

ORIGINAL ARTICLE

Annotated checklist, distribution and regional status of the bats (Mammalia: Chiroptera) of Kerala, South India

Sreehari Raman^{1,2,3,*}, Akhil Padmarajan⁴, Muhammed A. Faizal³, Akhil A. Das³, Pooja Ushakumari⁵, Sweta Singh⁶, Alice C. Hughes^{1,2,7,*}

¹Center for Integrative Conservation, Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences, Menglun, Mengla, Yunnan Province, 666303, PR China

²University of Chinese Academy of Sciences, Beijing 100049, PR China

³College of Forestry, Kerala Agricultural University, KAU P.O. (680656), Vellanikkara, Thrissur, Kerala, India

⁴Rani Bhavan, Muttappalam, Perumguzhy P.O., Chirayinkeezhu, 695305, Thiruvananthapuram, Kerala, India

⁵College of Veterinary and Animal Sciences, Kerala Veterinary and Animal Sciences University, Pookode, Wayanad, Kerala 673576, India

⁶201, Sangam Paradise apartment 7th H-cross, Chinnapannahalli Doddanekundi Marathalli, Bengaluru-560037

⁷Southeast Asia Biodiversity Research Institute, Chinese Academy of Sciences, Menglun, Mengla, Yunnan, 666303, PR China

*Corresponding author:

sreehari.raman@kau.in, ach_conservation2@hotmail.com

DOI: <https://doi.org/10.14709/BarbJ.14.1.2021.17>

Keywords: endangered, endemic, harp trap, mammals, new records, roost, threatened species, Western Ghats

received: September, 30th 2021

accepted: December, 24th 2021

ABSTRACT

Understanding species diversity and species distributions across the region provides a crucial baseline for developing effective conservation plans. Several checklists of bats of Kerala have already been published in combination with other mammal groups. However distribution data has been largely unavailable. A comprehensive bat survey was conducted at 43 different locations across various protected and non-protected areas of Kerala. Bats were monitored using harp traps (398 trap-nights), mist nets (51 trap-nights) and direct roost visits. Our sampling yielded a total of 42 species from 23 genera and seven families, of which three species (*Barbastella darjelingensis*, *Hesperoptenus tickelli* and *Kerivoula hardwickii*) are new records for Kerala and four Vespertilionid species belong to the genus *Harpiocephalus*, *Kerivoula*, *Murina* and *Tylonycteris* are potentially undescribed species. Previous records of 41 species were also gathered from various literature sources but six of these were not detected during our survey. After collating all the available data, here we produce the first comprehensive review on the distribution and occurrence of 48 bat species in Kerala (20 Vespertilionids, 6 Pteropodids, 6 Hipposiderids, 5 Rhinolophids, 3 Emballonurids, 3 Molossids, 2 Megadermatids, 2 Miniopterids and 1 Rhinopomatid). Regional assessment based on the occurrence data further classified bat species into rare (16 spp.), common (13 spp.), abundant (9 spp.), however the status of remaining 10 spp. remains unknown. We also present a simplified dichotomous key for the identification of bats in Kerala.

INTRODUCTION

The Western Ghats (WG) mountain range of peninsular India is identified as one of the major bat hotspots in India with 63 species (Raman & Hughes 2020). The southern part of the WG harbours rich biodiversity and higher endemism in terms of both flora and fauna than the rest of the Ghats region (Gimaret-Carpentier et al. 2003, Dahanukar et al. 2004, Pascal et al. 2004, Davidar et al. 2007, Raman et al. In review). The majority of the southern WG region lies within the political boundary of Kerala (Nair 1991). In the last few decades, much of the natural habitats of WG has been transformed due to habitat modification (Gadgil et al. 2011). Alteration in land use and changing climatic conditions have likely influenced the distribution and habitat use of various

species, including bats (Hughes et al. 2012, Frick et al. 2020, Raman et al. 2020a). Over 1400 species of bats have so far been described globally (Wilson & Mittermeier 2019), constituting over 50% of mammal species in tropical forests (Davison & Zubaid 2007). Many bat species exhibit specific habitat associations which means they are potentially good bioindicators of an ecosystem's health (Jones et al. 2009). They provide crucial ecosystem services as seed dispersers, pollinators, controlling pest-insect populations and for recycling nutrients (Ramírez-Francel et al. 2021). Hence, knowledge of different species' distributional ranges is important for conservation decision planning.

Systematic studies of bats in India started during the second half of the 19th century and this time is considered

the golden era of Indian chiropterology (Saikia 2018). The comprehensive work conducted by Bates & Harrison (1997) is considered to be the fundamental reference for bat research in India. They summarised all the previous work and provided detailed taxonomic descriptions along with the distribution of 109 bat species in India. Unlike other tropical regions, bat diversity in this region is comparatively low (Alves et al. 2018). Recently Saikia (2018) reported 127 bat species from India but the number is increasing with discoveries of new species and range extensions. For example, *Myotis frater* (Chakravarty et al. 2020), *Phoniscus jagorii* (Raman et al. 2020b) and *Eudiscopus denticulus* (Saikia et al. 2021) were very recently recorded from India, demonstrating bat richness in India is underestimated and further surveys can boost the species richness in this region. In recent years, bats researchers in India have focused more on echolocation studies (Thabah et al. 2006, Chattopadhyay et al. 2010, Raghuram et al. 2014, Wordley et al. 2014, Deshpande & Kelkar 2015, 2019, Srinivasulu et al. 2015a, Srinivasulu et al. 2015b, 2016, Srinivasulu & Srinivasulu 2017, Chakravarty et al. 2020, Raman & Hughes 2020, Prakash et al. 2021a); DNA barcoding (Thabah et al. 2006, Karuppudurai et al. 2007, Rajan et al. 2009, Kanagaraj et al. 2010, Chinnasamy et al. 2011, Chattopadhyay et al. 2012, Ruedi et al. 2012, Chattopadhyay et al. 2016, Chakravarty et al. 2020, Chattopadhyay et al. 2021); habitat suitability modelling (Wordley et al. 2015, Debata et al. 2019, Raman et al. 2020a); functional traits (Wordley et al. 2017, Chakravarty et al. 2021); radiotelemetry (Prakash et al. 2021b), and zoonotics (Yadav et al. 2012, Mani et al. 2017, Paul 2018, Br et al. 2019, Dovich et al. 2019, Plowright et al. 2019, Yadav et al. 2019), which highlights increasing interest and effort into bat research in India.

Several published checklists of bats include Kerala as part of a broader region and/or in combination with other mammal groups (Bates & Harrison 1997, Nameer 2000, 2015, Nameer et al. 2001, Dinesan et al. 2004, Easa & Ramachandran 2005, Korad et al. 2007, Dinesan et al. 2010, Menon 2014, Plowright et al. 2019, Raman & Hughes 2020). However distribution data is largely unavailable. Intermittent surveys have been carried out by researchers and scientists from various institutes and these have contributed significantly to the taxonomy and geographical distribution of bats in this region (Deshpande & Kelkar 2015, 2019, Nameer et al. 2016, Srinivasulu & Srinivasulu 2017). To our knowledge, a comprehensive checklist of bats specifically for Kerala has never been published. Few studies also show that bats in this region are facing severe threats. For instance, WG endemic and endangered *Latidens salimalii* is highly habitat-specific and is at risk of habitat loss due to changing climatic conditions (Raman et al. 2020a). The recent Nipah outbreak also added to the existing threat to bats of this region (Plowright et al. 2019). It is therefore timely to intensively resurvey to gather information on current bat diversity and their distribution. With this background, we conducted a detailed bat survey in Kerala to record the current distribution and compiled information from secondary sources. The present study will therefore expand the current knowledge of past-present distributions and habitat usage of all the known bats in Kerala to form the basis for developing suitable conservation plans.

MATERIALS AND METHODS

Study area and sampling sites

Kerala state is located in southern India along the Arabian Sea (8°17'–12°47'N and 74°52'–77°22'E) with a total extent of 38,852 sq. km and an elevation ranging from 0–2695m (Fig. 1). Located within the humid equatorial tropics, Kerala is characterized by high rainfall and humidity. Annual rainfall varies from 1,520 to 4,075mm, and the temperature ranges from 19.8°C to 36.7°C. It is estimated that around 28% of the land area is forested, of which tropical wet evergreen and semi-evergreen constitutes 34.28%, tropical moist deciduous (31.97%), tropical dry deciduous (3.46%), montane sub-tropical temperate sholas (3.42%), grasslands (4.43%) (KFD 2015, FSI 2019). Sampling sites were identified at every one-degree latitude starting from 8.5°N to 12.5°N. Systematic sampling was conducted from July 2017–June 2019 at 43 different locations across varying elevations and in two different habitats (evergreen and deciduous) in Kerala. More details on sampling sites are provided in Supplementary Material Table 1.

Primary data collection

Sampling was carried out using a pair of four-bank harp traps of the dimensions 1.5m wide, 2.2m high, 7.5cm between each of four frames, 2.5cm between vertical monofilament fishing lines, and four-shelved mist nets of 38mm mesh size. Harp traps were open throughout the night (398 trap-nights) while the mist nets were deployed between 18:00–21:00 hours (51 trap-nights). Local people provided information on the location of active roosts which were then sampled using a hand net. Once captured, standard morphometric measurements were taken immediately after capture at the study sites for species identification (Bates & Harrison 1997). These included forearm length (FA; from the extremity of the elbow to the extremity of the carpus with wings folded), head-body length (HBL; from the tip of the snout to the base of the tail), tail length (TL; from the tip of the tail to its base adjacent to the anus), ear length (E; from the tip of the pinna to the lower border of the external auditory meatus), and the hind foot length (HF; from the extremity of the heel to the extremity of the longest claw, excluding hairs). All the measurements were taken to the nearest 0.1mm accuracy using an SPI electronic calliper. The individuals were released at the sampling sites after recording their respective echolocation calls. Acoustic parameters of various echolocating bats are available at Raman & Hughes (2020) (Supplementary Material 1). Voucher specimens of unambiguous species and wing punches were preserved in ethanol and deposited at Museum at College of Forestry, Kerala Agricultural University (KAU). The sampling and handling of bats was conducted by following the standard protocol (Sikes & ACUC 2016). Species-level identification was conducted using morphometric keys (Bates & Harrison 1997, Francis 2008, Srinivasulu et al. 2010) and a regional echolocation call library (Raman & Hughes 2020).

Secondary data collection

A literature review was conducted for the period between January 2020 and April 2021. The dataset was compiled

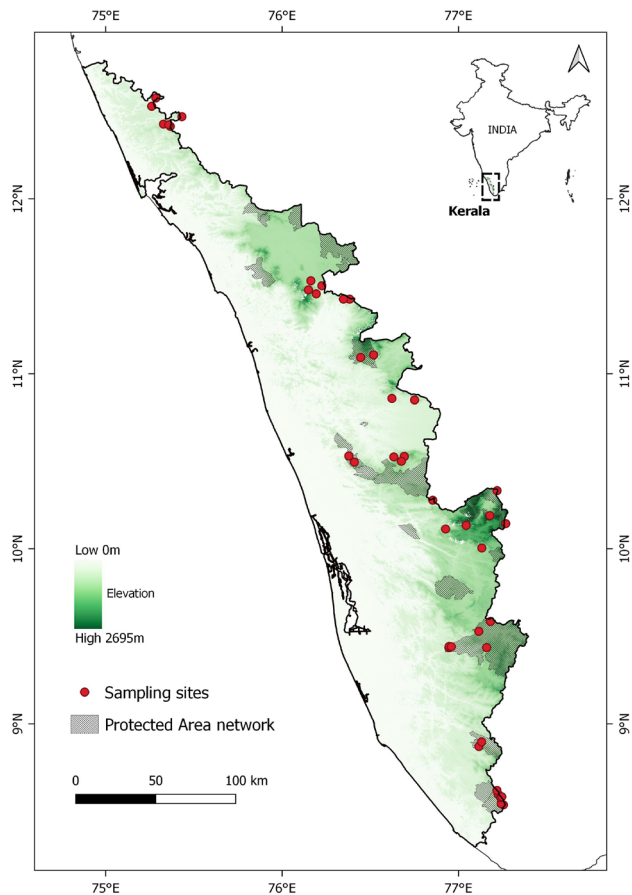


Fig. 1 - Location map of the study area. Colour gradient (light green to dark green) indicates low to high elevation, red dots indicate the sampling sites.

based on the literature collated from Google Scholar (<https://scholar.google.com>), PubMed (<https://pubmed.ncbi.nlm.nih.gov/>), self-archived ResearchGate (<https://www.researchgate.net>) and personal communications with bat experts working in Kerala. We used the keywords (bat* OR Chiroptera) AND (Kerala* OR Western Ghats OR South India OR Peninsular India) to screen the literature. To maximize the output for our dataset, we also incorporated technical reports published online and survey reports submitted to the state forest department. Specimen collections at the Natural History Museum of KAU and the Zoological Survey of India were examined as part of this study. Citizens who took explicit bat pictures and posted them on various social media platforms were personally contacted for respective location details. The pictures were carefully examined and included in the dataset after taking consent from the relevant person.

Regional assessment

In the present study, the regional status of each bat species was determined and categorized as 'rare' (known only from ≤ 9 locations), 'common' (10–19 locations) and 'abundant' (≥ 20 locations). However, due to the inadequacy of aerial sampling, Molossids, Emballonurids and Rhinopomatid were underrepresented and hence were classified as 'unknown'. The geographical distribution of each species was visualised using the diagram function of QGIS 3.18 Zürich (QGIS Development Team 2021).

RESULTS

Systematics

The survey recorded a total of 1,555 individuals of 42 species from 43 sites distributed across Kerala. This includes three new records (*Barbastella darjelingensis*, *Hesperoptenus tickelli* and *Kerivoula hardwickii*) and four potentially new species belonging to the genera *Harpiocephalus*, *Kerivoula*, *Murina* and *Tylonycteris*. Of all bats we recorded, 75% of records were from five species: *Rhinolophus indorouxii* (21.29%), *Rhinolophus lepidus* (18.78%), *Hipposideros speoris* (14.15%), *Miniopterus pusillus* (13.38%) and *Hipposideros pomona* (7.40%) (Supplementary Material Fig. 2). The literature review also revealed the presence of 41 species from Kerala. Hence the overall bat diversity of Kerala is now 48 species belonging to nine families (20 Vespertilionids, 6 Pteropodids, 6 Hipposiderids, 5 Rhinolophids, 3 Emballonurids, 3 Molossids, 2 Megadermatids, 2 Miniopterids and 1 Rhinopomatid). Based on the number of occurrence records, we categorised 9 species as abundant, 13 as common and 16 as rare (Table 1). Due to insufficient evidence, the remaining 10 species were categorised as 'unknown'. The taxonomy and nomenclature of this section largely follows Wilson & Mittermeier (2019) and Simmons & Cirranello (2021). A simplified dichotomous key for the identification of bat species seen in Kerala and its adjoining regions is given in Supplementary Material 1. Table 2 provides external measurements of the bats we examined, and changes in the taxonomy of some species are provided as notes. We discuss these cases in detail and highlight the importance of further surveys to determine their occurrences and resolve the taxonomy of bat species in WG with implications for conservation priorities. Here we used the abbreviations for National Park (NP), Wildlife Sanctuary (WLS), Biological Park (BP), Bird Sanctuary (BS), Tiger Reserve (TR), Reserved Forest (RF) and Forest Division (FD) wherever applicable.

Species Account

Family Pteropodidae

Old world fruit bats or Pteropodidae are a diverse group of bats, distributed throughout the tropical regions of Africa, Asia and Indo-Australia (Hill & Smith 1984). The fruit bat diversity of Kerala is represented by six species belonging to five different genera: *Cynopterus* (2 species), *Eonycteris* (1 species), *Pteropus* (1 species), *Rousettus* (1 species) and the monotypic *Latidens*. Fig. 2 shows the distribution records of Pteropodids in Kerala. A brief note on the taxonomy and nomenclature of *Pteropus medius* is also provided below.

Cynopterus brachyotis ceylonensis (Gray, 1871) Lesser Short-nosed Fruit Bat

Previous records: Silent Valley National Park, Parambikulam TR (Das 1986, Dinesan et al. 2004, Menon 2014)

New records: Agasthyavanam Biological Park, Periyar TR, Eravikulam NP, Mathikettanshola NP, Chimmomy WLS, Peechi WLS, Nelliampathy RF, Meppady RF, Elayerithitta (Kannur)

Note: Five lineages of *C. brachyotis* complex were described from South and Southeast Asia. Phylogenetic analysis shows that the southern India-Sri Lanka population (*C. b. ceylonensis*) could be a potential new species and further studies are required for resolving the taxonomic ambiguity (Campbell et al. 2004, Campbell et al. 2006, Jayaraj et al. 2012). During the present study, a total of five individuals were caught in mist-nets and one individual in a harp trap within dense forest. The species was also found roosting in an abandoned well at Wayanad with a colony size of 12. A mixed colony of *C. b. ceylonensis*, *Miniopterus fuliginosus* and *Rhinolophus pusillus* was also recorded inside a laterite stone cave located at Elayerithitta (northern Kerala).

***Cynopterus sphinx* (Vahl, 1797)**
Greater Short-nosed Fruit Bat

Previous records: Trivandrum (Azhoor, Kalli), Shendhuruni WLS, Kumarakom, Thattekkad BS, Ernakulam, Chimmony WLS, Peechi WLS, Thrissur District (KAU campus, Cherpu, Paralam, Kodanur, Venginissery, Chenam, Chirakkal) (Andersen 1912, Bates & Harrison 1997, Easa et al. 2001, Dinesan et al. 2004, Cyriac et al. 2005, Menon 2014)

New records: Neyyar WLS, Arippa (Kollam), Periyar TR, Mathikettanshola NP, Pampadamshola NP, Anamudishola NP, Cherthala, Vaikom, Peechi WLS, Nelliampathy RF, Silent Valley NP, Waynad WLS, Meppady RF, Ranipuram RF (Kasaragod)

Note: The species is observed from the plains to high elevational regions of Kerala. In Wayanad and Ranipuram, day roosting of nine and seven individuals respectively were observed in live tents constructed in palm leaves, while in Arippa (Kollam) the species was found roosting inside cracks in coconut palm (*Cocos nucifera*). Predation of *C. sphinx* by WG endemic Malabar Grey Hornbill (*Ocyrceros griseus*) is also recorded from Arippa (Amal et al. In press).

***Eonycteris spelaea* (Dobson, 1871)**
Lesser Dawn Bat

Previous records: Parambikulam TR (Nameer et al. 2016)

New records: Agasthyavanam BP, Vithura (Trivandrum), Sholayar RF

Note: Until 2019, the species was known only from a single locality in central Kerala (Nameer et al. 2016). However, this study shows it is also distributed in the southern regions of Kerala. Of the four individuals trapped, one individual was recorded from a rubber plantation located at Vithura (Trivandrum) while the other individuals were from evergreen forests. Presence of kidney-shaped glands on either side of the anal opening, the absence of a second digit claw, an elongated and narrow muzzle with protrusible tongue all make *E. spelaea* easily distinguishable from other fruit bats of this region (Bates & Harrison 1997, Francis 2008, Srinivasulu et al. 2010). In Southeast Asia, the species is known to roost in large colonies in caves and other man-made structures (Waldien et al. 2020), in association with other cave-dwelling bats such as *Rousettus leschenaultii*, *Hipposideros lankadiva* and *Hipposideros*

speoris (Bates & Harrison 1997). However, the present study failed to observe any roosting sites and the restricted distribution means it qualifies as a rare species in Kerala. We recommend further cave surveys to identify roosting sites and undertake population estimation studies in WG.

***Latidens salimalii* Thonglongya, 1972**
Salim Ali's Fruit Bat

Previous record: Periyar TR, Mankulam RF, Malayattoor FD, Silent Valley NP (Easa et al. 2001, Molur & Vanitharani 2008, Raman et al. 2020a)

Note: It is also categorised as a rare species of fruit bat seen in Kerala due to its restricted distribution. We observed the largest colony of 600–800 individuals from Mankulam FD. A mother with pup was observed during the month of June 2018. It is an endemic and endangered fruit bat seen in the humid mountains ranges of southern WG (Raman et al. 2020a, Srinivasulu & Srinivasulu 2020). Recent studies show that there is around 10,000 sq.km of potential habitat for *L. salimalii* in southern WG, and the species is endangered due to local hunting and possibly from the impacts of climate change (Raman et al. 2020a).

***Pteropus medius* (Temminck, 1825)**
Indian Flying Fox

Previous records: Mangalavanam BS, KAU campus, Palakkad District (Kunnukadu, Cherumkad, Vadakencherry) (Jayson & Easa 1999, Cyriac et al. 2005, Reginald et al. 2008)

New records: Trivandrum District (Trivandrum zoo, Karyavattom, Kowdiar, MLA hostel, Akkulam), Kollam District (Mundrothuruthu, Ilippakulam, Kundara, Parvathy mill compound, Ammachiveedu, Ayathil, Thevally, Kadakkal-Chingely), Pathanamthitta (Pandalam), Alleppy District (Thottapally), Idukki District (Thekkady), Ernakulam District (Panangad, Irigole Kavu, Kodakara, Malayattoor, Kodanad, Wilington Island), Thrissur District (East Fort, Mukkattukara, Chalakkudy, Mudikodu, Guruvayoor), Palakkad District (Palakkad Fort, Malampuzha) Malappuram District (Kunnummal, Nilambur-Conoly plot), Wayanad District (Panamaram, Mananthavady Pazhassi Park, Sulthan Bathery, Nambyakunnu Temple, Pookode, Panamaram bridge, near Banasura dam), Kozhikode District (near Lalithakala Academy), Kannur District (Chekkikattukavu, Cherkala, Chettamkuzhi, Madhur, Vidhyanager, Manathana, Nilamuttam, Edakkadu, Muzhakkunu, Manna, Mattannur), Kasaragod District (Periya, Kuttikol, Neeleswaram)

Note: The Indian Flying Fox was previously recognised as *Pteropus giganteus* Brünnich, 1782. However the recent phylogenetic studies classified Indian *Pteropus* to *P. medius* Temminck, 1825 (Giannini et al. 2008, O'Brien et al. 2009, Chan et al. 2011), which is the oldest name available for this species. It is widely distributed across various landscapes of Kerala. Their colonies were located on tall trees, bamboo stands and in mangroves. However the species has a restricted distribution inside forested areas. Recently, individuals collected from the northern Kerala was tested positive for NiV virus (Yadav et al. 2019).

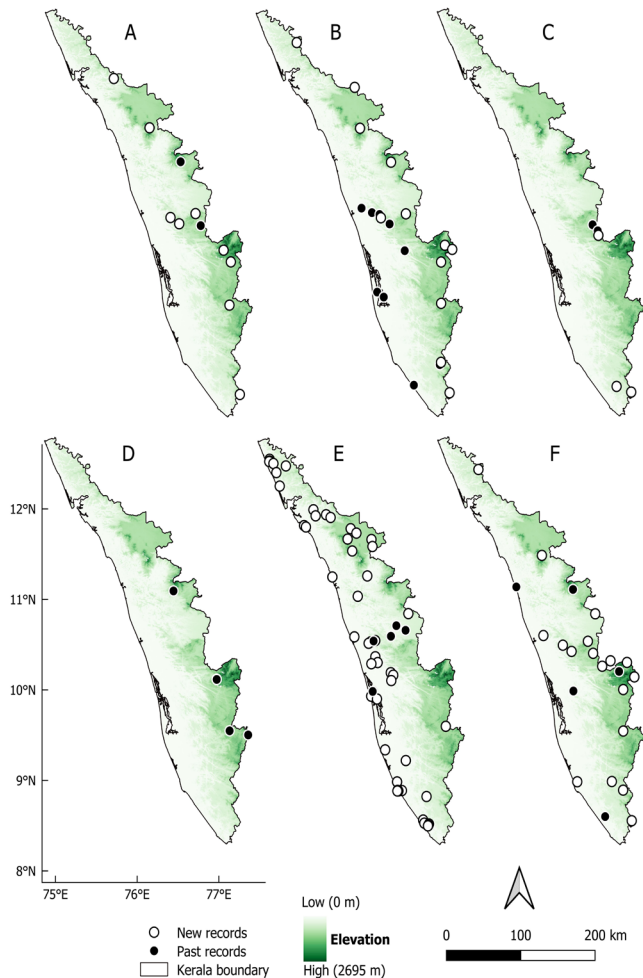


Fig. 2 - Map showing the distribution records of Pteropodids in Kerala. A: *Cynopterus brachyotis ceylonensis*, B: *Cynopterus sphinx*, C: *Eonycteris spelaea*, D: *Latidens salimalii*, E: *Pteropus medius*, F: *Rousettus leschenaultii*.

Rousettus leschenaultii (Desmarest, 1820) Leschenault's Rousette

Previous records: Trivandrum, Eravikulam NP, Ernakulam, Silent Valley NP, Kadalundy (Das 1986, Bates & Harrison 1997, Easa et al. 2001)

New records: Shendhuruni WLS, Mundrothuruthu (Kollam), Pathanapuram, Periyar TR, Mathikettanshola NP, Pampadumshola NP, Chinnar WLS, Parambikulam TR, Chimmony WLS, Peechi WLS, Nelliampathy RF, Walayar RF, Pookottukavu (Palakkad), Silent Valley NP, Meppady RF, Ranipuram RF

Note: Abandoned buildings and caves are the preferred roosting sites of *R. leschenaultii* in Kerala. The largest roost that we observed is located at Mambara (Peechi WLS) with 5,000–6,000 individuals. The colony size of *R. leschenaultii* was found in proportional with the available roosting space. An abandoned building (area ~1000 sq.ft) in Mundrothuruthu (Kollam Dst.) has a colony size of 800–1,000 individuals, while an abandoned house (area ~300 sq.ft) in Peechi (Thrissur Dst.) has a colony size of 150–200 individuals.

Family Rhinolophidae

Rhinolophidae is a monogeneric family represented by 106 species globally (Simmons & Cirranello 2021). In Kerala, the family is represented by five described species (Fig. 3).

Rhinolophus beddomei K. Andersen, 1905 Beddome's Horseshoe Bat

Previous records: Shendhuruni WLS, Periyar TR, Thrissur District (Kottekadu, Pallipuram, Paralam, Venginissery), Palakkad, Wayanad, Thalassery, Kannur (Jerdon 1874, Lindsay 1927, Bates & Harrison 1997, Madhavan 2000, Dinesan et al. 2004, Padmanabhan 2009, Deshpande 2012, Menon 2014)

New records: Agasthyavanam BP, Neyyar WLS, Periyar TR, Mathikettanshola NP, Pampadumshola NP, Ayyapancovil (Idukki), Parambikulam TR, Chimmony WLS, Peechi WLS, KAU campus, Nelliampathy RF, Pulapetta (Palakkad), Silent Valley NP, Vazhykadavu (Nilambur North), Kottiyoor WLS, Meppady RF, Kasargod RF

Note: They are normally observed singly or in small groups (2–4 individuals) between the elevational range 30–1155m from evergreen and deciduous forest types as well as from fringe areas. They are found roosting inside abandoned buildings, large tree holes, cave entrances and under bridges.

Rhinolophus lepidus Blyth, 1844 Blyth's Horseshoe Bat

Previous records: Kollam, Shendhuruni WLS, Thrissur, Silent Valley NP, Parambikulam TR, Palakkad, Kozhikode (Das 1986, Bates & Harrison 1997, Madhavan 2000, Dinesan et al. 2004, Padmanabhan 2009, Menon 2014)

New records: Agasthyavanam BP, Neyyar WLS, Periyar TR, Ayyapancovil (Idukki), Mathikettanshola NP, Eravikulam NP, Pampadumshola NP, Kuttampuzha, Anamudishola NP, Chinnar WLS, Sholayar, Vazhachal, Parambikulam TR, Peechi WLS, Nelliampathy RF, Dhoni RF, Walayar RF, Silent Valley NP, Nilambur North, Meppady RF, Ranipuram RF, Kasaragod RF.

Note: The species is recorded throughout the forested tracts of Kerala from dense to open forest as well as from modified landscapes between the elevational range 95–1155m. Morphological differences were noticed in two individuals that were harp trapped from Neyyar WLS and one from Ranipuram RF. The first individual had a rudimentary lancet, the sella of the second individual had a broad superior connecting process while the other lacked an anterior notch (Fig. 4). Considerable variation in the nose leaf characteristics was previously reported by Bates & Harrison (1997). Further molecular studies using CO1 gene showed no variation with the southern WG population of *R. lepidus*. The echolocation characteristics of the anomalous individuals also matched references in the regional call library (Raman & Hughes 2020). However multivariate analysis on the south Indian population of *R. lepidus* revealed the presence of cryptic diversity and phenotypic variation across latitudinal gradient (Chattopadhyay et al. 2021).

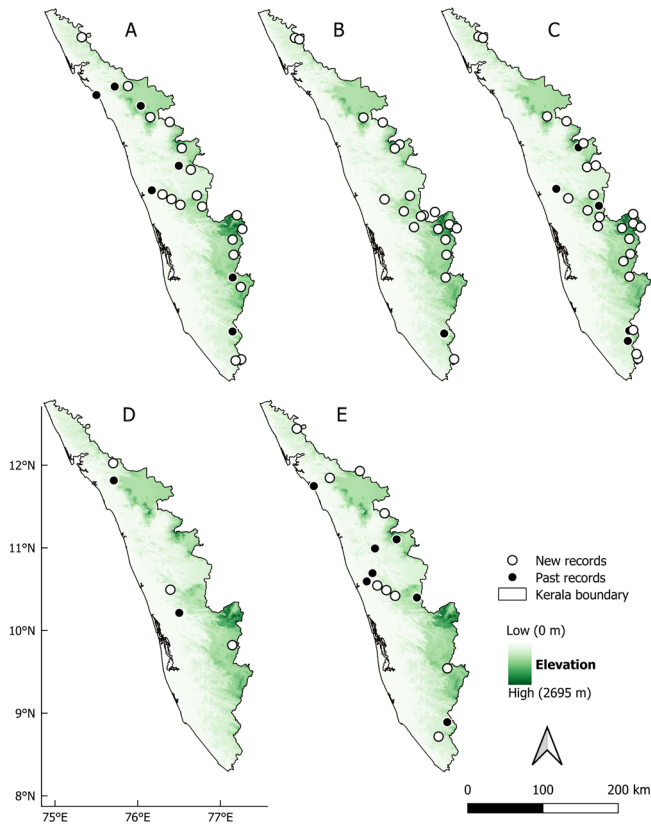


Fig. 3 - Map showing the distribution records of Rhinolophids in Kerala. A: *Rhinolophus beddomei*, B: *Rhinolophus indorouxii*, C: *Rhinolophus lepidus*, D: *Rhinolophus pusillus*, E: *Rhinolophus rouxii*.

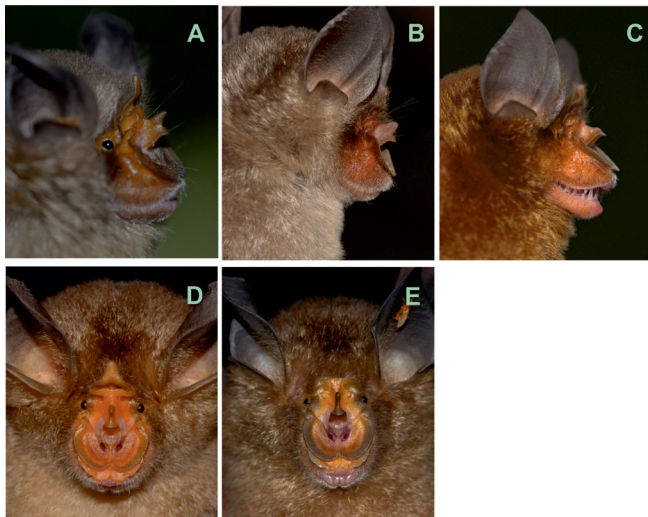


Fig. 4 - Images showing the variation in the noseleaf structure and cot colour in *R. lepidus* sampled from Kerala. A: typical sella of *R. lepidus*, B: sella with a broad superior connecting process, C: sella without a notch, D: typical shape of lancet in *R. lepidus*, and E: noseleaf without a pointed lancet. Images: Sreehari Raman

***Rhinolophus pusillus* Temminck, 1834**
Least Horseshoe Bat

Previous records: Ernakulam, Malabar (Bates & Harrison 1997, Dinesan et al. 2004)

New records: Ayyapancovil, Peechi WLS, Elayerithitta (Kannur)

Note: The species looks similar to *R. lepidus* morphologically, but is smaller in size (Bates & Harrison 1997). The species is rare and the present observations were from low to mid elevation forests of Kerala. In Elayerithitta, the species was found roosting in a laterite stone cave with *M. fuliginosus* and *C. b. ceylonensis*.

***Rhinolophus indorouxii* Chattopadhyay et al., 2012**
Greater Rufous Horseshoe Bat

Previous records: Shendhuruni WLS (Deshpande 2012)

New records: Neyyar WLS, Periyar TR, Mathikettanshola NP, Eravikulam NP, Pampadumshola NP, Kuttampuzha, Anamudishola NP, Vazhachal, Peechi WLS, Nelliampathy RF, Sholayar, Silent Valley NP, Bommiyampady (Attappadi), Nilambur North, Muthenga, Meppady RF, Kasargod RF, Ranipuram RF

Note: The southern Indian population of *R. rouxii* was considered to be the subspecies *R. rouxii rouxii* (Bates & Harrison 1997). Molecular and acoustic studies validate the presence of a distinct species *R. indorouxii* in peninsular India (Chattopadhyay et al. 2010, 2012). The present study shows that the *R. indorouxii* has a wide distribution in the tropical evergreen and deciduous forests of Kerala between the elevational range 124–1155m. The species is locally common and also shows considerable variation in the pelage colour, similar to its sister species *R. rouxii* (Bates & Harrison 1997). The species is categorised as Data Deficient (Chattopadhyay & Kandula 2017) and our observations can significantly add to the distribution of the species.

***Rhinolophus rouxii* Temminck, 1835**
Rufous Horseshoe Bat

Previous records: Shendhuruni WLS, Ernakulam, Kottekadu (Thrissur), Parambikulam TR, Palakkad, Malappuram, Thalasherry (Kannur), Silent Valley NP (Jerdon 1874, Das 1986, Bates & Harrison 1997, Madhavan 2000, Dinesan et al. 2004, Padmanabhan 2009, Deshpande 2012, Menon 2014)

New records: Palode (Trivandrum), Periyar TR, Chimmony WLS, Peechi WLS, KAU campus, Nilambur North, Waynad WLS, Punnappalam (Kannur), Kasargod

Note: It is morphologically similar but slightly smaller in size than *R. indorouxii* (Table 2). The species was observed between the elevational range 40–950m from moist deciduous forest tracts, as well as from human modified habitats. They also co-occur with *R. indorouxii* in some of its distributional range (Deshpande & Kelkar 2019).

Family Hipposideridae

The family is represented by 90 species globally (Simmons & Cirranello 2021) of which nine are observed in WG (Raman & Hughes 2020) and six in Kerala (Fig. 5).

Hipposideros ater Templeton, 1848 Dusky Leaf-nosed Bat

Previous records: Trivandrum, Alapuzha, Thrissur District (KAU Campus, Pazhayannur, Kodungallur, Mathilakom, Paralam, Pallipuram, Chenam, Alapad), Ernakulam, Kozhikode (Bates & Harrison 1997, Madhavan 2000, Dinesan et al. 2004, Cyriac et al. 2005, Padmanabhan 2009)

New records: Neyyar WLS, Mundrothururthu (Kollam), Mannuthy (Thrissur)

Note: All the observations were from human modified habitats. Two individuals were harp trapped from agricultural land dominated by coconut trees, whereas roosting colonies were observed in semi-urban areas with colony sizes ranging from 2–30 individuals.

Hipposideros fulvus Gray, 1838 Fulvus Leaf-nosed Bat

Previous records: Ernakulam, Thrissur, Parambikulam TR (Bates & Harrison 1997, Madhavan 2000, Dinesan et al. 2004, Padmanabhan 2009, Menon 2014)

New records: Chinnar WLS, Peechi WLS, Vazhikadavu (Nilambur)

Notes: Individuals were harp trapped from low-mid elevation deciduous forest, riverine habitat (Chinnar WLS) and in human inhabited areas.

Hipposideros lankadiva Kelaart, 1850 Indian Leaf-nosed Bat

Note: The IUCN range map shows the species occurs in Northern Kerala, and Plowright et al. (2019) also listed the species among the bats of Kerala. However, exact localities for this species is still unavailable. The species was not detected during this study and hence we infer that the distributional ranges of *H. lankadiva* may likely fall outside our sampling sites or the occurrence of the species in Kerala is questionable.

Hipposideros pomona K. Andersen, 1918 Pomona Leaf-nosed Bat

Previous records: Alapuzha, Shendhuruni WLS, Thrissur District (Kodungallur, Venginissery) (Bates & Harrison 1997, Madhavan 2000, Dinesan et al. 2004, Padmanabhan 2009)

New records: Agasthyavanam BP, Neyyar WLS, Periyar TR, Idukki, Mathikettanshola NP, Eravikulam NP, Pampadumshola NP, Kuttampuzha, Anamudishola NP, Sholayar, Vazhachal, Nelliampathy RF, Dhoni (Palakkad), Silent Valley NP, Meppady RF, Ranipuram RF

Notes: Recent morphometric, bacular, and acoustic studies on the South Asian *H. bicolor* group has resolved

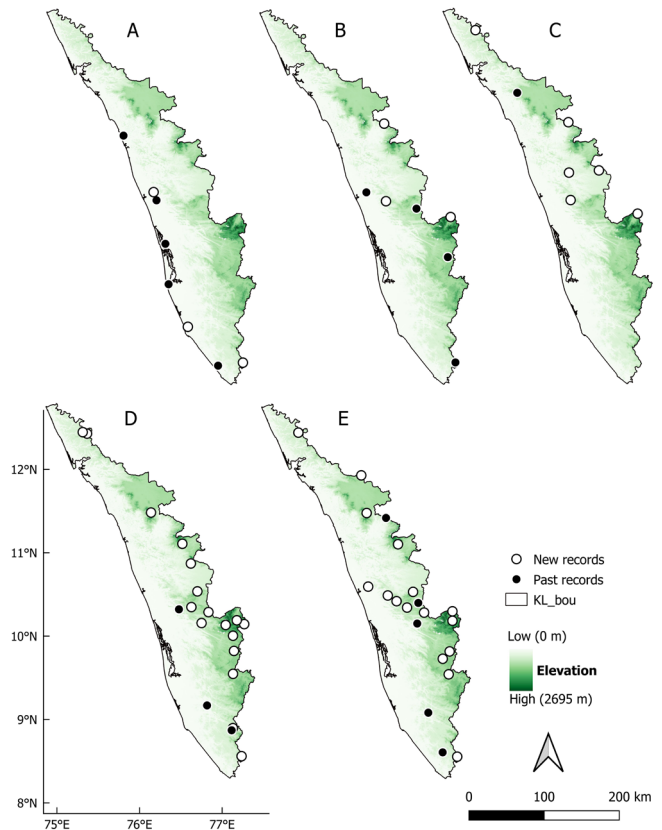


Fig. 5 - Map showing the distribution records of Hipposiderids in Kerala. A: *Hipposideros ater*, B: *Hipposideros fulvus*, C: *Hipposideros galeritus*, D: *Hipposideros pomona*, E: *Hipposideros speoris*.

the taxonomic ambiguity that prevailed in the southern Indian population, and *H. pomona* was recently split into a distinct species (Srinivasulu & Srinivasulu 2018, Srinivasulu et al. 2020a). Until 2020, the species was categorised as Least Concern but the status has now been elevated to the Endangered category (criterion B2ab (ii,iii,iv,v)) owing to its restricted and fragmented distribution in southern WG (Srinivasulu et al. 2020b). The present study shows that the species is abundant in most of the forested tracts in Kerala between the elevational range 124–1155m and was reported predominately from evergreen forests and adjoining deciduous forest types. Hence the previous records of the species from urban and semi-urban landscapes such as Alapuzha, Kodungallur and Venginissery are doubtful or may be misidentified.

Hipposideros galeritus Cantor, 1846 C antor's Leaf-nosed Bat

Previous records: Veliangad (Kozhikode) (Srinivasulu & Srinivasulu 2017)

New records: Peechi WLS, Chinnar WLS, Walayar RF, Kasargod FD, Ottapalam, Nilambur

Notes: The species was first recorded from Kerala by Srinivasulu & Srinivasulu (2017) and the present study recorded three individuals from low-lying, dry forest tracks of Kerala.

***Hipposideros speoris* (Schneider, 1800)**
Schneider's Leaf-nosed Bat

Previous records: Nedumangadu (Trivandrum), Pathanapuram, Kozhikode, Ernakulam, Parambikulam TR (Bates & Harrison 1997, Madhavan 2000, Dinesan et al. 2004, Padmanabhan 2009, Menon 2014)

New records: Agasthyavanam BP, Neyyar WLS, Periyar TR, Ayyapancovil, Kuttampuzha, Anamudishola NP, Sholayar, Chinnar WLS, Vazhachal, Chimmony WLS, Peechi WLS, Nelliampathy RF, Silent Valley NP, Nilambur North, Meppady RF, Waynad WLS, Kasaragod

Notes: This is also an abundant species of *Hipposideros* in moderately dense to very dense forests of WG between the elevational range 124–995m. Large colonies were observed inside caves, as well as in laterite hill mines of northern Kerala. Colour variations within the population were also observed during the present study.

Family Emballonuridae

In Kerala, Emballonurids are represented by three species and in two different genera. During the study period we did not trap any of the emballonurids in harp traps or in understory mist-nests. The low representation of Emballonurids in traps may be due to lack of aerial sampling. However, day roosts for two species were identified during the present study. Fig. 6 shows the distribution of Emballonurids in Kerala.

***Saccolaimus saccolaimus* (Temminck, 1838) N**
aked-rumped Pouched Bat

Previous records: Shendhuruni WLS, Ernakulam, Thrissur District (Kottakadu, Mannuthy, Pallipuram, Paralam, Venginissery, Venlangallur), Silent Valley NP (Ramakrishna & Madhavan 1977, Gopalakrishna & Madhavan 1978, Madhavan 2000, Bates & Harrison 1997, Dinesan et al. 2004, Padmanabhan 2009, Deshpande 2012)

New records: Mannuthy (Thrissur)

Note: A day roost was observed with a colony size of 12 individuals in an active building located at Mannuthy. Pregnant females were observed during the month of October. They produce low frequency echolocation calls (Hughes et al. 2011) and fly high in open spaces, and hence understory trapping was found to be ineffective for sampling this species.

***Taphozous longimanus* Hardwicke, 1825**
Long-winged Tomb Bat

Previous records: Ernakulam, Thrissur (Bates & Harrison 1997, Madhavan 2000, Dinesan et al. 2004, Padmanabhan 2009)

New record: Palai (Kottayam)

Note: On 12 Nov 2021, an injured male individual was spotted inside third floor of a building (around 30m above the ground level) located at a semi-urban landscape of Palai. Like other Emballonurids, *T. longimanus* is also known to be

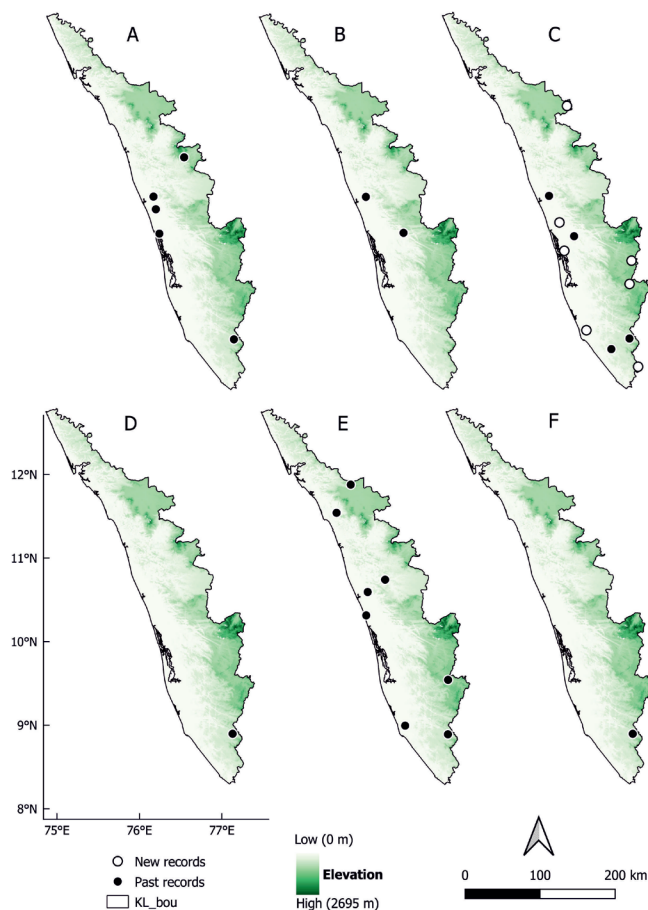


Fig. 6 - Map showing the distribution records of Emballonurids and Molossids in Kerala. A: *Saccolaimus saccolaimus*, B: *Taphozous longimanus*, C: *Taphozous melanopogon*, D: *Mops plicatus*, E: *Tadarida aegyptiaca*, F: *Tadarida teniotis*.

an aerial feeder and fly at heights of 25m to 62m (Pearch & Writer 2009).

***Taphozous melanopogon* Temminck, 1841**
Black-bearded Tomb Bat

Previous records: Trivandrum, Shendhuruni WLS, Ernakulam, Thrissur (Bates & Harrison 1997, Madhavan 2000, Easa et al. 2001, Dinesan et al. 2004, Padmanabhan 2009, Deshpande 2012)

New records: Agasthyavanam BP, Mundrothuruthu (Kollam), Periyar TR, Tripunithura (Ernakulam), Ashtamichira (Thrissur), Ayyapancovil, Waynad WLS

Note: The species is adapted to a wide range of habitats from coastal regions to montane forests, with varying climatic conditions. A colony of 250–300 individuals was observed inside a tile roofed building located in a semi-urban area, while another colony of three individuals were observed inside large tree hole in a forested area.

Family Molossidae

In Kerala the family is represented by three species. Similar to Emballonurids, the Molossidae were also poorly documented during the present study due to lack of aerial sampling. A brief note on the taxonomy and nomenclature

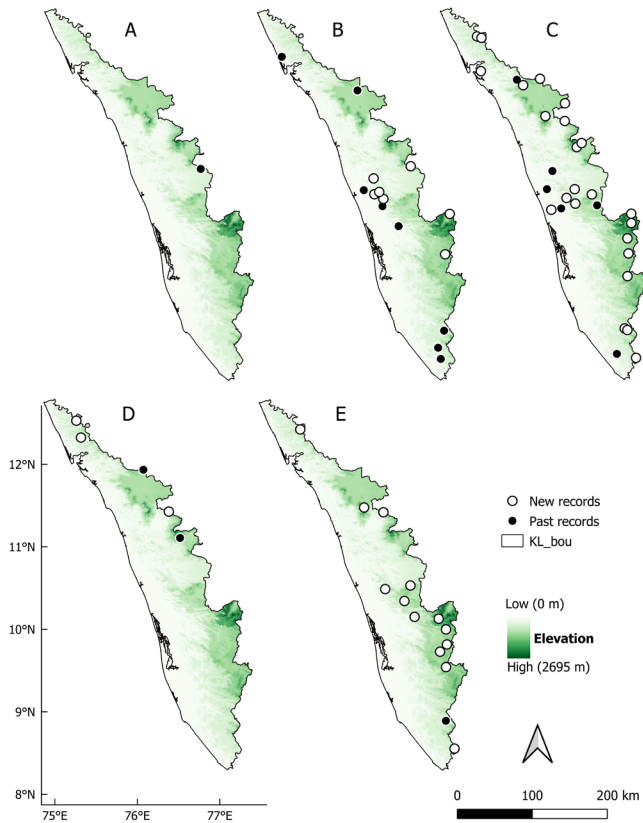


Fig. 7 - Map showing the distribution records of Rhinopomatid, Megadermatids and Miniopterids in Kerala [A: *Rhinopoma hardwickii*, B: *Lyroderma lyra*, C: *Megaderma spasma*, D: *Miniopterus fuliginosus*, E: *Miniopterus pusillus*]

of *Mops plicatus* is included below. Fig. 6 shows the distribution of Molossids in Kerala.

***Mops plicatus* (Buchanan, 1800)
Wrinkle-lipped Free-tailed Bat**

Previous records: Shendhuruni WLS (Deshpande & Kelkar 2015)

Note: *M. plicatus* was previously classified under the genus *Tadarida* (Corbet & Hill 1986, 1992, Bates & Harrison 1997) and subsequently classified under *Chaerephon* (Freeman 1981, Koopman 1984, Borissenko & Kruskop 2003, Simmons 2005, Francis 2008). Recent phylogenetic studies (Ammerman et al. 2012, Amador et al. 2018) showed the close relationship of old world *Chaerephon* with *Mops*, and further reclassified the species under *Mops* (Gregorin & Cirranello 2015). During the present study we did not detect the presence of the species at any of the sampling sites.

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

Previous records: Shendhuruni WLS, Thrissur District (Kodungallur, Venginissery), Ernakulam, Malabar region (Bates & Harrison 1997, Madhavan 2000, Dinesan et al. 2004, Padmanabhan 2009, Deshpande & Kelkar 2015)

***Tadarida teniotis* (Rafinesque, 1814)
European Free-tailed Bat**

Previous records: Shendhuruni WLS (Deshpande & Kelkar 2015)

Note: Similar to any other Molossids in Kerala, the present study also failed to record the species at any of the sampling sites in Kerala.

Family Rhinopomatidae

This is a monogeneric family and all species are classified as *Rhinopoma* (Simmons 2005). In Kerala, the family is represented by only one species.

***Rhinopoma hardwickii* Gray, 1831
Lesser Mouse-tailed Bat**

Previous records: Walayar RF (Srinivasulu & Srinivasulu 2017) (Fig. 7).

Note: In Kerala, the species was previously known from only one rocky cave located at Walayar (Srinivasulu & Srinivasulu 2017). However, the present survey failed to detect the species at this location and at the other sampling sites in Kerala.

Family Megadermatidae

In India, the family is represented by two species in two distinct genera and both the species were reported from Kerala (Fig. 7).

***Lyroderma lyra* E. Geoffroy, 1810
Greater False Vampire Bat**

Previous records: Nedumangadu, Trivandrum, Shendhuruni WLS, Thrissur District (Mathailakom, Paralam, Chenam, Thalikkulam, Urakam, Venginissery), Ernakulam, Kuruva (Wayanad), Cheruvathur (Kasaragod) (Bates & Harrison 1997, Madhavan 2000, Easa et al. 2001, Sharma et al. 2003, Dinesan et al. 2004, Padmanabhan 2009, Deshpande 2012)

New records: Ayyapancovil, Chinnar WLS, Peechi WLS, KAU campus, Vellanipacha (Thrissur), Cheruthuruthy (Wadakkanchery), Walayar RF

Notes: The species was previously included under the genus *Megaderma* (Brosset 1962, Corbet & Hill 1992, Sinha 1994, Bates & Harrison 1997), but later considered distinct (Griffiths et al. 1992, Hand 1996, Eick et al. 2005, Benda & Gaisler 2015, Kaňuch et al. 2015, Shi & Rabosky 2015, Soisook et al. 2015, Amador et al. 2018). All the new observations were from low to mid-elevation, dry zone forest as well as from forest-edge areas. In Walayar, the species was found roosting inside a rocky cave with a colony size of 100-120 individuals, while other reports were mostly from temporary night roosts.

***Megaderma spasma* (Linnaeus, 1758)
Lesser False Vampire Bat**

Previous records: Nedumangadu (Trivandrum), Ernakulam, Thrissur District (Venginissery, Paralam), Palakkad, Parambikulam TR (Bates & Harrison 1997, Madhavan 2000, Dinesan et al. 2004, Padmanabhan 2009, Menon 2014)

New records: Neyyar WLS, Shendhuruni WLS, Periyar TR, Mathikettanshola NP, Anamudishola NP, Chinnar WLS, Chimmony WLS, Peechi WLS, Irinjalakuda, Vadakkencherry, Nelliampathy RF, Silent Valley NP, Bommiyampady (Attappadi), Perambra (Kozhikod), Nilambur North, Kottiyoor WLS, Meppady RF, Waynad WLS, Ranipuram RF

Notes: Small colonies were observed inside tree holes, unused wells and treetop huts. However a single, large colony of 100–120 individuals was observed in an abandoned building in Bommiyampady (Attappadi) with *R. indorouxii*.

Family Miniopteridae

In Kerala, the family is represented by two species. Fig. 7 shows the distribution of Miniopterids in Kerala.

***Miniopterus fuliginosus* (Hodgson, 1835)
Eastern Bent-winged Bat**

Previous records: Silent Valley NP, Waynad WLS (Srinivasulu & Srinivasulu 2017, Menon et al. 2018)

New record: Elayerithitta (Kannur), Kasargod FD, Nilambur North FD (Edavanna)

Note: The species is rare and was recorded from the drier habitats of Kerala, especially north of Palakad gap. They were found roosting inside a laterite stone cave (70m) with other cave-dwelling bats, such as *C. b. ceylonensis* and *R. pusillus*.

***Miniopterus pusillus* Dobson, 1876
Small Long-fingered Bat**

Previous record: Shendhuruni WLS (Deshpande 2012)

New records: Neyyar WLS, Periyar TR, Mathikettanshola NP, Eravikulam NP, Kuttampuzha RF, Sholayar RF, Vazhachal RF, Peechi WLS, Nelliampathy RF, Vazhikadavu (Nilambur North), Meppady RF, Ranipuram RF

Note: The species is seen mostly in dense forest types between the elevational range 95–1155m and are locally abundant. In Silent Valley NP, the species is found roosting in crevices inside a tunnel and share roosting sites with *Myotis peytoni*.

Family Vespertilionidae

The family Vespertilionidae was the most species-rich group with 20 species (Fig. 8), of which four species belonging to the genera *Harpiocephalus*, *Kerivoula*, *Murina* and *Tylonycteris* respectively are potentially new species. A brief note on the taxonomy and nomenclature of *Barbastella darjelingensis*, *Hypsugo affinis* and *M. peytoni* are described below.

***Barbastella darjelingensis* Hodgson [in Horsfeld], 1855
Darjeeling Barbastelle**

New record: Sholayar RF

Note: *Barbastella* in SE Asia used to be assigned to *B. leucomelas* (Francis 2008) but following Benda et al. (2008), bats in south Asia are now recognised as *B. darjelingensis* (Duckworth & Pons 2011). The present record is the first record of the species from Kerala and the second record from Peninsular India. The species has previously been recorded from the Anamalai Hills in southern WG (Wordley et al. 2014), which is 14 km east of Sholayar. They are seen at high-elevations and prefer to forage along the forest edge. There is little natural history available for the species in the WG and we recommend further bioacoustics and molecular studies of *B. darjelingensis* in Peninsular India.

***Harpiocephalus harpia* (Temminck 1840)
Lesser Hairy-winged Bat**

Previous records: Baliparathodu (Palakkad), Malabar coast, Silent Valley NP (Blandford 1888-1891, Das 1986, Bates & Harrison 1997, Dinesan et al. 2004)

New records: Eravikulam NP, Chimmony WLS, Silent Valley NP, Meppady RF

Note: We recorded *H. harpia* from high elevation, montane forests (900–1100m) and the individuals were harp trapped near small rivulets running through evergreen forest. Our preliminary analysis of the cytochrome oxidase 1 (CO1) gene, extracted from the wing punch of the individual sampled from Wayanad, indicates the presence of a potential cryptic species within the population.

***Hesperoptenus tickelli* (Blyth, 1851)
Tickell's Bat**

New record: Malakkapara (Sholayar)

Note: This is the second record of the species from Kerala after Plowright et al. (2019), however the previous known location details were unavailable. The species was rarely reported from WG (Korad et al. 2007, Wordley et al. 2014). They are open space foragers and are distributed from the lowlands to mid-elevation primary forest and in human modified landscapes, including coffee and tea plantations (Molur et al. 2002, Wordley et al. 2014). The present observation was from a forest fringe area dominated by tea plantations at an elevation of 740m.

***Hypsugo affinis* (Dobson, 1871) Chocolate Pipistrelle**

Previous records: Wayanad (Bates & Harrison 1997, Dinesan et al. 2004, Padmanabhan 2009)

New records: Periyar TR, Peechi WLS, Waynad WLS

Note: Until recently, this species was assigned to *Falsistrellus affinis* Dobson, 1871. Integrative taxonomic studies reclassified the Asian population of *Falsistrellus* under the genus *Hypsugo* (Görföl & Csorba 2018). During these surveys, three individuals were harp trapped from mid-elevation, moderately dense forests in Kerala.

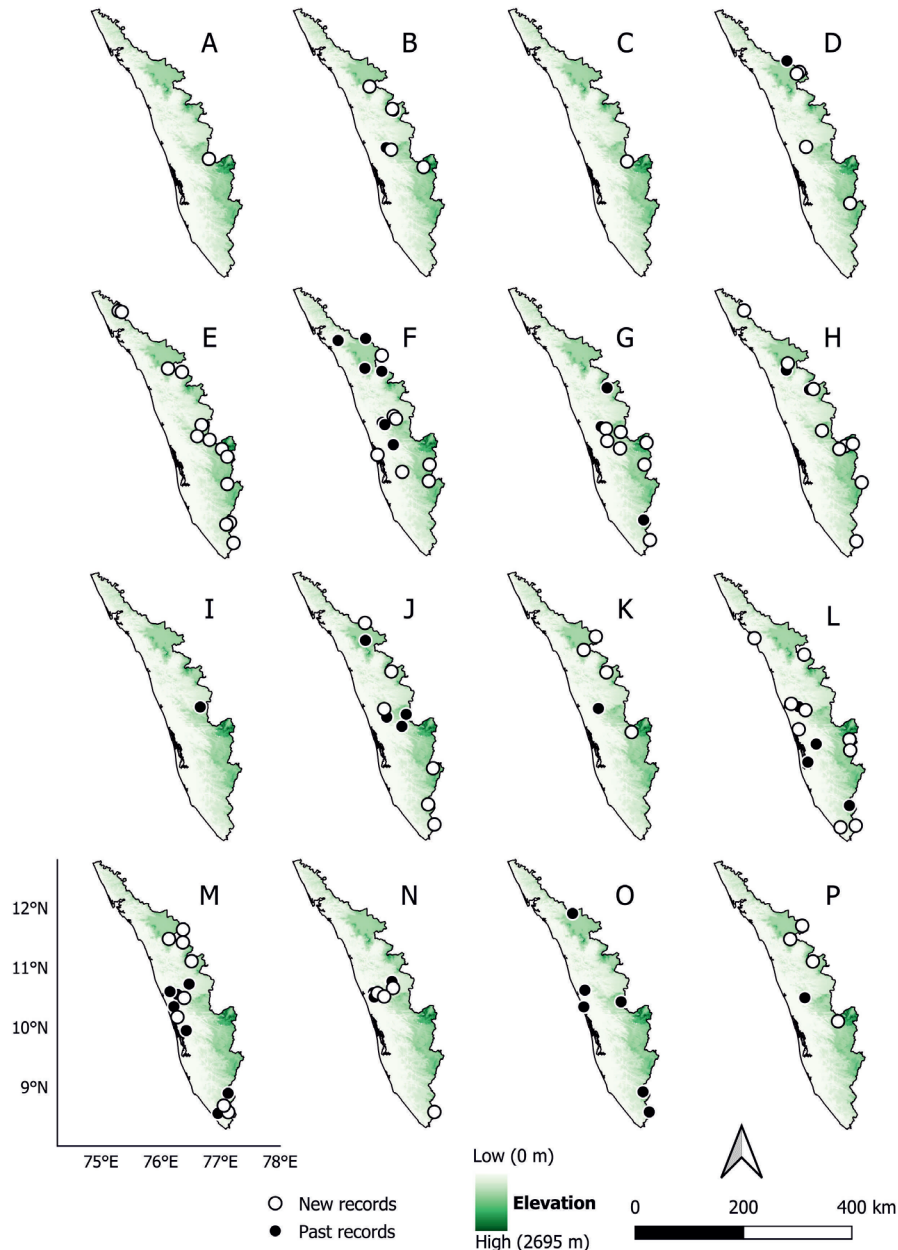


Fig. 8 - Map showing the distribution records of Vespertilionids in Kerala. A: *Barbastella darjelingensis*, B: *Harpiocephalus harpia*, C: *Hesperoptenus tickelli*, D: *Hypsugo affinis*, E: *Kerivoula hardwickii*, F: *Kerivoula picta*, G: *Myotis horsfieldii*, H: *Myotis peytoni*, I: *Phoniscus jagorii*, J: *Pipistrellus ceylonicus*, K: *Pipistrellus coromandra*, L: *Pipistrellus tenuis*, M: *Scotophilus heathii*, N: *Scotophilus kuhlii*, O: *Scotozous dormeri*, P: *Tylonycteris pachypus*.

***Kerivoula hardwickii* (Horsfield, 1824)**
Hardwicke's Woolly Bat

New records: Neyyar WLS, Periyar TR, Mathikettanshola NP, Eravikulam NP, Sholayar, Vazhachal, Nelliampathy RF, Nilambur North, Meppady RF, Ranipuram RF

Note: This is the first record of *K. hardwickii* from Kerala. During the recent survey, individuals were harp trapped between the elevational range 524–1155m. They are commonly found in moderately dense to very dense forest tracts of Kerala.

***Kerivoula picta* (Pallas, 1767)**
Painted Woolly Bat

Previous records: Mangalavanam BS, Kottayam, Thrissur (Althara, Kannara, Mannuthy, Oorakam, Pallipuram, Paralam,

Peechi, Venginissery, KAU campus), Nilambur, Kozhikode, Wayanad, Kannur (Ramachandran & Jayson 1994, Bates & Harrison 1997, Jayson & Easa 1999, Madhavan 2000, Easa et al. 2001, Cyriac et al. 2005, Padmanabhan 2009)

New records: Kumarakom, Palai, Ayyapancovil, Periyar TR, Palakkad (Nenmara, Alathur, Thachampara), Waynad WLS

Note: The species is common in Kerala and most of the new records were from low to mid-elevation, fringe areas and cultivated land, predominantly of banana. However, a few individuals were recorded when foraging inside houses. Two road kills of *K. picta* were also observed on the Mnanthavady-Kutta highway passing through Waynad WLS. Due to the increased demand for the species for ornamental purposes, as well as due to habitat modifications, the species is now categorised as Near Threatened (Huang et al. 2020).

***Myotis horsfieldii* (Temminck, 1840)
Horsfield's Myotis**

Previous records: Shendhuruni WLS, Silent Valley NP, Baliaparathodu (Palakkad), Kozhikode (Das 1986, Bates & Harrison 1997, Madhavan 2000, Padmanabhan 2009, Deshpande 2012)

New records: Agasthyavanam BP, Ayyapancovil, Anamudishola NP, Chimmony WLS, Malayatoor RF, Thatekkadu BS

Note: Most of the observations were made from secondary forests. During the survey, two individuals were found foraging near a termite mound in Malayatoor RF. They are good trawlers as their large hind feet and long calcars enable them to forage more efficiently (Fenton & Bogdanowicz 2002).

***Myotis peytoni* Wroughton & Ryley, 1913
Peyton's Whiskered Myotis**

Previous records: Anakkampoyil (Kozhikode), Silent Valley NP (Bates & Harrison 1997, Madhavan 2000, Padmanabhan 2009, Srinivasulu & Srinivasulu 2017)

New records: Agasthyavanam BP, Mathikettanshola NP, Eravikulam NP, Mankulam RF, Silent Valley NP, Meppady RF, Ranipuram RF

Note: Until recently, *M. peytoni* was considered as a subspecies of *M. montivagus* (Bates & Harrison 1997) and in the recent taxonomic revision, the Indian subpopulation was separated as a distinct species (Görföl et al. 2013) and categorised as Data Deficient (Csorba & Görföl 2017). The species was previously known from only two locations in northern Kerala. However, the present survey shows a wider distribution across Kerala. All the records were from evergreen forest tracts between the elevational range 674–1061 m. In Silent Valley NP, the species was found roosting in crevices inside a tunnel and was found to share roost sites with *M. pusillus*.

***Phoniscus jagorii* (Peters, 1866)
Peters's Trumpet-eared Bat**

Previous records: Nelliampathy RF (Raman et al. 2020b)

Note: Our earlier study (Raman et al. 2020b) reported one female *P. jagorii* from an evergreen forest tract at Nelliampathy Hills of Kerala. This was the first record from the country and only the second from South Asia.

***Pipistrellus ceylonicus* (Kelaart, 1852)
Kelaart's Pipistrelle**

Previous records: Ernakulam, Thrissur District (Chenam, Chirakkal, Kodanur, Pallipuram, Paralam, Taniyam, Venginissery, KAU campus), Parambikulam TR, Wayanad (Blandford 1888-1891, Bates & Harrison 1997, Madhavan 2000, Cyriac et al. 2005, Padmanabhan 2009, Menon 2014)

New Records: Agasthyavanam BP, Shendhuruni WLS, Periyar TR, Peechi WLS, Silent Valley NP, Waynad WLS

Note: All the individuals were caught in harp traps in the mid-high elevation, evergreen forest of WG.

***Pipistrellus coromandra* (Gray, 1838)
Indian Pipistrelle**

Previous records: Shendhuruni WLS, Kumarakom, KAU campus, Wayanad (Easa et al. 2001, Cyriac et al. 2005, Deshpande 2012, Menon 2014)

New records: Agasthyavanam BP, Mukkunada (Trivandrum), Ayyapancovil, Vaikkom (Kottayam), Peechi WLS, Korangad (Kozhikode)

Note: Overlapping morphological characteristics mean it is difficult to distinguish *P. coromandra* from *P. tenuis*. However, the presence of hairs on the uropatagium near to body and tail (Bates & Harrison 1997) and significant acoustic variation help inform correct identification (Raghuram et al. 2014, Raman & Hughes 2020). They are recorded mostly from low to mid-elevation regions (<500m). They forage in forest as well as in modified habitats close to human settlements. The species was found roosting singly in a small crack on the main bole of a tree.

***Pipistrellus tenuis* (Temminck, 1840)
Least Pipistrelle**

Previous records: Kumarakom, Shendhuruni WLS, Thrissur (Chirakkal, Pallipuram, Paralam, Venginissery), Ernakulam (Bates & Harrison 1997, Madhavan 2000, Deshpande 2012, Menon 2014)

New records: Agasthyavanam BP, Vattiyoorkavu (Trivandrum), Ayyapancovil, Mathikettanshola NP, Kunnukara (Ernakulam), Peechi WLS, KAU campus, Atholi (Kozhikode), north Nilambur FD

Note: They are open space foragers and most of the individuals were found roosting solitary or in pairs under clay roof tiles and crevices in building walls.

***Scotophilus heathii* (Horsfield, 1831)
Greater Asiatic Yellow House Bat**

Previous records: Trivandrum, Shendhuruni WLS, Ernakulam, Irinjalakuda, Thrissur District (Chenam, Kandassankadavu, Ollur, Palisseri, Pallipuram, Paralam, Venginissery, Venkitangu, KAU campus), Choolannur Peacock Sanctuary (Ramakrishna & Madhavan 1977, Gopalakrishna & Madhavan 1978, Bates & Harrison 1997, Madhavan 2000, Cyriac et al. 2005, Padmanabhan 2009, Deshpande 2012, Menon 2014)

New records: Agasthyavanam BP, Nedumangadu (Trivandrum), Kunnukara (Ernakulam), Peechi WLS, Silent Valley NP, Nilambur North, Muthenga (Wayanad WLS), Meppady RF

Note: They are found foraging in open space and prefer fringe areas, croplands and other human modified landscapes. In Wayanad, the species was found roosting under the leaf sheath of Areca-nut palm with a colony size of 12.

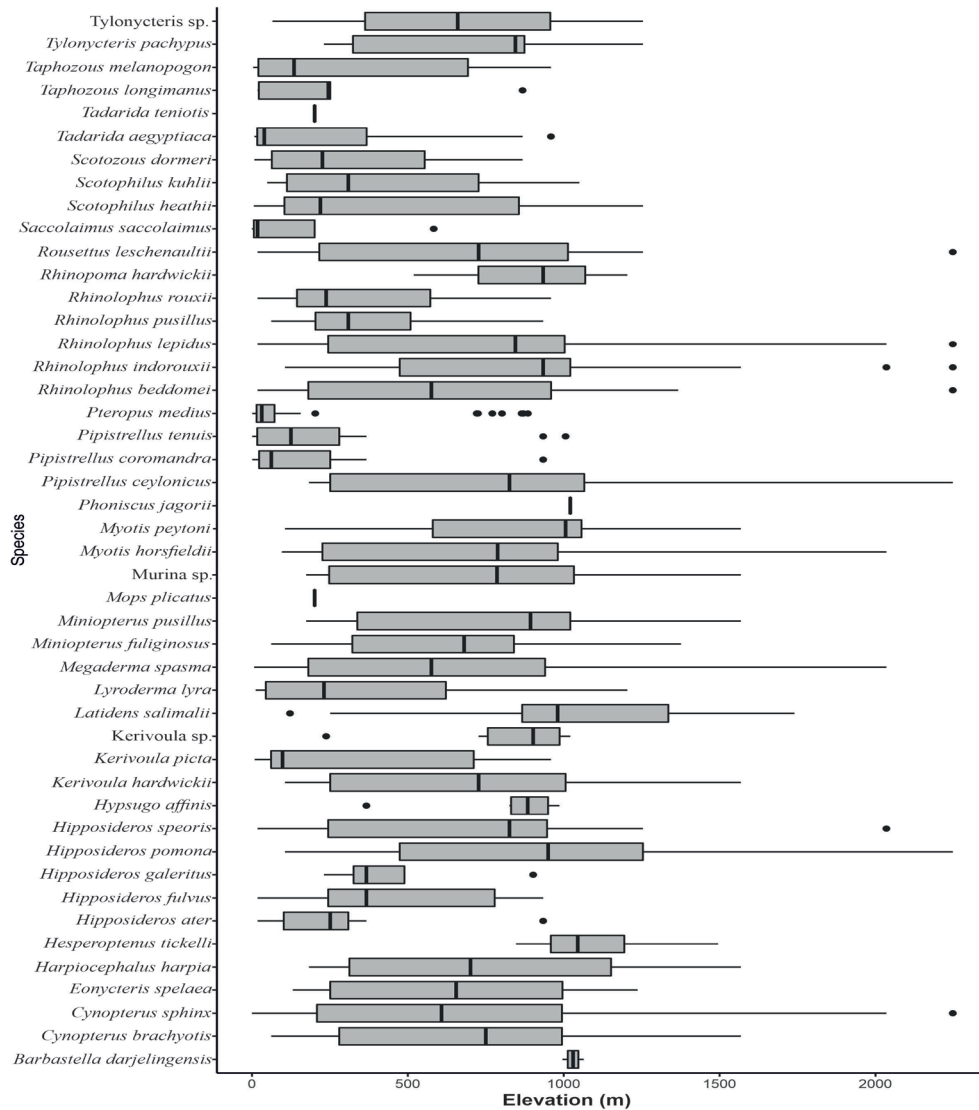


Fig. 9 - Boxplot showing the elevational range of bats seen in Kerala.

Scotophilus kuhlii Leach, 1821
Lesser Asiatic Yellow House Bat

Previous records: Thrissur District (Paralam, Ollur, Pallipuram, Venginissery, Chenam, Kandassankadavu, Palisseri, Venkitangu), Palakkad (Lindsay 1927, Bates & Harrison 1997, Padmanabhan 2009, Deshpande 2012)

New records: Agasthyavanam BP, Peechi, KAU campus, Alathur (Palakkad)

Note: *S. heathii* and *S. kuhlii* are sympatric species and co-exist in most of their distributional ranges in Kerala. Harp traps and ground mist nets are ineffective for sampling *S. heathii* and *S. kuhlii*, whereas aerial sampling and bioacoustics studies are found to be better alternatives for monitoring these species. During the study period, we observed day roosts of *S. kuhlii* in the attics of old houses located in the semi-urban regions of Palakkad and Thrissur district.

Scotozous dormeri Dobson, 1875
Dormer’s Pipistrelle

Previous records: Shendhuruni WLS, Kochi, Thrissur District (Chenam, Kodungallur, Pallipuram, Paralam, Venginissery), Parambikulam TR (Bates & Harrison 1997, Madhavan 2000, Padmanabhan 2009, Menon 2014)

Note: We did not observe the species from any of the sampling sites in Kerala.

Tylonycteris pachypus (Temminck, 1840)
Lesser Bamboo Bat

Previous records: Thrissur District (Cherpu, Kodanur, Mannuthy, Ollur, Padinjattumuri, Pallipuram, Paralam, Taniyam, Urakam, Vallachira, Venginissery) (Bates & Harrison 1997, Madhavan 2000, Padmanabhan 2009)

New Records: Mankulam RF, Silent Valley NP, Meppady RF, Waynad WLS

Note: Recent taxonomic studies on the genus *Tylonycteris* have suggested it may be a distinct taxon in peninsular India (Tu et al. 2017).

Table 1: Checklist of the bats of Kerala with their status. WG: Western Ghats endemic, PI: Peninsular India endemic, EN: Endangered, DD: Data Deficient, NT: Near Threatened, NE: Not Evaluated, # potential new species, rare (n ≤ 9), common (10–19), abundant (n ≥ 20) where n is the number of sites in which the species was recorded (includes both primary and secondary data). M: Mist netting, H: harp trapping, R: roost survey, L: literature review, S: social media

Scientific name	Common Name	Vernacular Name	Elevation range (m)	Kerala status	Detection Method	n
Family Pteropodidae						
1. <i>Cynopterus brachyotis ceylonensis</i>	Lesser Short-nosed Fruit Bat	ശ്വാനമുഖൻ വാമ്പാൽ	100–1600	common	M, H, L	14
2. <i>Cynopterus sphinx</i>	Greater Short-nosed Fruit Bat	കുറുമുക്കൻ വാമ്പാൽ	0–2250	abundant	M, R, L, S	21
3. <i>Eonycteris spelaea</i>	Lesser Dawn Bat	പ്രഭാത വാമ്പാൽ	250–1250	rare	M, L	5
4. <i>Latidens salimalii</i> ^{WG, EN}	Salim Ali's Fruit Bat	സലീംഅലീൻ പഴവാമ്പാൽ	600–1750	rare	R, L	6
5. <i>Pteropus medius</i>	Indian Flying Fox	ഇന്ത്യൻ പഴവാമ്പാൽ	0–900	abundant	R, L, S	52
6. <i>Rousettus leschenaultii</i>	Leschenault's Roussette	മഞ്ഞച്ചുവപ്പൻ പഴവാമ്പാൽ	0–1250	abundant	M, R, L, S	22
Family Megadermatidae						
7. <i>Lyroderma lyra</i>	Greater False Vampire Bat	വലിയ നരിചീർ	0–1200	common	R, L, S	15
8. <i>Megaderma spasma</i>	Lesser False Vampire Bat	ചെറിയ നരിചീർ	0–2050	abundant	H, R, L, S	29
Family Rhinolophidae						
9. <i>Rhinolophus beddomei</i>	Beddome's Horseshoe Bat	ചിന്ന കുതിരലാടവാവ	0–2250	abundant	H, R, L, S	26
10. <i>Rhinolophus indorouxii</i> ^{PI, DD}	Greater Rufous Horseshoe Bat	വലിയ ചെമ്മ്പൻ കുതിരലാടൻവാവ	100–2250	abundant	H, R, L	21
11. <i>Rhinolophus lepidus</i>	Blyth's Horseshoe Bat	ചെറു കുതിരലാടവാവ	50–2250	abundant	H, R, L	31
12. <i>Rhinolophus pusillus</i>	Least Horseshoe Bat	കുറുനൻ കുതിരലാടവാവ	50–950	rare	H, R, L	5
13. <i>Rhinolophus rouxii</i>	Rufous Horseshoe Bat	ചെമ്മ്പൻ കുതിരലാടവാവ	0–950	common	H, R, L	15
Family Rhinopomatidae						
14. <i>Rhinopoma hardwickii</i>	Lesser Mouse-tailed Bat	ചെറിയ എലിവാലൻവാവ	320	unknown	L	1
Family Hipposideridae						
15. <i>Hipposideros ater</i>	Dusky Leaf-nosed Bat	ഇരുളൻ ഇലമുക്കൻവാവ	0–950	rare	H, R, L	8
16. <i>Hipposideros fulvus</i>	Fulvous Leaf-nosed Bat	തവിടൻ ഇലമുക്കൻവാവ	0–950	rare	H, L	7
17. <i>Hipposideros galeritus</i>	Cantor's Leaf-nosed Bat	കാന്ററുടെ ഇലമുക്കൻവാവ	250–900	rare	H, L	5
18. <i>Hipposideros tankadiva</i>	Indian Leaf-nosed Bat	ഇന്ത്യൻ ഇലമുക്കൻവാവ	na	unknown	L	
19. <i>Hipposideros pomona</i> ^{WG, EN}	Pomona Leaf-nosed Bat	അൻറൺസൺൻറെ ഇലമുക്കൻവാവ	100–2250	abundant	H, L	21
20. <i>Hipposideros speoris</i> ^{PI}	Schneider's Leaf-nosed Bat	ഷ്നൈഡറിൻറെ ഇലമുക്കൻവാവ	50–2050	abundant	H, R, L	22

Table 1 - Continuation: Checklist of the bats of Kerala with their status. WG: Western Ghats endemic, Pi: Peninsular India endemic, EN: Endangered, DD: Data Deficient, NT: Near Threatened, NE: Not Evaluated, # potential new species, rare ($n \leq 9$), common ($n \geq 20$) where n is the number of sites in which the species was recorded (includes both primary and secondary data). M: Mist netting, H: harp trapping, R: roost survey, L: literature review, S: social media

Scientific name	Common Name	Vernacular Name	Elevation range (m)	Kerala status	Detection Method	n
Family Miniopteridae						
21. <i>Miniopterus fuliginosus</i> ^{NE}	Eastern Bent-winged Bat	തവിട്ട് വിരലൻവാവ	50–1300	rare	R, L	5
22. <i>Miniopterus pusillus</i>	Small Long-fingered Bat	ചെറു നീളൻകയ്യൻ വാവാ	200–1600	common	H, R, L	14
Family Emballonuridae						
23. <i>Saccolaimus saccolaimus</i>	Naked-rumped Pouched Bat	സഞ്ചിവാഹി ഉറവാലൻവാവ	0–600	unknown	R, L	5
24. <i>Taphozous longimanus</i>	Long-winged Tomb Bat	നീശ്കക്കയ്യൻ ഉറവാലൻവാവ	0–250	unknown	R, L	5
25. <i>Taphozous melanopogon</i>	Black-bearded Tomb Bat	കരിന്താടി ഉറവാലൻവാവ	0–1000	unknown	R, L	11
Family Molossidae						
26. <i>Mops plicatus</i>	Wrinkle-lipped Free-tailed Bat		200	unknown	L	1
27. <i>Tadarida aegyptiaca</i>	Egyptian Free-tailed Bat	ഊജിപ്പഷയൻ വാലൻവാവ	0–1000	unknown	L	8
28. <i>Tadarida teniotis</i>	European Free-tailed Bat		200	unknown	L	1
Family Vespertilionidae						
29. <i>Barbastella darjilingensis</i> ^{NE}	Darjeeling/Indian Barbastelle	ഡാർജ്ജിംഗി ഖാരബസൂറിലെ	1000	rare	M	2
30. <i>Harpiocephalus harpia</i>	Lesser Hairy-winged Bat	രഠോമച്ചിറകൻ വാവ	250–1600	rare	H, L	5
31. <i>Hesperoptenus tickelli</i>	Tickell's Bat	തിക്കൽസ് വാവ	850–1500	rare	M	4
32. <i>Hypsugo affinis</i>	Chocolate Pipistrelle	തവിടൻ അടക്കവാവ	400–1000	rare	H, L	4
33. <i>Kerivoula hardwickii</i>	Hardwicke's Woolly Bat	പുകയൻ രഠോമവൻവാവ	100–1600	common	H	13
34. <i>Kerivoula picta</i> ^{NT}	Painted Woolly Bat	ചിത്രവാവ	0–1000	common	R, L, S	14
35. <i>Myotis horsfieldii</i>	Horsfield's Myotis	ചെവിയൻ വാവ	100–2050	common	H, L	11
36. <i>Myotis peytoni</i> ^{PI, DD}	Peyton's Whiskered Myotis	മീശവാവ	100–1600	common	H, R, L	11
37. <i>Phoniscus jagorii</i>	Peters's Trumpet-eared Bat	നക്ഷത്രവാവ	1050	rare	H	1
38. <i>Pipistrellus ceylonicus</i>	Kelaart's Pipistrelle	സിലഭോണ് അടക്കവാവ	200–2250	common	H, L	10
39. <i>Pipistrellus coromandra</i>	Indian Pipistrelle	ഇന്ത്യൻ അടക്കവാവ	0–1000	common	H, L	10
40. <i>Pipistrellus tenuis</i>	Least Pipistrelle	കുറുനൻ അടക്കവാവ	0–1000	common	R, L	13
41. <i>Scotophilus heathii</i>	Greater Asiatic Yellow House Bat	മഞ്ഞവാവ	0–1250	common	R, L	14

Table 1 - Continuation: Checklist of the bats of Kerala with their status. WG: Western Ghats endemic, PI: Peninsular India endemic, EN: Endangered, DD: Data Deficient, NT: Near Threatened, NE: Not Evaluated, # potential new species, rare (n ≤ 9), common (10–19), abundant (n ≥ 20) where n is the number of sites in which the species was recorded (includes both primary and secondary data). M: Mist netting, H: harp trapping, R: roost survey, L: literature review, S: social media

Scientific name	Common Name	Vernacular Name	Elevation range (m)	Kerala status	Detection Method	n
42. <i>Scotophilus kuhlii</i>	Lesser Asiatic Yellow House Bat	ചെറു മുഞ്ഞപ്പൊലിൽ	50–1050	unknown	R, L	6
43. <i>Scotozous dormeri</i>	Dormer's Pipistrelle	ഡോർമർ മിനുസ അടക്കപ്പൊലി	0–650	unknown	L	6
44. <i>Tylonycteris pachypus</i>	Lesser Bamboo Bat	മുളപ്പൊലി	250–1250	rare	H, L	5
45. <i>Harpiocephalus</i> sp.#			900	rare	H	1
46. <i>Kerivoula</i> sp.#			250–1050	rare	H	6
47. <i>Murina</i> sp.#			250–1600	common	H	10
48. <i>Tylonycteris</i> sp.#			100	rare	H	2

Table 2: External measurements (in mm) expressed as mean ± standard deviation (minimum–maximum) of the 25 species of bats captured during the study, including forearm length (FA), head-and-body length (HB), tail length (TL), tibia length (TIB) hind foot length (HF), ear length (E), n indicates the number of individuals examined.

Species	FA	HB	TL	TIB	HF	EL	n
1. <i>Cynopterus brachyotis ceylonensis</i>	57.42	65.22		20.99	13.82	15.86	1
2. <i>Cynopterus sphinx</i>	68.46±2.29 (65.86–71.45)	81.25±10.25 (72.33–92.1)		26.05±2.63 (23.78–29.72)	14.07±1.27 (12.5–15.58)	17.27±1.96 (14.57–19.2)	4
3. <i>Eonycteris spelaea</i>	74.6	98.1	13.0	37.8	17.4	18.2	1
4. <i>Harpiocephalus harpia</i>	47.74	62.49	38.83	20.83	8.72	15.9	1
5. <i>Hipposideros ater</i>	36.01	42.78	20.45	14.34	6.41	17.94	1
6. <i>Hipposideros fulvus</i>	42.12	44.33	33.5	19	9.1	24.15	1
7. <i>Hipposideros galeritus</i>	48.47	45.56	29.34	19.05	7.53	15.27	1
8. <i>Hipposideros pomona</i>	40.89±1.19 (38.64–43.66)	40.80±1.39 (38.5–45.14)	25.72±2.10 (15.17–27)	17.40±0.50 (15.43–18.19)	7.02±0.62 (5.64–8.27)	17.76±1.34 (11.44–19.65)	85
9. <i>Hipposideros speoris</i>	50.02±2.44 (45.63–53.91)	53.00±4.67 (44.28–61.9)	24.70±2.44 (17.9–28.95)	21.17±1.24 (18.57–23.13)	8.85±1.18 (7.12–10.99)	15.66±1.28 (12.96–18.08)	98
10. <i>Hypsugo affinis</i>	38.64	49.59	37.43	14.61	9.64	14.39	1
11. <i>Kerivoula hardwickii</i>	31.79±1.15 (30–33.38)	38.25±2.92 (33.97–41.92)	36.60±4.06 (27.71–41.86)	15.45±2.38 (8.91–18.53)	7.39±3.21 (5.68–17.43)	12.15±1.06 (10.18–13.44)	12

Table 2 - Continuation: External measurements (in mm) expressed as mean \pm standard deviation (minimum–maximum) of the 25 species of bats captured during the study, including forearm length (FA), head-and-body length (HB), tail length (TL), tibia length (TIB), hind foot length (HF), ear length (E), n indicates the number of individuals examined.

Species	FA	HBL	TL	TIB	HF	EL	n
12. <i>Kerivoula picta</i>	34.5	41.04	35.54	15.37	08.65	13.93	1
13. <i>Latidens salimalii</i>	69.3, 70.2	111.8, 108.7		33.1, 32.3	13.2, 13.1	17.8, 17.1	2
14. <i>Lyroderma lyra</i>	67.12	65.79		36.52	17.70	40.11	1
15. <i>Megaderma spasma</i>	57.7 \pm 2.46 (54.09–61.87)	64.80 \pm 7.28 (53.19–79.97)		31.43 \pm 0.81 (30.1–32.9)	15.50 \pm 1.43 (11.04–16.99)	35.97 \pm 2.38 (30.73–39.96)	25
16. <i>Miniopterus fuliginosus</i>	47.44	55.90	47.82	19.89	9.01	10.14	1
17. <i>Miniopterus pusillus</i>	40.09 \pm 1.44 (35.56–42.05)	44.79 \pm 2.49 (36.4–50.62)	40.12 \pm 3.46 (23.15–46.26)	15.53 \pm 0.89 (13.97–17.23)	7.64 \pm 0.48 (6.46–8.7)	8.99 \pm 1.30 (6.21–16.62)	63
18. <i>Myotis horsfieldii</i>	37.34	49.15	37.99	17.21	8.08	13.90	1
19. <i>Myotis peytoni</i>	44.14 \pm 1.5 (42.07–46.56)	51.23 \pm 4.12 (47.86–59.09)	38.49 \pm 4.57 (34.34–46.9)	18.29 \pm 1.00 (16.97–19.66)	8.96 \pm 0.71 (7.72–9.64)	13.68 \pm 1.39 (11.23–15.1)	6
20. <i>Phoniscus jagorii</i>	38.2	42.09	45.22	16.54	9.82	15.13	1
21. <i>Pipistrellus ceylonicus</i>	38.56	47	38	16	7.71	8.68	1
22. <i>Pipistrellus coromandra</i>	27.51	34.82	27.06	10.59	4.47	7.73	1
23. <i>Pipistrellus tenuis</i>	22.95	30.29	18.74	9.96	5.12	7.78	1
24. <i>Rhinolophus beddomei</i>	62.20 \pm 1.58 (56.39–63.77)	69.24 \pm 4.95 (59.13–74.93)	43.53 \pm 5.27 (32.46–47.88)	31.43 \pm 0.68 (30.01–32.77)	15.38 \pm 2.30 (10.46–17.96)	30.09 \pm 1.90 (27.02–33.35)	29
25. <i>Rhinolophus indorouxii</i>	51.11 \pm 0.65 (50.1–52.29)	51.97 \pm 4.49 (44.49–59.91)	29.82 \pm 3.11 (17.57–32.95)	21.86 \pm 1.69 (19.14–24.39)	10.19 \pm 1.64 (7.22–12.79)	18.66 \pm 2.05 (14.84–21.99)	72
26. <i>Rhinolophus lepidus</i>	40.35 \pm 0.92 (38.59–43.26)	42.60 \pm 5.45 (31.16–52.65)	20.70 \pm 3.90 (12.46–38.97)	16.17 \pm 1.08 (13.9–18.08)	7.63 \pm 1.25 (5.44–10.05)	16.68 \pm 2.04 (7.49–19.97)	132
27. <i>Rhinolophus pusillus</i>	37.44	39.12	17.50	15.33	6.04	16.21	1
28. <i>Rhinolophus rouxii</i>	49.48 \pm 0.73 (47.52–50.71)	50.04 \pm 3.76 (40.96–55.44)	24.99 \pm 4.30 (18.9–32.43)	21.74 \pm 1.13 (19.53–23.93)	10.09 \pm 1.39 (7.22–12.51)	17.07 \pm 1.59 (15.02–21.31)	29
29. <i>Rousettus leschenaulti</i>	66.58	76.25	26.24	27.2	14.83	16.7	1

Table 2 - Continuation: External measurements (in mm) expressed as mean \pm standard deviation (minimum–maximum) of the 25 species of bats captured during the study, including forearm length (FA), head-and-body length (HB), tail length (TL), tibia length (TIB) hind foot length (HF), ear length (E), n indicates the number of individuals examined.

Species	FA	HB	TL	TIB	HF	EL	n
30. <i>Saccolaimus saccolaimus</i>	64.03	88.1	27.98	23.21	14.90	18.11	1
31. <i>Scotophilus heathii</i>	62.71	59.02	66.59	24.0	11.99	17.21	1
32. <i>Scotophilus kuhlii</i>	51.29	71.11	55.0	19.12	12.78	14.15	1
33. <i>Taphozous melanopogon</i>	66.34	78.6	28.12	24.0	12.14	18.7	1
34. <i>Tylonycteris pachypus</i>	29.44	39.91	29.96	13.66	6.43	8.23	1

DISCUSSION

Bat richness

We provide a comprehensive review of the distribution of 48 bat species from Kerala, which constitutes around 43% of the terrestrial mammalian diversity of the state. Three species are reported for the first time from Kerala and four are potentially new species, highlighting the crucial need for further bat research in the area. However, we did not catch six bat species (*H. lankadiva*, *M. plicatus*, *R. hardwickii*, *S. dormeri*, *T. aegyptiaca* and *T. teniotis*) that were previously reported from Kerala. Among the bats of Kerala, *L. salimalii* and *H. pomona* are endemic to southern WG (Raman et al. 2020a, Srinivasulu & Srinivasulu 2020, Srinivasulu et al. 2020b), while *H. speoris*, *M. peytoni* and *R. indorouxii* are endemic to peninsular India (Chattopadhyay & Kandula 2017, Csorba & Görföl 2017, Srinivasulu & Srinivasulu 2019). Apart from *R. hardwickii*, *T. teniotis* and *T. aegyptiaca*, the remaining species were Indomalayan species that are known from South and Southeast Asia (Bates & Harrison 1997, Molur et al. 2002, Francis 2008).

Regional status

Based on their frequency, we categorised nine species as abundant, 13 as common and 16 as rare. Some of the forest-dwelling species such as *H. pomona*, *H. speoris*, *R. indorouxii* and *R. lepidus* are locally abundant. *C. sphinx*, *P. medius*, *R. leschenaultii*, *M. spasma* and *R. beddomei* were also observed throughout various habitats of Kerala. In contrast species like *B. darjelingensis*, *E. spelaea*, *L. salimalii*, *R. pusillus*, *H. ater*, *H. fulvus*, *H. galeritus*, *M. fuliginosus*, *H. harpia*, *H. tickelli*, *H. affinis*, *P. jajorii*, *S. dormeri* and *T. pachypus* were rarely observed. The poor representation of Molossids, Emballonurids and Rhinopomatidae during the study may be due to a lack of aerial sampling. They use open space foraging strategies and fly at high speeds in open areas usually above 10m above the ground (Neuweiler et al. 1984, Heller 1995, Pearch & Writer 2009). Among the Molossids, *T. aegyptiaca* is known from many locations but *M. plicatus* and *T. teniotis* are relatively uncommon (Bates & Harrison 1997).

Elevational preferences

The present study shows that at least 17 species (*H. ater*, *H. fulvus*, *H. galeritus*, *K. picta*, *L. lyra*, *M. plicatus*, *P. coromandra*, *P. tenuis*, *P. medius*, *S. saccolaimus*, *S. heathii*, *S. kuhlii*, *S. dormeri*, *T. aegyptiaca*, *T. teniotis*, *T. melanopogon* and *T. longimanus*) are found in lower elevations (0–500m). The remaining species were mostly forest-dwelling and predominantly occur in mid-elevation zones (Fig. 9). In the tropics, mid-elevations support high species richness than low and high-elevations (Sánchez-Cordero 2001, Curran et al. 2012, Mongombe et al. 2019, Arias-Aguilar et al. 2020). However, several studies also shown a linear decline in species richness along elevational gradients (McCain 2007).

Conservation implications

Among the known bat species of Kerala, the IUCN (Ver. 2021-1) categorised 84% as Least Concern (37 species), two as Endangered (*L. salimalii* and *H. pomona*), one as Near Threatened (*K. picta*), two as Data Deficient (*R. indorouxii* and *M. peytoni*), and two as Not Evaluated (*M. fuliginosus* and *B. darjelingensis*). Many species are persecuted despite their ecological role in maintaining the balance of the ecosystem. Some are often killed for bushmeat (for example *P. medius*, *R. leschenaultii*). However, cave dwelling micro-bats are hunted and consumed more infrequently by indigenous forest-dwelling people primarily for medicinal purposes (Mickleburgh et al. 2009, Murugan et al. 2020). The recent Nipah outbreak in Kerala killed 21 people (Sadanadan et al. 2018) and several species are known to be carriers (Plowright et al. 2019). This likely only represents a subset of species that are carriers as testing for the virus has been limited. This includes five pteropodids (*C. brachyotis*, *C. sphinx*, *E. spelaea*, *P. medius* and *R. leschenaultii*) and eight non-pteropodids, (*H. ater*, *H. pomona*, *M. spasma*, *M. plicatus*, *S. saccolaimus*, *S. kuhlii*, *T. melanopogon* and *T. longimanus*), though the occurrences of the virus may vary regionally. Recent studies also showed that people do not perceive a health threat due to bat meat consumption (Murugan et al. 2020). Moreover, many sites that we surveyed were subject to extreme disturbance. For instance, the use of firecrackers, closure of roost entrances, the felling of roosting trees, setting fire to roosts to deprive bats were all also observed (Raman per ob.), and further efforts are needed to restore and protect sites. Our data thus contributes significantly towards the understanding of these species and their restricted distribution which can be used reassess the IUCN RedList categories.

CONCLUSIONS

The present study provides a detailed understanding of the diversity, status and distribution of 48 bats in Kerala. In comparison with the neighbouring states of Peninsular India, Kerala has higher biodiversity and bats alone constitute 43% of the terrestrial mammalian diversity of the state. Several species that we recorded from Kerala have not yet been documented from adjacent states, and further work is needed in nearby landscapes. Understanding the geographical distribution and habitat choice of a species can further aid accurate species identification while monitoring acoustically. The data will contribute significantly towards the understanding of species with restricted distributions, and facilitate reassessment IUCN RedList categories for the most poorly known species. Finally, we recommend further long-term bioacoustic monitoring studies in remote and understudied regions to provide a clear picture of the overall distribution and changes to populations.

ACKNOWLEDGEMENT

The study is undertaken in accordance with the permit granted by Kerala Forests and Wildlife Department, Ministry of Environment, Forest and Climate Change (MoEF & CC) (Order # WL10-14322/2017, 2018). We thank Dr. Rajeeve Raghavan (Kerala University of Fisheries and Ocean Studies)

and Dr. Sajeeve T. K. (Kerala Forest Research Institute) for permission to access to the molecular lab. We thank Aneesh C. R., Rajeeve Balakrishnan, Anoop V. K. and Salish Menachery for helping in the field. We thank Kiran S. Kumar, Kalesh Sadasivan, Sandeep Das, Rajkumar K. P., Nithin Divakar, Prajith M. P., Charan Hariharan, Dhaneesh Bhaskar, Jithin Johnson and Mathew Thomas for sharing location details of bat; Arya S., Liju Thomas for helping in extracting bat DNA. We are also grateful to IDEA WILD for providing equipments for monitoring bats. This project is also supported by the Chinese National Natural Science Foundation (Grant No. U1602265, Mapping Karst Biodiversity in Yunnan), the Strategic Priority Research Program of the Chinese Academy of Sciences (Grant # XDA20050202), the Chinese Academy of Sciences Southeast Asia Biodiversity Research Center fund (Grant # Y4ZK111B01) through Landscape Ecology Group, Center for Integrative Conservation, Xishuangbanna Tropical Botanical Garden.

Conflicts of interest/Competing interests

The authors declare that they have no competing interests

REFERENCES

- ALVES, D. M. C. C., DINIZ-FILHO, J. A. F., SOUZA, K. DA S., GOUVEIA, S. F. & VILLALOBOS, F. (2018). Geographic variation in the relationship between large-scale environmental determinants and bat species richness. *Basic Appl Ecol*, 27: 1-8. <https://doi.org/10.1016/j.baae.2017.12.002>
- AMADOR, L. I., MOYERS ARÉVALO, R. L., ALMEIDA, F. C., CATALANO, S. A. & GIANNINI, N. P. (2018). Bat systematics in the light of unconstrained analyses of a comprehensive molecular supermatrix. *J Mamm Evol*, 25: 37-70. <https://doi.org/10.1007/s10914-016-9363-8>
- AMAL, U. S., RAMAN, S. & HUGHES, A. C. (*In press*). First record of predation of a fruit bat by Malabar Grey Hornbill (*Ocyrceros griseus*) from southern Western Ghats, India. *Wilson J Ornithol*.
- AMMERMAN, L. K., LEE, D. N. & TIPPS, T. M. (2012). First molecular phylogenetic insights into the evolution of free-tailed bats in the subfamily Molossinae (Molossidae, Chiroptera). *J Mammal*, 93(1): 12-28. <https://doi.org/10.1644/11-MAMM-A-103.1>
- ANDERSEN, K. (1912). Catalogue of the Chiroptera in the collection of British Museum, Volume 1. Megachiroptera. ed.: Natural History Museum. London, United Kingdom, 854 pp.
- ARIAS-AGUILAR, A., CHACÓN-MADRIGAL, E., LAVAL, R. & RODRÍGUEZ-HERRERA, B. (2020). Diversity and activity patterns of aerial insectivorous bats along an altitudinal gradient in a tropical forest in Costa Rica. *Hystrix*, 31(1): 58-63. <https://doi.org/10.4404/hystrix-00244-2019>
- BATES, P. J. J. & HARRISON, D. L. (1997). Bats of the Indian subcontinent. ed.: Harrison Zoological Museum publication. Sevenoaks, Kent, United Kingdom, 258 pp.

- BENDA, P., DIETZ, C. H., ANDREAS, M., HOTOVÝ, J., LUČAN, R. K., MALTBY, A., MEAKIN, K., TRUSCOTT, J. & VALLO, P. (2008). Bats (Mammalia: Chiroptera) of the Eastern Mediterranean and Middle East. Part 6. Bats of Sinai (Egypt) with some taxonomic, ecological and echolocation data on that fauna. *Acta Soc Zool Bohem*, 72: 1-103.
- BENDA, P. & GAISLER, J. (2015). Bats (Mammalia: Chiroptera) of the Eastern Mediterranean and Middle East. Part 12. Bat fauna of Afghanistan: revision of distribution and taxonomy. *Acta Soc Zool Bohem*, 79: 267-458.
- BLANDFORD, W. T. (1888-1891). Fauna of British India, including Ceylon and Burma. Mammalia. Part I and II. ed.: Taylor and Francis, Red Lion Court, Fleet Street. London, United Kingdom, 617 pp.
- BORISSENKO, A. V. & KRUSKOP, S. V. (2003). Bats of Vietnam and adjacent territories. An identification manual. ed.: Zoological Museum of Moscow State University, Russian-Vietnamese Tropical Centre. Moscow, Russia, 203 pp.
- BR, A., DOVIH, P., RAMAKRISHNAN, U., LIANG, E., MENDENHALL, I., WEN HONG, D. L. & SMITH, G. J. D. (2019). Evidence of filovirus and henipavirus in bats and bat harvesters, India. *Int J Infect Dis*, 79(1): 60. <https://doi.org/https://doi.org/10.1016/j.ijid.2018.11.156>
- BROSSET, A. (1962). The bats of central and western India. Part II. *JBNHS*, 59: 583-624.
- CAMPBELL, P., SCHNEIDER, C. J., ADNAN, A. M., ZUBAID, A. & KUNZ, T. H. (2004). Phylogeny and phylogeography of Old World fruit bats in the *Cynopterus brachyotis* complex. *Mol Phylogenet Evol*, 33(3): 764-781. <https://doi.org/10.1016/j.ympev.2004.06.019>
- CAMPBELL, P., SCHNEIDER, C. J., ADNAN, A. M., ZUBAID, A. & KUNZ, T. H. (2006). Comparative population structure of *Cynopterus* fruit bats in peninsular Malaysia and southern Thailand. *Mol Ecol*, 15(1): 29-47. <https://doi.org/10.1111/j.1365-294X.2005.02769.x>
- CHAKRAVARTY, R., RUEDI, M. & ISHTIAQ, F. (2020). A recent survey of bats with descriptions of echolocation calls and new records from the western Himalayan region of Uttarakhand, India. *Acta Chiropterol*, 22(1): 197-224. <https://doi.org/10.3161/15081109ACC2020.22.1.019>
- CHAKRAVARTY, R., MOHAN, R., VOIGT, C., KRISHNAN, A. & RADCHUK, V. (2021). Functional diversity of Himalayan bat communities declines at high elevation without the loss of phylogenetic diversity. *Sci Rep-UK*, 11: 22556. <https://doi.org/10.1038/s41598-021-01939-3>
- FFDDs, L. M., GOODMAN, S. M., NOWAK, M. D., WEISROCK, D. W. & YODER, A. D. (2011). Increased population sampling confirms low genetic divergence among *Pteropus* (Chiroptera: Pteropodidae) fruit bats of Madagascar and other western Indian Ocean islands. *Plos Curr*, 21: 1-17. <https://doi.org/10.1371%2Fcurrents.RRN1226>
- CHATTOPADYAY, B. & KANDULA, S. (2017). *Rhinolophus indorouxii*. The IUCN Red List of Threatened Species 2017: e.T84376286A84378918. <https://doi.org/10.2305/IUCN.UK.2017-2.RLTS.T84376286A84378918.en>
- CHATTOPADHYAY, B., SCHULLER, G., GARG, K. M. & KANDULA, S. (2010). A new phonic type of the rufous horseshoe bat *Rhinolophus rouxii* from southern India. *Curr Sci India*, 99(1): 114-118.
- CHATTOPADHYAY, B., GARG, K. M., VINOTH KUMAR A. K., DOSS D., P. S., RAMAKRISHNAN, U. & KANDULA, S. (2012). Sibling species in South Indian populations of the rufous horse-shoe bat *Rhinolophus rouxii*. *Conserv Genet*, 13: 1435-1445. <https://doi.org/10.1007/s10592-012-0361-y>
- CHATTOPADHYAY, B., GARG, K. M., KUMAR, A. K. V., DOSS, D. P. S., RHEINDT, F. E., KANDULA, S. & RAMAKRISHNAN, U. (2016). Genome-wide data reveal cryptic diversity and genetic introgression in an Oriental cynopterine fruit bat radiation. *BMC Evol Biol*, 16: 41. <https://doi.org/10.1186/s12862-016-0599-y>
- CHATTOPADHYAY, B., GARG, K. M., SWAMI DOSS, D. P., VINOTHKUMAR, A. K., KANDULA, S., RHEINDT, F. E. & RAMAKRISHNAN, U. (2021). Cryptic diversity of *Rhinolophus lepidus* in South Asia and differentiation across a biogeographic barrier. *Front Biogeogr*, 13(4): e49625. <https://doi.org/10.21425/f5fbg49625>
- CHINNASAMY, K., PITCHAMUTHU, M., DOSS, P. S., MARIMUTHU, G. & RAJAN, K. E. (2011). Genetic diversity and population structure of leaf-nosed bat *Hipposideros speoris* (Chiroptera: Hipposideridae) in Indian subcontinent. *Afr J Biotechnol*, 10(8): 1320-1328. <https://doi.org/10.5897/AJB10.1888>
- CORBET, G. B. & HILL, J. E. (1986). A world list of mammalian species. 2nd edition. ed.: British Museum (Natural History) Publications. London, United Kingdom, 254 pp.
- CORBET, G. B. & HILL, J. E. (1992). The mammals of Indomalayan region: a systematic review. ed.: Oxford University Press. Oxford, United Kingdom, 488 pp.
- CSORBA, G. & GÖRFÖL, T. (2017). *Myotis peytoni*. The IUCN Red List of Threatened Species 2017: e.T85568321A85568324. <https://doi.org/10.2305/IUCN.UK.2017-2.RLTS.T85568321A85568324.en>
- CURRAN, M., KOPP, M., BECK, J. & FAHR, J. (2012). Species diversity of bats along an altitudinal gradient on Mount Mulanje, southern Malawi. *J Trop Ecol*, 28(3): 243-253. <https://doi.org/10.1017/S0266467412000193>
- CYRIAC, T. R., NAMEER, P. O., RADHAKRISHNAN, S. R. & HARI, R. (2005). Diversity of bats in Kerala Agricultural University Campus, Thrissur. *Bat Net Newsletter*, 6(2): 12-13.
- DAHANUKAR, N., RAUT, R. & BHAT, A. (2004). Distribution, endemism and threat status of freshwater fishes in the Western Ghats of India. *J Biogeogr*, 31(1): 123-136. <https://doi.org/10.1046/j.0305-0270.2003.01016.x>

- DAS, P. K. (1986). Studies on the taxonomy and geographical distribution of the species of bats obtained by the Silent Valley (Kerala, India) expedition, 1980. *Rec Zool Surv India*, 84(1-4): 259-276. <https://doi.org/10.26515/rzsi%2Fv84%2Fi1-4%2F1986%2F161097>
- DAVIDAR, P., RAJAGOPAL, B., MOHANDASS, D., PUYYRAVAUD, J. -P., CONDIT, R., WRIGHT, S. J. & LEIGH JR, E. G. (2007). The effect of climatic gradients, topographic variation and species traits on the beta diversity of rain forest trees. *Global Ecol Biogeogr*, 16(4): 510-518. <https://doi.org/https://doi.org/10.1111/j.1466-8238.2007.00307.x>
- DAVISON, G. W. H. & ZUBAID, A. (2007). The status of mammalian biodiversity in Malaysia. In: Status of biological diversity in Malaysia and threat assessment of plant species in Malaysia proceedings of the seminar and workshop 28-30 June 2005. ed.: Forest Research Institute Malaysia (FRIM). Kuala Lumpur, Malaysia, p.3-28.
- DEBATA, S., PANDA, R. M. & PALITA, S. K. (2019). Chiropteran diversity and the key determinants of their distribution in Eastern Ghats, India. *Biodivers Conserv*, 28: 2385-2404. <https://doi.org/10.1007/s10531-019-01715-w>
- DESHPANDE, K. (2012). Assessing diversity and distribution of bats in relation to land-use and anthropogenic threats in the southern Western Ghats, India. ed.: Rufford small grants foundation. 30 pp.
- DESHPANDE, K. & KELKAR, N. (2015). Acoustic identification of *Otomops wroughtoni* and other free-tailed bat species (Chiroptera: Molossidae) from India. *Acta Chiropterol*, 17(2): 419-428. <https://doi.org/10.3161/150811094CC2015.17.2.018>
- DESHPANDE, K. & KELKAR, N. (2019). Environmental influences on acoustic divergence in *Rhinolophus* bats of the Western Ghats-Sri Lanka region. *Biorxiv*, 1-34. <https://doi.org/10.1101/661314>
- DINESAN, C., RADHAKRISHNAN, C. & PALOT, M. J. (2004). A systematic list of mammals reported from Kerala, India. *Indian For*, 130(10): 1113-1131.
- DINESAN, C., RADHAKRISHNAN, C. & PALOT, M. J. (2010). Keralathile Sasthanikal (Mammals of Kerala). ed.: Malabar Natural History Society. Kozhikode, India, 174 pp.
- DOVIH, P., LAING, E. D., CHEN, Y., LOW, D. H. W., ANSIL, B. R., YANG, X., SHI, Z., BRODER, C. C., SMITH, G. J. D., LINSTER, M., et al. (2019). Filovirus-reactive antibodies in humans and bats in Northeast India imply zoonotic spillover. *Plos Neglect Trop D*, 13(10): e0007733. <https://doi.org/10.1371/journal.pntd.0007733>
- DUCKWORTH, J. W. & PONS, J. -M. (2011). Reinstatement of *Barbastella* (Chiroptera, Vespertilionidae) and *Eothenomys* (Rodentia, Cricetidae) to the Lao fauna. *Mammalia*, 75(1): 93-95. <https://doi.org/10.1515/mamm.2010.073>
- EASA, P. S., ZACHARIAS, J. & PADMANABHAN, P. (2001). Survey of small mammals in Kerala with special reference to endangered species. KFRI research report no. 207. ed.: Kerala Forest Research Institute. Peechi, India, 34 pp.
- EASA, P. S. & RAMACHANDRAN, K. K. (2005). Biodiversity Documentation for Kerala. Part 12 - Mammals. ed.: Kerala Forest Research Institute. Peechi, India, 40 pp.
- EICK, G. N., JACOBS, D. S. & MATTHEE, C. A. (2005). A nuclear DNA phylogenetic perspective on the evolution of echolocation and historical biogeography of extant bats (Chiroptera). *Mol Biol Evol*, 22(9): 1869-1886. <https://doi.org/10.1093/molbev/msi180>
- FENTON, M. B. & BOGDANOWICZ, W. (2002). Relationships between external morphology and foraging behaviour: bats in the genus *Myotis*. *Can J Zool*, 80(6): 1004-1013. <https://doi.org/10.1139/z02-083>
- FRANCIS, C. M. (2008). A guide to the Mammals of Southeast Asia. ed.: Princeton University Press. Princeton, USA, 392 pp.
- FREEMAN, P. W. (1981). Correspondence of food habits and morphology in insectivorous bats. *J Mammal*, 62(1): 166-173. <https://doi.org/10.2307/1380489>
- FRICK, W. F., KINGSTON, T. & FLANDERS, J. (2020). A review of the major threats and challenges to global bat conservation. *Ann Ny Acad Sci*, 1469(1): 5-25. <https://doi.org/10.1111/nyas.14045>
- FSI. (2019). India State of Forest report 2019 - Volume II. ed.: Forest Survey of India. Dehradun, India, 349 pp.
- GADGIL, M., KRISHNAN, B. J., GANESHIAIAH, K. N., VIJAYAN, V. S., BORGES, R., SUKUMAR, R., NORONHA, L., NAYAK, V. S., SUBRAMANIAM, D. K., VARMA, R. V., et al. (2011). Report of the Western Ghats Ecology Expert Panel (WGEEP) - Part 1 and 2. ed.: Ministry of Environment and Forests, Government of India. New Delhi, India, 327 pp.
- GIANNINI, N. P., ALMEIDA, F. C., SIMMONS, N. B. & HELGEN, K. M. (2008). The systematic position of *Pteropus leucopterus* and its bearing on the monophyly and relationships of *Pteropus* (Chiroptera: Pteropodidae). *Acta Chiropterol*, 10(1): 11-20. <https://doi.org/10.3161/150811008X331054>
- GIMARET-CARPENTIER, C., DRAY, S. & PASCAL, J. -P. (2003). Broad-scale biodiversity pattern of the endemic tree flora of the Western Ghats (India) using canonical correlation analysis of herbarium records. *Ecography*, 26(4): 429-444. <http://www.jstor.org/stable/3683568>
- GOPALAKRISHNA, A. & MADHAVAN, A. (1978). Viability of inseminated spermatozoa in the Indian vespertilionid bat *Scotophilus heathi* (horsefield). *Indian J Exp Biol*, 16(7): 852-854.
- GÖRFÖL, T., ESTÓK, P. & CSORBA, G. (2013). The subspecies of *Myotis montivagus* - Taxonomic revision and species limits (Mammalia: Chiroptera: Vespertilionidae). *Acta Zool Acad Sci H*, 59(1): 41-59.

- GÖRFÖL, T. & CSORBA, G. (2018). Integrative taxonomy places Asian species of *Falsistrellus* (Chiroptera: Vespertilionidae) into *Hypsugo*. *Mamm Biol*, 93: 56-63. <https://doi.org/10.1016/j.mambio.2018.08.004>
- GREGORIN, R. & CIRRANELLO, A. (2015). Phylogeny of Molossidae Gervais (Mammalia: Chiroptera) inferred by morphological data. *Cladistics*, 32(1): 2-35. <https://doi.org/10.1111/cla.12117>
- GRIFFITHS, T. A., TRUCKENBROD, A. & SPONHOLTZ, P. J. (1992). Systematics of Megadermatid bats (Chiroptera, Megadermatidae), based on hyoid morphology. *Am Mus Novit*, 3041: 1-21.
- HAND, S. J. (1996). New Miocene and Pliocene megadermatids (Mammalia, Microchiroptera) from Australia, with comments on broader aspects of megadermatid evolution. *Geobios-Lyon*, 29(3): 365-377. [https://doi.org/10.1016/S0016-6995\(96\)80038-6](https://doi.org/10.1016/S0016-6995(96)80038-6)
- HELLER, K. -G. (1995). Echolocation and body size in insectivorous bats: the case of the giant naked bat *Cheiromeles torquatus* (Molossidae). *Le Rhinolophe*, 11: 27-38.
- HILL, J. E. & SMITH, J. D. (1984). Bats: a natural history. ed.: British Museum (Natural History). London, United Kingdom, 243 pp.
- HUANG, J. C. -C., LIM, L. S. & CHAKRAVARTY, R. (2020). *Kerivoula picta*. The IUCN Red List of Threatened Species 2020: e.T10985A22022952. <https://doi.org/10.2305/IUCN.UK.2020-2.RLTS.T10985A22022952.en>
- HUGHES, A. C., SATASOOK, C., BATES, P. J. J., SOISOOK, P., SRITONGCHUAY, T., JONES, G. & BUMRUNGSRI, S. (2011). Using echolocation calls to identify Thai bat species: Vespertilionidae, Emballonuridae, Nycteridae and Megadermatidae. *Acta Chiropterol*, 13(2): 447-455. <https://doi.org/10.3161/150811011X624938>
- HUGHES, A. C., SATASOOK, C., BATES, P. J. J., BUMRUNGSRI, S. & JONES, G. (2012). The projected effects of climatic and vegetation changes on the distribution and diversity of Southeast Asian bats. *Glob Change Biol*, 18(6): 1854-1865. <https://doi.org/10.1111/j.1365-2486.2012.02641.x>
- JAYARAJ, V. K., LAMAN, C. J. & ABDULLAH, M. T. (2012). A predictive model to differentiate the fruit bats *Cynopterus brachyotis* and *C. cf. brachyotis* forest (Chiroptera: Pteropodidae) from Malaysia using multivariate analysis. *Zool Stud*, 51(2): 259-271.
- JAYSON, E. A. & EASA, P. S. (1999). Documentation of vertebrate fauna in Mangalavanam mangrove area. KFRI research report 183. ed.: Kerala Forest Research Institute. Thrissur, India, 42 pp.
- JERDON, T. C. (1874). The Mammals of India: a natural history of all the animals known to inhabit continental India. ed.: John Wheldon. London, United Kingdom, 336 pp.
- JONES, G., JACOBS, D. S., KUNZ, T. H., WILLIG, M. R. & RACEY, P. A. (2009). Carpe noctem: the importance of bats as bioindicators. *Endanger Species Res*, 8(1): 93-115. <https://doi.org/10.3354/esr00182>
- KANAGARAJ, C., MARIMUTHU, G. & EMMANUVEL RAJAN, K. (2010). Genetic analysis on three South Indian sympatric Hipposiderid bats (Chiroptera, Hipposideridae). *Anim Biodiv Conserv*, 33(2): 187-94. <https://doi.org/214979>
- KAŇUCH, P., AGHOVÁ, T., MEHERETU, Y., ŠUMBERA, R. & BRYJA, J. (2015). New discoveries on the ecology and echolocation of the heart-nosed bat *Cardioderma cor* with a contribution to the phylogeny of Megadermatidae. *Afr Zool*, 50(1): 53-57. <https://doi.org/10.1080/15627020.2015.1021711>
- KARUPPUDURAI, T., SRIPATHI, K., GOPUKUMAR, N., ELANGO VAN, V. & MARIMUTHU, G. (2007). Genetic diversity within and among populations of the Indian short-nosed fruit bat, *Cynopterus sphinx* assessed through RAPD analysis. *Curr Sci India*, 93(7): 942-950.
- KFD. (2015). Administration Report 2015-16. ed.: Kerala Forest & Wildlife Department. Trivandrum, India, 106 pp.
- KOOPMAN, K. (1984). A synopsis of the families of bats, part V. *Bat Research News*, 24: 36-38.
- KORAD, V., YARDI, K. & RAUT, R. (2007). Diversity and distribution of bats in the Western Ghats of India. *Zoos' Print Journal*, 22(7): 2752-2758.
- LINDSAY, H. M. (1927). Bombay Natural History Society's Mammal Survey of India, Burma and Ceylon. Report No. 43, Nelliampathy Plateau and Palni Hills. *J Bombay Nat Hist Soc*, 31: 591-614.
- MADHAVAN, A. (2000). A catalogue of bats recorded in Thrissur District, Kerala. *Zoos' Print Journal*, 15(11): 355-358.
- MANI, R. S., DOVIH, D. P., ASHWINI, M. A., CHATTOPADHYAY, B., HARSHA, P. K., GARG, K. M., SUDARSHAN, S., PUTTASWAMIAH, R., RAMAKRISHNAN, U. & MADHUSUDANA, S. (2017). Serological evidence of *Lyssavirus* infection among bats in Nagaland, a north-eastern state in India. *Epidemiol Infect*, 145(8): 1635-1641. <https://doi.org/10.1017/S0950268817000310>
- MCCAIN, C. M. (2007). Area and mammalian elevational diversity. *Ecology*, 88(1): 76-86. [https://doi.org/10.1890/0012-9658\(2007\)88\[76:AAMED\]2.0.CO;2](https://doi.org/10.1890/0012-9658(2007)88[76:AAMED]2.0.CO;2)
- MENON, V. (2014). Indian mammals. A field guide. ed.: Hachette India. India, 528 pp.
- MENON, A., DAS, A. A. & NAMEER, P. O. (2018). Eastern Bent-wing bat: a new record of *Miniopterus fuliginosus* (Hodgson, 1835) from Wayanad Wildlife Sanctuary, Western Ghats, India. *Zoo's Print*, 33(10): 15-19.
- MICKLEBURGH, S., WAYLEN, K. & RACEY, P. (2009). Bats as bushmeat: a global review. *Oryx*, 43(2): 217-234. <https://doi.org/10.1017/S0030605308000938>

- MOLUR, S., MARIMUTHU, G., SRINIVASULU, C., MISTRY, S., HUTSON, A. M., BATES, P. J. J., WALKER, S., PADMA PRIYA, K. & BINU PRIYA, A. R. (2002). Status of South Asian Chiroptera: Conservation Assessment and Management Plan (C.A.M.P.) Workshop Report. ed.: Zoo Outreach Organisation, CBSG South Asia and WILD. Coimbatore, India, 320 pp.
- MOLUR, S. & VANITHARANI, J. (2008). *Latidens salimalii*. The IUCN Red List of Threatened Species 2008: eT11374A3274238. <https://doi.org/10.2305/IUCN.UK.2008.RLTS.T11374A3274238.en>
- MONGOMBE, A. M., FILS, E. -M. B. & TAMESSE, J. L. (2019). Diversity and altitudinal distribution of bats (Mammalia: Chiroptera) on Mount Cameroon. *Trop Zool*, 32(4): 166-187. <https://doi.org/10.1080/03946975.2019.1680077>
- MURUGAN, C. M., BHAVAN, P. S., MAHANDRAN, V. & NATHAN, P. T. (2020). Hunting bats for bushmeat despite Nipah concerns in Idukki, Kerala, India. *Ecotropica*, 22: 1-6. <https://doi.org/10.30427/ecotrop202006>
- NAIR, S. C. (1991). The southern Western Ghats: a biodiversity conservation plan. ed.: Indian national trust for art and cultural heritage. New Delhi, India, 92 pp.
- NAMEER, P. O. (2000). Checklist of Indian Mammals. ed.: Kerala State Forest Department and Kerala Agricultural University. Thrissur, India, 90 pp.
- NAMEER, P. O., SANJAY, M. & WALKER, S. (2001). Mammals of Western Ghats: a simplistic overview. *Zoos' Print Journal*, 16(11): 629-639. <https://doi.org/10.11609/JoTT.ZPJ.16.11.629-39>
- NAMEER, P. O. (2015). A checklist of mammals of Kerala, India. *J Threat Taxa*, 7(13): 7971-7982. <https://doi.org/10.11609/jott.2000.7.13.7971-7982>
- NAMEER, P. O., ASHMI, R., ARAVIND, S. K. & SREEHARI, R. (2016). First record of Dobson's Long-tongued Fruit Bat *Eonycteris spelaea* (Dobson, 1871) (Mammalia: Chiroptera: Pteropodidae) from Kerala, India. *Journal of Threatened Taxa*. 8(11): 9371-9374. <https://doi.org/10.11609/jott.2496.8.11.9371-9374>
- NEUWEILER, G., SINGH, S. & SRIPATHI, K. (1984). Audiograms of a South Indian bat community. *J Comp Physiol A*, 154: 133-142. <https://doi.org/10.1007/BF00605398>
- O'BRIEN, J., MARIANI, C., OLSON, L., RUSSELL, A. L., SAY, L., YODER, A. D. & HAYDEN, T. J. (2009). Multiple colonisations of the western Indian Ocean by *Pteropus* fruit bats (Megachiroptera: Pteropodidae): the furthest islands were colonised first. *Mol Phylogenet Evol*, 51(2): 294-303. <https://doi.org/10.1016/j.ympev.2009.02.010>
- PADMANABHAN, P. (2009). Documentation and conservation of small mammals in the sacred groves of Kerala, peninsular India. KFRI Research Report 406. ed.: Kerala Forest Research Institute. Peechi, Thrissur, 35 pp.
- PASCAL, J. P., RAMESH, B. R. & DE FRANCESCHI, D. (2004). Wet evergreen forest types of the southern Western Ghats, India. *Trop Ecol*, 45(2): 281-292.
- PAUL, L. (2018). Nipah virus in Kerala: a deadly Zoonosis. *Clin Microbiol Infec*, 24(10): 1113-1114. <https://doi.org/10.1016/j.cmi.2018.06.017>
- PEARCH, M. J. & WRITER, T. O. D. (2009). South-east Asian bat database. ed.: Harrison Institute. Sevenoaks, Kent, United Kingdom, 258 pp.
- PLOWRIGHT, R. K., BECKER, D. J., CROWLEY, D. E., WASHBURNE, A. D., HUANG, T., NAMEER, P. O., GURLEY, E. S. & HAN, B. A. (2019). Prioritizing surveillance of Nipah virus in India. *Plos Negl Trop Dis*, 13(6): e0007393. <https://doi.org/10.1371/journal.pntd.0007393>
- PRAKASH, H., GREIF, S., YOVEL, Y. & BALAKRISHNAN, R. (2021a). Acoustically eavesdropping bat predators take longer to capture katydid prey signalling in aggregation. *J Exp Biol*, 224(10): jeb233262. <https://doi.org/10.1242/jeb.233262>
- PRAKASH, H., SAHA, K., SAHU, S. & BALAKRISHNAN, R. (2021b). Ecological drivers of selection for remnant forest habitats by an insectivorous bat in a tropical, human-modified landscape. *Forest Ecol Manag*, 496: 119451. <https://doi.org/10.1016/j.foreco.2021.119451>
- QGIS DEVELOPMENT TEAM. (2021). QGIS Geographic Information System. Open Source Geospatial Foundation Project. <https://www.qgis.org>
- RAGHURAM, H., JAIN, M. & BALAKRISHNAN, R. (2014). Species and acoustic diversity of bats in a palaeotropical wet evergreen forest in southern India. *Curr Sci India*, 107(4): 631-641.
- RAJAN, K. E., ARUL SUNDARI, A. & MARIMUTHU, G. (2009). Isolation and characterization of microsatellite loci in the Indian false vampire bat *Megaderma lyra*. *Conserv Genet Resour*, 1: 369-371. <https://doi.org/10.1007/s12686-009-9085-9>
- RAMACHANDRAN, K. K. & JAYSON, E. A. (1994). Note on the breeding period of the painted bat (*Kerivoula picta*). *J Bombay Nat Hist Soc*, 91: 447-447.
- RAMAKRISHNA, P. A. & MADHAVAN, A. (1977). Foetal membranes and placentation in the vespertilionid bat *Scotophilus heathi* (Horsfield). *Proceedings Indian Acad Sci B*, 86(2): 117-126.
- RAMAN, S. & HUGHES, A. C. (2020). Echobank for the bats of Western Ghats biodiversity hotspot, India. *Acta Chiropterol*, 22(2): 349-364. <https://doi.org/10.3161/15081109ACC2020.22.2.010>
- RAMAN, S., SHAMEER, T. T., CHARLES, B. & SANIL, R. (2020a). Habitat suitability model of endangered *Latidens salimalii* and the probable consequences of global warming. *Trop Ecol*, 61: 570-582. <https://doi.org/10.1007/s42965-020-00114-5>

- RAMAN, S., PADMARAJAN, A., THOMAS, L., SIDHARTHAN, A. & HUGHES, A. C. (2020b). New geographic record of Peters's Trumpet-eared bat *Phoniscus jagorii* (Peters, 1866) from India. *JBRC*, 13(1): 66-73. <https://doi.org/10.14709/Barbj.13.1.2020.12>
- RAMAN, S., SHAMEER, T. T., POOJA, U. & HUGHES, A. C. (In review). Identifying priority areas for bat conservation in peninsular India. *J Mammal*.
- RAMÍREZ-FRÁNCEL, L. A., GARCÍA-HERRERA, L. V., LOSADA-PRADO, S., REINOSO-FLÓREZ, G., SÁNCHEZ-HERNÁNDEZ, A., ESTRADA-VILLEGAS, A., LIM, B. K. & GUEVARA, G. (2021). Bats and their vital ecosystem services: a global review. *Integr Zool*, 17(1): 2-23. <https://doi.org/10.1111/1749-4877.12552>
- REGINALD, J. L., PRASATH, P. M., MAHENDRAN, C., VENKATASAN, A., PRABHU, K., RAVICHANDRAN, B. & MOLUS, S. (2008). A survey on the roosting sites of Indian Flying fox *Pteropus giganteus* Brunnich, 1782 in and around Coimbatore and Palakkad districts, India. *Bat Net Newsletter*, 9(1): 11-12.
- RUEDI, M., BISWAS, J. & CSORBA, G. (2012). Bats from the wet: two new species of Tube-nosed bats (Chiroptera: Vespertilionidae) from Meghalaya, India. *Rev Suisse Zool*, 119(1): 111-135. <https://doi.org/10.5962/bhl.part.150145>
- SADANADAN, R., ARUNKUMAR, G., LASERSON, K. F., HERETIK, K. H., SINGH, S., MOURYA, D. T., GANGAKHEDKAR, R. R., GUPTA, N., SHARMA, R., DHURIA, M., et al. (2018). Towards global health security: response to the May 2018 Nipah virus outbreak linked to *Pteropus* bats in Kerala, India. *BMJ Glob Health*, 3(6): e001086. <https://doi.org/10.1136/bmjgh-2018-001086>
- SAIKIA, U. (2018). A review of chiropterological studies and a distributional list of the bat fauna of India. *Rec Zool Surv India*, 118(3): 242-280.
- SAIKIA, U., CHAKRAVARTY, R., HEGDE, V. D., MEETEI, A. B., KRUSKOP, S., CSORBA, G. & RUEDI, M. (2021). First record of Disk-footed bat *Eudiscopus denticulus* (Osgood, 1932) (Chiroptera: Vespertilionidae) from India with notes on its ecology and genetics. *Rev Suisse Zool*, 128(1): 187-198. <https://doi.org/10.35929/RSZ.0044>
- SÁNCHEZ-CORDERO, V. (2001). Elevation gradients of diversity for rodents and bats in Oaxaca, Mexico. *Global Ecol Biogeogr*, 10(1): 63-76. <https://doi.org/10.1046/j.1466-822x.2001.00235.x>
- SHARMA, J. K., EASA, P. S. & MATHEW, G. (2003). Monitoring biodiversity in selected landscapes in the Kerala part of Western Ghats. KFRRI research report no. 283. ed.: Kerala Forest Research Institute. Peechi, Thrissur, India, 182 pp.
- SHI, J. J. & RABOSKY, D. L. (2015). Speciation dynamics during the global radiation of extant bats. *Evolution*, 69(6): 1528-1545. <https://doi.org/10.1111/evo.12681>
- SIKES, R. S. & ACUC (The Animal Care and Use Committee of the American Society of Mammalogists) (2016). Guidelines of the American Society of Mammalogists for the use of wild mammals in research and education. *J Mammal*, 97(3): 663-688. <https://doi.org/10.1093/jmammal/gyw078>
- SIMMONS, N. B. (2005). Order Chiroptera. In: *Mammal species of the World: a taxonomic and geographic reference*. 3rd edition. ed.: The Johns Hopkins University Press. Baltimore, USA, p.312-529.
- SIMMONS, N. B. & CIRRANELLO, A. L. (2021). Bat species of the world: a taxonomic and geographic database. www.batnames.org
- SINHA, Y. P. (1994). Some behavioural activities of the Indian false vampire, *Megaderma lyra* Geoffroy 1810, in village Harpur Osti, Bihar. *Geobios News Reports*, 13: 61-64.
- SOISOOK, P., PRAJAKJITR, A., KARAPAN, S., FRANCIS, C. M. & BATES, P. J. J. (2015). A new genus and species of false vampire (Chiroptera: Megadermatidae) from peninsular Thailand. *Zootaxa*, 3931(4): 528-550. <https://doi.org/10.11646/zootaxa.3931.4.4>
- SRINIVASULU, C., RACEY, P. A. & MISTRY, S. (2010). A key to the bats (Mammalia: Chiroptera) of South Asia. *J Threat Taxa*, 2(7): 1001-1076. <https://doi.org/10.11609/JoTT.02352.1001-76>
- SRINIVASULU, B., SRINIVASULU, C. & KAUR, H. (2015a). Echolocation calls of four species of leaf-nosed bats (genus *Hipposideros*) from central peninsular India. *Curr Sci India*, 108(6): 1055-1057.
- SRINIVASULU, C., SRINIVASULU, B., KAUR, H., SHAH, T. A. & DEVENDER, G. (2015b). New records of *Rhinolophus beddomei* Andersen, 1905 (Chiroptera: Rhinolophidae) from central peninsular region of India, including echolocation call characteristics. *Mammalia*, 79(3): 369-373. <https://doi.org/10.1515/mammalia-2013-0180>
- SRINIVASULU, B., SRINIVASULU, C. & KAUR, H. (2016). Echolocation calls of the two endemic leaf-nosed bats (Chiroptera: Yinpterochiroptera: Hipposideridae) of India: *Hipposideros hypophyllus* Kock & Bhat, 1994 and *Hipposideros durgadasi* Khajuria, 1970. *J Threat Taxa*, 8(14): 9667-9672. <https://doi.org/10.11609/jott.2783.8.14.9667-9672>
- SRINIVASULU, B. & SRINIVASULU, C. (2017). A first record of three hitherto unreported species of bats from Kerala, India with a note on *Myotis peytoni* (Mammalia: Chiroptera: Vespertilionidae). *J Threat Taxa*, 9(5): 10216-10222. <http://doi.org/10.11609/jott.3324.9.5.10216-10222>
- SRINIVASULU, B. & SRINIVASULU, C. (2018). In plain sight: bacular and noseleaf morphology supports distinct specific status of Roundleaf bats *Hipposideros pomona* Andersen, 1918 and *Hipposideros gentilis* Andersen, 1918 (Chiroptera: Hipposideridae). *J Threat Taxa*, 10(8): 12018-12026. <https://doi.org/10.11609/jott.4111.10.8.12018-12026>

- SRINIVASULU, B. & SRINIVASULU, C. (2019). *Hipposideros speoris*. The IUCN Red List of Threatened Species 2019: e.T10162A22099260. <https://doi.org/10.2305/IUCN.UK.2019-2.RLTS.T10162A22099260.en>
- SRINIVASULU, C. & SRINIVASULU, B. (2020). *Latidens salimalii*. The IUCN Red List of Threatened Species 2020: e.T11374A22103756. <https://doi.org/10.2305/IUCN.UK.2020-3.RLTS.T11374A22103756.en>
- SRINIVASULU, B., KAUR, H., SHAH, T. A., GUNDENA, D., ASAD, G., RAMAN, S. & SRINIVASULU, C. (2020a). A review of the bacular morphology of some Indian bats (Mammalia: Chiroptera). *J Threat Taxa*, 12(9): 15985-16005. <https://doi.org/10.11609/jott.5650.12.9.15985-16005>
- SRINIVASULU, C., SRINIVASULU, B. & SRINIVASULU, A. (2020b). *Hipposideros pomona*. The IUCN Red List of Threatened Species 2020: e.T180990825A180990948. <https://doi.org/10.2305/IUCN.UK.2020-3.RLTS.T180990825A180990948.en>
- THABAH, A., ROSSITER, S. J., KINGSTON, T., ZHANG, S., PARSONS, S., MYA, K. M., AKBAR, Z. & JONES, G. (2006). Genetic divergence and echolocation call frequency in cryptic species of *Hipposideros larvatus s.l.* (Chiroptera: Hipposideridae) from the Indo-Malayan region. *Biol J Linn Soc*, 88(1): 119-130. <https://doi.org/10.1111/j.1095-8312.2006.00602.x>
- TU, V. T., CSORBA, G., RUEDI, M., FUREY, N. M., SON, N. T., THONG, V. D., BONILLO, C. & HASSANIN, A. (2017). Comparative phylogeography of bamboo bats of the genus *Tylonycteris* (Chiroptera, Vespertilionidae) in Southeast Asia. *Eur J Taxon*, 274: 1-38. <https://doi.org/10.5852/ejt.2017.274>
- WALDIEN, D. L., ADLESON, S. & WILSON, Z. (2020). *Eonycteris spelaea*. The IUCN Red List of Threatened Species 2020: e.T7787A22128326. <https://doi.org/10.2305/IUCN.UK.2020-3.RLTS.T7787A22128326.en>
- WILSON, D. E. & MITTERMEIER, R. A. (2019). Handbook of the mammals of the world. Vol. 9, bats. ed.: Lynx Edicions. Barcelona, Spain, 1008 pp.
- WORDLEY, C. F. R., FOUI, E. K., MUDAPPA, D., SANKARAN, M. & ALTRINGHAM, J. D. (2014). Acoustic identification of bats in the southern Western Ghats, India. *Acta Chiropterol*, 16(1): 213-222. <https://doi.org/10.3161/150811014X683408>
- WORDLEY, C. F. R., SANKARAN, M., MUDAPPA, S. & ALTRINGHAM, J. D. (2015). Landscape scale habitat suitability modelling of bats in the Western Ghats of India: bats like something in their tea. *Biol Conserv*, 191: 529-536. <https://doi.org/10.1016/j.biocon.2015.08.005>
- WORDLEY, C. F. R., SANKARAN, M., MUDAPPA, S. & ALTRINGHAM, J. D. (2017). Bats in the Ghats: agricultural intensification reduces functional diversity and increases trait filtering in a biodiversity hotspot in India. *Biol Conserv*, 210(Part A): 48-55. <https://doi.org/10.1016/j.biocon.2017.03.026>
- YADAV, P. D., RAUT, C. G., SHETE, A. M., MISHRA, A. C., TOWNER, J. S., NICHOL, S. T. & MOURYA, D. T. (2012). Detection of Nipah virus RNA in fruit bat (*Pteropus giganteus*) from India. *Am J Trop Med Hyg*, 87(3): 576-578. <https://doi.org/10.4269/ajtmh.2012.11-0416>
- YADAV, P. D., SHETE, A. M., KUMAR, G., SARKALE, P., SAHAY, R. R., RADHAKRISHNAN, C., LAKRA, R., PARDESHI, P., GUPTA, N., GANGAKHEDKAR, R. R., et al. (2019). Nipah virus sequences from humans and bats during Nipah outbreak, Kerala, India, 2018. *Emerg Infect Dis*, 25(5): 1003-1006. <https://doi.org/10.3201/eid2505.181076>