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Short Communication

A new record of the rare Hardwicke's Woolly Bat *Kerivoula hardwickii* (Horsefield, 1824) (Mammalia: Chiroptera: Vespertilionidae) after 23 years from a lowland rainforest of Sri Lanka

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A new record of the rare Hardwicke's Woolly Bat *Kerivoula hardwickii* (Horsefield, 1824) (Mammalia: Chiroptera: Vespertilionidae) after 23 years from a lowland rainforest of Sri Lanka

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Abstract: Distribution of *Kerivoula hardwickii*, Hardwicke's Woolly Bat, in Sri Lanka is restricted to the central highlands and to the northeastern region of the country, and so far, only recorded from four distinct locations. In Sri Lanka, this species was last documented in the year 1994 and no subsequent surveys recorded this species in Sri Lanka, thus considered rare in Sri Lanka. In contrast, within its South Asian biogeography, *K. hardwickii* is widely distributed, particularly in Southeast Asia. In this study, a single male of *K. hardwickii* was observed in lowland rainforest ecoregion of Sri Lanka near Labugama-Kalatuwana Forest Reserve where the bat was roosting on a curled live banana frond. The bat was roosting 1.8m above the ground. This was the first instance *K. hardwickii* recorded in the lowland rainforests of Sri Lanka, which extends this species' biogeography of Sri Lanka into the lowland wet zone. Thus, distribution range of *K. hardwickii* in Sri Lanka could be broader than historically documented. Intensive surveys, particularly in lowland rainforest regions, are required to validate the true distribution of this bat in Sri Lanka.

Keyword: Banana frond, canopy cover, distribution, *Kerivoula*, pitcher plants, threatened.

Sri Lanka, though a relatively small island (~65,610km^2) located in the Indian ocean, provides habitats for a rich assemblage of mammalian fauna. Of the 95 species of terrestrial mammals recorded in the island, bats are the second most diverse mammalian order with 32 species (13 yinpterochiropteran and 19 yangochiropteran species) closely behind rodents with 34 species (Phillips 1980; Leowinta & Luk 2016; Yapa 2017; Edirisinghe et al. 2018). Among Sri Lankan bats, two microbat species of the genus *Kerivoula represented are K. picta* (Painted Bat) and *K. hardwickii* (Hardwicke's Woolly Bat) (Phillips 1935; Yapa & Ratnasooriya 2012; Yapa & Ratnavira 2013). Although the latter species has a wide distribution range covering both southern and northern South Asia, southern China, and throughout continental and insular Southeast Asia, distribution of *K. hardwickii* in Sri Lanka is restricted to the central

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highlands and northeastern part of the country (Bates & Harrison 1997, 2000; Francis 2008; Slade 2017). This species is widespread in Southeast Asia, including Myanmar, Thailand, Laos, Vietnam, Cambodia, Peninsular and Bornean Malaysia, Indonesia, and the Philippines, but show a patchy and relatively isolated distribution in India, Pakistan, and China (Bates & Harrison 1997; Menon 2003; Francis 2008). Distribution of *K. hardwickii* is not well studied in Sri Lanka and recent surveys failed to document this species in or outside its historical range (Rubsamen et al. 2004; Yapa et al. 2005; DWC 2007a,b, 2008a,b; Yapa & Ratnasooriya 2012; Kusuminda et al. 2013; Yapa 2017; Edirisinghe et al. 2018). Given the marked deferential distribution status, there is a discrepancy in the conservation status of *K. hardwickii* in the IUCN Red List of Threatened Fauna and Flora of Sri Lanka (Critically Endangered: Ministry of Environment 2012) versus the Global Red List (Least Concern: Rosell-Ambal et al. 2008). Given the frequent records of *K. hardwickii* elsewhere, the low encounter rate of this species in Sri Lanka could be an artifact of imperfect detection or inadequacy of countrywide surveys on bats. Here, we report documentation of *K. hardwickii* in lowland rainforests of Sri Lanka.

Materials and Methods

We conducted field excursions for a period of six days (06-11 of August, 2017) in the vicinity of Labugama-Kalatuwana Forest Reserve (6.842–6.886^{0}N & 80.220–80.259^{0}E, altitude ranges 30–202 m) in southwestern Sri Lanka (lowland wet zone; average annual precipitation >2,000mm, elevation <300m). The general area is a habitat mosaic where lowland evergreen rainforests of secondary origin is the most dominant vegetation type. In addition, agricultural land-cover types such as rubber, coconut, and banana plantations, paddy fields, and home gardens are scattered around our study area. Through random walks, we first documented suitable bat roosting sites and subsequently surveyed each potential roosting site during both day (08:00–14:00 hr) and night (17:00–21:30 hr) and captured any bats present in the roosting site using a hand net (net depth: 45cm, net diameter: 30cm, mesh size: 1.5x1.5 mm). To confirm species identification, we used several standard guides and keys (Phillips 1980; Srinivasulu et al. 2010; Yapa & Ratnavira 2013). For all captured bats, we documented both morphological characteristics and morphometric variables using a digital Vernier calliper (RD-10, China), photographed (Canon 60D DSLR camera with EF 100mm f/2.8L Macro IS USM Lens) specimens, and immediately released them back to the site of capture. In addition, we recorded air temperature and relative humidity using a multi-digital hygrometer (TA-138, China), and wind speed using a digital anemometer (MS-6252-A, China).

Results

A single male of *K. hardwickii* (Image 1) was observed (17:19hr on 10 August 2017) roosting on a curled live banana frond of a mature banana tree *Musa paradisiaca* located in a secondary forest patch (~163ha in size). This site (6.866^{0}N–80.241^{0}E, altitude ~174m) is located 3.6km northeast of Labugama-Kalatuwana Forest Reserve in Thoranagoda (3.5km northwest of from Eheliyagoda City), situated in Ratnapura District within Sabaragamuwa Province of Sri Lanka (Fig. 1). The roosting site (1.8m height) had about 70% canopy cover. During the time of observations, the wind speed was 1.22–2.16 km/h (average 1.68 km/h), temperature 25.3–28.2 ^{0}C (average 26.7^{0}C), and humidity 57–83 % (average 69.5%). From our first time of observation, the bat remained in its roost for 51 minutes and left

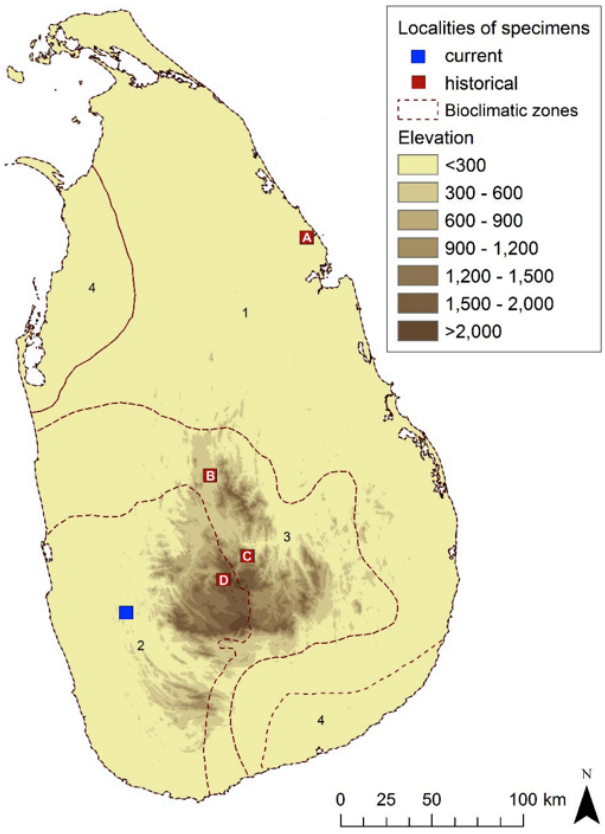

Figure 1. Historical and current distribution of *Kerivoula hardwickii* in Sri Lanka: Historical locations are according to Phillips (1980), Bates & Harrison (1997), and Slade (2017): (a) Nilaweli, (b) Pallama, (c) Kumbalgamuwa, (d) Pundaluoya, and new locality at Thoranagoda (blue square). Bioclimatic zones of Sri Lanka: (1) lowland dry zone, (2) lowland wet zone, (3) intermediate zone, and (4) arid zone.

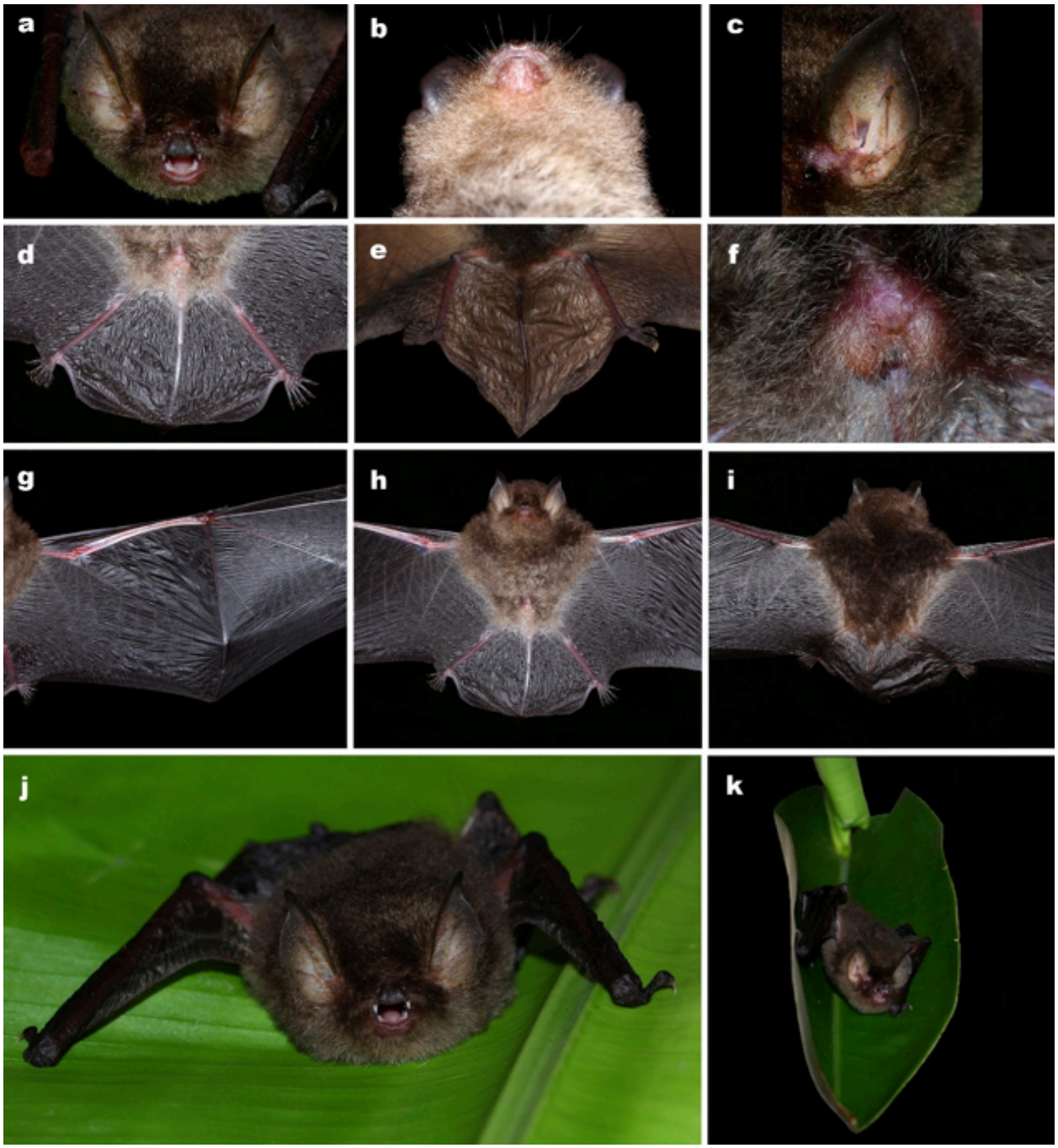

Image 1. Unique characters of *Kerivoula hardwickii* specimen recorded from Thoranagoda area: (a) facial structure, (b) throat area and fur color, (c) external ear lobe and tragus with a prominent notch, (d) and (e) ventral and dorsal aspects of the semitransparent interfemoral membrane (tail membrane), (f) presence of light brown, short hairs in the penis and the scrotum, (g) the ventral view of the wing membrane (patagium), (h) and (i) dorsal and ventral aspects of the bat, including the proximal parts of the patagium, (j) and (k) live specimen in the roosting site (banana frond). © Madhava Botejue.

the roost around 18:10hr, immediately after the sun set. The morphological and morphometrics featured of this individual resembled general description of *K. hardwickii* (Table 1 and 2). Other bat species we documented in this survey included *Pteropus giganteus, Rousettus leschenaulti, Cynopterus sphinx, Hipposideros ater, Hipposideros speoris, Pipistrellus tenuis,* and *Rhinolophus rouxii*.

Table 1. Morphometric variables recorded on *Kerivoula hardwickii* specimen recorded from Thoranagoda area, Sri Lanka, in this study, and also Phillips (1935), Bates & Harrison (1997) (measurements in mm.).

Measurement	2017	1935	1997
Head & Body length	40.37	43	39.0–55.0
Ear length	12.53	32	11.0–15.0
Ear width	6.20	-	-
Tragus length	5.98	-	-
Tragus width	1.16	-	-
Forearm length	32.47	32	31.7–36.0
1mt thumb +1st claw length	5.00	-	-
2nd metacarpal	33.42	-	-
3rd metacarpal	34.77	-	30.9–38.1
4th metacarpal	33.64	-	-
5th metacarpal	31.41	-	-
1ph 3mt length	14.22	-	-
2ph 3mt length	20.13	-	-
1ph 4mt length	9.53	-	-
2ph 4mt length	9.54	-	-
1ph 5mt length	8.24	-	-
2ph 5mt length	9.93	-	-
Wingspan length	230	-	-
Penis length	3.50	-	-
Penis width	1.19	-	-
Testicle height	1.54	-	-
Testicle width	1.33	-	-
Tibia length	17.21	-	-
Calcar length	13.44	-	-
Hind foot length	6.70	5	5.0–8.0
Tail length	38.50	-	35.0–43.0

Discussion

Previously-known occurrence of *K. hardwickii* in Sri Lanka was limited to four locations (Fig. 1)—Kumbalgamuwa (1931, 914m, near Walapane, Nuwara-Eliya District, Central Province, Natural History Museum of London, Cat No. BMNH.1931.11.7.1 (Phillips 1932)); Pundaluoya (1,062m, near Kikiliyamana, Nuwara-Eliya District, Central Province, Natural History Museum of London, Cat No. BMNH.3840346 (Bates & Harrison 1997)); and Pallama (1994, 500m, near Matale, Matale District, Central Province, Harrison Zoological Museum Cat No. HZM.3.31606 (Bates & Harrison 1997)); and Nilaweli (1945, 8m, near Kumpurupiddi, Trincomalee District, Eastern Province, Kansas University Biodiversity Institute, Cat No. KUM.135734, (Slade 2017)).

In Sri Lanka, this species is purported to occur in small numbers and inhabit warm, montane (500–1,100 m) well-sheltered forested valleys throughout the central highlands of Sri Lanka. According to our knowledge, this is the first photographic evidence of *K. hardwickii* from Sri Lanka with detailed morphological and morphometrics descriptions, and this is the first documentation after 1994 (Bates & Harrison 1997). Our sighting suggests a greater distribution range of *K. hardwickii,* which may extend beyond the central highlands and northeastern lowland dry zone, into the lowland wet zone of Sri Lanka. Since our encounter is limited to a single bat we draw a cautionary note regarding updating its conservation status. Further research with a combination of repeated visits and mist netting should be carried out in this region prior to updating the species extent of occurrence and area of occupancy. Moreover, we are also uncertain of the reason for low encounter rate of *K. hardwickii* and can be attributed to a combination of this species' illusive behavior, small-size, use of cryptic roosting sites, and lower population density stemming from lack of suitable habitats and low availability of critical resources.

Within its South Asian biogeography, this species is mostly found in forests and woodlands (Molur et al. 2002), but they are also found in forest edges, paddy fields, home gardens. Our documentation agrees with previous records of this species outside Sri Lanka as the landscape context of our study site is a habitat mosaic with home gardens, agricultural lands, isolated woodlands undergoing frequent anthropogenic disturbances, and many other forms of modified land-cover types. For instance, *K. hardwickii* is found in both subtropical and tropical China, and inhabits both forested and agricultural habitats, and forages around home gardens, paddy fields, and rural human settlements (Smith & Xie 2008). In Southeast Asia, *K. hardwickii* has been recorded from primary forests, secondary and disturbed forests, and montane forests (Rosell-Ambal et al. 2008). Throughout the overall distribution, *K. hardwickii* occurs along a broad elevation range (60–2,060 m) (Bates & Harrison 1997). Our observation is the first documentation of *K. hardwickii* from lowland rainforests of Sri Lanka, which in combination with its historic records from montane humid forests and dry mixed evergreen forests may suggest that this bat occupies a wider range of ecoregions within Sri Lanka similar to its biogeography in eastern and Southeast Asia.

Kerivoula hardwickii inhabits a wide variety of roosting habitats. Most often, they are found in buildings (both abandoned and those occupied by humans), large dead or dry leaves that are hanging downwards (which

Table 2. Detailed morphological features of *Kerivoula hardwickii* recorded from Thoranagoda area, Sri Lanka, in this study.

Morphological characters	Present specimen (Male)
Nose shape	Simple nostrils.
Head	Muzzle relatively small; Eyes small; The face covered in hair except for the nostrils, which are angled slightly downwards and outwards; the whiskers are conspicuous and protrude beyond the hairs on the snout.
Ears	Mostly naked but dark brown colour few short hairs present, Relatively large, funnel-shaped, tip-rounded.
Tip of the ear	Hair absent.
Tragus	Long and attenuated, narrowing gradually to a sharp point. A prominent notch present. Slightly concave, with a less angular tip.
Chin	Light brown, few short hairs present around the chin.
Throat	Light brown, few short hair present
Dorsal area	Dark brownish to grey or light brown, hair present throughout head and body.
Ventral area	Dark brown hair present in the nape and the chest. Light grey and light brown hair present on the abdomen.
Ante-brachial membrane	Present (Semi- transparent, thin in texture)
Radio metacarpal pouch	Absent.
Wing membrane	Well developed; the patagium and the skeletal elements supporting the patagium are naked. The wings and interfemoral membrane are brown; nearly transparent.
Forearm; 1st, 2nd, 3rd, 4th and 5th, metacarpals; 1st, 2nd, 3rd, 4th, and 5th phalanx to 1st, 2nd, 3rd, 4th, and 5th metacarpals	Naked.
Dorsal surface of tibia	Light brown, short hair present.
Inter-femoral membrane Dorsal area	Light brown, short hair present.
Inter-femoral membrane Ventral area	Light brown, short hair present.
Wing attached to	The base of the outer toe.
Penis (Foreskin)	Light brown, short hair present.
Testicles	Light brown, short hair present.
Anus	Light brown, short hair present.
Hind feet	Well-developed, light brown short hair present.
Calcar	Well-developed, light brown short hair present.
Tail	Enclosed with Inter-femoral membrane

conforms with our observation), clusters of dead leaves, hollow tree trunks, tall trees and dense bushes, and bamboo thickets (Bates & Harrison 2000; Francis 2008; Rosell-Ambal et al. 2008). A unique roosting habit of *K. hardwickii* has recently been documented from Southeast Asian island of Borneo where the bat roosts inside aerial pitchers of Raffles' Pitcher plant (*Nepenthes rafflesianaelongata*). This is considered a resource-service mutualistic association where bat excreta provide nitrogen for the plant and the aerial pitcher shelters and protects the bat from predators (Bauer et al. 2011; Grafe et al. 2011). In Sri Lanka, *K. hardwickii* has not been documented in pitcher plants so far. Although pitcher plants are abundant in and around our study site, we did not find *K. hardwickii* to associate pitcher plants for roosting purposes.

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Communications

Urban biodiversity: an insight into the terrestrial vertebrate diversity of Guwahati, India
-- Jayaditya Purkayastha, Pp. 12299–12316

Status of raptors in the Moyar River Valley, Western Ghats, India
-- N.R. Anoop, S. Babu, S. Bharathidasan & R. Nagarajan, Pp. 12317–12327

Species composition and abundance estimates of reptiles in selected agroecosystems in southern Western Ghats, India
-- Abhirami Mini Jayakumar & Paingamadathil Ommer Nameer, Pp. 12328–12336

Comparison of beach profiles conducive for turtle nesting in Andaman
-- Subramanian Narayani, Sasidharan Venu & Andrea Joan D'Silva, Pp. 12337–12343

Short Communications

A new record of the rare Hardwicke's Woolly Bat *Kerivoula hardwickii* (Horsefield, 1824) (Mammalia: Chiroptera: Vespertilionidae) after 23 years from a lowland rainforest of Sri Lanka
-- Dinesh Gabadage, Gayan Edirisinghe, Madhava Botejue, Kalika Perera, Thilina Surasinghe & Suranjan Karunarathna, Pp. 12344–12349

Alarming population status of the Grizzled Giant Squirrel *Ratufa macroura* (Mammalia: Rodentia: Sciuridae) in Chinnar Wildlife Sanctuary, the Western Ghats, India
-- Kiran Thomas & Paingamadathil Ommer Nameer, Pp. 12350–12356

Distribution and population status of Sambar *Rusa unicolor* (Mammalia: Cetartiodactyla: Cervidae) from Aravalli landscape with a note on its first record from Aravalli Hills of Haryana, India
-- Paridhi Jain, Anchal Bhasin, Gautam Talukdar & Bilal Habib, Pp. 12357–12362

Delayed peracute capture myopathy in a Himalayan Ibex *Capra sibirica* (Mammalia: Cetartiodactyla: Bovidae)
-- Umar Nazir Zahid, Latief Mohammad Dar, Umar Amin, Showkat Ahmad Shah, Rashid Yahya Naqash, Dil Mohammed Makhdoomi, Shayuaib Ahmad Kamil & Intesar Suhail, Pp. 12363–12367

Checklist of the avifauna of Sagareshwar Wildlife Sanctuary, Maharashtra, India
-- Sharad Datt Apte, Vijay Bhagwan Tuljapurkar & Girish Avinash Jathar, Pp. 12368–12375

The rediscovery of Rurk's Cat Skink *Ristella rurkii* Gray, 1839 (Reptilia: Ristellidae) with remarks on distribution and natural history
-- Sumaithangi Rajagopalan Ganesh, Pp. 12376–12381

Dietary assessment of five species of anuran tadpoles from northern Odisha, India
-- Syed Asrafuzzaman, Susmita Mahapatra, Jasmin Rout & Gunanidhi Sahoo, Pp. 12382–12388

Inventory of prong-gilled mayflies (Ephemeroptera: Leptophlebiidae) of India with records of endemic taxa
-- C. Selvakumar, Kailash Chandra & K.G. Sivaramakrishnan, Pp. 12389–12406

First record of a coreid bug *Anhomoeus fusiformis* Hsiao (Hemiptera: Heteroptera: Coreidae: Coreinae: Anhomoeini) from India
-- Sadashiv V. More & Hemant V. Ghate, Pp. 12407–12412

The gilled mushroom *Amanita spissacea* (Amanitaceae): a new report for India
-- Hmar Lalrinawmi, John Zothanzama, Benjamin W. Held, Josiah M.C. Vabeikhokhei, Zohmangaiha & Robert A. Blanchette, Pp. 12413–12417

Notes

Foraging habits of the Red Fox *Vulpes vulpes* (Mammalia: Carnivora: Canidae) in the Himalaya, India
-- Aishwarya Maheshwari, Pp. 12418–12421

First record of Yellow-Rumped Flycatcher *Ficedula zanthopygia* (Hay, 1845) (Aves: Passeriformes: Muscicapidae) in eastern India
-- Manaranjan Das & Subrat Debata, Pp. 12422–12424

Additional field records provide further resolution of the distribution of the Water Monitor *Varanus salvator* (Squamata: Varanidae) in northwestern Myanmar
-- Steven G. Platt, Myo Min Win & Thomas R. Rainwater, Pp. 12425–12428

The first record of The Blue Admiral *Kaniska canace* Linnaeus, 1763 (Nymphalidae: Lepidoptera) from Bangladesh
-- Amit Kumer Neogi, Md Jayedul Islam, Md Shalauddin, Anik Chandra Mondal & Safayat Hossain, Pp. 12429–12431

First record of *Hislopia malayensis* Annandale, 1916 (Bryozoa: Gymnolaemata) from freshwaters of India
-- Ananta Dnyanoba Harkal & Satish Sumanrao Mokashe, Pp. 12432–12433

An extended distribution record of Western Ghats species *Litsea oleoides* (Meissn.) Hook.f. (Lauraceae) from Matheran, Maharashtra, India
-- Radha Veach & Gurumurthi Hegde, Pp. 12434–12438

Notes on *Jasminum andamanicum* N.P. Balakr. & N.G. Nair (Oleaceae) from Andaman & Nicobar Islands, India
-- P. Murugan & K. Karthigeyan, Pp. 12439–12441

Miscellaneous

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