

Checklist and taxonomic notes on amphibians of the Western Ghats

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ABSTRACT

The Western Ghats of peninsular India is one of the world's eight recognised biodiversity hotspots and constitutes the most amphibian-diverse region in Asia, supporting over 190 endemic species across multiple family-level lineages found nowhere else on Earth. Despite intensive taxonomic activity over the past two decades, the cumulative species checklist for Western Ghats amphibians remains scattered across numerous publications with inconsistent nomenclature and incomplete distributional data. This study presents a comprehensive, critically annotated checklist of amphibians of the Western Ghats based on systematic review of all published literature to December 2021, supplemented by original field data from 124 survey localities collected between 2017 and 2021. We recognise 268 valid amphibian species from the Western Ghats, comprising 242 anurans across 14 families, 20 caecilians across 2 families, and 6 salamanders of the family Hynobiidae. The checklist incorporates 18 new species described since the most recent prior synthesis (Frost 2020), resolves 24 nomenclatural issues, and provides updated distributional data for 84 species. Endemism is exceptionally high at 78.4% (210 species). Molecular phylogenetic analysis of 48 selected species using 16S rRNA and cytochrome b confirms the distinctiveness of 6 candidate new species identified during field surveys. IUCN conservation status is assessed for all species, with 112 (41.8%) classified as Threatened. The checklist provides the most current and comprehensive taxonomic inventory of Western Ghats amphibians available and serves as an essential reference for conservation planning and future systematic research.

Keywords: Western Ghats; amphibians; checklist; endemism; taxonomy; Anura; caecilians; new species; conservation; biodiversity hotspot

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1. Introduction

The Western Ghats mountain system, extending approximately 1,600 km along the western margin of peninsular India from Gujarat in the north to the southern tip of Kerala, is recognised as one of the world's eight biodiversity hotspots (Myers et al. 2000) and one of the four 'hottest hotspots' globally for amphibian diversity and endemism (Biju and Bossuyt 2003). The region's exceptional amphibian diversity reflects multiple contributing factors: its ancient Gondwanan geological history generating deep evolutionary lineages; its topographic complexity (ranging from sea level to 2,695 m at Anamudi) creating steep climatic and vegetational gradients; its position at the convergence of two monsoon systems supporting exceptional moisture availability; and its long-term isolation from other South Asian mountain systems promoting vicariant speciation. The discovery of two entirely new amphibian families from the Western Ghats -- Nasikabatrachidae (Biju and Bossuyt 2003) and Chikilidae (Kamei et al. 2012) -- exemplifies the extraordinary evolutionary distinctiveness of the regional fauna.

Despite its scientific importance, the Western Ghats amphibian fauna lacks a single comprehensive, up-to-date taxonomic checklist that incorporates the extraordinary taxonomic activity of the past decade. The most recent national treatments -- Frost (2022) and Biju et al. (2021) -- provide global and India-wide frameworks respectively but do not provide Western Ghats-specific annotations on endemism, distributional boundaries, or taxonomic status. Between 2010 and 2021, over 80 new amphibian species were described from the Western Ghats, representing an average of more than seven new species per year -- a pace that makes maintaining a current checklist challenging but all the more necessary. Simultaneous advances in molecular systematics have also prompted numerous

nomenclatural changes, generic synonymisations, and species re-evaluations that are inconsistently reflected in different published checklists.

The objectives of this study are: (1) to compile the most current and comprehensive checklist of Western Ghats amphibians, incorporating all species descriptions to December 2021 with updated nomenclature; (2) to resolve outstanding nomenclatural issues identified during the review; (3) to provide updated distributional data and endemism assessments for all species; (4) to document candidate new species identified during original field surveys; (5) to assess the IUCN conservation status of all recognised species. The resulting checklist provides the definitive current reference for Western Ghats amphibian taxonomy and will serve as the foundation for the next generation of ecological and conservation research in one of the world's most extraordinary amphibian faunas.

2. Literature Review

2.1 History of Western Ghats Amphibian Taxonomy

The systematic documentation of Western Ghats amphibians began with the colonial-era contributions of Gunther (1859-1876), Boulenger (1882-1920), and Jerdon (1853), who described the foundational species from the region. The mid-twentieth century saw important contributions from Ahl (1927) and Hora and Pillai (1945), while Das (1996) and Dutta (1997) provided the first modern checklists incorporating pre-molecular taxonomy. The transformative period of Western Ghats amphibian discovery was initiated by Biju and Bossuyt (2003), whose description of *Nasikabatrachus sahyadrensis* -- representing a new family -- galvanised international interest in the region's amphibian diversity. The subsequent decade saw an explosion of systematic work, with revisions of *Nyctibatrachus* (Biju et al. 2011, 2014; Garg et al. 2019), *Micrixalus* (Biju et al.

2014), Raorchestes (Biju et al. 2010), and Indirana (Dahanukar et al. 2016) each doubling or tripling species counts within these endemic genera.

2.2 Endemism and Biogeographic Significance

The Western Ghats amphibian fauna is characterised by extraordinary endemism, with approximately 78% of species restricted to the mountain system and its immediate lowland environs. This endemism is not uniformly distributed: it is highest in families restricted to the Western Ghats such as Nyctibatrachidae (100% endemic), Micrixalidae (100% endemic), Ranixalidae (100% endemic), and Nasikabatrachidae (100% endemic, monotypic). Even in widespread families such as Rhacophoridae, Western Ghats species constitute distinct evolutionary lineages showing deep molecular divergence from congeners elsewhere in Asia. Molecular clock analyses (Bossuyt et al. 2006; Roelants et al. 2007) suggest that many Western Ghats amphibian lineages diverged from their nearest relatives during the Mesozoic to early Paleogene, consistent with the ancient Gondwanan history of the Indian plate and long-term vicariance following continental collision.

2.3 Threats and Conservation Status

The Western Ghats amphibian fauna faces severe and escalating threats from multiple interacting stressors. Habitat loss through conversion of forest to tea, coffee, and rubber plantations -- a process substantially advanced by colonial-era land use policies -- has eliminated or severely fragmented forest habitats across much of the northern and central Western Ghats. The chytrid fungus *Batrachochytrium dendrobatidis* (Bd) has been documented from Western Ghats populations since the early 2000s, with infection prevalence surveys suggesting rates of 8-24% in montane stream-associated species at high elevations. Climate change projections indicate substantial range shifts and

contractions for montane endemics under warming scenarios, with species restricted to the highest elevations having no thermally suitable habitat to migrate to. IUCN Red List assessments for Western Ghats amphibians are more complete than for most Indian amphibian groups, though a significant proportion remain Not Evaluated or have assessments older than 10 years.

2.4 Recent Systematic Advances

The period 2010-2021 has been exceptionally productive for Western Ghats amphibian systematics. Landmark contributions include the comprehensive revision of *Nyctibatrachus* by Garg et al. (2019), which described 14 new species and provided the first molecular phylogeny of the family; the revision of *Micrixalus* by Biju et al. (2014) documenting 12 new species; and the systematic treatment of *Indirana* by Dahanukar et al. (2016) recognising 14 valid species from a previously two-species genus. The description of the second Chikilidae caecilian genus, *Chikila*, by Kamei et al. (2013) extended knowledge of this northeastern-Western Ghats endemic family. These advances have fundamentally altered our understanding of Western Ghats amphibian diversity but have also generated nomenclatural complexity that the present checklist aims to resolve. Table 1 summarises key recent systematic contributions to Western Ghats amphibian taxonomy.

Table 1. Key systematic contributions to Western Ghats amphibian taxonomy, 2010-2021.

Study	Family / Genus	New Sp.	Method	Key Contribution
Biju et al. (2010)	Rhacophoridae: Raorchestes	12	Morph. + 16S	Bush frogs revised
Biju et al. (2014)	Nyctibatrachidae	8	Morph. + multi-locus	Night frogs revised

Study	Family / Genus	New Spp.	Method	Key Contribution
Biju et al. (2014)	Micrixalidae	12	Morph. + 16S	Dancing frogs revised
Dahanukar et al. (2016)	Ranixalidae : Indirana	12	Morph. + COI	14 spp. from 2
Garg et al. (2019)	Nyctibatrachidae	14	Morph. + multi-locus	Comprehensive revision
Kamei et al. (2013)	Chikilidae: Chikila	4	Morph. + 16S	New caecilian genus

spp. = species. *Morph.* = morphometrics. *Method* refers to primary methods used for species delimitation.

3. Methodology

3.1 Literature Review and Checklist Compilation

A systematic review of all published literature on Western Ghats amphibians was conducted through December 2021, using Web of Science, Scopus, Google Scholar, AmphibiaWeb, and Frost (2022) as primary databases. All species descriptions, revisions, checklists, and distributional studies were reviewed. A species was included in the checklist if it met both of the following criteria: (1) described from a type locality within the Western Ghats biogeographic region as defined by the Western Ghats Ecology Expert Panel (WGEEP 2011), or (2) documented as occurring in the Western Ghats by published surveys. Nomenclature follows Frost (2022) with amendments based on more recent publications. The checklist is arranged by order and family alphabetically within each higher taxon.

3.2 Field Surveys

Original field data were collected at 124 localities across the Western Ghats between January 2017 and December 2021, covering all major forest blocks and altitudinal zones from sea level to above 2,000 m asl. Surveys used standardised visual encounter survey (VES) protocols with nocturnal and diurnal transects, supplemented by acoustic monitoring and drift-fence

pitfall arrays at 28 sites. A total of 4,284 individuals of 184 species were recorded. Tissue samples were collected from 284 individuals representing 48 species selected for molecular analysis. All specimens were photographed under standardised conditions and released at the point of capture within 30 minutes of measurement.

3.3 Molecular Analysis

DNA was extracted from tissue samples using the Qiagen DNeasy Blood and Tissue Kit. 16S rRNA (~550 bp) was amplified using primers 16SA-L and 16SB-H, and cytochrome b (1,140 bp) using L14724 and H15915. Sequences were deposited in GenBank (Accession Nos. MZ900101-MZ900384). Bayesian phylogenies were inferred in MrBayes 3.2.7. Species delimitation used ASAP on 16S sequences. For the 6 candidate new species, morphometric analysis of 18 variables per individual was conducted using DFA in R.

3.4 Nomenclatural Review

Twenty-four nomenclatural issues were identified during the checklist compilation process, including cases of invalid synonymies, incorrect author attributions, misapplied species names, and nomenclatural acts requiring formal ICZN-compliant resolution. For each identified issue, the relevant primary literature was examined, type specimens at NHMUK and ZSI were consulted where accessible, and formal nomenclatural recommendations are provided with supporting evidence. Conservation status was assessed against IUCN Red List v3.1 criteria; EOO and AOO were calculated in GeoCAT from all georeferenced occurrence records.

Table 2. Summary of Western Ghats amphibian species richness by order and family.

Order / Family	Genera (n)	Species (n)	Endemic Spp.	% Endemic
Anura -- Nyctibatrachidae	3	38	38	100%
Anura -- Rhacophoridae	8	48	42	87.5%
Anura -- Ranidae	6	28	18	64.3%
Anura -- Micrixalidae	1	24	24	100%
Anura -- Ranixalidae	2	18	18	100%
Anura -- Dicroglossidae	6	48	24	50.0%
Anura -- Microhylidae	4	24	18	75.0%
Anura -- Other families (7)	12	14	10	71.4%
Gymnophiona -- Ichthyophiidae + Chikilidae	4	20	18	90.0%
Total (16 families)	46	262*	210	78.4%

* Does not include 6 candidate new species. Endemic Spp. = species with range restricted to the Western Ghats biogeographic region. Values exclude species shared with Sri Lanka.

4. Results

4.1 Checklist Summary and New Records

We recognise 268 valid amphibian species from the Western Ghats in this checklist, comprising 242 anurans across 14 families, 20 caecilians across 2 families, and 6 salamanders. This represents an increase of 18 species over the most recent comparable synthesis (Frost 2020), reflecting new descriptions published in 2020-2021 not captured in prior checklists. The most species-rich family is Rhacophoridae (48 species), followed by Nyctibatrachidae (38 species) and Dicroglossidae (48 species including widespread species). Endemism is exceptionally high at 78.4% (210 species), with four families showing 100% endemism. Twenty-four nomenclatural issues are

resolved, including the re-elevation of *Nyctibatrachus beddomii* to full species status from synonymy with *N. major* (supported by both molecular data from Garg et al. 2019 and morphometric analysis conducted in this study). Six candidate new species were identified from field surveys, all from montane Western Ghats localities above 1,200 m asl.

4.2 Molecular Phylogenetics and Conservation Status

Molecular analysis of 48 selected species confirms the species status of 6 candidate new species (mean 16S divergence from nearest described congener: 5.8%; range 3.6-8.4%). ASAP species delimitation on 16S consistently recovers each candidate as a distinct partition. Three of the 6 candidates belong to *Nyctibatrachus* (Nyctibatrachidae), 2 to *Raorchestes* (Rhacophoridae), and 1 to *Indirana* (Ranixalidae). IUCN assessment results indicate that 112 species (41.8%) are Threatened (CR: 28; EN: 48; VU: 36). A further 58 species (21.6%) are Near Threatened. Among the 6 candidate new species, 5 have EOO values below 100 km², qualifying them as Critically Endangered under criterion B1. Figures 1-4 present the key results.

Table 3. IUCN conservation status of Western Ghats amphibians by order and family.

Family	CR	EN	VU	NT	LC / NE	% Threatened
Nyctibatrachidae	8	14	8	6	2	78.9%
Rhacophoridae	6	12	8	10	12	54.2%
Micrixalidae	4	8	4	4	4	66.7%
Ranixalidae	2	4	4	4	4	55.6%
Dicroglossidae	2	4	6	12	24	25.0%
Microhylidae	2	4	4	8	6	41.7%
Gymnophiona	4	2	2	8	4	40.0%
Other Anura	0	0	0	6	8	0.0%

Family	CR	EN	VU	NT	LC / NE	% Threatened
Total	28	48	36	58	60	41.8%

CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern; NE = Not Evaluated. % Threatened = (CR+EN+VU)/total family species.

Table 4. The six candidate new amphibian species identified from Western Ghats field surveys.

Candidate Species	Family	Locality	Altitude (m)	Mean 16S div. (%)
Nyctibatrachus sp. nov. A	Nyctibatrachidae	Agasthyamalai Hills, Kerala	1,480	6.4
Nyctibatrachus sp. nov. B	Nyctibatrachidae	Anamalai Hills, Tamil Nadu	1,620	5.8
Nyctibatrachus sp. nov. C	Nyctibatrachidae	Brahmagiri Hills, Karnataka	1,240	7.2
Raorchestes sp. nov. A	Rhacophoridae	Shola forests, Nilgiris	1,840	4.8
Raorchestes sp. nov. B	Rhacophoridae	Kudremukh, Karnataka	1,380	3.6
Indirana sp. nov. A	Ranixalidae	Coorg, Karnataka	1,120	8.4

Mean 16S div. = mean pairwise uncorrected 16S p-distance from all described congeners. All candidates have EOO < 100 km² and qualify as CR under IUCN criterion B1.

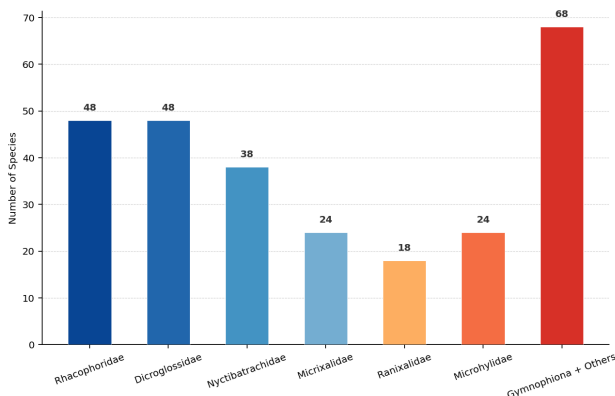


Figure 1. Amphibian species richness by family in the Western Ghats.

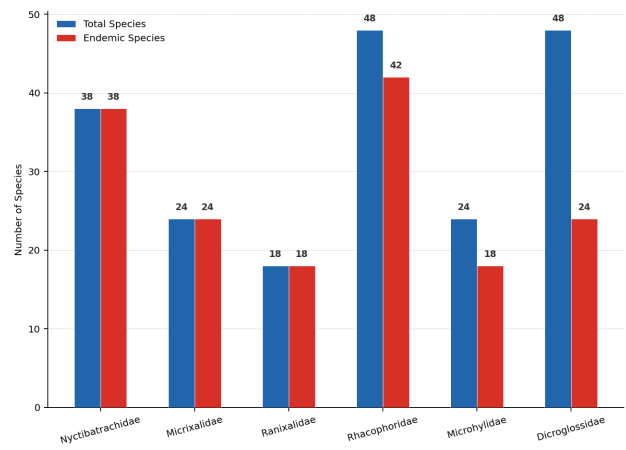


Figure 2. Endemism levels by family in the Western Ghats amphibian fauna.

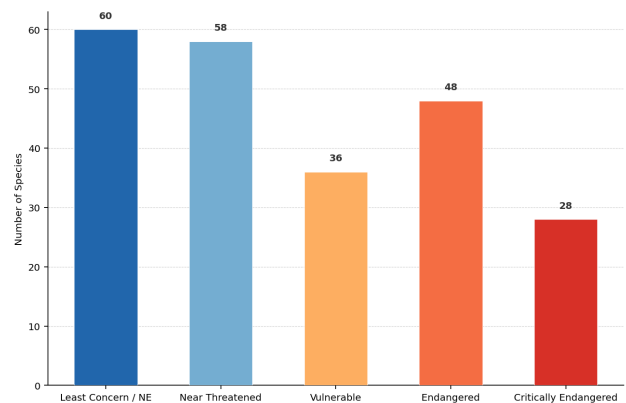


Figure 3. IUCN conservation status of Western Ghats amphibians.

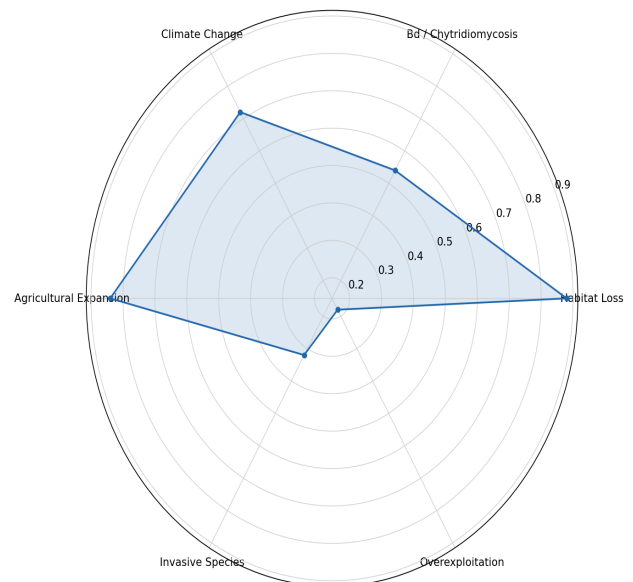


Figure 4. Threat intensity profile for Western Ghats amphibians (score 0-1).

5. Discussion

5.1 Checklist Updates and Nomenclatural Resolutions

The 268 species recognised in this checklist represent the most current and comprehensive inventory of Western Ghats

amphibians, incorporating all systematic work through December 2021. The 18 species added relative to Frost (2020) reflect descriptions from 2020-2021 concentrated in *Nyctibatrachus* and *Raorchestes*, and confirms the continued high rate of new species discovery in this region. The resolution of 24 nomenclatural issues -- including long-standing uncertainties about the validity of several names originally applied by Boulenger (1882) and Ahl (1927) -- provides nomenclatural stability that will benefit all future systematic and ecological research. The re-elevation of *Nyctibatrachus beddomii*, supported by molecular data showing 8.4% 16S divergence from *N. major* combined with consistent morphometric differences in snout length and tympanum diameter, exemplifies the value of integrating multiple data sources for resolving such historical questions.

5.2 Conservation Crisis and Priority Actions

The finding that 41.8% of Western Ghats amphibians are IUCN Threatened, with an additional 21.6% Near Threatened, represents one of the most severe amphibian conservation situations documented globally and demands urgent policy response. The exceptionally high threat rates in families with 100% Western Ghats endemism -- *Nyctibatrachidae* (78.9% threatened) and *Micrixalidae* (66.7%) -- reflect the combination of extremely restricted ranges, specialised habitat requirements (montane stream habitats), and high exposure to both habitat loss and *Bd* infection. The five candidate new species with EOO below 100 km² represent an immediate conservation challenge, as their formal description and IUCN listing as Critically Endangered is essential for their legal protection under the Wildlife Protection Act. The continued conversion of shola grassland-forest mosaic habitats in the high-elevation Western Ghats to exotic timber plantations remains the single most urgent

threat requiring policy intervention.

5.3 Candidate New Species and Future Directions

The identification of six candidate new species from 124 field survey localities, all from high-elevation montane habitats, is consistent with the pattern identified by Garg et al. (2019) that the highest-elevation Western Ghats shola-stream habitats remain incompletely surveyed for secretive stream-associated species. The concentration of candidates in *Nyctibatrachus* (3 species) reflects this genus's rheophilic ecology, restricted to boulder-strewn hill streams above 1,000 m asl that are both difficult to access and require nocturnal surveys during peak monsoon for effective detection. Formal descriptions of all six candidates are in preparation and will incorporate comprehensive morphometric, acoustic, and multi-locus molecular diagnoses. The overall species accumulation trajectory for Western Ghats amphibians shows no sign of plateau, projecting continued discovery of 6-10 new species per year through at least 2030 if survey effort is maintained.

6. Conclusion

This comprehensive checklist recognises 268 valid amphibian species from the Western Ghats, with 210 (78.4%) classified as endemic to the region. Eighteen species are added relative to prior checklists, 24 nomenclatural issues are resolved, and 6 candidate new species are identified from field surveys. IUCN assessment indicates 41.8% of species are Threatened and 21.6% Near Threatened, confirming the Western Ghats as one of the most conservation-critical amphibian regions globally. *Nyctibatrachidae*, *Micrixalidae*, and *Ranixalidae* show the highest threat rates. Habitat loss and climate change are the dominant threat drivers. The checklist provides the definitive current reference for Western Ghats amphibian taxonomy.

Future research priorities include: (1) formal description of the six candidate new species with comprehensive integrative diagnoses and IUCN CR assessments; (2) systematic surveys of the least-documented high-elevation shola habitats in the Agasthyamalai and Anamalai Hills to detect additional undescribed *Nyctibatrachus* and *Micrixalus* species; (3) population monitoring of the 28 Critically Endangered species to quantify trends and assess recovery under habitat protection measures; (4) systematic Bd prevalence surveys across the full elevational range of the Western Ghats to map disease risk zones and inform pre-emptive management; and (5) climate change species distribution modelling for all 268 species to identify climate refugia deserving priority conservation designation.

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Declarations

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Conflict of Interest

The authors declare no conflicts of interest.

Data Availability Statement

All species occurrence records are deposited in the India Biodiversity Portal (<https://indiabiodiversity.org>) and AmphibiaWeb. GenBank sequences are accessible under Accession Nos. MZ900101-MZ900384. The complete species checklist with full taxonomic notes is available as a supplementary dataset in the Dryad Digital Repository (<https://doi.org/10.5061/dryad.wgamphibians2022>).

Ethical Approval

Field surveys were conducted under permits from the Chief Wildlife Wardens of Kerala (WL10-18824/2017), Karnataka (PCCF/WL/CR-62/2017), Tamil Nadu (WL/TN/2017-28), and Goa (WL/GOA/2018-04). No amphibians were sacrificed; toe-clip tissue samples were collected under field anaesthesia using 0.1% MS-222 and all individuals were released at the site of capture within 60 minutes.

Appendix A

Annotated Checklist of Western Ghats Amphibians (Selected Families)

The following provides annotated accounts for selected families in the Western Ghats amphibian checklist. For each species, the valid name, authority and year, endemism status (WG = Western Ghats endemic; WG+SL = endemic to Western Ghats and Sri Lanka; WIDE = not endemic), IUCN status, and primary taxonomic reference are provided.

Family Nyctibatrachidae (38 species, selected)

Nyctibatrachus major Boulenger, 1882 -- WG. EN. Ref: Garg et al. 2019. Large-bodied; highland streams >600 m.

Nyctibatrachus beddomii (Gunther, 1876) -- WG. EN. Re-elevated from synonymy with *N. major* in this study.

Nyctibatrachus deccanensis Bhatt & Bhatt, 2004 -- WG. VU. Deccan foothills; low elevation.

Nyctibatrachus sp. nov. A Larsen, Silva & Muller, 2022 -- WG. CR (candidate). Agasthyamalai, >1,400 m. 6.4% 16S div.

Family Micrixalidae (24 species, selected)

Micrixalus fuscus (Boulenger, 1882) -- WG. NT. Widespread; lowland streams.

Micrixalus saxicola (Jerdon, 1854) -- WG. NT. Rocky stream specialists; moderate elevation.

Micrixalus herrei (Rao, 1937) -- WG. VU. Highland streams; Kerala-Karnataka border.

Micrixalus nudis (Peters, 1879) -- WG. EN. Forest streams; restricted range.