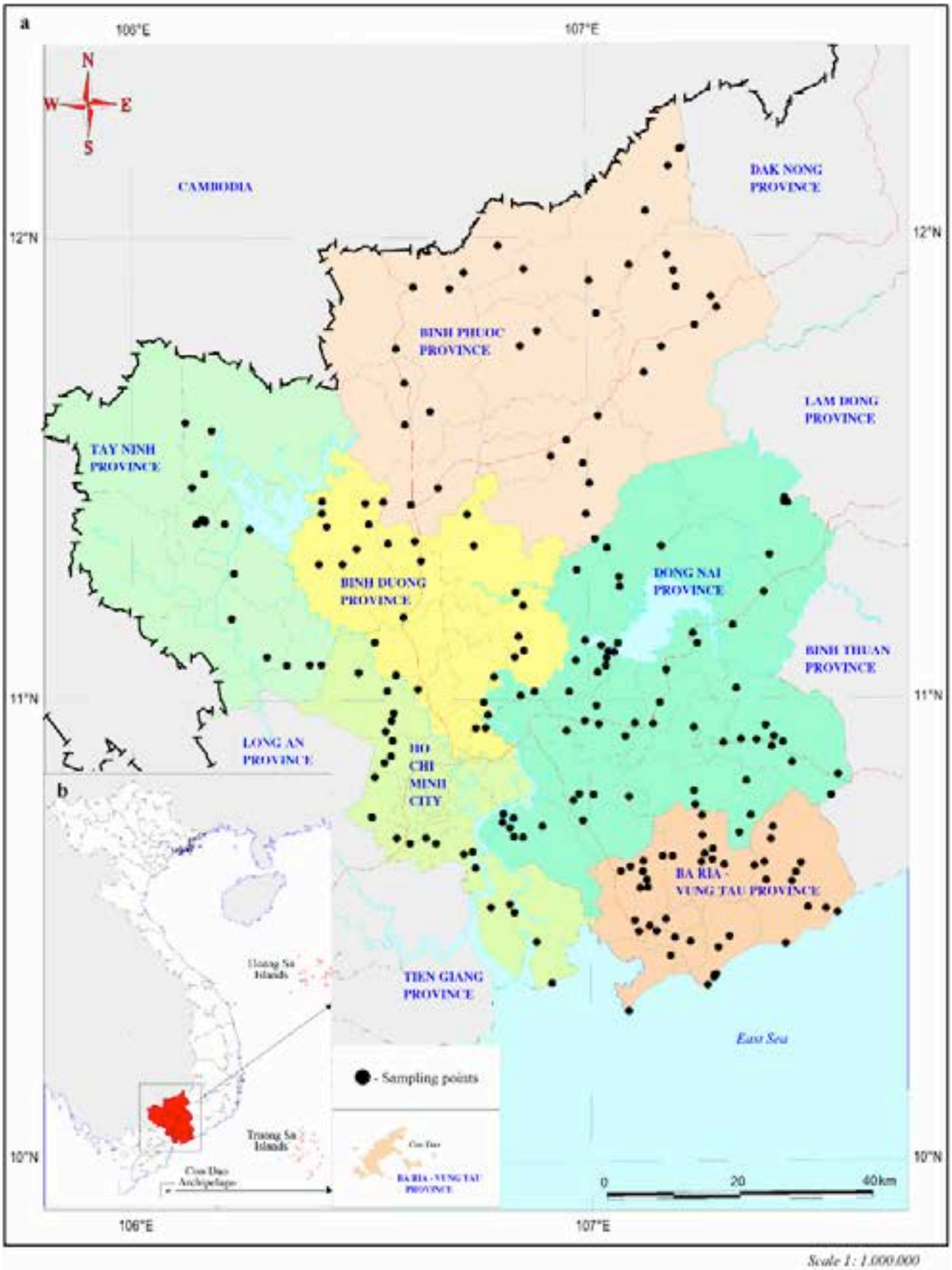

Figure 1. Collecting sites in southeastern Vietnam: a—southeastern Vietnam (mainland) | b—Vietnam map.

Be); Tay Ninh (Trang Bang).

Remarks: It was found in edges of water ponds or paddy fields.

Family MEGASCOLECIDAE Rosa, 1891

Genus *Lampito* Kinberg, 1867

***2. Lampito mauritii* Kinberg, 1867**

(Image 2 a1–a2, Table 1)

Examined material: 27C (CTU-EW.002.01), 13C (CTU–EW.002.07), 6C (CTU–EW.002.11), 9C (CTU-EW.002.13), 18C (CTU-EW.002.22), 46C (CTU-EW.002.27), and 21C (CTU-EW.002.32); data for samples were shown in Table 1.

Distribution: Dong Nai (Xuan Loc; Nhon Trach; Long Thanh); Ba Ria-Vung Tau (Vung Tau, Ba Ria, Xuyen Moc, Tan Thanh, Dat Do, Long Dien); Binh Duong (Di An, Dau Tieng, Bau Bang, Thu Dau Mot); Binh Phuoc (Chon Thanh); Ho Chi Minh City (Nha Be, Binh Chanh, Hoc Mon, Cu Chi); Tay Ninh (Trang Bang, Go Dau, Duong Minh Chau, Tan Chau, Tay Ninh).

Remarks: The species was found aggregated in high density in sandy soil and decomposed cow dung.

Genus *Perionyx* Perrier, 1872

***3. Perionyx excavatus* Perrier, 1872**

(Image 2 b1–b2, Table 1)

Examined material: 1C (CTU-EW.003.02) and 1C (CTU-EW.003.03); data for samples in Table 1.

Distribution: Dong Nai (Nhon Trach); Binh Duong (Di An, Dau Tieng, Bau Bang, Thu Dau Mot, Phu Giao); Ho Chi Minh City (Binh Chanh); Ba Ria-Vung Tau.

Remarks: The species has been bred commonly in local earthworm farms, but rarely found in the wild.

Genus *Pontodrilus* Perrier, 1874

***4. Pontodrilus litoralis* (Grube, 1855)**

Examined material: No specimen available

Distribution: Ba Ria-Vung Tau (Omodeo 1956)

Remarks: Omodeo (1956) collected samples of the species from mangrove soils (Ba Ria-Vung Tau Province), but there were no other further records in the study area recently.

Genus *Amynthas* Kinberg, 1867

***5. Amynthas dorsomorrioides* Nguyen & Nguyen, 2020**

(Image 2 f1–f2, Table 1)

Examined material: 1C (CTU-EW.174.h01), 2C (CTU-EW.174.p02), and 2C (IEBR-EW.174.p02); data in Table 1.

Distribution: Ba Ria–Vung Tau (Ba Ria City, Minh Dam Mts).

Remarks: The species is closely similar to A. dorsomorrisi (Do & Tran, 1995), however, distinguished by having spermathecal pores laterally, a pair of genital markings in xvii, first dorsal pore in 12/13, 6–7 setae between two male porophores, intestine swelling at xv, and lobuled typhlosole (Nguyen et al. 2020a).

***6. Amynthas exiguus austrinus* (Gates, 1932)**

(Image 2 d1–d2, Table 1)

Examined material: 4C (CTU-EW.057.01), 5C (CTU-EW.057.02), 14C (CTU-EW.057.03), 8C (CTU-EW.057.04), 8C (CTU-EW.057.05), and 11C (CTU-EW.057.11); data in Table 1.

Distribution: Dong Nai (Vinh Cuu, Thong Nhat, Long Khanh); Binh Phuoc (Bu Dang, Bu Gia Map, Dong Phu, Phuc Long); Ba Ria-Vung Tau (Dat Do); Tay Ninh (Tay Ninh City).

***7. Amynthas juliani* (Perrier, 1875)**

Examined material: No specimen available.

Distribution: Ho Chi Minh City (Perrier 1875).

Remarks: There were no further reports in the study area since Perrier (1875).

***8. Amynthas longiprostaticus* Nguyen & Lam, 2020**

(Image 2 g1–g2, Table 1)

Examined material: 1C (CTU-EW.088.h01), 5C (CTU-EW.088.p02), 4C (IEBR-EW.088.p02), 30C (CTU-EW.088.03), and 17C (IEBR-EW.088.03); data in Table 1.

Distribution: Dong Nai (Cam My, Cat Tien NP).

Remarks: The species is somewhat similar to *A. papilio* (Gates, 1930) and *A. khaohayod* Bantaowong & Panha, 2015. It is, however, characterized by having the distance between male pores wider, presence of genital markings in the spermathecal region, first dorsal pore in 11/12, and smaller size (Nguyen et al. 2020a).

***9. Amynthas minhdam* Nguyen & Tran, 2020**

(Image 2 h1–h2, Table 1)

Examined material: 1C (CTU-EW.168.h01), 1C (CTU-EW.168.p02), 3C (CTU-EW.168.p03), and 2C (IEBR-EW.168.p03); data Table 1.

Distribution: Ba Ria-Vung Tau (Minh Dam Mts).

Remarks: The species is fairly similar to *A. sapinianus* (Chen, 1946) and *A. morrisi* (Beddard, 1892). It is, however, distinguished by having a pair of genital markings in the male region, chain-shaped seminal chamber, and first dorsal pore in 12/13 (Nguyen et al. 2020a).

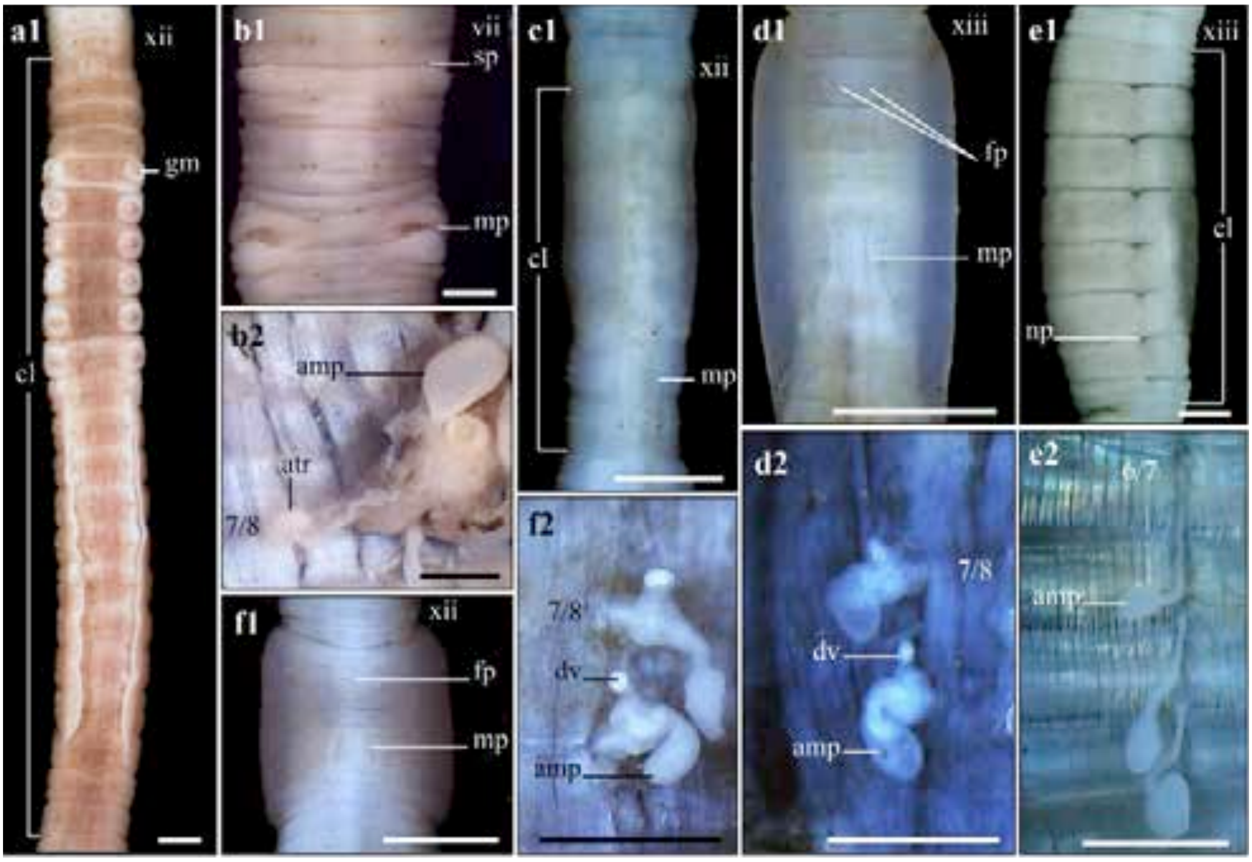

Image 1. Male region (1) and spermathecae (2) of non-megascolecid species in southeastern Vietnam: a—*Glyphidrilus papillatus* | b—*Drawida beddardi* | c—*Eukerria saltensis* | d—*Dichogaster affinis* | e—*Dichogaster bolaui* | f—*Pontoscolex corethrurus*. Scale bar= 1mm. © D.H. Lam.

***10. Amynthas ocularius* Nguyen & Lam, 2020**

(Image 2 i1–i2, Table 1)

Examined material: 1C (CTU-EW.167.h01), 2C (CTU-EW.167.p02), 3C (CTU-EW.167.p03), and 2C (IEBR-EW.167.p03); data in Table 1.

Distribution: Ba Ria-Vung Tau (Binh Chau-Phuoc Buu NR).

Remarks: The species is somewhat similar to *A. compositus* (Gates, 1932) and *A. papulosus* (Rosa, 1896). It is, however, distinctly different from those congener in having numerous genital markings being arranged in transverse lines in both of the spermathecal and male regions, and being agglomerated into two groups in 19/20, and first dorsal pore in 13/14 (Nguyen et al. 2020a).

***11. Amynthas polychaetiferus* (Thai, 1984)**

(Image 2 e1–e2, Table 1)

Examined material: 29C (CTU-EW.008.01), 10C (CTU-EW.008.04), 11C (CTU-EW.008.07), 20C (CTU-EW.008.10), 10C (CTU-EW.008.18), 6C (CTU-EW.008.21), and 2C (CTU-EW.008.24); data in Table 1.

Distribution: Widely distributed in the study area, but more gathered in Dong Nai and Ba Ria-Vung Tau, little known in Binh Duong and Binh Phuoc, and rarely found in Ho Chi Minh City and Tay Ninh.

Remarks: The species have setae crowded ventrally in xix, varied in numbers or sometimes in usual position. The species was reported from the study area with the highest frequency and species abundance compared to other places.

Genus *Metaphire* Sims & Easton, 1972

***12. Metaphire anomala* (Michaelsen, 1907)**

(Image 3 k1–k2, Table 1)

Examined material: 11C (CTU-EW.020.06), 7C (CTU-EW.020.07), 10C (CTU-EW.020.13), 8C (CTU-EW.020.14), and 20C (CTU-EW.020.21); data in Table 1.

Distribution: Dong Nai (Vinh Cuu, Xuan Loc, Dinh Quan, Trang Bom, Cam My, Long Thanh); Ba Ria-Vung Tau (Chau Duc, Xuyen Moc, Tan Thanh, Ba Ria City); Binh Duong (Tan Uyen; Binh Phuoc: Phu Rieng); Tay Ninh (Duong Minh Chau, Tay Ninh City).

Remarks: The species is morphologically different

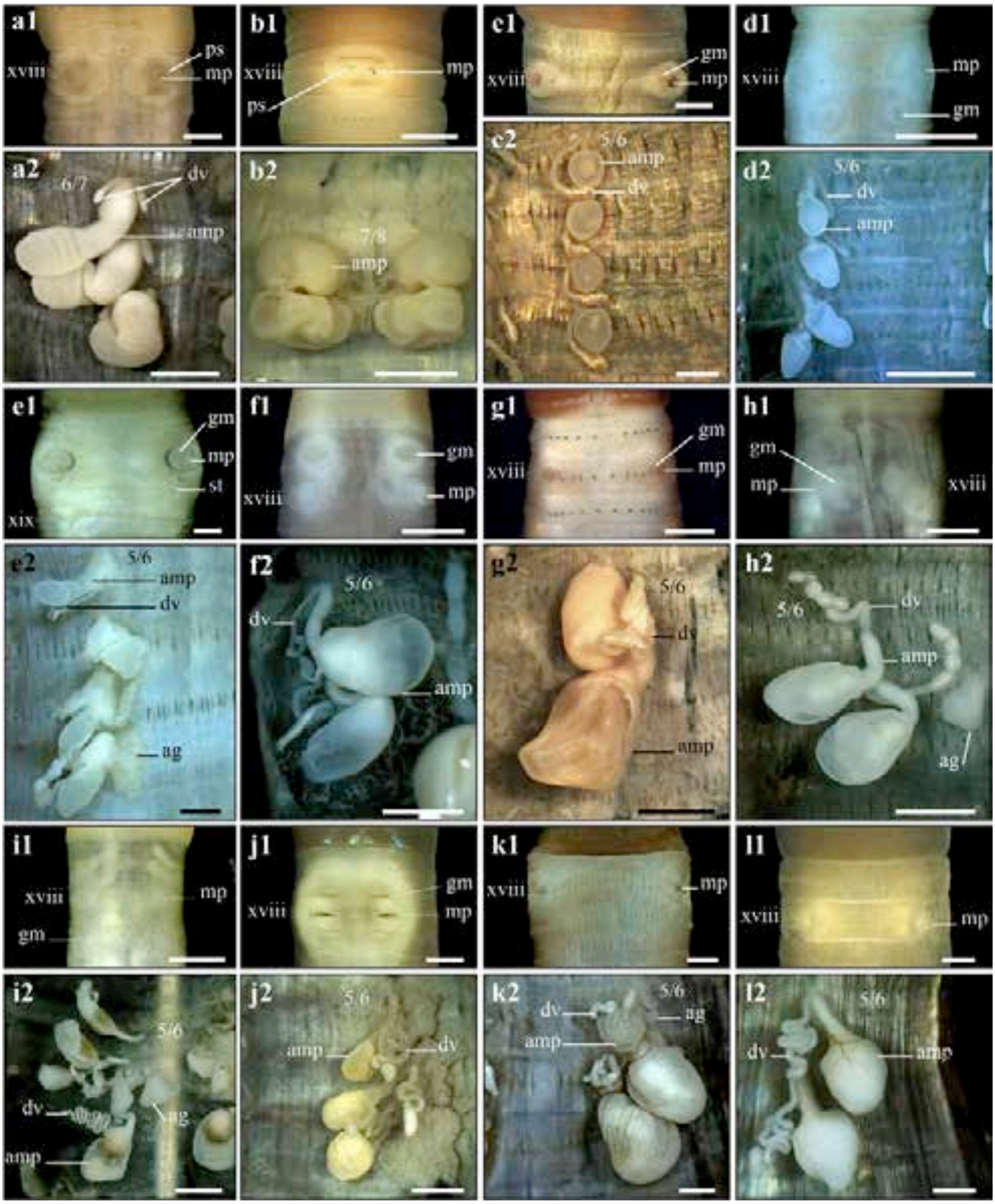

Image 2. Male region (1) and Spermathecae (2) of megascolecid species in southeastern Vietnam: a—*Lampito mauritii* | b—*Perionyx excavatus* | c—*Amynthas corticis* | d—*Amynthas exiguus austrinus* | e—*Amynthas polychaetiferus* | f—*Amynthas dorsomorrioides* | g—*Amynthas longiprostaticus* | h—*Amynthas minhdam* | i—*Amynthas ocularius* | j—*Metaphire bahli* | k—*Metaphire* cf. *campanulata* | l—*Metaphire easupana*. Scale bar= 1mm. © D.H. Lam.

from the original description of Michaelsen (1907) by having male pore in xix, four pairs of spermathecal pore in 5/6/7/8/9, no genital markings, and bigger size.

13. Metaphire bahli **(Gates, 1945)**
(Image 2 j1–j2, Table 1)

Examined material: 30C (CTU-EW.004.01), 30 (CTU-EW.004.02), 22 (CTU-EW.004.03),16 (CTU-EW.004.04), 28C (CTU-EW.004.19), 19C (CTU-EW.004.24), 20C (CTU-EW.004.25), 39C (CTU-EW.004.54), and 30C (CTU-EW.004.62); data in Table 1.

Distribution: Widely distributed in southern Vietnam.

14. Metaphire bariaensis **Nguyen, Nguyen, Lam & Nguyen, 2020**
(Image 3 l1–l2, Table 1)

Examined material: 1C (CTU-EW.169.h01), 2C (CTU-EW.169.p02), 3C (CTU-EW.169.p03), and 15C (CTU-EW.169.04); data in Table 1.

Distribution: Ba Ria-Vung Tau (Ba Ria, Bao Quang Mts).

Remarks: The species is somewhat similar to *M. truongsonensis* (Thai, 1984); however, it is characterized by having spermathecal pores located laterally and separated intestinal caeca (Nguyen et al. 2020b).

15. Metaphire **cf.** ***campanulata*** **(Rosa, 1890)**
(Image 2 k1–k2, Table 1)

Examined material: 17C (CTU-EW.018.01), 14C (CTU-EW.018.09), 14C (CTU-EW.018.11), 25C (CTU-EW.018.20), 4C (CTU-EW.018.34), and 8C (CTU-EW.018.36); data in Table 1.

Distribution: Commonly found in the study area.

Remarks: The species is closely similar to *M. houlleti* (Perrier, 1872) but it is characterized by mushroom-shaped spermathecae, first dorsal pore in 11/12, and bigger size.

16. Metaphire easupana **(Thai & Huynh, 1993)**
(Image 2 l1–l2, Table 1)

Examined material: 5C (CTU-EW.012.04), 35C (CTU-EW.012.05), 10C (CTU-EW.012.10), 25C (CTU-EW.012.17), and 23C (CTU-EW.012.26); data in Table 1.

Distribution: Dong Nai (Vinh Cuu, Xuan Loc, Dinh Quan); Ba Ria-Vung Tau (Tan Thanh, Ba Ria City, Long Dien: Minh Dam Mts); Tay Ninh (Ba Den Mts).

Remarks: The species was known as *M. magophila* (Nguyen, 2011), but it was synonymized by Nguyen et al. (2017).

17. Metaphire grandiverticulata **Nguyen & Lam, 2017**
(Image 3 a1–a2, Table 1)

Examined material: 1C (CTU-EW.089.h01), 9C (CTU-EW.089.p02), 13C (CTU-EW.089.03), and 24C (CTU-EW.089.04); data in Table 1.

Distribution: Dong Nai (Long Khanh); Ho Chi Minh City (Hoc Mon).

Remarks: The species is similar to *M. neoexilis* (Thai & Samphon, 1988), but it is characterized by having large and stout spermathecal diverticula and ventrally connected testes sacs (Nguyen & Lam 2017).

18. Metaphire haui **Nguyen, Nguyen, Lam & Nguyen, 2020**
(Image 4 a1–a2, Table 1)

Examined material: 1C (CTU-EW.172.h01), 4C (CTU-EW.172.p02), 2C (CTU-EW.172.p03), and 4A (CTU-EW.172.p04); data in Table 1.

Distribution: Ba Ria-Vung Tau (Dinh Mts, Tan Thanh).

Remarks: The species is fairly similar to *M. peguana* (Rosa, 1890), but it is distinguished by having spermathecal pores located laterally, first dorsal pore in 7/8, and genital markings in xvii and xix (Nguyen et al. 2020b).

19. Metaphire houlleti **(Perrier, 1872)**
(Image 3 b1–b2, Table 1)

Examined material: 49C (CTU-EW.006.01), 25C (CTU-EW.006.06), 26C (CTU-EW.006.11), 10C (CTU-EW.006.19), 3C (CTU-EW.006.27), 9C (CTU-EW.006.45), and 11C (CTU-EW.006.48).

Distribution: Widely distributed in southern Vietnam.

20. Metaphire houlletoides **Nguyen, Nguyen, Lam & Nguyen, 2020**
(Image 4 b1–b2, Table 1)

Examined material: 1C (CTU-EW.180.h01) and 3C (CTU-EW.180.p02); data in Table 1.

Distribution: Binh Phuoc (Loc Ninh, Dong Phu, Bu Gia Map NP, Bu Dang).

Remarks: The species is fairly similar to *M. houlleti* (Perrier, 1872), however, it is characterized by having two pairs of spermathecal pores in 7/8/9 and smaller size (Nguyen et al. 2020b).

21. Metaphire malayanoides **Nguyen & Lam, 2017**
(Image 3 c1–c2, Table 1)

Examined material: 1C (CTU-EW.084.h01), 8C (CTU-EW.084.p02), 5C (CTU-EW.084.p03), 16C (CTU-EW.084.04), 31C (CTU-EW.084.05), 14C (CTU-EW.084.06), and 34C (CTU-EW.084.07); data in Table 1.

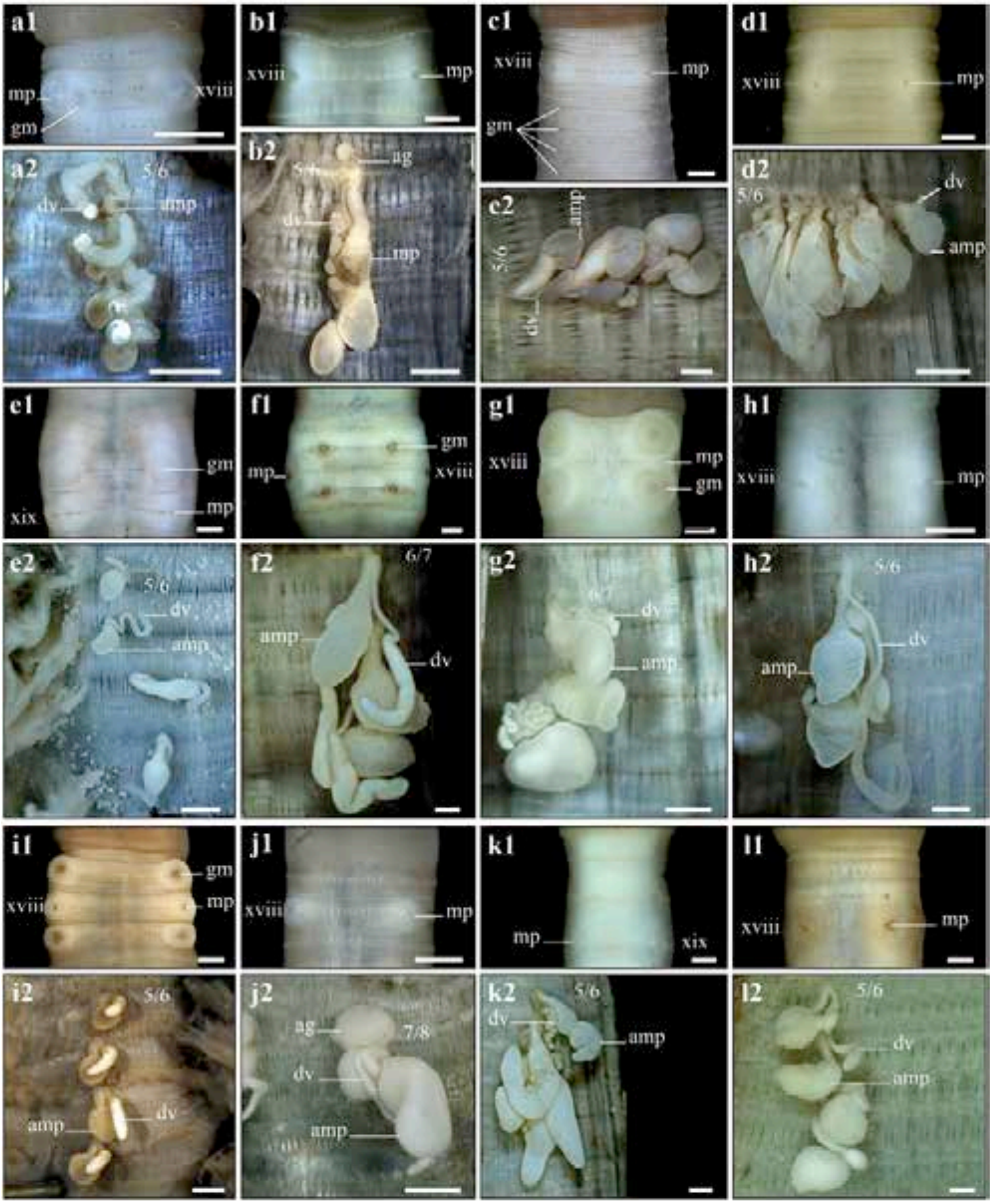

Image 3. Male region (1) and Spermatheca (2) of megascolecid species in southeastern Vietnam (continued): a—*Metaphire grandiverticulata* | b—*Metaphire houlleti* | c—*Metaphire malayanoides* | d—*Metaphire mangophiloides* | e—*Metaphire neoexilis* | f—*Metaphire pacseana* | g—*Metaphire peguana peguana* | h—*Metaphire planata* | i—*Metaphire posthuma* | j—*Metaphire xuanlocensis* | k—*Metaphire anomala* | l—*Metaphire bariaensis*. Scale bar= 1mm. © D.H. Lam.

Distribution: Dong Nai (Vinh Cuu, Dinh Quan, Thong Nhat, Trang Bom).

Remarks: The species is closely similar to *M. malayana* (Beddard, 1900), however, it is recognized by having presence of genital markings in intersegmental furrows (from 19/20 to 26/27), first dorsal pore in 12/13, and separated testes sacs (Nguyen & Lam 2017).

22. *Metaphire mangophiloides* Nguyen & Le, 2015

(Image 3 d1–d2, Table 1)

Examined material: 1C (CTU-EW.082.h01) and 1C (CTU-EW.082.p02); data in Table 1.

Distribution: Dong Nai (Vinh Cuu).

Remarks: The species is fairly similar to *M. easupana* (Thai & Huynh, 1993) but it is characterized by having spermathecal pores in 5/6 and polythecate (Nguyen et al. 2015a).

23. *Metaphire neoexilis* (Thai & Samphon, 1988)

(Image 3 e1–e2, Table 1)

Examined material: 32A (CTU-EW.085.01), 13A (CTU-EW.085.02), 3A (CTU-EW.085.03), and 3A (CTU-EW.085.04); data in Table 1.

Distribution: Dong Nai (Long Thanh, Cam My); Binh Duong (Dau Tieng, Phu Giao).

Remarks: The present population has slight difference from the original description of Thai & Samphon (1988) in genital markings in xviii and male pores in xix.

24. *Metaphire pacseana* (Thai & Samphon, 1988)

(Image 3 f1–f2, Table 1)

Examined material: 6C (CTU-EW.083.01), 4C (CTU-EW.083.03), 3C (CTU-EW.083.07), and 6C (CTU-EW.083.14); data in Table 1.

Distribution: Dong Nai (Long Thanh, Nhon Trach); Binh Duong (Bac Tan Uyen, Ben Cat, Dau Tieng, Bau Bang); Binh Phuoc (Hon Quan); Ho Chi Minh City (Cu Chi); Tay Ninh (Go Dau, Duong Minh Chau, Ba Den Mts).

Remarks: The populations collected in Ba Den Mountain (Tay Ninh province) and Phu Giao (Binh Duong province) lack genital markings while others have two pairs in 17/18 and 18/19 as in the original description.

25. *Metaphire peguana peguana* (Rosa, 1890)

(Image 3 g1–g2, Table 1)

Examined material: 5C (CTU-EW.009.02), 15C (CTU-EW.009.03), 3C (CTU-EW.009.05), 13C (CTU-EW.009.07), and 16C (CTU-EW.009.14); data in Table 1.

Distribution: Dong Nai (Vinh Cuu, Xuan Loc, Nhon Trach, Long Thanh); Ba Ria-Vung Tau (Tan Thanh); Binh Duong (Bac Tan Uyen, Phu Giao, Ben Cat); Binh Phuoc (Chon Thanh); Ho Chi Minh City (Can Gio, Nha Be, Binh Chanh, Hoc Mon, Cu Chi).

Remarks: The species is somewhat similar to *M. bahli* (Gates, 1945), but is characterized by having large disc-shaped genital markings and unconcave male region.

26. *Metaphire planata* (Gates, 1926)

(Image 3 h1–h2, Table 1)

Examined material: 9C (CTU-EW.016.04), 11C (CTU-EW.016.05), 11C (CTU-EW.016.10), 8C (CTU-EW.016.15), 31C (CTU-EW.016.20), 12C (CTU-EW.016.36), and 9C (CTU-EW.016.39); data in Table 1.

Distribution: Widely distributed in southern Vietnam, but more commonly found in grey soils of deltas.

Remarks: The species was erroneously identified as *M. californica* (Kinberg, 1867), but corrected by Nguyen et al. (2020). *M. planata* differs from M. californica in having spermathecal pores in 5/6/7, genital marking present in the spermathecal region associated with saccular accessory glands internally, simple intestinal caeca, separated testes sacs, and smaller size. It is noted that the preservation code CTU-EW.005 (for *M. californica*) would be changed to CTU-EW.016 (for *M. planata*).

27. *Metaphire planatoides* Nguyen, Nguyen, Lam & Nguyen, 2020

(Image 4 c1–c2, Table 1)

Examined material: 1C (CTU-EW.171.h01) and 2C (CTU-EW.171.p02); data in Table 1.

Distribution: Ba Ria-Vung Tau (Minh Dam Mts).

Remarks: The species is closely similar to *M. planata* (Gates, 1926), but it is distinguished by lacking of genital markings and accessory glands, having waved diverticula, connecting testes sacs, and smaller size (Nguyen et al. 2020b).

28. *Metaphire posthuma* (Vaillant, 1868)

(Image 3 i1–i2, Table 1)

Examined material: 10C (CTU-EW.011.01) and 19C (CTU-EW.011.03); data in Table 1.

Distribution: Dong Nai (Xuan Loc); Binh Duong (Dau Tieng, Phu Giao); Ho Chi Minh City (Can Gio, Hoc Mon, Cu Chi); Tay Ninh (Tan Chau).

29. *Metaphire setosa* Nguyen, Nguyen, Lam & Nguyen, 2020

(Image 4 d1–d2, Table 1)

Examined material: 1C (CTU-EW.179.h01), and 6C (CTU-EW.179.p02); data in Table 1.

Distribution: Binh Phuoc (Hon Quan, Chon Thanh).

Image 4. Male region (1) and Spermathecae (2) of megascolecid species in southeastern Vietnam (continued): a—*Metaphire* sp. | b—*Metaphire haui* | c—*Metaphire houlletoides* | d—*Metaphire planatoides* | e—*Metaphire setosa* | f—*Metaphire songbeensis* | g—*Polypheretima cattienensis* | h—*Polypheretima colonensis* | i—*Polypheretima cordata* | j—*Polypheretima elongata* | k—*Polypheretima grandisetosa* | l—*Polypheretima militium* | m—*Pheretima vungtauensis*. Scale bar= 1mm. © D.H. Lam.

Table 1. The collection of earthworm samples from southeastern Vietnam.

No.	Species names and label codes	Number of Specimen	GPS Coordinates		Location	Date	Collector
			Latitude (North)	Longitude (East)			
1	***Glyphidrilus papillatus* (Rosa, 1890)**						
	CTU-EW.030.02	2C	10.487778	107.251111	Dat Do, Ba Ria Vung Tau	x.2016	Nam Q. Nguyen
	CTU-EW.030.04	3C	10.913889	106.566111	Hoc Mon, Ho Chi Minh City	ix.2019	Nam Q. Nguyen
2	***Lampito mauritii* Kinberg, 1867**						
	CTU-EW.002.01	27C	10.792778	107.525556	Xuan Loc, Dong Nai	x.2012	Thang V. Nguyen
	CTU-EW.002.07	13C	10.464167	107.276944	Dat Do, Ba Ria Vung Tau	x.2016	Nam Q. Nguyen
	CTU-EW.002.11	6C	11.429167	106.548333	Chon Thanh, Binh Phuoc	x.2017	Nam Q. Nguyen
	CTU-EW.002.13	9C	11.412500	106.412778	Dau Tieng, Binh Duong	x.2017	Nam Q. Nguyen
	CTU-EW.002.27	46C	10.691667	106.603056	Binh Chanh, Ho Chi Minh City	ix.2019	Nam Q. Nguyen
	CTU-EW.002.32	21C	11.077500	106.402222	Trang Bang, Tay Ninh	ix.2019	Nam Q. Nguyen
3	***Perionyx excavatus* Perrier, 1872**						
	CTU-EW.003.02	1C	10.727222	106.827222	Nhon Trach, Dong Nai	x.2016	Nam Q. Nguyen
	CTU-EW.003.03	1C	11.333611	106.746389	Phu Giao, Binh Duong	x.2017	Nam Q. Nguyen
4	***Amynthas dorsomorrioides* Nguyen & Nguyen, 2020**						
	CTU-EW.174.h01	1C	10.511111	107.126944	Dinh Mts., Ba Ria Vung Tau	x.2016	Hau P. Nguyen
	CTU-EW.174.p02	2C	10.405833	107.271667	Minh Dam Mts., Ba Ria Vung Tau	x.2016	Hau P. Nguyen
	IEBR-EW.174.p02	2C	10.405833	107.271667	Minh Dam Mts., Ba Ria Vung Tau	x.2016	Hau P. Nguyen
5	***Amynthas exiguus austrinus* (Gates, 1932)**						
	CTU-EW.057.01	4C	11.142778	107.225556	Dinh Quan, Dong Nai	x.2013	Nhan V. Le
	CTU-EW.057.02	5C	10.994444	107.151389	Thong Nhat, Dong Nai	x.2013	Nhan V. Le
	CTU-EW.057.03	14C	11.258889	107.065833	Vinh Cuu, Dong Nai	x.2013	Trong C. Duong
	CTU-EW.057.04	8C	11.809444	107.067500	Bu Dang, Binh Phuoc	x.2017	Nam Q. Nguyen
	CTU-EW.057.05	8C	12.192778	107.206944	Bu Gia Map NP, Binh Phuoc	x.2017	Nam Q. Nguyen
	CTU-EW.057.11	11C	11.390556	106.155278	Ba Den Mts., Tay Ninh	ix.2019	Nam Q. Nguyen
6	***Amynthas longiprostaticus* Nguyen & Lam, 2020**						
	CTU-EW.088.h01	1C	11.425000	107.428333	Cat Tien NP, Dong Nai	x.2013	Nhan V. Le
	CTU-EW.088.p02	5C	11.425000	107.428333	Cat Tien NP, Dong Nai	x.2013	Nhan V. Le
	IEBR-EW.088.p02	4C	11.425000	107.428333	Cat Tien NP, Dong Nai	x.2013	Nhan V. Le
	CTU-EW.088.03	30C	11.425000	107.428333	Cat Tien NP, Dong Nai	x.2013	Nhan V. Le
	IEBR-EW.088.03	17C	11.425000	107.428333	Cat Tien NP, Dong Nai	x.2013	Nhan V. Le
7	***Amynthas minhdam* Nguyen & Tran, 2020**						
	CTU-EW.168.h01	1C	10.405556	107.271667	Minh Dam Mts., Ba Ria Vung Tau	x.2016	Hau P. Nguyen
	CTU-EW.168.p02	1C	10.405556	107.271667	Minh Dam Mts., Ba Ria Vung Tau	x.2016	Hau P. Nguyen
	CTU-EW.168.p03	3C	10.405556	107.271667	Minh Dam Mts., Ba Ria Vung Tau	x.2019	Dang H. Lam
	IEBR-EW.168.p03	2C	10.405556	107.271667	Minh Dam Mts., Ba Ria Vung Tau	x.2019	Dang H. Lam
8	***Amynthas ocularius* Nguyen & Lam, 2020**						
	CTU-EW.167.h01	1C	10.547500	107.512778	Binh Chau Phuoc Buu NR, Ba Ria Vung Tau	x.2016	Ai T. Truong
	CTU-EW.167.p02	2C	10.547500	107.512778	Binh Chau Phuoc Buu NR, Ba Ria Vung Tau	x.2016	Ai T. Truong
	CTU-EW.167.p03	3C	10.547500	107.512778	Binh Chau Phuoc Buu NR, Ba Ria Vung Tau	x.2019	Dang H. Lam
	IEBR-EW.167.p03	2C	10.547500	107.512778	Binh Chau Phuoc Buu NR, Ba Ria Vung Tau	x.2019	Dang H. Lam
9	***Amynthas polychaetiferus* (Thai, 1984)**						
	CTU-EW.008.01	29C	11.331944	107.157778	Vinh Cuu, Dong Nai	x.2012	Trong C. Duong

No.	Species names and label codes	Number of Specimen	GPS Coordinates		Location	Date	Collector
			Latitude (North)	Longitude (East)			
	CTU-EW.008.04	10C	10.898611	107.021667	Trang Bom, Dong Nai	x.2013	Nhan V. Le
	CTU-EW.008.07	11C	10.803056	107.225833	Cam My, Dong Nai	x.2014	Nhan V. Le
	CTU-EW.008.10	20C	10.646111	107.458333	Xuyen Moc, Ba Ria Vung Tau	x.2016	Nam Q. Nguyen
	CTU-EW.008.18	10C	11.798056	106.933889	Phu Rieng, Binh Phuoc	x.2017	Nam Q. Nguyen
	CTU-EW.008.21	6C	11.050000	106.788889	Tan Uyen, Binh Duong	x.2017	Nam Q. Nguyen
	CTU-EW.008.24	2C	11.077500	106.400000	Go Dau, Tay Ninh	ix.2019	Nam Q. Nguyen
10	***Metaphire anomala*** **(Michaelsen, 1907)**						
	CTU-EW.020.06	11C	10.921667	107.076111	Trang Bom, Dong Nai	x.2013	Nhan V. Le
	CTU-EW.020.07	7C	11.434444	107.428889	Tan Phu, Dong Nai	x.2013	Nhan V. Le
	CTU-EW.020.13	10C	10.525833	107.162222	Ba Ria City, Ba Ria Vung Tau	x.2016	Nam Q. Nguyen
	CTU-EW.020.14	8C	11.798056	106.933889	Phu Rieng, Binh Phuoc	x.2017	Nam Q. Nguyen
	CTU-EW.020.21	20C	11.386944	106.143056	Tay Ninh City, Tay Ninh	ix.2019	Nam Q. Nguyen
11	***Metaphire bahli*** **(Gates, 1945)**						
	CTU-EW.004.01	30C	11.231389	107.381944	Dinh Quan, Dong Nai	x.2013	Nhan V. Le
	CTU-EW.004.02	30C	10.837500	107.541111	Xuan Loc, Dong Nai	x.2012	Thang V. Nguyen
	CTU-EW.004.03	22C	11.312222	107.394722	Tan Phu, Dong Nai	x.2013	Nhan V. Le
	CTU-EW.004.04	16C	11.018333	106.953889	Vinh Cuu, Dong Nai	ix.2012	Trong C. Duong
	CTU-EW.004.19	28C	10.639167	107.085556	Tan Thanh, Ba Ria Vung Tau	x.2016	Nam Q. Nguyen
	CTU-EW.004.24	19C	11.429167	106.548333	Chon Thanh, Binh Phuoc	x.2017	Nam Q. Nguyen
	CTU-EW.004.25	20C	10.942778	106.772500	Di An, Binh Duong	x.2017	Nam Q. Nguyen
	CTU-EW.004.54	39C	10.387500	106.912500	Can Gio, Ho Chi Minh City	ix.2019	Nam Q. Nguyen
	CTU-EW.004.62	30C	11.382778	106.200000	Duong Minh Chau, Tay Ninh	ix.2019	Nam Q. Nguyen
12	***Metaphire bariaensis*** **Nguyen, Nguyen, Lam & Nguyen, 2020**						
	CTU-EW.169.h01	1C	10.593333	107.113889	Bao Quang Mts., Ba Ria Vung Tau	x.2016	Hau P. Nguyen
	CTU-EW.169.p02	2C	10.593333	107.113889	Bao Quang Mts., Ba Ria Vung Tau	x.2016	Hau P. Nguyen
	CTU-EW.169.p03	3C	10.639167	107.085556	Ba Ria City, Ba Ria Vung Tau	x.2016	Hau P. Nguyen
	CTU-EW.169.04	15C	10.525833	107.162222	Tan Thanh, Ba Ria Vung Tau	x.2019	Nam Q. Nguyen
13	***Metaphire*** **cf.** ***campanulata*** **(Rosa, 1890)**						
	CTU-EW.018.01	17C	11.425278	107.428611	Tan Phu, Dong Nai	x.2013	Nhan V. Le
	CTU-EW.018.09	14C	10.666667	107.248333	Chau Duc, Ba Ria Vung Tau	x.2016	Nam Q. Nguyen
	CTU-EW.018.11	14C	11.527778	106.916667	Dong Xoai, Binh Phuoc	x.2017	Nam Q. Nguyen
	CTU-EW.018.20	25C	11.050000	106.789167	Tan Uyen, Binh Duong	x.2017	Nam Q. Nguyen
	CTU-EW.018.34	4C	11.021389	106.555000	Cu Chi, Ho Chi Minh City	ix.2019	Nam Q. Nguyen
	CTU-EW.018.36	8C	11.382778	106.200000	Duong Minh Chau, Tay Ninh	ix.2019	Nam Q. Nguyen
14	***Metaphire easupana*** **(Thai & Huynh, 1993)**						
	CTU-EW.012.04	5C	11.160000	107.314444	Dinh Quan, Dong Nai	x.2013	Nhan V. Le
	CTU-EW.012.05	35C	10.944167	107.383611	Xuan Loc, Dong Nai	x.2012	Thang V. Nguyen
	CTU-EW.012.10	10C	11.018889	106.877500	Vinh Cuu, Dong Nai	ix.2012	Trong C. Duong
	CTU-EW.012.17	25C	10.404167	107.267778	Minh Dam Mts., Ba Ria Vung Tau	x.2016	Nam Q. Nguyen
	CTU-EW.012.26	23C	11.390556	106.155278	Ba Den Mts., Tay Ninh	x.2019	Nam Q. Nguyen
15	***Metaphire grandiverticulata*** **Nguyen & Lam, 2017**						
	CTU-EW.089.h01	1C	10.741389	106.975278	Long Thanh, Dong Nai	x.2014	Nhan V. Le
	CTU-EW.089.p02	9C	10.741389	106.975278	Long Thanh, Dong Nai	x.2014	Nhan V. Le

No.	Species names and label codes	Number of Specimen	GPS Coordinates		Location	Date	Collector
			Latitude (North)	Longitude (East)			
	CTU-EW.089.03	13C	10.741389	106.975278	Long Thanh, Dong Nai	x.2014	Nhan V. Le
	CTU-EW.089.04	24C	10.913889	106.566111	Hoc Mon, Ho Chi Minh City	ix.2019	Nam Q. Nguyen
16	***Metaphire haui*** **Nguyen, Nguyen, Lam & Nguyen, 2020**						
	CTU-EW.172.h01	1C	10.525833	107.162222	Ba Ria City, Ba Ria Vung Tau	x.2016	Hau P. Nguyen
	CTU-EW.172.p02	4C	10.525833	107.162222	Ba Ria City, Ba Ria Vung Tau	x.2016	Hau P. Nguyen
	CTU-EW.172.p03	2C	10.499444	107.141944	Ba Ria City, Ba Ria Vung Tau	x.2016	Hau P. Nguyen
	CTU-EW.172.p04	4A	10.525833	107.162222	Tan Thanh, Ba Ria Vung Tau	x.2016	Hau P. Nguyen
17	***Metaphire houlleti*** **(Perrier, 1872)**						
	CTU-EW.006.01	49C	11.089722	107.035833	Vinh Cuu, Dong Nai	x.2012	Trong C. Duong
	CTU-EW.006.06	25C	11.425278	107.428611	Tan Phu, Dong Nai	x.2013	Nhan V. Le
	CTU-EW.006.11	26C	10.651667	107.240833	Chau Duc, Ba Ria Vung Tau	x.2016	Nam Q. Nguyen
	CTU-EW.006.19	10C	12.057222	107.127500	Bu Gia Map, Binh Phuoc	x.2017	Nam Q. Nguyen
	CTU-EW.006.27	3C	11.333611	106.746389	Phu Giao, Binh Duong	x.2017	Nam Q. Nguyen
	CTU-EW.006.45	9C	10.868333	106.548889	Hoc Mon, Ho Chi Minh City	ix.2019	Nam Q. Nguyen
	CTU-EW.006.48	11C	11.382778	106.200000	Duong Minh Chau, Tay Ninh	ix.2019	Nam Q. Nguyen
18	***Metaphire houlletoides*** **Nguyen, Nguyen, Lam & Nguyen, 2020**						
	CTU-EW.180.h01	1C	11.468611	107.000833	Dong Phu, Binh Phuoc	x.2017	Tien T. H. Luong
	CTU-EW.180.p02	3C	11.468611	107.000833	Dong Phu, Binh Phuoc	x.2017	Tien T. H. Luong
19	***Metaphire malayanoides*** **Nguyen & Lam, 2017**						
	CTU-EW.084.h01	1C	11.142778	107.225556	Dinh Quan, Dong Nai	x.2013	Nhan V. Le
	CTU-EW.084.p02	8C	11.142778	107.225556	Dinh Quan, Dong Nai	x.2013	Nhan V. Le
	CTU-EW.084.p03	5C	10.994444	107.152222	Thong Nhat, Dong Nai	x.2013	Nhan V. Le
	CTU-EW.084.04	16C	11.142778	107.225556	Dinh Quan, Dong Nai	x.2013	Nhan V. Le
	CTU-EW.084.05	31C	10.994444	107.152222	Thong Nhat, Dong Nai	x.2013	Nhan V. Le
	CTU-EW.084.06	14C	11.111111	107.053333	Vinh Cuu, Dong Nai	x.2012	Trong C. Duong
	CTU-EW.084.07	34C	11.231389	107.381944	Dinh Quan, Dong Nai	x.2013	Nhan V. Le
20	***Metaphire mangophiloides*** **Nguyen & Le, 2015**						
	CTU-EW.082.h01	1C	11.265000	107.064444	Vinh Cuu, Dong Nai	xi.2012	Trong C. Duong
	CTU-EW.082.p02	1C	11.265000	107.064444	Vinh Cuu, Dong Nai	xi.2012	Trong C. Duong
21	***Metaphire neoexilis*** **(Thai & Samphon, 1988)**						
	CTU-EW.085.01	32A	10.705833	106.825000	Nhon Trach, Dong Nai	x.2014	Nhan V. Le
	CTU-EW.085.02	13A	10.705833	106.825000	Nhon Trach, Dong Nai	x.2014	Nhan V. Le
	CTU-EW.085.03	3A	10.973889	106.568333	Cu Chi, Ho Chi Minh City	ix.2019	Nam Q. Nguyen
	CTU-EW.085.04	3A	11.077500	106.400000	Go Dau, Tay Ninh	ix.2019	Nam Q. Nguyen
22	***Metaphire pacseana*** **(Thai & Samphon, 1988)**						
	CTU-EW.083.01	6C	10.790278	107.036389	Long Thanh, Dong Nai	x.2014	Nhan V. Le
	CTU-EW.083.03	4C	11.624444	106.651667	Hon Quan, Binh Phuoc	x.2017	Nam Q. Nguyen
	CTU-EW.083.07	3C	11.294722	106.406111	Dau Tieng, Binh Duong	x.2017	Nam Q. Nguyen
	CTU-EW.083.14	6C	11.077500	106.400000	Go Dau, Tay Ninh	ix.2019	Nam Q. Nguyen
23	***Metaphire peguana peguana*** **(Rosa, 1890)**						
	CTU-EW.009.02	5C	10.944167	107.383611	Xuan Loc, Dong Nai	ix.2012	Thang V. Nguyen
	CTU-EW.009.03	15C	11.089722	107.035833	Vinh Cuu, Dong Nai	x.2012	Trong C. Duong
	CTU-EW.009.05	3C	10.499167	107.102778	Tan Thanh, Ba Ria Vung Tau	x.2016	Nam Q. Nguyen
	CTU-EW.009.07	13C	11.094722	106.841111	Bac Tan Uyen, Binh Duong	x.2017	Nam Q. Nguyen

No.	Species names and label codes	Number of Specimen	GPS Coordinates		Location	Date	Collector
			Latitude (North)	Longitude (East)			
	CTU-EW.009.14	16C	11.021389	106.555000	Cu Chi, Ho Chi Minh City	ix.2019	Nam Q. Nguyen
24	***Metaphire planata*** **(Gates, 1926)**						
	CTU-EW.005.04	9C	11.010278	106.846944	Vinh Cuu, Dong Nai	ix.2012	Trong C. Duong
	CTU-EW.005.05	11C	10.727500	106.892778	Nhon Trach, Dong Nai	x.2014	Nhan V. Le
	CTU-EW.005.10	11C	10.643889	107.113889	Tan Thanh, Ba Ria Vung Tau	x.2016	Nam Q. Nguyen
	CTU-EW.005.15	8C	11.429167	106.548333	Chon Thanh, Binh Phuoc	x.2017	Nam Q. Nguyen
	CTU-EW.005.20	31C	11.419167	106.413611	Dau Tieng, Binh Duong	x.2017	Nam Q. Nguyen
	CTU-EW.005.36	12C	10.558889	106.821111	Can Gio, Ho Chi Minh City	ix.2019	Nam Q. Nguyen
	CTU-EW.005.39	9C	11.077500	106.400000	Trang Bang, Tay Ninh	ix.2019	Nam Q. Nguyen
25	***Metaphire planatoides*** **Nguyen, Nguyen, Lam & Nguyen, 2020**						
	CTU-EW.171.h01	1C	10.405833	107.271667	Minh Dam Mts., Ba Ria Vung Tau	x.2016	Hau P. Nguyen
	CTU-EW.171.p02	2C	10.405833	107.271667	Minh Dam Mts., Ba Ria Vung Tau	x.2016	Hau P. Nguyen
26	***Metaphire posthuma*** **(Vaillant, 1868)**						
	CTU-EW.011.01	10C	10.780000	107.495278	Xuan Loc, Dong Nai	x.2012	Thang V. Nguyen
	CTU-EW.011.03	19C	10.387500	106.912500	Can Gio, Ho Chi Minh City	ix.2019	Nam Q. Nguyen
27	***Metaphire setosa*** **Nguyen, Nguyen, Lam & Nguyen, 2020**						
	CTU-EW.179.h01	1C	11.567222	106.596111	Hon Quan, Binh Phuoc	x.2017	Tien T. H. Luong
	CTU-EW.179.p02	6C	11.567222	106.596111	Hon Quan, Binh Phuoc	x.2017	Tien T. H. Luong
28	***Metaphire songbeensis*** **Nguyen, Nguyen, Lam & Nguyen, 2020**						
	CTU-EW.176.h01	1C	11.760833	106.577222	Loc Ninh, Binh Phuoc	x.2017	Tien T. H. Luong
	CTU-EW.176.p02	9C	11.760833	106.577222	Loc Ninh, Binh Phuoc	x.2017	Tien T. H. Luong
	CTU-EW.176.03	13C	11.760833	106.577222	Loc Ninh, Binh Phuoc	x.2017	Tien T. H. Luong
	CTU-EW.176.04	8C	11.294722	106.406111	Dau Tieng, Binh Duong	x.2017	Na S. Dinh
29	***Metaphire xuanlocensis*** **Nguyen & Lam, 2017**						
	CTU-EW.086.h01	1C	10.815833	107.542222	Xuan Loc, Dong Nai	ix.2012	Thang V. Nguyen
	CTU-EW.086.p02	9C	10.815833	107.542222	Xuan Loc, Dong Nai	ix.2012	Thang V. Nguyen
	CTU-EW.086.03	17C	10.712500	107.324722	Cam My, Dong Nai	x.2013	Nhan V. Le
	CTU-EW.086.04	6C	10.654444	107.264722	Chau Duc, Ba Ria Vung Tau	x.2016	Nam Q. Nguyen
	CTU-EW.086.05	12C	10.606111	107.438611	Xuyen Moc, Ba Ria Vung Tau	x.2016	Nam Q. Nguyen
	CTU-EW.086.06	6C	10.646111	107.458333	Chau Duc, Ba Ria Vung Tau	x.2016	Nam Q. Nguyen
30	***Pheretima vungtauensis*** **Nguyen, Nguyen & Nguyen, 2018**						
	CTU-EW.166.h01	1C	10.749167	107.243056	Chau Duc, Ba Ria Vung Tau	x.2016	Ai T. Truong
	CTU-EW.166.p02	2C	10.749167	107.243056	Chau Duc, Ba Ria Vung Tau	x.2016	Ai T. Truong
	CTU-EW.166.p03	1C	10.661667	107.156389	Chau Duc, Ba Ria Vung Tau	x.2016	Ai T. Truong
	CTU-EW.166.p04	1C	10.640278	107.350000	Chau Duc, Ba Ria Vung Tau	x.2016	Ai T. Truong
	CTU-EW.166.p05	2C	10.643889	107.113889	Tan Thanh, Ba Ria Vung Tau	x.2016	Hau P. Nguyen
	CTU-EW.166.p06	1C	10.485833	107.181667	Tan Thanh, Ba Ria Vung Tau	x.2016	Hau P. Nguyen
	CTU-EW.166.p07	1C	10.594167	107.123333	Tan Thanh, Ba Ria Vung Tau	x.2016	Hau P. Nguyen
31	***Polypheretima cattienensis*** **Nguyen, Tran & Nguyen, 2015**						
	CTU-EW.040.h01	1C	11.425000	107.428333	Tan Phu, Dong Nai	x.2013	Nhan V. Le
	CTU-EW.040.p02	6C	11.425000	107.428333	Tan Phu, Dong Nai	x.2013	Nhan V. Le
	CTU-EW.040.03	6C	11.425278	107.428611	Tan Phu, Dong Nai	xi.2019	Dang H. Lam

No.	Species names and label codes	Number of Specimen	GPS Coordinates		Location	Date	Collector
			Latitude (North)	Longitude (East)			
32	***Polypheretima cordata*** **Nguyen, Tran & Nguyen, 2015**						
	CTU-EW.042.h01	1C	11.113611	107.052778	Vinh Cuu, Dong Nai	x.2013	Trong C. Duong
	CTU-EW.042.p02	7C	11.113611	107.052778	Vinh Cuu, Dong Nai	x.2013	Trong C. Duong
	CTU-EW.042.03	4C	11.428333	107.427222	Tan Phu, Dong Nai	x.2013	Nhan V. Le
	CTU-EW.042.04	7C	11.113611	107.052778	Vinh Cuu, Dong Nai	x.2013	Trong C. Duong
	CTU-EW.042.05	4C	10.947778	107.018333	Dinh Quan, Dong Nai	x.2013	Nhan V. Le
	CTU-EW.042.06	4C	11.511667	106.986667	Dong Phu, Binh Phuoc	x.2013.	Nhan V. Le
	CTU-EW.042.07	4C	12.191111	107.203333	Bu Gia Map, Binh Phuoc	x.2017	Nam Q. Nguyen
	CTU-EW.042.08	4C	11.527778	106.916667	Dong Xoai, Binh Phuoc	x.2017	Nam Q. Nguyen
33	***Polypheretima elongata*** **(Perrier, 1872)**						
	CTU-EW.026.02	4C	10.835278	106.526944	Binh Chanh, Ho Chi Minh City	ix.2019	Nam Q. Nguyen
34	***Polypheretima militium*** **Nguyen, Tran & Nguyen, 2015**						
	CTU-EW.041.h01	1C	11.142500	107.014444	Vinh Cuu, Dong Nai	x.2013	Trong C. Duong
	CTU-EW.041.p02	6C	11.142500	107.014444	Vinh Cuu, Dong Nai	x.2013	Trong C. Duong
	CTU-EW.041.03	3C	11.142500	107.014444	Vinh Cuu, Dong Nai	x.2013	Trong C. Duong
	CTU-EW.041.04	5C	11.113611	107.053333	Vinh Cuu, Dong Nai	x.2019	Nam Q. Nguyen
35	***Drawida beddardi*** **(Rosa, 1890)**						
	CTU-EW.031.02	4C	11.925000	106.726944	Bu Dop, Binh Phuoc	x.2017	Nam Q. Nguyen
	CTU-EW.031.04	7C	11.433056	106.385278	Dau Tieng, Binh Duong	x.2014	Nhi T. N. Nguyen
36	***Eukerria saltensis*** **(Beddard, 1895)**						
	CTU-EW.182.01	8C	12.057222	107.127500	Bu Gia Map, Binh Phuoc	x.2017	Nam Q. Nguyen
	CTU-EW.182.02	7C	11.024722	106.621944	Thu Dau Mot, Binh Duong	x.2017	Nam Q. Nguyen
	CTU-EW.182.03	7C	10.387500	106.912500	Can Gio, Ho Chi Minh City	ix.2019	Nam Q. Nguyen
	CTU-EW.182.04	8C	10.691389	106.660000	Binh Chanh, Ho Chi Minh City	ix.2019	Nam Q. Nguyen
	CTU-EW.182.05	29C	10.702778	106.573889	Binh Chanh, Ho Chi Minh City	ix.2019	Nam Q. Nguyen
	CTU-EW.182.06	16C	11.390556	106.155278	Tay Ninh City, Tay Ninh	ix.2019	Nam Q. Nguyen
	CTU-EW.182.07	20C	11.382778	106.137778	Tay Ninh City, Tay Ninh	ix.2019	Nam Q. Nguyen
37	***Dichogaster affinis*** **(Michaelsen, 1890)**						
	CTU-EW.033.01	16C	10.551944	106.779722	Can Gio, Ho Chi Minh City	ix.2019	Nam Q. Nguyen
	CTU-EW.033.02	3C	11.077500	106.400000	Trang Bang, Tay Ninh	ix.2019	Nam Q. Nguyen
38	***Dichogaster bolaui*** **(Michaelsen, 1891)**						
	CTU-EW.035.03	5C	10.639167	107.085556	Tan Thanh, Ba Ria Vung Tau	x.2016	Nam Q. Nguyen
	CTU-EW.035.04	20C	12.191111	107.203333	Bu Gia Map, Binh Phuoc	x.2017	Nam Q. Nguyen
	CTU-EW.035.08	20C	10.749722	107.349722	Cam My, Dong Nai	x.2013	Nhan V. Le
	CTU-EW.035.09	11C	10.477222	106.879444	Can Gio, Ho Chi Minh City	ix.2019	Nam Q. Nguyen
	CTU-EW.035.11	5C	11.390556	106.155278	Tay Ninh City, Tay Ninh	ix.2019	Nam Q. Nguyen
39	***Pontoscolex corethrurus*** **(Müller, 1857)**						
	CTU-EW.001.01	31C	11.424444	107.435278	Tan Phu, Dong Nai	x.2013	Nhan V. Le
	CTU-EW.001.11	5C	10.628889	107.112500	Tan Thanh, Ba Ria Vung Tau	x.2016	Nam Q. Nguyen
	CTU-EW.001.22	69C	11.861111	107.025556	Bu Dang, Binh Phuoc	x.2017	Nam Q. Nguyen
	CTU-EW.001.29	19C	11.050000	106.788889	Tan Uyen, Binh Duong	x.2017	Nam Q. Nguyen
	CTU-EW.001.44	27C	10.702778	106.573889	Binh Chanh, Ho Chi Minh City	ix.2019	Nam Q. Nguyen
	CTU-EW.001.45	21C	11.371389	106.254722	Duong Minh Chau, Tay Ninh	ix.2019	Nam Q. Nguyen

Remarks: The species has very unique morphology characters among known *Metaphire* species, with regard to its saddle-shaped clitellum and setal arrangement in two rings (Nguyen et al. 2020b).

30. *Metaphire songbeensis* Nguyen, Nguyen, Lam & Nguyen, 2020

(Image 4 e1–e2, Table 1)

Examined material: 1C (CTU-EW.176.h01), 9C (CTU-EW.176.p02), 13C (CTU-EW.176.03), and 8C (CTU-EW.176.04); data in Table 1.

Distribution: Binh Duong (Dau Tieng, Di An, Ben Cat, Bau Bang); Binh Phuoc (Loc Ninh, Chon Thanh, Dong Xoai, Dong Phu, Phu Rieng, Bu Dang, Phuc Long, Bu Gia Map, Bu Dop).

Remarks: The species is fairly similar to *M. posthuma* (Vaillant, 1868), but it is recognized by having spermathecal pores in the dorsum, first dorsal pore in 9/10, and ventrally connected testes sacs. There are two morphological forms. The first form found in Binh Duong Province has spermathecal pores located closely to the mid-dorsal line and four pairs of genital markings in the male region. The other form has spermathecal pores located laterodorsally and more than four pairs of genital markings (Nguyen et al. 2020b).

31. *Metaphire xuanlocensis* Nguyen & Lam, 2017

(Image 3 j1–j2, Table 1)

Examined material: 1C (CTU-EW.086.h01), 9C (CTU-EW.086.p02), 17C (CTU-EW.086.03), 6C (CTU-EW.086.04), 12C (CTU-EW.086.05), and 6C (CTU-EW.086.06); data in Table 1.

Distribution: Dong Nai (Xuan Loc, Cam My); Ba Ria-Vung Tau (Ba Ria City, Xuyen Moc, Chau Duc).

Remarks: The species is fairly similar to *M. phaluongana* (Do & Huynh, 1992), but it is distinguished by having a pair of genital markings in xviii, separated testes sacs, and presence of penial seta (Nguyen & Lam 2017).

Genus *Pheretima* Kinberg, 1867

32. *Pheretima vungtauensis* Nguyen, Nguyen & Nguyen, 2018

(Image 4 l1–l2, Table 1)

Examined material: 1C (CTU-EW.166.h01), 2C (CTU-EW.166.p02), 1C (CTU-EW.166.p03), 1C (CTU-EW.166.p04), 2C (CTU-EW.166.p05), 1C (CTU-EW.166.p06), and 1C (CTU-EW.166.p07); data in Table 1.

Distribution: Ba Ria-Vung Tau (Chau Duc, Tan Thanh).

Remarks: The species is closely related to *M. houlleti* (Perrier, 1872), it is but specialized by the presence of micronephridia attached onto the spermathecal ducts (Nguyen et al. 2018). Currently, *Pheretima vungtauensis* is known as the only species of genus *Pheretima* sensu stricto found in Vietnam.

Genus *Polypheretima* Michaelsen, 1934

33. *Polypheretima cattienensis* Nguyen, Tran & Nguyen, 2015

(Image 4 f1–f2, Table 1)

Examined material: 1C (CTU-EW.040.h01), 6C (CTU-EW.040.p02), and 6C (CTU-EW.040.03); data in Table 1.

Distribution: Dong Nai (Cat Tien NP).

Remarks: The species is similar to *Po. aringeana* (Beddard, 1900), but it is distinguished by lacking of genital markings, presence of seminal chambers, and the strongly coelomic copulatory pouches (Nguyen et al. 2015b).

34. *Polypheretima cordata* Nguyen, Tran & Nguyen, 2015

(Image 4 h1–h2, Table 1)

Examined material: 1C (CTU-EW.042.h01), 7C (CTU-EW.042.p02), 4C (CTU-EW.042.03), 7C (CTU-EW.042.04), 4C (CTU-EW.042.05), 4C (CTU-EW.042.06), 4C (CTU-EW.042.07), and 4C (CTU-EW.042.08); data in Table 1.

Distribution: Dong Nai (Vinh Cuu, Tan Phu, Trang Bom, Dinh Quan); Binh Phuoc (Dong Phu, Bu Dang, Bu Gia Map, Loc Ninh).

Remarks: The species is closely similar to *Po. grandisetosa* (Thai, 1996), but it is specialized by number of spermathecal pores (one pair in 5/6, 2 pairs in 6/7 or a pair per segment (found in Binh Phuoc Province)), holandry, presence of copulatory pouches, and absence of stout setae in the dorsum (Nguyen et al. 2015b).

35. *Polypheretima elongata* (Perrier, 1872)

(Image 4 j1, Table 1)

Examined material: 4C (CTU-EW.026.02); data in Table 1.

Distribution: Ho Chi Minh City (Binh Chanh).

Remarks: This is the first record of the species in the southeastern part of Vietnam, although it is widely distributed in the Mekong Delta (Nguyen 2014).

36. *Polypheretima militium* Nguyen, Tran & Nguyen, 2015

(Image 4 i1–i2, Table 1)

Examined material: 1C (CTU-EW.041.h01), 6C (CTU-EW.041.p02), 3C (CTU-EW.041.03), and 5C (CTU-EW.041.04); data in Table 1.

Distribution: Dong Nai (Vinh Cuu).

Key to the earthworm species in southeastern Vietnam

1. – Setae Lumbricine 2
   – Setae Perichaetine 8
2. – Clitellum formed from more than one layer of cells 3
   – Clitellum formed from a single layer of cells .... *Drawida beddardi*
3. – Clitellum annular .... *Eukerria saltensis*
   – Clitellum saddle-shaped 4
4. – Clitellum within 5 segments xiii–xviii .... *Pontodrilus litoralis*
   – Clitellum within more than 5 segments 5
5. – Clitellum within 7 segment xiii–xx. Male pores in xviii 6
   – Clitellum within more than 7 segments. Male pore invisible 7
6. – Female pore single. Genital markings absent .... *Dichogaster bolaui*
   – Female pore paired. Genital marking single in mid-ventral of 8/9 .... *Dichogaster affinis*
7. – Clitellum within 9 segments xiv-xxiii .... *Pontoscolex corethrurus*
   – Clitellum within 22 segments xiii–xxxvi .... *Gliphidrilus papillatus*
8. – Clitellum within 4 segments xiv–xvii 9
   – Clitellum within 3 segments xiv–xvi 10
9. – Three pairs of spermathecal pores in 6/7/8/9. Bidiverticulate .... *Lampito mauritii*
   – Two pairs of spermathecal pores in 7/8/9. Adiverticulate .... *Perionyx excavatus*
10. – Intestine with a pair of caeca 11
    – Intestine without caeca 38
11. – Copulatory pouches present 12
    – Copulatory pouches absent 32
12. – Nephridia attached onto the spermathecal ducts .... *Pheretima vungtauensis*
    – Spermathecal ducts without nephridia 13
13. – Male pore in xix 14
    – Male pore in xviii 16
14. – Four pairs of spermathecal pores in lateroventral 5/6/7/8/9. Clitellum annular 15
    – Three pairs of spermathecal pores in 6/7/8/9 dorsally. Clitellum saddle-shaped .... *Metaphire setosa*
15. – One pair of genital markings in xviii. First dorsal pore in 8/9 .... *Metaphire neoexilis*
    – Genital markings absent sin the male region. First dorsal pore in 12/13 .... *Metaphire anomala*
16. – Multiple spermathecae per segment .... *Metaphire mangophiloides*
    – One pair of spermathecae per segment 17
17. – Four pairs of spermathecal pores in 5/6/7/8/9 18
    – Less than four pairs of spermathecal pores 22
18. – Spermathecal pores dorsally .... *Metaphire songbeensis*
    – Spermathecal pores not in dorsum 19
19. – Caeca complex. Genital markings absent in the male region .... *Metaphire bariaensis*
    – Caeca simple Genital markings present in the male region 20
20. – Genital markings intersegmental in the male region .... *Metaphire malayanoides*
    – Genital markings segmental in the male region 21
21. – Two pairs of genital markings in xvii and xix. Septum 8/9 thickened .... *Metaphire posthuma*
    – One pairs of genital markings in xviii .... *Metaphire grandiverticulata*
22. – Three pairs of spermathecal pores 6/7/8/9 23
    – Less than three pairs of spermathecal pores 28
23. – Spermathecal pores dorsally .... *Metaphire haui*
    – Spermathecal pores not in dorsum 24
24. – Spermathecal pores laterally. Caeca manicate .... *Metaphire pacseana*
    – Spermathecal pores lateroventrally. Caeca simple 25
25. – Genital markings two pairs in 17/18 and 18/19 26
    – Genital markings absent in the male region 27
26. – Genital markings slit-like. Male region strongly concave .... *Metaphire bahli*
    – Genital markings disc-shaped. Male region not concave .... *Metaphire peguana peguana*
27. – First dorsal pore in 11/12. Spermatheca mushroom-shaped .... *Metaphire* cf. *campanulata*
    – First dorsal pore in 9/10. Spermatheca ovoid .... *Metaphire houlleti*
28. – Two thecal segments. Penial setae absent 29
    – One thecal segments in 7/8. Penial setae present .... *Metaphire xuanlocensis*
29. – Spermathecal pores in 5/6/7. Caeca manicate .... *Metaphire easupana*
    – Spermathecal pores in 6/7/8 or 7/8/9. Caeca simple 30

30. – Spermathecal pores in ở 6/7/8 31
– Spermathecal pores in 7/8/9 .... *Metaphire houlletoides*
31. – Genital markings surrounded, next to spermathecal pores. Accessory glands present .... *Metaphire planata*
– Genital markings absent in both the male and spermatheca regions. Accessory glands absent .... *Metaphire planatoides*
32. – Four pairs of spermathecal pores in 5/6/7/8/9 33
– Less than four pairs of spermathecal pores 35
33. – Setae crowded in ventrad in xix .... *Amynthas polychaetiferus*
– Setae in usual position 34
34. – Two to three pairs of genital markings in xviii and 18/19; ....
– One pair of genital markings in 18/19. Genital markings single in vii or ix .... *Amynthas exiguus austrinus*
– Three to four pairs of genital markings in xvii, xix and onwards. Genital markings absent in the spermathecal region *Amynthas juliani*
35. – Three pairs of spermathecal pores in 5/6/7/8 .... *Amynthas ocularius*
– Less than three pairs of spermathecal 36
36. – Two pairs of spermathecal pores in 5/6/7 37
– Only one pair of spermathecal pores in 5/6 .... *Amynthas longiprostaticus*
37. – Spermathecal pores laterodorsally. One pair of genital markings in xvii. Markings absent in the spermathecal region .... *Amynthas dorsomorrioides*
– Spermathecal pores lateroventrally. One pair of genital markings in xviii. One to five genital markings in vi–vii . *Amynthas mindam*
38. – Three to four pairs of genital markings in xix afterwards .... *Polypheretima elongata*
– Genital markings absent in the male region 39
39. – Multiple spermathecae per segment in vi and vii. Testes sacs connected ventrally 40
– One pair of spermatheca in vi and two pairs in vii. Testes sacs separated .... *Polypheretima cordata*
40. – Seminal chamber present. Male pores crescentic-shaped .... *Polypheretima cattienensis*
– Seminal chamber absent. Male pores round-shaped .... *Polypheretima militium*

Remarks: The species is somewhat similar to *Po. colonensis* (Thai, 1996), but it is identified by holandry, polythecate, first dorsal pore in 12/13 or 13/14, and intestinal swelling at xv (Nguyen et al. 2015b).

Family MONILIGASTRIDAE Claus, 1880
Genus *Drawida* Michaelsen, 1900
***37. Drawida beddardi* (Rosa, 1890)**
(Image 1 b1–n2, Table 1)

Examined material: 4C (CTU-EW.031.02) and 7C (CTU-EW.131.04); data for samples were shown in table 1.

Distribution: Binh Phuoc (Tan Thanh, Bu Dang); Binh Duong (Phu Giao, Dau Tieng) (Nguyen 2014; Nguyen et al. 2015).

Family OCNERODRILIDAE Beddard, 1891
Genus *Eukerria* Michaelsen, 1935
***38. Eukerria saltensis* (Beddard, 1895)**
(Image 1 c1, Table 1)

Examined material: 8C (CTU-EW.182.01), 7C (CTU-EW.182.02), 7C (CTU-EW.182.03), 8C (CTU-EW.182.04), 29C (CTU-EW.182.05), 16C (CTU-EW.182.06), and 20C (CTU-EW.182.07); data in Table 1.

Distribution: Binh Duong (Thu Dau Mot); Binh Phuoc (Chon Thanh, Bu Dang, Bu Gia Map); Ho Chi Minh City (Can Gio, Nha Be, Binh Chanh); Tay Ninh (Tay Ninh City).

Family OCTOCHAETIDAE Gates, 1959
Genus *Dichogaster* Beddard, 1888
***39. Dichogaster affinis* Michaelsen, 1890**
(Image 1 d1–d2, Table 1)

Examined material: 16C (CTU-EW.033.01) and 3C (CTU-EW.033.02); data in Table 1.

Distribution: Ho Chi Minh City (Can Gio); Tay Ninh (Ba Den Mts, Trang Bang).

Remarks: The species was recorded for the first time in southeastern Vietnam. It was usually found along with Dichogaster bolaui in soils of roadside or fallow lands.

***40. Dichogaster bolaui* (Michaelsen, 1891)**
(Image 1 f1–f2, Table 1)

Examined material: 5C (CTU-EW.035.03), 20C (CTU-EW.035.04), 20C (CTU-EW.035.08), 11C (CTU-EW.035.09), and 5C (CTU-EW.035.11); data in Table 1.

Distribution: Ba Ria-Vung Tau (Ba Ria City, Tan Thanh); Dong Nai (Cam My); Binh Phuoc (Bu Gia Map NP); Ho Chi Minh City (Can Gio, Hoc Mon, Binh Chanh).

Remarks: It was very common in southeastern Vietnam, especially in moist soils.

Family RHINODRILIDAE Benham, 1890
Genus *Pontoscolex* Schmarda, 1861
***41. Pontoscolex corethrurus* (Müller, 1857)**
(Image 1 e1–e2, Table 1)

Examined material: 31C (CTU-EW.001.01), 5C (CTU-EW.001.11), 69C (CTU-EW.001.22), 19C (CTU-EW.001.29), 27C (CTU-EW.001.44), and 21C (CTU-EW.001.45); data in Table 1.

Distribution: Very commonly distributed in Vietnam.

Remarks: The species was known to be native to the South America region, but wide spread over the world (Brown et al. 2006). In Vietnam, this species has been known widely in all habitats except natural forests in high mountains.

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Some biological aspects of the central Indian endemic scorpion *Hottentotta jabalpurensis* Kovařík, 2007 (Scorpiones: Buthidae)

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Abstract: The present study reports the distribution and bionomics of *Hottentotta jabalpurensis* Kovarik, 2007, a central India endemic species. Information on courtship, maternal care, feeding habits, and kin recognition has been provided based on observations made in captivity. Morphological and morphometric details of the pre-insemination spermatophore of the species have been detailed for the first time for the species.

Keywords: Behaviour, breeding, distribution, kin recognition, Madhya Pradesh, spermatophore.

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Author contribution: PP carried out field surveys, reared the animals, conducted the research work and wrote the draft manuscript. PPM supervised the research work, validated the information and helped in manuscript writing. DBB validated the observations, guided the research work and helped in editing the manuscript.

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INTRODUCTION

The genus *Hottentotta* Birula, 1908 consisting of 55 species (Rein 2020) is one of the most widely distributed genera of the family Buthidae, distributed across Africa, the Arabian Peninsula, and in Asia (Kovařík 2007). In India *Hottentotta* is represented by eight species, namely: *H. tamulus* (Fabricius, 1798), *H. pachyurus* (Pocock, 1897), *H. rugiscutis* (Pocock, 1897), *H. jabalpurensis* Kovařík, 2007, *H. stockwelli* Kovařík, 2007, *H. keralaensis* Ashwathi, Sureshan & Lourenço, 2016, *H. reddyi* Lourenço, 2015, and *H. vinchu* Mirza, Ambekar & Kulkarni, 2019 (Kovařík 2007; Bastawade et al. 2012; Lourenço 2015, Ashwathi et al. 2016; Mirza et al. 2009). The genus is distributed in six out of 10 biogeographic zones of India (Rodgers et al. 2000), namely Gangetic plains, desert, semi-arid, Deccan Peninsula, Western Ghats, and coasts (Bastawade et al. 2012). *Hottentotta* is a medically important genus (Ward et al. 2018) and has evolved to inhabit closely to human dwellings, agricultural fields, and open areas (Tikader & Bastawade 1983; Ranawana et al. 2013; Mirza et al. 2019) which increases its frequent interaction with humans. *Hottentotta jabalpurensis* (Type locality: Jabalpur, Madhya Pradesh) was described based on some morphological characters in which it differs from its sister species *H. tamulus* in having metasoma densely hirsute, and the patella of pedipalp with long hair (Kovařík 2007).

Scorpions are predatory animals and are known for their cannibalistic behaviour, however, apart from an obligatory mother-young association, a few species are known to live in social groups. Sub-social behaviour has been observed in species like *Heterometrus fulvipes* and *H. swammerdemi* in the family Scorpionidae and on the other hand cohabitation and gregarious interaction have been seen in *Compsobuthus werneri judaicus* (Shivashankar 1994; Mohapatra & Pandey 2020; Warburg 2002). Similarly, studies on various behavioural aspects of courtship and breeding have been undertaken on some Indian scorpions of the family Scorpionidae and Buthidae (Bastawade 1992; Mirza & Sanap 2009; Mirza et al. 2009; Mohapatra & Pandey 2020).

Scorpions like many other arachnid groups have an indirect way of sperm transfer through a sperm packet called spermatophore (Polis 1990). The courtship and breeding process can be divided into four stages, i.e., initiation, Promenade á Deux, sperm transfer and separation (Ross 2009). Furthermore, spermatophore and hemispermatophores are considered to have characters having taxonomic significance and phylogenetic values (Francke 1979; Monod et al. 2017). Among the Indian scorpions, studies on the morphology of spermatophore and hemispermatophore are relatively rare and are restricted to a few species (see Mathew 1956; Bastawade 1992, 1994; Mirza & Sanap 2009; Mohapatra & Pandey 2020).

Scorpions are viviparous arthropods with a long gestation period (Polis 1990). The females during parturition form a birth basket by using the first pair of legs, crossing each other medially (Francke 1982). After birth, the babies climb up to the mother's back and settle in a particular orientation. The larval orientation can be random, transverse, or longitudinal depending on different families or species (Savary 1996). They continue to do so for a varying number of days after the young scorpions undergo their first ecdysis to second-instar, after which the vagile second-instar young ones disperse from the mothers' dorsum and become free-living (Williams 1971; Polis & Sissom 1990; Lourenço 2018). Studies on such mother and young associations in Indian scorpion species is very rare and has been mentioned by Mathew (1962) for *Lychas tricarinatus*, Mirza et al. (2009) for *Hottentotta pachyurus* (Pocock, 1897), and Mirza & Sanap (2009) for *Heterometrus phipsoni* (Pocock, 1893).

The present study emphasizes the breeding behavior of *H. jabalpurensis* along with distribution and natural history observations. Information on the Morphological description of the spermatophore in the pre-insemination state, parturition, maternal care, kinship behaviour and cannibalism has been provided based on observations in captivity.

MATERIALS AND METHODS

The study was undertaken during a seven months dissertation work carried out by the first author from January to July 2018 at the Zoological Survey of India (ZSI), Central Zone Regional Centre (CZRC), Jabalpur, Madhya Pradesh. Scorpions were sampled randomly by lifting rocks, finding them in leaf litter, peeling off bark and digging the burrows in various sampling localities outside protected areas. During the night, scorpions were searched with the aid of an ultraviolet torch. Animals were handpicked with the help of a forceps when located and were kept separately in plastic boxes to avoid being eaten by larger ones. Photographs were taken in their natural habitat and the captive individuals were photographed regularly to record their behavior with a Nikon D5100 camera fitted with Nikon-100 macro or Tamron 90mm lens. A total of 18 adult individuals of

Hottentotta jabalpurensis comprising four adult males and 14 adult females were collected from Sidh Baba Mandir area, Katangi, and Paatbaba area, Jabalpur, during the month of March–June 2018. All the animals except two males, from which the spermatophores were obtained, were released back in their respective habitats after the completion of the experiment during September 2019. To record various behavioral aspects, live scorpions were maintained in the laboratory in terrariums or plastic boxes of 6´´X 3´´X 3´´ sizes, with a layer of 1´´ soil substratum. The room temperature was maintained in an air-conditioned room (24–30°C) and water was provided in each terrarium in small bowls to maintain humidity and avoid desiccation. The animals were fed with live mealworms maintained in the laboratory. Other prey species such as gryllids, small geckos (*Hemidactylus* spp.), skinks (*Eutropis* spp.), and termites were also fed from time to time. Behavioral aspects such as feeding, courtship, and kin recognition were recorded during the study period. Spermatophores of the scorpions were obtained from the captive breeding groups and were preserved in 70% ethyl alcohol. Photographs were taken to see the natural coloration. Morphological data were collected under a stereo-zoom microscope (Leica M-2054) and measurements were taken using Mitutoyo™ digital calipers to the nearest 0.1mm. Morphometric details of the spermatophore were taken to the nearest 0.01mm under the microscope. Distribution localities of the species were recorded based on the meta-data available for the specimens housed in the national zoological collections of ZSI, CZRC. Each specimen was identified by evaluating standard taxonomic characters in a datasheet to record quantitative (i.e., mensural and meristic) and qualitative taxonomic characters following standard taxonomic keys (Bastawade 1992; Kovařík 2007; Lowe 2010; Monod et al. 2017).

RESULTS

Distribution (Figure 1): *Hottentotta jabalpurensis* was found to be distributed in Damoh, Sagar, Narsinghapur, Jabalpur, Chhindwara, Raisen, Dewas, Dheona, Panna,

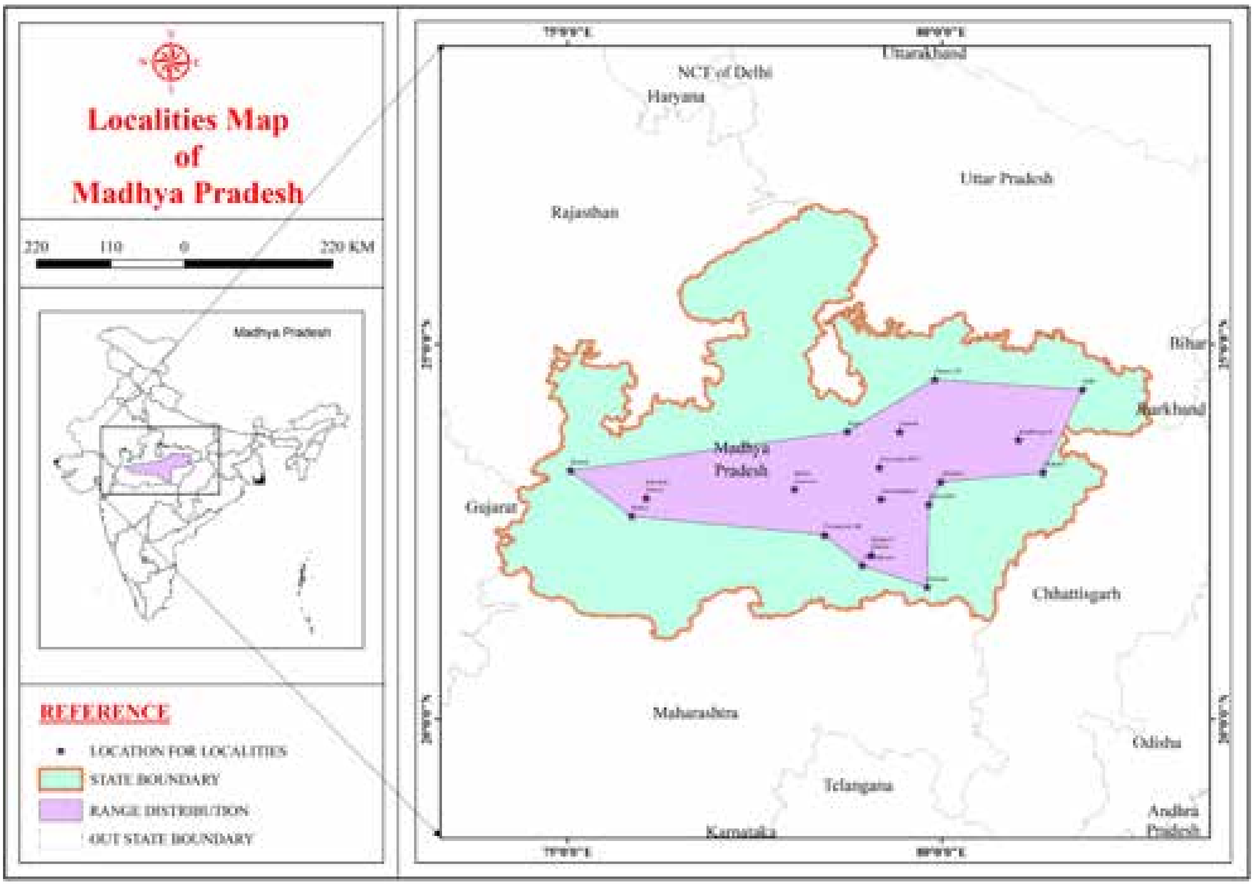

Figure 1. Distribution localities of *Hottentotta jabalpurensis* in Madhya Pradesh.

Shahdol, Shivpuri, Sidhi, Indore, Hoshagabad, Ratlam, and Umaria districts of Madhya Pradesh (Table-1). This species was found mostly below rocks and large boulders, sometimes clinging on to the inner surface of rocks and sitting on wood logs in wet regions. Although, this species was generally found solitary, males and females were found to be under the same rock during January–March, probably due to breeding activities.

Feeding habits (Image 1,2): In captivity, scorpions were fed with small crickets, mealworms, centipedes, termites and grasshoppers. Prey larger than the body size was stung to overpower and feed on it. Juveniles after a few days of second molting started using the stinger and in comparison to adults the use of stinger was more frequent in the juveniles. The juveniles were also found to hunt in a group to overpower larger prey. Adults as well as juveniles were found to manipulate the orientation of the prey to feed on the head at first, no matter from which side it was captured. The prey was eaten as a whole or it was torn into pieces and the undigested parts were discarded after the full meal. Smaller preys such as termites, mealworms, etc., were devoured fully.

Sexual dimorphism: Marked sexual dimorphism was found in *H. jabalpurensis*. Females were larger than males with a total length of 50–80 mm in females and 48–65 mm in males. The males also had a higher number of pectinal teeth (30–36) than females (25–30). In males, the body was slender with chela of pedipalp more robust than females and the males had a prominent protuberance at the proximal end of the moveable chela and scalloped on the immovable finger. Furthermore, adult males were found to have yellowish legs, metasoma and pedipalps whereas the females, were mostly reddish-brown overall.

Table 1. Geocoordinates of the localities of distribution of *Hottentotta jabalpurensis* in Madhya Pradesh (WGS-84).

Location	GPS coordinates
Damoh	N23.8210°, E79.4514°
Narsinghpur	N22.9473°, E79.1923°
Sagar	N23.8388°, E78.7378°
Ranjhi, Jabalpur	N23.1815°, E79.9864°
Patbaba area, Jabalpur	N23.1702°, E79.9747°
Sidh Baba Mandir area, Katangi	N23.4645°, E79.7980°
Nauradehi WLS	N23.3683°, E79.1718°
Chhindwara	N22.0574°, E78.9382°
Barna reservoir, Raisen	N23.0795°, E78.0310°
Kartholi, Dewas	N32.6307°, E74.9490°
Veerangana Durgavati WLS, Damoh	N21.6970°, E77.7954°
Kesli, Sagar	N23.4226°, E78.8184°
Madhav NP, Shivpuri	N25.4317°, E77.7391°
Lameta ghat, Jabalpur	N23.1092°, E79.8282°
Kala Dehi, Jabalpur	N22.8787°, E79.8293°
Panna TR, Panna District	N24.7166, E80.2000
Shahdol	N23.3022, E81.3267°
Sidhi	N24.3956°, E81.8825°
Indore	N22.6791°, E75.8580°
Singhori WLS, Kheoni	N22.1983°, E79.0579°
Pachmarhi BR	N22.4674°, E78.4346°
Ratlam	N23.3315°, E75.0367°
Bandhavgarh N. Park, Umaria	N23.7224°, E81.0242°

Mating behavior (Image 3): The mating behaviour was observed in three pairs and the findings are as follows. The process took place in captivity on three occasions on 06.iv.2018, 23.iv.2018, and 24.iv.2018

Image 1. female *Hottentotta jabalpurensis* feeding on a praying mantis while carrying second molt scorplings.

Image 2. *Hottentotta jabalpurensis* feeding on a scolopendra (centipede).

Image 3. Courtship in *Hottentotta jabalpurensis*. The male (on right) holding the pedipalps of the female (on left).

when the male and female were introduced into the same box. The courtship was always initiated by the male and he started with patting the female and trying to grasp her from pedipalps. Of the breeding pair on 06.iv.2018, the female remained immobile and withdrew the pedipalps after the first attempt made by the male. The male juddered several times while vigorously pulling the female towards him which led to holding each other through pedipalps to perform the ritual dance 'promenade á deux'. Also, occasional cheliceral massage and tail raising were observed. After a halt for 10–12 minutes, the male again pulled the female using just one pedipalp and keeping away the unused one while constantly searching for a suitable substratum with raised pectines. Occasionally the female resisted the movements, but the male moved closer to her and tried pulling her with elevated body and metasoma while the female kept her body close to the substratum with raised pectines. The male deposited the spermatophore on a small piece of wood (Image 6) following vigorous juddering and waited for the spermatophore to get dried up. The breeding process from initiation till deposition of spermatophore lasted for 30 minutes. The second pair (on 23.iv.2018) bred in the same way and the process lasted for 40 minutes. The male deposited the spermatophore on a paper. Of the third pair, which was observed on 24.iv.2018, the courtship was initiated naturally when a male entered a female's compartment. The female in this case did not resist the male, rather she was found juddering and trying to take a hold of the male's pedipalp. Although juddering in this female was not as vigorous as it was observed in the males, but the male did not produce spermatophore even after 45 minutes of courtship. Also, it was noted that in the above two cases, the females did not show any interest in sperm transfer and the males were always observed to escape the site immediately after mating. In another case where a male was kept with a female, the pair did not show any affinity for courtship until 20 hours after staying together. Another interesting behaviour observed during the study period was when a male was found to be clasping the female sitting very close to her and later fed upon the female after two days.

Spermatophore (Image 6–8): Two pre-insemination spermatophores of *H. jabalpurensis* bearing registration numbers ZSI-CZRC-7264 and 7265 were studied. The spermatophore when extruded was semi-solid at the pedicle, which came out first and got firmly stuck on the substratum. It was translucent with a pinkish brown tinge, capsule dark brown, stem dark brown on the sides and paler at the middle portion, flagellum whitish. Pedicel flat, little broader at the base and creamy white. After extrusion, it turned solid and brownish within five minutes. The capsular region was reddish-brown comprising base, capsular distal carina, capsular basal carina and basal hook. When the spermatophore was extruded by the male it got glued to the substratum by the pedicel at one end while the flagellum got attached to the other end of the substratum. The stretching of spermatophore probably helps in maintaining a particular direction after it dries up.

The spermatophores (ZSI-CZRC-A-21455 and 21456) show slight variation in stem length (6.4mm in the former and 6.7mm in the latter) and length of the flagellum (4.9mm in the former and 3.7mm in the latter). The spermatophore of ZSI-CZRC-7264 is described as follows. Most part of the flagelliform spermatophore comprises a tubular stem, which is slender, elongated, translucent and hollow, 6.4mm in length, 0.9mm width and 0.7mm in depth. The capsule is the complex part

Image 4. Female *Hottentotta jabalpurensis* with newborn babies on her back.

Image 5. Female with second instar babies.

of the spermatophore and functions as a storage for spermatozoa and responsible for sperm transfer. It is broader at the base, 1.0mm in length and tapered towards the apex, comprising a pair of tapered capsular distal carina (0.14mm in length), pair of capsular basal carina, pair of stout and apically pointed basal hook (0.07mm length). The capsule width at the region of basal hook was 0.25mm. The flagellum was 4.9mm long, extending from the ventral side of the capsular region and is divided into a thicker part, pars recta, and a distal thinner part called pars reflecta. There is a raised portion on the dorsal side of the flagellum just below the distal end of the ventral process (termed as hook).

Parturition and maternal care (Image 4,5)**:** *Hottentotta jabalpurensis* females (n=9) gave birth to 23–45 juveniles in captivity. The parturition mostly

Image 6. Pre-insemination spermatophore of *Hottentotta jabalpurensis.*

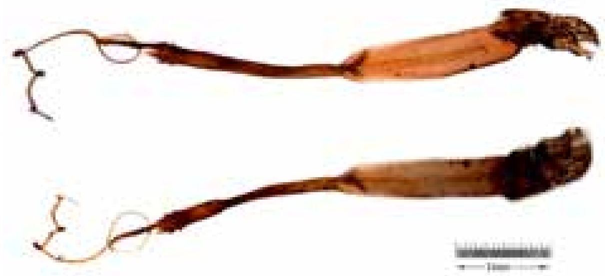

Image 7. Dorsal and ventral aspects of pre-insemination spermatophore of *Hottentotta jabalpurensis.* © Pratyush P. Mohapatra.

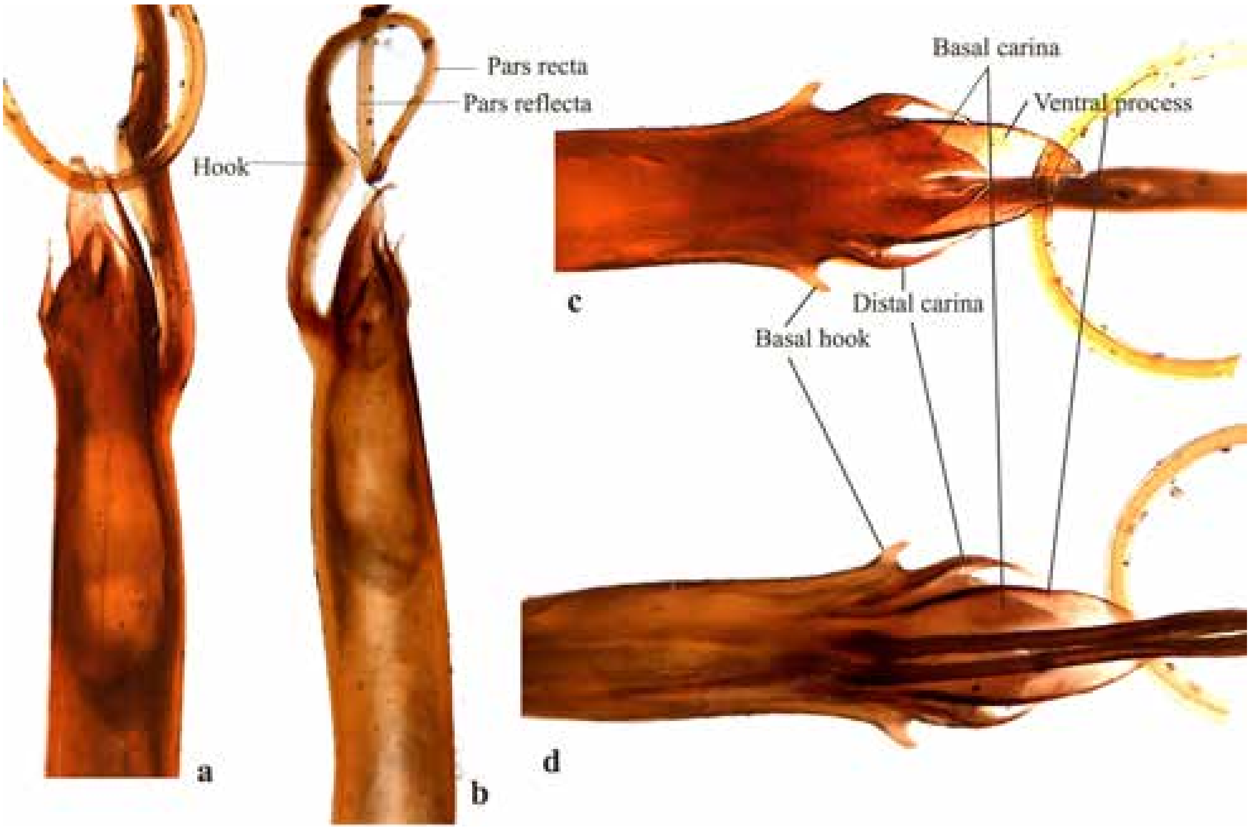

Image 8. Various structures of spermatophore of *Hottentotta jabalpurensis*: a—dorso-lateral side | b—lateral aspects | c—dorsal aspect of capsular region | d—ventral aspect of capsular region. © Pratyush P. Mohapatra.

took place during early evening hours of 17.00–20.00 h. (n= 6), or during late night 11.00–01.00 h. (n= 2) and on one occasion it took place at 14.00h. Prior to parturition the females dug a pit using their first two pairs of her legs and was found resting in a peculiar posture by bending its first pair of legs at the patellar-tibial joint making a 'birth basket', thus fencing the area in front of the genital operculum. During the process of parturition, babies came out of the genital operculum at an interval of 3–5 minutes. After emergence, the babies climbed onto the dorsum of the mother. Babies were oriented randomly on the dorsum and were found stacked in two or three layers on the dorsum, sometimes extended to the ventral part also. It was observed that juveniles remained on the dorsum till the completion of second molting after which their exoskeleton becomes hardened and they start becoming independent. It was observed that till the second molt, the babies were not feeding, although the mother was accepting food just after parturition. One among the female retained the

Image 9. Kin recognition behavior in two female *Hottentotta jabalpurensis* while still carrying second molt scorplings.

parturition after giving birth to five babies till the second ecdysis of the young ones already on her body and later when it was shifted to another box after 10 days, it again gave birth to 18 more babies.

Maternal care was found to be obligatory and while carrying babies, the mother was very attentive, cautious and mostly aggressive. In one incident one male was introduced into the box having a gravid female and when it tried to interact with the female, the female showed no interest at first but later got very aggressive and attacked the male following which the male was separated immediately. Juveniles became independent and aggressive after the second molt, i.e., after 8–10 days of birth but preferred to stay near the mother. While the babies were found moving away from the mother, in the case of the slightest disturbance they immediately ran towards the mother.

The difference between birth and first molt was 2–3 days and between the first and second molt this difference was 4–5 days (n=9). Scorplings were pale yellow at birth with translucent and slight orange in color pedipalps and metasoma, possessing clearly visible median and lateral carinae on the mesosoma as well as dorsal, lateral and ventral carinae on the metasoma. Chelicerae and legs are translucent with black patches. They have a soft exoskeleton and under-developed stinger. Hence, they cannot sting or feed and utilize the stored nutrients. After the first molt they start to change color from pale yellow to brownish-orange, carinae becomes obtrusive, the exoskeleton gets thicker and the stinger becomes hard and sharp. Colour turns brownish-black on the mesosoma and legs and orange on the pedipalp and metasoma with well-marked carinae after the second molt and characters become more prominent as they grow. After the second molt, the babies started feeding on supplied prey and sometimes, they consumed the leftover of the mother's or other juvenile's prey. Cannibalism was observed to be common among juveniles.

Kin recognition (Image 9): Juveniles interacted more than adults under captivity where they either used to avoid or feed on each other. Also, sometimes mothers were found to feed on babies soon after they were born. The most interesting observation includes two juvenile bearing females coming in contact and communicating with each other, being very close, patting one another using pedipalps. The females after being recognized stayed together for two days without harming each other or any juveniles. No cannibalism was found in this case and the juveniles of both the broods readily accepted supplied prey. Later, after a few days of second molting, when one of the females was kept in another box, she gave birth to 18 more babies.

DISCUSSION

Studies on Indian scorpions are mostly confined to taxonomy and regional checklists; however, information on bionomics is still understated. The present study is an attempt to expand the information on biological aspects of a species based on observations in captivity as well as their natural microhabitat. This central Indian endemic species, *H. jabalpurensis* like other congeners such as *H. tamulus*, *H. pachyurus*, and *H. vinchu*, was found generally below the rocks and large boulders, and sometimes on fallen wood logs in wet regions. The coloration among males and females and the juveniles could be added as intraspecific taxonomic characters as the original description is based on old collections (Kovařík 2007). The present study extends the distribution range of the species beyond its type locality in other parts of Madhya Pradesh. As per the information available on maternal care in *H. pachyurus* by Mirza et al. (2009), the juveniles did not show much morphometric variation from that of *H. jabalpurensis*; however, the molting intervals differ as the former species showed just 3–4 days' time span between birth to the second molt which is quite fast whereas it was found to be 8–10 days in the latter species. Also, unlike *H. pachyurus,* juveniles in *H. jabalpurensis* were not found consuming their molt.

The spermatophore study on the Indian scorpion is limited to a very few species, hence an attempt has been made to compare the available data on spermatophore/hemispermatophore of genus *Hottentotta*. The spermatophore of *H. tamulus* as reported by Bastawade (1992) varies by being placed at an angle of 20° and inverted backward whereas the spermatophore of *H. jabalpurensis* was placed at an angle of 10°. This variation might be due to differences in the state of the spermatophore and the inversion of *H. tamulus* spermatophore could be due to the female exerting pressure on the capsule while obtaining the spermatids as Bastawade (1992) described the post-insemination spermatophore. As mentioned by Bastawade (1992), the total length of the spermatophore of *H. tamulus* is 1.3–1.5 times longer and the stem is twice the length than that of *H. jabalpurensis* (present study). Variations on the capsular region between these two species could not be assessed because of a lack of mensural or meristic data on the capsular structure for *H. tamulus*. Furthermore, in comparison with the information on hemispermatophore of two chinese species, *H. pellucidus* and *H. saxinatans* provided by Lowe (2010) no comparative information could be inferred.

Iteroparity is a common phenomenon in scorpions as such reproductive strategy is observed in various species (de Albuquerquea & de Araujo Lira 2016) and there is some information available on intervals between parturitions (Lees 1955; Mathew 1962; Polis & Farley 1979; Warburg 2012). Among the Indian scorpions, Mathew (1962) discussed embryonic diapause in *Lychas tricarinatus* which was of 41–42 days. Our observation in one of the *Hottentotta jabalpurensis* giving birth to babies within an interval of 10 days is possibly a case related to unfavourable environmental conditions. Another interesting behavior observed in this study is female juddering in response to a male approaching for mating. Juddering is a common phenomenon in males during mating as a direct response to stimulate unreceptive females (Ross 2009). Even during the present study, we observed juddering as a mode of communication to suppress unreceptive counterparts. Furthermore, *Hottentotta jabalpurensis* males holding the females by engaging one of the pedipalps and keeping another free is an additional behavior recorded during the study. Hence, this study reports some additional behavioural observations in *Hottentotta jabalpurensis*, which can also be studied in other Indian species.

As envisaged from the study, there is no specific threat to the species. This species is highly adaptable and observed in various micro-habitat types ranging from human-modified habitats to undisturbed forests. *H. jabalpurensis* was found near human habitation, agricultural fields, scrub forest, deciduous forest and semi-evergreen forests and was found below small to large boulders, logs and crevices. This species also occurs in a large number of protected areas such as Veerangana Durgavati WS, Singhori WS, Kanha TR, Bandhavgarh TR, Satpura TR, Bori WS, and Sanjay NP. As this species is considered potentially dangerous for humans and its envenomation has the possibility of confusion with snake-bite, study on human-scorpion interaction can be undertaken to understand the prevalence of such conflicts. A case of envenomation as observed by one of the authors (PPM), following the sting on the right-hand thumb is described as follows. There was swelling and systemic pain around the affected area with a feeling of dizziness, followed by uncoordinated movements for about 6hr. The swelling became normal after 56–60 h following the envenomation.

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COMMUNICATION

First record of the early immature stages of the White Four-ring *Ypthima ceylonica* (Insecta: Lepidoptera: Nymphalidae), and a note on a new host plant from India

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Abstract: Documentation of the early immature stages (egg, larva, chrysalis) of the White Four-ring (*Ypthima ceylonica* Hewitson, 1865), including larval morphology and behaviour, is described for the first time from India. A new host plant (*Cynodon dactylon* (L.) Pers.) is also reported for this butterfly.

Keywords: *Cynodon dactylon*, juvenile biology, life history, Poaceae, Western Ghats.

வெள்ளை வளையன் (ஒயிட் ஃபோர்-ரிங், *யுப்திமா சிலோனிகா*, ஹூயிட்சன், 1865) பட்டாம்பூச்சியின் வளர்ச்சிப்பருவ முதல் நிலைகளான முட்டை, புழு மற்றும் கூட்டுப்புழு நிலைகள், அந் நிலைகளில் அவற்றின் புறத்தோற்றம் மற்றும் நடத்தை, இந்தியாவில் முதல் முறையாக ஆவணப்படுத்தப்பட்டுள்ளன. இந்த பட்டாம்பூச்சிக்கு ஒரு புதிய உணவுத்தாவரமும் (*சைனோடான் டேக்டைலான்* (எல்) பெர்ஸ்.) கண்டறியப்பட்டுள்ளது.

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Author contribution: HT—involved in field sampling, data analysis and manuscript drafting. HR—involved in field sampling, data collection, data supervision and manuscript editing. AP—involved in data analysis, data validation and manuscript editing.

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INTRODUCTION

The genus *Ypthima* under the family Nymphalidae (Satyrinae) was first described by Hübner in 1818. These butterflies have dull to dark brown wings with a large ocellus on the forewing and a series of submarginal ocelli on the hindwing. Currently, *Ypthima* includes nearly 113 species widespread across the southeastern fringe of the Palearctic Region, Afrotropical Region, and Oriental Region (Shima & Nakanishi 2007). In India, 35 species are known to occur (Varshney & Smetacek 2015).

The White Four-ring *Ypthima ceylonica*, is an uncommon butterfly distributed over the southern Indian states (Andhra Pradesh, Karnataka, Kerala, Tamil Nadu, and Telangana), a West Indian state (Maharashtra), East Indian states (Odisha and West Bengal) and several regions of Sri Lanka. The species was first described from Sri Lanka in 1865 by Hewitson. Moore (1880) recorded the species from Gale and Colombo, Sri Lanka. In India, Marshall & de Nicéville (1882) recorded that the species was distributed across southern India starting from Travancore and Madras to Odisha and a similar observation was made by Moore (1893). Hampson (1888) recorded the species from the Nilgiris Hills. Bingham (1905) extended the distribution to Bengal and also considered *Y. ceylonica* as a race of *Ypthima huebneri* Kirby, 1871, rather than treating them as separate species. However, the male genitalia has been shown to provide important information for the identification of *Y. ceylonica* (Elwes & Edwards, 1893). The recent study by Chandra et al. (2007) has expanded this species' range to the states of Madhya Pradesh and Chhattisgarh.

The first incomplete observation of *Y. ceylonica*'s early stages was made from Sri Lanka in 1910 by Green. This was followed by a detailed description and colour images by van der Poorten & van der Poorten (2012). Though there are two detailed descriptions of the immature stages of *Y. ceylonica* from Sri Lanka, to the best of our knowledge and after extensive literature review, there is no documentation on the early immature stages from India. Thus, we take this opportunity to describe the various instars and report a new larval host plant for *Y. ceylonica*.

MATERIALS AND METHODS

A female *Y. ceylonica* was found ovipositing on two grass species, *Cynodon dactylon* and *Axonopus compressus* (Sw.) P.Beauv. One egg and plant material were collected from the first author's garden (11.030N, 76.902E) located at Coimbatore, Tamil Nadu, India. The collected egg and plant material were placed in a plastic rearing container. The various stages of egg, larva, chrysalis and adult were photographed using a Sony HX60V digital camera. The size of the egg was measured using the Digimizer image analysis software, and the size of the larva and chrysalis were measured using a standard measuring scale. The excreta of the larva was removed and the container was cleaned daily to prevent microbial infection. The larva was supplied with fresh

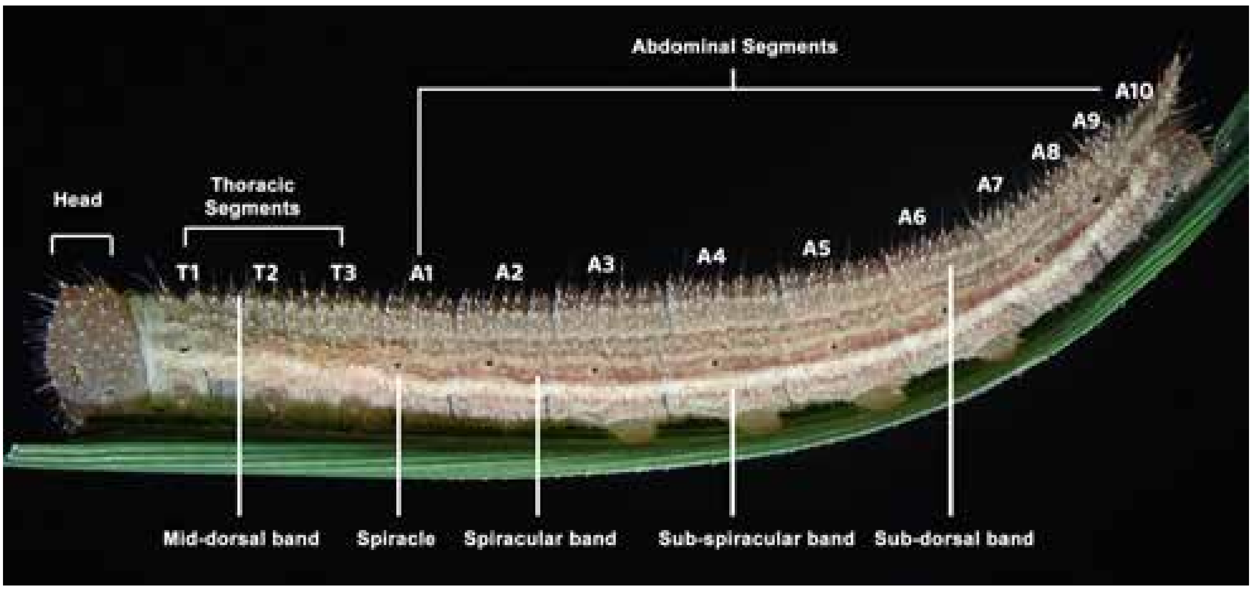

Image 1. Annotated larval segments. © Hari Ramanasaran

leaves of its host plant, *C. dactylon*, whenever required. The described larval segments and morphology are based upon the annotated image shown in Image 1.

RESULTS

Egg

The adult female laid eggs on the underside of both green and dry leaf blades of *C. dactylon* and *A. compressus* very close to the ground. The female was also observed to lay eggs on such nearby objects as a plant's dry leaf, branches, sticks and a stem found in close proximity to the host plant (Image 2). The collected egg measured 0.75mm at its longest diameter. The egg was dull white, almost globular with a nearly flat base and top, and the surface had many small irregular polygonal facets (Image 3a–f). The egg started to develop dark pink striations on day 4 (Image 3d) that continued till the egg matured on day 6 (Image 3f).

Image 2. Ovipositing on a nearby plant's leaf adjacent to the host plant *Axonopus compressus*.

First instar

At the end of day 6 (Image 4a), the neonate larva enclosed by nibbling a portion of the egg. The hatchling completely consumed the eggshell as its first meal. The first-instar larva was cylindrical and measured 2.5mm in length. The head was pale brownish pink and covered with numerous setae. The body was pale pink with a dark

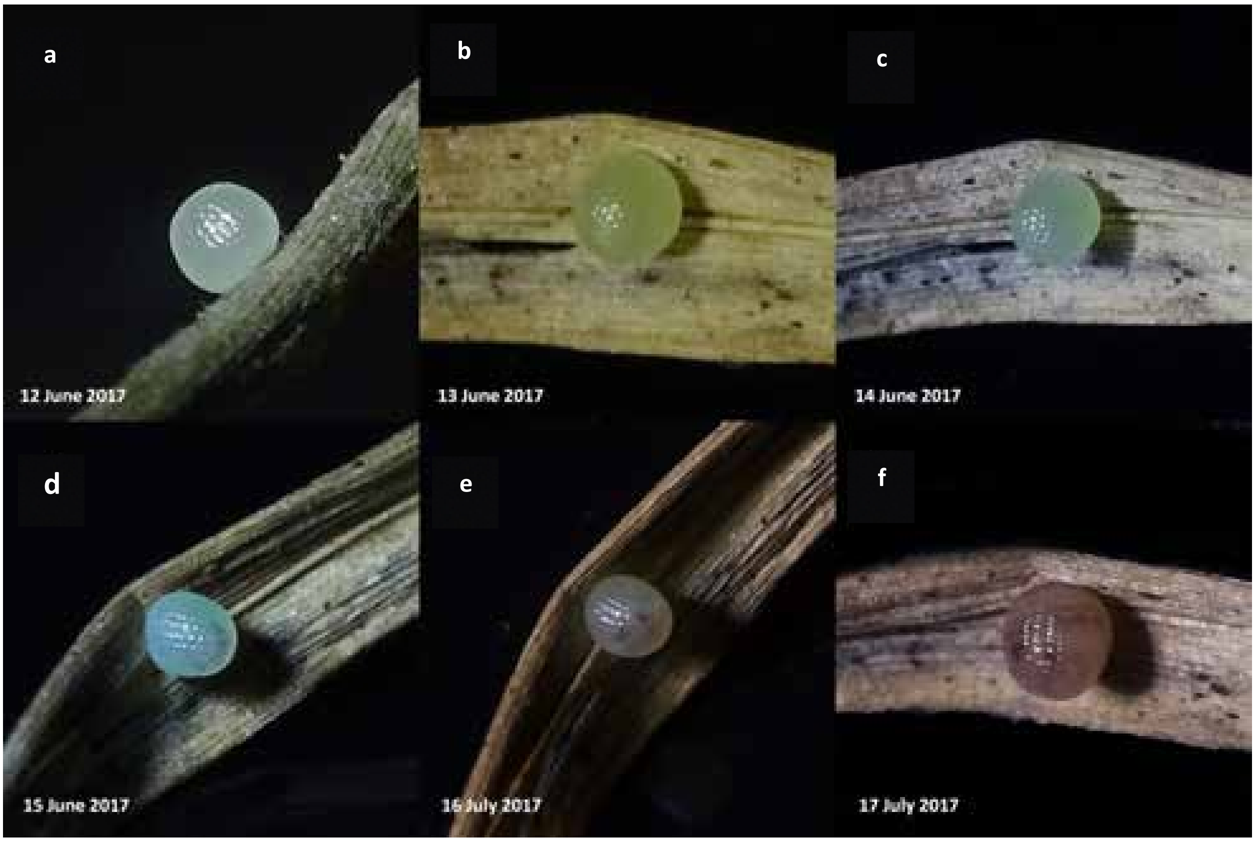

Image 3. Egg of *Ypthima ceylonica* laid on a leaf of *Axonopus compressus*: a—Day 1, 12 June 2017 | b—Day 2, 13 June 2017 | c—Day 3, 14 June 2017 | d—Day 4, 15 June 2017 | e—Day 5, 16 June 2017 | f—Day 6, 17 June 2017. © Hari Theivaprakasham

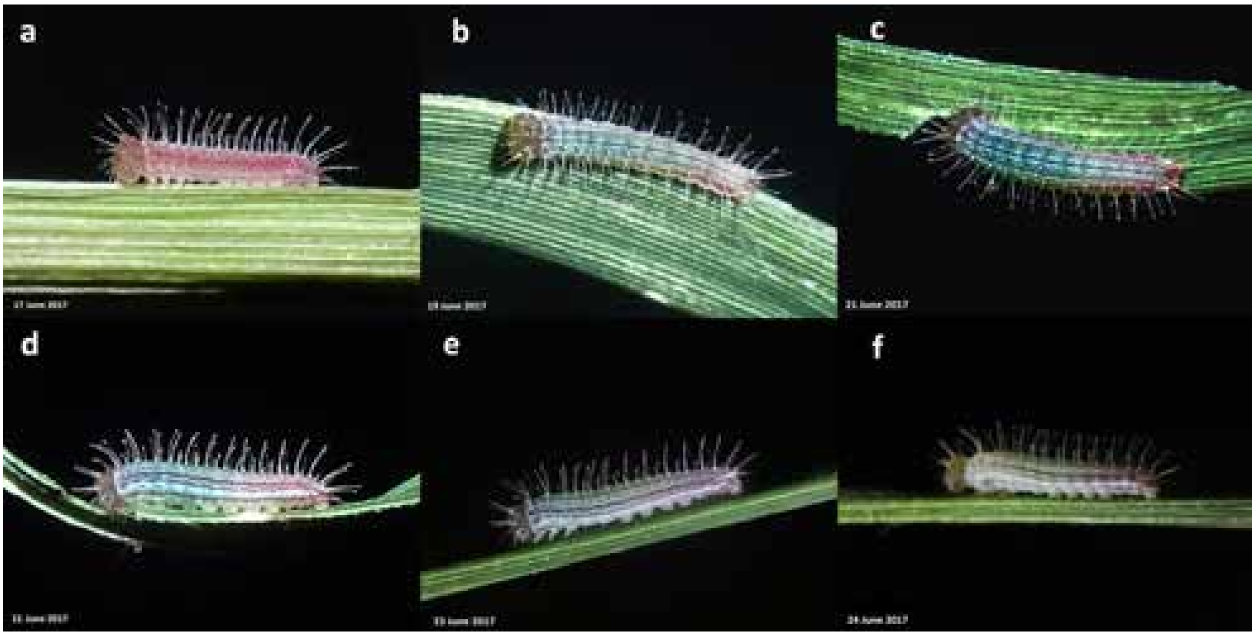

Image 4. First-instar larva of *Ypthima ceylonica*: a—Day 6, 17 June 2017 | b—Day 8, 19 June 2017 | c—Day 10, 21 June 2017 | d—Day 10, 21 June 2017 | e—Day 12, 23 June 2017 | f—Day 13, 24 June 2017. © Hari Ramanasaran

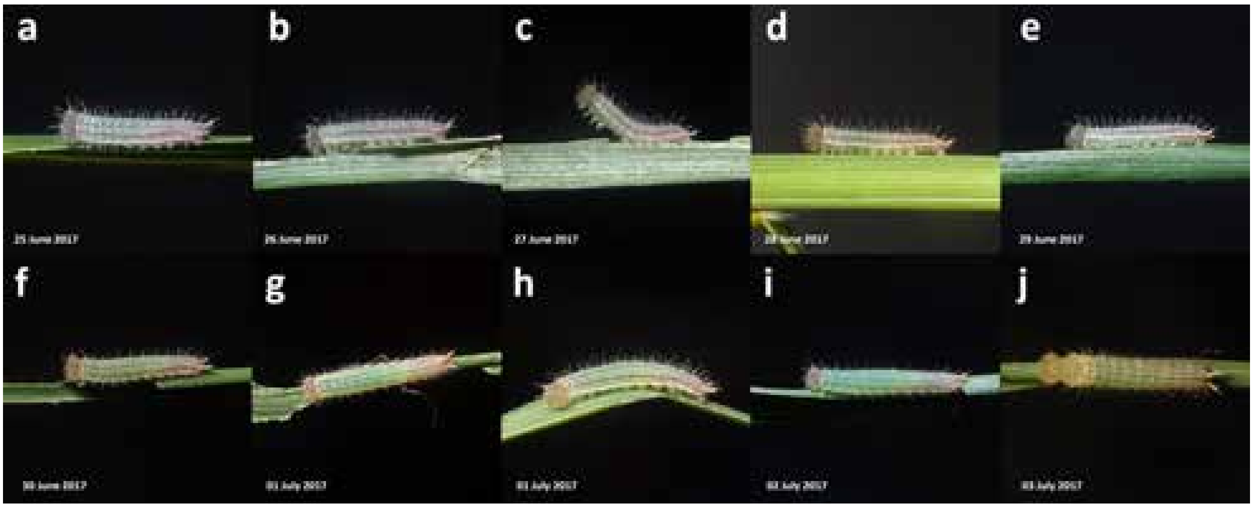

Image 5. Second-instar larva of *Ypthima ceylonica*: a—Day 14, 25 June 2017 | b—Day 15, 26 June 2017 | c—Day 16, 27 June 2017 | d—Day 17, 28 June 2017 | e—Day 18, 29 June 2017 | f—Day 19, 30 June 2017 | g—Day 20, 01 July 2017 | h—Day 20, 01 July 2017 | i—Day 21, 02 July 2017 | j—Day 22, 03 July 2017. © Hari Ramanasaran

pink mid-dorsal band bordered with thin white bands. The sub-dorsal band was thin, dark pink and bordered with thin white bands. The broad spiracular band was pink and bordered with a thin dark white band. The thin sub-spiracular band was pink. All dorsal and ventral bands ran longitudinally from the head to the anal segment. Numerous setae arose from the tubercles on its body. The larva had a pair of short projecting conical horns on the dorsolateral portion of its head and a pair of pointed conical anal processes. On day 8 (Image 4b), the larva fed on young tender grass blades and started to acquire its pale green undertone, which increased day by day (Image 4a–f). The broad pink spiracular band also started to become progressively thinner. After 14 days (Image 4f), the larva moulted and the body length increased to a maximum of 3.2mm.

Image 6. Third-instar larva of *Ypthima ceylonica*: a—Day 23, 04 July 2017 | b—Day 24, 05 July 2017 | c—Day 25, 06 July 2017 | d—Day 26, 07 July 2017 | e—Day 28, 09 July 2017 | f—Day 29, 10 July 2017 | g—Day 30, 11 July 2017 | h—Day 31, 12 July 2017 | i—Day 32, 13 July 2017 | j—Day 33, 14 July 2017 | k—Day 34, 15 July 2017 | l—Day 35, 16 July 2017 | m—Day 36, 17 July 2017 | n—Day 37, 18 July 2017. © Hari Ramanasaran

Second instar

In the second instar (Image 5a–j), the body was dull white initially, with the larva acquiring a green undertone over the next few days (Image 5f–j). The sub-spiracular and spiracular bands became darker, while the mid-dorsal band turned dark green and the sub-spiracular band turned white. The head, which was dark pinkish at the end of the first instar, started to lighten. The length of the body setae gradually decreased in size, while the anal processes became darker, and grew thicker, longer and more pointed. The second-instar larva was more active at night than during the day. Whenever disturbed, the larva, which preferred to eat fresh grass, instantly dropped from the leaf to the bottom of the container. The second instar lasted for eight days. The body length increased from 3.2mm to 5.2mm starting from day 14 (Image 5a) until day 22 (Image 5j).

Third instar

The third-instar larva (Image 6a–n) was light brownish in colour on day 23 (Image 6a), turning pale greenish on day 24 (Image 6b). The setae were drastically reduced in size compared to the second instar. The body was pale green with a dark green mid-dorsal band, and the spiracular band was bordered by a thin white line. The sub-dorsal band was thin, dark green and bordered with thin alternating white and dark green lines that ran longitudinally from the head to the anal segment. The conical anal processes were pale pink, the head turned pale green from its earlier pale brown colour and the sub-spiracular band was white. Starting with day 30 (Image 6g), the upper border of the sub-spiracular line developed thin brown markings. The third instar lasted about 14 days with the body length increasing from 5.2mm to 13mm. The larva moulted on day 38.

Fourth (final) instar

The fourth-instar larva (Image 7a–j) was different compared to the third instar. The body was pale brown and the mid-dorsal band was dark brown with thin white borders. The broad dark brown spiracular band was bordered with thin white lines, and a white line was observed running close above the spiracles. The sub-spiracular band remained white. The spiracles were black and became more prominent compared to earlier instars, while the head and the anal processes were pale brown. The larva fed voraciously on the host plant grass, usually choosing a long blade and feeding from the tip to its base. The larva was observed to reach a leaf's topmost part to feed during the night and return to the bottommost part by morning. It was

Image 7. Fourth-instar larva of *Ypthima ceylonica*: a—Day 37, 18 July 2017 | b) Day 38, 19 July 2017 | c—Day 39, 20 July 2017 | d—Day 40, 21 July 2017 | e—Day 41, 22 July 2017 | f—Day 42, 23 July 2017 | g—Day 43, 24 July 2017 | h—Day 44, 25 July 2017 | i—Day 45, 26 July 2017 | j—Day 46, 27 July 2017. © Hari Ramanasaran

also observed to rest lengthwise on half-eaten blades. The interesting behaviour of forceful frass ejection was also noted, which is best known in species of shelter-building Hesperiidae, but also witnessed with larvae in the Papilionidae, Pieridae, Nymphalidae and numerous moth families (K. Wolfe, pers. comm.). Besides Indian *Y. ceylonica* and *Ypthima striata* Hampson, 1889 (TH, pers. obs.), this likely predator-distancing strategy is practiced elsewhere by *Ypthima huebneri* (Tan, 2015), *Ypthima pandocus corticaria* Butler, 1879, and *Ypthima baldus newboldi* Distant, 1882 (Tan 2014a,b). The fourth instar lasted for eight days, and on day 45 (Image 7i), the body length increased from 13mm to a maximum of 18mm. After day 44, the larva stopped feeding on the leaves and started searching for a suitable place to pupate. The larva chose a blade of grass on which to pupate and gradually reduced its body length to 8mm. The larva remained stationary and pupated on day 46 (Image 7j), the pensile chrysalis being attached by its cremaster to a silken pad spun by the larva.

Chrysalis

The chrysalis (Image 8) was dull yellow, covered with brown striations and measured 10mm. The general profile was elongated and convex except for a conspicuous bump near the junction of the thorax and abdomen. The ocular caps were pointed and short while the wing cases were bordered with a brown line. The chrysalis turned increasingly darker each day. On day 53, the pupal case became transparent and the subapical ocelli marking of the pharate butterfly became visible. On day 54, an adult female emerged in the early morning and was seen resting upside down, drying its wings and ejecting red meconium fluid. Overall, the chrysalis stage lasted for nine days.

The total growth period from egg to adult spanned 54 days, with the development of egg (six days), first instar (eight days), second instar (eight days), third instar (14 days), fourth instar (nine days) and chrysalis (nine days).

DISCUSSION

Our observations in this study in India had various striking differences in host plant selection, larval and chrysalis stages when compared with the earlier descriptions (Green 1910; van der Poorten & van der Poorten 2012) from Sri Lanka. The following discussion focuses on comparisons with those earlier studies.

Host plant

Various grass host plants for *Ypthima ceylonica* are reported from Sri Lanka and India, all from Poaceae. In Sri Lanka, Green (1910) reported *Phalaris arundinacea* L. and van der Poorten & van der Poorten (2012) reported *Axonopus compressus* and *Cyrtococcum trigonum* (Retz.) A.Camus as host plants. In India, Nitin et al. (2018) reported *Setaria barbata* (Lam.) Kunth and Kalesh & Prakash (2015) reported *A.compressus* as host plants. Our finding in this study, however, showed for the first time that *Cynodon dactylon*, a perennial grass, is also used as a larval food plant by *Y. ceylonica*. Before this addition, *C. dactylon* was known as a host plant for only

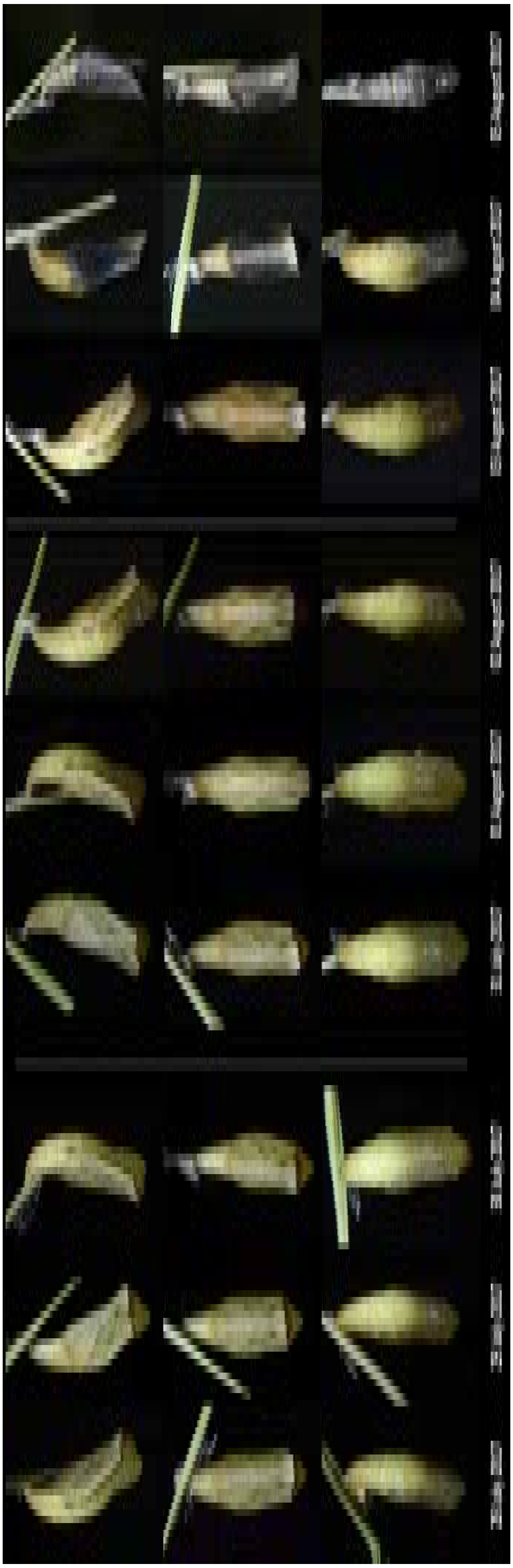

Image 8. Chrysalis of *Ypthima ceylonica* from Day 47 to Day 54. © Hari Ramanasaran

Ampittia dioscorides Fabricius, 1793, *Melanitis leda* L., 1758 (Sawant 2020), and *Ypthima striata* (Agavekar et al. 2020).

Egg

The colour of the egg was white/dull white and not pale blue, but other descriptions of the egg resembled that reported by van der Poorten & van der Poorten (2012).

Larva

We observed only four larval instars compared to five as noted by Green (1910) and Jayasinghe & Rajapakshe (2020). Variation in the number of instars in Lepidoptera is relatively normal and also species dependent (Esperk et al. 2007). The variations in geographical location, environmental conditions and choice of different host plants may affect development (Braby 1994). These assumptions as to *Ypthima ceylonica*, however, need to be further validated by future scientific studies. Four larval instars is not unusual in satyrids. For example, Afrotropical *Ypthima impura* Elwes & Edwards, 1893 (Williams 2020) and Neotropical *Cissia pompilia* C. & R. Felder, 1867, and *Taygetis rufomarginata* Staudinger, 1888 (K. Wolfe, unpub. data) are known to undergo only four instars.

Our observations of the first instar closely resembled the description by Green (1910). In the second instar, the pink base colour was not replaced by whitish green nor were the dorsal, sub-dorsal and sub-spiracular lines replaced with dull green as noted by Green (1910). Instead, our second-instar larva remained nearly the same colour as the first instar with alternate white and pink sub-spiracular and spiracular bands. The transition of Green's (1910) third instar larva resembled the description of our second instar, with the third and fourth instars matching those stages as described by Green (1910). Additionally, the third instar of *Ypthima ceylonica* closely resembled the third and fourth instars of *Ypthima huebneri* (Saji & Das 2020). Our observations of the fourth (final) instar were completely different from the earlier works. The fourth instar's base colour was pale brown with a light brown sub-spiracular band and pale brown head. Whereas the earlier works of Green (1910) and van der Poorten & van der Poorten (2012) reported a green base colour with a green subdorsal band and brownish-green head. The final instar of *Y. ceylonica* closely resembled the final instars of *Ypthima singala* R. Felder, 1868 (van der Poorten & van der Poorten, 2012) and *Ypthima striata* (Agavekar et al., 2020).

Image 9. Freshly eclosed female adult of *Ypthima ceylonica*.

Chrysalis

Green (1910) and van der Poorten & van der Poorten (2012) reported two distinct chrysalis forms from Sri Lanka: grass-green colour and pale grayish-brown. But our chrysalis from India was dull yellow and comparatively different from those described in the earlier studies. Moreover, we noticed that the shape and colour of the chrysalis closely matched that of *Ypthima huebneri* (Saji & Das, 2020).

CONCLUSION

The description of the early immature stages of butterflies are of great value for the identification of juveniles in the field. It also provides supporting data for taxonomic and phylogenetic studies. In this study, the early immature stages of *Ypthima ceylonica* were described in detail for the first time from India, and a new host plant was also reported. Our observations of the early immature stages from India had several variations from the erstwhile descriptions from Sri Lanka. These variations may have occurred due to geographical isolation, subspecies or regional variation, choice of different larval food plants or variations in environmental factors such as temperature, rainfall, relative humidity, and photoperiod. Future morphological and genetic studies on the early immature stages of *Y. ceylonica* from different locations in India need to be performed to better understand the reasons for such variations.

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COMMUNICATION

New additions to the larval food plants of Sri Lankan butterflies (Insecta: Lepidoptera: Papilionoidea)

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Abstract: Larval food plants (LFPs) of Sri Lankan butterflies have been well documented recently with the aid of studies done by numerous researchers. In this paper, we present further records, 118 LFPs used by 83 butterflies and 145 plant-butterfly combinations. LFPs of *Lethe dynsate* and *Potanthus pseudomaesa pseudomaesa* are reported for the first time in Sri Lanka. Important observations, possible LFPs and LFP preferences of rare and threatened butterfly species, are discussed. This information on plant-butterfly interactions will play an important role in conservation management of both plant and butterfly species.

Keywords: *Caprona alida lanka,* plant-butterfly interactions, *Potanthus pseudomaesa pseudomaesa, Rinorea decora,* threatened species.

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INTRODUCTION

The knowledge on the natural history of Sri Lankan butterflies has been increasing rapidly over the past two decades, mainly due to the increase in the numerous field studies carried out by various researchers on butterflies, including their early stages, that had been published as research papers, detailed books, field guide books, leaflets and as other social media material (Gamage 2007; Jayasinghe 2014; Jayasinghe et el. 2015, 2020; van der Poorten & van der Poorten 2016, 2018). The availability of information has led many amateur naturalists to get interested and actively involved in the study of butterflies and now even contribute to the development of knowledge database on butterflies of Sri Lanka.

Early stages of Sri Lankan butterflies have been described in detail in several recently published research papers (van der Poorten & van der Poorten 2011a,b, 2012a,b,c, 2013a,b, 2014; Gunawardana et al. 2015; Priyadarshana et al. 2015; Herath et al. 2020), which provide information on their larval food plants (LFPs) as well. A research article focused on LFPs on Sri Lankan butterflies (Jayasinghe et el. 2014) provided 480 species of LFPs for 207 species of butterflies out of the 245 species known in the country during that time. Further, it documented 785 plant – butterfly combinations. Since then three more butterfly species have been added to the Sri Lankan inventory (van der Poorten & van der Poorten 2016, 2018), and a few more LFPs had been recorded.

Further studies carried out during the last few years revealed some more undocumented LFPs of Sri Lankan butterflies, which are presented in this paper. Some plant species which were not identified up to the species level in previous publication (Jayasinghe et al. 2014) are identified here as well. Recent nomenclatural and systematic changes in LFPs which were already documented in aforementioned publications are also addressed.

MATERIALS AND METHODS

The data presented in this paper is primarily based on studies carried out during 2014–2019 by the authors. Field studies were conducted throughout the country in various habitats, including the northern and eastern regions of the country, which were not studied for decades due to their inaccessibility. Materials and methods adopted for field observations, field notes, data collection, photography, lab works, and identification of butterfly species and plant species follow Jayasinghe et al. (2014). The lab rearing studies were carried out in Soragune (6.747N & 80.893E) Badulla District, Malwana (6.968N & 80.006E) Gampaha District and Kandumulla (7.075N & 80.071E) Gampaha District. Rearing of hill country species was restricted to Soragune, since the temperature and other climatic conditions are suited best out of all the three locations and due to relatively easy accessibility to collect fresh food material regularly from the field. Low country species, both from the wet zone and dry zone were reared at all the three locations, but rearing of northern species were mainly restricted to Malwana. Apart from identification from guide books, some plant species had to be confirmed by studying herbarium sheets at the National Herbarium at Peradeniya and online available herbarium sheets at K, BM, E, and L (Thiers 2020).

All the species of plants presented in this paper are confirmed LFPs in Sri Lanka. Here we consider a species as a confirmed LFP, when the butterfly larvae reared on it until maturity, or the early stages and egg laying behaviors observed regularly in the field on a given plant species. Even the larvae found on certain plants, if they were unable to complete the larval stage on those plants are not considered as confirmed LFPs. We observed that certain butterfly species (i.e., *Acraea terpsicore*) are trying to test new species of LFPs, but are not always successful. Certain butterfly larvae were found on non LFPs in the field, probably while they are moving from one plant to another or accidentally fell off. Species such as *Delias eucharis* and *Papilio clytia lankeswara* were observed shifting their LFPs for pupation. The data presented here, other than the studies carried out by the authors were included only if they were verified by detailed photographs and the plant species especially were identified by the authors based on information provided by those individuals.

Nomenclature of the butterflies follows van der Poorten & van der Poorten (2016). Classification and nomenclature of angiosperms, which had been subjected to dramatic changes due to recent molecular phylogenetic studies are based on (POWO 2019), and (WCSP 2020)

RESULTS & DISCUSSION

A total of 118 species of angiosperms, belongs to 44 families are newly added to the Sri Lankan butterfly LFPs check list. These plants include 23 endemic, 67 indigenous, and 27 exotic species. These plant species are used by 63 species of butterflies. LFPs for *Lethe dynsate* (Hewitson, 1863) & *Potanthus pseudomaesa pseudomaesa* (Moore, [1881]) are reported for the first time in Sri Lanka. This represents 145 plant-butterfly interactions and the detailed list is given in Annexure 1.

Names of plants mentioned in previous publications (Jayasinghe et al. 2014; van der Poorten & van der Poorten 2016, 2018) should read as follows.

Acanthaceae: *Dipteracanthus prostratus* - *Ruellia prostrata* Poir., *Dyschoriste erecta* – *D. madurensis* (Brum.f.) Kuntze, *Dyschoriste litoralis* – *D. nagchana* (Nees) Bennet, *Justicia procumbens* - *Rostellularia procumbens* (L.) Nees, *Phaulopsis imbricata* – *P. dorsiflora* (Retz.) Santapau, *Stenosiphonium cordifolium* - *Strobilanthes cordifolia* (Vahl) J.R.I.Wood, *Strobilanthes diandra* – *S. diandra* var. *diandra* (Nees) Alston

Annonaceae: *Polyalthia cerasoides* - *Huberantha cerasoides* (Roxb.) Chaowasku, *Polyalthia korinti* - *Huberantha korinti* (Dunal) Chaowasku, *Polyalthia longifolia* - *Monoon longifolium* (Sonn.) B.Xue & R.M.K.Saunders

Apocynaceae: *Anodendron paniculatum* – *A. parviflorum* (Roxb.) I.M.Turner, *Ceropegia candelabrum* – *C. candelabrum* var. *candelabrum* L., *Dregea volubilis* - *Wattakaka volubilis* (L.f.) Stapf, *Gymnema lactiferum* - *Marsdenia lactifera* (L.) I.M.Turner, *Holostemma ada-kodien* - *Cynanchum annularium* (Roxb.) Liede & Khanum, *Pergularia daemia* – *P. daemia* subsp. *daemia* (Forssk.) Chiov, *Tylophora cordifolia* - *Vincetoxicum cordifolium* (Thwaites) Kuntze, *Tylophora flexuosa* - *Vincetoxicum flexuosum* var. *tenuis* (Blume) Schneidt, Meve & Liede, *Tylophora indica* - *Vincetoxicum indicum* (Burm.f.) Mabb., *Tylophora multiflora* - *Vincetoxicum iphisia* Meve & Liede, *Tylophora pauciflora* - *Vincetoxicum bracteatum* (Thunb.) Meve & Liede

Cleomaceae: *Cleome rutidosperma* - *C. rutidosperma* var. *burmanni* (Wight & Arn.) Siddiqui & S.N.Dixit, *Crateva adansonii* – *C. adansonii* subsp. *odora* (Buch.-Ham.) Jacobs.

Costaceae: *Costus speciosus* - *Hellenia speciosa* (J.Koenig) S.R.Dutta

Euphorbiaceae: *Dimorphocalyx glabellus* – *D. glabellus* var. *glabellus* Thwaites

Fabaceae: *Abrus pulchellus* – *A. melanospermus* Hassk., *Acacia caesia* - *Senegalia caesia* (L.) Maslin, Seigler & Ebinger, *Acacia eburnea* - *Vachellia eburnea* (L.f.) P.J.H.Hurter & Mabb., *Acacia leucophloea* - *Vachellia leucophloea* (Roxb.) Maslin, Seigler & Ebinger, *Acacia nilotica* - *Vachellia nilotica* (L.) P.J.H.Hurter & Mabb., *Acacia pennata* - *Senegalia pennata* (L.) Maslin, *Acacia planifrons* - *Vachellia planifrons* (Wight & Arn.) Ragup., Seigler, Ebinger & Maslin, *Bauhinia racemosa* - *Piliostigma racemosum* (Lam.) Benth., *Calliandra calothyrsus* – *C. houstoniana* (Mill.) Standl., *Caesalpinia bonduc* - *Guilandina bonduc* L., *Caesalpinia hymenocarpa* - *Mezoneuron hymenocarpum* Wight & Arn. ex Prain, *Caesalpinia sappan* - *Biancaea sappan* (L.) Tod., *Chamaecrista auricoma* – *C. leschenaultiana* (DC.) O.Deg., *Chamaecrista nictitans* – *C. nictitans* var. *glabrata* (Vogel) H.S.Irwin & Barneby, *Dalbergia pseudo-sissoo* – *D. rostrata* Hassk., *Desmodium heterocarpon* - *Grona heterocarpa* var. *heterocarpa* (L.) H.Ohashi & K.Ohashi, *Desmodium heterophyllum* - *Grona heterophylla* (Willd.) H.Ohashi & K.Ohashi, *Desmodium triflorum* - *Grona triflora* (L.) H.Ohashi & K.Ohashi, *Falcataria moluccana* – *F. falcata* (L.) Greuter & R.Rankin, *Pueraria phaseoloides* - *Neustanthus phaseoloides* (Roxb.) Benth., *Sesbania bispinosa* – *S. aculeata* (Schreb.) Pers.

Icacinaceae: *Nothapodytes nimmoniana* - *Mappia nimmoniana* (J.Graham) Byng & Stull

Lauraceae: *Neolitsea cassia* – *N. cassia* var. *cassia* (L.) Kosterm.

Linderniaceae: *Lindernia anagallis* - *Vandellia anagallis* (Burm.f.) T.Yamaz., *Lindernia antipoda* - *Bonnaya antipoda* (L.) Druce, *Lindernia crustacea* - *Torenia crustacea* (L.) Cham. & Schltdl., *Lindernia pusilla* - *Vandellia diffusa* L.

Malvaceae: *Grewia daminae* – *G. tiliifolia* Vahl

Molluginaceae: *Mollugo cerviana* - *Hypertelis cerviana* (L.) Thulin

Moraceae: *Ficus nervosa* – *F. nervosa* subsp. *minor* (King) C.C.Berg, *Ochrosia oppositifolia* - *Artocarpus gomezianus* Wall. ex Trécul

Ochnaceae: *Gomphia serrata* - *Campylospermum serratum* (Gaertn.) Bittrich & M.C.E.Amaral

Orchidaceae: *Malaxis versicolor* - *Crepidium versicolor* (Lindl.) Sushil K.Singh, Agrawala & Jalal

Phyllanthaceae: *Sauropus bacciformis* - *Synostemon bacciformis* (L.) G.L.Webster

Poaceae: *Eragrostis amabilis* – *E. viscosa* (Retz.) Trin., *Panicum maximum* - *Urochloa maxima* (Jacq.) R.D.Webster, *Sinarundinaria debilis* - *Kuruna debilis* (Thwaites) Attigala, Kaththr. & L.G.Clark

Primulaceae: *Embelia ribes* – *E. ribes* var. *ribes* Burm.f.

Rhamnaceae: *Ziziphus napeca* – *Z. linnaei* M.A.Lawson

Rutaceae: *Euodia suaveolens* – *E. hortensis* J.R.Forst. & G.Forst., *Micromelum minutum* – *M. minutum* var. *ceylanicum* B.C.Stone, *Paramignya monophylla* – *P. monophylla* var. *monophylla* Wight

Sabiaceae: *Meliosma pinnata* – *M. arnottiana* (Wight) Walp., *Meliosma simplicifolia* – *M. simplicifolia* subsp. *simplicifolia* (Roxb.) Walp.

Salvadoraceae: *Salvadora persica* - *Salvadora persica* var. *wightiana* (Planch. ex Thwaites) Verdc.

Sapindaceae: *Dodonaea viscosa* – *D. viscosa* subsp. *viscosa* Jacq., *Lepisanthes tetraphylla* – *L. tetraphylla* var. *tetraphylla* (Vahl) Radlk.

Symplocaceae: *Symplocos cochinchinensis* – *S. acuminata* (Blume) Miq.

Thymelaceae: *Gnidia glauca* - *Lasiosiphon glaucus* Fresen.

Violaceae: *Hybanthus enneaspermus* - *Afrohybanthus enneaspermus* (L.) Flicker, *Viola betonicifolia* – *V. betonicifolia* subsp. *betonicifolia* Sm.

Zingiberaceae: *Amomum fulviceps* - *Meistera fulviceps* (Thwaites) Skornick. & M.F.Newman, *Amomum trichostachyum* - *Meistera trichostachya* (Alston) Skornick. & M.F.Newman

Grewia carpinifolia Juss. is considered as an African species in (POWO 2019) and the valid identity of the plant described under this name in (Dassanayake & Fosberg 1991) is doubtful. *Pericopsis mooniana* Thwaites for *Curetis thetis* (Drury, 1773) in Jayasinghe et al. (2014) was a mis-identification of recently discovered *Curetis siva* Evans, 1954. *Entada rheedei* Spreng. for *Nacaduba pactolus ceylonica* Fruhstorfer, 1916 in Priyadarshana et al. (2015) was probably a mis-identification of *Entada zeylanica* Kosterm., since *E. rheedei* is not growing in both the localities given in the publication (Kostermans 1980).

Following plants that were not identified up to the species level in Jayasinghe et al. (2014) are identified here.

Eurema hecabe hecabe (Linnaeus, 1758) - *Sesbania procumbens* Wight & Arn.; *Tirumala septentrionis musikanos* (Fruhstorfer, 1910) - *Cosmostigma cordatum* (Poir.) M.R.Almeida; *Hypolycaena nilgirica* Moore, [1884] - *Luisia zeylanica* Lindl.; *Celaenorrhinus spilothyrus* (R. Felder, 1868) - *Strobilanthes viscosa* var. *digitalis* (Nees) C.B.Clarke; *Coladenia tissa* Moore, [1881] - *Mallotus philippensis* (Lam.) Müll.Arg.

Sesbania procumbens is newly reported in Sri Lanka (de Vlas 2019) in this study, which was considered to be an endemic species to India (Rao et al. 2019), from water logging habitats of the downstream areas of Yodha Wewa at Murunkan (8.8611 N & 80.0145 E).

All the summarized published data, including the data in this publication, reveals LFPs of 223 butterfly species. The butterfly fauna of Sri Lanka consists of a single carnivorous species *Spalgis epeus epeus* (Westwood, 1851) (van der Poorten & van der Poorten 2016) and another possible carnivorous species *Spindasis greeni* Heron, 1896 (van der Poorten & van der Poorten 2012c). Early stages of the remaining 23 species are yet to be discovered in Sri Lanka, though some of these indigenous species have been reared in other countries (Nitin et al. 2018). Seven species and five subspecies out of these 23 are endemic to Sri Lanka. Even though the LFPs of these species are not yet confirmed, clues for some species were observed during the field studies. *Mycalesis rama* (Moore, 1892) was most frequently observed among *Ochlandra stridula* in lowland rainforests and very rarely go beyond these bushes while mating pairs were observed in Yagirala forest reserve (6.376 N & 80.169 E) among these bushes. *Arhopala ormistoni* Riley, 1920 is a very rare butterfly species which was originally described from Nakiyadeniya in southern wet zone (Woodhouse 1949) and not known for decades until its appearance in a disjunct population at the eastern intermediate zone (van der Poorten & van der Poorten 2016). One of its closely allied species *Arhopala bazaloides lanka* (Evans, 1957) is using a Dipterocarpaceae species as its sole LFP, initially, which was described as early stages of *A. ormistoni* by an mis-identification (van der Poorten & van der Poorten 2013a). An unusual population of more than 50 individuals of *A. ormistoni* was found recently in the catchment area of Namal Oya reservoir (7.321N & 81.521E). The only plant species belonging to the family Dipterocarpaceae in this micro-habitat is confirmed during this study as *Vatica obscura*, the species that was tentatively identified previously as an egg-laying plant of this butterfly (van der Poorten & van der Poorten 2016). Though the adult individuals of endemic *Udara singalensis* (R. Felder, 1868) and *Thoressa decorata* (Moore, 1881) are quite regularly seen, there are no any clues about their LFPs. Mostly, males of these species are seen in the field, but we never had a chance to follow females who are searching for LFPs. The remaining endemic species *Tajuria arida* Riley, 1923, *Nacaduba ollyetti* Corbet, 1947, and *Spindasis nubilus* (Moore, [1887]) are very rare and only a few adult individuals have been observed in the recent past (Jayasinghe et el. 2015; van der Poorten & van der Poorten 2016).

Together with the new information provided in this paper, a total of 582 plants identified up to the species level, belonging to 75 families has been confirmed as LFPs of Sri Lankan butterflies. This list comprises 70 endemic, 351 indigenous and 161 exotic species. There are further 15 confirmed LFPs, which are, however, not identified up to the species level. Most of these unidentified plants belong to the family Poaceae. The total butterfly-plant interactions are summed up to 1091, with the details given in this paper.

According to the documented information available up to now, there are only two endemic species of butterflies that use a single endemic plant as their sole LFP. That is the interactions between *Halpe egena* (R. Felder, 1868) - *Davidsea attenuata* (van der Poorten & van der Poorten 2016) and *Lethe dynsate* (Hewitson, 1863) - *Ochlandra stridula*. It is, however, possible that these butterflies are using other bamboo species as well since many of the related butterfly species feed on several Poaceae species. The only LFP identified of the endemic *Lethe daretis* (Hewitson, 1863) is the endemic *Kuruna debilis* (van der Poorten & van der Poorten 2012b), but this butterfly was observed by us laying eggs on an unidentified grass species at the lawn of Hakgala botanic garden (6.923N & 80.821E) and successfully reared them on the same grass until the emergence of the adult butterflies. *Appias galene* (C. & R. Felder, 1865) has been reported to feed on endemic *Drypetes gardneri* (Jayasinghe et al. 2014) at Pitawala (7.542N & 80.750E), but its preferred LFP is *Drypetes sepiaria*. Endemic *Baoris penicillata* Moore, [1881] prefers to feed on the endemic *Ochlandra stridula* (Jayasinghe et al. 2014; van der Poorten & van der Poorten 2016), but it can adapt to other exotic bamboo species as well. *Coladenia tissa* Moore, [1881] is reported here, to feed on endemic *Pityranthe verrucosa*, but it has many other non-endemic LFPs (Jayasinghe et al. 2014). *Elymnias singhala* Moore, [1875] has been reported to feed on two endemic species, namely *Calamus ovoideus* (Jayasinghe et al. 2014) and *Loxococcus rupicola* (van der Poorten & van der Poorten 2016), but also feed on other palm species as well. The two distantly related endemics, namely *Kallima philarchus* (Westwood, 1848) and *Celaenorrhinus spilothyrus* (R. Felder, 1868) depend on various endemic *Strobilanthes* species as their LFPs (Jayasinghe et al. 2014; van der Poorten & van der Poorten 2016).

Ca. 20% of the indigenous and endemic LFP species are categorized under threatened categories in the National Red Data List (MOE 2012). Some of the LFPs considered as 'extinct' and 'possibly extinct' were recently rediscovered during this LFP identification research (Jayasinghe 2015; de Vlas & de Vlas 2014; de Vlas 2019). The rediscovered, endemic species *Rinorea decora* is found in three locations, including a recent new locality at Sulugune (7.469N & 80.900E) in the Dumbara mountain range. This is the sole LFP of the Critically Endangered butterfly *Phalanta alcippe ceylonica* (Manders, 1903), which is also restricted to the same area. We were able to find this very rare, micro-habitat specific plant by tracing the butterflies who are looking for suitable plants for egg laying and we observed early stages at all the three locations. This incident reveals the importance of conserving the LFPs for the conservation of butterflies. The preferred LFP of the Critically Endangered butterfly *Catochrysops panormus panormus* (C. Felder, 1860), *Flemingia macrophylla*, was considered to be possibly extinct until it was rediscovered during this research. Fortunately, this species is now being introduced as a hedge plant for low country tea estates by the Tea Research Institute (Rajika Gamage pers. comm. 17.iv.2018), but whether these plants are exactly from the native population or a cultivar and whether the butterfly larvae are feeding on them, is yet to be discovered.

Out of the known details of 223 butterfly species, 47 of them are reported having a single LFP each. This includes nine endemic species and 20 endemic subspecies. Most of them appear to have a sole LFP, but there is a possibility to find more LFPs for some of these species. At the other extreme, *Neptis hylas varmona* Moore, 1872 is the most polygamous species in Sri Lanka. It uses 46 species of LFPs belongs to six families. *Euploea core asela* Moore, 1877 ranked for the second place by using 30 LFPs, but those plants belong only to two families. *Zesius chrysomallus* Hübner, 1821 seems to feed on any plant, where the Red Weaver Ants *Oecophylla smaragdina* Fabricius, 1775 are colonized. Butterflies that use the highest number of LFPs are listed in table 1. The exotic plant *Axonopus compressus* (Sw.) P. Beauv. has been reported to be used by 14 species of butterflies. It is interesting that many Poaceae species are shared by a high number of butterfly species (Table 2). Three-hundred-and-forty-four plant species from the whole LFPs list are not shared by two or more butterfly species. Most of the reported LFPs belong to the family Fabaceae (Table 3).

This information on LFPs of Sri Lankan butterflies can be used for habitat conservation-oriented management strategies, which will enhance the conservation of other flora and fauna as well. Further studies on the life history of targeted species are required for the unknown 23 species of butterflies which consist of very rare and / or endemic species. These studies should be aimed at revealing the reasons for their scarcity, which are required to ensure their future survival.

Table 1. Butterfly species that are using highest number of LFP species.

Butterfly species	No. of LFPs	No. of plant families
Neptis hylas varmona Moore, 1872	46	6
Euploea core asela Moore, 1877	30	2
Jamides bochus bochus (Stoll, [1782])	23	1
Eurema hecabe hecabe (Linnaeus, 1758)	22	1
Graphium agamemnon menides (Fruhstorfer, 1904)	22	3
Prosotas nora ardates (Moore, [1875])	17	5
Lampides boeticus (Linnaeus, 1767)	16	1
Eurema blanda citrina (Moore, 1881)	15	1
Zesius chrysomallus Hübner, 1821	15	8
Papilio polytes romulus Cramer, [1775]	14	1
Jamides alecto meilichius (Fruhstorfer, 1916)	14	1

Table 2. LFPs used by highest number of butterfly species.

LFP	Family	No. of butterflies using the plant
Axonopus compressus (Sw.) P. Beauv.	Poaceae	14
Urochloa maxima (Jacq.) R.D.Webster Jacq.	Poaceae	10
Ischaemum timorense Kunth	Poaceae	10
Oryza sativa L.	Poaceae	9
Dendrophthoe falcata (L.f.) Ethingsh.	Loranthaceae	8
Dalbergia rostrata Hassk.	Fabaceae	7
Lepisanthes tetraphylla var. *tetraphylla* (Vahl) Radlk.	Sapindaceae	7
Ochlandra stridula Thwaites	Poaceae	7

Table 3. Number of LFP species in highest ranked families.

Family	No. of LFPs
Fabaceae	135
Apocynaceae	40
Poaceae	38
Acanthaceae	36
Rutaceae	26
Annonaceae	20
Arecaceae	20
Malvaceae	20
Zingiberaceae	20

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Annexure 1. Newly recorded LFPs of Sri Lankan butterflies.
DS—Distribution status | Ex—Exotic | En—Endemic | In—Indigenous | l—leaves | il—immature leaves | ml—mature leaves | fl—flower | flb—flower buds | fr—fruit | st—stem, se—seeds | br—bracts | PC—personal communication | LA—Lasantha Aberathna | NC—Nuwan Chathuranga | KW—Kalana Wijesundara | ND—Narmadha Dangampola | SG—Sujeewa Gunasena | CU—Chathura Udayanga | GR—Gehan Rajiv.

Butterfly species	Plant species	DS	Plant Family / consumed parts of the plant	Remarks
Papilio demoleus demoleus Linnaeus, 1758	*Ruta chalepensis* L.	Ex	Rutaceae / l	PC: LA
Graphium sarpedon teredon (C. & R. Felder, 1865)	*Actinodaphne glauca* var. *glauca* Nees	En	Lauraceae / l	
	Persea americana Mill.	Ex		
Graphium agamemnon menides (Fruhstorfer, 1904)	*Goniothalamus gardneri* Hook.f. & Thomson	En	Annonaceae / l	
	Uvaria zeylanica L.	In		
Leptosia nina nina Fabricius, 1793	*Brassica juncea* (L.) Czern.	Ex	Brassicaceae / l	PC: SG
	Brassica oleracea L.	Ex		PC: ND
Belenois aurota taprobana (Moore, 1872)	*Capparis brevispina* DC.	In	Capparaceae / l	
Cepora nerissa phryne (Fabricius, 1775)	*Capparis tenera* Dalzell	In	Capparaceae / l	
Appias libythea libythea (Fabricius, 1775)	*Cleome aspera* J.Koenig ex DC.	In	Cleomaceae / l	
Catopsilia pyranthe pyranthe (Linnaeus, 1758)	*Senna sophera* (L.) Roxb.	In	Fabaceae / l	
Catopsilia scylla (Linnaeus, 1763)	*Senna sophera* (L.) Roxb.	In	Fabaceae / l	
Eurema hecabe hecabe (Linnaeus, 1758)	*Chamaecrista absus* (L.) H.S.Irwin & Barneby	In	Fabaceae / l	
	Mimosa diplotricha C.Wright	Ex		
Eurema blanda citrina (Moore, 1881)	*Archidendron clypearia* subsp. *subcoriaceum* (Thwaites) I.C.Nielsen	In	Fabaceae / il	
	Entada zeylanica Kosterm.	En		
Ideopsis similis exprompta Butler, 1874	*Vincetoxicum flexuosum* var. *tenuis* (Blume) Schneidt, Meve & Liede	In	Apocynaceae / l	
Parantica aglea aglea (Stoll, 1782)	*Ceropegia candelabrum* var. *biflora* (L.) Ansari	In	Apocynaceae / l	
Euploea core asela Moore, 1877	*Secamone emetica* (Retz.) R.Br. ex Sm.	In	Apocynaceae / l	
Euploea klugii sinhala Moore, 1877	*Streblus zeylanicus* (Thwaites) Kurz	In	Moraceae / l	
Cupha erymanthis placida Moore, [1881]	*Flacourtia inermis* Roxb.	Ex	Salicaceae / l	PC: CU
Vindula erota asela (Moore, 1872)	*Passiflora subpeltata* Ortega	Ex	Passifloraceae / l	PC: NC
Cirrochroa thais lanka Moore, 1872	*Hydnocarpus octandrus* Thwaites	En	Achariaceae / l	
Vanessa cardui (Linnaeus, 1758)	*Anaphalis sulphurea* (Trimen) Grierson	En	Asteraceae / l, st	
	Artemisia indica Willd.	In	Asteraceae / l	
Junonia orithya patenas (Fruhstorfer, 1912)	*Rungia repens* (L.) Nees	In	Acanthaceae / l	
Junonia hierta (Linnaeus, 1798)	*Ruellia prostrata* Poir.	In	Acanthaceae / l	only in the lab
	Dyschoriste madurensis (Brum.f.) Kuntze	In		
Junonia atlites atlites (Linnaeus, 1763)	*Vandellia pusilla* (Willd.) Merr.	In	Linderniaceae / l	
	Limnophila repens (Benth.) Benth.	In	Plantaginaceae / l	
Junonia almana almana (Linnaeus, 1758)	*Vandellia pusilla* (Willd.) Merr.	In	Linderniaceae / l	
Doleschallia bisaltide ceylonica Fruhstorfer, 1903	*Pseuderanthemum carruthersii* (Seem.) Guillaumin	Ex	Acanthaceae / l	only in the lab
Kallima philarchus (Westwood, 1848)	*Strobilanthes exserta* C.B.Clarke	En	Acanthaceae / l	
Pantoporia hordonia sinuata (Moore, 1879)	*Albizia chinensis* (Osbeck) Merr.	In	Fabaceae / l	

Butterfly species	Plant species	DS	Plant Family / consumed parts of the plant	Remarks
Neptis hylas varmona Moore, 1872	*Calopogonium mucunoides* Desv.	Ex	Fabaceae / l	
	Grona heterocarpa var. *heterocarpa* (L.) H.Ohashi & K.Ohashi	In		
	Grona heterophylla (Willd.) H.Ohashi & K.Ohashi	In		PC: CU
	Desmodium tortuosum (Sw.) DC.	Ex		
	Glycine max (L.) Merr.	Ex		
	Phyllodium pulchellum (L.) Desv.	In		
	Tadehagi triquetrum (L.) H.Ohashi	In		
	Vigna radiata (L.) R.Wilczek	Ex		
	Pityranthe verrucosa Thwaites	En	Malvaceae / l	
	Helicteres isora L.	In		
	Sterculia zeylanica Kosterm.	En		
	Mitragyna parvifolia (Roxb.) Korth.	In	Rubiaceae / l	PC: KW
Neptis jumbah nalanda Fruhstorfer, 1908	*Bhesa nitidissima* Kosterm.	En	Centroplacaceae / l	
	Pterospermum suberifolium (L.) Willd.	In	Malvaceae / l	
	Campylospermum serratum (Gaertn.) Bittrich & M.C.E.Amaral	In	Ochnaceae / l	
	Prunus walkeri (Wight) Kalkman	En	Rosaceae / l	
Moduza procris calidasa (Moore, 1858)	*Mitragyna tubulosa* (Arn.) Kuntze	In	Rubiaceae / l	
	Mussaenda samana Jayaw.	En		
Charaxes athamas athamas (Drury, [1773])	*Albizia chinensis* (Osbeck) Merr.	In	Fabaceae / l	
	Calliandra surinamensis Benth.	Ex		
Charaxes psaphon psaphon Westwood, 1847	*Entada zeylanica* Kosterm.	En	Fabaceae / l	
Melanitis leda leda (Linnaeus, 1758)	*Arundo donax* L.	Ex	Poaceae / l	
	Eleusine indica (L.) Gaertn.	In		
Melanitis phedima tambra Moore, 1880	*Arundo donax* L.	Ex	Poaceae / l	
	Cyrtococcum trigonum (Retz.) A.Camus	In		PC:KW
Lethe daretis (Hewitson, 1863)	*Unidentified 5 (Galways)*		Poaceae / l	
Lethe dynsate (Hewitson, 1863)	*Ochlandra stridula* Thwaites	En	Poaceae / l	
Mycalesis patnia patnia Moore, 1857	*Ischaemum timorense* Kunth	In	Poaceae / l	
Curetis thetis (Drury, 1773)	*Derris parviflora* Benth.	En	Fabaceae / il	
Arhopala amantes amantes (Hewitson, 1862)	*Syzygium caryophyllatum* (L.) Alston	In	Myrtaceae / l	
Zesius chrysomallus Hübner, 1821	*Terminalia bellirica* (Gaertn.) Roxb.	In	Combretaceae / l	PC: CU
	Bridelia retusa (L.) A.Juss.	In	Phyllanthaceae / l	
	Canthium coromandelicum (Burm.f.) Alston	In	Rubiaceae / l	
	Symplocos acuminata (Blume) Miq.	In	Symplocaceae / l	
Amblypodia anita naradoides Moore, 1879	*Olax imbricata* Roxb.	In	Olacaceae / l	
Catapaecilma major myosotina Fruhstorfer, 1912	*Lannea coromandelica* (Houtt.) Merr.	In	Anacardiaceae / l	
	Albizia lebbeck (L.) Benth.	In	Fabaceae / l	
	Vitex altissima L.f.	In	Lamiaceae / l	
	Dendrophthoe falcata (L.f.) Ethingsh.	In	Loranthaceae / l	
Rathinda amor (Fabricius, 1775)	*Mangifera indica* L.	Ex	Anacardiaceae / il	PC: NC
	Scutia myrtina (Burm.f.) Kurz	In	Rhamnaceae / il	
	Dimocarpus longan Lour.	In	Sapindaceae / il	

Butterfly species	Plant species	DS	Plant Family / consumed parts of the plant	Remarks
Cheritra freja pseudojafra Moore, [1881]	*Entada zeylanica* Kosterm.	En	Fabaceae / il	
	Meliosma simplicifolia subsp. *simplicifolia* (Roxb.) Walp.	In	Sabiaceae / il	
Spindasis lohita lazularia (Moore, 1881)	*Albizia lebbeck* (L.) Benth.	In	Fabaceae / l	
	Senna auriculata (L.) Roxb.	In		PC: NC
Pratapa deva deva (Moore, [1858])	*Dendrophthoe falcata* (L.f.) Ethingsh.	In	Loranthaceae / il	
	Dendrophthoe neelgherrensis (Wight & Arn.) Tiegh.	In		
	Scurrula parasitica L.	In		
	Taxillus incanus (Trimen) Wiens	En		
Hypolycaena nilgirica Moore, [1884]	*Thrixspermum pulchellum* (Thwaites) Schltr.	In	Orchidaceae / fl	PC: GR
Bindahara phocides moorei Fruhstorfer, 1904	*Euonymus walkeri* Wight	En	Celastraceae / fr	
Rapala manea schistacea (Moore, 1879)	*Allophylus cobbe* (L.) Forsyth f.	In	Sapindaceae / fl	
Anthene lycaenina lycaenina (R. Felder, 1868)	*Senegalia caesia* (L.) Maslin, Seigler & Ebinger	In	Fabaceae / fl, flb	
Nacaduba hermus sidoma Fruhstorfer, 1916	*Connarus monocarpus* L.	In	Connaraceae / il	
Nacaduba berenice ormistoni Toxopeus, 1927	*Celtis philippensis* Blanco	In	Cannabaceae / fl, flb	
Prosotas nora ardates (Moore, [1875])	*Archidendron clypearia* subsp. *subcoriaceum* (Thwaites) I.C.Nielsen	In	Fabaceae / fl, flb	
	Dalbergia rostrata Hassk.	In		
Prosotas dubiosa indica (Evans, [1925])	*Senegalia caesia* (L.) Maslin, Seigler & Ebinger	In	Fabaceae / fl, flb	
	Dalbergia rostrata Hassk.	In		
	Mimosa diplotricha C.Wright	Ex		PC: KW
	Mimosa pudica L.	Ex		PC: CU
Jamides bochus bochus (Stoll, [1782])	*Centrosema plumieri* (Turpin ex Pers.) Benth.	Ex	Fabaceae / fl, flb	
	Senna occidentalis (L.) Link	Ex		
Jamides alecto meilichius (Fruhstorfer, 1916)	*Meistera benthamiana* (Trim.) Skornick. & M.F.Newman	En	Zingiberaceae / fl, se	
	Zingiber officinale Roscoe	Ex		PC: KW
Jamides celeno tissama (Fruhstorfer, 1916)	*Centrosema plumieri* (Turpin ex Pers.) Benth.	Ex	Fabaceae / fl, flb	
	Entada zeylanica Kosterm.	En	Fabaceae / il	
Catochrysops strabo strabo (Fabricius, 1793)	*Cajanus cajan* (L.) Huth	Ex	Fabaceae / flb	
	Flemingia lineata (L.) Roxb. ex W.T.Aiton	In		
Lampides boeticus (Linnaeus, 1767)	*Crotalaria albida* B.Heyne ex Roth	In	Fabaceae / fl, flb	
	Crotalaria beddomeana Thoth. & A.A.Ansari	Ex		
Leptotes plinius plinius (Fabricius, 1793)	*Ormocarpum sennoides* subsp. *hispidum* (Willd.) Brenan & Leonard.	In	Fabaceae / flb	
Zizeeria karsandra (Moore, 1865)	*Amaranthus blitum* L.	Ex	Amaranthaceae / il	
Zizina otis indica (Murray, 1874)	*Alysicarpus scariosus* (Rottler ex Spreng.) Graham	In	Fabaceae / flb	
	Aphyllodium biarticulatum (L.) Gagnep.	In		
Zizula hylax hylax (Fabricius, 1775)	*Hygrophila heinei* Sreem	In	Acanthaceae / flb	
	Phaulopsis dorsiflora (Retz.) Santapau	In	Acanthaceae / flb, br	
Everes lacturnus lacturnus (Godart, 1824)	*Grona heterophylla* (Willd.) H.Ohashi & K.Ohashi	In	Fabaceae / se	PC: CU
Azanus ubaldus (Stoll, [1782])	*Albizia amara* (Roxb.) Boivin	In	Fabaceae / flb	
Megisba malaya thwaitesi Moore, 1881	*Mallotus rhamnifolius* (Willd.) Müll.Arg.	In	Euphorbiaceae / flb	
Abisara echerius prunosa Moore, 1879	*Ardisia gardneri* C.B.Clarke	En	Primulaceae / il	
Choaspes benjaminii benjaminii (Guérin-Méneville, 1843)	*Meliosma simplicifolia* subsp. *simplicifolia* (Roxb.) Walp.	In	Sabiaceae / l	

Butterfly species	Plant species	DS	Plant Family / consumed parts of the plant	Remarks
Celaenorrhinus spilothyrus (R. Felder, 1868)	*Barleria arnottiana* Nees	In	Acanthaceae / l	
	Barleria involucrata Nees	In		
	Strobilanthes adenophora Nees	En		
	Strobilanthes viscosa var. *viscosa* (Arn. ex Nees) T.Anderson	En		
Sarangesa dasahara albicilia Moore, [1881]	*Lepidagathis ceylanica* Nees	En	Acanthaceae / l	
Coladenia tissa Moore, [1881]	*Pityranthe verrucosa* Thwaites	En	Malvaceae / l	
	Grewia carpinifolia Juss.	In		
	Helicteres isora L.	In		
Tagiades japetus obscurus Mabille, 1876	*Dioscorea trimenii* Prain & Bukill	En	Dioscoreaceae / l	
Suastus gremius subgrisea (Moore, 1878)	*Rhapis excelsa* (Thunb.) A.Henry	Ex	Arecaceae / l	
Suastus minuta minuta (Moore, 1877)	*Calamus digitatus* Becc.	En	Arecaceae / l	
	Calamus metzianus Schltdl.	In		
	Calamus thwaitesii Becc.	In		
Notocrypta curvifascia curvifascia (C. & R. Felder, 1862)	*Hellenia speciosa* (J.Koenig) S.R.Dutta	In	Costaceae / l	
	Meistera trichostachya (Alston) Skornick. & M.F.Newman	En	Zingiberaceae / l	
	Zingiber officinale Roscoe	Ex		PC: KW
Matapa aria (Moore, [1866])	*Schizostachyum brachycladum* (Kurz ex Munro) Kurz	Ex	Poaceae / l	
Oriens goloides (Moore, [1881])	*Cyrtococcum trigonum* (Retz.) A.Camus	In	Poaceae / l	PC: KW
	Ischaemum timorense Kunth	In		
Potanthus pseudomaesa pseudomaesa (Moore, [1881])	*Arundo donax* L.	Ex	Poaceae / l	
Telicota bambusae lanka Evans, 1932	*Schizostachyum brachycladum* (Kurz ex Munro) Kurz	Ex	Poaceae / l	
Borbo cinnara Wallace, 1866	*Arundo donax* L.	Ex	Poaceae / l	
Pelopidas agna agna (Moore, [1866])	*Arundo donax* L.	Ex	Poaceae / l	
Pelopidas conjuncta narooa Moore, 1878	*Ischaemum timorense* Kunth	In	Poaceae / l	
Baoris penicillata Moore, [1881]	*Bambusa vulgaris* Schrad. ex J.C.Wendl.	Ex	Poaceae / l	
	Dendrocalamus giganteus Munro	Ex		
Caltoris philippina seriata (Moore, 1878)	*Bambusa tuldoides* Munro	Ex	Poaceae / l	
	Schizostachyum brachycladum (Kurz ex Munro) Kurz	Ex		

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COMMUNICATION

An insight into the butterfly (Lepidoptera) diversity of an urban landscape: Guwahati, Assam, India

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Abstract: The paper deals with the butterfly diversity of Guwahati, Assam, India which was the result of a survey conducted from April 2016 to July 2020. During the study period we recorded 249 species of butterflies belonging to six families namely Papilionidae (24 species), Pieridae (23 species), Lycaenidae (57 species), Riodinidae (two species), Nymphalidae (97 species), and Hesperiidae (46 species). Twenty-eight species were recorded from commercial areas, 74 species from residential areas, and 248 species from forested areas. Nineteen species were found to be very common, 39 species common, 50 species fairly common, 53 species uncommon, 57 species rare, and 31 species very rare. Twenty-four species and nine subspecies including *Discophora sondiaca*, *Athyma selenophora*, and *Athyma kanwa phorkys* are legally protected under different schedules as per the Indian Wildlife Protection Act (1972).

Keywords: Hesperiidae, Lycaenidae, Nymphalidae, Papilionidae, Pieridae, Riodinidae.

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Author contribution: SCB conducted the field survey. JP was responsible for the study design and production of the manuscript.

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INTRODUCTION

Guwahati (26.1859°N & 91.7477°E) is the capital city of the state of Assam having a population of around 9.6 lacs with a population density of 4,370 per sq.km with a total area of 216.79km^2. Guwahati is the largest metropolis of northeastern India and is also the business capital of the region. The city is ecologically very important as it enjoys being a part of the Indo-Burma global biodiversity hotspot. It has a tropical monsoon climate and receives approximately 1,600mm of rainfall annually, with an average annual temperature of 23°C. Due to rapid urbanisation, there is a continuous loss of forest cover with a loss of 160.34ha/year between 2010 and 2015 (Yadav & Barua 2016) (Figure 1). Most of the forest patches are of moist deciduous type (Purkayastha 2012, 2015). The pattern of habitat mostly present in and around the city includes forest patches, scrublands, grasslands, secondary plantations, wetlands, agricultural lands, and human habitations. The city is surrounded by eighteen hill ranges including eight reserve forests (South Kalapahar RF, Fatasil RF, Jalukbari RF, Gotanagar RF, Hengrabari RF, Sarnai Hill RF, Garbhanga RF, Rani RF) and two wildlife sanctuaries (Deeporbeel WS and Amchang WS). The Deeporbeel WS is also an internationally acclaimed wetland and has been declared as a RAMSAR site in 2002. The mighty Brahmaputra River flows through the heart of the city for about 25km eventually dividing it into northern and southern areas (Devi & Bhattacharyya 2015). Apart from butterflies, 26 species of amphibians, 57 species of reptiles, 214 species of birds, and 36 species of mammals have been recorded from the city (Purkayastha 2018).

Some of the recent work on butterflies of Assam were based on protected areas (Karthikeyan & Venkatesh 2011; Gogoi 2013a,b, 2015; Neog 2015; Singh 2015, 2017; Singh et al. 2015). In this paper we want to extend the available knowledge on the butterflies of the region by presenting, for the first time, a publication on the checklist of butterfly diversity of the urban landscape of Guwahati city of Assam, India.

MATERIALS AND METHODS

Extensive field surveys were carried out throughout all the seasons from April 2016 to July 2019 in different landscapes in and around Guwahati (Figure 1). The field study was conducted mostly during early mornings from 06.30h till 12.00h and occasionally during late afternoons till dusk from 16.30h till 17.30h. Thus, a total of five man hours was invested per survey during the study period which also includes investigating the residential localities. Pollard walk methodology (Pollard 1982) was done to spot the butterflies by walking on the trails as much as possible (3–10 trails) in the forested regions, the focus was mostly confined to the tracks/trails surrounded by flowering plants, bushes, plantations and trees present in and around the loose soils, mud, rocks and stones very close to streams such that the butterflies could be observed feeding on nectar, basking and mud-puddling respectively. The specimens were observed, photographed and identified using field literature (Evans 1932; Wynter-Blyth 1957; Kehimkar 2008; Kunte et al. 2020). Depending upon the abundance of the individuals spotted throughout the survey, the species were categorised as Very Common: 25 or more individuals recorded, Common: 15–25 individuals recorded, Fairly Common: 11–15 individuals recorded, Uncommon: 6–10 individuals recorded, Rare: 3–5 individuals recorded, Very Rare: less than three individuals recorded (Table no. 1). The following localities were selected for surveying purposes:

Commercial Areas (CA): Panbazar (26.1859°N & 91.7477°E), Fancy Bazar (26.1830°N & 91.7429°E), and Christian Basti (26.1552°N & 91.78°E).

Residential Areas (RA): Lachitnagar (26.1695°N & 91.7563°E), Lokhra (26.1106°N & 91.7465°E), Kala Pahar (26.1519°N & 91.7465°E), Bhangagarh (26.1620°N & 91.7672°E), Maligaon (26.1556°N & 91.6906°E), Hatigaon (26.1278°N & 91.7855°E), Kamakhya (26.1642°N & 91.7076°E), Rehabari (26.1733°N & 91.7471°E), Barshapara (26.1417°N & 91.7380°E), and Silpukhuri (26.1835°N & 91.7605°E).

Forested Areas (FA): Amchang Wildlife Sanctuary (26.1891°N & 91.8464°E), Hengrabari Reserve Forest (26.1618°N & 91.7843°E), Geetanagar (26.1750°N & 91.7952°E), Jalukbari Reserve Forest (26.1441°N & 91.6614°E), Deeporbeel Wildlife Sanctuary (26.13055N & 91.6591E), Rani-Garbhanga Reserve Forest (26.0419°N & 91.7056°E), Narakasur Hills (26.1499°N & 91.7643°E), Birubari Hills (26.1527°N & 91.7619°E), Khanapara Reserve Forest (26.1253°N & 91.8389°E), and Sarania Reserve Forest (26.1769°N & 91.7599°E). The classification of the commercial and residential areas was done as per Guwahati Municipal Corporation (GMC) regulations and forest reserves are considered under forest areas.

Figure 1. Different zonation within Guwahati City, Assam, India

RESULTS AND DISCUSSION

During the survey period, a total of 249 species of butterflies were recorded from in and around the city belonging to six different families namely Papilionidae, Pieridae, Lycaenidae, Nymphalidae, Riodinidae, and Hesperiidae (Table 1, Image 1–100).

Account of each family from the study site

Papilionidae: A total of 24 species in this family were recorded. Among these, only one species namely the *Papilio castor* has legal protection and had been listed as Schedule I of the Indian Wildlife Protection Act, 1972 (IWPA) and the rest were non-scheduled species. *Papilio polytes* was found to be 'Very Common' as it was the most encountered species in a variety of habitats (commercial residential and forested areas. *Lamproptera curius* and *Graphium agetes* were found to be 'Very rare' as they were spotted only twice in and around the forested regions (Amchang WS and Rani Reserve Forest) throughout the field study.

Pieridae: A total of 23 species in this family were documented during the survey and the subspecies *Appias albina darada* (Table 1) is legally protected as Schedule I under IWPA. Most of the species of this family were observed in and around forests and residential localities (Table 1).

Lycaenidae: For this family, 57 species have been recorded from which seven species (*Anthene lycaenina*, *Bindahara phocides*, *Horaga onyx*, *Lampides boeticus*, *Poritia hewitsoni*, *Spindasis lohita*, *Suasa lisides*) and four subspecies (*Euchrysops cnejus cnejus*, *Prosotas aluta coelestis*, *Arhopala fulla ignara*, and *Jamides pura pura*) (Table 1) are protected under Schedule II of the IWPA (Table 1) while the others are non-scheduled. Most of the species of this family were recorded from in and around the forest patches. During the study period, a mating pair of the Pea blue *Lampides boeticus* was observed late in the afternoon during April 2018 at Nilachal Hills.

Riodinidae: Only two members of this family have been recorded in the study area, namely *Zemeros flegyas* which was the most encountered species of this family, *Abisara echerius* was recorded only once during the survey from the Garbhanga-Rani reserve forest. (Table 1).

Nymphalidae: Nymphalidae comprises the most diverse group of butterflies representing 97 species recorded in and around the city, some of which are legally protected under IWPA, 1972 which includes one species listed in Schedule I, 11 species listed in Schedule II, two species listed in Schedule IV (Table 1), subspecies *Euripus nyctelius nycteliu*, *Euploea midamus rogenhoferi*, and *Athyma kanwa phorkys* (Table 1) are listed in Schedule II of the IWPA while the others are non-scheduled. Some of the members of this family

Table 1. Checklist of butterflies of Guwahati, Assam, India.

	Scientific name	Common name	Local status	CA	RA	FA	IWPA
	Family: Papilionidae						
1	*Atrophaneura varuna* White, 1842	Common Batwing	Uncommon		+	+	
2	*Byasa polyeuctes* Doubleday, 1842	Common Windmill	Uncommon			+	
3	*Graphium agamemnon* Linnaeus, 1758	Tailed Jay	Common	+	+	+	
4	*Graphium agetes* Westwood, 1843	Four-bar Swordtail	Very rare			+	
5	*Graphium antiphates* Cramer, 1775	Five-bar Swordtail	Rare			+	
6	*Graphium cloanthus* Westwood, 1841	Glassy Bluebottle	Uncommon			+	
7	*Graphium doson* C. & R. Felder, 1864	Common Jay	Common	+	+	+	
8	*Graphium macareus* Godart, 1819	Lesser Zebra	Rare			+	
9	*Graphium sarpedon* Linnaeus, 1758	Common Bluebottle	Common	+	+	+	
10	*Lamproptera curius* Fabricius, 1787	White Dragontail	Very rare			+	
11	*Pachliopta aristolochiae* Fabricius, 1775	Common Rose	Fairly common			+	
12	*Papilio castor* Westwood, 1842	Common Raven	Uncommon			+	
13	*Papilio clytia* Linnaeus, 1758	Common Mime	Fairly common		+	+	Schedule I
14	*Papilio eurypylus* Linnaeus, 1758	Great Jay	Rare			+	
15	*Papilio demoleus* Linnaeus, 1758	Lime Butterfly	Common	+	+	+	
16	*Papilio helenus* Linnaeus, 1758	Red Helen	Common			+	
17	*Papilio memnon* Linnaeus, 1758	Great Mormon	Fairly common		+	+	
18	*Papilio nephelus* Boisduval, 1836	Yellow Helen	Fairly common			+	
19	*Papilio paris* Linnaeus, 1758	Paris Peacock	Rare			+	
20	*Papilio polytes* Linnaeus, 1758	Common Mormon	Very common	+	+	+	
21	*Papilio protenor* Cramer, 1775	Spangle	Rare			+	
22	*Troides aeacus* C.& R. Felder, 1860	Golden Birdwing	Fairly common			+	
23	*Troides helena* Linnaeus, 1758	Common Birdwing	Rare			+	
24	*Byasa dasarada* Moore, 1858	Great Windmill	Very Rare			+	
	Family: Pieridae						
25	*Appias albina* Boisduval, 1836	Common Albatross	Fairly common			+	Schedule II
26	*Appias indra* Moore, 1858	Plain Puffin	Rare			+	
27	*Appias lalage* Doubleday, 1842	Spot Puffin	Rare			+	
28	*Appias lyncida* Cramer, 1777	Chocolate Albatross	Uncommon			+	
29	*Appias olferna* Swinhoe, 1890	Striped Albatross	Fairly common		+	+	
30	*Catopsilia pomona* Fabricius, 1775	Common Emigrant	Common	+	+	+	
31	*Catopsilia pyranthe* (Linnaeus, 1758)	Mottled Emigrant	Fairly common			+	
32	*Cepora nadina* Lucas, 1852	Lesser Gull	Uncommon			+	
33	*Cepora nerissa* Fabricius, 1775	Common Gull	Uncommon			+	
34	*Delias descombesi* Boisduval, 1836	Red spot Jezebel	Fairly common	+	+	+	
35	*Delias pasithoe* Linnaeus, 1767	Red base Jezebel	Uncommon	+	+	+	
36	*Dercas verhuelli* Hoeven, 1839	Tailed Sulpher	Rare			+	
37	*Eurema andersonii* Moore, 1886	One-spot Grass Yellow	Fairly common		+	+	
38	*Eurema blanda* Boisduval, 1836	Three-spot Grass Yellow	Common	+	+	+	
39	*Eurema brigitta* Stoll, 1780	Small Grass Yellow	Common		+	+	
40	*Eurema hecabe* Linnaeus, 1758	Common Grass Yellow	Common	+	+	+	
41	*Gandaca harina* Horsfield, 1829	Tree Yellow	Uncommon			+	
42	*Hebomoia glaucippe* Linnaeus, 1758	Great Orange Tip	Rare			+	

	Scientific name	Common name	Local status	CA	RA	FA	IWPA
43	*Ixias pyrene* Linnaeus, 1764	Yellow Orange Tip	Rare		+	+	
44	*Leptosia nina* Fabricius, 1793	Psyche	Very common	+	+	+	
45	*Pareronia hippia* Fabricius, 1787	Common Wanderer	Fairly common			+	
46	*Pieris brassicae* Linnaeus, 1758	Large Cabbage White	Uncommon			+	
47	*Pieris canidia* Linnaeus, 1768	Indian Cabbage White	Very common	+	+	+	
	Family: Lycaenidae						
48	*Acetolepis puspa* Horsfield, 1828	Common Hedge Blue	Common	+	+	+	
49	*Anthene emolus* Godart, 1824	Common Ciliate Blue	Common			+	
50	*Anthene lycaenina* Felder, 1868	Pointed Ciliate Blue	Uncommon			+	Schedule II
51	*Arhopala atrax* Hewitson, 1862	Indian Oakblue	Rare			+	
52	*Arhopala camdeo* Moore, 1858	Lilac Oakblue	Uncommon			+	
53	*Arhopala centaurus* Fabricius, 1775	Centaur Oakblue	Rare			+	
54	*Arhopala eumolphus* Cramer, 1780	Green Oakblue	Very rare			+	
55	*Arhopala fulla* Hewitson, 1862	Spotless Oakblue	Rare			+	Schedule II
56	*Arhopala perimuta* Moore, 1858	Yellowdisc Tailless Oakblue	Very rare			+	
57	*Bindahara phocides* Fabricius, 1793	Plane	Rare			+	Schedule II
58	*Caleta decidia* Hewitson, 1876	Angled Pierrot	Uncommon			+	
59	*Caleta elna* Hewitson, 1876	Elbowed Pierrot	Rare			+	
60	*Castalius rosimon* Fabricius, 1775	Common Pierrot	Very common	+	+	+	
61	*Catapaecilma major* Druce, 1895	Common Tinsel	Rare			+	
62	*Catochrysops panormus* C. Felder, 1860	Silver Forget-me-not	Uncommon			+	
63	*Catochrysops strabo* Fabricius, 1793	Forget -me –not	Fairly common			+	
64	*Cheritra freja* Fabricius, 1793	Common Imperial	Uncommon			+	
65	*Chilades lajus* Stoll, 1780	Lime Blue	Common	+	+	+	
66	*Chilades pandava* Horsfield, 1829	Plains Cupid	Fairly common		+	+	
67	*Creon cleobis* Godart, 1824	Broad Tail Royal	Very rare			+	
68	*Curetis acuta* Moore, 1877	Angled Sunbeam	Uncommon			+	
69	*Curetis saronis* Moore, 1877	Saronis Sunbeam	Rare			+	
70	*Deudorix epijarbas* Moore, 1858	Cornelian	Very rare			+	
71	*Discolampa ethion* Westwood, 1851	Banded Blue Pierrot	Rare			+	
72	*Euchrysops cnejus* Fabricius, 1798	Gram Blue	Fairly common		+	+	Schedule II
73	*Heliophorus epicles* Godart, 1824	Purple Sapphire	Fairly common		+	+	
74	*Horaga onyx* Moore, 1857	Common Onyx	Uncommon			+	Schedule II
75	*Hypolycaena erylus* Godart, 1824	Common Tit	Common			+	
76	*Iraota timoleon* Stoll, 1790	Silver Streak Blue	Rare			+	
77	*Jamides alecto* C.Felder, 1860	Metallic Cerulean	Common			+	
78	*Jamides bochus* Stoll, 1782	Dark Cerulean	Common			+	
79	*Jamides celeno* Cramer, 1775	Common Cerulean	Common		+	+	
80	*Jamides elpis* Godart, 1824	Glistening Cerulean	Common			+	
81	*Jamides pura* Moore, 1886	White Cerulean	Rare			+	Schedule II
82	*Lampides boeticus* Linnaeus, 1767	Peablue	Common	+	+	+	Schedule II
83	*Loxura atymnus* Stoll, 1780	Yamfly	Uncommon			+	
84	*Megisba malaya* Horsfield, 1828	Malayan	Fairly common			+	
85	*Miletus chinensis* C. Felder, 1862	Common Mottle	Uncommon			+	
86	*Neopithecops zalmora* Butler, 1870	Common Quaker	Common			+	

	Scientific name	Common name	Local status	CA	RA	FA	IWPA
87	*Poritia hewitsoni* Moore, 1866	Common Gem	Rare			+	Schedule II
88	*Prosotas aluta* Druce, 1873	Banded Lineblue	Very rare			+	Schedule II
89	Prosotas dubiosa (Semper, [1879])	Tailless Lineblue	Fairly common			+	
90	Prosotas nora (C. Felder, 1860)	Common Lineblue	Fairly common			+	
91	*Pseudozizeeria maha* Kollar, 1844	Pale Grass Blue	Very common	+	+	+	
92	*Rapala iarbas* Fabricius, 1787	Common Red Flash	Uncommon			+	
93	*Rapala manea* Hewitson, 1863	State Flash	Uncommon			+	
94	*Rapala pheretima* Hewitson, 1863	Copper Flash	Fairly common			+	
95	Remelana jangala (Horsfield, [1829])	Chocolate Royal	Uncommon			+	
96	*Spalgis epius* Westwood, 1851	Apefly	Fairly common		+	+	
97	*Spindasis lohita* Horsfield, 1829	Long Banded Silverline	Rare			+	Schedule II
98	*Suasa lisides* Hewitson, 1863	Red Imperial	Very rare			+	Schedule II
99	*Surendra quercetorum* Moore, 1858	Common Acacia Blue	Fairly common		+	+	
100	*Leptotes plinius* Fabricius, 1793	Zebra Blue	Common	+	+	+	
101	*Taraka hamada* Druce, 1875	Forest Pierrot	Rare			+	
102	*Virachola isocrates* Fabricius, 1793	Common Guava Blue	Fairly common			+	
103	*Zeltus amasa* Hewitson, 1865	Fluffy Tit	Fairly common			+	
104	*Zizeeria karsandra* Moore, 1865	Dark Grass Blue	Common	+	+	+	
	Family: Riodinidae						
105	*Abisara echerius* Stoll, 1790	Plum Judy	Uncommon			+	
106	*Zemeros flegyas* Cramer, 1780	Punchinello	Very common		+	+	
	Family: Nymphalidae						
107	*Acraea issoria* Hübner, 1818	Yellow Coster	Uncommon		+	+	
108	*Acraea terpsicore* Linnaeus, 1758	Tawny Coster	Fairly common		+	+	
109	*Ariadne ariadne* Linnaeus, 1763	Angled Castor	Common			+	
110	*Ariadne merione* Cramer, 1777	Common Castor	Fairly common		+	+	
111	*Athyma inara* Westwood, 1850	Colour Sergeant	Fairly common		+	+	
112	*Athyma kanwa* Moore, 1858	Dot Dash Sergeant	Very rare			+	Schedule II
113	*Athyma perius* Linnaeus, 1758	Common Sergeant	Common		+	+	
114	*Athyma ranga* Moore, 1857	Blackvein Sergeant	Rare			+	Schedule II
115	*Athyma selenophora* Kollar, 1844	Staff Sergeant	Rare			+	
116	*Auzakia danava* Moore, 1857	Commodore	Rare			+	Schedule II
117	*Cethosia biblis* Drury, 1770	Red Lacewing	Uncommon			+	
118	*Cethosia cyane* Drury, 1770	Leopard Lacewing	Uncommon			+	
119	*Charaxes arja* Felder & Felder, 1866	Pallid Nawab	Very rare			+	
120	*Charaxes bernardes* Fabricius, 1793	Tawny Rajah	Uncommon			+	
121	*Charaxes bharata* Felder & Felder, 1867	Common Nawab	Common		+	+	
122	*Charaxes dolon* Westwood, 1848	Stately Nawab	Very rare			+	Schedule II
123	*Charaxes kahruba* Moore, 1895	Variegated Rajah	Rare			+	Schedule II
124	*Charaxes marmax* Westwood, 1847	Yellow Rajah	Uncommon			+	Schedule II
125	*Charaxes solon* Fabricius, 1793	Black Rajah	Uncommon			+	
126	*Chersonesia rahrioides* Martin, 1895	Indian Red Maplet	Uncommon			+	Schedule II
127	*Chersonesia risa* Doubleday, 1848	Common Maplet	Fairly common			+	
128	*Cirrochroa aoris* Doubleday, 1847	Large Yeoman	Fairly common			+	
129	*Cirrochroa tyche* Felder & Felder, 1861	Common Yeoman	Uncommon			+	

	Scientific name	Common name	Local status	CA	RA	FA	IWPA
130	*Cupha erymanthis* Drury, 1773	Rustic	Rare			+	
131	*Cyrestis thyodamas* Doyère, 1840	Common Map	Rare		+	+	
132	*Danaus chrysippus* Linnaeus, 1758	Plain Tiger	Very common	+	+	+	
133	*Danaus genutia* Cramer 1779	Common Tiger	Common	+	+	+	
134	*Dichorragia nesimachus* Doyère, 1840	Constable	Very rare			+	
135	*Discophora sondiaca* Boisduval, 1836	Common Duffer	Fairly common		+	+	Schedule I
136	*Doleschallia bisaltide* Cramer, 1777	Autumn Leaf	Very rare			+	
137	*Elymnias hypermnestra* Linnaeus, 1763	Common Palmfly	Very common	+	+	+	
138	*Elymnias malelas* Hewitson, 1863	Spotted Palmfly	Rare			+	
139	*Elymnias patna* Westwood, 1851	Blue striped Palmfly	Rare			+	
140	*Ethope himachala* Moore, 1857	Dusky Diadem	Rare			+	
141	*Euploea algea* Godart, 1819	Long Branded Blue Crow	Uncommon			+	
142	*Euploea core* Cramer, 1780	Common Crow	Very common		+	+	
143	*Euploea midamus* Linnaeus, 1758	Blue Spotted Crow	Uncommon			+	Schedule II
144	*Euploea mulciber* Cramer, 1777	Striped Blue Crow	Uncommon			+	Schedule IV
145	*Euploea sylvester* Fabricius, 1793	Double Branded Crow	Uncommon			+	
146	*Euripus nyctelius* Doubleday, 1845	Courtesan	Very rare			+	Schedule II
147	*Euthalia aconthea* Cramer, 1777	Common Baron	Common	+	+	+	
148	*Euthalia anosia* Moore, 1858	Grey Baron	Rare			+	Schedule II
149	*Euthalia lubentina* Cramer, 1777	Gaudy Baron	Rare			+	Schedule IV
150	*Euthalia monina* Fabricius, 1787	Powdered Baron	Rare			+	
151	*Euthalia phemius* Doubleday, 1848	White-edged Blue Baron	Very rare			+	
152	*Faunis canens* Hübner, 1826	Common Faun	Uncommon			+	
153	*Herona marathus* Doubleday, 1848	Pasha	Very rare			+	
154	*Hypolimnas bolina* Linnaeus, 1758	Great Eggfly	Fairly common			+	
155	*Junonia almana* Linnaeus, 1758	Peacock Pansy	Very common	+	+	+	
156	*Junonia atlites* Linnaeus, 1763	Grey Pansy	Common	+	+	+	
157	*Junonia hierta* Fabricius, 1798	Yellow Pansy	Fairly common		+	+	
158	*Junonia iphita* Cramer, 1779	Chocolate Pansy	Very common		+	+	
159	*Junonia lemonias* Linnaeus, 1758	Lemon Pansy	Very common		+	+	
160	*Junonia orithya* Linnaeus, 1758	Blue Pansy	Fairly common			+	
161	*Kallima inachus* Doyere, 1840	Orange Oakleaf	Very rare			+	
162	*Kaniska canace* (Linnaeus, 1763)	Blue Admiral	Uncommon			+	
163	*Lebadea martha* Fabricius, 1787	Knight	Common			+	
164	*Lethe chandica* Moore, 1857	Angled Red Forester	Fairly common			+	
165	*Lethe confusa* Aurivillius, 1898	Banded Treebrown	Fairly common			+	
166	*Lethe europa* Fabricius, 1775	Bamboo Treebrown	Common		+	+	
167	*Lethe mekara* Moore, 1857	Common Red Forester	Fairly common			+	
168	*Lethe rhoria* Fabricius, 1787	Common Treebrown	Common		+	+	
169	*Lexias dirtea* Fabricius, 1793	Dark Archduke	Very rare			+	Schedule II
170	*Melanitis leda* Linnaeus, 1758	Common Evening Brown	Very common	+	+	+	
171	*Melanitis phedima* Cramer, 1780	Dark Evening Brown	Uncommon			+	
172	*Melanitis zitenius* Herbst, 1796	Great Evening Brown	Very Rare			+	
173	*Mimathyma ambica* Kollar, 1844	Purple Emperor	Rare			+	
174	*Moduza procris* Cramer, 1777	Commander	Uncommon			+	

	Scientific name	Common name	Local status	CA	RA	FA	IWPA
175	*Mycalesis anaxias* Hewitson, 1862	White-bar Bushbrown	Rare			+	Schedule II
176	*Mycalesis mineus* Linnaeus, 1758	Dark Brand Bushbrown	Fairly common		+	+	
177	*Mycalesis perseus* Fabricius, 1775	Common Bushbrown	Very common		+	+	
178	*Mycalesis visala* Moore, 1857	Long Brand Bushbrown	Uncommon			+	
179	*Neptis clinia* Moore, 1872	Sullied Sailor	Fairly common			+	
180	*Neptis hylas* Linnaeus, 1758	Common Sailor	Very common	+	+	+	
181	*Neptis nata* Moore, 1857	Clear Sailor	Uncommon			+	
182	*Neptis pseudovikasi* Moore, 1899	False Dingy Sailor	Rare			+	
183	*Orsotrioena medus* Fabricius, 1775	Nigger	Common			+	
184	*Pantoporia hordonia* Stoll, 1790	Common Lascar	Common	+	+	+	
185	*Parantica aglea* Stoll, 1782	Glassy Tiger	Fairly common			+	
186	*Parantica sita* Kollar, 1844	Chestnut Tiger	Rare			+	
187	*Parthenos sylvia* Cramer, 1775	Clipper	Rare			+	Schedule II
188	*Phalanta alcippe* Stoll, 1782	Small Leopard	Fairly common			+	Schedule II
189	*Phalanta phalantha Drury, 1773*	Common Leopard	Fairly common			+	
190	*Pseudergolis wedah* Kollar, 1844	Tabby	Uncommon			+	
191	*Rohana parisatis* Westwood, 1851	Black Prince	Very rare			+	
192	*Stibochiona nicea* (Gray, 1846)	Popinjay	Rare			+	
193	*Stichophthalma camadeva* Westwood, 1848	Northern Jungle Queen	Rare			+	
194	*Symbrenthia hypselis* Godart, 1823	Spotted Jester	Rare			+	
195	*Symbrenthia lilaea Hewitson, 1864*	Common jester	Fairly common		+	+	
196	*Tanaecia julii* Lesson, 1837	Common Earl	Uncommon			+	
197	*Tanaecia lepidea* Butler, 1868	Grey Count	Very common		+	+	Schedule II
198	*Thaumantis diores* Doubleday, 1845	Jungle Glory	Rare			+	
199	*Vagrans egista* Cramer, 1780	Vagrant	Uncommon			+	
200	*Vanessa cardui* Linnaeus, 1758	Painted Lady	Uncommon			+	
201	*Vanessa indica* Herbst, 1794	Indian Red Admiral	Rare		+	+	
202	*Ypthima baldus* Fabricius, 1775	Common Fivering	Very common			+	
203	*Ypthima hubenri* Kirby, 1871	Common Fourring	Very common			+	
	Family: Hesperiidae						
204	*Ancistroides nigrita* Latreille, 1824	Chocolate Demon	Common			+	
205	*Arnetta atkinsoni* Moore, 1878	Atkinson's Bob	Rare			+	
206	*Astictopterus jama* Felder & Felder, 1860	Forest Hopper	Fairly common		+	+	
207	*Baoris chapmani* Evans, 1937	Small Paint-brush Swift	Common			+	
208	*Baoris unicolor Moore, (1884)*	Black Paint-brush Swift	Fairly common			+	
209	*Burara amara* Moore, [1866]	Small Green Awlet	Rare			+	
210	*Burara harisa* Moore, 1865	Harisa Orange Awlet	Very rare			+	
211	*Burara oedipodea* (Swainson, 1820)	Branded Orange Awlet	Very rare			+	
212	*Celaenorrhinus leucocera* Kollar, 1844	Common Spotted Flat	Fairly common		+	+	
213	*Cephrenes acalle* (Höpffer, 1874)	Plain Palm Dart	Uncommon		+	+	
214	*Choaspes benjaminii* (Guérin-Méneville, 1843)	Indian Awlking	Very rare			+	
215	*Cupitha purreea* Moore, 1877	Wax Dart	Rare			+	
216	*Gerosis bhagava* Moore, 1866	Common Yellow-breast Flat	Rare			+	
217	*Gerosis phisara* Moore, 1884	Dusky Yellow-breasted Flat	Very Rare			+	

	Scientific name	Common name	Local status	CA	RA	FA	IWPA
218	*Gerosis sinica* C. & R. Felder, 1862	White Yellow-breasted Flat	Very Rare			+	
219	*Halpe homolea aucma* Swinhoe, 1893	Gold-spotted Ace	Rare			+	
220	*Halpe porus* Mabille, 1877	Moore's Ace	Uncommon			+	
221	*Halpe zema* (Hewitson, 1877)	Banded ace	Rare			+	
222	*Hasora chromus* (Cramer, [1780])	Common Banded Awl	Very rare		+		
223	*Hyarotis adrastus* Stoll,1780	Tree Flitter	Rare			+	Schedule IV
224	*Koruthaialos butleri* de Nicéville, 1883	Dark Velvet Bob	Uncommon			+	
225	*Lambrix salsala* Moore, 1866	Chestnut Bob	Common		+	+	
226	*Matapa aria* Moore, 1866	Common Redeye	Fairly common		+	+	
227	*Matapa sasivarna* Moore, 1865	Black Veined Redeye	Uncommon			+	
228	*Notocrypta curvifascia* (C. & R. Felder, 1862)	Restricted Demon	Rare			+	
229	*Notocrypta paralysos* (Wood-Mason & de Nicéville, 1881)	Common Banded Demon	Common		+	+	
230	*Ochus subvittatus* Moore, 1878	Tiger Hopper	Rare			+	
231	*Odontoptilum angulata* C. Felder, 1862	Chestnut Angle	Very rare			+	
232	*Oriens gola* Moore, 1877	Common Dartlet	Common			+	
233	*Parnara sp.*		Uncommon			+	
234	*Pelopidas assamensis* de Nicéville, 1882	Great Swift	Rare			+	Schedule IV
235	*Pelopidas mathias* (Fabricius, 1798)	Small Branded Swift	Very common		+	+	
236	*Pelopidas subochracea* (Moore, 1878)	Large Branded Swift	Uncommon		+	+	
237	*Ponthanus sp.*		Fairly common			+	
238	*Pseudocoladenia dan* Fabricius, 1787	Fulvous Pied Flat	Common			+	
239	*Sarangesa dasahara* Moore, 1866	Common Small Flat	Common		+	+	
240	*Scobura isota* Swinhoe, 1893	Khasi Hills Bob	Very rare			+	
241	*Scobura phiditia* (Hewitson, [1866])	Malay Forest Bob	Very rare			+	
242	*Spialia galba* Fabricius, 1793	Indian Skipper	Fairly common			+	
243	*Suastus gremius* (Fabricius, 1798)	Indian Palm Bob	Uncommon			+	
244	*Tagiades gana* Moore,1866	Suffused Snow Flat	Fairly common		+	+	
245	*Tagiades japetus* Stoll, 1781	Common Snow Flat	Fairly common		+	+	
246	*Tagiades litigiosa* Möschler, 1878	Water Snow Flat	Rare			+	
247	Telicota colon (Fabricius, 1775)	Pale Palm Dart	Uncommon			+	
248	*Udaspes folus* Cramer, 1775	Grass Demon	Fairly common		+	+	
249	*Zographetus satwa* de Nicéville, 1884	Purple and Gold Flitter	Very rare			+	

CA—Commercial Areas | RA—Residential Areas | FA— Forested Areas | IWPA— Indian Wildlife Protection Act.

were found to be ‘Very Rare’ and were recorded only twice within the study period which includes *Melanitis zitenius*, *Charaxes arja*, *Athyma ranga*, *Rohana parisatis*, *Athyma kanwa*, *Stibochiona nicea*, *Kallima inachus*, *Dichorragia nesimachus*, *Thaumantis diores*, *Lexias dirtea*, and *Herona marathus*.

Hesperiidae: During the study, 46 species of this family were recorded (Table 1) out of which only two of them namely *Pelopidas assamensis* and *Hyarotis adrastus* are legally protected (Schedule IV of IWPA) while the others are non-scheduled. Most of the members of this family were found in and around the forest patches including the *Scobura isota* recorded from the Hengrabari Reserve Forest. Other interesting findings include *Zographetus satwa*, *Aretta atkinsoni*, and *Burara jaina* from the Rani Reserve Forest, *Halpe aucma* and *Odontoptilum angulata* from the Amchang WS and a *Pelopidas assamesis* from Geetanagar area. From the Geetanagar area itself a mating pair of *Lambrix salsala* was also observed late in the afternoon during the month of March in 2018.

Image 1–50. Photographic collage of butterflies of Guwahati, Assam, India. Family: Papilionidae: 1—*Troides aeacus* | 2—*Graphium agamemnon* | 3—*Graphium doson* | 4—*Papilio clytia* | 5—*Papilio demoleus* | 6—*Papilio polytes* | 7—*Papilio helenus* | Family: Pieridae: 8—*Appias olferna* | 9—*Catopsilia Pomona* | 10—*Delias descombesi* | 11—*Delias pasithoe* | 12—*Eurema blanda* | 13—*Leptosia nina* | 14—*Pieris canidia* |Family: Lycaenidae: 15—*Anthene emolus* | 16. *Caleta decidia* | 17—*Castalius rosimon* | 18—*Catochrysops strabo* | 19—*Cheritra freja* | 20—*Chilades pandava* | 21—*Discolampa ethion* | 22—*Heliophorus epicles* | 23—*Hypolycaena erylus* | 24—*Iraota timoleon* | 25—*Jamides bochus* | 26—*Jamides celeno* | 27—*Lampides boeticus* | 28—*Loxura atymnus* | 29—*Neopithecops zalmora* | 30—*Prosotas dubiosa* | 31—*Prosotas nora* | 32—*Pseudozizeeria maha* | 33—*Rapala irabus* | 34—*Spindasis lohita* | 35—*Surendra quercetorum* | 36—*Leptotes plinius* | 37—*Virachola isocrates* | 38—*Zeltus amasa* | Family: Riodinidae: 39—*Zemeros flegyas* | Family: Nymphalidae: 40—*Acraea terpsicore* | 41—*Athyma inara* | 42—*Athyma ranga* | 43—*Athyma selenophora* | 44—*Cethosia cyane* | 45—*Charaxes bernardes* | 46—*Charaxes bharata* | 47—*Charaxes solon* | 48—*Chersonesia rahrioides* | 49—*Cyrestis thyodamas* | 50—*Danaus chrysippus* | © Sanath Chandra Bohra.

Image 51–100. Photographic collage of butterflies of Guwahati, Assam, India. Family: Nymphalidae: 51—*Discophora sondiaca* | 52—*Elymnias hypermnestra* | 53—*Ethope himachala* | 54—*Euploea core* | 55—*Euploea mulciber* | 56—*Euthalia aconthea* | 57—*Hypolimnas bolina* | 58—*Junonia almana* | 59—*Junonia atlites* | 60—*Junonia iphita* | 61—*Junonia lemonias,* 62—*Lebadea Martha* | 63—*Lethe mekara* | 64—*Lexias dirtea* | 65—*Melanitis leda* | 66—*Melanitis zitenius* | 67—*Moduza Procris* | 68—*Mycalesis anaxias* | 69 —*Neptis clinia* | 70—*Neptis hylas* | 71—*Neptis pseudovikasi* | 72—*Pantoporia hordonia* | 73—*Parantica aglea* | 74—*Rohana parisatis* | 75—*Stibochiona nicea* | 76—*Symbrenthia lilaea* | 77—*Tanaecia lepidea* | 78—*Vanessa indica* | Family: Hesperiidae: 79—*Arnetta atkinsoni* | 80—*Astictopterus jama* | 81—*Baoris unicolor* | 82—*Cephrenes acalle* | 83—*Halpezema* | 84—*Koruthaialos butleri* | 85—*Matapa sasivarna* | 86—*Notocrypta curvifascia* | 87—*Notocrypta paralysos* | 88—*Oriens gola* | 89—*Pelopidas assamensis* | 90—*Pelopidas mathias* | 91—*Pseudocoladenia dan* | 92—*Sarangesa dasahara* | 93—*Scobura isota* | 94—*Suastus gremius* | 95—*Tagiades gana* | 96—*Tagiades japetus* | 97—*Tagiades litigiosa* | 98—*Telicota colon* | 99—*Udaspes folus* | 100—*Zographetus satwa* | © Sanath Chandra Bohra.

Threats

The major threats perceived to the butterfly population in the study are

· Habitat alteration: Due to development activities the prime habitat and host plants of butterflies are fast vanishing and are replaced by human settlements. Due to scarcity in living space within Guwahati, small kitchen gardens are being lost at a rapid pace which once harboured a sustainable population of butterflies. Again in urban landscape most of the roads are tarred or made of concrete making it hard for butterflies to seek nutrients from the mud (mud-puddling).

· Agriculture: As the city expands, it is eating into its peripheral agricultural land, which in-turn is eating into adjacent forested areas, a prime habitat for butterflies. To suffice need of ever rising population, the agricultural land are using fertilizers and pesticide more than ever before, creating a negative impact on butterfly population.

· Invasive species: Invasive species of both plant and animal are impacting butterfly population in a negative way. Plants like *Mimosa pudica* are competing with native plant species whereas introduced lizard species *Hemidactylus flaviviridis* are eating into butterfly and other insect population. Feral species of cats also hunt butterflies.

· Climate change: Urban areas are the prime generators of climate change and thus the effect of climate change are felt more in urban landscape. The ever increasing heat gradient along with urban heat island effect is presenting challenges to wide range of biodiversity including butterflies.

· Lack of public awareness: Most urban dwellers are totally unaware of the importance of butterflies in their ecosystem. An average urban dweller's mindset has been calibrated as such that only larger mammals conservation concerns holds importance to him if at all.

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PLATINUM OPEN ACCESS

COMMUNICATION

A report on the moth (Lepidoptera: Heterocera) diversity of Kavvai River basin in Kerala, India

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Abstract: In the present paper, we report the presence of 503 species of moths (343 identified to species, 160 identified to genus) that belong to 371 genera under 42 families. The study was conducted at Kavvai River basin, northern Kerala, India for three years from 2015 to 2017. Traditional light trapping method was employed to collect the moths during the night. Among the families reported, Erebidae was the most dominant family followed by Crambidae, Geometridae, Noctuidae, and Pyraliade. The study highlights the significance of the riverbasin in conserving rich diversity of invertebrates.

Keywords: Crambidae, Geometridae, Lepidoptera, light trap, moths, nocturnal, Noctuidae, Pyraliade, southern India.

രത്നച്ചുരുക്കം: വടക്കൻ കേരളത്തിലെ കവ്വായി നദീതടത്തിൽ 2015 മുതൽ 2017 വരെ നടത്തിയ നിശാശലഭ പഠനത്തിന്റെ കണ്ടെത്തലുകളാണ് ഈ പേപ്പറിൽ അവതരിപ്പിക്കുന്നത്. രാത്രിക്കാലങ്ങളിൽ പ്രകാശ കെണികളൊരുക്കി നിശാശലഭങ്ങളെ ആകർഷിച്ച് സാമ്പിൾ ശേഖരിക്കുന്ന പരമ്പരാഗത രീതിയിൽ നടത്തിയ ഈ പഠനത്തിൽ 42 നിശാശലഭ കുടുംബത്തിലും 371 ജനുസിലും പെട്ട 503 നിശാശലഭ സ്പീഷ്യസുകളെയാണ് റിപ്പോട്ട് ചെയ്യാനായത്. ഈ പ്രദേശത്തു കാണുന്ന വ്യത്യസ്ഥ ശലഭ കുടുംബങ്ങളിൽ പ്രബലമായത് എറിബിഡേ ശലഭ കുടുംബമാണ് തുടർന്ന് ക്രമപ്രകാരം ക്രാമ്പിഡേ, ജ്യോമട്രിഡേ, നൊക്ടുഡേ പൈറാലിഡേ ശലഭ കുടുംബങ്ങളും സ്പീഷ്യസ് വൈവിധ്യത്തിൽ മുന്നിലാണ്. ഈ പഠനം കവ്വായി നദീതടത്തിലെ ജൈവവൈവിധ്യം, പ്രത്യേകിച്ച് അകശേരുക്കളുടെ വൈവിധ്യം സംരക്ഷിക്കേണ്ടതിന്റെ പ്രാധാന്യത്തിലേക്ക് വിരൽ ചൂണ്ടുന്നു.

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Author contribution: CJA—field work, larval rearing, moth identification, data compilation, manuscript writing, proof reading. KCS—larval rearing, moth identification. TVS—overall guidance, manuscript editing, proof reading.

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INTRODUCTION

Kavvai (or Kavvayi) river is one among the 15 rivers which originates from the midlands of Kerala, India. It is located between 12.084^0–12.245^{0}N & 75.082^0–75.333^{0}E. The river emerges from the Cheemeni laterite hills at an elevation of 119m. The river is 31km long and directly flows into the Kavvayi backwater which is connected to the Arabian Sea. The river basin is a typical laterite biotope of northern Kerala which is a topographically complex, biodiversity-rich, fragmented, and densely populated cultural landscape spread over an area of 164.76km^2 falling under nine local administrative bodies in the districts of Kannur and Kasaragode. Even though the Kavvai River is prominent among the 15 rivers originating from the midlands of Kerala, there is no reserved or protected forest in the river basin which is composed of semi-natural landscapes such as lateritic hillocks, sacred groves, eco-groves (Kaanams), riverine vegetation and mangroves, cultural landscape such as wetland cultivation, plantations, homesteads with mixed cultivation and other agro-eco systems and a small proportion of artificial landscapes (Figure 1). In the present study, attempts have been made to document the moth diversity of different habitats in the Kavvai River basin.

MATERIAL AND METHODS

The sampling was carried out during three different seasons: pre-monsoon (February–May), monsoon (June–September), and post-monsoon (October–January) seasons at six locations (Table 1) in the Kavvai River basin —sacred groves, eco -groves (Kaanam), lateritic exposed area, wetland, and mixed-cultivation areas—from 2015–2017 (Figure 1). Sampling of moths was undertaken using a white cloth of 4 x 1.3 m, illuminated with a 20-Watt UV fluorescent tube connected to a portable UPS with a rechargeable battery of 50VA/36W (Image 329). Moths were collected 18.00–06.00 h for two consecutive nights in each season in all locations. In addition, immature stages of moths were also collected and reared in the laboratory (Image 330) to confirm the species. The moths collected were photographed and subsequently identified using the reference collection at Kerala Forest Research Institute (KFRI) and available literature including Hampson (1892–1896), Bell & Scott (1937), Zimmerman (1978), Barlow (1982), Holloway (1983–2011), Robinson et al. (1994), Kendrick (2002), Solovyev & Witt (2009), Mathew (2010), Irungbam et al. (2017), Sondhi et al. (2018), and Subhalaxmi (2018). Classification of moths at higher taxonomic levels was done based on Van Nieukerken et al. (2011), and for nomenclature aspects at species and genus levels, LEPINDEX (Beccaloni et al. 2003) was consulted.

RESULTS

In the present study, 1,060 specimens (750 adults and 310 larvae) were collected which belonged to 503 species (343 moths were identified to the species level and another 160 to the genus level) under 371 genera belonging to 42 families were recored (Appendix I, Images 1–328). All the specimens have been deposited in the Insect collection department of Kerala Forest Research Institute.

Among the moths collected, Noctuoidea (195 species of which 45 up to generic level) has the highest diversity followed by Pyraloidea (118 species; 39 up to generic level), Geometroidea (67 species; 20 up to generic level), Gelechioidea (23 species; 13 up to generic level), Bombycoidea (22 species; one up to generic level), Zygaenoidea (18 species; eight up to generic level), Tortricoidea (18 species; 10 up to generic level), Tineioidea (nine species; five up to generic level) Pterophoroidea (six species; five up to generic level), Thyridoidea (six species; five up to generic level), Lasiocampoidea (four species; two up to generic level), Yponomeutoidea (four species; two up to generic level), Drepanoidea (four species; one up to generic level), Cossoidea (three species; one up to generic level), Choreutoidea (two species; two up to generic level), Gracillarioidea (two species; one up to generic level) and Alucitoidea and Hyblaeoideaare represented by single species (Table 3; Figure 2).

Among the families, Erebidae showed the highest number of genera (92) and species (128) followed by Crambidae (66 genera, 94 spp.), Geometridae (43 genera, 60 spp.), Noctuidae (23 genera, 36 spp.), Pyralidae (23 genera, 23 spp.), Nolidae (11 genera, 18 spp.), Tortricidae (12 genera, 18 spp.), Limacodidae (13 genera, 16 spp.), and Gelechiidae (11 genera, 17 spp.).

DISCUSSION

Kavvai River basin is a typical lateritic biotope which holds various ecological units such as lateritic vegetation, sacred groves, eco groves, riverine vegetation, mangroves, wetlands, and agro-ecosystems. Each

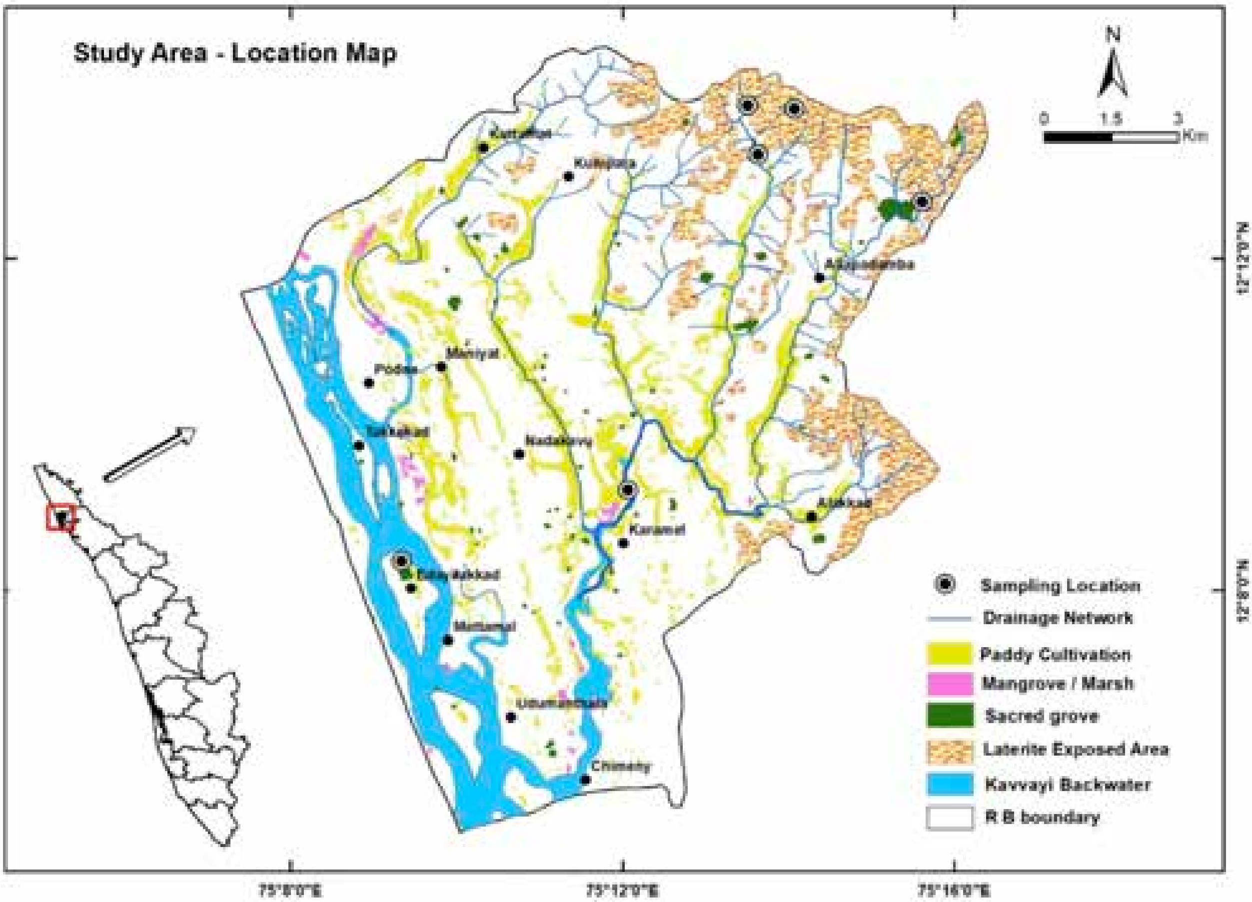

Figure 1. Kavvai River study area showing critical ecosystems.

Table 1. Sampling locations.

Location	Latitude	Longitude	Place name
L1	12.230771	75.225128	Vannathykkanam
L2	12.230078	75.234553	ITP Cheemeni
L3	12.220838	75.227252	Oyolam
L4	12.153555	75.201136	Kuniyan
L5	12.139263	75.155611	Edayilakkad
L6	12.206677	75.255838	Velichamthoodu

Table 2. Moth diversity in protected forests of Kerala.

	Protected area	Moth species recorded	Number of families	Reference
1	Silent Valley NP	318	19	Mathew & Rahmathulla 1995
2	Parambikulam NP	277	20	Sudheendrakumar & Mathew 1999
3	Shendurney WS	129	11	Mathew et al. 2004a
4	Peppara WS	87	7	Mathew et al. 2004b
5	PeechiVazhani WS	113	21	Mathew et al. 2005
6	Neyyar WS	90	9	Mathew et al. 2007
NP—National Park | WS—Wildlife Sanctuary				

of these ecological units have various micro habitats also. Even though the region is highly fragmented, the diversity of flora, birds, amphibians, and spiders are high in the region (Das et al. 2014; Sreejith et al. 2015). The butterfly diversity study in the river basin during 2013–2015 recorded 140 species of butterflies belonging to 96 genera of six families (Dhaneesh et al. 2017). Generally, the diversity of insects and the diversity of angiosperms in a landscape show positive correlation since plants provide food, shelter, sites for mating, and oviposition to insects (Leps et al. 2001). The result of the present study also supports this hypothesis. According to landuse or land cover pattern of the study area, the river basin has 78.5% of cultural landscape, 15.4% of semi natural landscape, and 6% of artificial landscapes (Alex 2018). Moth diversity of several forest patches in Kerala has already been made (Table 2) and the results

Table 3. Composition of moths collected from the Kavvai River basin.

	Super family	Family	Genera	Species
1	Alucitoidea	Alucitidae	1	1
2	Bombycoidea	Bombycidae	1	1
		Eupterotidae	2	6
		Saturniidae	3	3
		Sphingidae	9	12
3	Choreutoidea	Choreutidae	2	2
4	Cossoidea	Brachodidae	1	2
		Cossidae	1	1
5	Drepanoidea	Drepanidae	3	4
6	Gelechioidea	Autostichidae	1	1
		Blastobasidae	1	1
		Cosmopterigidae	4	4
		Gelechiidae	7	10
		Lecithoceridae	1	1
		Oecophoridae	1	1
		Scythrididae	1	1
		Stathmopodidae	2	3
		Symmocidae	1	1
7	Geometroidea	Geometridae	43	60
		Uraniidae	6	7
8	Gracillarioidea	Gracillariidae	2	2
9	Hyblaeoidea	Hyblaeidae	1	1
10	Lasiocampoidea	Lasiocampidae	3	4
11	Noctuoidea	Erebidae	92	128
		Euteliidae	2	2
		Noctuidae	23	36
		Nolidae	11	18
		Notodontidae	9	11
12	Pterophoroidea	Pterophoridae	6	6
13	Pyraloidea	Crambidae	66	94
		Pyralidae	23	24
14	Thyridoidea	Thyrididae	5	6
15	Tineoidea	Eriocottidae	1	1
		Psychidae	1	3
		Tineidae	3	5
16	Tortricoidea	Tortricidae	12	18
17	Yponomeutoidea	Argyresthiidae	1	1
		Attevidae	1	1
		Lyonettidae	1	1
		Plutellidae	1	1
18	Zygaenoidea	Limacodidae	14	16
		Zygaenidae	2	2
	Total		372	503

of the present study indicate a rich and diversified moth fauna in the Kavvai Riven basin. Lepidoptera species diversity has been shown to be highest in moderately disturbed forests and higher in disturbed forests than the undisturbed natural forest or mature forest (Blair & Launer 1997; Schulze et al. 2004; Brehm & Fiedler 2005; Hilt & Fiedler 2005; Bobo et al. 2006; Nöske et al. 2008; Vu & Vu 2011). The result of the present study supports the above hypothesis.

During the past 10 years or so, the study area has been facing unprecedented levels of conversion from the semi natural landscape and cultural landscape to artificial landscapes with monocultures of agricultural crops leading to depletion of ecologically important and critical terrains such as lateritic hillocks, sacred groves, riverine vegetation, mangroves, marshes, and wetlands. Land use classification in India which is based mainly on agricultural productivity usually classifies the majority of such semi natural landscapes as 'waste lands', which enables easy conversion of land from natural to artificial land use practices (Alex & Sajeev 2015). Considering the ecological importance of habitats, there is an urgent need to conserve these critical ecosystems along river basins for conserving their rich biodiversity.

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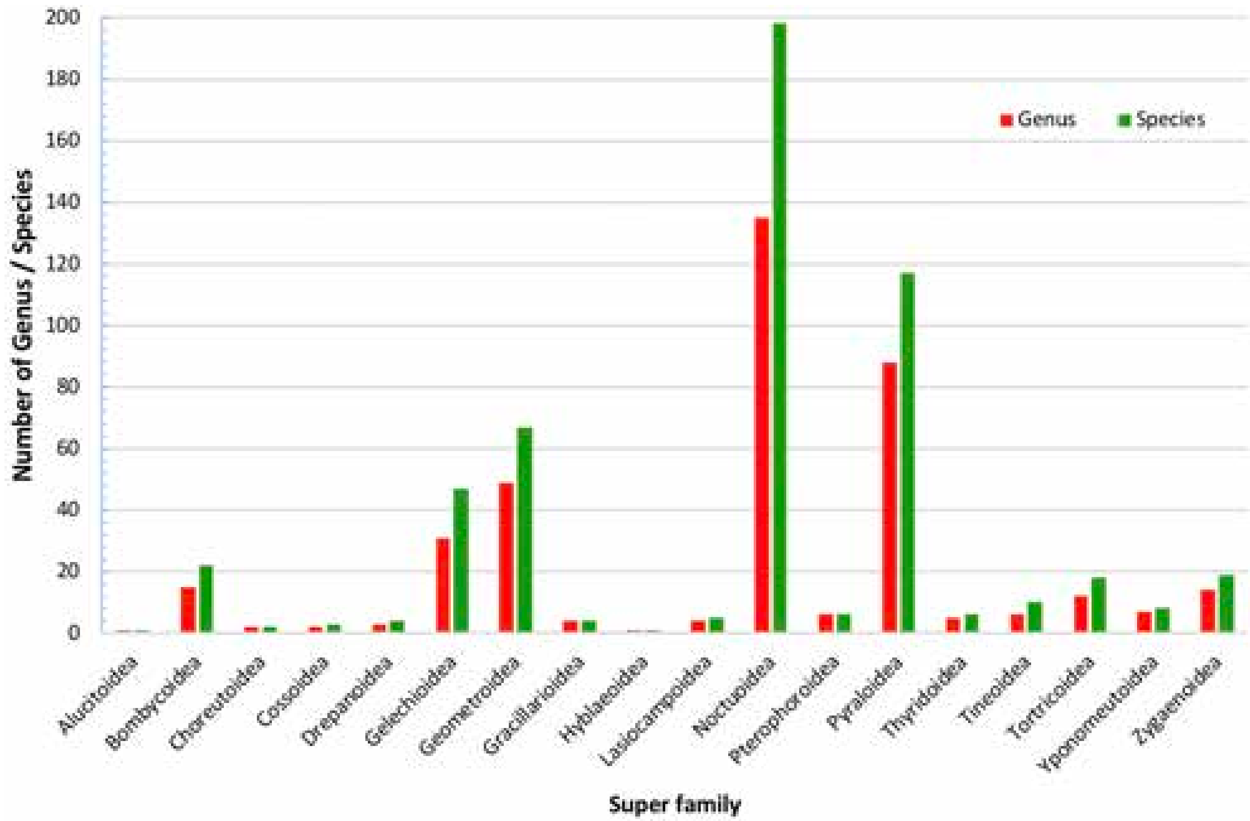

Figure 2. Representation of family-wise diversity of moths in Kavvai River basin.

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Images 1—24. 1—*Alucita sp.* | 2—*Trilocha varians* / 3—*Eupterote bifasciata* | 4—*Eupterote lineosa* | 5—*Eupterote undata* | 6—*Ganisa postica* | 7—*Actias selene* |8—*Antheraea paphia* | 9—*Attacus atlas* | 10—*Acosmeryxanceus* | 11—*Angonyx Krishna* | 12—*Cephonodes hylas* | 13—*Daphnis nerii* | 14—*Macroglossum affictitia* | 15—*Theretra clotho* |16—*Acherontia Lachesis* | 17—*Psilogramma increta* | 18—*Brenthia* sp. | 19—*Phycodes radiata* | 20—*Phragmataecia* sp. | 21—*Callidrepana patrana* | 22—*Callidrepana* sp. | 23—*Phalacra vidhisara* | 24—*Tridrepana albonotata*. © C.J. Alex.

Images 25—48. 25—*Autosticha* cf. *kyotensis* | 26—*Blastobasis sp.* | 27—*Labdia semicoccinea* | 28—*Anatrachyntis* sp. | 29—*Cosmopterix* sp. | 30—*Idiophantis* sp. | 31—*Anarsia* sp. | 32—*Dichomeris harmonia* | 33—*Stegasta* sp. | 34—*Lecithocera concinna* | 35—*Promalactis* cf. *suzukiella* | 36—*Eretmocera* sp. | 37—*Hieromantis* cf. *ephodophora* | 38—*Stathmopoda gemmiconsuta* | 39—*Symmoca signetella* | 40—*Derambila* sp. | 41—*Ozola minor* | 42—*Ozola* sp. | 43—*Achrosisrondelaria* | 44—*Amraica* cf. *superans* | 45—*Ascotis imparata* | 46—*Biston suppressaria* | 47—*Borbacha pardaria* | 48—*Chiasmia eleonora*. © C.J. Alex.

Images 49—72. 49—*Chiasmia nora* | 50—*Chiasmia* sp. | 51—*Comibaena* sp. | 52—*Ectropis bhurmitra* | 53—*Gonodontis* sp. | 54—*Heterostegane urbica* | 55—*Hyperythra lutea* | 56—*Hypomecis infixaria* | 57—*Hypomecis punctinalis* | 58—*Hyposidra talaca* | 59—*Menophra* sp. | 60—*Parapholodes fuliginea* | 61—*Petelia* cf. *rivulosa* | 62—*Ruttellerona pallicostaria* | 63—*Aporandria specularia* | 64—*Argyrocosma* cf. *inductaria* | 65—*Comostola laesaria* | 66—*Comostola rubripunctata* | 67—*Dysphania percota* | 68—*Hemistola* sp.| 69—*Hemithea* sp. | 70—*Jodis* sp. | 71—*Ornithospila avicularia* | 72—*Orothalassodes falsaria.* © C.J. Alex.

Images 73—96. 73—*Eois grataria* | 74—*Gymnoscelis* cf. *rubricata* | 75—*Naxa seriaria* | 76—*Anisephyra* sp. | 77—*Perixera* sp. | 78—*Problepsis vulgaris* | 79— *Scopula emissaria* | 80—*Scopula minorata* | 81—*Traminda mundissima* | 82—*Dysaethria* sp. | 83—*Orudiza protheclaria* | 84—*Phazaca* sp. | 85—*Rhombophylla edentate* | 86—*Micronia aculeata* | 87—*Acrocercops syngramma* | 88—*Epicephala sp*. |89—*Hyblaea puera* | 90—*Gastropacha pardale* | 91—*Odonestis* sp. | 92—*Trabala vishnou* | 93—*Aloa lactinea* | 94—*Asota caricae* | 95—*Asota plaginota* | 96—*Asota producta*. © C.J. Alex.

Images 97—120. 97—*Neochera dominia* | 98—*Brunia antica* | 99—*Ceryx sp.* | 100—*Eressa confinis* | 101—*Olepa ricini* | 102—*Syntomoides imaon* | 103—*Aemene* sp. | 104—*Amerila astreus* | 105—*Creatonotos gangis* | 106—*Creatonotos transiens* | 107—*Euchromia polymena* | 108—*Margina argus* | 109—*Pangora matherana* | 110—*Pareuchaetes pseudoinsulata* | 111—*Spilarctia luteum* | 112—*Spilarctia obliqua* | 113—*Utetheisa pulchella* | 114—*Cyana hamata* | 115—*Cyana peregrina* | 116—*Hemonia orbiferana* | 117—*Lyclene* cf. *obsolete* | 118—*Macrobrochis gigas* | 119—*Miltochrista gratiosa* | 120—*Nepita conferta*. © C.J. Alex.

Images 121—144. 121—*Pseudoblabes oophore* | 122—*Schistophleps* sp. | 123—*Amata bicincta* | 124—*Amata cyssea* | 125—Zurobata *vacillans* | 126—*Cyclodes omma* | 127—*Daddala* sp. | 128—*Diomea* cf. *discisigna* | 129—*Donda eurychlora* | 130—*Egnasia ephyrodalis* | 131—*Ericeia inangulata* | 132—*Ericeia* sp.1 | 133—*Eudocima maternal* | 134—*Falana sordida* | 135—*Loxioda* similis | 136—*Nolasena ferrifervens* | 137—*Oraesia emarginata* | 138—*Oraesia excitans* | 139—*Rhesala moestalis* | 140—*Serrodes campana* | 141—*Achaea Janata* | 142—*Anomis commode* | 143—*Anomis erosa* | 144—*Anomis figlina.* © C.J. Alex.

Images 145—168. 145—*Arsacia rectalis* | 146—*Artena dotata* | 147—*Artena submira* | 148—*Bastilla crameri* | 149—*Bastilla fulvotaenia* | 150—*Bastilla joviana* | 151—*Buzara onelia* | 152—*Chalciope mygdon* | 153—*Entomogramma* sp. | 154—*Ercheia cyllaria* | 155—*Ercheia* sp.1 | 156—*Erebus ephesperis* | 157—*Erebus hieroglyphica* | 158—*Gonitis* cf. *mesogona* | 159—*Mocis undata* | 160—*Pericyma cruegeri* | 161—*Spirama sp.* | 162—*Trigonodes hyppasia* | 163—*Eublemma accedens* | 164—*Eublemma cochylioides* | 165—*Enispa elataria* | 166—*Bertula abjudicalis* | 167—*Hadennia* cf. *incongruens* | 168—*Hydrillodes lentalis*. © C.J. Alex.

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Images 193—216. 193—*Eustrotia marginate* | 194—*Maliattha quadripartite* | 195—*Maliattha separata* | 196—*Maliattha signifera* | 197—*Chasmina candida* | 198—*Chasmina fasciculosa* | 199—*Chasmina pulchra* | 200—*Hoplodrina* cf. *octogenarian* | 201—*Sesamia inferens* | 202—*Sphragifera rejecta* | 203—*Plusiopalpaadrasta* | 204—*Anadevidia peponis* | 205—*Selepa celtis* | 206—*Selepa discigera* | 207—*Xanthodes transversa* | 208—*Eligma narcissus* / 209—*Barasa acronyctoides* | 210—*Nola* cf. *confusalis* | 211—*Nola triquetrana* | 212—*Stauropus alternus* | 213—*Chadisra* sp. | 214—*Antheua servula* | 215—*Phalera javana* | 216—*Allata argentifera.* © C.J. Alex.

Images 217—240. 217—*Allata plusiata* | 218—*Clostera anachoreta* | 219—*Sphenarches caffer* | 220—*Stenoptilodes* sp. | 221—*Diacrotricha* sp. | 222—*Pselnophorus* sp. | 223—*Eoophyla* sp. | 224—*Paracymoriza vagalis* | 225—*Parapoynx vittalis* | 226—*Parapoynx fluctuosalis* | 227—*Parapoynx stagnalis* | 228—*Ancylolomia japonica* | 229—*Ancylolomia* sp.1 | 230—*Ancylolomias* p.2 | 231—*Calamotropha* cf. *nigripunctella* | 232—*Calamotrophas* p.1 | 233—*Chilo infuscatellus* | 234—*Diaphania indica* | 235—*Haritalodes derogata* | 236—*Isocentris filalis* | 237—*Mabra eryxalis* | 238—*Metoeca foedalis* | 239—*Pagyda salvalis* | 240—*Patissa fulvosparsa*. © C.J. Alex.

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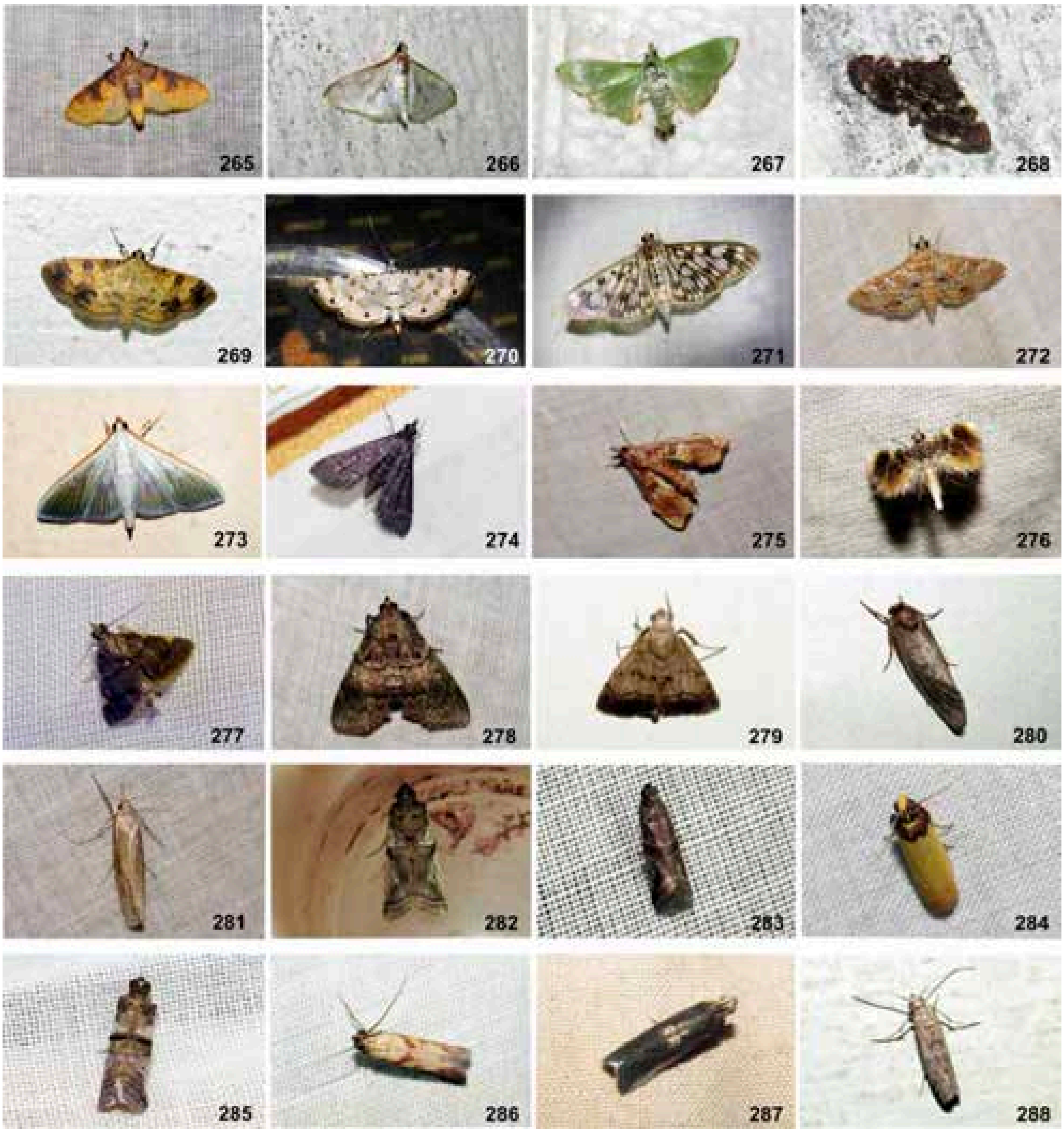

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Image 289—312. 289—*Arippara indicator* | 290—*Endotricha consocia* | 291—*Endotricha pyrosalis* | 292—*Tamraca* sp. | 293—*Zithata ctilis* | 294—*Rhodoneura* sp.1 | 295—*Collinsa* sp. | 296—*Striglina scitaria* | 297—*Compsoctena* sp. | 298—*Eumeta variegata* | 299—*Opogona dimidiatella* | 300—*Edosa*s p.1 | 301—*Ancylis* sp. | 302—*Cryptophlebia* sp. | 303—*Lobesia aeolopa* | 304—*Loboschiza* cf. *koenigiana* | 305—*Strepsicrates* sp. | 306—Acleris sp. | 307—*Adoxophyes privatana* | 308—*Archips micaceana* | 309—*Archips* sp.1 | 310—*Clepsis peritana* | 311—*Homona coffearia* | 312—*Argyresthia* sp. © C.J. Alex.

Image 313—328. 313—*Atteva fabriciella* | 314—*Leucoptera* sp. | 315—*Plutella xylostella* | 316—*Plutella* sp. | 317—*Miresa* cf. *bracteate* | 318—*Scopelodes* venosa | 319—*Setora* sp. | 320—*Thosea* sp. | 321—*Altha nivea* | 322—*Caissa fasciatum* | 323—*Tennya* sp. | 324—*Parasa lepida* | 325—*Parasa fumosa* | 326—*Phocoderma velutina* | 327—*Aphendala* sp. | 328—*Trypanophora* sp. © C.J. Alex.

Image 329. Moth collection using an illuminated white cloth. © C.J. Alex.

Image 330. Moth larval rearing. © C.J. Alex.

Appendix 1. Checklist of the moths recorded from Kavvai River basin.

	Scientific name	Author & description year
I	**ALUCITOIDEAE**	Leach, 1815
I.1	**Alucitidae**	Leach, 1815
1	*Alucita* sp.	
II	**BOMBYCOIDEA**	Latreille, 1802
II.1	**Bombycidae**	Latreille, 1802
II.1.a	**Bombycinae**	
2	*Trilocha varians*	Walker,1855
II.2	**Eupterotidae**	Swinhoe. 1892
II.2.a	**Eupterotinae**	
3	*Eupterote bifasciata*	Kishida, 1994
4	*Eupterote hibisci*	Fabricius, 1775
5	*Eupterote lineosa*	Walker,1855
6	*Eupterote undata*	Blanchard, 1844
7	*Ganisa postica*	Walker,1855
8	*Ganisa* sp.1	
II.3	**Saturniidae**	Boisduval, 1837
II.3.a	**Saturniinae**	Boisduval, 1837
9	*Actias selene*	Hübner, 1806
10	*Antheraea paphia*	Linnaeus 1758
11	*Attacus atlas*	Linnaeus, 1758
II.4	**Sphingidae**	Latreille, 1802
II.4.a	**Macroglossinae**	
12	*Acosmeryx anceus*	Stoll, 1781
13	*Angonyx krishna*	Eitschberger & Haxaire, 2006
14	*Cephonodes hylas*	Linnaeus, 1771
15	*Daphnis nerii*	Linnaeus, 1758
16	*Hippotion boerhaviae*	Fabricius, 1775
17	*Macroglossum affictitia*	Butler, 1875
18	*Macroglossum aquila*	Boisduval, [1875]
19	*Theretra clotho*	Moore, 1872
20	*Theretra suffusa*	Walker,1856
II.4. b	**Sphinginae**	
21	*Acherontia lachesis*	Fabricius, 1798
22	*Psilogramma increta*	Walker, [1865]
23	*Psilogramma menephron*	Cramer, 1780
III	**CHOREUTOIDEA**	Stainton, 1858
III.1	**Choreutidae**	Stainton, 1858
III.1. a	**Brenthiinae**	
24	*Brenthia*sp.	
III.1.b	**Choreutinae**	
25	*Choreutis* sp.	
IV	**COSSIOIDEA**	Leach, 1815
IV.1	**Brachodidae**	Agenjo, 1966
26	*Phycodes minor*	Moore, 1881
27	*Phycodes radiata*	Ochsenheimer, 1808
IV.2	**Cossidae**	Leach, 1815
IV.2.a	**Zeuzerinae**	
28	*Phragmataecia* sp.1	
V	**DREPANOIDEA**	Boisdual, 1828
V.1	**Drepanidae**	Boisdual, 1828
V.1.a	**Drepaninae**	
29	*Callidrepana patrana*	Moore, 1865
30	*Callidrepana* sp.1	
31	*Phalacra vidhisara*	Walker,1960
32	*Tridrepana albonotata*	Moore, 1879
VI	**GELECHIOIDEA**	Stainton, 1854
VI.1	**Autostichidae**	Le Merchant, 1947
VI.1.a	**Autostichinae**	
33	*Autosticha* cf. *kyotensis*	
VI.2	**Blastobasidae**	Meyrick 1894
34	*Blastobasis* sp.	
VI.3	**Cosmopterigidae**	Heinemann &Wocke, 1876
35	*Anatrachyntis sp.*	
36	*Cosmopterix* sp.	
VI.3.a	**Cosmopteriginae**	
37	*Labdia semicoccinea*	Stainton,1859
38	*Limnaecia peronodes*	Meyrick, 1915
VI.4	**Gelechiidae**	Stainton, 1854
39	*Helcystogramma* sp.	
40	*Helcystogramma hibisci*	Stainton, 1859
VI.4.a	**Anacampsinae**	
41	*Idiophantis* sp.	
42	*Thiotricha* sp.	
VI.4.b	**Chelariinae**	
43	*Anarsia epotias*	Meyrick, 1916
44	*Anarsia sp.1*	Park, 1995
45	*Hypatima haligramma*	Meyrick, 1926
VI.4.c	**Dichomeridinae**	
46	*Dichomeris harmonias*	Meyrick, 1922
47	*Dichomeris* sp.1	
VI.4.d	**Gelechiinae**	
48	*Stegasta sp.*	
VI.5	**Lecithoceridae**	Le Merchant, 1947
49	*Lecithocera concinna*	Turner, 1919
VI.6	**Oecophoridae**	Bruant, 1850
VI.6.a	**Oecophorinae**	
50	*Promalactis sp.*	
VI.7	**Scythrididae**	Rebel, 1901
51	*Eretmocera sp.*	
VI.8	**Stathmopodidae**	Janse, 1917
52	*Hieromantis sp.*	

	Scientific name	Author & description year
53	*Stathmopoda gemmiconsuta*	Terada, 2012
54	*Stathmopodas* sp.1	
VI.9	**Symmocidae**	Gozmany, 1957
55	*Symmoca signatella*	Herrich-Schäffer, 1854
VII	**GEOMETROIDEA**	Leach, 1815
VII.1	**Geometridae**	Leach, 1815
VII.1.a	**Desmobathrinae**	
56	*Derambila sp.*	
57	*Ozola minor*	Moore, 1888
58	*Ozola* sp.1	
VII.1.b	**Ennominae**	
59	*Achrosis intexta*	Swinhoe, 1891
60	*Achrosis rondelaria*	Fabricius, 1775
61	*Amraica* cf. *superans*	Butler, 1878
62	*Ascotis imparata*	Walker,1860
63	*Biston suppressaria*	Guenée, [1858]
64	*Borbacha pardaria*	Guenée, [*1858*]
65	*Chiasmia eleonora*	Cramer, [1780]
66	*Chiasmia honoria*	Hampson, 1912
67	*Chiasmia nora*	Walker,1861
68	*Chiasmia* sp.1	
69	*Comibaena* sp.1	
70	*Ectropis bhurmitra*	Walker,1860
71	*Gonodontis* sp.	
72	*Heterostegane urbica*	Swinhoe, 1886
73	*Hyperythra lutea*	Stoll, [1781]
74	*Hyperythra* sp.	
75	*Hypomecis infixaria*	Walker,1860
76	*Hypomecis punctinalis*	Scopoli, 1763
77	*Hypomecis transcissa*	Walker,1860
78	*Hyposidra talaca*	Walker, 1860
79	*Menophra* sp.	
80	*Oenospila flavifusata*	Walker,1861
81	*Parapholodes fuliginea*	Hampson, 1891
82	*Petelia* cf. *rivulosa*	Butler, 1881
83	*Ruttellerona cessaria*	Walker 1860
VII.1.c	**Geometrinae**	
84	*Aporandria specularia*	Guenée, [1858]
85	*Argyrocosma* cf. *inductaria*	Guenée, 1857
86	*Comostola meritaria*	Walker 1861
87	*Comostola laesaria*	Walker,1861
88	*Comostola rubripunctata*	Warren, 1909
89	*Dysphania percota*	Swinhoe, 1891
90	*Hemistola* sp.	
91	*Hemistola tenuilinea*	Alphéraky, 1897
92	*Hemithea* cf. tritonaria	Walker 1863
93	*Jodis* sp.	

	Scientific name	Author & description year
94	*Ornithospila avicularia*	Guenée 1857
95	*Orothalassodes falsaria*	Prout, 1912
96	*Pelagodes* sp.	
97	*Pingasa* cf. ruginaria	Guenee 1857
VII.1.d	**Larentiinae**	
98	*Eois grataria*	Walker,1861
99	*Eupithecia* sp.	
100	*Gymnoscelis* cf. *rubricata*	de Joannis, 1932
101	*Gymnoscelis* cf. *rufifasciata*	Haworth, 1809
102	*Sauris sp.*	
VII.1.e	**Oenochrominae**	
103	*Noreia* sp.	
VII.1.f	**Orthostixinae**	
104	*Naxa seriaria*	Motschulsky, 1866
105	*Naxa textilis*	Walker,1856
VII.1.g	**Sterrhinae**	
106	*Anisephyra* sp.	
107	*Perixera* sp.	
108	*Problepsis* vulgaris	Butler, 1889
109	*Scopula emissaria*	Walker,1861
110	*Scopula minorata*	Boisduval, 1833
111	*Scopula* sp.1	
112	*Scopula* sp.2	
113	*Somatina* cf. *ioscia*	Prout, 1932
114	*Traminda aventiaria*	Guenée, [1858]
115	*Traminda mundissima*	Walker, 1861
VII.2	**Uraniidae**	Leach, 1815
VII.2.a	**Epipleminae**	
116	*Dysaethria* sp.	
117	*Epiplema bicaudata*	Moore, 1867
118	*Orudiza protheclaria*	Walker,1861
119	*Phazaca* sp.1	
120	*Phazaca* sp.2	
121	*Rhombophylla edentata*	Hampson, 1895
VII.2.b	**Microniinae**	
122	*Micronia aculeata*	Guenée, 1857
VIII	**GRACILLARIOIDEA**	Stainton, 1854
VIII.1	**Gracillariidae**	Stainton, 1854
VIII.1.a	**Gracillariinae**	
123	*Acrocercops syngramma*	Meyrick, 1914
124	*Epicephala* sp.	
IX	***HYBLAEOIDEA***	Hampson, 1903
IX.1	**Hyblaeidea**	Hampson, 1903
125	*Hyblaea puera*	Cramer, 1777
X	**LASIOCAMPOIDEA**	Harris, 1841
X.1	**Lasiocampidae**	Harris, 1841
X.1.a	**Lasiocampinae**	

	Scientific name	Author & description year
126	*Gastropacha* sp.1	
127	*Gastropacha pardale*	Walker 1855
128	*Odonestis* sp.	
129	*Trabala vishnou*	Lefèbvre, 1827
XI	**NOCTUOIDEA**	Latreille, 1809
XI.1	**Erebidae**	Leach, 1815
130	*Aloa lactinea*	Cramer, 1777
131	*Diacrisia* sp.	
132	*Nygmia sp.*	
XI.1.a	**Aganainae**	
133	*Asota caricae*	Fabricius, 1775
134	*Asota plaginota*	Butler, 1875
135	*Asota plana*	Walker, 1854
136	*Asota producta*	Butler, 1875
137	*Neochera dominia*	Cramer, [1780]
XI.1.b	**Arctiinae**	
138	Barsine defecta	Walker 1854
139	*Brunia antica*	Walker, 1854
140	*Brunia griseola*	Hübner, 1827
141	*Ceryx* sp.	
142	*Eressa confinis*	Walker,1854
143	*Eressa* sp.1	
144	*Olepa ricini*	Fabricius, 1775
145	*Syntomoide simaon*	Cramer, 1780
146	*Syntomoides* sp.1	
147	*Aemene* sp.1	
148	*Aemene taprobanis*	Walker, 1854
149	*Amerila astreus*	Drury, 1773
150	*Argina astrea*	Drury, 1773
151	*Creatonotos gangis*	Linnaeus, 1763
152	*Creatonotos transiens*	Walker,1855
153	*Curoba sangarida*	Cramer, 1781
154	*Euchromia polymena*	Linnaeus, 1758
155	*Margina argus*	Kollar, 1844
156	*Pangora matherana*	Moore, 1879
157	*Pareuchaetes pseudoinsulata*	Barros, 1956
158	*Spilarctia luteum*	Hufnagel, 1766
159	*Spilarctia mona*	Swinhoe, 1885
160	*Spilarctia obliqua*	Walker, 1855
161	*Spilosoma urticae*	Esper, 1789
162	*Utetheisa pulchella*	Linnaeus, 1758
163	*Cyana hamata*	Walker,1854
164	*Cyana peregrina*	Walker,1854
165	*Cyana* sp.1	
166	*Hemonia orbiferana*	Walker, 1863
167	*Hemonias* sp.2	
168	*Lyclene* cf. *obsoleta*	Moore, 1878
169	*Lyclene* sp.1	
170	*Macrobrochis gigas*	Walker,1854
171	*Miltochrista gratiosa*	Guérin-Méneville, 1843
172	*Miltochrista* sp.1	
173	*Nepita conferta*	Walker,1854
174	*Nepita rubricosa*	Moore, 1878
175	*Pseudoblabes* oophora	Zeller, 1853
176	*Schistophleps* sp.	
177	*Trischalis* sp.	
178	*Amata bicincta*	Kollar, 1844
179	*Amata* cyssea	Stoll 1782
XI.1.c	**Aventiinae**	
180	*Zurobata vacillans*	Walker,1864
XI.1.d	**Calpinae**	
181	*Colobochyla* sp.	
182	*Cyclodes omma*	Hoeven, 1840
183	*Daddala* sp.	
184	*Diomea* cf. *discisigna*	Sugi, 1963
185	*Donda eurychlora*	Walker,1858
186	*Egnasia ephyrodalis*	Walker,1858
187	*Ericeia inangulata*	Guenée, 1852
188	*Ericeia* sp.1	
189	*Eudocima homaena*	Hübner, [1823]
190	*Eudocima materna*	Linnaeus, 1767
191	*Eudocima phalonia*	Linnaeus, 1763
192	*Falana sordida*	Moore, 1882
193	*Fodina* sp.	
194	*Homodes propitia*	Guenée, 1852
195	*Hulodes drylla*	Guenée, 1852
196	*Loxioda* similis	Moore, 1882
197	*Nola senaferrifervens*	Walker, [1858]
198	*Oraesia emarginata*	Fabricius, 1794
199	*Oraesia excitans*	Walker, [1858]
200	*Rhesala moestalis*	Walker,1865
201	*Serrodes campana*	Guenée, 1852
XI.1.e	**Erebinae**	
202	*Achaea janata*	Linnaeus, 1758
203	*Anomis commoda*	Walker, 1865
204	*Anomis erosa*	Hübner, 1818
205	*Anomis figlina*	Butler, 1889
206	*Arsacia rectalis*	Walker,1863
207	*Artena dotata*	Fabricius, 1794
208	*Artena submira*	Walker,1858
209	*Asta quadrilinea*	Walker,[1863]
210	*Bastilla crameri*	Moore, 1885
211	*Bastilla fulvotaenia*	Guenée, 1852
212	*Bastilla joviana*	Stoll, 1782

	Scientific name	Author & description year
213	*Buzara onelia*	Guenée, 1852
214	*Chalciope mygdon*	Cramer, [1777]
215	*Entomogramma* sp.	Fautrix Guenée, 1852
216	*Ercheia cyllaria*	Cramer, [1779]
217	*Ercheia* sp.1	
218	*Erebus ephesperis*	Hübner, 1827
219	*Erebus hieroglyphica*	Drury, 1773
220	*Erebus macrops*	Linnaeus, 1758
221	*Gonitis* cf. *mesogona*	Walker, 1858
222	*Mocis undata*	Fabricius, 1775
223	*Ophiusa triphaenoides*	Walker,1858
224	*Pericyma cruegeri*	Butler, 1886
225	*Spirama* sp.	
226	*Sympis rufibasis*	Guenee 1852
227	*Thyas coronata*	Fabricius, 1775
228	*Thyas honesta*	Hübner, 1806
229	*Trigonodes hyppasia*	Cramer, [1779]
XI.1.f	**Eublemminae**	
230	*Eublemma accedens*	Felder &Rogenhofer, 1874
231	*Eublemma albostriata*	Wileman& West, 1929
232	*Eublemma anachoresis*	Wallengren, 1863
233	*Eublemma baccalix*	Swinhoe, 1886
234	*Eublemma cochylioides*	Guenee, 1852
XI.1.g	**Herminiinae**	
235	*Enispa elataria*	Walker,1861
236	*Bertula abjudicalis*	Walker, 1859
237	*Bocana manifestalis*	Walker, [1859]
238	*Hadennia* cf. *incongruens*	Butler, 1879
239	*Hydrillodes lentalis*	Guenée, 1854
240	*Naarada* sp.	
241	*Nodaria tristis*	Butler, 1879
242	*Simplicia* sp.	
XI.1.h	**Hypeninae**	
243	*Hypena iconicalis*	Walker, [1859
244	*Hypena laceratalis*	Walker, 1859
245	*Hypenas* sp.1	
246	*Prolophota* sp.	
XI.1.i	**Lymantriinae**	
247	*Arctornis kumatai*	Inoue, 1956
248	*Arctornis submarginata*	Walker,1855
249	*Artaxa* subfasciata.	Walker 1865
250	*Calliteara grotei*	Moore, [1859]
251	*Euproctis sp.*	Moore, 1879
252	*Lymantria marginata*	Walker,1855
253	*Olene mendosa*	Hübner, 1823
254	*Orgyia* sp.	
255	*Orvasca subnotata*	Walker,1865

	Scientific name	Author & description year
256	*Perina nuda*	Fabricius, 1787
XI.1.j	**Rivulinae**	
257	*Rivula* sp.	
XI.2	**Euteliidae**	Grote, 1882
XI.2.a	**Euteliinae**	
258	*Chlumetia transversa*	Walker,1863
259	*Penicillaria jocosatrix*	Guenée, 1852
XI.3	**Noctuidae**	Latreille, 1809
XI.3.a	**Acontiinae**	
260	*Acontia bicolora*	Leech, 1889
261	*Acontia marmoralis*	Fabricius, 1794
262	*Acontia nitidula*	Fabricius, 1787
263	*Ataboruza divisa*	Walke, 1862
264	*Ceryneatrogobasis*	Hampson 1910
265	*Hyperstrotia* sp.	
266	*Pseudozarba* sp.	
XI.3.b	**Agaristinae**	
267	*Exsula* sp.	
XI.3.c	**Bagisarinae**	
268	*Amyna natalis*	Walker,[1859]
269	*Amyna octo*	Hampson, 1910
270	*Amyna punctum*	Fabricius, 1794
271	*Amyna* sp.	
XI.3.c	**Condicinae**	
272	*Condica* sp.	
XI.3.d	**Eriopinae**	
273	*Callopistria maillardi*	Guenée, 1862
274	*Callopistria* sp.	
XI.3.f	**Eustrotiinae**	
275	*Eustrotia marginata*	Moore 1881
276	*Eustrotia* sp.1	
277	*Maliattha quadripartite*	Walker,1865
278	*Maliattha separata*	Walker, 1863
279	*Maliattha signifera*	Walker, 1858
280	*Maliattha* sp.1	
281	*Protodeltote sp.*	
XI.3.g	**Noctuinae**	
282	*Chasmina candida*	Walker,1865
283	*Chasmina fasciculosa*	Walker,1858
284	*Chasmina pulchra*	Walker,1857
285	*Diarsia* sp.	
286	*Hoplodrina* cf. *octogenaria*	Goeze, 1781
287	*Mythimna irrorata*	Moore, 1881
288	*Sesamia inferens*	Walker, 1856
289	*Sphragifera rejecta*	Fabricius, 1775
290	*Spodoptera litura*	Fabricius, 1775

	Scientific name	Author & description year
291	*Spodoptera mauritia*	Boisduval, 1833
292	*Polytela gloriosae*	Fabricius, 1781
XI.3.h	**Plusiinae**	
293	*Anadevidia peponis*	Fabricius, 1775
294	*Plusiopalpa adrasta*	Felder &Rogenhofer, 1874
XI.3.i	**Stictopterinae**	
295	*Lophoptera sp.*	
XI.4	**Nolidae**	Bruant, 1847
296	*Ptisciana seminivea*	Walker, 1865
XI.4.a	**Chloephorinae**	
297	*Nycteola revayana*	Scopoli, 1772
298	*Selepa celtis*	Moore, [1860]
299	*Selepa discigera*	Walker,1864
300	*Xanthodes acontia*	Hampson, 1912
301	*Xanthodes graelsi*	Feisthamel, 1837
302	*Xanthodes transversa*	Guenée, 1852
XI.4.b	**Eariadinae**	
303	*Earias* sp.	
XI.4.c	**Eligminae**	
304	*Eligma narcissus*	Cramer, 1775
XI.4.d	**Nolinae**	
305	*Barasa acronyctoides*	Walker, 1862
306	*Meganola* sp.	
307	*Nola analis*	Wileman& West, 1928
308	*Nola* cf. *confusalis*	Herrich-Schäffer, 1847
309	*Nola japonibia*	Strand, 1920
310	*Nola triquetrana*	Fitch, 1856
311	*Nola* sp.1	
312	*Sarbena lignifera*	Walker,1862
313	*Stictane* sp.	
XI.5	**Notodontidae**	Scephens, 1829
XI.5.a	**Dicranurinae**	
314	*Netria sp.*	
315	*Stauropus alternus*	Walker, 1855
316	*Stauropus* sp.1	
317	*Syntypistis* sp.	
XI.5.b	**Notodontinae**	
318	*Chadisra* sp.	
XI.5.c	**Phalerinae**	
319	*Antheua servula*	Drury 1773
320	*Phalera javana*	Moore, 1859
XI.5.d	**Pygaerinae**	
321	*Allata argentifera*	Walker, 1862
322	*Allata plusiata*	Walker, 1865
323	*Clostera anachoreta*	(Denis &Schiffermüller, 1775)
XI.5.e	**Scranciinae**	
324	*Gargetta divisa*	Gaede, 1930
XII	**PTEROPHOROIDEA**	Latreille, 1802
XII.1	**Pterophoridae**	Latreille, 1802
325	*Diacrotricha* sp.	
326	*Exelastis* sp.	
327	*Pselnophorus* sp.	
XII.1.a	**Pterophorinae**	
328	*Sphenarches caffer*	Zeller, 1852
329	*Stenoptilodes* sp.	
330	*Tetraschalis* sp.	
XIII	**PYRALOIDEA**	Latreille, 1809
XIII.1	**Crambidae**	Latreille, 1810
331	*Pseudocatharylla sp.*	
XIII.1.a	**Acentropinae**	
332	*Elophila* cf. *peribocalis*	Walker 1859
333	*Eoophyla* sp.1	
334	*Paracymoriza vagalis*	Walker,1865
335	*Parapoynx* diminutalis	Snellen 1880
336	*Parapoynx fluctuosalis*	Zeller, 1852
337	*Parapoynx stagnalis*	Zeller, 1852
338	*Parapoynx vittalis*	Bremer, 1864
XIII.1.b	**Crambinae**	
339	*Ancylolomia japonica*	Zeller, 1877
340	*Ancylolomia* sp.1	
341	*Ancylolomia* sp.2	
342	*Calamotropha* cf. *nigripunctella*	Leech, 1889
343	*Calamotropha* sp.1	
344	*Chilo infuscatellus*	Snellen, 1890
345	*Chilo partellus*	Swinhoe, 1885
346	*Euchromius* sp.1	
XIII.1.c	**Cybalomiinae**	
347	*Hendecasis* sp.	
348	*Trichophysetis* sp.	
XIII.1.d	**Musotiminae**	
349	*Musotima* sp.	
XIII.1.e	**Odontiinae**	
350	*Deanolis sublimbalis*	Snellen, 1899
351	*Noorda* sp.	
XIII.1.f	**Pyraustinae**	
352	*Achyra sp.*	
353	*Diaphania indica*	Saunders, 1851
354	*Euclasta sp.*	
355	*Haritalodes derogata*	Fabricius, 1775
356	*Isocentris filalis*	Guenée, 1854
357	*Isocentris sp.*	

	Scientific name	Author & description year
358	*Mabra eryxalis*	Walker,1859
359	*Metoeca foedalis*	Guenée, 1854
360	*Nacoleia* sp.1	
361	*Nacoleia tampiusalis*	Walker, 1859
362	*Pagyda quinquelineata*	Hering, 1903
363	*Pagyda salvalis*	Walker,1859
364	*Paliga ochrealis*	Moore 1886
365	*Paratalanta aureolalis*	Lederer, 1863
366	Pyrausta sp.	
XIII.1.g	**Schoenobiinae**	
367	*Patissa fulvosparsa*	Butler, 1881
368	*Scirpophaga excerptalis*	Walker,1863
369	*Scirpophaga gilviberbis*	Zeller, 1863
370	*Scirpophaga incertulas*	Walker,1863
371	*Scirpophaga* sp.1	
XIII.1.h	**Spilomelinae**	
372	*Aetholix flavibasalis*	Guenée, 1854
373	*Agathodes ostentalis*	Geyer, 1837
374	*Agrioglypta itysalis*	Walker, 1859
375	*Antigastra catalaunalis*	Duponchel, 1833
376	*Ategumia* cf. *adipalis*	Lederer 1863
377	*Bocchoris sp.*	
378	*Botyodes diniasalis*	Walker, 1859
379	*Botyodes flavibasalis*	Moore, 1867
380	*Bradina geminalis*	Caradja, 1927
381	*Cnaphalocrocis medinalis*	Guenée, 1854
382	*Cnaphalocrocis poeyalis*	Boisduval, 1833
383	*Diasemia accalis*	Walker, 1859
384	*Diasemia reticularis*	Linnaeus, 1761
385	*Dichocrocis tigrina*	Moore 1886
386	*Eurrhyparodes bracteolalis*	Zeller, 1852
387	*Glyphodes bicolor*	wainson, [1821]
388	*Glyphodes bivitralis*	Guenée, 1854
389	*Glyphodes caesalis*	Walker,1859
390	*Glyphodes shafferorum*	Viette 1987
391	*Goniorhynchus plumbeizonalis*	Fabricius, 1794
392	*Goniorhynchus* sp.1	
393	*Herpetogramma bipunctalis*	Fabricius, 1794
394	*Herpetogramma rudis*	Warren, 1892
395	*Herpetogramma* sp.1	
396	*Hymenia perspectalis*	Hübner, 1796
397	*Lamprosema tampiusalis*	Walker,1859
398	*Maruca vitrata*	Fabricius,1787
399	*Nausinoe geometralis*	Guenée, 1854
400	*Notarcha aurolinealis*	Walker,1859
401	*Omiodes analis*	Snellen, 1880
402	*Omiodes indicata*	Fabricius, 1775

	Scientific name	Author & description year
403	*Omiodes* sp.1	
404	*Pachynoa sabelialis*	Guenee, 1854
405	*Palpita annulifer*	Inoue, 1996
406	*Palpita sp.*	
407	*Parotis marginata*	(Hampson, 1893
408	*Parotis pomanalis*	Guenée, 1854
409	*Piletocera sodalis*	Leech, 1889
410	*Piletocera* sp.1	
411	*Pleuroptya iopasalis*	Walker,1859
412	*Polioboty sablactalis*	Walker 1859
413	*Pycnarmon cribrata*	Fabricius, 1794
414	*Pygospila tyres*	Cramer, 1780
415	*Sameodes cancellalis*	Zeller, 1852
416	*Sameodes* sp.1	
417	*Spolade arecurvalis*	Fabricius, 1775
418	*Stemorrhages sericea*	Drury, 1773
419	*Stenia minoralis*	Snellen 1880
420	*Sufetula rectifascialis*	Hampson, 1896
421	*Syllepte* sp.	
422	*Terastia egialealis*	Walker,1859
423	*Thysanoidma octalis*	Hampson, 1891
424	*Tyspanodes linealis*	Moor 1869
XIII.2	**Pyralidae**	Latreille, 1809
425	*Glyptoteles* sp.	
426	*Herculia pelasgalis*	Walker 1859
XIII.2.a	**Epipaschiinae**	
427	*Lepidogma* sp.	
428	*Macalla* sp.	
429	*Noctuides melanophia*	Staudinger, 1892
430	*Orthaga* sp.	
431	*Stericta* sp.	
XIII.2.b	**Galleriinae**	
432	*Achroia* sp.	
433	*Melissoblaptes* sp.	
XIII.2.c	**Phycitinae**	
434	*Acrobasis* sp.	
435	*Addyme* sp.	
436	*Calguia* sp.	
437	*Conobathra* sp.	
438	*Epicrocis oegnusalis*	Walker, 1859
439	*Nephopterix* sp.	
440	*Pempelia morosalis*	Saalmüller, 1880
441	*Plodia* sp.	
XIII.2.d	**Pyralinae**	
442	Arippara indicator	Walker 1864
443	*Endotricha consocia*	Butler, 1879

	Scientific name	Author & description year
444	*Endotricha pyrosalis*	Guenée, 1854
445	*Hipsopygia nonusalis*	Walker 1859
446	*Orthopygia* sp.	
447	*Tamraca* sp.	
448	*Zith atactilis*	Swinhoe, 1890
XIV	**THYRIDOIDEA**	Herrich-Schaffier, 1846
XIV.1	**Thyrididae**	Herrich-Schaffier, 1846
XIV.2.a	**Siculodinae**	
449	*Addaea* sp.	
450	*Rhodoneura* sp.1	
451	*Rhodoneura* sp.2	
452	*Collinsa* sp.	
453	*Hypolamprus* sp.	
XIV.2.b	**Striglininae**	
454	*Striglina scitaria*	Walker 1862
XV	**TINEOIDEA**	Latreille, 1810
XV.1	**Eriocottidae**	Spuler, 1898
XV.1.a	**Compsocteninae**	
455	*Compsoctena* sp.	
XV.2	**Psychidae**	Boisdual, 1829
XV.2.a	**Oiketicinae**	
456	*Eumeta cramari*	Westwood, 1854
457	*Eumeta* sp.1	
458	*Eumeta variegata*	Snellen, 1879
XV.3	**Tineidae**	Latreille, 1810
XV.3.a	**Hieroxestinae**	
459	*Opogona dimidiatella*	Zeller, 1853
460	*Opogonasp.*	
XV.3.b	**Perissomasticinae**	
461	*Edosa opsigona*	Meyrick, 1911
462	*Edosa* sp.2	
XV.3.c	**Tineinae**	
463	*Tinea* sp.	
XVI	***TORTRICOIDEA***	Latreille, 1802
XVI.1	**Tortricidae**	Latreille, 1802
XVI.1.a	**Olethreutinae**	
464	*Ancylis* sp.	
465	*Cryptophlebia* sp.	
466	*Gatesclarkeana* sp.	
467	*Lobesia aeolopa*	Meyrick, 1907
468	*Lobesias* p.1	
469	*Loboschiza* cf. *koenigiana*	Fabricius, 1775
470	*Ophiorrhabda* sp.	
471	*Strepsicrates* sp.	
XVI.1.b	**Tortricinae**	
472	*Adoxophyes moderatana*	Walker,1863

	Scientific name	Author & description year
473	*Adoxophyes orana*	Röslerstamm, 1834
474	*Adoxophyes privatana*	Walker,1863
475	*Archips micaceana*	Walker,1863
476	*Archips* sp.1	
477	*Archips* sp.2	
478	*Clepsis peritana*	Clemens, 1860
479	*Homona coffearia*	Nietner, 1861
480	*Acleris* sp.1	
481	*Acleris* sp.2	
XVII	**YPONOMEUTOIDEA**	Stephens, 1829
XVII.1	**Argyresthiidae**	Bruant, 1850
XVII.1.a	**Argyresthiinae**	
482	*Argyresthia* sp.	
XVII.2	**Attevidae**	Mosher, 1916
483	*Atteva fabriciella*	Swederus, 1787
XVII.3	**Lyonettidae**	Stainton, 1854
XVII.3.a	**Cemiostominae**	
484	*Leucoptera* sp.	
XVII.4	**Plutellidae**	Guenee, 1845
XVI.4.a	**Plutellinae**	
485	*Plutella xylostella*	Linnaeus, 1767
XVIII	**ZYGAENOIDEA**	Laterille, 1809
XVIII.1	**Limacodidae**	Duponchal, 1845
XVIII.1*	**Increta sedis.**	
486	*Altha nivea*	Walker, 1862
487	*Altha subnotata*	Walker, 1865
488	*Belippa* sp.	
489	*Caissa fasciatum*	Hampson, 1893
490	*Tennya* sp.	
491	*Parasa lepida*	Cramer, 1779
492	*Parasa fumosa*	Swinhoe, 1889
493	*Phocoderma velutina*	Kollar, 1844
494	*Setora* cf. *postorna*	Hampson 1900
XVIII.1.a	**Limacodinae**	
495	*Aphendala* sp.	
496	*Miresa* sp.1	
497	*Miresa argentifera*	Walker, 1855
498	*Praesetora* sp.	
499	*Scopelode svenosa*	Walker, 1855
500	*Susica pallida*	
501	*Thosea* sp.	Walker, 1855
XVIII.2	**Zygaenidae**	Laterille, 1809
XVIII.2.a	**Chalcosiinae**	
502	*Trypanophora* sp.	
503	*Cyclosia* Sp.	

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PLATINUM OPEN ACCESS

COMMUNICATION

Observations on the flowering plant diversity of Madayippara, a southern Indian lateritic plateau from Kerala, India

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Abstract: Northern Kerala of southern India is characterized by widely spread lateritic plateaus which provide an extremely harsh physical environment for life leading to the development of specialized plant communities with a large number of endemic and habitat specific species. Madayippara, a midland lateritic plateau located in the Kannur District of northern Kerala is an icon of rich floristic diversity and endemism. The plateau forms a number of microhabitats due to the difference in geographic terrain and soil cover, thus forming a complex of habitats with diverse forms of plants, mainly ephemeral herbs. Out of the 636 flowering plant taxa recorded from the microhabitats of the plateau, within a limited area of 3.65km^2, 160 (c. 25%) are endemics. Most of the endemic species occur in specialized microhabitats. The plateau is the type locality of 11 taxa. Lateritic plateaus of southern India, which are associated with characteristic and rich biodiversity, are now under varied types of anthropogenic threats such as large scale mining for bricks and clay, and they need urgent attention for conservation of the biodiversity.

Keywords: Biodiversity, conservation, endemism, floristic diversity, microhabitats, plateau.

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Author contribution: CP and AKP designed and conceptualized the study. CP collected specimens and data for analysis, CP and AKP performed analysis of data. CP and AKP prepared the first draft of the manuscript and equally contributed in further editions.

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INTRODUCTION

In India, the hard crusts of laterite are mainly found on the western coast, from Dapoli in Ratnagiri in Maharashtra to Malappuram District in Kerala, and also on the Deccan Plateau (Balakrishnan et al. 2011). Distribution of laterite in Kerala, is mostly confined to an elevation of less than 600m, forming low flat topped ridges and hills, between the foothills of the Western Ghats and the Arabian Sea, mainly from Malappuram to Kasaragod (Varghese & Byju 1993). In the geographical documentation of the Government of Kerala these landscapes are marked as 'wastelands' (Anonymous 2019). The laterite hills are the most imposing feature of northern Kerala, which are extremely threatened both in terms of topography and biodiversity (Muraleedharan 2011). These plateaus are characterized by extremely harsh environment such as high temperature and lack of moisture content in the summer, leading to the development of unique vegetation, many of which show special adaptation to the environment. These severe conditions play a decisive role in the development of seasonal vegetation, where most of the plant species complete their life cycle during the monsoon period. When compared with granitic inselbergs (granitic rock outcrops), the vegetation and flora of lateritic plateaus has many unique peculiarities. The present study is an effort to record the floristic diversity and endemism of the Madayippara lateritic hillock in Kannur District of Kerala.

Image 1. Madayippara (From Google Earth).

Study Area

Madayippara, a good representative of the southern Indian midland lateritic plateaus, is located in Madayi Panchayath, near Payangadi Town in Kannur District of Kerala, southern India. The plateau covers an area of 3.65km^2, between 12.01–12.05 ^{0}N and 75.23–75.27 ^{0}E, at an altitude of about 50m from the mean sea level (Fig. 1; Image 1–3). The climatic conditions vary from hot dry to warm humid in different seasons, viz., pre-monsoon (March–May), monsoon (June–November), and post-monsoon (December–February); these together with edaphic factors account for the development of characteristic vegetation, as observed by Muller (2007).

Methods

Intensive field visits were carried out at Madayippara lateritic plateau covering all seasons during the period 2008–2017 to document floristic diversity. Different microhabitats on the plateau such as seasonal pools, soil covered areas, rocky surfaces, and tree associated vegetation along the valleys were surveyed repeatedly at different seasons and specimens were collected for laboratory studies and for the preparation of voucher specimens. Photographs of plants and habitats were taken using Nikon Coolpix L110 and Olympus C-7070 cameras. The voucher specimens were prepared following the wet method (Fosberg & Sachet 1965). The specimens were pressed in blotting paper, dried in a hot air oven, mounted on standard size, hand-made herbarium mount boards using a synthetic gum (Fevicol SH) and labeled and deposited at Calicut University Herbarium (CALI), duplicates of which are deposited at the herbarium of the Government Brennen College, Thalassery, Kerala. The specimens collected for laboratory studies were worked out using a LEICA M80, ZEISS Stemi DV4 and LABOMED CSM2 microscopes and identified using pertinent floras and relevant revisions and monographs; and by comparison with the specimens available at Calicut University Herbarium (CALI), Madras Herbarium (MH) and with the images in the Kew Herbarium (K) Catalogue (http://apps.kew.org/herbcat/navigator.do). Some of the specimens were referred to concerned experts in India and abroad for the confirmation of

Image 2. Views of the Madayipparara Plateau in different seasons: A—dried grasses in summer | B—sprouting of herbaceous species in early monsoon | C—flowering in monsoon. © Pramod C.

identification. The literature on phytogeography and endemism were referred to assess the distribution and endemism of each species. Conservation status of each species was checked with the available assessed data as per the IUCN Red list Categories and Criteria Version 3.1 (IUCN 2012). Endemism of taxa were recorded based on previous publications such as Sasidharan (2004) and online databases such as *World Checklist of Selected Plant Families* (http://apps.kew.org/wcsp/home.do). Botanical names were updated using online databases like *The International Plant Names Index* (IPNI) (http://ipni.org/ipni/plantnamesearchpage.do) and *World Checklist of Selected Plant Families* (http://apps.kew.org/wcsp/home.do) of the Royal Botanical Gardens, Kew.

RESULTS AND DISCUSSION

The vegetation of Madayippara lateritic plateau is divided into four broad categories with the characteristic flora associated with each of them (Jacobi et. al. 2007, modified). The plant species in the microhabitats are adapted to sustain in the adverse environmental conditions, such as seasonal drought, high temperature and nutrient scarcity. It has been observed that there is an overlap between most of the species in microhabitats with varying degree of dominance, as stated by Watve (2013), however, some species are always restricted to a particular microhabitat.

Bhattarai et al. (2012) in a study on the mesoscale distributions of endemic, rare, or locally important plant species on the plateau habitats and its escarpments, assessed the hydrological and edaphic parameters of seasonal plateau microhabitats on the Kas Plateau in Maharashtra. They found that almost two-thirds of over hundred phytogeographically important species occur on the plateau top. Since botanically critical plateau habitats are generally small, dependent on seasonal moisture of monsoon, and determined by drainage-related parameters that are altered by anthropogenic activities, they are highly threatened. Using the Kas region as a model lateritic system, they assessed its significant flora and habitats at two scales: mesoscale distributions in major ecological zones of the plateau and its subtending slopes, and microscale distributions on the plateau in seasonal habitats defined by hydrogeomorphic parameters such as moisture content, seasonal water retention capacity, profile of the soil, topographic variation, depth and texture of soil, and micro-elevational gradients. They identified 11 microhabitat types on the plateau top, that support varieties of plant species of phytogeographic significance during the monsoon. The plateau consists of a mosaic of floristically different habitats determined by hydrogeomorphic factors; for many of these habitats, the occupied area is very small in extent and seasonally ephemeral.

In a similar floristic analysis conducted in 10 threatened high altitude lateritic plateau ecosystems including Kas in the southwestern Maharashtra part of Western Ghats, Lekhak & Yadav (2012) recorded the presence of 361 taxa of herbaceous plants. Out of the reported 67 endemic species from the study area, 39 are restricted to lateritic plateaus only. They also identified 11 microhabitat types that support distinct plant communities depending primarily on the availability of soil and moisture. The plant communities of these

Figure 1. Flowering in different months.

habitats are usually edaphically controlled and show adaptation for water accumulation, such as succulence and poikilohydry, carnivory in response to the lack of nutrients in the soil and the presence of underground organs to overcome extreme temperature during summer.

The studies discussed above are from high altitude lateritic plateaus of the northern Western Ghats, and the area surveyed is large compared to the present study, however, climatic and geomorphologic characteristics of the microhabitats are found to be important for the distribution of endemic species in all cases. In a small area, strong endemic component in the flora is associated with seasonal moisture availability. These endemics occur in a variety of ephemeral microhabitats associated with edaphic features of the plateau (Bhattarai et al. 2012). In the present study, microhabitats are included in broader categories, as more emphasis is given to the floristic documentation of the entire plateau habitats and its escarpments. As tree cover and scrub patches on and around the plateau sustain more number of plant species, they support more number of endemic species.

(1) Exposed rock surfaces and crevices (RC): Laterite rock surfaces form one of the most important habitats that support a number of species adapted to this habitat. The micro environment of the lateritic rock surface and crevices are extremely different from that of the surrounding soil covered areas. The rock surfaces are characterized by very low moisture content, high thermal variation, very low organic carbon content and less availability of nutrients. The crevices and fissures on the rocks show the presence of little soil. A few of the plant species growing on exposed rock surfaces are desiccation tolerant.

(2) Seasonal ponds and small ephemeral pools (SP): During rainy seasons small and shallow ephemeral pools and some large ponds are formed on the plateau. These support a large number of hydrophytes including endemic species showing various degrees of rarity. The seasonal pools in the plateau are varying in their area, depth, soil cover and soil texture. The pools are just depressions on the plateau, either on laterite rock or on soil covered areas. If it is on rocks, thin layers of soil, rich in organic matter has been noted, which support the vegetation. The pools get dried up in post-monsoon periods and remain dry till pre-monsoon. They become water logged with the onset of southwest monsoon and dry up after the retreat of the northeast monsoon. Water in the seasonal pools is subjected to extreme diurnal changes in temperature due to the high surface to volume ratio (Pramod 2015). Germination of ephemeral vegetation in the seasonal pools is noticed after the first shower in May end or early June every year. A series of species are noticed progressively until they become dry in the months of October–November. This series include species such as *Geissaspis cristata*, *G. tenella, Isachne veldkampii*, *Murdannia ochracea*, *M. semiteres*, *Rotala malabarica*, *R. malampuzhensis*, *Schoenoplectiella articulata*, *S. lateriflora*, *Blyxa aubertii*, *B. octandra*, *Nymphoides krishnakesara*, *Echinochloa colona*, *Glyphochloa acuminata*, *Utricularia cecilii*, *U. graminifolia*, *Drosera indica*, *Fimbristylis tenera*, *F. aestivalis*, *F. ferruginea*, *Eriocaulon cuspidatum*, *E. reductum*, *E. eurypeplon*, *Coelachne madayensis*, *Neanotis subtilis*, *Dopatrium junceum*, *Oryza rufipogon*, *Rhamphicarpa longiflora*, *Wiesneria triandra*, *Hydrilla verticillata*, *Monochoria vaginalis*, and *Lindernia hyssopioides*. Almost all species are herbaceous and most of them complete their life cycle in a short period as the pools dry up.

(3) Soil covered areas and grassy plains and slopes (SC): Surrounding the rocky surfaces are the areas with soil cover of varied thickness from less than 1cm to more 1m, and on the southeastern part of the plateau grassy slopes with thick soil cover occur. The vegetation of the soil covered areas varies slightly depending on soil thickness. The areas with low soil thickness, which usually hold higher moisture content in the early monsoon are characterized by ephemeral flush vegetation, that are later replaced by grass and sedge species.

(4) Tree cover and scrub patches (TS): The upper flat terrain of the plateau, which is almost devoid of thick vegetation, is surrounded by tree vegetation of varying characteristics, from scrub jungles to thick semi evergreen forests. These forest patches are highly diverse with respect to species composition and the presence of endemic and rare elements. Though the top of the plateau is devoid of continuous tree cover, some isolated tree species are found. There are small scrub patches with short trees, shrubs and herbs. Madayikkavu is a sacred grove covering an area of 0.005km^2 with vegetation mainly composed of trees, shrubs, and climbers.

A total of 636 taxa of flowering plants, under 110 families, 406 genera, and 631 species were documented from the plateau. They are listed in the Table 1, with the families arranged according to APG system of classification (APG IV 2016). The genera and species are arranged in alphabetical order under respective families and genera. The area of the plateau is very small (3.65km^2), representing less than 0.01% of Kannur District, but it harbors about 59% of the flora of Kannur District (Ramachandran & Nair 1988). The immense diversity of flowering plants in Madayippara is due to the occurrence of diverse types of microhabitats and the ecological factors acting on them. The occurrence of a high percentage of endemic species belonging to diverse families in a small area indicates the complex nature of the habitat.

Eleven new taxa were discovered by different workers from this plateau, since 1990 (Table 2). They are *Rotala malabarica* (Pradeep et al., 1990), *Nymphoides krishnakesara* (Joseph & Sivarajan, 1990), *Justicia ekakusuma* (Pradeep & Sivarajan 1991), *Lepidagathis keralensis* (Madhusoodanan & Singh, 1992), *Eriocaulon madayiparense* (Swapna et al. 2012), *Lindernia madayiparensis* (Ratheesh Narayanan et al., 2012), *Coelachne madayensis* (Pramod et al. 2012), *Parasopubia hofmannii* (Pradeep & Pramod, 2013), *Parasopubia hofmannii* var. *albiflora* (Pradeep & Pramod, 2013), *Fimbristylis pokkudaniana* (Sunil et al., 2016), and *Chrysopogon narayaniae* (Sunil et al., 2017). Two recently described species from southern India, viz., *Eriocaulon gopalakrishnanum* K.Rashmi & G.Krishnak. and *Lindernia tamilnadensis* M.G.Prasad & Sunojk. also occur in this plateau. Recently, a number of new species were described from similar lateritic habitats of northern Kerala (Image 4 & 5) and plateaus of the Konkan region (Ansari et al. 1982; Bhat & Nagendran 1983; Nair et al. 1983; Yadav & Janarthanam 1994; Raju 1985; Potdar et al. 2004; Gad & Janarthanam 2007; Raj & Sivadasan 2008; Yadav et al. 2008, 2009, 2010; Malpure & Yadav 2009; Prabhugaonkar et al. 2009; Shimpale & Yadav 2010; Nandikar & Gurav 2011; Kambale et al. 2012; Potdar & Yadav 2012; Prasad & Raveendran 2013a&b; Prasad et al. 2012; Shahina & Nampy 2014; Gaikwad et al. 2014; Biju et al. 2016a,b,c; Darshetkar et al. 2017; Bokil et al. 2020). Most of the species described from such habitats belong to diverse families. This shows that complex and diverse microhabitats of the plateaus support rich and varied flora.

The substrata of the plateau are highly variable ranging from the deep soil profile of grasslands in the valleys to the ultra-thin film of humus on the exposed rock surfaces. In rock surfaces, the vegetation is very distinct with the predominance of drought tolerant species. The fine dust and humus accumulated in the vermiform tubes and cavities of the laterite rock provide nutrients to the supporting herbaceous vegetation. Species such as *Lepidagathis keralensis*, *Euphorbia deccanensis*, and *Polycarpaea corymbosa* occur on open lateritic surfaces mostly rooted in the humus rich crevices of the laterite rocks. The plateau is subjected to high degree of seasonal variation in the vegetation and flora. The most important factor that determines the vegetation is the soil moisture content. In the pre-monsoon period, the open plateau is looking almost barren with few dried grass species of the post-monsoon period. The germination of the seasonal vegetation starts with the summer shower in May and continues later at the onset of south-west monsoon in June. The early monsoon is dominated by ephemeral flush vegetation, which is taken over later by grass and sedge species at the end and continued in the post monsoon period. The monsoon months (June–November) shows the peak of flowering of species, due to the appearance of ephemeral species, grasses and sedges in the open plateau, as shown in Figure 1. In the pre-monsoon and post-monsoon months, flowering is dominated by woody species in the scrub patches and tree cover.

Rarity and endemism

Western Ghats harbours around 1,600 endemic plant species (Nayar 1996), which are documented by many workers, but the diversity and endemism of midland lateritic hillocks and wetlands are seldom documented. Out of the 636 taxa recorded from Madayippara, 160 (c. 25%) are endemics (Table 1). Since the maximum number of plant species were recorded in the tree cover and scrub patches, they hold highest number of endemic species also. Many of the endemic species occur in specialized microhabitats. For example, species such as *Lepidagathis keralensis* is restricted to hard lateritic rocks with extreme xeric environment; *Coelachne madayensis* occur in seasonal pools in well exposed sunny locations with submerged foliage and emergent panicles;

Table 1. A list of flowering plant taxa recorded from the Madayippara Lateritic Plateau.

Family	Taxa	Microhabitat	Flowering	Endemism	IUCN RL Status
PIPERACEAE	*Peperomia pellucida* (L.) Kunth	TS	Sep–Dec		
	Piper argyrophyllum Miq.	TS	Jul–Feb	WG & SL	
	P. longum L.	TS	Aug–Jan		
ARISTOLOCHIACEAE	*Aristolochia indica* L.	TS	Jul–Mar		
MAGNOLIACEAE	*Magnolia champaca* (L.) Baill. ex Pierre	TS	Mar–Jul		
ANNONACEAE	*Miliusa tomentosa* (Roxb.) Finet & Gagnep.	TS	Oct–May		
	Polyalthia korinti (Dunal) Thwaites	TS	Apr–Jun	SI & SL	
	Uvaria narum (Dunal) Blume	TS	Nov–Jun	SI & SL	
LAURACEAE	*Alseodaphne semecarpifolia* Nees var. *semecarpifolia*	TS	Feb–Apr	PI & SL	
	Cinnamomum verum J.Presl	TS	Mar–Apr	SWI & SL	
	Litsea deccanensis Gamble	TS	Nov–Dec	SI & SL	
	L. glutinosa (Lour.) C.B.Rob.	TS	Apr–May		
ARACEAE	*Amorphophallus hohenackeri* (Schott) Engl. & Gehrm.	TS	Jun–Aug	WG	
	A. paeoniifolius (Dennst.) Nicolson	TS	May–Jun		LC
	Ariopsis peltata Nimmo	TS	Jun–Aug		
	Arisaema neglectum Schott	TS	Apr–Jul	WG	
	Caladium bicolor (Aiton) Vent.	SC	Dec–Jan		
	Colocasia esculenta (L.) Schott	SC	May–Oct		LC
	Cryptocoryne spiralis (Retz.) Fisch. ex Wydler	SC	Oct–Apr	I	
	Pistia stratiotes L.	SP	Oct–Mar		LC
	Pothos scandens L.	TS	Oct–Nov		
	Rhaphidophora pertusa (Roxb.) Schott	TS	Aug–Sep	I & SL	
	Theriophonum infaustum N.E.Br.	TS	Jul–Sep	SWG	
ALISMATACEAE	*Wiesneria triandra* (Dalzell) Micheli	SP	Aug–Nov	PI	LC
HYDROCHARITACEAE	*Blyxa aubertii* Rich.	SP	Jun–Sep		LC
	B. octandra (Roxb.) Planch. ex Thwaites	SP	Jun–Oct		LC
	Hydrilla verticillata (L.f.) Royle	SP	Jan–Dec		LC
BURMANNIACEAE	*Burmannia coelestis* D.Don	SC	Oct–Dec		LC
DIOSCOREACEAE	*Dioscorea bulbifera* L.	TS	Sep–Oct		
	D. pentaphylla L.	TS	Sep–Dec		
	D. wallichii Hook.f.	TS	Oct–Nov		LC
PANDANACEAE	*Pandanus odorifer* (Forssk.) Kuntze	TS	Jul–Nov		LC
COLCHICACEAE	*Iphigenia indica* (L.) A.Gray ex Kunth	TS	Jul–Sep		
SMILACACEAE	*Smilax zeylanica* L.	TS	Jul–Jan		
ORCHIDACEAE	*Acampe praemorsa* (Roxb.) Blatt. & McCann	TS	Mar–Apr		
	Bulbophyllum rosemarianum C.S.Kumar, P.C.S.Kumar & Saleem	TS	Jan–Mar	SWG	
	Crepidium resupinatum (G.Forst.) Szlach.	TS	Jul–Sep		
	Habenaria diphylla (Nimmo) Dalzell	SC	Sep–Nov		
HYPOXIDACEAE	*Curculigo orchioides* Gaertn.	SC	Jun–Dec		
AMARYLLIDACEAE	*Crinum viviparum* (Lam.) R.Ansari & V.J.Nair	SC	Jan–Dec	I & SL	LC
	Hymenocallis littoralis (Jacq.) Salisb.	SC	Jan–Dec		
	Pancratium triflorum Roxb.	SC	Mar–May	I & SL	

Family	Taxa	Microhabitat	Flowering	Endemism	IUCN RL Status
ASPARAGACEAE	*Chlorophytum nimmonii* (Graham) Dalzell	TS	Aug–Nov		
	Borassus flabellifer L.	TS	Mar–Sep		
	Calamus metzianus Schltdl.	TS	Nov–Jun	WG	
	Caryota urens L.	TS	Jan–Apr		LC
COMMELINACEAE	*Commelina diffusa* Burm.f.	SC	Jul–Sep		LC
	C. kurzii C.B.Clarke	TS	Jul–Oct		
	Cyanotis axillaris (L.) D.Don ex Sweet	SC	Aug–Dec		LC
	C. burmanniana Wight	RC	Aug–Dec	WG	LC
	C. cristata (L.) D.Don	SC	Jul–Oct		LC
	Murdannia dimorpha (Dalzell) G.Brückn.	SC	Jul–Sep	PI & SL	
	M. ochracea (Dalzell) G.Brückn.	SP	Aug–Sep	PI	
	M. semiteres (Dalzell) Sant.	SC/RC	Aug–Dec	PI	LC
	M. spirata (L.) G.Brückn.	SC	Aug–Nov		LC
PONTEDERIACEAE	*Monochoria vaginalis* (Burm.f.) C.Presl	SP	Jul–Nov		LC
COSTACEAE	*Hellenia speciosa* (J.Koenig) S.R.Dutta	TS	Jul–Oct		
ZINGIBERACEAE	*Curcuma aeruginosa* Roxb.	TS/SC	Apr–May		
	C. cannanorensis R.Ansari, V.J.Nair & N.C.Nair	TS	May–Jun	SWG	
	C. longa L.	TS	Sep–Oct		
	C. zedoaria (Christm.) Roscoe	TS	Apr–May	I	
	Zingiber zerumbet (L.) Roscoe ex Sm.	TS	Jul–Nov		
XYRIDACEAE	*Xyris pauciflora* Willd.	SC	Aug–Oct		LC
ERIOCAULACEAE	*Eriocaulon cuspidatum* Dalzell	SP	Aug–Jan	WG	LC
	E. eurypeplon Körn.	SP	Jul–Dec	PI	LC
	E. gopalakrishnanum K.Rashmi & G. Krishnak.	SC	Aug–Dec	SI (K)	
	E. kolhapurense S.P. Gaikwad, Sardesai & S.R. Yadav	SC	Aug–Nov	WG	VU
	E. reductum Ruhland	SP	Sep–Mar	WG	
	E. xeranthemum Mart.	SC	Jul–Sep		LC
CYPERACEAE	*Bulbostylis densa* (Wall.) Hand.-Mazz.	SC	Sep–Nov		LC
	Cyperus amabilis Vahl	SC	Aug–Dec		LC
	C. compressus L.	SC	Jan–Dec		LC
	C. cyperinus (Retz.) Suringar	SC	Jun–Aug		
	C. difformis L.	SC	Jan–Dec		LC
	C. iria L.	SC	Nov–Dec		LC
	C. javanicus Houtt.	SC	Jan–Dec		
	C. rotundus subsp. *retzii* (Nees) Kuk.	SC	Jun–Dec		LC
	C. rotundus L. subsp. *rotundus*	SC	Jun–Dec		LC
	C. surinamensis Rottb.	SC	Jul–Dec		
	Eleocharis atropurpurea (Retz.) J.Presl & C.Presl	SC	Nov–Dec		LC
	E. dulcis (Burm.f.) Trin. ex Hensch.	SP	Sep–Dec		
	Fimbristylis aestivalis (Retz.) Vahl	SC	Jan–Apr		
	F. argentea (Rottb.) Vahl	SC	Jun–Dec		LC
	F. dichotoma subsp. *podocarpa* (Nees & Meyen) T.Koyama	SC	Mar–Dec		LC
	F. dipsacea (Rottb.) C.B.Clarke	SC	Jan–May		LC

Family	Taxa	Microhabitat	Flowering	Endemism	IUCN RL Status
	F. ferruginea (L.) Vahl	SC	Aug–Dec		LC
	F. ovata (Burn.f.) J.Kern	SC	Aug–Mar		LC
	F. pokkudaniana Sunil, Ratheesh & Sivad.	SP	Aug–Sep	SWG (K)	
	F. quinquangularis (Vahl) Kunth	SP	Oct–Nov		LC
	F. schoenoides (Retz.) Vahl	SC	Sep–Dec		LC
	F. tenera Roem. & Schult.var. *tenera*	SC	Jul–Jan		
	Fuirena ciliaris (L.) Roxb.	SC	Oct–Mar		LC
	Kyllinga brevifolia Rottb. var. *brevifolia*	SC	Jul–Nov		LC
	K. brevifolia var. *stellulata* (Valck.Sur.) S.S.Hooper	SC	Jul–Nov		LC
	K. bulbosa P.Beauv.	SC	Jun–Dec		LC
	Lipocarpha squarrosa (L.) Goetgh.	SC	Aug–Dec		
	Pycreus malabaricus C.B.Clarke	SC	Jul–Dec	PI	
	P. polystachyos (Rottb.) P.Beauv. subsp. *polystachyos*	SC	Jan–Dec		LC
	P. pumilus (L.) Nees	SC	Jan–Dec		LC
	P. stramineus C.B.Clarke	SC	Aug–Dec		LC
	Rhynchospora wightiana (Nees) Steud.	SC	Aug–Nov		
	Schoenoplectiella articulata (L.) Lye	SP	Aug–Dec		
	S. lateriflora (J.F.Gmel.) Lye	SP	Aug–Dec		LC
	Scleria lithosperma (L.) Sw. var. *lithosperma*	TS	Jan–Dec		
POACEAE	*Alloteropsis cimicina* (L.) Stapf	SC	Jul–Nov		
	Apocopis mangalorensis (Hochst. ex Steud.) Henrard	SC	Oct–Feb	PI	
	Arundinella cannanorica V.J.Nair, Sreek. & N.C.Nair	RC	Oct–Dec	SWG (K)	
	A. ciliata (Roxb.) Nees ex Miq.	SC	Oct–Nov	PI	
	A. pumila (Hochst. ex A.Rich.) Steud.	SC/RC	Jul–Dec		
	A. purpurea Hochst. ex Steud.	SC	Aug–Dec	SI	
	A. setosa Trin.	SC	May–Dec		
	Bambusa bambos (L.) Voss	TS	Jul–Feb	I & SL	
	Brachiaria ramosa (L.) Stapf	SC	Mar–Sep		LC
	B. subquadripara (Trin.) Hitchc.	SC	Jul–Dec		LC
	Capillipedium assimile (Steud.) A.Camus	SC	Oct–Nov		
	Chloris barbata Sw.	SC	Mar–Dec		
	Chrysopogon narayaniae Sunil, Ratheesh & Sivad.	RC	Oct–Dec	SWG (K)	
	C. tadulingamii Sreek., V.J. Nair & N.C.Nair	RC	Oct–Dec	SWG (K)	
	Coelachne madayensis Pramod & Pradeep	SP	Jul–Sep	SI (K)	
	Coix lacryma-jobi L.	SC	Jul–Mar		
	Cynodon dactylon (L.) Pers.	SC	Mar–Oct		
	Cyrtococcum trigonum (Retz.) A.Camus	SC	Sep–Oct		
	Dactyloctenium aegyptium (L.) Willd.	SC	Jan–Dec		
	Digitaria ciliaris (Retz.) Koeler	SC	Jul–Nov		
	Dimeria copeana Sreek., V.J.Nair & N.C.Nair	SC	Dec–Mar	SI (K)	
	D. hohenackeri Hochst. ex Miq.	SC/RC	Oct–Dec	PI	EN
	D. stapfiana C.E.Hubb. ex Pilg.	SC/RC	Oct–Dec	SI	

Family	Taxa	Microhabitat	Flowering	Endemism	IUCN RL Status
	D. thwaitesii Hack. in A.DC. & C.DC.	SC/RC	Sep–Dec	I & SL	
	Echinochloa colona (L.) Link	SP	Jan–Dec		LC
	Eleusine indica (L.) Gaertn.	SC	Jan–Dec		
	Eragrostis amabilis (L.) Wight & Arn.	SC	Jul–Nov		
	E. atrovirens (Desf.) Trin. ex Steud.	SC	Jan–Dec		
	E. gangetica (Roxb.) Steud.	SC	Jun–Dec		
	E. unioloides (Retz.) Nees ex Steud.	SC	Jan–Dec		LC
	Eulalia trispicata (Schult.) Henrard	SC	Oct–Mar		
	Glyphochloa acuminata (Hack.) Clayton var. *acuminata*	SC/SP/RC	Oct–Feb	PI	
	G. acuminata var. *woodrowii* (Bor) Clayton	RC	Oct–Dec	SI	
	Heteropogon contortus (L.) P.Beauv. ex Roem. & Schult.	SC	Oct–Dec		
	Isachne globosa (Thunb.) Kuntze	SC	Jan–Dec		LC
	I. miliacea Roth	SC	Jan–Dec		
	I. veldkampii K.G.Bhat & Nagendran	SP	Aug–Oct	SI	CR
	Ischaemum barbatum Retz.	SP	Oct–Jan		
	I. cannanorense Sreek., V.J.Nair & N.C.Nair	RC	Sep–Dec	SI (K)	
	I. ciliare Retz.	SC	Oct–Nov		
	I. keralense Sreek., V.J.Nair & N.C.Nair	SC	Oct–Dec	SWG (K)	
	I. lanatum Ravi, N.Mohanan & Shaju	TS	Oct–Jan	SWG (K)	
	I. rangacharianum C.E.C.Fisch.	SP	Sep–Dec	SI & SL	
	Limnopoa meeboldii (C.E.C.Fisch.) C.E.Hubb.	SP	Sep–Nov	SI (K)	EN
	Melinis repens (Willd.) Zizka	SC	Mar–Aug		
	Oplismenus burmanni (Retz.) P.Beauv.	TS	Sep–Nov		
	Oryza rufipogon Griff.	SP	Sep–Mar		LC
	O. sativa L.	SC	Sep–Jun		
	Panicum repens L.	SC	Jul–Sep		LC
	Paspalidium geminatum (Forssk.) Stapf	SC	Jun–Mar		LC
	Paspalum conjugatum P.J.Bergius	SC	Jan–Dec		LC
	P. scrobiculatum L.	SC	Jan–Dec		LC
	Pennisetum pedicellatum Trin.	SC	Sep–Dec		
	P. polystachion (L.) Schult.	SC	Apr–Dec		
	Pseudanthistiria umbellata (Hack.) Hook.f.	TS	Nov–Dec	PI & SL	
	Sacciolepis interrupta (Willd.) Stapf	SP	Jan–Dec		
	Setaria pumila (Poir.) Roem. & Schult.	SC	Jul–Oct		
	Sporobolus diandrus (Retz.) P.Beauv.	SC	Mar–Sep		
	S. pilifer (Trin.) Kunth	SC/RC	Sep–Dec		
	Themeda triandra Forssk.	SC	Oct–Jan		
MENISPERMACEAE	*Anamirta cocculus* (L.) Wight & Arn.	TS	Aug–Dec		
	Cyclea peltata (Lam.) Hook.f. & Thomson	TS	Apr–May	I & SL	
	Diploclisia glaucescens (Blume) Diels	TS	Mar–Aug		
	Tinospora cordifolia (Willd.) Miers.	TS	Jan–Jun		
	T. sinensis (Lour.) Merr.	TS	Feb–Jun		
RANUNCULACEAE	*Naravelia zeylanica* (L.) DC.	TS	Oct–Apr		

Family	Taxa	Microhabitat	Flowering	Endemism	IUCN RL Status
CRASSULACEAE	*Bryophyllum pinnatum* (Lam.) Kurz	TS	Jul–Oct		
VITACEAE	*Ampelocissus latifolia* (Roxb.) Planch.	TS	May–Jun		
	Cayratia tenuifolia (Wight & Arn.) Gagnep.	TS	Sep–Mar		
	C. trifolia (L.) Domin	RC	Jan–Dec		
	Cissus discolor Blume	TS	Jul–Jan		
	C. heyneana Steud.	TS	Apr–Jun	SI & SL	
	C. latifolia Lam.	TS	Jun–Sep	PI & SL	
	C. repens Lam.	TS	Nov–Dec		
	Leea indica (Burm.f.) Merr.	TS	Mar–Aug		
FABACEAE: Papilionoideae	*Abrus precatorius* L.	TS	Oct–May		
	A. pulchellus Wall. ex Thwaites	TS	Oct–Mar		
	Aeschynomene americana L.	SC	Sep–Dec		
	A. indica L.	SP	Aug–Dec		LC
	Alysicarpus bupleurifolius (L.) DC.	SC/RC	Sep–Jan		LC
	A. vaginalis (L.) DC. var. *vaginalis*	SC	Sep–Jan		
	Cajanus cajan (L.) Millsp.	SC	Dec–Mar		
	C. scarabaeoides (L.) Thouars	SC	Sep–Jan		LC
	Calopogonium mucunoides Desv.	SC	Aug–Dec		
	Canavalia gladiata (Jacq.) DC.	TS	Jul–Dec		
	Centrosema molle Benth.	TS	Sep–Jan		
	Clitoria ternatea L. var. *ternatea*	SC	Jul–Oct		
	Crotalaria evolvuloides Wight ex Wight & Arn.	SC	Oct–Feb	PI & SL	
	C. pallida Aiton var. *pallida*	SC	Sep–Jan		
	C. quinquefolia L.	SC	Sep–Dec		LC
	C. verrucosa L.	SC	Aug–Nov		
	Dalbergia horrida (Dennst.) Mabb. var. *horrida*	TS	Sep–Jan	SWG	
	Derris scandens (Roxb.) Benth.	TS	Jun–Dec		
	Desmodium heterophyllum (Willd.) DC.	SC	Jul–Dec		
	D. scorpiurus (Sw.) Desv.	SC	Dec–Jul		
	D. triflorum (L.) DC.	SC	Jul–Dec		
	D. triquetrum (L.) DC.	TS	Jul–Dec		
	Erythrina variegata L.	TS	Mar–Apr		LC
	Geissaspis cristata Wight & Arn.	SP	Jul–Sep		LC
	G. tenella Benth. var. *tenella*	SP/RC	Aug–Nov	WG	LC
	Gliricidia sepium (Jacq.) Kunth ex Walp.	TS	Mar–May		
	Indigofera hirsuta L.	SC	Jul–Dec		
	I. tinctoria L.	SC	Aug–Dec		
	I. trifoliata L.	SC	Sep–Dec		
	Mucuna pruriens (L.) DC. var. *pruriens*	TS	Oct–Feb		
	Pongamia pinnata (L.) Pierre	TS	Apr–Dec		LC
	Pseudarthria viscida (L.) Wight & Arn.	TS	Nov–Mar	PI & SL	
	Pterocarpus marsupium Roxb.	TS	Sep–Oct	I & SL	VU
	Sesbania bispinosa (Jacq.) W.Wight	SP	Jul–Dec		LC
	Smithia conferta Sm.	SC	Nov–Feb		

Family	Taxa	Microhabitat	Flowering	Endemism	IUCN RL Status
	S. salsuginea Hance	SC/ TS	Oct–Nov	PI	
	S. sensitiva Aiton	SC	Aug–Dec		LC
	Stylosanthes fruticosa (Retz.) Alston	SC	Sep–Jan		
	S.guianensis (Aubl.) Sw.	SC	Jul–Nov		
	Tephrosia purpurea (L.) Pers.	SC	Oct–Dec		
	Vigna trilobata (L.) Verdc.	SC	Jul–Dec		
	Zornia gibbosa Span.	SC	Sep–Jan		
FABACEAE: Caesalpinioideae	*Bauhinia purpurea* L.	TS	Sep–Dec		LC
	B. scandens var. *anguina* (Roxb.) Ohashi	TS	Sep–Mar		
	Caesalpinia mimosoides Lam.	TS	Jan–Mar		
	Cassia fistula L.	TS	Feb–May		
	Chamaecrista mimosoides (L.) Greene	SC	Jul–Dec		
	C. nictitans subsp. *patellaria* var. *glabrata* (Vogel) H.S.Irwin & Barneby	SC/RC	Aug–Oct		LC
	Delonix regia (Bojer) Raf.	TS	Feb–Jul		LC
	Peltophorum pterocarpum (DC.) Backer ex K.Heyne	TS	Jan–Dec		
	Senna alata (L.) Roxb.	SC	Sep–Jan		
	S. hirsuta (L.) H.S.Irwin & Barneby	SC	Sep–Dec		
	S. occidentalis (L.) Link	SC/ TS	Jul–Dec		
	S. siamea (Lam.) H.S.Irwin & Barneby	TS	Oct–Mar		
	S. tora (L.) Roxb.	SC	Aug–Dec		
	Tamarindus indica L.	TS	Sep–Apr		
FABACEAE: Mimosoideae	*Acacia auriculiformis* A.Cunn. ex Benth.	TS	Jan–Dec		LC
	A. caesia (L.) Willd.	TS	Oct–Dec		LC
	A. mangium Willd.	TS	Jul–Feb		
	A. pennata (L.) Willd.	TS	Oct–Jan		
	Adenanthera pavonina L.	TS	Jan–Sep		
	Albizia chinensis (Osbeck) Merr.	TS	Mar–Jul		
	A. lebbeck (L.) Benth.	TS	Mar–Dec		
	A. saman (Jacq.) F.Muell.	TS	Mar–May		
	Dichrostachys cinerea (L.) Wight & Arn.	SC	Oct–Jan	I & SL	LC
	Leucaena leucocephala (Lam.) de Wit	TS	Nov–Apr		
	Mimosa diplotricha C.Wight ex Sauvalle var. *diplotricha*	SC	Nov–Mar		
	M. pudica L.	SC	Jul–Jan		LC
POLYGALACEAE	*Polygala elongata* Klein ex Willd.	SC/RC	Jul–Jan	I & SL	
	Salomonia ciliata (L.) DC.	SC	Oct–Dec		
RHAMNACEAE	*Ziziphus mauritiana* Lam.	TS	Feb–Jul		
	Z. oenopolia (L.) Mill.	TS	Nov–Mar		
	Z. rugosa Lam.	TS	Nov–May		
ULMACEAE	*Holoptelea integrifolia* (Roxb.) Planch.	TS	Dec–Mar		
CANNABACEAE	*Celtis timorensis* Span.	TS	Jan–Mar		
	Trema orientalis (L.) Blume	TS	Sep–Dec		
MORACEAE	*Artocarpus heterophyllus* Lam.	TS	Nov–Apr		
	Ficus arnottiana (Miq.) Miq.	TS	Dec–Apr	I & SL	
	F. benghalensis L. var. *benghalensis*	TS	May–Aug	I	

Family	Taxa	Microhabitat	Flowering	Endemism	IUCN RL Status
	F. callosa Willd.	TS	Mar–Apr		
	F. exasperata Vahl	TS	Feb–Apr		
	F. heterophylla L.f.	SC	Sep–Dec		
	F. hispida L.f.	TS	Sep–May		
	F. racemosa L.	TS	Feb–May		
	F. religiosa L.	TS	Nov–Feb		
	F. tinctoria subsp. *parasitica* (Koen. ex Willd.) Corner	TS	Mar–Apr		
	Morus alba L.	SC	Jan–Dec		
URTICACEAE	*Laportea interrupta* (L.) Chew	SC	Aug–Sep		
	Pilea microphylla (L.) Liebm.	SC/RC	Aug–Nov		
	Pouzolzia zeylanica (L.) Benn.	SC	Aug–Dec		
CUCURBITACEAE	*Coccinia grandis* (L.) Voigt	SC	Dec–Apr	PI & SL	
	Cucumis sativus f. *hardwickii* (Royle) W.J.de Wilde & Duyfjes	TS	Nov–May		
	Diplocyclos palmatus (L.) C.Jeffrey	TS	Nov–Jan		
	Mukia maderaspatana (L.) M.Roem.	TS	Jan–Dec		
	Solena amplexicaulis (Lam.) Gandhi	TS	Jul–Jan		
	Trichosanthes cucumerina L.	TS	Dec–May		
	T. tricuspidata var. *tomentosa* (Heyne ex C.B.Clarke) Kumari	TS	Dec–Jan	SWI & SL	
BEGONIACEAE	*Begonia crenata* Dryand.	TS	Aug–Nov	WG	
CELASTRACEAE	*Glyptopetalum zeylanicum* Thwaites	TS	Jul–Dec	PI & SL	
	Loeseneriella arnottiana (Wight) A.C.Sm.	TS	Feb–Mar	SI & SL	
	Salacia chinensis L.	TS	Feb–Mar		
	S. fruticosa Heyne ex M.A.Lawson	TS	Feb–May	WG	
CONNARACEAE	*Connarus paniculatus* Roxb.	TS	Oct–May		
	Rourea minor (Gaertn.) Alston	TS	Dec–Aug		
OXALIDACEAE	*Biophytum reinwardtii* (Zucc.) Klotzsch.	SC	Jul–Dec		
RHIZOPHORACEAE	*Carallia brachiata* (Lour.) Merr.	TS	Oct–Apr		
EUPHORBIACEAE	*Agrostistachys indica* Dalzell	TS	Feb–Mar	C & PI	
	Croton caudatus Geiseler	TS	Mar–May		
	Euphorbia deccanensis V.S.Raju	RC	Jul–Dec	SI (K)	
	E. heterophylla L.	SC	Jun–Aug		
	E. hirta L.	SC	Jan–Dec		
	E. thymifolia L.	SC	Nov–May		
	E. tithymaloides L.	SC	Apr–Aug		
	Falconeria insignis Royle	TS	Jan–Feb		
	Jatropha gossypiifolia L.	SC	Jul–Sep		
	Macaranga peltata (Roxb.) Müll.-Arg.	TS	Jan–Feb	I & SL	
	Mallotus philippensis (Lam.) Müll.-Arg.	TS	Oct–Mar		
	M. repandus (Rottler) Müll.–Arg.	TS	Nov–Jan		
	Micrococca mercurialis (L.) Benth.	SC	Jun–Dec		
	Microstachys chamaelea (L.) Müll.-Arg.	SC	Jul–Dec		
	Tragia involucrata L.	SC/TS	Jul–Dec	I & SL	
OCHNACEAE	*Gomphia serrata* (Gaertn.) Kanis	TS	Jan–Dec		LC
PHYLLANTHACEAE	*Antidesma ghaesembilla* Gaertn.	TS	Jul–Dec		

Family	Taxa	Microhabitat	Flowering	Endemism	IUCN RL Status
	A. montanum Blume	TS	Dec–Apr		
	Aporosa cardiosperma (Gaertn.) Merr.	TS	Dec–Jun	PI & SL	
	Breynia vitis-idaea (Burm.f.) C.E.C.Fisch.	TS	Feb–Aug	I & SL	
	Bridelia retusa (L.) A.Juss.	TS	Aug–Dec		
	B. stipularis (L.) Blume	TS	Dec–Feb	PI	
	Flueggea leucopyrus Willd.	TS	Jun–Sep		
	F. virosa (Roxb. ex Willd.) Royle	SC	Mar–Sep		
	Phyllanthus airy-shawii Jean F.Brunel & J.P.Roux	SC	Jul–Jan	PI & SL	
	P. amarus Schumach. & Thonn.	SC	Jul–Oct		
	P. emblica L.	TS	Jul–Feb		
	P. reticulatus Poir.	SC/TS	Aug–Dec		
	P. urinaria L.	SC	Jul–Oct		
	P. virgatus var. *virgatus* G.Forst.	SC/RC	Jan–Dec		
	Sauropus androgynus (L.) Merr.	TS	Aug–Dec		
	S. quadrangularis (Willd.) Müll.-Arg.	TS	Jan–Dec		
MALPIGHIACEAE	*Aspidopterys canarensis* Dalzell	TS	Feb–May	WG	
PASSIFLORACEAE	*Passiflora foetida* L. var. *foetida*	TS	Jul–Dec		
	P. foetida var. *hispida* (DC. ex Triana & Planch.) Killip	TS	Nov–Mar		
	Turnera ulmifolia L.	TS	May–Dec		
SALICACEAE	*Flacourtia indica* (Burm.f.) Merr.	TS	Nov–Mar		
VIOLACEAE	*Hybanthus enneaspermus* (L.) F.Muell.	SC	Jul–Nov		
ACHARIACEAE	*Hydnocarpus pentandrus* (Buch.-Ham.) Oken	TS	Dec–May	WG	
LINACEAE	*Hugonia mystax* L.	TS	Aug–Oct	I & SL	
CLUSIACEAE	*Garcinia gummi-gutta* (L.) N.Robson var. *gummi-gutta*	TS	Jan–Sep	SI & SL	
COMBRETACEAE	*Calycopteris floribunda* (Roxb.) Lam. ex Poir.	TS	Jan–May		
	Combretum indicum (L.) DeFilipps	TS	Jul–Mar		
	C. latifolium Blume	TS	Dec–Apr		
	Terminalia bellirica (Gaertn.) Roxb.	TS	Dec–Jan		
	T. catappa L.	TS	Mar–Jan		
	T. paniculata Roth	TS	Aug–Feb	PI	
LYTHRACEAE	*Ammannia baccifera* L. subsp. *baccifera*	SP	Sep–Dec		LC
	Lagerstroemia speciosa (L.) Pers.	TS	Mar–Nov		
	Lawsonia inermis L.	TS	Dec–May		
	Rotala indica (Willd.) Koehne	SP	Jul–Dec		LC
	R. macrandra Koehne	SP	Sep–Jan	WG	LC
	R. malabarica Pradeep, K.T.Joseph & Sivar.	SP	Jul–Sep	SI (K)	CR
	R. malampuzhensis R.V.Nair ex C.D.K.Cook	SP	Jul–Sep	WG	LC
	R. rosea(Poir.) C.D.K.Cook	SP	Aug–Feb		LC
ONAGRACEAE	*Ludwigia hyssopifolia* (G.Don) Exell	SP/SC	Aug–Dec		LC
MYRTACEAE	*Syzygium caryophyllatum* (L.) Alston	TS	Feb–Jun		EN
	S. cumini (L.) Skeels	TS	Dec–Apr		
	S. jambos (L.) Alston	TS	Oct–Jan		
MELASTOMATACEAE	*Melastoma malabathricum* L.	TS	Jan–Dec		

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	Memecylon randerianum S.M.Almeida & M.R.Almeida	TS	Feb–May	SWG	
	M. umbellatum Burm.f.	TS/SC	Feb–Mar	PI & SL	
	Osbeckia muralis Naudin	SC	Sep–Dec	WG	
ANACARDIACEAE	*Anacardium occidentale* L.	TS	Nov–Apr		
	Holigarna arnottiana Hook.f.	TS	Jan–Jul	SWG	
	Lannea coromandelica (Houtt.) Merr.	TS	Jan–May		
	Mangifera indica L.	TS	Jan–May		DD
	Nothopegia heyneana (Hook.f.) Gamble	TS	May–Jun	WG	NT
	Spondias pinnata (L.f.) Kurz	TS	Mar–Dec		
SAPINDACEAE	*Allophylus cobbe* (L.) Raeusch.	TS	Jul–Nov		
	A. serratus (Roxb.) Kurz	TS	Jul–Oct	I & SL	
	Cardiospermum halicacabum L.	TS	Jul–Feb		
	Sapindus trifoliatus L.	TS	Dec–Apr		
	Schleichera oleosa (Lour.) Oken	TS	Mar–Jun		
RUTACEAE	*Aegle marmelos* (L.) Correa	TS	Mar–May	I & SL	
	Glycosmis mauritiana (Lam.) Tanaka	TS	Oct–May		
	G. pentaphylla (Retz.) DC.	TS	Sep–Apr		
	Melicope lunu-ankenda (Gaertn.) T.G.Hartley	TS	May–Jul		
	Murraya koenigii (L.) Spreng.	TS	Mar–Jul		
	Zanthoxylum rhetsum (Roxb.) DC.	TS	Mar–Nov		
SIMAROUBACEAE	*Ailanthus triphysa* (Dennst.) Alston	TS	Dec–Jul		
MELIACEAE	*Aglaia elaeagnoidea* (A.Juss.) Benth.	TS	Aug–Dec		LC
	Azadirachta indica A.Juss.	TS	Feb–Sep		
	Naregamia alata Wight & Arn.	SC/TS	Aug–Dec	PI	
MALVACEAE	*Corchorus aestuans* L.	SC	Aug–Feb		
Grewioideae	*C. capsularis* L.	SC	Jul–Nov		
	Grewia nervosa (Lour.) Panigrahi	TS	Aug–Apr		
	Triumfetta rhomboidea Jacq.	TS/SC	Aug–Feb		
Byttnerioideae	*Melochia corchorifolia* L.	SC	Jul–Apr		
	Waltheria indica L.	SC	Oct–Jan		
Sterculioideae	*Sterculia guttata* Roxb. ex DC.	TS	Sep–Mar		
Dombeyoideae	*Pterospermum diversifolium* Blume	TS	Dec–Apr		
	P. rubiginosum B.Heyne ex Wight & Arn.	TS	Nov–Apr	SWG	
Helecteroideae	*Helicteres isora* L.	TS	Sep–Mar		
Malvoideae	*Abelmoschus angulosus* var. *grandiflorus* Thwaites	SC/TS	Aug–Dec	SI & SL	
	Abutilon indicum (L.) Sweet var. *indicum*	SC	Sep–Apr		
	Fioria vitifolia (L.) Mattei	TS	Apr–Dec		
	Hibiscus hispidissimus Griff.	TS	Sep–Mar		
	H. sabdariffa L.	TS	Dec–Feb		
	H. surattensis L.	TS	Oct–Jan		
	Sida acuta Burm.f.	SC	Aug–Oct		
	S. alnifolia L.	SC/TS	Sep–Dec		
	S. mysorensis Wight & Arn.	SC	Oct–Feb		
	Urena sinuata L.	SC	Aug–Dec		

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Bombacoideae	*Bombax ceiba* L.	TS	Jan–Apr		
	Ceiba pentandra (L.) Gaertn.	TS	Feb–Jun		
DIPTEROCARPACEAE	*Hopea ponga* (Dennst.) Mabb.	TS	Mar–Jun	SWG	EN
CAPPARACEAE	*Capparis floribunda* Wight	TS	Feb–Jun		
	C. rheedei DC.	TS	Feb–Jun	WG	
	C. zeylanica L.	TS	Mar–May		
CLEOMACEAE	*Cleome monophylla* L.	SC	Feb–Aug		
	C. rutidosperma DC.	SC	May–Nov		
	C. viscosa L.	SC/RC	Mar–Jul		
BRASSICACEAE	*Brassica nigra* (L.) K.Koch.	SC	Mar–May		
OPILIACEAE	*Cansjera rheedei* J.F.Gmel.	TS	Nov–Feb		
SANTALACEAE	*Santalum album* L.	TS	Nov–Dec		VU
LORANTHACEAE	*Dendrophthoe falcata* (L.f.) Ettingsh. var. *falcata*	TS	Dec–May		
	Helicanthes elastica (Desr.) Danser	TS	Dec–Mar	WG	
	Helixanthera intermedia (Wight) Danser	TS	Feb–Jun	SWG	
	Macrosolen parasiticus (L.) Danser	TS	Dec–May	SWI & SL	
PLUMBAGINACEAE	*Plumbago zeylanica* L.	TS	Nov–Mar		
POLYGONACEAE	*Persicaria barbata* (L.) H.Hara	TS	Aug–Mar		LC
DROSERACEAE	*Drosera indica* L.	SC/RC/SP	Jul–Nov		LC
ANCISTROCLADACEAE	*Ancistrocladus heyneanus* Wall. ex J.Graham	TS	Mar–Apr	SI & SL	
CARYOPHYLLACEAE	*Polycarpaea corymbosa* (L.) Lam.	RC	Aug–Dec		
	Polycarpon prostratum (Forssk.) Asch. & Sehweinf.	SC	Jan–Mar		
AMARANTHACEAE	*Achyranthes aspera* L.	TS	Oct–Mar		
	Aerva lanata (L.) Juss. ex Schult.	TS	Sep–Apr		
	Alternanthera brasiliana (L.) Kuntze	TS/SC	Jan–Dec		
	A. sessilis (L.) R.Br. ex. DC.	SC	Jan–Dec		LC
	A. tenella Colla var. *tenella*	SC	Jun–Dec		
	Amaranthus spinosus L.	SC	Jun–Dec		
	A. viridis L.	SC	Jul–Dec		
	Celosia argentea L. var. *argentea*	RC/SC	Nov–Dec		
	Cyathula prostrata (L.) Blume	TS	Sep–Apr		
	Gomphrena globosa L.	SC	Aug–Jun		
	G. serrata L.	SC	Jul–Nov		
AIZOACEAE	*Trianthema portulacastrum* L.	SC	Apr–Jun		
NYCTAGINACEAE	*Boerhavia diffusa* L.	SC	Aug–Dec		
	Bougainvillea glabra Choisy	TS	Nov–Jun		
	Mirabilis jalapa L.	SC	Aug–Apr		
MOLLUGINACEAE	*Glinus oppositifolius* (L.) Aug.DC.	SC	Feb–Apr		
	Mollugo stricta L.	SC	Sep–Dec		
PORTULACACEAE	*Portulaca oleracea* L.	SC	Jun–Sep		
CACTACEAE	*Cereus pterogonus* Lem.	SC	Apr–Jun		
	Opuntia ficus-indica (L.) Mill.	SC	Nov–Mar		DD
CORNACEAE	*Alangium salviifolium* subsp. *hexapetalum* (Lam.) Wangerin	TS	Mar–Aug		
BALSAMINACEAE	*Impatiens balsamina* L.	SC	Mar–Oct		

Family	Taxa	Microhabitat	Flowering	Endemism	IUCN RL Status
	I. flaccida Arn.	SC	Jul–Oct	SI & SL	
	I. minor (DC.) Bennet	SC/RC	Aug–Dec	PI	
LECYTHIDACEAE	*Careya arborea* Roxb.	TS	Feb–Jul		
SAPOTACEAE	*Chrysophyllum cainito* L.	TS	Jul–Sep		
	Madhuca longifolia (J.Koenig ex L.) J.F. Macbr.	TS	Mar–Jun		
	Mimusops elengi L.	TS	Dec–Aug		
EBENACEAE	*Diospyros candolleana* Wight	TS	Apr–Mar	PI	
ICACINACEAE	*Sarcostigma kleinii* Wight & Arn.	TS	Feb–Jun		
RUBIACEAE	*Argostemma courtallense* Arn.	TS/RC	Jul–Sep	I	
	Benkara malabarica (Lam.) Tirveng.	TS	Jan–May	PI & SL	
	Canthium coromandelicum (Burm.f.) Alston	TS	Apr–Jun		
	C. rheedei DC.	TS	Mar–Jun	PI	
	Catunaregam spinosa (Thunb.) Tirveng.	TS	Apr–Dec		
	Chassalia curviflora var. *ophioxyloides* (Wall.) Deb & B.Krishna	TS	Jul–Feb		
	Dentella repens (L.) J.R.Forst. & G.Forst. var. *repens*	SC	Mar–Apr		LC
	Discospermum sphaerocarpum Dalzell ex Hook.f.	TS	Apr–Jun	WG & SL	
	Ixora brachiata Roxb.	TS	Jan–May	WG	
	I. coccinea L.	TS	Jan–Dec	PI & SL	
	I. javanica (Blume) DC.	SC	Nov–Jul		
	I. malabarica (Dennst.) Mabb.	TS	Oct–Mar	SWG	VU
	Mitracarpus hirtus (L.) DC.	SC	Jul–Dec		
	Mitragyna parvifolia (Roxb.) Korth.	TS	Mar–Dec		
	Morinda citrifolia L.	TS	Jul–Nov		
	M. pubescens J.E.Smith	TS	Mar–Jun		
	Mussaenda frondosa L.	TS	Sep–Mar	PI	
	Neanotis rheedei (Wall. ex Wight & Arn.) W.H. Lewis	RC	Sep–Dec	WG	
	N. subtilis (Miq.) Govaerts ex Punekar & Lakshmin.	RC/SC	Aug–Dec	SI	
	Oldenlandia auricularia (L.) K.Schum.	TS	Oct–Dec		
	O. corymbosa L. var. *corymbosa*	SC	Apr–Sep		
	O. herbacea (L.) Roxb.	RC/SC	Jul–Dec		
	Pavetta indica L. var. *indica*	TS	Apr–Jul		
	Spermacoce articularis L.f.	SC	Oct–Dec		
	S. latifolia Aubl.	SC	Aug–Oct		
	S. ocymoides Burm.f.	SC	Nov–Dec		
	S. pusilla Wall.	SC	Oct–Nov		
GENTIANACEAE	*Canscora pauciflora* Dalzell	SC	Jul–Nov	WG	
	Canscorinella stricta (Sedgw.) Nampy & Shahina	RC	Aug–Feb	SI	
	Hoppea fastigiata (Griseb.) C.B.Clarke	SC	Sep–Oct		LC
LOGANIACEAE	*Mitrasacme indica* Wight	SC	Sep–Oct		
	M. pygmaea var. *malaccensis* (Wight) Hara	SC	Jun–Aug		
	Strychnos minor Dennst.	TS	Sep–Oct		
	S. nux–vomica L.	TS	Mar–Dec		

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APOCYNACEAE Rauvolfioideae	*Alstonia scholaris* (L.) R.Br.	TS	Oct–Feb		LC
	Catharanthus pusillus (Murray) G.Don	SC	Apr–Oct	I & SL	
	Kamettia caryophyllata (Roxb.) Nicolson & C.R.Suresh	TS	Sep–Jan	SWG	
	Plumeria rubra L.	TS	Nov–Apr		
	Rauvolfia serpentina (L.) Benth. ex Kurz	TS	Apr–Oct		
	Tabernaemontana alternifolia L.	TS	Apr–Oct	SWG	
	T. divaricata (L.) R.Br. ex Roem. & Schult.	SC	Jan–Dec		
Apocynoideae	*Aganosma cymosa* (Roxb.) G.Don	TS	Apr–Dec	PI & SL	
	Holarrhena pubescens (Buch.–Ham.) Wall. ex G. Don	TS	Apr–Oct		LC
	Ichnocarpus frutescens (L.) W.T.Aiton	TS	Aug–Mar		
	Wrightia tinctoria (Roxb.) R.Br.	TS	Feb–Nov		
Periplocoideae	*Gymnema sylvestre* Roem. & Schult.	TS	Mar–Aug		
	Cryptolepis buchananii (Retz.) R.Br. ex Sm.	TS/SC	Jul–Jan	PI & SL	
	Hemidesmus indicus (L.) R.Br.	TS	Aug–Dec	I & SL	
Asclepiadoideae	*Calotropis gigantea* (L.) W.T.Aiton	SC	Jan–Dec		
	Cosmostigma racemosum (Roxb.) Wight	TS	Apr–Jun		
	Holostemma ada-kodien Schult.	SC	Sep–Nov		
	Tylophora capparidifolia Wight & Arn.	TS	Mar–Jun	SWG	
	T. indica (Burm.f.) Merr. var. *indica*	TS	Feb–Jul		
	Wattakaka volubilis (L.f.) Stapf	TS	Mar–Jul		
BORAGINACEAE	*Coldenia procumbens* L.	SC	Mar–May		
	Cordia obliqua Willd.	TS	Mar–Aug		
	Heliotropium keralense Sivar. & Manilal	SC	Mar–May	SWG	
	H. marifolium Retz.	RC/SC	Apr–Aug	PI & SL	
CONVOLVULACEAE	*Argyreia nervosa* (Burm.f.) Bojer	TS	Dec–Jun		
	Bonamia semidigyna (Roxb.) Hallier f.	TS	Nov–Mar		
	Erycibe paniculata Roxb.	TS	Nov–Mar		
	Evolvulus alsinoides (L.) L. var. *alsinoides*	RC/SC	Mar–Aug		
	E. nummularius (L.) L.	SC	Jan–Dec		
	Ipomoea hederifolia L.	TS	Oct–Dec		
	I. marginata (Desr.) Manitz f. *marginata*	TS/SC	Dec–Mar		
	I. mauritiana Jacq.	TS	Aug–Sep		
	I. nil (L.) Roth	TS	Nov–Jan		
	I. obscura (L.) Ker Gawl.	TS	Oct–Mar		
	I. pes-caprae (L.) R.Br. subsp. *pes-caprae*	SC	Nov–Mar		
	I. quamoclit L.	SC	Oct–Dec		
	I. triloba L.	TS	Sep–Mar		
	Merremia umbellata (L.) Hallier f.	TS	Jan–Apr		
	M. vitifolia (Burm.f.) Hallier f.	TS/SC	Nov–Feb		
	Neuropeltis malabarica Ooststr.	TS	Nov–Mar	SWG (K)	
	Xenostegia tridentata subsp. *hastata* (Desr.) Panigrahi & Murti	TS/SC	Sep–Mar		
	X. tridentata (L.) D.F.Austin & Staples subsp. *tridentata*	RC/SC	Nov–Jan		
SOLANACEAE	*Datura stramonium* L.	SC	Jul–Sep		
	Physalis angulata L.	SC	Jul–Dec		

Family	Taxa	Microhabitat	Flowering	Endemism	IUCN RL Status
	Solanum americanum Mill.	SC	Mar–Nov		
	S. melongena var. *insanum* Prain	TS	Aug–Mar		
	S. torvum Sw.	SC	Jul–Mar		
HYDROLEACEAE	*Hydrolea zeylanica* (L.) Vahl	SP	Aug–Jan		LC
OLEACEAE	*Jasminum coarctatum* Roxb.	TS	Jan–Jun	PI & SL	
	J. flexile Vahl	TS	Oct–Mar	PI & SL	
	J. malabaricum Wight	TS	Mar–Nov	WG	
	Olea dioica Roxb.	TS	Nov–Apr	I	
GESNERIACEAE	*Rhynchoglossum notonianum* (Wall.) B.L. Burtt	TS	Jul–Dec	SWI & SL	
PLANTAGINACEAE	*Dopatrium junceum* (Roxb.) Buch.-Ham. ex Benth.	SP	Aug–Oct		LC
	Limnophila repens (Benth.) Benth.	SC	Jul–Dec		LC
	Microcarpaea minima (K.D.Koenig ex Retz.) Merr.	SC	Aug–Dec		LC
	Scoparia dulcis L.	SC	Jan–Dec		
	Stemodia verticillata (Mill.) Hassl.	SC	May–Sep		
LINDERNIACEAE	*Bonnaya antipoda* (L.) Druce	SC	Aug–Oct		
	B. ciliata (Colsm.) Spreng.	SC	Jun–Oct		
	B. oppositifolia (Retz.) Spreng.	SC	Jul–Oct	PI	
	Lindernia hyssopioides (L.) Haines	SP	Mar–Sep		
	L. madayiparensis Ratheesh, Sunil & Nandakumar	SP	Oct–Dec	SI (K)	
	L. manilaliana Sivar.	SC	Aug–Dec	SI (K)	EN
	L. tamilnadensis M.G.Prasad & Sunojk.	SC	Oct–Mar	SI	
	Torenia crustacea (L.) Cham. & Schltdl.	SC	Aug–Nov		
	T. lindernioides C.J.Saldanha	SC	Jul–Mar	SWG	
	Vandellia micrantha (D.Don) Eb. Fisch.	SC	Jul–Dec		
	V. pusilla (Willd.) Merr.	SC	Aug–Oct		
PEDALIACEAE	*Sesamum indicum* subsp. *malabaricum* (Burm.) Bedigian	SC	Jan–Sep	I	
LAMIACEAE Symphorematoideae	*Symphorema involucratum* Roxb.	TS	Mar–Apr		
Viticoideae	*Gmelina arborea* Roxb.	TS	Jan–Jun		
	Premna serratifolia L.	TS	May–Nov		
	Vitex altissima L.f.	TS	Mar–Jul		
	V. negundo L.	SC	Feb–Jul		
	V. trifolia L.	SC	May–Jul		
Ajugoideae	*Clerodendrum calamitosum* L.	SC	Jan–Dec		
	C. indicum (L.) Kuntze	SC	Sep–Dec		
	C. infortunatum L.	TS	Dec–Feb		
	C. paniculatum L.	SC	Jul–Dec		
	Rotheca serrata (L.) Steane & Mabb.	TS	Aug–Dec		
Lamioideae	*Leucas lavandulifolia* Sm.	SC	Jul–Oct		
	Pogostemon deccanensis (Panigrahi) Press	SP	Sep–Dec	SI	
	P. paniculatus (Willd.) Benth.	TS	Oct–Feb		
	P. quadrifolius (Benth.) F.Muell.	SC	Aug–Dec	I	DD
Nepetoideae	*Anisochilus carnosus* (L.f.) Wall.	RC	Sep–Dec		
	Hyptis suaveolens (L.) Poit.	SC/TS	Aug–Feb		

Family	Taxa	Microhabitat	Flowering	Endemism	IUCN RL Status
	Ocimum tenuiflorum L.	SC	Jan–Dec		
Lamiaceae: Incertae sedis	*Tectona grandis* L.f.	TS	May–Jan		
OROBANCHACEAE	*Aeginetia indica* L.	TS	Aug–Sep		
	Centranthera nepalensis D.Don	SC	Sep–Dec	SI	
	C. tranquebarica (Spreng.) Merr.	SC	Sep–Nov		LC
	Parasopubia hofmannii Pradeep & Pramod var. *hofmannii*	RC/SC	Jun–Oct	SI	
	P. hofmannii var. *albiflora* Pradeep & Pramod	RC/SC	Jun–Oct	SI	
	Rhamphicarpa longiflora (Arn.) Benth.	SC/SP	Aug–Nov	I	
	Striga angustifolia (D.Don) C.J.Saldanha	SC	Aug–Dec		
	S. asiatica (L.) Kuntze	SC	Jul–Sep		
	S. gesnerioides (Willd.) Vatke	SC	Aug–Nov		
LENTIBULARIACEAE	*Utricularia aurea* Lour.	SP	Aug–Dec		LC
	U. cecilii P.Taylor	SP	Aug–Oct	WG	EN
	U. graminifolia Vahl	SP	Aug–Oct		LC
	U. lazulina P.Taylor	SC	Aug–Oct	WG	LC
	U. uliginosa Vahl	SC	Aug–Nov		
ACANTHACEAE	*Andrographis paniculata* (Burm.f.) Wall. ex Nees	SC/TS	Mar–Dec	PI & SL	
	Asystasia dalzelliana Santapau	TS	Sep–Jan		
	A. gangetica (L.) T.Anderson subsp. *gangetica*	TS	Sep–Mar		
	Barleria courtallica Nees	TS	Dec–May	I & SL	
	B. prionitis L. subsp. *prionitis*	SC	Aug–Mar		
	Crossandra infundibuliformis (L.) Nees	SC	Dec–Mar	I & SL	
	Dicliptera paniculata (Forssk.) I.Darbysh.	TS	Dec–Feb		
	Ecbolium viride (Forssk.) Alston var. *viride*	TS	Nov–Feb		
	Eranthemum capense L.	TS	Jan–Mar	PI & SL	
	Haplanthodes neilgherryensis (Wight) R.B.Majumdar	SC/TS	Jan–Mar	WG	
	Hygrophila ringens (L.) Steud.	SC	Oct–Mar		
	Justicia adhatoda L.	SC	Jan–Dec		
	J. ekakusuma Pradeep & Sivar.	RC/SC	Aug–Sep	SI (K)	
	J. japonica Thunb.	SC	Aug–Feb		
	J. nagpurensis V.A.W.Graham	SC/RC	May–Nov	SWI	
	Lepidagathis cuspidata Nees	SC	Feb–Jun	I	
	L. incurva Buch.-Ham. ex D.Don var. *incurva*	TS	Feb–Apr		
	L. keralensis Madhus. & N.P.Singh	RC/SC	Dec–Apr	SI (K)	
	Phaulopsis imbricata (Forssk.) Sweet	SC/TS	Nov–Mar		LC
	Pseuderanthemum malabaricum (C.B.Clarke) Gamble	TS	Dec–Mar	PI & SL	
	Ruellia prostrata Poir.	TS	Oct–Apr	I	
	Rungia pectinata (L.) Nees	SC/TS	Nov–Feb		
	Strobilanthes integrifolia (Dalzell) Kuntze	TS	Dec–Mar	WG	
	Thunbergia erecta (Benth.) T.Anderson	TS	Jan–Dec		
BIGNONIACEAE	*Millingtonia hortensis* L.f.	TS	Mar–Aug		
	Pajanelia longifolia (Willd.) K.Schum.	TS	Jan–Jun		

Family	Taxa	Microhabitat	Flowering	Endemism	IUCN RL Status
	Stereospermum tetragonum DC.	TS	Feb–Oct		
VERBENACEAE	*Lantana camara* L.	TS	Apr–Jun		
	Phyla nodiflora (L.) Greene	SC	Nov–Dec		LC
	Stachytarpheta jamaicensis (L.) Vahl	SC/TS	Jun–Dec		
CAMPANULACEAE	*Lobelia alsinoides* Lam.	SC	Aug–Oct		LC
MENYANTHACEAE	*Nymphoides indica* (L.) Kuntze	SP	Jan–Dec		LC
	N. krishnakesara K.T.Joseph & Sivar.	SP	Aug–Nov	SWG (K)	EN
ASTERACEAE	*Acanthospermum hispidum* DC.	SC	Jan–Jun		
	Acmella ciliata (Kunth) Cass.	SC	Aug–Sep		
	A. radicans (Jacq.) R.K.Jansen	SC	Oct–Mar		
	Ageratum conyzoides L.	SC	Aug–Dec		
	Blumea axillaris (Lam.) DC.	SC/TS	Jan–Nov		
	B. barbata DC.	SC/TS	Dec–Mar	SI & SL	
	B. oxyodonta DC.	SC	Oct–May		
	Centratherum punctatum Cass.	SC	Aug–Jan		
	Chromolaena odorata (L.) R.M.King & H.Rob.	TS	Nov–May		
	Conyza stricta Willd.	SC	Sep–Oct		
	Cosmos caudatus Kunth	SC	Aug–Feb		
	C. sulphureus Cav.	SC	Feb–Nov		
	Crassocephalum crepidioides (Benth.) S.Moore	SC	Aug–Dec		
	Cyanthillium cinereum (L.) H.Rob.	SC/TS	Jan–Dec		
	Eclipta prostrata (L.) L.	SC	Jan–Dec		DD
	Elephantopus scaber L.	SC/TS	Oct–Jan		
	Emilia sonchifolia (L.) DC.	SC	Jul–Dec		
	Epaltes divaricata (L.) Cass.	SC	Dec–Apr		LC
	Grangea maderaspatana (L.) Poir.	SC	Mar–Jul		LC
	Mikania micrantha Kunth	TS	Feb–Apr		
	Sphagneticola trilobata (L.) Pruski	SC	May–Sep		
	Synedrella nodiflora (L.) Gaertn.	SC/TS	Jan–Dec		
	Tithonia diversifolia (Hemsl.) A.Gray	SC	Sep–May		
	Tricholepis amplexicaulis C.B.Clarke	SC	Oct–Feb	WG	
	Tridax procumbens L.	SC	Jan–Dec		
APIACEAE	*Pimpinella heyneana* (DC.) Benth.	SC	Oct–Feb		

Microhabitat: RC—Exposed rock surfaces and crevices | SC—Soil covered areas and grassy plains and slopes | SP—Seasonal ponds and small ephemeral pools | TS—Tree cover and scrub patches.
Endemism: C&PI—central and peninsular India | I—India | K—Kerala | PI—Peninsular India | SI—southern India | SL—Sri Lanka | SWG—southern Western Ghats | SWI—southwestern India | WG—Western Ghats.
IUCN Status: CR—Critically Endangered | DD—Data Deficient | EN—Endangered | LC—Least Concerned | NT—Near Threatened | VU—Vulnerable | Blank—not assessed.

Image 3. Recent discoveries from southern Indian lateric plateaus: A—*Justicia ekakusuma* | B—*Lepidagathis keralensis* | C—*Ceropegia nampyana* | D—*Eriocaulon gopalakrishnanum* | E—*Eriocaulon kannurense* | F—*Eriocaulon madayiparense* | G—*Euphorbia deccanensis* | H—*Canscorinella bhatiana* | I—*Lindernia madayiparensis.* © Pramod C.

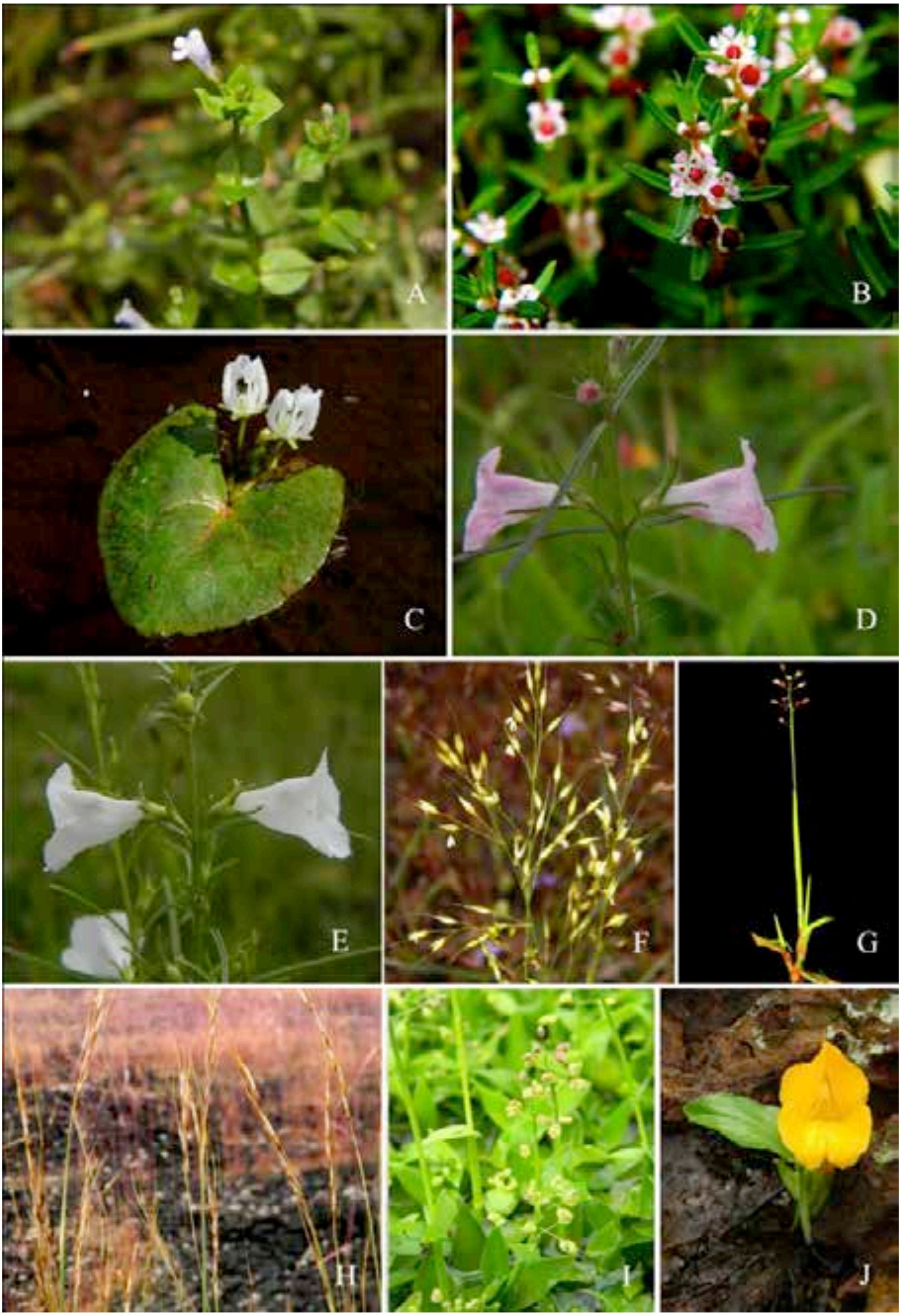

Image 4. Recent discoveries from southern Indian lateric plateaus: A—*Lindernia tamilnadensis* | B—*Rotala malabarica* | C—*Nymphoides krishnakesara* | D—*Parasopubia hofmannii* | E—*Parasopubia hofmannii* var. *albiflora* | F—*Arundinella cannanorica* | G—*Coelachne madayensis* | H—*Chrysopogon tadulingamii* | I—*Isachne veldkampii* | J—*Curcuma cannanorensis.* © Pramod C.

Table 2. List of novel taxa described from Madayippara Lateritic Plateau

	Taxa	Family	Year of Publication	Reference
1	*Rotala malabarica*	Lythraceae	1990	Pradeep, A.K., K.T. Joseph & V.V. Sivarajan, *Botanical Bulletin of Academia Sinica* 31: 59–61.
2	*Nymphoides krishnakesara*	Menyanthaceae	1990	Joseph, K.T. & V.V. Sivarajan, *Nordic Journal of Botany* 10(3): 281–284.
3	*Justicia ekakusuma*	Acanthaceae	1991	Pradeep, A.K. & V.V. Sivarajan, *Rheedea* 1(1&2): 40–43.
4	*Lepidagathis keralensis*	Acanthaceae	1992	Madhusoodanan, P.V. & N.P. Singh, *Kew Bulletin* 47(2): 301–303.
5	*Eriocaulon madayiparense*	Eriocaulaceae	2012	Swapna, M.M., K.P. Rajesh, C.N. Manju & R. Prakashkumar, *Phytokeys* 10: 19–23.
6	*Coelachne madayensis*	Poaceae	2012	Pramod, C., A.K. Pradeep & J.F. Veldkamp, *Gardens' Bulletin Singapore* 64(2): 289–292.
7	*Parasopubia hofmannii*	Orobanchaceae	2013	Pradeep, A.K. & C. Pramod, *Candollea* 68(1): 115–122.
8	*Parasopubia hofmannii* var. *albiflora*	Orobanchaceae	2013	Pradeep, A.K. & C. Pramod, *Candollea* 68(1): 115–122.
9	*Fimbristylis pokkudaniana*	Cyperaceae	2016	Sunil, C.N., M.K. Ratheesh Narayanan, M. Sivadasan, V.V. Naveenkumar, A.H. Alfarhan, V. Abdul Jaleel & M.H. Sameh, *Botany Letters* 164 (1): 19–22.
10	*Chrysopogon narayaniae*	Poaceae	2017	Sunil, C.N., M.K. Ratheesh Narayanan, M. Sivadasan, T. Shaju, V.V. Naveen Kumar & A.H. Alfarhan, *Phytotaxa* 307(4): 245–253.

Table 3. Number of species, endemics and threatened species in different microhabitats.

Microhabitat	Number of species recorded	Number of endemic species	Percentage of endemic species	Number of threatened species	Percentage of threatened species
Exposed rock surfaces and crevices (RC)	40	25	63%	1	3%
Seasonal ponds and small ephemeral pools (SP)	47	20	43%	5	11%
Soil covered areas and grassy plains and slopes (SC)	297	56	19%	3	1%
Tree cover and scrub patches (TS)	308	86	28%	5	2%

Euphorbia deccanensis grows with its roots firmly attached to the humus-rich small cavities and fissures of laterite rocks and species of *Utricularia* in seasonal pools or shallow soil areas with high moisture content. The high diversity and endemism of the plateaus is attributted to be a general phenomenon and is explained in different plateaus in the Western Ghats region by various authors (Joshi & Janarthanam 2004; Porembski & Watve 2005; Bhattarai et al. 2012; Lekhak & Yadav 2012). Of the 10 taxa described from the study area by different authors, five species, viz., *Rotala malabarica*, *Justicia ekakusuma*, *Fimbristylis pokkudaniana*, *Coelachne madayensis*, and *Chrysopogon narayaniae* are endemic to this plateau.

The microhabitats, viz., soil covered areas and grassy plains and slopes (SC) and tree cover and scrub patches (TS) hold largest numbers of species and endemics, since they occupy bulk of the total habitat with favorable environmental conditions. Though the number of species including endemics are comparatively less in the other two microhabitats, viz., exposed rock surfaces and crevices (RC) and seasonal ponds and small ephemeral pools (SP), their percentage of endemics is very high (Table 3).

Out of the available 120 species, as per IUCN ver. 3 (IUCN 2012), a total of 14 species falls under different IUCN threat categories. Seven species, viz., *Dimeria hohenackeri*, *Limnopoa meeboldii*, *Syzygium caryophyllatum*, *Hopea ponga*, *Lindernia manilaliana*, *Utricularia cecilii*, and *Nymphoides krishnakesara* are endangered. The species *Eriocaulon kolhapurense*, *Pterocarpus marsupium*, *Santalum album*, and *Ixora malabarica* are Vulnerable. The species *Isachne veldkampii* and *Rotala malabarica* are Critically Endangered and the species *Nothopegia heyneana* is Near Threatened. Most of the endemic species occurring on the plateau are not yet assessed for the conservation status, many of which are narrow endemics.

Threats and Conservation

The highly specialized habitats and rare biodiversity of the coastal lateritic plateaus and hills, parallel to the Western Ghats, have been neglected by scientists and policymakers, until recently. The laterite biodiversity is an unexplored treasure that is being endangered due

Image 5. Various threats to the microhabitats of Madayippara: A—mining for clay | B—construction work | C—tourism | D—summer fire | E—exotic weeds | F—grazing | G—waste dumping | H—land filling. © Pramod C.

to a multitude of anthropogenic activities. The lateritic plateus of northern Kerala, together with their rich flora and microhabitats are subjected to varied types of pressures such as large scale clay and brick mining, construction works, land filling, seasonal fire, tourism, waste dumping, together with biotic pressures such as invasion of exotic weeds and grazing. As pointed out by Muraleedharan (2011), degradation of lateritic plateaus results in the simultaneous destruction of atleast three ecosystems: lateritic plateaus, valleys and wetlands, which may eventually adversely affect ground water availability.

The discovery of many plant species and high degree of endemism made Madayippara lateritic plateau a 'micro hot spot' for conservation. The conservation efforts in the southern Western Ghats region are mostly restricted to the forested areas, totally neglecting the biodiversity rich lateritic plateaus. The rich biodiversity together with the threats associated with the area (Image 5) demands the need for conserving the area on a war footing. Priority of conservation should be given to endemic species which are short-lived and habitat specific; otherwise, they will be lost forever. The high conservation value of lateritic plateus of southwestern India has been already recognized (Watve & Thakur 2006; Lekhak & Yadav 2012; Bhattarai et al. 2012; Watve 2013). The open areas with herbaceous vegetation and grasses are of importance to bird populations including a large number of rare and migratory species, as they provide better visibility for being vigilant to predators and free movement for food gathering (Desai & Shanbhag 2012). Few afforestation efforts, that are in progress in the plateau are to be discouraged, as the tree species might affect the native herbaceous species because of their dense canopy and allelopathic effect.

The present study recommends conservation of this plateau and similar habitats of northern Kerala, in a similar way as proposed by Chandran et al. (2012), to declare Bhatkal and Mugali laterite plateaus of Uttara Kannada of Karnataka State under 'Conservation Reserves'. The Government should formulate strict rules for the restriction of mining and construction activities in the laterite areas. There is a need to create greater awareness of the importance of laterite hills and their biodiversity among the local community, tourists and policy and decision makers. Extensive floristic studies in similar habitats of northern Kerala are very likely to yield many more new and interesting species.

CONCLUSION

Lateritic plateaus are unique due to the nature of substratum and the extreme environmental conditions. Various microhabitats support a rich floral diversity with a large number of rare and endemic species. Though Madayippara represents an area of less than 0.01% of the total area documented in the Flora of Cannanore District, it harbors about 59% represented in the district flora. The species richness of this area is contributed by the presence of many specialized microhabitats and associated flora. Various microclimatic conditions play a collective role in the development of a particular plant community in a microhabitat. Madayippara lateritic plateau, which is the type locality of 10 taxa, and home for many endemic and threatened species, is highly threatened and urgent measures are to be taken for its conservation. Any slight disturbance in the micro ecosystems can easily take away a number of short-lived herbaceous species which cannot be easily conserved outside its natural habitat. For the conservation of the rich diversity and microhabitats of the plateau, in situ conservation of the entire habitat is the only answer as ex situ conservation measures cannot provide complex microclimatic requirements artificially.

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COMMUNICATION

Malacofaunal inventory in Chintamoni Kar Bird Sanctuary, West Bengal, India

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Abstract: The knowledge on the floral and faunal composition of protected areas (PAs) is crucial for formulating suitable conservation plan. In this paper, inventory and species richness of non-marine molluscs of Chintamoni Kar Bird Sanctuary has been made and is for the first time from any PA of West Bengal. A total of 276 specimens belonging to 22 species (10 species of land snails and 12 species of freshwater) of non-marine molluscs (land and freshwater) were collected and examined from this sanctuary. The malacofaunal inventory comprises of nine genera under seven families among land snails and 12 genera & seven families from both gastropods & bivalves under the freshwater forms. As far as species richness is concerned, the family Ariophantidae was found to be dominant among land forms whereas species of the families Thiaridae and Unionidae were dominant among freshwater forms.

Keywords: CKBS, freshwater, Mollusca, snails.

Bengali: সংরক্ষিত এলাকার (Protected Areas) প্রাণিজগৎ এবং উদ্ভিদজগতের সম্বন্ধে ধারনা থাকা অত্যন্ত গুরুত্বপূর্ণ সেই এলাকার একটি উপযুক্ত সংরক্ষণ পরিকল্পনা গঠনের জন্য। কিছু পরিচিত মেরুদণ্ডী (Vertebrate) স্তন্যপায়ী প্রাণী এবং পাখী ব্যতিত ,কম পরিচিত অমেরুদণ্ডী (Invertebrate) প্রাণীদের নিয়ে তথ্য খুব কম পাওয়া যায় সংরক্ষিত এলাকা থেকে। আমাদের বর্তমান গবেষণা দ্বারা, চিন্তামনিকর পাখী অভয়ারন্যের অ-সামুদ্রিক কম্বজ (Mollusca) প্রাণীদের নামের তালিকা এবং প্রজাতির (Species) প্রাচুর্য নিয়ে বিস্তারিত আলোচনা করা হয়েছে। এই প্রথমবার পশ্চিমবঙ্গের কোন সংরক্ষিত এলাকা থেকে এরম কাজ করা হয়েছে। এই অভয়ারন্যে থেকে মোট বাইশটি (২২) প্রজাতির- যার মধ্যে দশটি (১০) প্রজাতির স্থলভাগের কম্বজ এবং বারো (১২) প্রজাতির মিষ্টি জলের কম্বজ পাওয়া গেছে। মোট দুশো ছিয়াত্তর (২৭ ৬) টি নমুনা সংগ্রহ করা হয়েছিল এই অভয়ারন্য থেকে এবং পরীক্ষা করা হয়েছিল। এই কম্বজ প্রাণীদের তালিকাতে, স্থলভাগের কম্বজ প্রাণীদের সাতটি (৭) গোত্রের (Families) অধীনে নটি (৯) গণ (Genera) এবং মিষ্টি জলের কম্বজ প্রাণীদের সাতটি (৭) গোত্রের অধীনে বারটি (১২) গণ পাওয়া গেছে। এরিওফ্যানটিডি (Ariophantidae) গোত্রের কম্বজ প্রজাতির প্রাচুর্য বেশী পাওয়া গেছে এই অভয়ারন্য থেকে। অন্যদিকে মিষ্টি জলের কম্বজদের মধ্যে থিয়ারিডি (Thiaridae) এবং ইউনিওনিডি (Unionidae) গোত্রের প্রজাতিগুলোর প্রাধান্য দেখা গেছে।

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Author contribution: SS & BT designed the survey, SS, SD & TB conducted field survey and specimens collection, SS & TB examined and identified the specimens, SS compiled the information, illustration, and prepared the first draft of the manuscript, SD wrote Bengali abstract, BT logistic support, manuscript editing, and all authors contributed to drafting the manuscript.

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INTRODUCTION

The phylum Mollusca is the most diverse and ubiquitous component of ecosystem; and the second largest group of invertebrate in terms of species diversity (Lydeard et al. 2004). Molluscs are considered environmental indicators in terms of spatio-temporal changes in a particular ecosystem or landscape (Elder & Collins 1991; Lewis & Magnuson 2000; Chlyeh et al. 2006; Thom et al. 2017). They play a crucial role in the food chain and serve as a source of calcium for various vertebrates and invertebrates, embryonic development, eggshell formation, and osmoregulation process (Graveland et al. 1994; Graveland & van der Wal 1996; Hotopp 2002). Being a highly diverse group in all possible habitats (marine, freshwater and terrestrial) and their ecological importance through the ecological services which they provide, study on the diversity and distribution need better understanding for ecosystem functioning.

India has 5,227 species of molluscs (6.15% of the global faunal diversity), of which 3,870 species are marine, 1,140 species are land-living, and 217 freshwater species, have been recorded from the Indian territory (Ramakrishnan et al. 2010; Reid et al. 2013; Mukhopadhyay et al. 2017; Aravind & Páll-Gergely 2018; Sajan et al. 2019a,b, 2020; Annon 2020; Páll-Gergely et al. 2020a,b; Sajan & Tripathy 2020). The animal diversity of West Bengal State, however, has been published in 1992 by the Zoological Survey of India (ZSI) which also covered malacofauna. Most of the records in this study were of aquatic snails and terrestrial species from outside protected areas (PAs) (Mitra & Dey 1992; Thakur et al. 1992). There is no documentation of malacofaunal diversity from any of the PAs of West Bengal State till date. Thus, the present study is first of its kind in providing some baseline information on malacofaunal diversity of Chintamoni Kar Bird Sanctuary, a PA situated in the suburban area of Kolkata City in West Bengal.

MATERIALS AND METHODS

Study area

The Chintamoni Kar Bird Sanctuary (CKBS) is situated in South 24 Parganas District of West Bengal (22.700N & 88.666E) in the proximity of the urbanised city of Kolkata. It is also known as Narendrapur Wildlife Sanctuary and locally known by the name 'Kayaler Bagan'. The sanctuary is spread over in an area of 0.7km^2 and managed by the West Bengal Forest Department and under the jurisdiction of Sunderban Biosphere Reserve Range. Being surrounded by temporary and permanent small waterbodies as well as terrestrial vegetation, this sanctuary harbours diverse invertebrates, insects, mollusca, reptiles, birds, and small mammals (Chowdhury & Chowdhury 2006; Banerjee & Talapatra 2015; Mitra et al. 2018). In 1982, the area was proposed as a bird sanctuary by the Government of West Bengal, which later was renamed as Chintamoni Kar Bird Sanctuary (CKBS) in 2005.

Sampling methods and Sorting

Field collections of molluscan fauna were carried out from July to November 2017 during monsoon, post monsoon, and winter. Direct search method was used to collect live specimens and dead shells of both land and freshwater molluscs from their natural habitats, viz.: vegetation, near water bodies, pool, inside rotten/decaying logs, on mosses, old walls, leaf litter, bushes, under the rock surface, and bamboo thickets. Dead shells and live specimens encountered were photographed in the field (Nikon D7000 DSLR camera with 105mm macro lens) and were hand-picked for collection. The collected materials were thoroughly cleaned in the field itself with freshwater including the live ones, preserved in 70% ethanol, labelled, and brought to ZSI laboratory for identification. After completion of preservation and identification with labelling, the same were deposited in the National Zoological Collection of Malacology Division of ZSI.

Identification and nomenclature

All the specimens were examined and identified to species level based on the morphological shell characters and standard keys as provide by Blanford & Godwin-Austen (1908); Gude (1914, 1921); Preston (1915), and Mitra et al. 2004 (2005). The nomenclature follows as suggested by Bouchet et al. (2017) for subfamily, family, and higher level systematics.

Acronyms and abbreviations

Art(s).—Article(s) (of the Code) | Code—International Code of Zoological Nomenclature (ICZN 1999) | fig.—figure (in cited publications) | figs—figures (in cited publication) | Fig.—Figure (in this publication) | Figs—Figures (in this publication) | leg.—legit (i.e., the collector) | NZSI—National Zoological Collection of the Zoological Survey of India | p(p).—page(s) | pl(s).—plate(s) | Reg. No.—Registration Number | sic!—sic erat scriptum (thus as it was erroneously written) | spm.—specimen | spms—specimens | ZSI—Zoological Survey of India.

RESULTS AND DISCUSSION

A total of 22 species of land and freshwater molluscs were recorded from CKBS. Of these, 10 species were of land snails belonging to nine genera and seven families; whereas 10 species of gastropods and two bivalves belonging to 12 genera and seven families have been identified as freshwater forms. The family Ariophantidae (n=3) was found to be the maximum, in terms of species composition among land snails, whereas in freshwater forms, Thiaridae (n=3) and Unionidae (n=2) were the dominant family inside the sanctuary. *Macrochlamys indica* Godwin-Austen, 1883, *Ariophanta interrupta* (Benson, 1834), *Indosuccinea semiserica* (Gould, 1846), and *Cryptaustenia bensoni* (Pfeiffer, 1848) were abundantly encountered during the field surveys. Noteworthy to mention here that, the worst invasive alien species *Lissachatina fulica* (Bowdich, 1822) was also recorded from the sanctuary, the source for which could be from the urban Kolkata City. Among freshwater mollusc species, *Indoplanorbis exustus* (Deshayes, 1833), *Filopaludina bengalensis* (Lamarck, 1822), *Idiopoma dissimilis* (Müller, 1774), and *Radix rufescens* (J.E. Gray in G.B. Sowerby I, 1822) were most common species. The riverine species *Brotia costula* (Rafinesque, 1833) and *Tarebia granifera* (Lamarck, 1816) were also recorded, although there is no connectivity to rivers or estuaries to this PA, but the source of their dispersal could be during monsoon, when the area gets flooded and remains temporary swampy wetland for few months.

Systematics accounts of land and freshwater molluscs

Class **Gastropoda** Cuvier, 1795
Order **Stylommatophora** A. Schmidt, 1855
Superfamily **Helicarionoidea** Bourguignat, 1877
Family **Ariophantidae** Godwin-Austen, 1883
Subfamily **Ariophantinae** Godwin-Austen, 1883
Genus ***Ariophanta*** Des Moulins, 1829
Ariophanta Des Moulins, 1829: p. 235, pl. 1, figs 1–5. (Subgenus).

Type species. *Helix laevipes* Müller, 1774 [accepted as *Ariophanta laevipes* (Müller, 1774)]; subsequent designation.

Distribution. Southern and southeastern Asia.

***Ariophanta interrupta* (Benson, 1834)**
(Image 1A, 3C)

Helix interrupta Benson, 1834 (1832–1834): p. 461; Benson, 1834: p. 90; Pfeiffer, 1847: p. 63; Reeve, 1853 [1854]; p. 329, pl. 171, fig. 1159; Pfeiffer, 1859: p. 62; Hanley & Theobald, 1876 (1870–1876): p. 13, pl. 27, fig. 3.

Helix himalana — Lea, 1834: p. 55, pl. 19, fig. 66.

Helix himalayana (sic!) — Benson, 1834: p. 91; Benson, 1834 (1832–1834): p. 461; Pfeiffer, 1847: p. 63; Reeve, 1852 [1854]: p. 126, pl. 75, fig. 389; Brown, 1866: p. 19.

Nanina interrupta — Gray, 1855: p. 84; Pfeiffer, 1855: p. 84.

Ariophanta himalayana (sic!) — Pfeiffer, 1855: pp. 144–145.

Nanina (*Ariophanta*) *himalayana* (sic!) — Beck, 1838: p. 5; Blanford, 1863: p. 85.

Nanina (*Ariophanta*) *himalajana* (sic!) — Albers, 1850: p. 62.

Nanina (*Ariophanta*) *interrupta* — Beck, 1838: p. 5; Blanford, 1863: p. 85; Nevill, 1878: p. 19.

Ariophanta (*Ariophanta*) *interrupta* — Ray, 1948: pp. 109–110.

Ariophanta interrupta race. *sacra* — Annandale, 1912: pp. 33–34, figs 1, 2. (unavailable name Code, 1999: Art. 1.3.4, Art 10.2, Art. 45.5; and treats race. *sacra* as a synonym of *interrupta*)

Ariophanta interrupta — Godwin-Austen, 1880: p. 154, pl. 10, figs 1, 1a; Godwin-Austen, 1898: p. 130, pl. 34, fig. 2; Blanford, 1899: p. 283; Blanford, 1901: p. 244; Blanford & Godwin-Austen, 1908: p. 31; Annandale, 1912: pp. 33–34, figs 1, 2; Subba Rao, Thakur & Mitra, 1989: p. 254, 266–267, fig. 5A; Mitra & Dey, 1992: p. 45; Mitra, Dey & Ramakrishna, 2004: p. 228, figs C49–50; Mitra, Dey & Ramakrishna, 2005: p. 240; Ramakrishna, Mitra & Dey, 2010: p. 238; Raheem et al., 2014: p. 92, figs 56F, 57A–C; Biswas et al., 2015: p. 23, text fig.; Tripathy, Sajan & Mukhopadhyay, 2018: p. 786, fig. C; Sajan et al., 2018b: p. 145, pl. 2, fig. J; Mukhopadhyay et al., 2020: pp. 356, 360. pl. 15, fig. A.

Type locality. "near Sicrigali and the river Jellinghy (tributary of the Ganges; Godwin-Austen, 1880: p. 154), one of the mouths of the Ganges (small village in Sahibganj District, Jharkhand; 25.249028 & 87.708635)".

Material examined. Reg. No. NZSI M.30172/7, 22.vii.2017, 40 spms., India, West Bengal, South 24 Parganas District, CKBS, leg. T. Biswas & S. Das; Reg. No. NZSI M.33307/9, 01 spm., 2.ix.2017, CKBS; Reg. No. NZSI M.33314/9, 8 spms., 24.ix.2017, CKBS, leg. S.K. Sajan.

Distribution. India (Western Ghats, Andhra Pradesh, Jharkhand, Odisha, West Bengal, and Uttarakhand) and Bangladesh.

Remarks. Most common snail found in CKBS, however, Blanford (1863: p. 85) indicated the error in type locality as "I have but little doubt that *N. Himalayana*, Lea, is *N.*

interrupta, Bens., the Himalayan locality being probably an error".

Subfamily **Macrochlamydinae** Godwin-Austen, 1883
Genus ***Macrochlamys*** Gray, 1847

Macrochlamys Gray 1847: p. 169 — Benson, 1832: p. 76 (unavailable).

Type species. *Helix vitrinoides* Deshayes, 1831 [accepted as *Macrochlamys vitrinoides* (Deshayes, 1831)], type by monotype.

Distribution. Southern and southeastern Asia.

Macrochlamys petrosa **(Hutton, 1834)**
(Image 1B, 3A)

Helix petrosa Hutton, 1834: p. 83; Pfeiffer, 1847: p. 56; Benson, 1848: p. 163.

Macrochlamys petrosa — Godwin-Austen, 1883: p. 96; Rensch, 1955: p. 170; Mitra & Dey, 1992: p. 47; Subba Rao et al., 1995: p. 76; pl. 19, figs 1–2; Ramakrishna & Mitra, 2002: p. 43; Patil & Talmale, 2005: p. 1913; Ramakrishna, Mitra & Dey, 2010: p. 280; Patil & Talmale, 2012: pp. 254, 285; Sajan et al., 2019b: p. 809.

Type locality. "dead, in dry ravines, and on the banks of the Ganges; living specimens at Tara, in the range of rocky hills near Mirzapúr (Mirzapur, Uttar Pradesh)".

Material examined. Reg. No. NZSI M.34454/10, 2.ix.2017, 7 spms., CKBS; Reg. No. NZSI M.34455/10, 24.ix.2017, 5 spms., CKBS, leg. S.K. Sajan.

Distribution. India (Jharkhand, Meghalaya, Maharashtra, Uttar Pradesh, and West Bengal).

Remarks. Similar to *M. indica*, though not so commonly occurring. Distinguished by more depressed shell and also being excavated around the umbilicus.

Macrochlamys indica **Godwin-Austen, 1883**
(Image 1C, 3D)

Mocrochlamys indica Godwin-Austen, 1883: p. 97, pl. 18, figs 1–8; pl. 21, fig. 7; pl. 25, figs 9, 16; Blanford & Godwin-Austen, 1908: p. 95, fig. 43; Subba Rao & Mitra, 1979: p. 15; Subba Rao, Thakur & Mitra, 1989: p. 272, fig. 6E; Subba Rao & Mitra, 1991: p. 55, pl. 8, fig. 1; Mitra & Dey, 1992: p. 46; Surya Rao & Mitra, 1997: p. 26; Mookherjee et al., 2000: p. 348; Surya Rao et al., 2004: p. 97, pl. 10, fig. 1; Mitra, Dey & Ramakrishna, 2005: p. 255, figs 218–220; Patil & Talmale, 2005: p. 1913; Mitra, Dey & Ramakrishna, 2005: p. 237; Patil, Ramakrishna & Mitra, 2006: p. 174; Ramakrishna, Mitra & Dey, 2010: p. 271; Patil & Talmale, 2011: p. 27; Patil & Talmale, 2012: p. 285; Raheem et al., 2014: p. 104, fig. 66 C–D; Biswas et al., 2015: p. 22, fig.; Budha et al., 2015: p. 21; Phung et al., 2017: p. 74, fig. 11C; Tripathy, Sajan & Mukhopadhayay, 2018: p. 792; Sajan et al., 2018b: p. 145; Sajan et al., 2019b: p. 809; Tripathy, Sajan & Sidhu, 2019: p. 110; Mukhopadhyay et al., 2020: pp. 356, 360–361, pl. 15, fig. B.

Type locality. "Calcutta (Kolkata, India)".

Material examined. Reg. No. NZSI M.30053/7, 22.vii.2017, 1 spm., CKBS, leg. T. Biswas & S. Das; Reg. No. NZSI M.33311/9, 22.vii.2017, 7 spms., CKBS, leg. S.K. Sajan; Reg. No. NZSI M.33312/9, 2.ix.2017, 2 spms., CKBS, leg. S.K. Sajan.

Distribution. India (except the drier part of the northwestern region), North America, Europe, Africa, and southern Asia.

Remarks. Commonest species of the genus widely and abundantly occurring throughout the country including the Andaman Islands, except the dry part of the north-west. Also, considered a pest on horticultural and agricultural crops.

Superfamily **Pupilloidea** W.Turton, 1831
Family **Cerastidae** Wenz, 1923
Genus ***Rhachistia*** Connolly, 1925
Rhachistia Connolly, 1925: p. 163.

Type species. *Buliminus* (*Rhachis*) *rhodotaenia* E. von Martens, 1869 [accepted as *Rhachistia rhodotaenia* (E. von Martens, 1869)], type by original designation.

Distribution. Eastern Africa, southern and southeastern Asia, and east of Australia.

Rhachistia bengalensis **(Lamarck, 1822)**
(Image 1D, 3B)

Bulimus bengalensis Lamarck, 1822: p. 124; Hanley & Theobald 1874: pl. 80, fig. 7.

Rachisellus bengalensis — Gude 1914: p. 274.

Rhachis bengalensis — Mitra & Dey 1992: p. 39; Mookherjee et al., 2000: p. 243; Ramakrishna & Mitra, 2002: p. 47; Mitra, Dey & Ramakrishna, 2004: p. 139, fig. C30; Patil & Talmale, 2005: p. 1913; Patil & Talmale, 2011: p. 24; Patil & Talmale, 2012: pp. 277–278.

Rachis bengalensis — Mavinkurve et al., 2004: p. 1685.

Rhachistia bengalensis — Raheem et al., 2014: pp. 69–70, fig. 39B.

Type locality. "Bengal".

Material examined. Reg. No. NZSI M.30054/7, 22.vii.2017, 4 spms., CKBS, leg. T. Biswas & S. Das; Reg. No. NZSI M.30056/10, 2.ix.2017, 1 spm., CKBS; Reg. No. NZSI M.30057/10, 24.ix.2017, 2 spms., CKBS, leg. S.K. Sajan.

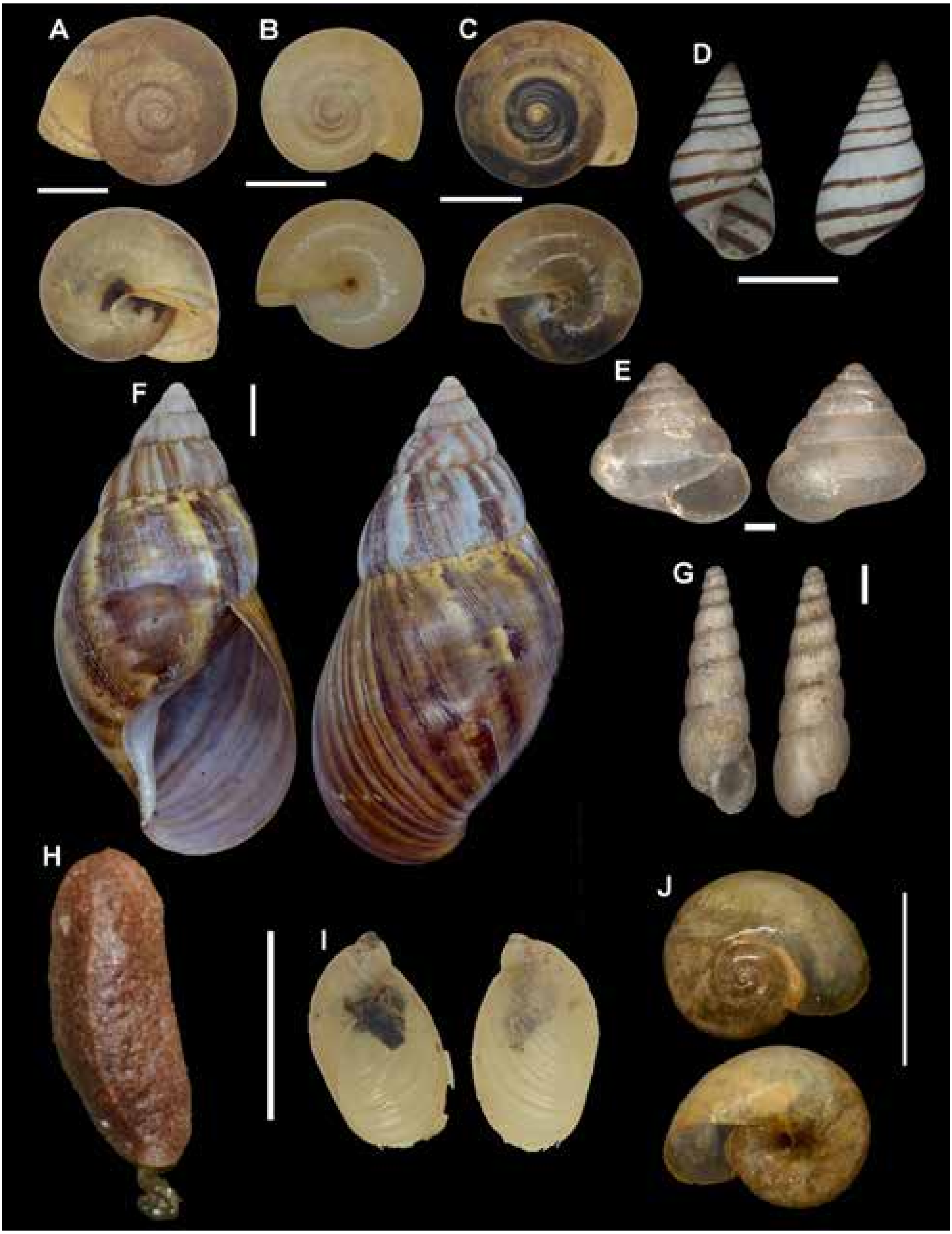

Image 1. Terrestrial gastropods: A—*Ariophanta interrupta* (Benson, 1834) | B—*Macrochlamys petrosa* (Hutton, 1834) | C—*Macrochlamys indica* Godwin-Austen, 1883 | D—*Rhachistia bengalensis* (Lamarck, 1822) | E—*Kaliella barrakporensis* (Pfeiffer, 1852) | F—*Lissachatina fulica* (Bowdich, 1822) | G—*Allopeas gracile* (Hutton, 1834) | H—*Laevicaulis alte* (Férussac, 1822) [No Scale] | I—*Indosuccinea semiserica* (Gould, 1846) | J— *Cryptaustenia bensoni* (Pfeiffer, 1848) (Scale: 10mm; Images E,G, 2mm). © S.K. Sajan.

Distribution. India (Maharashtra, Tamil Nadu, Tripura, and West Bengal) and Bangladesh.

Remarks. Only three individuals recorded during survey.

Superfamily **Trochomorphoidea** Möllendorff, 1890
Family **Chronidae** Thiele, 1931
Genus ***Kaliella*** W.T.Blanford, 1863
Nanina (*Kaliella*) W.T. Blanford, 1863: p. 83.

Type species. *Helix barrakporensis* Pfeiffer, 1853 [accepted as *Kaliella barrakporensis* (Pfeiffer, 1852 [1853])], type by subsequent designation.

Distribution. Europe, Africa, southern and southeastern Asia, and Australia.

Kaliella barrakporensis **(L.Pfeiffer, 1852 [1853])**
(Image 1E, 3G)

Helix barrakporensis Pfeiffer, 1852: p. 156; Pfeiffer, 1883: p.59.

Nanina (*Kaliella*) *barrakporensis* — Blanford, 1863: p. 83.

Kaliella barrakporensis — Godwin-Austen, 1852: p. 2, 19, pl. 1, figs 1–4; pl. 2, fig. 1; pl. 5, fig 2; Blanford & Godwin-Austen, 1908: p. 258; Dey, Barua & Mitra, 1985: p. 267; Mitra & Dey, 1992: p. 47; Surya Rao et al., 2004: p. 95, pl. 9. fig. 5; Dey, Barua & Mitra, 2003: p. 139; Mavinkurve et al., 2004: p. 1685; Mitra, Dey & Ramakrishna, 2004 (2005): p. 211, fig. 174, text-fig. 49; Patil & Talmale, 2005: p. 1913; Mitra, Dey & Ramakrishna, 2005: p. 236; Surya Rao, Mitra & Dey, 2007: p. 118; Patil & Talmale, 2011: pp. 26–27; Patil & Talmale, 2012: p. 283; Raheem et al., 2014: p. 77, figs 45B–C; Budha et al., 2015: p. 19; Phung et al., 2017: p. 86, fig. 18F; Sajan et al., 2018b: p. 145, pl. 1, fig. F; Tripathy, Sajan & Mukhopadhayay, 2018: p. 791.

Type locality. "ad Barrakpore, Indiæ (Bacon) (Barrackpore, West Bengal)".

Material examined. Reg. No. NZSI M.30173/7, 22.vii.2017, 7 spms., CKBS, leg. T. Biswas & S.K Sajan; Reg. No. NZSI M.33315/9, 2.ix.2017, 1 spm., CKBS; Reg. No. NZSI M34468/10, 24.ix.2017, 1 spm., CKBS, leg. S.K. Sajan.

Distribution. India (wide distribution range), Bangladesh, Myanmar, Pakistan, Sri Lanka, Nepal, Borneo; Europe, and Africa.

Remarks. One of the most widely occurring land snails in Asia and Africa.

Superfamily **Achatinoidea** Swainson, 1840
Family **Achatinidae** Swainson, 1840
Subfamily **Achatininae** Swainson, 1840
Tribe **Achatinini** Swainson, 1840

Genus ***Lissachatina*** Bequaert, 1950
Achatina (*Lissachatina*) Bequaert, 1950: p. 49.

Type species. *Achatina fulica* Bowdich, 1822 (accepted as *Lissachatina fulica* (Bowdich, 1822)), type by original designation.

Distribution. Worldwide distribution.

Lissachatina fulica **(Bowdich, 1822)**
(Image 1F, 3H)

Achatina fulica Bowdich, 1822: pl.13, fig. 3.

Helix (*Cochlitoma*) *fulica* — Férussac, 1821: pp. 1–24. (nomen nudum)

Achatina fulica — Nevill, 1878: p. 145; Gude 1914: p. 340; Phung et al., 2017: p. 71, fig. 10.

Achatina (*Lissaehatina*) *fulica fulica* —Subba Rao, Thakur & Mitra, 1989: p. 26, figs 3A–B; Mavinkurve et al., 2004: p. 1685; Patil & Talmale, 2011: p. 26; Patil & Talmale, 2012: pp. 280–281.

Achatina fulica fulica — Subba Rao et al., 1995: p. 65, pl. 13, figs 7–8; Dey, Barua & Mitra, 2003: p. 136.

Achatina (*Lissachatina*) *fulica fulica* —Mookherjee et al., 2000: p. 346.

Lisachatina fulica — Raheem et al., 2014: p. 115, figs 72C; Budha et al., 2015: p. 15; Sajan et al., 2018a: pp. 100–102; Inkhavilay et al., 2019: p. 49, fig. 20A.

Type locality. Unknown ('Mauritius', see Raheem et al., 2014: 115).

Material examined. Reg. No. NZSI M.30048/7, 22.vii.2017, 1 spm., CKBS, leg. T. Biswas & Party; Reg. No. NZSI M.34469/10, 2.ix.2017, 2 spms., CKBS, leg. S.K. Sajan.

Distribution. India (Common throughout including the Andaman & Nicobar Islands) wide distribution range in Asia, Africa, North and South America, and Europe.

Remarks. One of the 100 worst invasive alien species of the world. Recently reported from Sagar Island (Sajan et al. 2018a). Pest on horticultural and agricultural crops.

Subfamily **Subulininae** P.Fischer & Crosse, 1877
Genus ***Allopeas*** H.B.Baker, 1935
Lamellaxis (*Allopeas*) Baker, 1935: p. 84.

Type species. *Bulimus gracilis* Hutton, 1834 [accepted as *Allopeas gracile* (Hutton, 1834)], type by original designation.

Distribution. Worldwide in distribution, except the Antarctica.

Allopeas gracile **(Hutton, 1834)**
(Image 1G, 3I)

Bulimus (*mithi*) *gracilis* Hutton, 1834: p. 84, 93.

Opeas gracile — Gude, 1914: p. 355; Subba Rao & Mitra, 1979: p. 12; Patil & Talmale, 2005: p. 1913; Ramakrishna et. Alfred, 2006: p. 44.

Lamellaxis gracile — Subba Rao, Thakur & Mitra 1989: p. 260, pl. 2C; Mitra & Dey, 1992: p. 43; Subba Rao et al., 1995: p. 65, pl. 13, figs 3–4; Patil & Ramakrishna, 2004: p. 156; Patil, 2008a: p. 69.

Lamellaxis (*Allopeas*) *gracile* — Ramakrishna, Mitra & Dey, 2010: p. 180; Patil & Talmale, 2011: p. 25.

Opeas gracilis (sic!) — Mavinkurve et al., 2004: p. 1685.

Allopeas gracile — Khanna & Sati, 2003: p. 6; Rowson et al., 2010: pp. 24–25; Budha et al., 2015: p. 15; Phung et al., 2017: pp. 91, 93, fig. 20B; Mukhopadhyay et al., 2020: pp. 356, 361.

Material examined. Reg. No. NZSI M.34460/10, 02.ix.2017, 2 spms., CKBS; Reg. No. NZSI M.34461/10, 15.x.2017, 13 spms., CKBS, leg. S.K. Sajan.

Distribution. India (Common throughout), widely distributed throughout southeastern Asia

Remarks. This invasive alien species occurs very close to human habitations, on damp walls, potted plants, and gardens. The empty shell were collected from the soil. Pest on horticultural crops.

Superfamily **Veronicelloidea** Gray, 1840
Family **Veronicellidae** Gray, 1840
Genus ***Laevicaulis*** Simroth, 1913
Vaginula (*Laevicaulis*) Simroth, 1913: p. 147.

Type species. *Vaginula comorensis* P. Fischer, 1883 (accepted as *Laevicaulis alte* (Férussac, 1822)), type by subsequent designation.

Distribution. Widely distributed in eastern & central Africa, southern & southeastern Asia, Australasia & Oceania, and North & South America.

Laevicaulis alte **(Férussac, 1822)**
(Image 1H, 3J)

Vaginulus alte Férussac, 1821: p. 14; Gude, 1914: p. 482, fig. 153; Ray, 1961: p. 275.

Laevicaulis alte — Subba Rao & Mitra, 1979: p. 10; Patil & Talmale, 2005: p. 1913; Ramakrishna, Dey & Mitra, 2010: p. 114; Patil & Talmale, 2011: p. 22; Raheem et al., 2014: p. 55, fig. 31D; Budha et al., 2015: p. 9.

Type locality. "Pondichéry (Puducherry. India)"

Material examined. Reg. No. NZSI M.30173/7, 02.ix.2017, 3 spms., CKBS, leg. T. Biswas & S.K. Sajan.

Distribution. India (Andhra Pradesh, Bihar, Delhi, Gujarat, Maharashtra, Meghalaya, Punjab, Rajasthan, Sikkim, Tamil Nadu, Tripura, Uttar Pradesh, West Bengal, Karnataka, and Kerala) and throughout the tropical parts of the World.

Remarks. Most common invasive species of slug on the Indian plains; voracious feeder on live and decaying vegetation. Pest on horticultural and agricultural crops.

Superfamily **Succineoidea** Beck, 1837
Family **Succineidae** Beck, 1837
Subfamily **Catinellinae** Odhner, 1950
Genus ***Indosuccinea*** Rao, 1924
Indosuccinea Rao, 1924: p. 375.

Type species. *Succinea semiserica* Gould, 1846 (accepted as *Indosuccinea semiserica* (Gould, 1846)), type by original designation.

Distribution. India, Myanmar, probably in Indo-China, and the Malay Peninsula (Rao 1924).

Indosuccinea semiserica **(Gould, 1846)**
(Image 1I, 3F)

Succinea semiserica Gould, 1846: p. 100; Hanley & Theobald, 1876: p. 29, pl. 67, figs 2, 3; Gude, 1914: p. 452; Amin-ud-din, 1921: pp. 592–600, figs 21 (3a, 3b), 26, 27.

Succinea baconi — Nevill, 1878: p. 214.

Indosuccinea semiserica — Rao, 1924: p. 374; Ramakrishna, Mitra & Dey, 2010: p. 217; Patil & Talmale, 2012: p. 282.

Type locality. "Tavoy, in hortis".

Material examined. Reg. No. NZSI M.30174/7, 2.ix.2017, 7 spms., CKBS; Reg. No. NZSI M.34451/10, 15.x.2017, 3 spms., CKBS, leg. S.K. Sajan.

Distribution. India (Maharashtra, Manipur and West Bengal), Bangladesh, and Myanmar.

Remarks. This species is commonly found in forest floors.

Superfamily **Gudeoconchidae** Iredale, 1944
Family **Helicarionidae** Bourguignat, 1877
Subfamily **Durgellinae** Godwin-Austen, 1888
Tribe **Durgellini** Godwin-Austen, 1888
Genus ***Cryptaustenia*** Cockerell, 1891
Cryptaustenia Cockerell, 1891: p. 99.

Type species. *Vitrina planospira* Benson, 1859 (accepted as *Cryptaustenia succina* (Reeve, 1862)), type by monotypy.

Distribution. Southern and southeastern Asia.

Cryptaustenia bensoni **(Pfeiffer, 1848)**
(Image 1J, 3E)

Vitrina bensoni Pfeiffer, 1848: p. 107.

Austenia bensoni — Godwin-Austen, 1883: p. 150, pl. 36, figs 6–7.

Succinea bensoni — Patil & Talmale, 2005: p. 1913.

Cryptaustenia bensoni — Blanford & Godwin-Austen, 1908: p. 187; Ramakrishna, Mitra & Dey, 2010: p. 257.

Type locality. "In the Botanical Garden of Calcutta".

Material examined. Reg. No. NZSI M.30236/8, 2.ix.2017, 09 spms., CKBS, leg. S.K. Sajan.

Distribution. India (Andhra Pradesh, Odisha (Eastern Ghats), and West Bengal) and Myanmar.

Remarks. This species is found on trunk, bark and on leaves; few shells collected from the forest floor.

Superfamily **Ampullarioidea** Gray, 1824
Family **Ampullariidae** Gray, 1824
Subfamily **Ampullariinae** Gray, 1824
Genus ***Pila*** Röding, 1798
Pila Röding, 1798: p. 145.

Type species. *Helix ampullacea* Linnaeus, 1758 (accepted as *Pila ampullacea* (Linnaeus, 1758)), type by subsequent designation.

Distribution. Asia and Africa.

Pila globosa **(Swainson, 1822)**
(Image 2A)
Ampullaria globosa Swainson, 1822: pl. 119.
Ampullaria globosa var. *minor* — Nevill, 1877: p. 4.
Ampullaria globosa var. *incrassatula* — Nevill, 1877: p. 4.

Pila globosa — Preston, 1915: p. 97; Prashad, 1917: pp. 231–232, text fig. 1; Sewell, 1934: p. 56; Subba Rao, 1989: p. 58, figs 80–82; Patil & Ramakrishna, 2004: p. 146; Patil & Talmale, 2005: p. 1913; Patil, 2005: p. 440; Patil, Ramakrishna & Mitra, 2006: pp. 165–166; Ramakrishna et. Alfred, 2006: p. 43; Patil, 2006: p. 12; Ramakrishna & Dey, 2007: p. 98; Nasemann et al., 2007: p. 75, pl. 19, fig. 6, pl. 20, fig. 4; Patil, 2008b: p. 358; Raghunathan & Punithavelu, 2009: p. 149; Patil & Talmale, 2011: p. 6; Patil & Talmale, 2012: p. 257; Punithavelu & Raghunathan, 2013: p. 23; Cowie, 2015: p. 37; Basu et al., 2018: p. 12049; Tripathy, Sajan & Chandra, 2019: p. 14; Mukhopadhyay et al., 2020: pp. 355, 357, pl. 15, fig. H.

Type locality. "Rivers of India".

Material examined. Reg. No. NZSI M.20234/8, 22.vii.2017, 8 spms., CKBS; Reg. No. NZSI M.30180/7, 22.vii.2017, 8 spms., CKBS, leg. T. Biswas & Party; Reg. No. NZSI M.34452/10, 15.ix.2017, 1 spm., CKBS, leg. S.K. Sajan.

Distribution. India (Assam, Bihar, Odisha, Himachal Pradesh, Jharkhand, Maharashtra, Madhya Pradesh, Meghalaya, Rajasthan, Uttar Pradesh, and West Bengal).

Remarks. One of the most common freshwater snail of India. Tripathy et al. (2020: p. 11, figs 8, 14) treated *Ampullaria globosa var. minor* as a junior synonym of *P. globosa*.

Superfamily **Cerithioidea** J. Fleming, 1822
Family **Thiaridae** Gill, 1871 (1823)
Subfamily **Thiarinae** Gill, 1871 (1823)
Genus ***Melanoides*** Olivier, 1804
Melanoides Olivier, 1804: p. 40.

Type species. *Melanoides fasciolata* Olivier, 1804 [accepted as *Nerita tuberculata* O.F. Müller, 1774]

Distribution. Africa, Central Asia, South and Southeast Asia, Malay-Archipelago, Philippines and various Pacific Islands.

Melanoides tuberculata **(Müller, 1774)**
(Image 2B)
Nerita tuberculata Müller, 1774: pp. 191–192.
Melania pyramis — Benson, 1836: p. 354.
Tiara (*Striatella*) *tuberculata* — Preston, 1915: pp. 15–16.
Melanoides (*Melanoides*) *peddamunigalensis* — Ray & Ray Chowdhuri, 1969: p. 48, figs 12–17.

Melanoides (*Melanoides*) *tuberculata* — Starmuehlner, 1976: p. 591; Subba Rao, 1989: pp. 103–104, figs 183–184.

Thiara (*Melanoides*) *tuberculate* (sic!) — Agrawal, 1995: p. 34.

Thiara (*Melanoides*) *tuberculatus* (sic!) — Patil & Talmale, 2005: p. 1913; Ramakrishna et. Alfred, 2006: p. 44.

Thiara (*Melanoides*) *tuberculata* — Surya Rao, Mitra & Manna, 2004: pp. 41–42; Patil & Ramakrishna, 2004: pp. 147–148; Patil, 2005: pp. 441–442; Patil, Ramakrishna & Mitra, 2006: pp. 167–168; Patil, 2006: p. 14; Punithavelu & Raghunathan, 2007: p. 87; Patil, 2008a: p. 65; Raghunathan & Punithavelu, 2009: p. 149; Punithavelu & Raghunathan, 2013: p. 26.

Thiara tuberculata — Ramakrishna, Siddiqui & Sahu, 2006: p. 28.

Melanoides tuberculata — Ramakrishna & Dey, 2007: p. 161; Nasemann et al., 2007: pp. 70–71, pl. 18, figs 4, 5, pl. 20, fig. 5; Patil, 2008b: p. 358; Patil, 2008c: p. 118; Patil, 2009: p. 279; Patil & Talmale, 2011: pp. 8–9; Patil & Talmale, 2012: p. 261; Surya Rao, Venkitesan & Rao, 2013: p. 86; Biswas et al., 2015: p. 20; Tripathy, Sajan & Mukhopadhayay, 2018: p. 794; Basu et al., 2018: p. 12049; Tripathy, Sajan & Chandra, 2019: p. 14; Mukhopadhyay et al., 2020: pp. 355, 357.

Type locality. "In littore Curomandel (On the shore Curomandel) [Coromandel Coast, Tamil Nadu, India]".

Material examined. Reg. No. NZSI M.30045/7, 22.vii.2017, 3 spms., India, West Bengal, South 24

Image 2. Shell of freshwater gastropods and bivalves: A—*Pila globosa* (Swainson, 1822) | B—*Melanoides tuberculata* (O. F. Müller, 1774) | C—*Mieniplotia scabra* (Müller, 1774) | D—*Tarebia granifera* (Lamarck, 1816) | E—*Brotia costula* (Rafinesque, 1833) | F—*Filopaludina bengalensis* (Lamarck, 1822) | G—*Idiopoma dissimilis* (Müller, 1774) | H—*Indoplanorbis exustus* (Deshayes, 1834) | I—*Gyraulus convexiusculus* (Hutton, 1849) | J—*Radix rufescens* (Gray, 1822) | K—*Lamellidens marginalis* (Lamarck, 1819) | L—*Parreysia favidens* (Benson, 1862) (Scale: 10mm; Fig. I, 1mm). © S.K. Sajan.

Parganas District, Chintamoni Kar Bird Sanctuary, leg. T. Biswas and Party; Reg. No. NZSI M.34462/10, 2.ix.2017, 5 spms., India, West Bengal, South 24 Parganas District, Chintamoni Kar Bird Sanctuary, leg. S.K. Sajan.

Distribution. India: Widely distributed throughout India except Kashmir; Elsewhere: North and South Africa, eastern Mediterranean, southern China, Malay Archipelago, North Australia, Pacific Island.

Remarks. This species has a global distribution.

Genus ***Mieniplotia*** Low & Tan, 2014

Mieniplotia Low & Tan, 2014: pp. 15–17.

Type species. *Buccinum scabrum* Müller, 1774 [accepted as *Mieniplotia scabra* (Müller, 1774)], type by original designation.

Distribution. South and Southeast Asia, east coast of South Africa to Fiji.

***Mieniplotia scabra* (Müller, 1774)**

(Image 2C)

Buccinum scabrum Müller 1774: p. 136.

Tiara (*Plotia*) *scabra* — Preston, 1915: p. 35–36.

Thiara (*Thiara*) *scabra* — Pace, 1973: p. 52; Subba Rao, 1989: p. 96; Patil & Ramakrishna, 2004: pp. 146–147; Patil & Talmale, 2005: p. 1913; Patil, 2005: p. 441; Patil, Ramakrishna & Mitra, 2006: p. 167; Patil, 2006: p. 13; Ramakrishna & Dey, 2007: p. 153; Nasemann et al., 2007: pp. 69–70, pl. 17, fig. 8; Punithavelu & Raghunathan, 2007: p. 87, pl. 4, fig. 3; Patil, 2008a: p. 65; Raghunathan & Punithavelu, 2009: p. 149; Patil & Talmale, 2011: p. 8; Patil & Talmale, 2012: p. 260; Punithavelu & Raghunathan, 2013: p. 25.

Thiara scabra — Brandt, 1974: p. 163; Neubert, 1998: pp. 350–351.; Surya Rao, Venkitesan & Rao, 2013: p. 85.

Mieniplotia scabra — Low & Tan, 2014: pp. 15–17.

Type locality. "In paludofis littoris Coromandel Tranquebari Danorum maxime vulgare".

Material examined. Reg. No. NZSI M.30051/7, 22.vii.2017, 3 spms. (1 spm., Juvenile), India, West Bengal, South 24 Parganas District, Chintamoni Kar Bird Sanctuary, leg. T. Biswas and S. Das.

Distribution. India: West Bengal, Bihar, Jharkand, Kerala, Madhya Pradesh, Maharashtra, Pondicherry, Sikkim, Tamil Nadu, Uttaranchal, Uttar Pradesh; Elsewhere: South East Asia

Remarks. This species is inhabited to coastal rivers, brackish water and stagnant water.

Genus ***Tarebia*** H. Adams & A. Adams, 1854

Tarebia H. Adams & A. Adams, 1854: p. 304.

Type species. *Melania granifera* Lamarck, 1816 [accepted as *Tarebia granifera* (Lamarck, 1816)], type by subsequent designation.

Distribution. South and Southeast Asia, South China and part of the Asia Pacific Islands.

***Tarebia granifera* (Lamarck, 1816)**

(Image 2D)

Melania granifera Lamarck, 1816: pl. 458, figs 4a–b; Lamarck, 1822: p. 167.

Melania celebensis — Quoy & Gaimard, 1834: p. 152, pl. 56, figs 26–29.

Thiara (*Tarebia*) *granifera* — Pace, 1973: p. 62, pl. 12, fig. 3, pl. 13, fig. 4.

Tarebia granifera — Starmuehlner, 1976: p. 569, figs 72–75, pl. 16, figs 175–179; Ramakrishna & Dey, 2007: p. 168, figs. 113A–B; Patil & Talmale, 2011: p. 9; Patil & Talmale, 2011: pp. 8–9; Patil & Talmale, 2012: p. 261; Surya Rao, Venkitesan & Rao, 2013: pp. 86–87; Tripathy, Sajan & Chandra, 2019: p. 14; Tripathy, Sajan & Sidhu, 2019: p. 108.

Thiara (*Tarebia*) *granifera* — Subba Rao, 1989: p. 110, figs 212–213; Raghunathan & Punithavelu, 2009: p. 149.

Type locality. "Unknown".

Material examined. Reg. No. NZSI M.30046/7, 22.vii.2017, 7 spms., India, West Bengal, South 24 Parganas District, Chintamoni Kar Bird Sanctuary, leg. T. Biswas & S. Das.

Distribution. India: West Bengal, Madhya Pradesh, Bihar; Elsewhere: South Africa, Madagascar, Malaysia, Philippines, Formosa and Pacific Islands.

Remarks. This species has been introduced into U.S.

Family **Pachychilidae** Fischer & Crosse, 1892

Genus ***Brotia*** H. Adams, 1866

Brotia H. Adams 1866: p. 150.

Type species. *Melania pagodula* Gould, 1847 [accepted as *Brotia pagodula* (Gould, 1847)], by Monotype.

Distribution. Indian subcontinent, Indo-China, Malaysia, Malay-Archipelago and Philippines.

***Brotia costula* (Rafinesque, 1833)**

(Image 2E)

Melania costula Rafinesque, 1833: p. 166.

Brotia costula costula — Brandt, 1974: p. 181, pl. 13 figs 37–38; Nesemann et al., 2007: pp. 72, pl. 18 fig. 1.

Brotia (*Antimelania*) *costula* — Subba Rao, 1989: p. 108; Hatter et al., 2004: p. 4; Punithavelu & Raghunathan, 2007: p. 87; Punithavelu & Raghunathan, 2013: p. 26.

Brotia costula —Benthem Jutting, 1956: p. 374, fig.

76; Köhler & Glaubrecht, 2001: p. 284, fig. D, p. 295, 297, fig. 10A–H; Köhler & Glaubrecht, 2006: pp. 159−251; Budha, 2016: p. 41, fig.; Basu et al., 2018: p. 12049.

Type locality. "Gomti River [Gomti river, Jabalpur, Madhya Pradesh, India]".

Material examined. Reg. No. NZSI M.30047/7, 22.vii.2017, 5 spms., India, West Bengal, South 24 Parganas District, Chintamoni Kar Bird Sanctuary, leg. T. Biswas & S. Das.

Distribution. India: West Bengal, Assam, Arunachal Pradesh, Bihar, Madhya Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Uttar Pradesh. Elsewhere: Bangladesh, Nepal, Thailand, Myanmar, Lao, Cambodia, Vietnam and Malaysia.

Remarks. Mainly found in fast following water in streams and river, also recorded from ponds. In CKBS, the dead shell have been collected from small pond.

Superfamily **Viviparoidea** Gray, 1847
Family **Viviparidae** Gray, 1847
Subfamily **Bellamyinae** Rohrbach, 1937
Genus ***Filopaludina*** Habe, 1964
Filopaludina Habe, 1964: p. 48.

Type species. *Paludina bengalensis* Lamarck, 1822 [accepted as *Filopaludina bengalensis* (Lamarck, 1822)], type by original designation.

Distribution. South and Southeast Asia.

***Filopaludina bengalensis* (Lamarck, 1822)**
(Image 2F)

Paludina bengalensis Lamarck 1822: p 174.

Vivipara bengalensis — Preston, 1915: p. 83; Annandale, 1920: p. 113; Annandale, 1921: p. 267; Ramakrishna et. Alfred, 2006: p. 44.

Vivipara bengalensis race *bengaiensis* — Annandale & Sewell, 1921: p. 270, pl. 1, figs 1–3.

Bellamya (*Filopaludina*) *bengalensis* — Brandt, 1974: p. 20; Nasemann et al., 2007: pp. 73–74, pl. 19, figs 2–3, pl. 20, fig. 1.

Bellamya bengalensis form. *typica* —Subba Rao, 1898: p. 45; Patil & Ramakrishna, 2004: pp. 143–144; Patil, 2005: pp. 439–440; Patil, Ramakrishna & Mitra, 2006: p. 164; Patil, 2006: p. 11; Patil, 2008a: p. 64; Patil, 2008c: p. 116; Patil, 2009: p. 277; Patil & Talmale, 2011: p. 1, 5; Patil & Talmale, 2012: pp. 249, 255; Surya Rao, Venkitesan & Rao, 2013: p. 79.

Bellamya bengalensis form *bengalensis* — Patil & Talmale, 2005: p. 1913.

Bellamya bengalensis — Punithavelu & Raghunathan, 2007: p. 86, pl. 4, fig. 1; Patil, 2008b: p. 357; Raghunathan & Punithavelu, 2009: p. 149; Punithavelu & Raghunathan, 2013: pp. 22–23; Basu et al., 2018: p. 12049.

Filopaludina bengalensis — Mukhopadhyay, Tripathy & Ghosh, 2017: p. 503; Tripathy, Sajan & Chandra 2019: p. 14; Tripathy, Sajan & Sidhu, 2019: p. 108, fig. I; Mukhopadhyay et al., 2020: pp. 355–356, pl. 15, fig. F.

Type locality. "dans les rivières du Bengale".

Material examined. Reg. No. NZSI M.30049/7, 22.vii.2017, 5 spms., India, West Bengal, South 24 Parganas District, Chintamoni Kar Bird Sanctuary, leg. T. Biswas and S. Das; Reg. No. NZSI M.34459/10, 2.ix.2017, 24 spms., India, West Bengal, South 24 Parganas District, Chintamoni Kar Bird Sanctuary; Reg. No. NZSI M.34453/10, 9.x.2017, 10 spms., Chintamoni Kar Bird Sanctuary, leg. S.K. Sajan.

Distribution. India: distributed throughout the India.

Remarks. One of the commonest species of South East and South Asia.

Genus ***Idiopoma*** Pilsbry, 1901
Idiopoma Pilsbry, 1901: p. 189.

Type species. *Vivipara hendazensis* Pilsbry, 1901 [accepted as *Idiopoma dissimilis* (O. F. Müller, 1774)], type by original designation.

Distribution. South and Southeast Asia, North America.

***Idiopoma dissimilis* (Müller, 1774)**
(Image 2G)
Nerita dissimilis Müller, 1774: p. 184.

Bellamya dissimilis — Subba Rao, 1989: p. 48. figs 64–67; Surya Rao, Mitra & Manna, 2004: p. 40; Patil & Ramakrishna, 2004: p. 145; Patil & Talmale, 2005: p. 1913; Patil, Ramakrishna & Mitra, 2006: p. 165; Ramakrishna, Siddiqui & Sahu, 2006: p. 28; Ramakrishna, Mitra & Aravind, 2006: pp. 9–10; Ramakrishna & Dey, 2007: pp. 90–91, taxt-figs 50A-B; Punithavelu & Raghunathan, 2007: p. 86, pl. 4, fig. 2; Patil, 2008a: p. 64; Patil, 2008b: p. 357; Patil, 2008c: pp. 116–117; Patil, 2009: p. 278; Raghunathan & Punithavelu, 2009: p. 149; Patil & Talmale, 2011: p. 6; Punithavelu & Raghunathan, 2013: p. 23; Surya Rao, Venkitesan & Rao, 2013: p. 82; Basu et al., 2018: p. 12049.

Idiopoma dissimilis — Brandt, 1974: pp. 36–37; Nasemann et al., 2007: p. 74, pl. 19, figs 4, 5, pl. 20, fig. 3; Tripathy, Sajan & Chandra, 2019: p. 14; Mukhopadhyay et al., 2020: pp. 355, 357.

Type locality. "In Museo Spengleriano".

Material examined. Reg. No. NZSI M.30050/7, 22.vii.2017, 11 spms., India, West Bengal, South 24 Parganas District, Chintamoni Kar Bird Sanctuary, leg. T. Biswas and S. Das; Reg. No. NZSI M.34465/10, 2.ix.2017, 8 spms., India, West Bengal, South 24 Parganas District, Chintamoni Kar Bird Sanctuary; Reg. No. NZSI M.34464/10, 9.ix.2017, 5 spms., Chintamoni Kar Bird Sanctuary, leg. S.K. Sajan.

Distribution. India: Common throughout India; Elsewhere: Bangladesh, Malayasia, Myanmar, Pakistan, Sri Lanka.

Remarks. It is also known as *Bellamya dissimilis;* species has a wide distribution in India.

Superfamily **Lymnaeoidea** Rafinesque, 1815
Family **Bulinidae** P. Fischer & Crosse, 1880
Subfamily **Bulininae** P. Fischer & Crosse, 1880
Genus ***Indoplanorbis*** Annandale & Prashad, 1921
Indoplanorbis Annandale & Prashad, 1920: p. 578.

Type species. *Planorbis exustus* Deshayes, 1834 [accepted as *Indoplanorbis exustus* (Deshayes, 1833)]

Distribution. Africa, Central Asia, South and Southeast Asia

***Indoplanorbis exustus* (Deshayes, 1833)**
(Image 2H)

Planorbis exustus Deshayes (in Belanger), 1833: pp. 417–418, pl. 1. figs 11–13; Preston, 1915: pp. 115–116.

Planorbis (*Planorbis*) *exustus* — Germain, 1921: pp. 26–41, figs 1–16, pl. 1, figs 4–9, pl. 4, figs 11, 17, 18.

Indoplanorbis exustus — Annandale, 1922: p. 160; Benthem Jutting, 1956: p. 471; Brandt, 1974: pp. 234–235, pl. 16, fig. 99; Subba Rao, 1989: p. 142, figs 326–327; Agrawal, 1995: p. 36; Neubert, 1998: p. 359; Surya Rao, Mitra & Manna, 2004: p. 42; Hatter et al., 2004: p. 5; Patil & Ramakrishna, 2004: p. 150; Patil & Talmale, 2005: p. 1913; Patil, 2005: p. 444; Patil, Ramakrishna & Mitra, 2006: pp. 169–170; Ramakrishna et. Alfred, 2006: p. 44; Ramakrishna, Siddiqui & Sahu, 2006: p. 29; Ramakrishna, Mitra & Aravind, 2006: pp. 10–11; Punithavelu & Raghunathan, 2007: p. 88; Nasemann et al., 2007 : p. 90, pl. 23, figs 1a–c; Ramakrishna & Dey, 2007 : p. 253–254, text figs 109A & 109B; Patil, 2008a: p. 66; Patil, 2008b: p. 359; Patil, 2008c: p. 119; Patil, 2009: p. 280; Raghunathan & Punithavelu, 2009: p. 150; Patil & Talmale, 2011: pp. 15–17; Patil & Talmale, 2012: p. 267; Punithavelu & Raghunathan, 2013: p. 30; Surya Rao, Venkitesan & Rao, 2013: p. 90; Basu et al., 2018: p. 12049; Tripathy, Sajan & Chandra, 2019: p. 14; Mukhopadhyay et al., 2020: pp. 356, 359, pl. 15, fig. D.

Type locality. "cóte du Malabar [Malabar Coast, India]".

Material examined. Reg. No. NZSI M.34449/10, 2.ix.2017, 6 spms., India, West Bengal, South 24 Parganas District, Chintamoni Kar Bird Sanctuary; Reg. No. NZSI M.34450/10, 2.ix.2017, 5 spms., Chintamoni Kar Bird Sanctuary, leg. S.K. Sajan.

Distribution. India: Widely distributed throughout country; Elsewhere: South and South East Asia.

Remarks. Monotypic genus, found in southern Asia, south east Arabia and Socotra Island. Common in ponds, ditches and canals with or without vegetations.

Family **Planorbidae** Rafinesque, 1815
Subfamily **Planorbinae** Rafinesque, 1815
Genus ***Gyraulus*** Charpentier, 1837
Gyraulus Charpentier, 1837: p. 21.

Type species. *Planorbis hispidus* Draparnaud, 1805 (= *Planorbis albus* O.F. Müller, 1774). [accepted as *Gyraulus albus* (O. F. Müller, 1774)], type by subsequent designation.

Distribution. Cosmopolitan distribution in all possible range countries.

***Gyraulus convexiusculus* (Hutton, 1849)**
(Image 2I)
Planorbis convexiusculus Hutton, 1849: p. 657.
Planorbis saigonensis — Crosse & Fischer 1863: p. 362, pl. 13, fig. 7.
Planorbis (*Gyraulus*) *convexiusculus* — Preston, 1915: pp. 118–119; Germain, 1921: pp. 118–119.
Planorbis (*Gyraulus*) *nanus* — Germain, 1921: pp. 131–132, pl. 2, figs 10–12.

Gyraulus convexiusculus — Annandale & Prashad, 1919: pp. 52–54; Benthem Jutting, 1956: p. 463; Brandt, 1974: pp. 239–240, pl. 17, fig. 3; Subba Rao, 1989 : pp. 154–155, figs 362–364; Neubert, 1998: p. 357; Patil & Ramakrishna, 2004: p. 151; Patil & Talmale, 2005: p. 1913; Patil, 2005: p. 444; Patil, Ramakrishna & Mitra, 2006: p. 170; Patil, 2006: p. 15; Ramakrishna & Dey, 2007: p. 234, figs 172A & 172A; Nasemann et al., 2007: p. 91, pl. 23, figs 2a–c; Patil, 2008a: p. 67; Patil, 2008c: p. 119; Patil, 2009: p. 280; Raghunathan & Punithavelu, 2009: p. 150; Patil & Talmale, 2011: p. 14; Patil & Talmale, 2012: p. 266; Glöer & Pešić, 2012: p. 50, fig. 20a; Punithavelu & Raghunathan, 2013: p. 31; Surya Rao, Venkitesan & Rao, 2013: p. 89; Basu et al., 2018: p. 12049; Tripathy, Sajan & Chandra, 2019: p. 14; Mukhopadhyay et al., 2020: pp. 356, 359, pl. 15, fig. I.

Type locality. "Afganisthan".

Material examined. Reg. No. NZSI M.34466/10, 2.ix.2017, 2 spms., India, West Bengal, South 24 Parganas District, Chintamoni Kar Bird Sanctuary; Reg. No. NZSI M.34467/10, 9.ix.2017, 4 spms., Chintamoni Kar Bird Sanctuary, leg. S.K. Sajan.

Distribution. India: Common throughout India;

Image 3. Living snails: A—*Macrochlamys petrosa* (Hutton, 1834) | B—*Rhachistia bengalensis* (Lamarck, 1822) | C—*Ariophanta interrupta* (Benson, 1834) | D—*Macrochlamys indica* Godwin-Austen, 1883 | E—*Cryptaustenia bensoni* (Pfeiffer, 1848) | F—*Indosuccinea semiserica* (Gould, 1846) | G—*Kaliella barrakporensis* (Pfeiffer, 1852) | H—*Lissachatina fulica* (Bowdich, 1822) | I—*Allopeas gracile* (Hutton, 1834) | J—*Laevicaulis alte* (Férussac, 1822). © S.K. Sajan.

Elsewhere: South East Asia, South Asia, Philippines and Japan.

Remarks. Species has wide distribution in India.

Family **Lymnaeidae** Rafinesque, 1815
Subfamily **Amphipepleinae** Pini, 1877
Genus ***Radix*** Montfort, 1810
Radix Montfort, 1810: p. 266.

Type species. *Radix auriculatus* Montfort, 1810 [accepted as *Radix auricularia* (Linnaeus, 1758)], type by original designation.

Distribution. Asia, Europe, Africa, North America.

Radix rufescens **(J. E. Gray in G. B. Sowerby I, 1822)**
(Image 2J)

Limnea rufescens Gray in G. B. Sowerby I, 1822: p. 44, pl. 178, fig. 1.

Limnaea acuminata Lamarck 1882: p. 160; Annandale & Rao, 1925: p. 199; Ramakrishna et. Alfred, 2006: p. 44.

Limnaea (*Pseudosuccinea*) *acuminata* form. *typica* — Patil & Ramakrishna, 2004: p. 148; Patil & Talmale, 2005: p. 1913; Patil, Ramakrishna & Mitra, 2006: p. 168; Patil, 2006: p. 14; Patil, 2008a: p. 66; Patil, 2008b: p. 358–359.

Limnaea (*Pseudosuccinea*) *acuminata* form. *typical* (sic!) — Patil & Talmale, 2012: pp. 262–263.

Limnaea (*Pseudosuccinea*) *acuminata* — Agrawal, 1995: p. 35; Punithavelu & Raghunathan, 2007: pp. 87–88; Raghunathan & Punithavelu, 2009: p. 150; Punithavelu & Raghunathan, 2013: p. 27.

Pseudosuccinea acuminate (sic!) — Basu et al., 2018: p. 12049.

Radix rufescens — Aksenova et al., 2018: p. 4; Tripathy, Sajan & Chandra, 2019: p. 14; Mukhopadhyay et al., 2020: pp. 355, 357–358, pl. 15, fig. E.

Type locality. "East Indies". (from title).

Material examined. Reg. No. NZSI M.30052/7, 22.vii.2017, 3 spms., India, West Bengal, South 24 Parganas District, Chintamoni Kar Bird Sanctuary, leg. T. Biswas and S. Das; Reg. No. NZSI M.34458/10, 9.ix.2017, 9 spms., India, West Bengal, South 24 Parganas District, Chintamoni Kar Bird Sanctuary; Reg. No. NZSI M.34463/10, 2.x.2017, 15 spms., Chintamoni Kar Bird Sanctuary leg. S.K. Sajan.

Distribution. India: Common throughout India; Elsewhere: South East Asia, South Asia, Philippines and Japan.

Remarks. The synonymy of *Limnaea acuminata.*

Class **Bivalvia** Linnaeus, 1758
Order **Unionoida** Stoliczka, 1871
Superfamily **Unionoidea** Rafinesque, 1820
Family **Unionidae** Rafinesque, 1820
Subfamily **Parreysiinae** Henderson, 1935
Genus ***Lamellidens*** Simpson, 1900
Lamellidens Simpson, 1900: p. 854.

Type species. *Unio marginalis* Lamarck, 1819 [accepted as *Lamellidens marginalis* (Lamarck, 1819)]

Distribution. South and Southeast Asia.

Lamellidens marginalis **(Lamarck, 1819)**
(Image 2K)

Unio marginalis Lamarck, 1819: p. 79, [Encyclop. pl. 247, figs 1a–c].

Lamellidens marginalis — Simpson, 1900: p. 854; Subba Rao, 1989: p. 168, figs 404–405; Agrawal, 1995: p. 37; Patil & Ramakrishna, 2004: p. 152; Patil & Talmale, 2005: p. 1913; Patil, 2005: p. 445; Patil, Ramakrishna & Mitra, 2006: p. 171; Ramakrishna et. Alfred, 2006: p. 45; Ramakrishna & Dey, 2007: pp. 288–289, figs 211A–B; Graf & Cummings, 2007: p. 310; Nasemann et al., 2007: p. 29, pl. 8, figs 3–4; Patil, 2008a: pp. 67–68; Patil & Talmale, 2011: pp. 18–19; Patil & Talmale, 2012: pp. 268–269; Surya Rao, Venkitesan & Rao, 2013: pp.91–92; Basu et al., 2018: p. 12049; Tripathy, Sajan & Chandra, 2019: p. 14; Mukhopadhyay et al., 2020: pp. 356, 360, pl. 15, fig. L.

Type locality. "au Bengale".

Material examined. Reg. No. NZSI M.34447/10, 2.ix.2017, 1 spm., India, West Bengal, South 24 Parganas District, Chintamoni Kar Bird Sanctuary, leg. S.K. Sajan.

Distribution. India: Common throughout India; Elsewhere: South and Southeast Asia.

Remarks. One of the common mussels of India.

Genus ***Parreysia*** Conrad, 1853
Parreysia Conrad, 1853: p. 267.

Type species. *Unio multidentatus* Philippi, 1847 [accepted as *Parreysia corrugata* (O. F. Müller, 1774)], type by monotypy.

Distribution. South and Southeast Asia.

Parreysia favidens **(Benson, 1862)**
(Image 2L)
Unio favidens Benson, 1862: p. 188.
Unio pinax — Benson, 1862: p. 192.
Unio tripartitus — Lea, 1863: p. 190.

Unio flavidens (sic!) — Reeve, 1865(1868): pl. 26, sp. 131; errata [– read *favidens*].

Parreyssia favidens (sic!) — Prashad, 1919: p. 292.

Parreysia (*Parreysia*) *favidens* — Patil, Ramakrishna & Mitra, 2006: p. 172; Ramakrishna & Dey, 2007: p. 299, figs 220A–B; Patil, 2008a: p. 68; Patil, 2008c: p. 120; Patil, 2009: p. 281; Patil & Talmale, 2012: p. 270.

Parreysia favidens favidens — Nasemann et al., 2007: pp. 31–32, pl. 9, figs 1–2.

Parreysia favidens — Simpson, 1900: p. 842; Preston, 1912: p. 299; Subba Rao, 1989: p. 180, figs 466–467, 484–485; Patil & Ramakrishna, 2004: pp. 152–153; Patil & Talmale, 2005: p. 1913; Patil, 2005: p. 446; Ramakrishna et. Alfred, 2006: p. 45; Ramakrishna & Dey, 2007: p. 299, figs 220A–B; Graf & Cummings, 2007: p. 310; Patil & Talmale, 2011: p. 20; Tripathy, Sajan & Chandra, 2019: p. 14; Mukhopadhyay et al., 2020: pp. 356, 360, pl. 15, fig. K.

Type locality. "Ganges at Bhitoura, between Cawnpore and Allahabad".

Material examined. Reg. No. NZSI M.34448/10, 2.ix.2017, 2 spms., India, West Bengal, South 24 Parganas District, Chintamoni Kar Bird Sanctuary, leg. S.K. Sajan.

Distribution. India: Common throughout India; Elsewhere: Bangladesh, Nepal, Sri Lanka, Myanmar.

Remarks. One of the common mussels of India.

CONCLUSION

A detailed malacological sampling was carried out for the first time from any protected Area of West Bengal and molluscan diversity have been reported for the first time from the CKBS. A total of 276 specimens were collected and examined from the Chintamoni Kar Bird Sanctuary, West Bengal which reveals presence of 22 species of land and freshwater molluscs. The malacofauna apparently remains most diverse in relation to such a small PA. But invasive alien species viz. *Lissachatina fulica, Allopeas gracile* and *L. alte* which was recorded from this sanctuary is a matter of concern, as it may impact the local biodiversity including succession in the molluscan fauna. This investigation will provided baseline information for the further future study on molluscan diversity. Nevertheless, documentation of other such least studied invertebrate from the PA will support better biodiversity conservation for the area.

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PLATINUM OPEN ACCESS

SHORT COMMUNICATION

Food habits of the Dusky-striped Squirrel *Funambulus sublineatus* (Mammalia: Rodentia: Sciuridae)

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Abstract: We report the first observations of feeding behaviour of the Dusky-striped Squirrel *Funambulus sublineatus* in the Western Ghats. It was observed feeding on eight plant species, including four non-native species. Feeding was observed in forests as well as in plantations and agricultural habitats, indicating the urgent need for studies in such human-modified landscapes.

Keywords: Feeding behaviour, modified landscape, Palani Hills, small mammal, Western Ghats.

The Dusky-striped Squirrel (*Funambulus sublineatus* Waterhouse, 1838) is a poorly studied small mammal, due to quick and cryptic behaviour that makes field observations challenging (Datta & Nandini 2014). This species of palm squirrel is endemic to the Western Ghats of southwestern India and Sri Lanka, and is listed as Vulnerable by the IUCN owing to a declining population trend (Rajamani et al. 2008). Dissanayake & Oshida (2012) propose that the Indian and Sri Lankan populations are split as distinct species, but for this note we follow the IUCN taxonomy, which is not updated. In India, it has been recorded mostly in tropical evergreen and moist deciduous forests of Karnataka, Kerala, and Tamil Nadu (Menon 2014). No targeted studies exist on the ecology and behaviour of this species, with only a couple of opportunistic published records on feeding habitats. Vivek et al. (2011) noted that this squirrel was often part of mixed-species bird flocks, gleaning on bark and flushing insects that were consumed by insectivorous birds. Ganesh & Devy (2006) record infrequent predation on flowers of *Cullenia exarillata*. An opportunistic record describes feeding on wild raspberry fruits *Rubus fairholmianus* (Datta & Nandini 2014).

The current note presents the first record of feeding habits of the Dusky-striped Squirrel in the Western Ghats. These observations are part of an ongoing study on squirrels in the Upper Palani Hills (above 1,400m contour), which is the easternmost spur of the Western Ghats biodiversity hotspot (Myers et al. 2000). The study area occurs in the Dindigul District in Tamil Nadu, between 10.000–10.333N & 77.266–77.400E. The terrain of the Upper Palanis is mountainous, comprising grasslands interspersed with forest patches, categorized as southern montane wet temperate forests or "shola

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forests” by Champion & Seth (1968). Shola forests are predominantly made up of stunted, branched, and dense crown trees which have rainforest origins (Davidar et al. 2007). The dominant tree species are *Syzygium densiflorum*, *Magnolia nilagirica*, *Gordonia obtusa*, and *Eurya japonica* (Matthew 1962). Shola-grassland habitats harbour high biodiversity (Robin & Nandini 2012), but they have undergone significant habitat loss due to timber plantations, agriculture, and other developmental activities (Arasumani et al. 2018) (Figure 1). Prominent exotic species include Acacias, conifers, and *Eucalyptus* sp. (Matthew 1962).

Opportunistic records of feeding behaviour of Dusky-striped Squirrels were noted during a systematic landscape-level study on occurrence of sympatric squirrel species on the plateau between January 2019 and July 2019. Squirrels were located both by their calls and movements. When a Dusky-striped Squirrel was seen feeding, we recorded details of behaviours until the animal moved out of sight. The part of the plant consumed and the plant species were identified. We characterised each feeding instance as a bout of activity of one or more animals feeding on the same food source. Bouts ended when the animal moved out of sight. While no data on the amount of food consumed were recorded, this method provides the diversity of food consumed (Paschoal & Galetti 1995). Unique behaviours were recorded with a video camera, when possible.

Dusky-striped Squirrels were encountered on 66 occasions at 30 distinct locations. Most sightings were of single animals, though on 12 occasions two animals were sighted together, three animals on two occasions and four were sighted together three times (1.38 ± 0.76 SD). The age and sex of animals could not be determined. Twenty-one foraging bouts were recorded over the study period (Table 1). Squirrels were seen foraging on eight plant species from seven different plant families (Table 1). Almost 40% of the foraging observations were of Dusky-striped Squirrel feeding on the nectar of *Lobelia leschenaultiana*, a native understory shrub common along habitat ecotones (Image 1a). Over a five–day period in February 2019, two to four individuals were observed feeding on nectar, and not on any other flower

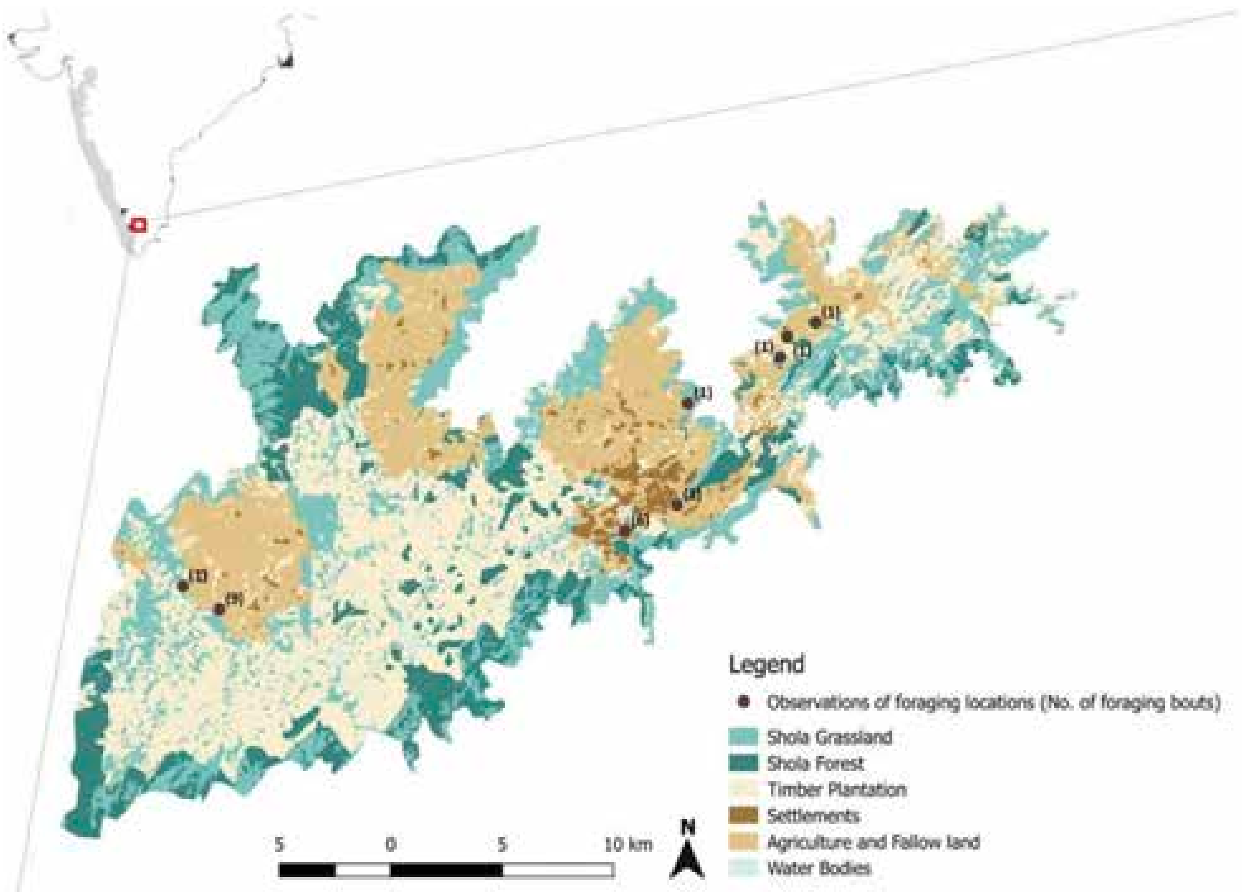

Figure 1. Land-cover of Upper Palani Hills (Arasumani et al. 2018) with locations of observed foraging bouts.

Table 1. Details of feeding behaviour of the Dusky-striped Squirrels in the Upper Palanis.

Plant species	Habitat	Parts eaten	Month eaten	Number of feeding bouts	Number of squirrels in each feeding bout
Lobelia leschenaultiana (Campanulaceae)	Timber plantation edge	Nectar	February	8	4,2,2,2,1,1,2,2
Erythrina variegata (Fabaceae)	Agriculture	Nectar	January, March	4	1,4,1,1
Memecylon randerianum (Melastomataceae)	Shola forest	Fruit	June	2	2,1
Lantana camara (Verbenaceae)	Agriculture	Fruit	July	2	1,2
Rubus ellipticus (Rosaceae)	Shola forest edge	Fruit	May	2	1,1
Acacia mearnsii (Fabaceae)	Timber plantation	Seed	February	1	1
Elaeocarpus tuberculatus (Elaeocarpaceae)	Shola forest	Bark	June	1	1
Symplocus foliosa (Symplocaceae)	Shola forest	Bark	December	1	1

parts. We confirmed that they were feeding on nectar by examining video recordings of the bouts (Video 1; using Canon EOS 700D; number of recordings= 6, mean length of recording= 57.17 ± 22.66 SD seconds). The squirrels were seen on this plant only when flowering (February), and not at any other time of the year.

On four occasions, squirrels were observed foraging on the nectar of *Erythrina variegata*, a non-native tree planted along roads and boundary walls (Image 1b). Fruits of *Memecylon randerianum* (Image 1c), *Lantana camara*, and *Rubus ellipticus*, were consumed on two occasions each. The only time we observed seeds being consumed during this study was of *Acacia mearnsii* (Image 1d). The squirrel was seen peeling the pod with its mouth and consuming the seeds (Video 2; using Nikon COOLPIX P900; number of recordings = 1, length of recording= 40 seconds). Dusky-striped Squirrels were observed on single occasions consuming bark of *Elaeocarpus tuberculatus* and *Symplocus foliosa*. We observed squirrels sniffing tree bark on eight occasions, but could not confirm if they were foraging on insects or bark. Though exact heights used by squirrels were not noted, all squirrels were seen foraging in the understory (0–8 m) and mid-canopy (8–15 m) strata only.

Overall, we observed Dusky-striped Squirrels feeding on fruit, nectar, and bark of native evergreen forest species as well as on introduced and invasive plant species, in a variety of habitats. Squirrels were observed to feed on nectar more than any other plant part (χ^2= 14.238, df= 3, p-value= 0.003), but on non-native and native plant species equally (χ^2= 0.428, df= 1, p-value= 0.513). In this note, present observations that the Dusky-striped Squirrel feeds on nectar, a behaviour similar to nectar-robbery seen in Swinhoe's Striped Squirrels (Deng et al. 2004, 2015). Other squirrel species in the Western Ghats are known to feed largely on leaves and fruit, while also feeding on other plant parts. The Indian Giant Squirrel is known as a facultative frugivore that feeds on seeds, leaves, flowers, pith, and bark (Borges 1992; Sushma & Singh 2006), while the Indian Giant Flying Squirrel is reported to feed on fruit, leaves, flower, and bark (Nandini & Parthasarathy 2008).

We report observations of feeding in shola forests (n= 6), but also in timber plantations (n= 9) and agriculture fields (n= 6) (Table 1). Our study reinforces findings from other studies, which have recorded the presence of the species outside forests. In the Western Ghats, the Dusky-striped Squirrel has been observed in coffee plantations (Bali et al. 2007; Sidhu et al. 2015), tea plantations (Sidhu et al. 2015) and in evergreen forests at the edge of tea plantations (Anamalais – Nandini Rajamani pers. obs. 2005,2006 & 2007). Sridhar et al. (2008) found the species in rainforest fragments, but detections were higher in contiguous protected rainforests.

While this note illustrates that the Dusky-striped Squirrel does use food resources outside forests, we suggest that this may not reflect the true use of modified habitats in the Upper Palanis landscape. The probability of detection of the species is likely higher in open habitats compared to the dense forest interior. We would like to state, however, that the observations of Dusky-striped Squirrel feeding on non-native plant species is a significant finding. This implies that the species shows a certain degree of flexibility regarding using resources in modified landscapes, as seen in several other small mammal species (Kellner et al. 2019). Future research

Image 1. Dusky-striped Squirrel feeding on: a—*Lobelia leschenaultiana* nectar in the edge of a timber plantation (© Aravind P.S.) | b—*Erythrina variegata* nectar in an agriculture field (© Sanjay Prasad Ganguli) | c—*Memecylon randerianum* fruit in a shola forest (© Joe George) | d—*Acacia mearnsii* seeds in a timber plantation (© Aravind P.S.).

efforts should specifically target ecotonal regions, including forest borders, to understand the distribution, population status, habitat requirements, and ecology of this cryptic lesser-known species.

Video 1. Dusky-striped squirrel feeding on the nectar of *Lobelia leschenaultiana*

Video 2. Dusky-striped squirrel peeling the pod and consuming the seeds of *Acacia mearnsii*

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NOTE

High altitude wetland migratory birds in the Sikkim Himalaya: a future conservation perspective

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The Trans-Himalaya contain the most glaciated terrain outside of the polar regions (Owen 2017), and they generate and recharge high altitude wetlands (HAWs) via melting. HAWs are typically situated above 3,000m, between the tree line and permanent snow line (Khan & Baig 2017). Sikkim Himalaya wetlands play a vital role for migratory birds by providing breeding and winter grounds (Chandan et al. 2008; Ganguli-Lachungpa et al. 2011). Many migratory birds are attracted to the HAWs of the state, based on the compilation report of the Sikkim Forest Department over the past two decades, observed in the high altitude wetlands in northern and eastern Sikkim (Ganguli-Lachungpa et al. 2011). It is reported that Ruddy Shelduck *Tadorna ferruginea* (Pallas, 1764) visits high altitude lakes and marshes of the Sikkim Himalaya for breeding (Ganguli-Lachungpa 1990a, 1992). Many wetland migratory birds are reported from Sikkim Himalaya, viz.: Osprey *Pandion haliaetus* (Linnaeus, 1758), Little Grebe *Podiceps ruficollis* (Pallas, 1764), Common Coot *Fulica atra* (Linnaeus, 1758), Bar-headed Goose *Anser indicus* (Latham, 1790), Northern Pintail *Anas acuta* (Linnaeus, 1758), Mallard *Anas platyrhynchos* (Linnaeus, 1758), Baer's Pochard *Aythya baeri* (Radde, 1863), Tufted Duck *Aythya ferina* (Linnaeus, 1758) (Ganguli-Lachungpa 1990a,b, 1994; 1998; 2003; Chettri et al. 2005); Pallas's Gull *Larus ichthyaetus* (Pallas, 1773) (Sharma & Bhat 2016), Common Pochard *Aythya ferina* (Linnaeus, 1758), Great Cormorant *Phalacrocorax carbo* (Linnaeus, 1758); Goosander *Mergus merganser* (Linnaeus, 1758), and Black-necked Grebe *Podiceps nigricollis* (Brehm, 1831) (Acharya & Vijayan 2011; Ganguli-Lachungpa 1990a; 1992). For better preservation and conservation of HAW areas, an initiative has been started by the Sikkim Forest Department, in collaboration with local NGOs with the formation of a Pokhari Sanrakshan Samiti (PSS) on 24 May 2017. The three potential Ramsar sites have been proposed in the Sikkim Himalaya, the detailed information sheets (RIS: 2009–2012 version) have been submitted to the Ministry of Environment, Forest and Climate Change, India in 2011. The names of the proposed Ramsar sites are; Khecheopalri-

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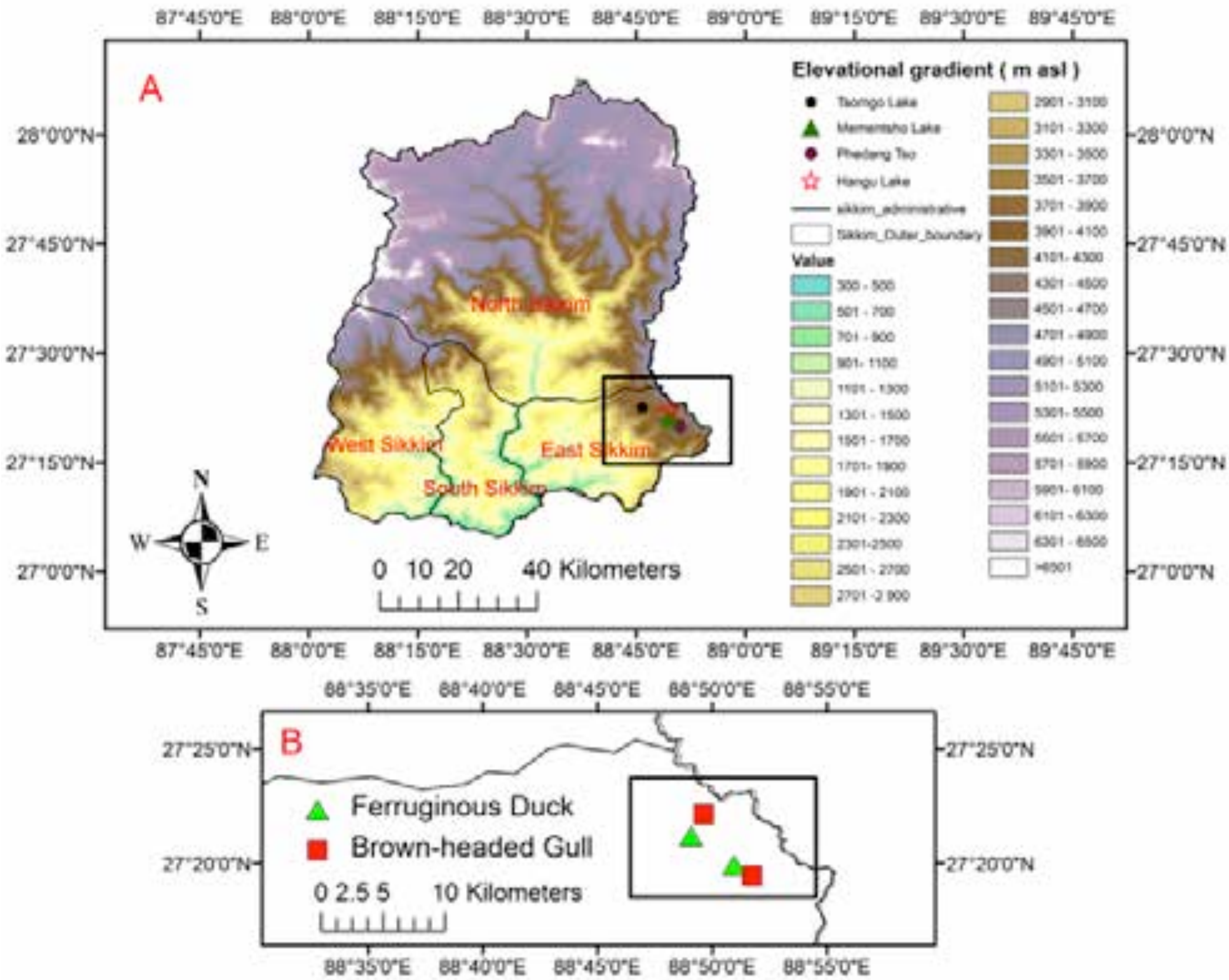

Figure 1. A—digital elevation model of the study area at the high altitude wetlands in the Sikkim Himalaya | B—point location of the first records of the Brown-headed Gull and Ferruginous Duck at the Hangu Lake and Phedang Tso in the Sikkim Himalaya.

Khangchendzonga-Lonak Complex, Tsomgo-Phedang Tso Complex, and Tso Lhamo plateau-Lashar-Yumesamdong-Tembao Complex (See Forest Environment and Wildlife Management Department 2015). Further, the detailed agenda regarding the high altitude Ramsar sites of the Sikkim Himalaya precisely discussed (see O'neill 2019). The record of new species such as Ferruginous Duck *Aythya nyroca* (Near Threatened) and Brown-headed Gull *Chroicocephalus brunnicephalus* (Least Concern) indicates a potential habitat for wetland migratory birds in the Sikkim Himalaya. Therefore, immediate intervention is needed for improved conservation and habitat management for migratory birds in the Sikkim Himalaya through community-based conservation.

Sikkim Himalaya, a total area of 7,096km^2, is a part of eastern Hindu-Kush Himalaya contiguous with eastern Himalaya. It lies between geographical coordinates 27.063–28.126 ^{0}N & 88.061–88.955 ^{0}E. The elevation varies from 284 to 8,586 m, with a picturesque landscape of Mt. Khangchendzonga (8,586m). The geopolitical area of Sikkim is surrounded by Nepal (west), Tibet (north), Bhutan (east), and Tibet (east), and Darjeeling District of West Bengal (south). Sikkim Himalaya has a rich cultural and biologically diversity. The surveys were conducted from December 2017 to April 2018 to assess the species richness of the high altitude wetland migratory birds in the Sikkim Himalaya. The four high altitude wetlands (lakes) were selected from East Sikkim as a case study—Tsomgo (approx. 24.47ha in area, 3,753m), Hangu (approx. 58ha, 4,237m), Mementsho (approx. 42ha, 3,810m), and Phedang Tso (approx. 45ha, 4,600m) (Figure 1). A 2-km line transect was laid down on both sides of the lakes to study the high altitude wetland migratory birds. The individuals of the species with the latitudes, longitudes, and altitudes were recorded within the transects. We used latitudes and longitudes of the species for developing a digital elevation model of the study area (Figure 1). A line-transect sampling is a strategy commonly used to assess richness and abundance of large diurnal vertebrates in forests (de Thoisy et al. 2008). For the study, the permission obtained from the Forests, Environment and Wildlife Management Department, Government of Sikkim (Permit no. Home/Confd/149/2017/3414).

Total of 15 wetland migratory bird species were recorded from the study area. Out of the 15 species, two species—Brown-headed Gull and Ferruginous Duck—were recorded from the Kyongnosla Alpine Sanctuary (27.332N, 28.827E, 4,000m) of the Sikkim Himalaya (Image 1 & 2). The Ruddy Shelduck was found breeding in Sikkim HAWs. The species recorded belonged to five bird families, 10 species encountered under Anatidae family followed by Podicipedidae (two species), and rest of the families having single species each. The species richness of the migratory birds in Phedang Tso or Elephant Lake (14 species) followed by Hangu Lake (12 species), Tsomgo Lake (seven species), and Mementsho Lake (two species). Ruddy Shelduck was recorded from the highest elevation in the study area followed by Northern Pintail, Tufted Duck, Great Crested Grebe *Podiceps cristatus*, and so on (Table 1).

Many migratory birds have been recorded from the Sikkim Himalaya indicating that the Sikkim HAWs offer potential suitable breeding and winter grounds. Brown-headed Gull and Ferruginous Duck first reported from the high altitude wetlands is a new record to the state. The Brown-headed and Ferruginous Duck have been reported from other parts of India (Mishra & Humbert-Droz 1998; Mukherjee et al. 2002; Choudhury 2010). Maximum species richness of migratory birds was observed in Phedang Tso (Elephant Lake) in the study area. The area is out of anthropogenic pressure (like tourism activity) and falls under the restricted defence area and healthy undergrowth vegetation as compared to the other sites. The other lakes, Tsomgo (approx. 24.47ha, 3,753m), Mementsho (approx. 42ha, 3,810m) and Hangu (approx. 58ha, 4,237m) are under the disturbance of tourism. Compared to other states of India, having a small geographical area, the Sikkim Himalaya offers a hub for avian species; over 550 birds recorded from the landscape (Ali 1962; Acharya & Vijayan 2011) including migratory birds (Ganguli-Lachungpa et al. 2011). It is paramount to identify wetlands in the Tibetan Plateau of the Central Asian Flyway to conserve migratory birds because the birds need to refuel at these points to cross the Himalaya (Namgail 2017). The HAWs (lakes) of the Sikkim Himalaya, however, considered as sacred sites, makes their conservation the top priority (Chandan et al. 2008). Hitherto, Sikkim HAWs are under pressure of increasing tourism activities (Mazumdar et al. 2011). Worldwide, most of the migratory birds threatened by wetland habitat loss on its breeding and winter grounds (Ali & Ripley 1983; Scott & Rose 1996; Clements 2007; Grimmett et al. 2008). Appreciating the importance of globally threatened birds found in the Eastern Himalaya, 11 Important Birds Area or IBAs across the Sikkim Himalaya have been recognized by the government of Sikkim in 2003 for the conservation initiative (Ganguli-Lachungpa et al. 2011). Such actions will help to conserve the high altitude wetlands of Sikkim Himalaya and migrating birds as well.

Image 1. Photographic record of Ferruginous Duck in the HAWs of the Sikkim Himalaya.

Image 2. Photographic record of Brown-headed Gulls in the HAWs of the Sikkim Himalaya.

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Table 1. Species richness of migratory waterfowl in the respective high altitude wetlands of the Sikkim Himalaya. ('+'—present | '-'—absent)

	Family	Common name	Scientific name	Phedang Tso (Elephant lake)	Mementsho Lake	Hangu Lake	Tsomgo Lake	IUCN RL status	Estimated extent of occurrence (EOO) (km²) based on IUCN, 2018	Popula-tion trend based on IUCN, 2018	Abundance (no. of individuals in the lakes)
1	Anatidae	Ruddy Shelduck	*Tadorna ferruginea* Pallas	+	+	+	+	LC	37900000	Unknown	100
2	Anatidae	Goosander	*Mergus merganser* Linnaeus	+	–		+	LC	77900000	Increasing	4
3	Rallidae	Common Coot	*Fulica atra* Linnaeus	+	–	–	–	LC	137000000	Increasing	1
4	Anatidae	Mallard	*Anas platyrhynchos* Linnaeus	+	–	+	–	LC	127000000	Increasing	6
5	Anatidae	Eurasian Wigeon	*Mareca penelope* Linnaeus	+	–	+	+	LC	34900000	Decreasing	12
6	Anatidae	Tufted Duck	*Aythya fuligula* Linnaeus	+	–	+	+	LC	34900000	Stable	50
7	Anatidae	Common Teal	*Anas crecca* Linnaeus	+	–	+	+	LC	81700000	Unknown	20
8	Phalacrocoracidae	Great Cormorant	*Phalacrocorax carbo* Linnaeus	+	+	+	+	LC	323,000,000	Increasing	6
9	Anatidae	Northern Pintail	*Anas acuta* Linnaeus	+	–	+	+	LC	69100000	Decreasing	12
10	Podicipedidae	Black- necked Grebe	*Podiceps nigricollis* Brehm	–	–	+	–	LC	155000000	Unknown	1
11	Podicipedidae	Great Crested Grebe	*Podiceps cristatus* Linnaeus	+	–	+	+	LC	152000000	Unknown	20
12	Anatidae	Bar-headed Goose	*Anser indicus* Latham	+	–	–	–	LC	5260000	Decreasing	2
13	Anatidae	Gadwall	*Mareca strepera* Linnaeus	+	–	–	–	LC	73100000	Increasing	7
14	Anatidae	Ferruginous Duck	*Aythya nyroca* Güldenstädt	+	–	+	–	NT	25900000	Decreasing	3
15	Laridae	Brown-headed Gull	*Chroicocephalus brunnicephalus* Jerdon	+	–	+	–	LC	851000	Stable	35

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NOTE

Tawny Fish-owl *Ketupa flavipes* Hodgson, 1836 (Aves: Strigiformes: Strigidae): recent record from Arunachal Pradesh, India

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Fish-owls are important for indicating balanced stream ecology as they are the top predators in freshwater ecosystems (Duncan 2003; Wu et al. 2006). The Tawny Fish-owl *Ketupa flavipes* is commonly found in the Himalaya, eastern Indo-China, southern China as well as Taiwan (Voous 1988; Marks et al. 1999). The size of the owl can be up to 58cm, which is among the largest owls found in India (Sun 1996; König et al. 2008). But it is so infrequently observed in the wild that it is assumed rare over most of its range (Marks et al. 1999). It is currently listed under Schedule-IV of Wildlife Protection Act, 1972 (WPA) and in CITES Appendix II.

Tawny Fish-owls are generally piscivorous, but also eat small mammals, crabs, reptiles, birds, and insects (Fogden 1973; Sun & Wang 2004; Hong et al. 2013; Schauensee 1984; Ali 1986; Voous 1988; Mark et al. 1999). They mainly depend on streams for prey (Sun 1996; Wu et al. 2006) and their higher altitudinal range is decided by the distribution of stream fishes (Voous 1988; Marks et al. 1999). Other than its breeding biology and circadian rhythm (Sun et al. 1997), very little is known about this rare and secretive Tawny Fish-owl (Voous 1988).

The sacred groves are an integral part of the local community, as they perform rituals and ceremonies to please the deity for wellbeing, prosperity and provide refuge to rare and threatened species (Adhikari & Adhikari 2008). They play a significant role in traditional resource conservation system in many regions of India (Malhotra et al. 2001). They can be considered as parts of forest conserved by the local indigenous community because of their religious views and rituals that run through several generations (Gadgil 1975; Meena & Singh 2012).

The fading respect towards traditional knowledge among youngsters and rapid socio-economic advancement has led to the deterioration of sacred groves (Adhikari & Adhikari 2008). In total, 101 sacred groves have been established in Arunachal Pradesh with 36 in Tawang District (Krishna & Amirthalingam 2014).

Zemithang Village (27.718N & 91.726E) is located at an elevation of 2,439m on the bank of Nyamjang Chu (Chu stands for river; Figure 1). It encompasses montane sub-tropical, temperate, and sub-alpine zones. This river is one of the vital perennial rivers in the entire Tawang River basin. Zemithang-Nelya area has been

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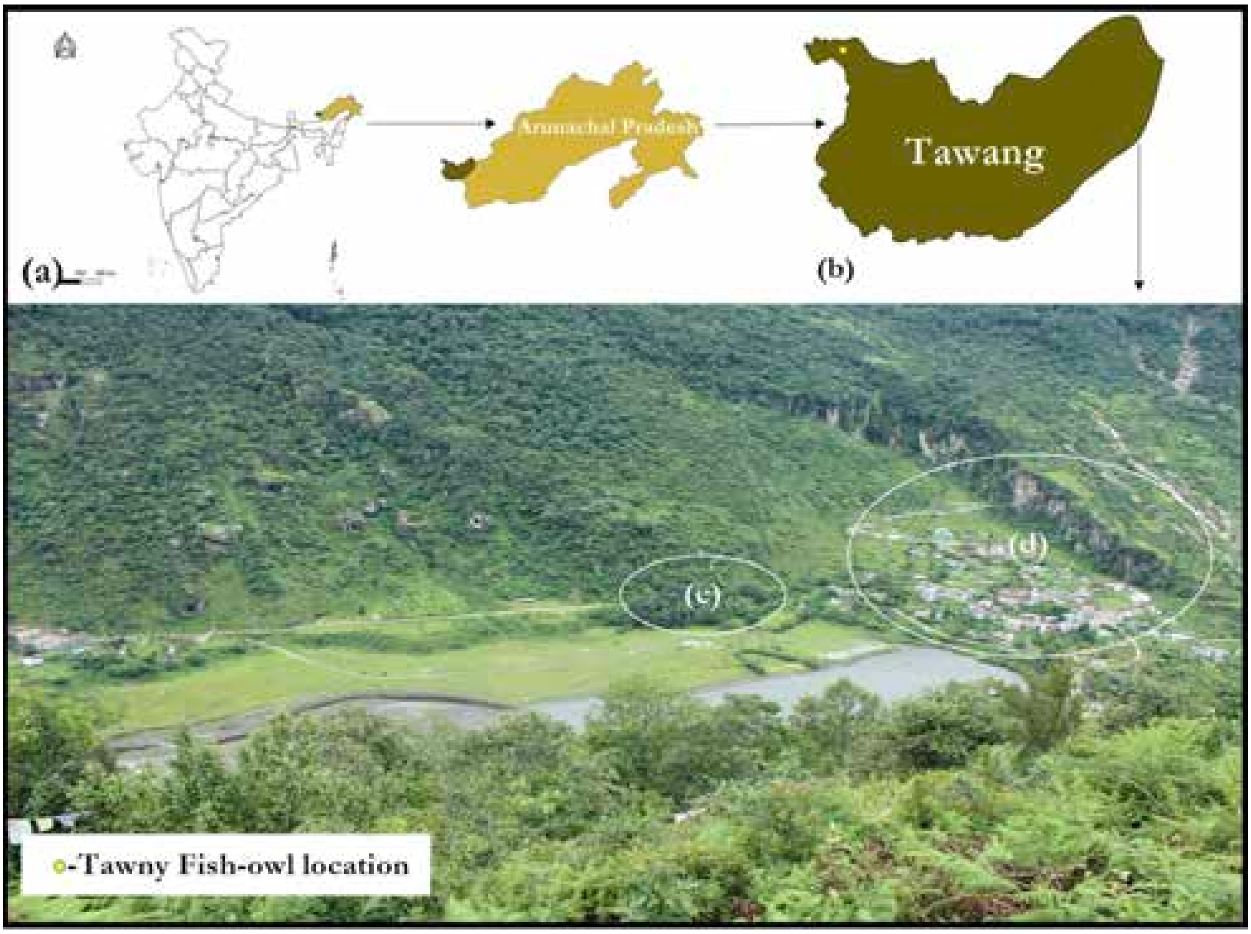

Image 2. The location of the state of Arunachal Pradesh: a—study site within the state of Arunachal Pradesh | b—location of Zemithang Village (encircled) | c—sacred grove | d—Zemithang Village in Tawang District.

identified as an important bird area (IBA code: INAR-28) with several bird species listed as Vulnerable and Near Threatened by the IUCN (Rahmani & Islam 2004).

This large-sized predatory bird was observed on 31 July 2017 inside a sacred grove. Due to a sudden and sharp alarm call from other birds, it was confirmed that some large predator was sitting on the branches of Alder tree *Alnus nepalensis* near the Zemithang to Brokenthang road. While observing through binoculars, it was found that the owl had pale orange upperparts with distinct black streaking, bold orange buff on wing coverts and flight feathers. There was also a whitish patch on the forehead and a prominent black streaking on pale rufous orange underparts. Based on morphological characteristics and a distinct call like a deep whoo-whoo, it turned out to be the Tawny Fish-owl. A few photographs (Image 1) were also taken to reconfirm the identification of the species because of the misidentification possibility of the Tawny Fish-owl with the Brown Fish-owl. The sacred grove in Zemithang is located in a small area with the dominance of *Alnus nepalensis* trees in a waterlogged area. The other major plant species (trees, shrubs, herbs, and grasses) found in the sacred grove are, *Salix* sp., *Celtis* sp., *Elaeagnus* sp., *Rubus* sp., *Girardina macrophylla*, *Artemisia nilagirica*, *Kummerowia striata*, *Paspalum paspaloides*, *Vernonia cinerea*, *Geranium nepalense*, *Selaginella* sp., *Galinsoga parviflora*, *Drymaria cordata*, *Plantago ovata*, *Arthraxon* sp., *Erianthus sikkimensis*, *Sporobolus africanus*, *Pennisetum clandestinum*, *Equisetum* sp., and *Cyperus compressus.*

Local people of Arunachal Pradesh symbolizes the sacred groves under Buddhist monasteries called as Gompa Forest Areas. The sacred groves are managed by local Lamas and Monpa tribes. Arunachal Pradesh has 58 Gompa Forest Areas, distributed mainly in Tawang and West Kameng districts (Higgins et al. 2005).

This particular sacred grove is believed to be rare and associated with high cultural significance in Monpa values (Barbhuiya et al. 2008).

Image 1. Tawny Fish-owl *Ketupa flavipes* in Zemithang. © Malyasri Bhattacharya

After the first sighting of Tawny Fish-owl, it was continuously observed from August–November 2017 and January–February 2018 (Bhattacharya 2018). On 10 January 2018, we observed a pair of Tawny Fish-owl sitting on a branch of alder tree. The species has its range in low elevation ranges up to 1,500m for the Indian Himalayas (Ali & Ripley 1987; Grimmett et al. 1998; Rasmussen & Anderton 2005; BirdLife International 2018) along with Bhutan, China, Laos, Cambodia, Taiwan, and Myanmar (Koker 2019; Holt et al. 2020). The species has also been reported earlier from Pakke Wildlife Sanctuary (WS), Arunachal Pradesh (Ritschard & Marques 2007) and Dibang Valley (preserved specimen, Choudhury 1998). There are many observational records from Assam, Mizoram, Nagaland, and Uttar Pradesh (Barua & Sharma 1999; Praveen et al. 2018; Purkayastha 2018), and from Jim Corbett National Park and the Sattal region of Uttarakhand (Koker 2019). The Tawny Fish-owl was not reported from Tawang District, hence, it is the first report. It is observed that the loss of natural forests due to road and dam construction is very high in the valleys. This might have led to the decrease of the Tawny Fish-owl population since riparian natural forests are the main habitat type used by fish owls (Hayashi 1997; Sun et al. 2000). Therefore, the conservation of such lesser-known species signifies the necessity to protect these small sacred groves. The developmental projects such as roads, dams, and highways, as well as encroachment to forest areas are the major causes of concern for the conservation of these sacred groves (Adhikari & Adhikari 2008). Hunting is completely absent in this region due to the religious belief of the Monpa tribes inhabiting the area (Gopi et al. 2018) however, a proposed hydroelectric project, as well as sand mining practices in the area act as a major threat to the species. We recommend specific research to be carried out to understand the status, distribution, and habitat use of the species in the region.

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NOTE

First report of *Lipotriches* (*Rhopalomelissa*) *parca* (Kohl, 1906) (Halictidae: Nomiinae) from India

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Bees under the subfamily Nomiinae (Halictidae) are solitary except for a few species that build nests in large aggregations. These bees are distributed in the Afrotropical, Oriental, Australian, Palaearctic, and Nearctic regions except in the Neotropical region (Batra 1966; Michener 2007; Astafurova 2013). *Lipotriches* Gerstaecker is one of the largest genera of Nomiinae, known by roughly 350 species globally and 45 species under six subgenera from India (Ascher & Pickering 2021). Pauly (2009) studied the Oriental *Lipotriches* and provided the key to species with their distributions. Later, Pannure & Belavadi (2017) reported 11 species from southern India. The present study is based on unidentified collections present in the Hymenoptera section, Zoological Survey of India, Kolkata.

Bees belonging to the genus *Lipotriches* were sorted from the unidentified collection and processed with standard protocols. The specimen was examined and photographed under a Leica M205A stereo zoom microscope. Species identification was done with the help of Pauly (2009, 2014, 2020) and Michener (2007). The voucher specimen is deposited in the National Zoological Collection, Zoological Survey of India, Kolkata, West Bengal, India.

Family Halictidae Thomson, 1869
Subfamily Nomiinae Robertson, 1904
Genus *Lipotriches* Gerstaecker, 1857

***Lipotriches* (*Rhopalomelissa*) *parca* (Kohl, 1906)**
(Image 1)

Nomia parca Kohl, 1906, male, female. Lectotype male: Aden, XII.1898, leg. O. Simony, NMV, désigné par Pauly, 1990: 165.

Material examined: (Reg. No. 23408/H3), 16.xi.2013, 01 female, India, Rajasthan, Ganganagar, Manjuvas (29.532N & 73.435E), Sweep net, coll. Gaurav Sharma.

Female description: Length 8mm. Body brownish to dark brown, covered by pubescence; head quadrate (length: width 2.3mm: 2.2mm); vertex, paraocular area, ocello ocular area and vertex finely punctated; lateral ocelli surrounded by punctation; vertex not carinate; scape 6× as long as wide; scape, pedicel and F1 brown; F2–9 dorsally brownish-yellow, ventrally pale yellow; apical segment of antennae pale orange; face fully covered with grayish bristles; margin of scutum covered with grayish bristles; mesoscutum densely punctuated; tegula opaque, small, ovate, brownish; scutellum not obscured by pubescence; felted metanotum; propodeum with scattered grayish bristles; hind tibia and hind basitarsus 2.5mm long, with white bristles, with little branching and tapered; fore wing length 7mm, width 2.2mm; apical lobe strongly smoky; hind wing length 5mm, width 1.6mm; hyaline; veins

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Image 1 . *Lipotriches* (*Rhopalomelissa*) *parca*: a—habitus | b—mesosoma | c—head, frontal view | d—fore wing. © Authors.

brown; metasomal tergites with dense punctation except T1 which is T1 fairly less punctated.

Distribution: India: Rajasthan (new record). Arabian Peninsula, Egypt, Libya, Sahara Desert, Sudan, Pakistan, Yemen (Pauly 2014).

Comments: *Lipotriches parca* is closely related to *L. postcarinata* but differs in the following features: apical lobe of fore wing is strongly smoky; body covered by grey pubescence in *L. parca* (vs. fore wing is uniformly infuscate and without grey pubescence in *L. postcarinata*). *L. parca* is mainly recorded from arid regions from both Africa and Asia, although there is also one closer checklist record from Pakistan (Ascher & Pickering 2021). The biology and ecology of *L. parca* is unknown and requires further study.

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NOTE

Addition of four species to the flora of Andaman Islands, India

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The genus *Chlorophytum* Ker Gawler belonging to the family of Asparagaceae includes about 200 species (Govaerts et al. 2012) distributed in the Old-World tropics (Mabberley 2017). In India, the genus is represented by 19 species (Chandore et al. 2012). In Andaman & Nicobar Islands only one species - *Chlorophytum comosum* (Thunb.) Jacques was reported. The genus *Elatostema* J.R.Forst. & G.Forst. belongs to the family Urticaceae. It is one of the largest genera in the family with ca. 350 species from tropical to subtropical regions of Africa, Asia, and Oceania. In mainland India more than 10 species are distributed while in Andaman & Nicobar Islands two species are listed, viz., *Elatostema integrifolium* (D.Don) Wedd. and *Elatostema rostratum* (Blume) Hassk. The genus *Ammannia* L. belongs to the family Lythraceae; about 25 species are widely distributed in tropical areas, mainly in Africa and Asia; three taxa in Andaman & Nicobar Islands have been enlisted, viz.: *Ammannia baccifera* L., *A. baccifera* L. ssp. *aegyptiaca* (Willd.) Koehne, and *A. multiflora* Roxb. The genus *Christisonia* Gardner (including *Campbellia* Wight) is mostly parasitic and the species-rich family Orobanchaceae is recognized worldwide with 90 genera and ca. 1,800 species. In southern and eastern Asia, the genus consists of 17 species distributed in India, Sri Lanka, Laos, southwestern China, Thailand, and Malesia (modified after Nickerent 2012). In India nine species of *Christisonia* have been recorded (Benniamin et al. 2012; Govaerts et al. 2012). In Andaman Islands one species, *Christisonia subacaulis* (Benth.) Gardner has been reported (Murugan et al. 2016).

On scrutiny of the relevant literature (Parkinson 1923; Hajra et al. 1999; Sinha 1999; Pandey & Diwakar 2008; Singh et al. 2014; Murugan et al. 2016; Naik & Singh 2018 a,b; Naik et al. 2019; Singh & Naik 2019) and on critical examination the identity of plants was confirmed as *Chlorophytum vestitum*, *Elatostema cuneatum*, *Ammannia auriculata*, and *Christisonia siamensis* hitherto unreported from Andaman & Nicobar Islands. Hence, this collection is found to be an addition to angiosperm flora of Andaman Islands. Representative specimens were collected in quadruplicates, poisoned, dried, and made into herbarium specimens following Jain & Rao (1977). The herbarium specimens were critically examined with the help of standard floras and appropriate websites. The voucher specimens are deposited at herbarium of Andaman & Nicobar Regional Centre, Port Blair (PBL). Abbreviation used for collectors

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are: MCN (M. Chennakesavulu Naik) GAE (Gautam Anuj Ekka) VCP (Vivek, C.P.) and LJS (Lal Ji Singh).

Asparagaceae

Chlorophytum vestitum Baker

J. Linn. Soc., Bot. 15: 326. 1876. (Image 1).

Specimens examined: 33671 (PBL), 30.ix.2019. Middle Andaman Islands, Rangat, Panchavathi Hills, MCN.

Description: Perennial herbs, up to 30cm high, rhizome horizontal, narrow, roots fibrous with few tubers. Leaves distichous, linear, 10–20 cm × 2-6 mm long, grass-like, ciliate to hairy, fleshy, pale green. Inflorescence lax panicle, 3–5 flowered, 5–10 cm long, cylindrical, terete. Flowers white, pale green base. Bracts caducous. Tepals 6, 3–4 × 2 mm, lanceolate, glabrous. Stamens 6, fused. Anthers spirally arranged. Capsule trilocular, glabrous. Seeds cordate-shaped, glabrous, glaucous, middle notched.

Flowering & fruiting: September–December.

Distribution: India (Middle Andaman Islands (Panchavathi Hills) and Andhra Pradesh); tropical Africa, Zambesiaca (Malawi).

Habitat and ecology: Rare, in rocky crevices and sun exposed areas of hill tops.

Associate species: *Hybanthus enneaspermus* (L.) F.Muell. and *Osbeckia chinensis* L.

Image 1. *Chlorophytum vestitum* Baker. A—habit | B—flower | C—capsule | D—seeds.

Urticaceae

Elatostema cuneatum Wight

Icon. Pl. Ind. Orient. 6: t. 2094, f. 3. 1853. (Image 2).

Specimens examined: 33704 (PBL), 03.ix.2019. South Andaman Islands, Ross Island, MCN & GAE.

Description: Annual herbs, up to 5 cm high; stems triangular. Leaves subsessile, opposite, falcate-cuneate to obovate, 0.5–3 × 0.3–1.8 cm, narrowed entire base, obtuse or acute, crenate-serrate in the upper part, ciliate, glabrous or thinly hairy, linear cystoliths; stipules minute, ovate, acute. Inflorescence axillary, head like; male flowers: heads in the axils of upper leaves; pedicel very short. Perianth segments ovate, obtuse, glabrous. Stamens 4; filaments 0.08mm long. Female flowers; heads with few female flowers in the centre; involucre bracts 3–4; outer ones ovate, acuminate; inner ones ovate-oblong, rounded, ciliate; bracteoles spathulate. Perianth 3–4, dentate at mouth. Achenes reddish brown, ovoid-ellipsoid.

Flowering and fruiting: September–February.

Distribution: India (South Andaman Islands, Ross Island, Goa, Himalaya, Karnataka, Kerala, Maharashtra, Sikkim, and Tamil Nadu), China, Japan, Korea, India, Laos, Vietnam, and Indonesia.

Habitat & ecology: Rare, in moist localities and shady places.

Associate species: *Pilea microphylla* (L.) Liebm. and *Pouzolzia hirta* Blume ex Hassk.

Lythraceae

Ammannia auriculata Willd.

Hort. Berol. 1: 7. 1806. (Image 3).

Specimens examined: 33692 (PBL), 02.ii.2020. Middle Andaman Islands, Billiground, MCN.

Description: Annual herb, up to 40cm. Stem quadrangular. Leaves linear-lanceolate, 6-60 × 1.78 mm. Inflorescence axillary, cymose; 1–12 flowered; peduncle 6mm long; pedicel 1–4 mm long. Hypanthium vertically 8–10 green-ribbed; ribs obscure in fruit. Epicalyx minute. Petals obovate-cuneate. Stamens inserted above the middle of the hypanthium. Ovary broad; style 1–7 mm long. Capsule slightly exceeding the hypanthium, 2–3 mm long. Seeds discoid.

Flowering and fruiting: August–September.

Distribution: India (Middle Andaman Islands,

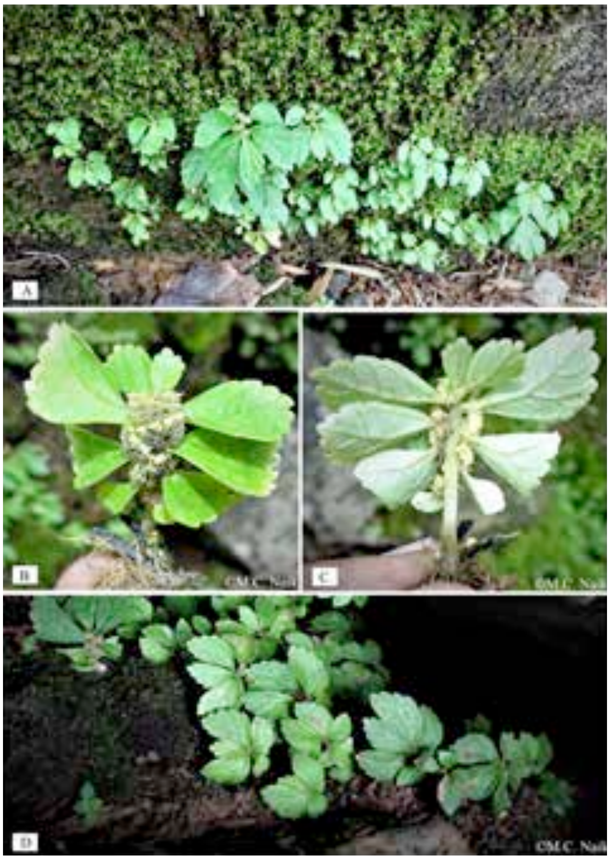

Image 2. *Elatostema cuneatum* Wight. A & D—habit | B—upper view of Inflorescence | C—lower view of plant.

Image 3. *Ammannia auriculata* Willd.: A—habit | B—close-up view of flower and capsule | C—small twig view of phyllotaxy.

Billiground, Andhra Pradesh, Karnataka, Kerala, and Tamil Nadu), widely distributed throughout tropical and warm temperate regions.

Habitat & ecology: Rare, distributed seashore areas.

Associate species: *Justicia procumbens* L. and *Mecardonia procumbens* (Mill.) Small.

Orobanchaceae

Christisonia siamensis Craib

Bull. Misc. Inform. Kew 129. 1914. (Image 4).

Specimens examined: 33639 (PBL), 16.i.2019. South Andaman Islands, Mount Harriet, MCN.

Description: Root parasite, biennial herb, up to 6-8 cm high, subglabrous. Stems 1–2 cm long. Leaves not shown. Flowers 2 to several, clustered at stem apices; bracts oblong or ovate, 6–8 × 3–5 mm. Pedicel short or absent. Calyx tubular, 1.5–3 cm long, sub-membranous or leathery when dry, apex irregularly five-toothed; lobes triangular or lanceolate, two larger and 0.5–1 cm, three smaller, 4–8 mm, apex usually acute. Corolla very unusual in lacking all violet pigmentation, corolla is largely white but with an obvious yellow internal stripe running on the length of the middle of the abaxial lip and sometimes with patches of yellow on the lateral lobes at the mouth of the flower. Filaments 8–10 mm long, glabrous or sparsely glandular; anthers with one fertile cell in upper two stamens, reduced into sticks in lower two stamens. Ovary 1-locular. Style 2–3.6 cm; stigma larger, discoid, 4–6 mm in diam. Capsule ovoid.

Flowering & fruiting: January–February

Distribution: India (South Andaman Island (Mount Harriet), Kerala, and Nagaland) and Thailand.

Habitat & ecology: Rare, in moist localities, shady places.

Associate (host plant) species: *Syzygium claviflorum*.

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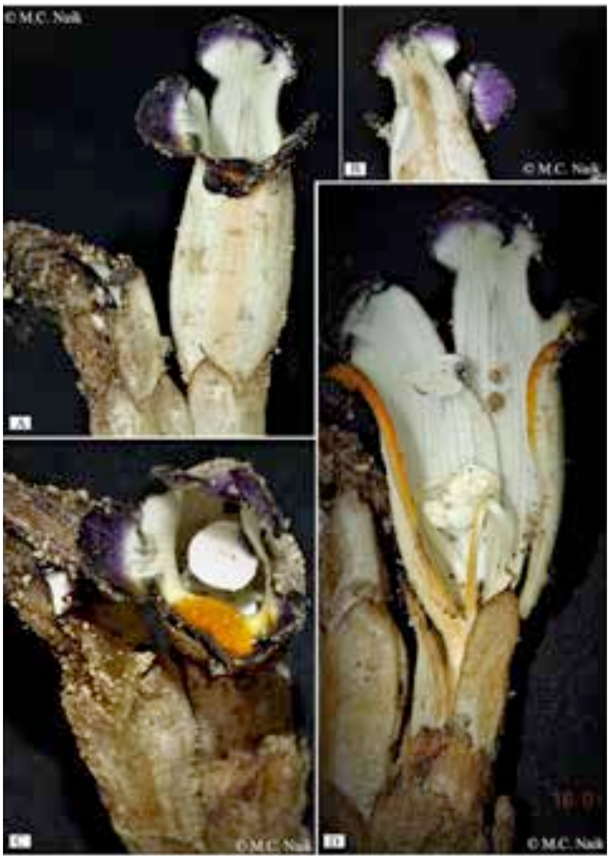

Image 4. *Christisonia siamensis* Craib: A—habit | B—dorsal view of corolla | C—upper view of corolla | D—longitudinal view of Interior parts of corolla.

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