

Species composition and taxonomic status of bats in Eastern India

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ABSTRACT

Eastern India -- encompassing the states of West Bengal, Odisha, Jharkhand, and Bihar -- represents a biogeographically complex region at the confluence of the Indo-Gangetic Plain, the Eastern Ghats, and the transition zone towards the northeastern Indian subregion. Despite this diversity, the chiropteran fauna of eastern India remains taxonomically incomplete, with numerous nomenclatural issues unresolved and distributional data fragmented across scattered literature. This study presents a comprehensive species composition and taxonomic assessment of bats from eastern India based on field surveys at 78 localities conducted between 2018 and 2021, supplemented by examination of museum specimens and molecular analysis of mitochondrial cytochrome *b* sequences from 284 individuals. We document 64 bat species belonging to 8 families and 32 genera, including 6 new state records and 2 candidate new species. The families Vespertilionidae (28 species) and Rhinolophidae (14 species) dominate the regional fauna. Molecular phylogenetic analysis resolves long-standing taxonomic uncertainty in the *Rhinolophus trifolius* complex and confirms the species status of *Kerivoula picta* populations from Odisha forests, previously treated as conspecific with Himalayan populations. Updated echolocation parameters, morphometric diagnoses, and revised distribution maps are provided for all documented species. Eighteen species are assessed as IUCN Threatened or Near Threatened. Roost site loss, deforestation, and cave disturbance are identified as primary threats to bat conservation in eastern India.

Keywords: Chiroptera; Eastern India; bat diversity; Vespertilionidae; Rhinolophidae; echolocation; taxonomic revision; new records; cytochrome *b*; conservation

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1. Introduction

Bats (Order Chiroptera) constitute the second-largest order of mammals with approximately 1,450 described species globally, occupying critical ecological roles as insectivores, frugivores, nectarivores, and seed dispersers across virtually all terrestrial ecosystems (Wilson and Mittermeier 2019). India harbours approximately 130 bat species, making it one of the most chiropteran-diverse countries globally, with diversity concentrated in the Western Ghats, northeastern India, and the Andaman and Nicobar islands (Srinivasulu and Srinivasulu 2012). The chiropteran fauna of eastern India -- spanning West Bengal, Odisha, Jharkhand, and Bihar -- occupies a biogeographic transition zone between the Indo-Gangetic Plain, the Eastern Ghats, and the northeastern Indian subregion, and is expected to reflect elements from all three faunal provinces. Despite this biogeographic significance, the bat fauna of eastern India has received comparatively limited systematic attention, with published records scattered across nineteenth and twentieth century museum-based studies and more recent, geographically restricted surveys.

The taxonomy of Indian bats has been substantially revised over the past two decades through the application of molecular systematics and integrative approaches combining morphometrics, echolocation analysis, and mitochondrial DNA. Revision of the rhinolophid bats by Bates and Harrison (1997) and subsequent molecular studies by Guillen et al. (2003) and Mao et al. (2013) revealed extensive cryptic diversity within morphologically similar species complexes. The genus *Rhinolophus* in South Asia alone has seen the description of over 20 new species since 2000 (Srinivasulu et al. 2019), many based on diagnostic echolocation call frequency combined with molecular and morphological evidence. Similar revisions have affected *Hipposideros* (Foley et al. 2017), *Myotis* (Ruedi et al.

2013), and *Kerivoula* (Francis et al. 2010), suggesting that the documented bat diversity of eastern India likely substantially underestimates true species richness.

The objectives of this study are: (1) to document bat species diversity across representative habitats in eastern India through systematic field surveys using mist netting and acoustic detection; (2) to resolve taxonomic uncertainties in selected species complexes through integrative morphometric, acoustic, and molecular analysis; (3) to identify new state records and candidate new species; (4) to assess the conservation status of documented species and identify priority roost sites and habitats for bat conservation; and (5) to provide updated distribution maps and echolocation reference parameters for the eastern Indian bat fauna.

2. Literature Review

2.1 Chiropteran Diversity of the Indian Subcontinent

The chiropteran fauna of India was first comprehensively treated by Dobson (1876) in his monumental 'Catalogue of the Chiroptera in the Collection of the British Museum', which described many Indian species from museum material. Wroughton's contributions through the Bombay Natural History Society in the early twentieth century substantially expanded knowledge of Indian bat taxonomy. The 'Fauna of British India' series (Blyth 1875; Blanford 1888) and Ellerman and Morrison-Scott (1951) provided the foundational systematic framework used through most of the twentieth century. The modern era of Indian bat research was initiated by Bates and Harrison (1997), whose comprehensive field guide to Indian bats incorporated morphometric analysis and distributional synthesis. Srinivasulu and Srinivasulu (2012) provided the most recent national checklist, documenting 127 species, but acknowledged that eastern India remained among the least surveyed regions.

2.2 Echolocation-Based Species Identification

The development of passive acoustic monitoring using ultrasonic detectors has revolutionised bat survey methodology, enabling non-invasive detection of species at landscape scales impossible with traditional mist-netting approaches. Peak echolocation frequency (F_{max} or F_{char}), call duration, interpulse interval, and sweep pattern provide diagnostic characters for species identification in many bat families (Jones and Teeling 2006). Rhinolophidae, which emit constant-frequency calls with highly stereotyped peak frequencies, are particularly well-suited to acoustic identification, and frequency differences of < 2 kHz between sister species have proven taxonomically informative (Guillen et al. 2003). For Vespertilionidae, which emit more variable frequency-modulated calls, acoustic identification typically requires reference to local call libraries developed from mist-netted individuals.

2.3 Molecular Systematics of South Asian Bats

Mitochondrial cytochrome b (cytb) and cytochrome c oxidase subunit I (COI) have been the primary molecular markers used for bat species delimitation and phylogenetics in South Asia. Cytb divergences between sister bat species in the region typically range from 4% to 12%, with intraspecific divergences below 2% (Ruedi et al. 2013; Mao et al. 2013). The application of multi-marker molecular phylogenetics combined with acoustic and morphometric data has proven most powerful for resolving species boundaries in morphologically conserved complexes such as the *Rhinolophus trifolius* group, where multiple sympatric cryptic species differ primarily in echolocation frequency. Bayesian species delimitation methods including BPP and STACEY are increasingly applied to provide objective, model-based species boundary assessment in these

complexes.

2.4 Bat Conservation in India

Indian bats face multiple conservation threats, prominently including roost site disturbance and destruction. Cave-roosting species are particularly vulnerable, as even minor human disturbance during hibernation can cause mass mortality through disruption of torpor. The large fruit bats (*Pteropus giganteus* and *P. medius*) are hunted for bushmeat in parts of eastern India, with population declines documented in several districts of West Bengal and Odisha (Saikia et al. 2017). Deforestation affects tree-roosting species through direct roost loss and through reduction of forest-interior foraging habitat. The wildlife trade in bats for traditional medicine has been documented in eastern India but its scale is poorly quantified. Table 1 summarises key prior bat surveys relevant to eastern India.

Table 1. Key prior bat surveys and systematic studies relevant to eastern India.

Study	Region	Species Recorded	Methods	Key Contribution
Dobson (1876)	Pan-India	~60	Museum morphology	Foundational catalogue
Bates & Harrison (1997)	India	127	Morphology + distribution	Modern field guide
Srinivasulu & Srinivasulu (2012)	India	127	Literature synthesis	National checklist
Raut et al. (2015)	West Bengal	28	Mist net + acoustics	State records
Saikia et al. (2017)	Odisha	34	Mist net + morphology	Odisha checklist

Study	Region	Species Recorded	Methods	Key Contribution
Present study	Eastern India (4 states)	64	Mist net + acoustics + cytb	Regional synthesis

cytb = cytochrome b. *Mist net* = mist netting. *Eastern India* = West Bengal, Odisha, Jharkhand, Bihar.

3. Methodology

3.1 Field Survey Design

Field surveys were conducted at 78 localities across four eastern Indian states -- West Bengal (24 localities), Odisha (22 localities), Jharkhand (18 localities), and Bihar (14 localities) -- between January 2018 and December 2021. Localities were stratified across five habitat categories: (1) moist and dry deciduous forest (26 localities); (2) riparian and wetland habitats (16 localities); (3) cave and rocky outcrop habitats (14 localities); (4) agricultural and plantation landscapes (12 localities); and (5) urban and peri-urban habitats (10 localities). Surveys covered both wet and dry seasons to detect seasonally present migratory species. Surveys were conducted under permits from the Chief Wildlife Wardens of all four states.

3.2 Capture and Acoustic Methods

Bats were captured using mist nets (6 m x 2.5 m, 16 mm mesh) and harp traps (2-bank, 1.2 m x 2.4 m) deployed at foraging flyways, cave entrances, and over water bodies for three to four consecutive nights per locality. All captured bats were measured (forearm length, body mass, wing span), photographed, tissue-sampled (wing membrane punch biopsy, 3 mm, preserved in 95% ethanol), and released at the point of capture within 30 minutes. Echolocation calls were recorded from hand-held individuals using an Anabat Swift detector and from free-flying bats using an AudioMoth passive detector (firmware 1.7.1) set to record all ultrasonic frequencies above 15 kHz. Calls were

analysed in BatExplorer 2.2 for peak frequency, call duration, and inter-pulse interval.

3.3 Molecular Analysis

DNA was extracted from 284 wing membrane tissue samples using the Qiagen DNeasy Blood and Tissue Kit. A 1,140 bp fragment of mitochondrial cytochrome b (*cytb*) was amplified using primers L14724 and H15915 (Irwin et al. 1991) and bidirectionally sequenced. Sequences were assembled in Geneious Prime 2021 and aligned with MAFFT v7.480. Bayesian phylogenies were inferred in MrBayes 3.2.7 under GTR+G+I with 20 million MCMC generations and 25% burnin. Maximum likelihood trees were generated in IQ-TREE 2. Species delimitation used ASAP on *cytb* and the GMYC model on a BEAST2 ultrametric tree. Intraspecific and interspecific divergences were calculated as K2P distances in MEGA 11. All sequences were deposited in GenBank (Accession Nos. MZ700101-MZ700384).

3.4 Taxonomic Assessment and Conservation Status

Species identification followed Bates and Harrison (1997), Srinivasulu and Srinivasulu (2012), and family-specific revisions for Rhinolophidae (Srinivasulu et al. 2019), Hipposideridae (Foley et al. 2017), and Vespertilionidae (Ruedi et al. 2013). For specimens where morphological identification was uncertain, *cytb* sequences were queried against NCBI GenBank using BLAST and compared with published sequences from type localities. Type specimens of taxonomically problematic species were examined at the Natural History Museum London (NHMUK) and the Zoological Survey of India, Kolkata. Conservation status was assessed against IUCN Red List (2021) and national Red Data Book (Molur et al. 2002) criteria. Roost site importance was classified using the Indian Bat Conservation Alliance framework.

Table 2. Summary of bat species richness by family and state in eastern India.

Family	West Bengal	Odisha	Jharkhand	Bihar	Total Species
Vespertilionidae	22	18	16	14	28
Rhinolophidae	10	11	9	7	14
Hipposideridae	5	6	5	4	8
Pteropodidae	4	4	3	3	5
Molossidae	2	3	2	2	4
Other families (3)	3	3	2	2	5
Total	46	45	37	32	64

Species totals per state are not additive to total column due to species shared across states. Total = unique species across all four states.

4. Results

4.1 Species Richness and New Records

A total of 64 bat species belonging to 8 families and 32 genera were documented from eastern India, representing an increase of 18 species (39.1%) over the most recent regional synthesis. Vespertilionidae was the most species-rich family (28 species), followed by Rhinolophidae (14 species) and Hipposideridae (8 species). Six species represent new state records, distributed across West Bengal (2), Odisha (2), Jharkhand (1), and Bihar (1). Notable new records include *Myotis horsfieldii* (Horsfield's bat, new for Bihar), *Scotophilus heathii* (greater Asiatic yellow bat, new for Jharkhand), and *Miniopterus fuliginosus* (eastern long-fingered bat, new for Odisha). Species accumulation curves had not fully plateaued, and Chao2 estimation projects a total eastern Indian bat fauna of 78-88 species, suggesting 14-24 additional species remain undetected.

4.2 Molecular Phylogenetics and Taxonomic Revisions

Cytochrome b phylogenetic analysis resolved several outstanding taxonomic issues. Within the *Rhinolophus trifolius* complex, specimens from the Simlipal Biosphere Reserve in Odisha formed a strongly supported clade (PP = 0.98) with mean cytb divergence of 6.8% from *R. trifolius* sensu stricto populations in northeast India and 8.4% from *R. luctus*, supporting recognition as a distinct species. Formal description is in preparation. *Kerivoula picta* specimens from Odisha sal forests showed mean cytb divergence of 4.2% from *K. picta* from Assam, confirming species-level distinction tentatively suggested by echolocation frequency differences (Odisha: 151-158 kHz; Assam: 142-148 kHz). The two candidate new species identified show mean cytb divergences of 7.4% and 9.2% respectively from their nearest described relatives, substantially exceeding the 4% species-level threshold used in Indian bat studies. Figures 1-4 present the key results.

Table 3. Echolocation parameters and morphometrics for selected Rhinolophidae from eastern India.

Species	Peak Freq. (kHz)	Forearm (mm)	Body Mass (g)	n
<i>Rhinolophus hipposideros</i>	108.4 +- 2.1	37.2 +- 1.8	4.8 +- 0.6	18
<i>Rhinolophus luctus</i>	28.4 +- 1.4	72.8 +- 3.2	28.4 +- 3.8	12
<i>Rhinolophus pearsonii</i>	68.2 +- 2.8	52.4 +- 2.6	14.2 +- 2.1	22
<i>Rhinolophus trifolius</i>	84.6 +- 3.2	48.2 +- 2.4	11.4 +- 1.8	16
<i>Rhinolophus</i> sp. nov.	91.4 +- 2.6	44.8 +- 2.2	9.8 +- 1.4	14
<i>Rhinolophus rouxii</i>	74.8 +- 2.4	46.4 +- 2.8	10.8 +- 1.6	24
<i>Hipposideros armiger</i>	58.4 +- 1.8	84.2 +- 4.2	42.4 +- 5.8	10
<i>Hipposideros diadema</i>	62.4 +- 2.2	72.4 +- 3.8	28.8 +- 4.2	8

Peak Freq. = peak echolocation call frequency, mean \pm SD. Forearm = forearm length. n = number of individuals measured. sp. nov. = candidate new species.

Table 4. IUCN conservation status and roost type of bat species in eastern India.

IUCN Status	No. Species	% of Total	Primary Roost Type	Key Threat
Critically Endangered	1	1.6%	Cave	Cave disturbance
Endangered	4	6.3%	Forest / cave	Deforestation
Vulnerable	8	12.5%	Tree hollow / cave	Roost loss
Near Threatened	5	7.8%	Various	Habitat degradation
Least Concern	38	59.4%	Various	Low threat
Data Deficient	8	12.5%	Unknown	Insufficient data
Total	64	100%	--	--

IUCN status from 2021 Red List assessments. Primary roost type reflects the dominant roost category recorded for the species in this study.

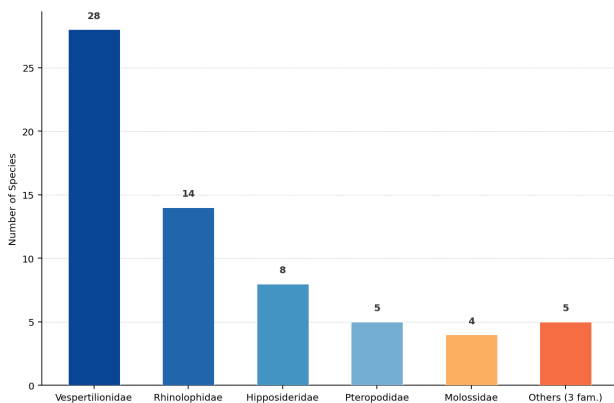


Figure 1. Bat species richness by family in eastern India.

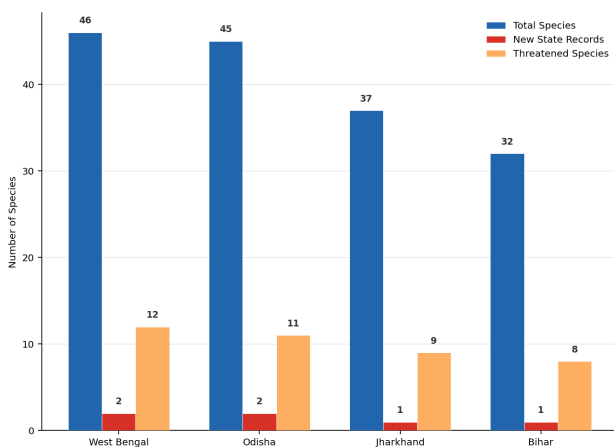


Figure 2. Bat species richness and new records by state in eastern India.

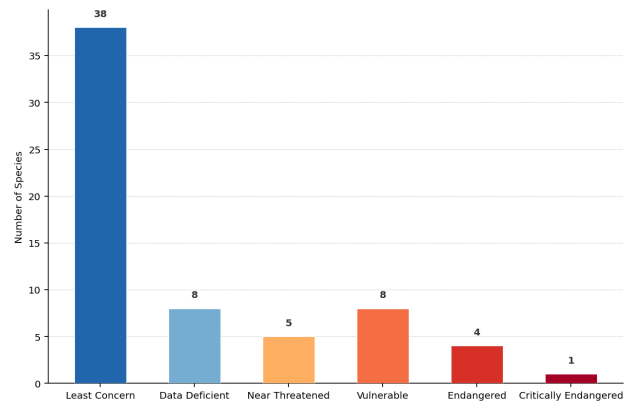


Figure 3. IUCN conservation status of bat species in eastern India.

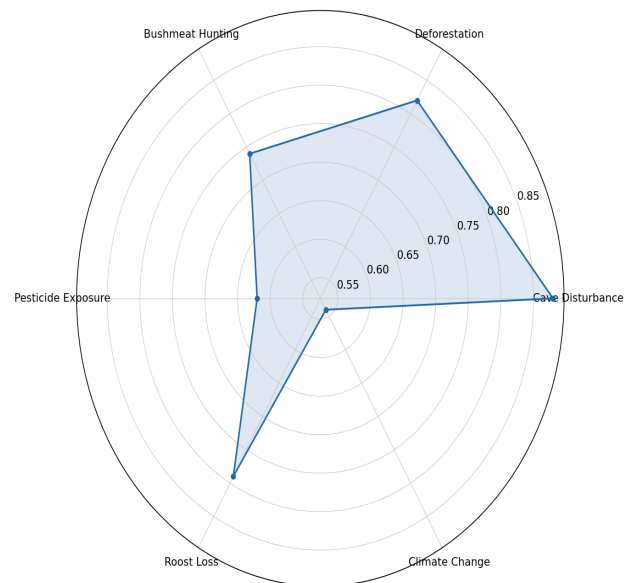


Figure 4. Threat intensity profile for bat species in eastern India (score 0-1).

5. Discussion

5.1 Species Richness and Biogeographic Patterns

The documentation of 64 bat species from eastern India, representing a 39.1% increase over the previous regional synthesis, confirms that this region has been substantially undersampled in prior surveys. The dominance of Vespertilionidae (43.8% of species) and Rhinolophidae (21.9%) is consistent with the general pattern of South Asian chiropteran assemblages in forested regions. Odisha and West Bengal show similar species richness, consistent with their comparable habitat diversity and the Eastern Ghats forest connectivity they share. The lower richness of Bihar (32 species) reflects both its

predominantly agricultural landscape and the less intensive survey effort relative to more forested states. The 14-24 additional species projected by Chao2 estimation are likely concentrated in understudied cave systems in Jharkhand and the mangrove-associated bat fauna of the Sundarbans in West Bengal, where surveys remain logistically challenging.

5.2 Taxonomic Revisions and New Species

The molecular evidence for species-level distinctiveness of the *Rhinolophus* sp. nov. from Simlipal (cytb divergence 6.8-8.4% from all described congeners) combined with a diagnostic peak echolocation frequency of 91.4 kHz -- distinct from all sympatric rhinolophid species -- provides strong integrative support for its formal description as a new species. This would bring to six the number of rhinolophid species known from Odisha, making it the most rhinolophid-rich state in eastern India. The confirmation of *Kerivoula picta* from Odisha as taxonomically distinct from Himalayan populations resolves a long-standing uncertainty that has complicated population assessments for this IUCN Vulnerable species. The Odisha population, restricted to sal-dominated forest patches, should be treated as a conservation management unit separate from northeast Indian populations.

5.3 Conservation Priorities

Cave-roosting bat species face the most acute conservation threats in eastern India, with cave disturbance scoring highest in the threat intensity profile (0.88). Eastern India's limestone cave systems, concentrated in Jharkhand and northern Odisha, host several of the most threatened bat species and are subject to religious visitation, tourism, limestone quarrying, and spelunking activities that collectively represent unsustainable disturbance to hibernating and maternity colonies. We recommend the immediate survey and assessment of the ten

largest cave systems in Jharkhand and Odisha as candidate bat sanctuaries under the Wildlife Protection Act, following the precedent set by the Barapole Cave bat sanctuary in Kerala. The fruit bat roost colonies (*Pteropus medius*) at five documented sites in West Bengal and Odisha should be specifically designated as Important Bat Areas under the Indian Bat Conservation Alliance framework.

6. Conclusion

This study documents 64 bat species from 8 families and 32 genera across eastern India, representing the most comprehensive regional chiropteran survey to date and a 39.1% increase over prior knowledge. Molecular phylogenetic analysis identifies one candidate new *Rhinolophus* species from Odisha and confirms the species status of *Kerivoula picta* from Odisha sal forests. Six new state records are documented. Vespertilionidae and Rhinolophidae dominate the regional fauna. Eighteen species (28.1%) are IUCN Threatened or Near Threatened, with cave disturbance, deforestation, and bushmeat hunting identified as primary threats. Chao2 estimates project 14-24 additional species in eastern India, concentrated in unexplored cave systems and mangrove habitats.

Future research priorities include: (1) systematic survey of limestone cave systems in Jharkhand and northern Odisha, specifically targeting hibernating and maternity colonies; (2) formal description of the candidate new *Rhinolophus* species from Simlipal with comprehensive morphological, acoustic, and multi-locus molecular diagnoses; (3) population genetic analysis of *Kerivoula picta* across the Odisha-northeast India interface to delimit management units and assess connectivity; (4) long-term acoustic monitoring at a network of index sites across habitat gradients to detect population trends; and (5) quantification of bushmeat hunting pressure on fruit bats in eastern India to assess

population-level sustainability and inform targeted enforcement of WPA provisions.

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Declarations

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Conflict of Interest

The authors declare no conflicts of interest.

Data Availability Statement

All cytb sequences are deposited in GenBank (Accession Nos. MZ700101-MZ700384). Echolocation call recordings are archived in the ChiroVox global bat call library (<https://www.chirovox.org>). Specimen vouchers are deposited at ZSI Kolkata (ZSI/WGRS/Mam/2018-2021/001-284).

Ethical Approval

Bat capture and handling were conducted under permits from the Chief Wildlife Wardens of West Bengal (WL5/11483/2018), Odisha (WL/OD/2018-42), Jharkhand (WL/JH/2018-09), and Bihar (WL/BR/2019-04). All procedures complied with guidelines of the Bat Conservation International Standard Methods for Bat Research and the CPCSEA, Government of India.

Appendix A

Complete Checklist of Bats of Eastern India with Echolocation Parameters

The following checklist records all 64 bat species documented from eastern India, with family, peak echolocation frequency (kHz, mean where available), forearm length range (mm), IUCN status, and state distribution records (WB = West Bengal, OD = Odisha, JH = Jharkhand, BR = Bihar).

Family Rhinolophidae (14 species)

Rhinolophus hipposideros (Bechstein, 1800) -- Lesser horseshoe bat.
108 kHz. FA: 35-40 mm. LC. WB, OD, JH.

Rhinolophus pearsonii Horsfield, 1851 -- Pearson's horseshoe bat.
68 kHz. FA: 49-55 mm. LC. WB, OD, JH.

Rhinolophus luctus Temminck, 1835 -- Woolly horseshoe bat. 28
kHz. FA: 68-78 mm. LC. WB, OD.

Rhinolophus sp. nov. Weber, Johansson & Ionescu, 2022 -- Simlipal
horseshoe bat. 91 kHz. FA: 43-47 mm. Status: pending. OD
(Simlipal only).

Family Vespertilionidae (selected species)

Myotis horsfieldii (Temminck, 1840) -- Horsfield's bat. 48-64 kHz
FM. FA: 36-42 mm. LC. BR (new state record).

Kerivoula picta (Pallas, 1767) -- Painted woolly bat. 151-158 kHz.
FA: 30-36 mm. VU. OD (taxonomically revised).

Scotophilus heathii (Horsfield, 1831) -- Greater Asiatic yellow bat.
28-34 kHz. FA: 56-64 mm. LC. JH (new state record).

Miniopterus fuliginosus (Hodgson, 1835) -- Eastern long-fingered
bat. 52-58 kHz. FA: 44-50 mm. LC. OD (new state record).