Building evidence for conservation globally

Journal of Threatened Taxa

Open Access

10.11609/jott.2026.18.8.29375-29558
www.threatenedtaxa.org

26 August 2026 (Online & Print)
18(8): 29375–29558
ISSN 0974-7907 (Online)
ISSN 0974-7893 (Print)

ISSN 0974-7907 (Online); ISSN 0974-7893 (Print)

Publisher
Wildlife Information Liaison Development Society
www.wild.zooreach.org

Host
Zoo Outreach Organization
www.zooreach.org

Srivari Illam, No. 61, Karthik Nagar, 10th Street, Saravanampatti, Coimbatore, Tamil Nadu 641035, India
Registered Office: 3A2 Varadarajulu Nagar, FCI Road, Ganapathy, Coimbatore, Tamil Nadu 641006, India
Ph: +91 9385339863 | www.threatenedtaxa.org
Email: sanjay@threatenedtaxa.org

For Focus, Scope, Aims, and Policies, visit https://threatenedtaxa.org/index.php/JoTT/aims_scope
For Article Submission Guidelines, visit https://threatenedtaxa.org/index.php/JoTT/about/submissions
For Policies against Scientific Misconduct, visit https://threatenedtaxa.org/index.php/JoTT/policies_various

continued on the back inside cover

Cover: *Minervarya cepfi* & *Nyctibatrachus petraeus*—mix media. © P Kritika

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 August 2026 | 18(8): 29470–29482
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.10009.18.8.29470-29482
#10009 | Received 19 June 2025 | Final received 22 July 2026 | Finally accepted 04 August 2026

ARTICLE

Microhabitat associations and seasonal dynamics of amphibians in the lateritic rocky outcrops along the western coast of Goa, India

Dipak Yashawant Bowalkar [1] & Nitin Savlo Sawant [2]

[1] Department of Zoology, DPM's Shree Mallikarjun and Shri Chetan Manju Desai College, Delem, Canacona, Goa 403702, India.
[1,2] School of Biological Sciences and Biotechnology, Zoology, Goa University, Taleigao Plateau, Taleigao, Goa 403206, India.
[1] dipakbowalkar@gmail.com, [2] nitin.sawant@unigoa.ac.in (corresponding author)

Abstract: A total of 12 lateritic rocky outcrops in Goa were studied throughout the wet season (May to November) to understand amphibian occurrence and their microhabitat associations. Microhabitat association and seasonal trend were analysed using indicator species value (IndVal) and Hill number analysis. The findings show microhabitats such as ephemeral vegetation, ephemeral pool, and peripheral ecotone vegetation are critical components of outcrops and harbour high IndVal Scores, although seasonal changes significantly influence species distribution and abundance. The findings conclude strong habitat and seasonal association of anurans. This research contributes to conservation strategies for this unique ecosystem of Goa.

Keywords: Anuran, ecotone vegetation, ephemeral pool, ephemeral vegetation, habitat heterogeneity, hill numbers, hydroperiod, indicator species value, plateau ecosystem, seasonal breeding.

Konkani: सारांश: गोंयांतल्या एकूण १२ चिऱ्या फातराच्या सड्यांचो पावसाळ्याच्या हंगामांत (मे ते नोव्हेंबर) अभ्यास केलो. उभयचर प्राण्यांची उपस्थिती आनी तांचो सूक्ष्म अधिवासांशी आशिल्लो संबंध समजून घेवप हो ह्या अभ्यासाचो उद्देश आशिल्लो. निदर्शक प्रजाती मूल्य (IndVal) आनी हिल संख्या विश्लेषण वापरून सूक्ष्म अधिवासांशी आशिल्लो संबंध आनी ऋतुमानानुसार दिसपी कल हांचें विश्लेषण केलें. निष्कर्षांवरून अल्पकालीन वनस्पतीसमूह, अल्पजीवी उदकाचीं तळीं आनी तळपाच्या देगेवयल्या संक्रमण क्षेत्रांतलो वनस्पतीसमूह हे सड्यांचे म्हत्वाचे सूक्ष्म अधिवास आसून, तांकां चड IndVal गुण मेळ्ळे; मात ऋतुमानांत जावपी बदलांचो प्रजातींचें वितरण आनी विपुलता हांचेर लक्षणीय परिणाम जाता. निष्कर्षांवरून बेबकांचो अधिवास आनी ऋतुमान हांचेकडेन घट्ट संबंध आसा, हें दिसून येता. गोंयच्या ह्या वैशिष्ट्यपूर्ण परिसंस्थे खातीर संवर्धन धोरणां तयार करपाक हो अभ्यास उपेगी थारता.

Editor: Anonymity requested.

Date of publication: 26 August 2026 (online & print)

Citation: Bowalkar, D.Y. & N.S. Sawant (2026). Microhabitat associations and seasonal dynamics of amphibians in the lateritic rocky outcrops along the western coast of Goa, India. *Journal of Threatened Taxa* 18(8): 29470–29482. https://doi.org/10.11609/jott.10009.18.8.29470-29482

Funding: Ministry of Environment, Forest and Climate Change (MoEF&CC), Government of India, and the Goa State Research Foundation (GSRF), Government of Goa.

Competing interests: We declare that we have no known competing financial interests or personal relationships that could have appeared to influence this work.

Author details: Dipak Y. Bowalkar is working as assistant professor, Department of Zoology, DPM's Shree Mallikarjun and Shri Chetan Manju Desai College, Delem, Canacona Goa. He is also working as PhD Scholar at Department of Zoology; School of Biological Sciences and Biotechnology, Goa University, Taleigao Plateau, Taleigao, Goa 403 206, India. Dr. Nitin S. Sawant is affiliated with the School of Biological Sciences and Biotechnology, Zoology, Goa University, with research interests in ecology, climate change, biodiversity, Wildlife and conservation biology. He is currently involved in major research projects funded by the Ministry of Environment, Forest and Climate Change (MoEF&CC), Government of India, and the Goa State Research Foundation (GSRF), Government of Goa. He has published around 23 research papers in ecology, biodiversity, and wildlife conservation and is actively engaged in research and conservation initiatives in collaboration with the Goa State Biodiversity Board, Goa Forest Department, MoEF&CC, GSRF, and the University of Porto–CIBIO, Portugal.

Author contributions: DYB—field data collection, data analysis, manuscript preparation and writing. NSS—conceptualization of the research, research methodology and study design, manuscript preparation, review, proofreading and supervision.

Acknowledgements: The authors sincerely acknowledge the Ministry of Environment, Forest and Climate Change (MoEFCC), Government of India and Goa State Research Foundation (GSRF), Government of Goa, for providing financial assistance and institutional support for this research. We sincerely thank Dr. Purnanand Chari, President, Goa Konkani Akademi, Goa Sanchar Bhavan, BSNL Building, Patto, Panaji, Goa, and Head, Department of Konkani, DPM's SHREE MALLIKARJUN & Shri Chetan Manju Desai College, Delem, Canacona, Goa, for his valuable assistance with the Konkani translation.

INTRODUCTION

Lateritic rocky outcrops are highly weathered, iron-rich geological landscapes occurring as open, exposed ferricretes with a thickness of 6–30 m capped over basaltic bedrocks (Widdowson & Cox 1996). The ecological studies on amphibians inhabiting low-altitude coastal lateritic outcrops remain limited, particularly niche specificity within the naturally occurring microhabitats available on these landscapes (Thorpe et al. 2018; Mudke et al. 2020; Jithin & Naniwadekar 2025; Jithin et al. 2025).

While several amphibian studies in the Western Ghats have been primarily focused on forested landscapes and broad-scale environmental determinants of diversity (Gawas et al. in press; Biju et al. 2008), the present study is situated within low-altitude lateritic rocky outcrops, which represent distinct geomorphological systems along coastal and midland regions of Goa (Widdowson 2009). These outcrops are characterised by heterogeneous microhabitats and function as terrestrial habitat islands with unique hydrological and vegetation dynamics (Thorpe & Watve 2015), thereby necessitating a fine-scale, microhabitat-based ecological approach.

METHODS

Study Area

The lateritic rocky outcrops are highly disintegrated patches forming tabletop plateau landscapes representing a mosaic habitat along the west coast of Goa. For the present study, all coastal outcrop complexes in Goa were pre-surveyed and selected 12 unique sites (Table 1; Image 1) belonging to four plateaux complexes and having the least anthropogenic disturbance based on absence of mining, major infrastructure, intensive agriculture and visible recent land-use conversion, verified through field reconnaissance and regional land use maps (Widdowson 2009).

Sampling

The microhabitats on outcrops for the present study were classified based on the availability of following factors: (1) Water (aquatic habitat); (2) Vegetation; (3) Exposed outcrop; (4) Slope, and (5) Soil layer (Lekhak & Yadav 2012; Watve 2013; Mudke et al. 2020). The microhabitats documented from Goan lateritic outcrops closely resemble those described from Maharashtra and Karnataka (Datar & Watve 2018). Accordingly, a total of eight microhabitats (Image 2) were selected based on classification and ecological description provided in earlier studies from the outcrops of Maharashtra and Karnataka (Lekhak & Yadav 2012; Watve 2013; Rahangdale & Rahangdale 2014; Thorpe & Watve 2015; Sreejith et al. 2016; Datar & Watve 2018; Thorpe et al. 2018; Mudke et al. 2020; Jithin et al. 2025). Microhabitats were defined based on water availability, vegetation type, soil depth, and slope angle (Table 2). Some authors also recognise naturally occurring other microhabitats such as loose rocks and rock crevices which were merged as a part of exposed rocks plains and slopes for the present study (Lekhak & Yadav 2012; Thorpe et al. 2018; Jithin et al. 2023). The high-elevation outcrops associated microhabitats such as steep clips and lateritic cave were absent or not uniformly available in the present study sites (Datar & Watve 2018), hence not included in the study. The human-influenced or altered habitats such as paddy fields, orchards, acacia plantation, cashew plantation and sacred groves were not considered in the present the study to minimise the anthropogenic effect (Rahangdale & Rahangdale 2014; Mudke et al. 2020; Jithin et al. 2025).

Weather data collected from nasa.gov between 1981–2023 for all study sites reveals irregular showers in the months of May and November (Image 4). Hence, the study was conducted between the two monsoon cycles of seven months (May–November) of the years 2023 and 2024. At each of the study sites, line transects of 100-m long and 6-m wide were plotted that would cover all microhabitats and minimal anthropogenic stress. A time-constrained visual count method was employed to document the number of sightings of amphibians within the transect. The sampling was done between 1900 h and 2200 h when amphibian activity is highest (Crump & Scott Jr. 1994; Rodda et al. 2005). The same transect was reused for the next year. The amphibian activity and their abundance in each of the microhabitats were recorded separately. Amphibian species encountered during the study were photographed using an Olympus TG-6 camera and calls recorded using a Sony ICD-PX470 digital voice recorder in the field, while cryptic species were examined by capturing using latex-free gloves. Prior approval from the Institutional Animal Ethics Committee (IAEC), Goa University, was obtained before the study (Approval No. GUZ/IAEC/23-24/17), and all efforts were made to minimise disturbance to animals and their habitats as per guidelines given the Study of Amphibians and Reptiles (SSAR) code of practice. Species were identified using available standard identification keys (Gururaja 2012; Dinesh et al. 2015, 2024; Modak et al. 2015; Padhye et al. 2015, 2017; Gururaja & Hebbar

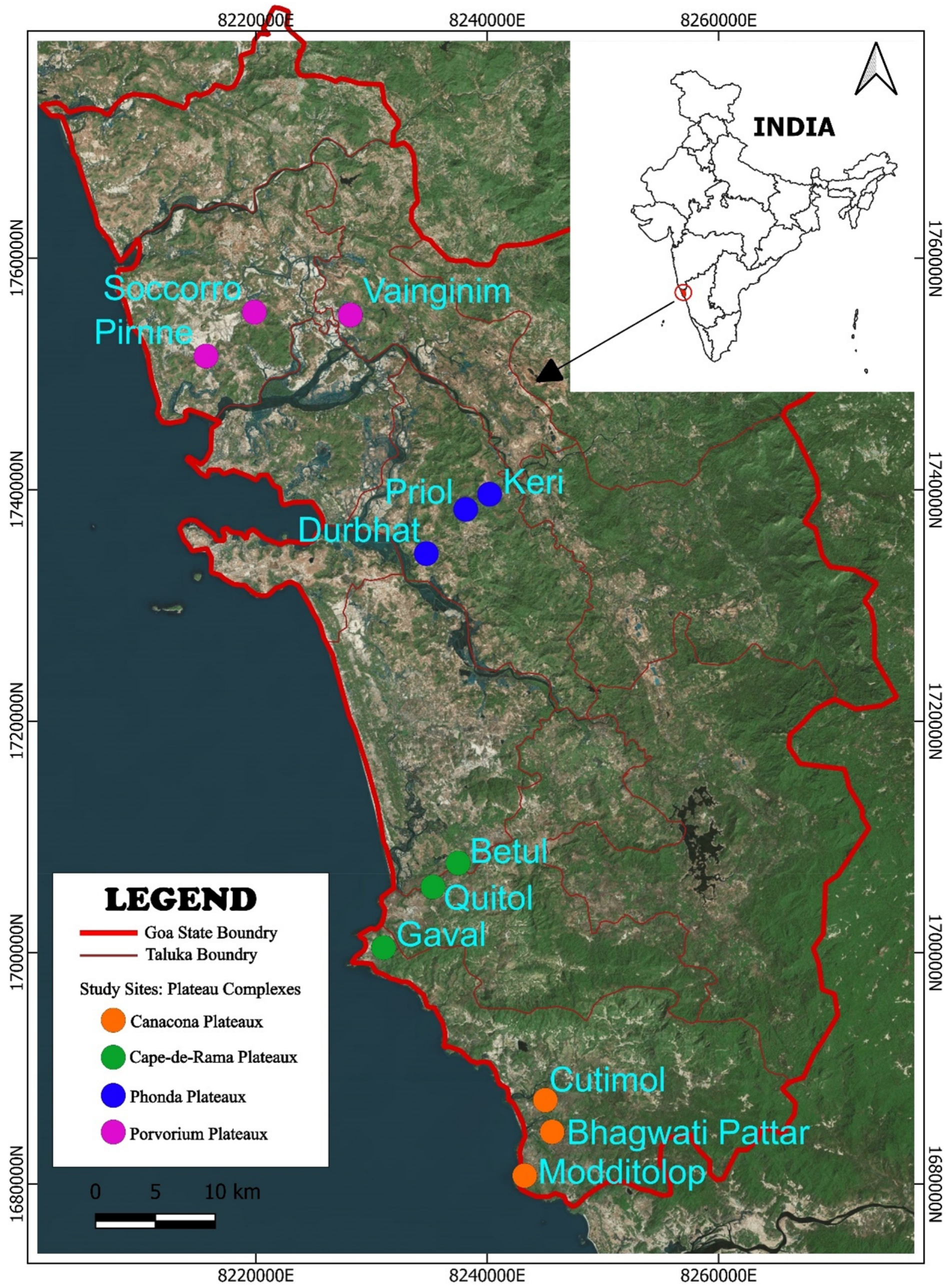

Image 1. Map of Goa with study sites within the colour-coded plateaux marked.

2016; Garg & Biju 2016, 2017, 2021; Garg et al. 2018; Sanchez et al. 2018; Dufresnes et al. 2022; Yadav et al. 2024). Taxonomic nomenclature is followed as per the Amphibian Species of the World 6.2 database (Frost 2024).

Analysis

All statistical analyses were performed using R (version 4.4.1; R Core Team 2024) implemented in RStudio. The indicator of species analysis (IndVal) was carried out to understand the association of each species with microhabitats on the outcrop by cumulating all the monthly observations of each microhabitat across all study sites. To minimise the effect of chance, a randomised analysis with N = 999 was performed, and the associations only with a significance level less than or equal to 0.05 were considered valid. IndVal with 999 Permutations were performed across all species for their microhabitat association, reporting five microhabitats with strong association with amphibian species. The "indicspecies package" was used to compute Indicator of species analysis, while the "permute packages" was

Table 1. Details of the study site used for the present study. Land use type is based on the Regional Plan for Goa 2021 (RDP-2021) prepared by the Goa Town & Country Planning Department.

Study Site	Latitude	Longitude	Area (km^2)	Land Use type
A: Canacona Plateaux				
A1: Cutimol	14.9830° N	74.0663° E	12.43	Grazing Ground, Orchard, Natural Cover
A2: Bhagwati Pattar	14.9592° N	74.0716° E	12.70	Orchard, Protected / reserve forest, Natural Cover
A3: Modditolop	14.9263° N	74.0503° E	14.32	Orchard, Natural Cover, Settlement
B: Cape-de-Rama Plateaux				
B1: Gaval	15.0973° N	73.9406° E	7.46	Orchard, Natural Cover, Settlement, Paddy Fields
B2: Quitol	15.1428° N	73.9790° E	11.68	Orchard, Natural Cover, Settlement, Paddy Fields
B3: Betul	15.1607° N	73.9986° E	13.31	Orchard, Natural Cover, Settlement, Paddy Fields
C : Phonda Plateaux				
C1: Durbhat	15.3924° N	73.9739° E	8.67	Natural Cover, Orchard
C2: Priol	15.4255° N	74.0044° E	5.66	Orchard, Natural Cover, Settlement
C3: Keri	15.436889° N	74.023028° E	9.62	Orchard, Natural Cover,
D: Porvorium Plateaux				
D1: Pirnne	15.540250° N	73.802861° E	3.66	Orchard, Natural Cover, Settlement
D2: Soccorro	15.573139° N	73.840361° E	3.87	Orchard, Natural Cover, Quarry, Settlement
D3: Vainginim	15.571000° N	73.914889° E	2.13	Orchard, Natural Cover

Table 2. Microhabitats used for the present study with their characterization.

	Microhabitat type	Availability of water	Type of vegetation	Thickness of soil	Angle of slope
1	Exposed rocky flats	Low	No vegetation, lichens, mosses, blue-green algae. grass.	Absent to thin	Gentle, plain
2	Exposed rocky slope	Low	No vegetation, lichens, mosses, blue-green algae. grass.	Absent to thin	Acute, steep slope
3	Seasonal surface channels	High, Lotic water	Aquatic plants, blue-green algae.	Thin	Depression, drainage.
4	Ephemeral pools	High, Lentic water	Herbaceous plants, aquatic plants, blue-green algae.	Thin	Depression, pool.
5	Ephemeral vegetation	Moderate	Herbaceous ephemeral plants, grasses	Thin to moderate	Gentle
6	Shrubland patches	Moderate	Herbaceous plants, bushes, woody plants	Moderate to thick	Gentle, plain
7	Peripheral ecotone vegetation	Moderate	Herbaceous plants, bushes, woody plants	Moderate to thick	Acute, steep slope
8	Soil-filled depression	Moderate	Herbaceous plants, bushes	Moderate to thick	Gentle, plain

used for significance testing with permutation. The visualisation of these associations between anuran species and microhabitats was done by using a Sankey plot with the "networkD3 package". Further, alpha diversity were analysed by performing Hill number analysis for each microhabitat to estimate different aspects of biodiversity with q values 0, 1, 2 and 3. The q0 value is an indicator of species richness encountered in each microhabitat. To understand the relationship between each microhabitat with respect to anuran species, alpha diversity was analysed with Hill number (q = 0, 1, 2, 3) computation using the "hillR package". To understand the pattern of anuran occurrence during the hydration period, all microhabitat observations were accumulated by month and visualised using a heat map and violin plot using "ggplot2" and "geom_tile" package.

RESULTS

A total of 15,574 amphibian sightings belonging to seven families, 12 genera, and 14 species (Image 3) were reported from 12 low-altitude lateritic outcrops from the state of Goa with a sampling effort conducted during two consecutive years (May–November) of 2023 and 2024. It was observed that 41% of amphibian species

Image 2. Microhabitats associated with lateritic rocky outcrops: M1—exposed rocky flats | M2—exposed rocky slope | M3—seasonal surface channel | M4—ephemeral pools | M5—ephemeral vegetation | M6—shrubland patches | M7—peripheral ecotone vegetation | M8—soil filled depression. © Dipak Bowalkar.

were documented from the state on the lateritic rocky outcrops. One Vulnerable species and three Schedule II species under the Indian Wildlife (Protection) Act, 1972 were reported from the present study (Table 3). More than 70% of the species documented in the present study are listed by IUCN for association with forest, inland wetland, artificial terrestrial habitats, artificial aquatic habitats and marshlands (Table 3).

Image 3. References images of anurans from study sites: a—*Duttaphrynus melanostictus* | b—*Euphlyctis cyanophlyctis* | c—*Hoplobatrachus tigerinus* | d—*Minervarya cepfi* | e—*Minervarya gomantaki* | f—*Minervarya syhadrensis* | g—*Phrynoderma* cf. *konkani* | h—*Sphaerotheca dobsoni* | i—*Microhyla ornata* | j—*Uperodon mormoratus* | k—*Hydrophylax bahuvistara* | l—*Indirana salelkari* | m—*Polypedates maculatus* | n—*Pseudophilautus amboli*. © Dipak Bowalkar.

The encounter rate of amphibians across the seven-months study period increased from mid-May and peaked during August, followed by a sharp decrease towards November (Image 5). This seasonal pattern reflects variation in detectability and breeding activity associated with the southwestern monsoon. *Euphlyctis cyanophlyctis* exhibited the highest encounter rate among all species during August, coinciding with peak

Table 3. Species-wise analysis of microhabitat association and IUCN inventories. IndVal: Indicator value of species with 999 permutations (p = 0.01) | LC—Least Concern | VU—Vulnerable | NE—Not Evaluated | *—endemic to the Western Ghats | #—Schedule-II species under WPA, 1972.

Species	IndVal%	Associated microhabitat	IUCN Red List status	IUCN population trend	IUCN Habitat type								
					Forest	Savanna	Shrubland	Grassland	Rocky areas	Wetlands	Artificial/ terrestrial	Artificial/ aquatic	Marine
Family: Bufonidae													
Duttaphrynus melanostictus	7.17	Peripheral vegetation	LC	↑se	+		+	+		+	+	+	+
Family: Dicroglossidae													
*Euphlyctis cyanophlyctis**#	43.6	Ephemeral pools	LC	Stable	+					+	+	+	+
Hoplobatrachus tigerinus#	16.4	Exposed rock	LC	Stable	+	+		+		+	+	+	+
*Minervarya cepfi**	38.8	Exposed rock	LC	↓se	+			+	+	+	+		
*Minervarya gomantaki**	44.8	Ephemeral vegetation	LC	↓se	+					+	+	+	+
Minervarya syhadrensis	14.3	Ephemeral vegetation	LC	↓se		+	+			+	+	+	+
Phrynoderma cf. *konkani**	3.6	Ephemeral pools	NE	-						-		-	-
*Sphaerotheca dobsoni**	10.9	Exposed rock	LC	↓se	+		+			+	+	+	+
Family: Microhylidae													
Microhyla ornata	30.3	Ephemeral vegetation	LC	Stable	+	+	+	+		+	+	+	+
*Uperodon mormoratus**	3.39	Peripheral vegetation	LC	↓se	+					+	+	+	+
Family: Ranidae													
Hydrophylax bahuvistara	7.86	Shrubs and bushes	LC	↓se	+					+	+	+	+
Family: Ranixalidae													
*Indirana salelkari**	11	Peripheral vegetation	VU	↓se	+					+	+		
Family: Rhacophoridae													
Polypedates maculatus	13.9	Ephemeral vegetation	LC	Unknown	+		+	+		+	+	+	+
*Pseudophilautus amboli**	37.6	Peripheral vegetation	LC	↓se	+						+		

monsoonal breeding activity (Image 8).

Ephemeral vegetation and peripheral ecotone vegetation showed the highest number of significant indicator species (four each), followed by exposed rocky plains, ephemeral pool, and shrubland patches, with three, two and one, respectively (Image 6). The microhabitats exposed rocky slope, surface runoff channel and soil-filled depression showed no significant correlation with any anuran species. Two species, *Minervarya gomantaki* and *Euphlyctis cyanophlyctis*, achieved maximum IndVal values of 44.8% and 43.6%, respectively, while *Phrynoderma* cf. *konkani* and *Uperodon mormoratus* exhibited the lowest IndVal values of 3.6% and 3.3%, respectively (Table 3).

The Hill number analysis revealed q = 0 values between 7 and 13 across all microhabitats associated with lateritic outcrops (Image 7). The sequence of q0 in decreasing order was observed to be shrubland patches -> ephemeral vegetation -> soil-filled depression -> peripheral ecotone vegetation -> ephemeral pool -> exposed rocky plains -> exposed rocky slopes -> runoff channels.. The q1 value is an indicator of effective species diversity and measures the exponential of Shannon entropy. Here, it was evaluated that q1 was highest in shrubland patches of 8.4, while lowest in the runoff channel and ephemeral pool with q1 of 2.4 for both. The Hill numbers q2 and q3 provide strong evidence regarding dominating species in a microhabitat by minimising the effect of rare species. Microhabitat types with woody plants and vegetation like shrubland

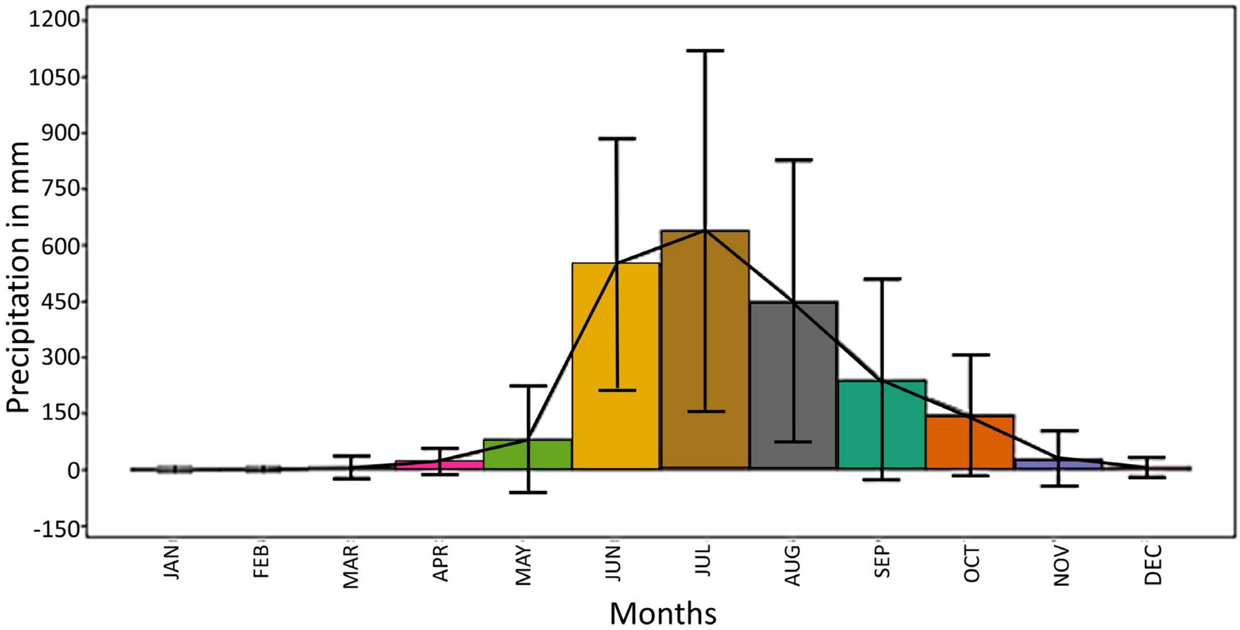

Image 4. Annual precipitation trend for study sites with cumulative average from 1981–2023.

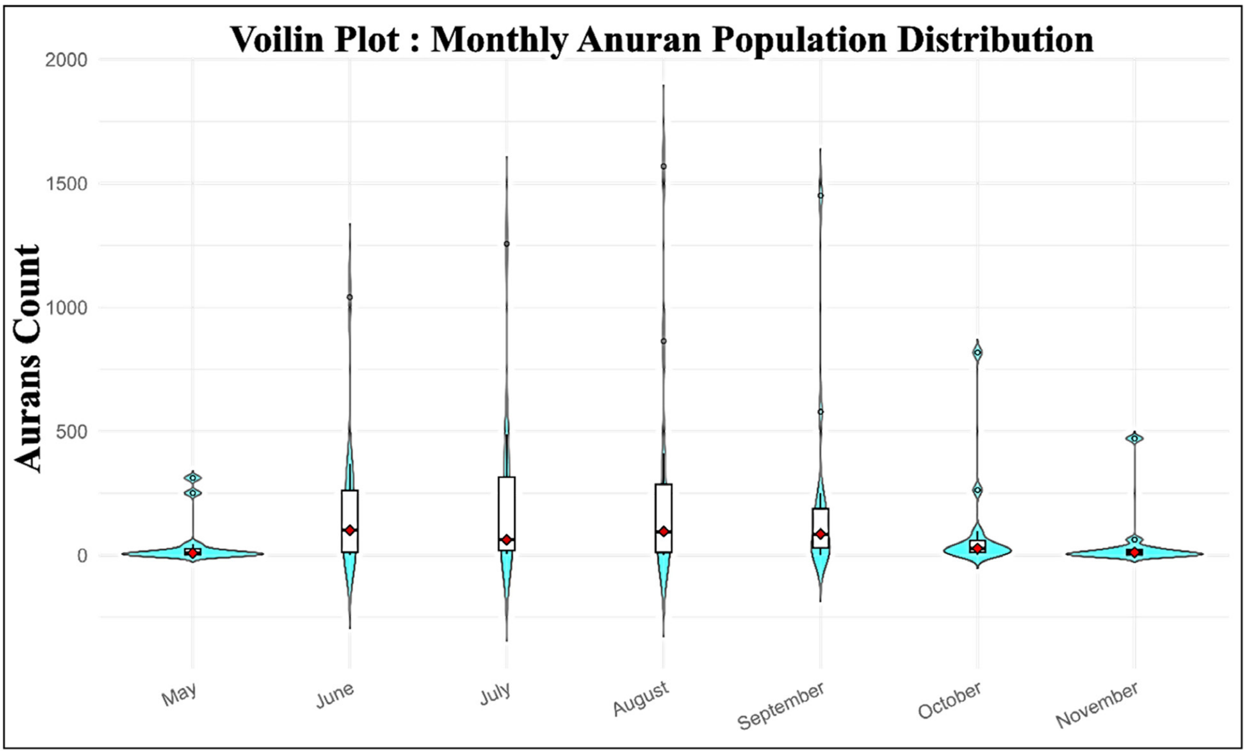

Image 5. Violin plot showing a monthly trend of anuran encounter cumulative of all study sites.

patches demonstrate the highest q2 and q3 of 6.6 and 5.8 measurements, respectively, while aquatic environments on outcrops, the surface runoff channels (q2 1.17; q3 1.12) and ephemeral pools (q2 1.16; q3 1.11) had the lowest measurements.

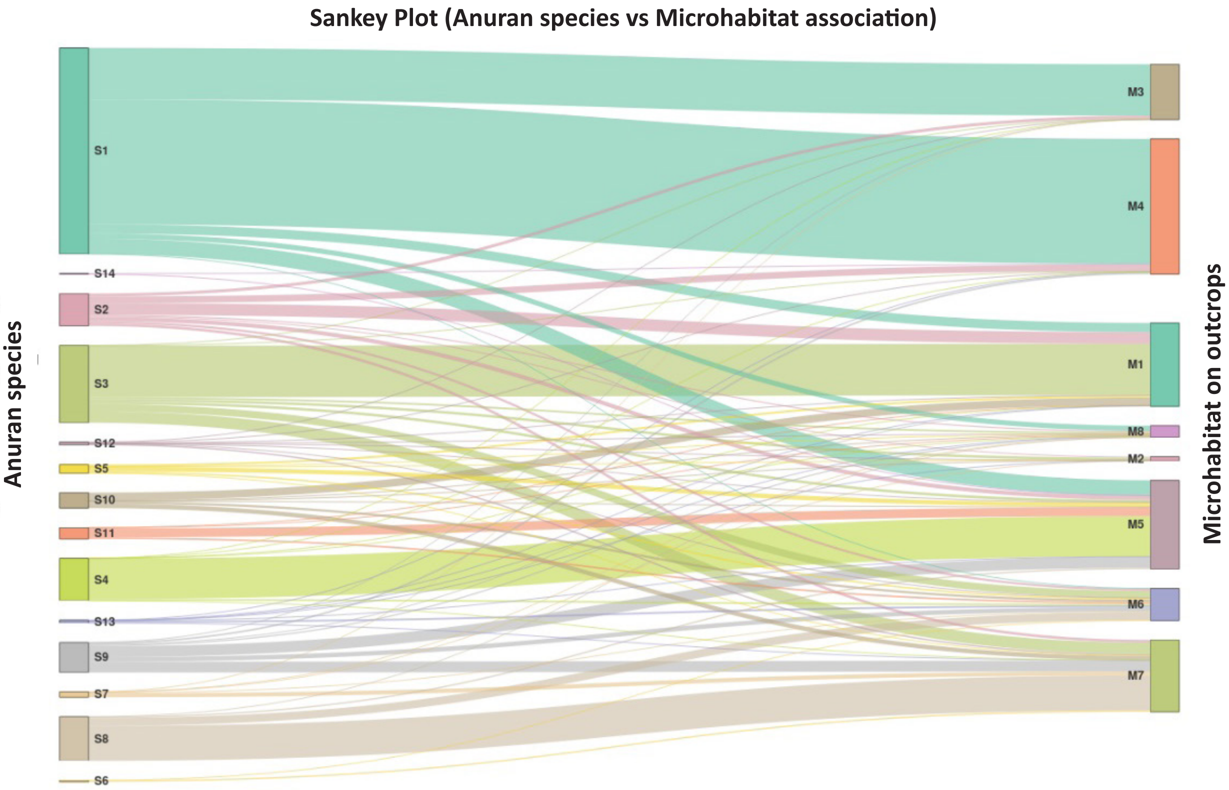

Image 6. Sankey plot visualising association of anuran species with respective microhabitats: S1—*Euphlyctis cyanophlyctis* | S2—*Hoplobatrachus tigerinus* | S3—*Minervarya cepfi* | S4—*Minervarya gomantaki* | S5—*Polypedates maculatus* | S6—*Uperodon mormoratus* | S7—*Indirana salelkari* | S8—*Pseudophilautus amboli* | S9—*Minervarya syhadrensis* | S10—*Sphaerotheca dobsoni* | S11—*Microhyla ornata* | S12—*Duttaphrynus melanostictus* | S13—*Hydrophylax bahuvistara* | S14—*Phrynoderma* cf. *konkani* | M1—Exposed rocky flats | M2—Exposed rocky slope | M3—Seasonal surface channel | M4—Ephemeral pools | M5—Ephemeral vegetation | M6—Shrubland patches | M7—Peripheral ecotone vegetation | M8—Soil-filled depression.

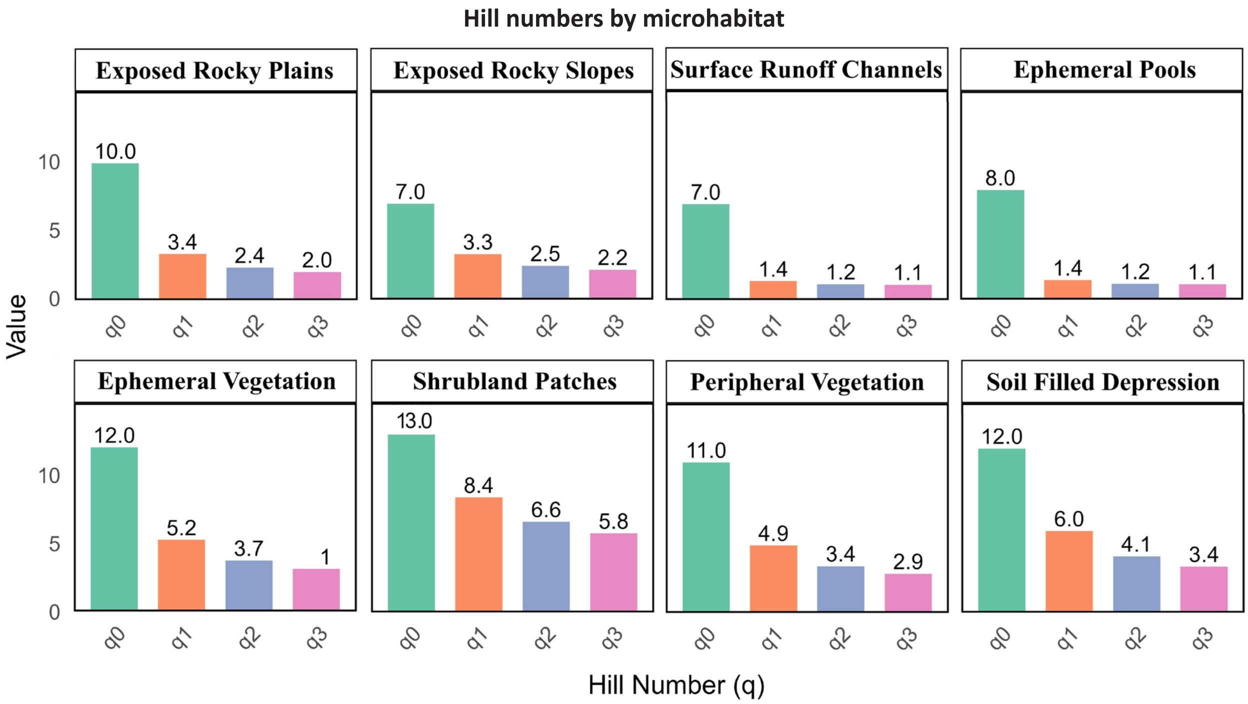

Image 7. Alpha diversity; Hill numbers (q_0–q_3) for eight microhabitats on Goa lateritic outcrops.

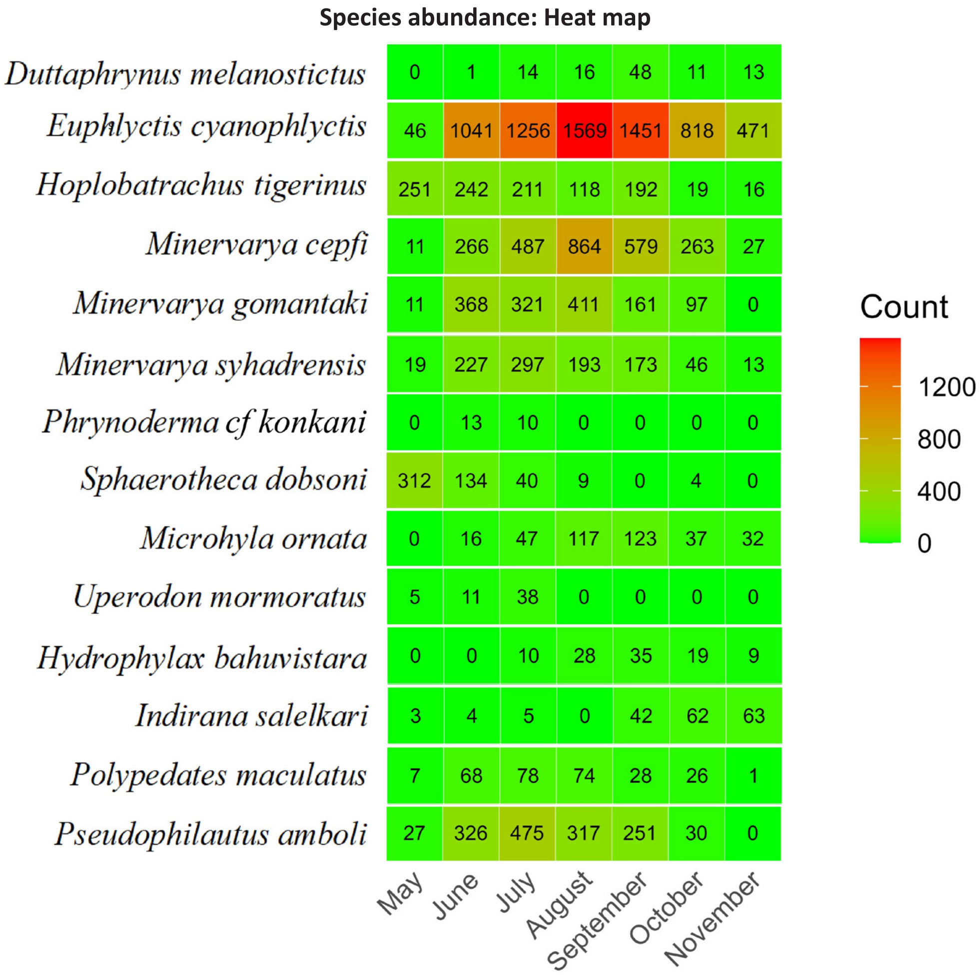

Image 8. Heatmap showing anuran species distribution across wet months on the plateau (May–November).

DISCUSSION

Previous anuran ecological studies have largely treated outcrop landscapes as a single unit (Jithin et al. 2025), while the present study examines here the microhabitat level studies on lateritic rocky outcrops in Goa. The study of these suggests that a few amphibian species are strongly associated with specific microhabitats (Thorpe et al. 2018; Mudke et al. 2020). The two aquatic anuran species *Euphlyctis cyanophlyctis* and *Phrynoderma* cf. *konkani* were observed to have a strong association with ephemeral pools (Mudke et al. 2020). *Euphlyctis cyanophlyctis* was previously been reported to shift from permanent water sources to rain fed shallow waterholes such as roadside ditches, paddy field and vernal water for breeding, which signifies their strong association with Ephemeral pools on the outcrop (Chowdhury et al. 2021). *Phrynoderma* cf. *konkani* also show similar habitat preference with more restriction to low lying wetlands and plateaus in coastal regions while this species was observed only from Socorro plateau in present study (Yadav et al. 2024). The small streams formed due to surface runoff cut through the outcrops and make channel towards periphery of outcrop in direction of slope and dries up faster while the ephemeral pools retain water for longer period (Porembski et al. 2016; Kulkarni et al. 2022). The observation in the field shows anurans such as *Minervarya cepfi* and *Euphlyctis cyanophlyctis* and *Hoplobatrachus tigerinus* optionally use this microhabitat to reduce competition. Due to lack of predators such as fishes, the shallow ephemeral pool is most preferred habitat for anurans tadpoles (Jithin & Naniwadekar 2025). The aquatic vegetation in this ephemeral pool gradually covers entire pools which provides shelter for anuran tadpoles (Kulkarni et al. 2022).

The ephemeral vegetation covers the short-length endemic herbaceous plants including grasses (Sreejith et al. 2016). It was found that this habitat was dominatingly used by *Minervarya gomantaki, Minervarya syhadrensis* and *Microhyla ornata*. The dense mesh of herbaceous plants in ephemeral vegetation also provide protection from predators for amphibians (Burrow & Maerz 2022). In the present study, it was observed that males of these species croak while hiding in the carpet of ephemeral vegetation. *Polypedates maculatus*, even though is of arboreal nature, was reported to breed and lay foam nests in ephemeral vegetation near ephemeral pools (Mudke et al. 2020). The rocky exposed laterites are periodically separated by shrubland patches composed of small bushes along with few woody plants are important microhabitat which act as a refuge to avoid the harsh temperature of day time for most of the anurans (Lekhak & Yadav 2012; Burrow & Maerz 2022). *Sphaerotheca dobsoni* and *Duttaphrynus melanostictus*, the ground-dwelling terrestrial anurans, were found foraging mostly on ground foliage in shrubland patches on the outcrops (Mudke et al. 2020).

The peripheral ecotone vegetation also serves as an important refuge for multiple anurans, while *Pseudophilautus amboli* and *Duttaphrynus melanostictus* was found to be the most dominant anuran species in this microhabitat. *Indirana* due to their primitive semi-terrestrial breeding strategy is strongly associated with forest and forest edges (Gaitonde & Giri 2014; Komanduri et al. 2023). Similar findings were reported in this study for *Indirana salelkari* which was strictly found in the peripheral ecotone vegetation. Studies show that *Uperodon mormoratus* is an early monsoon aquatic breeder that prefers forest habitat over the outcrops (Katwate & Apte 2019), which is consistent with our study, as this species was only reported from peripheral ecotone vegetation.

The exposed rocky plains during heavy precipitation temporarily submerge with surface flooding while merging with ephemeral pools, water channels and ephemeral vegetation (Thorpe et al. 2018). This microhabitat is strongly associated with *Minervarya cepfi* where males show mass accumulation during the peak monsoon at night while they take refugia under loose rocks and shrubland patches during daytime (Garg & Biju 2017). The exposed slope showed the least association with any anurans during the present study likely due to rapid drainage, reduced water retention and higher exposure to thermal stress compared to other microhabitats. However, the small crevices on the exposed rocky plains and slopes were used by males of *Hoplobatrachus tigerinus* and *Sphaerotheca dobsonii* to reduce predation risk during the peak activity period (Mudke et al. 2020; Komanduri et al. 2023).

Effect of Hydroperiod

Based on the hydroperiod on lateritic outcrops, two distinct seasonal patterns can be identified: the dry season from December to mid-May and the wet season from May to November (Jithin et al. 2025). Amphibians show periodic migration between their breeding habitat and refuge habitat (Snodgrass et al. 2000). Most amphibians show an explosive breeding strategy during the wet season on plateau outcrops, while during the dry season they either undergo aestivation or their population shifts to lowlands where water is available to return with the onset of monsoon (Burrow & Maerz 2022). Different species have evolved in response to changing hydroperiod often categorised as early explosive breeders, prolonged breeders and late seasonal breeders. Explosive breeders mate for a short duration when conditions are favourable, whereas prolonged breeders reproduce over an extended season (Soni et al. 2025). Though most anurans synchronise themselves with the precipitation trend across the wet period, from the present study we observed that anurans use these three selective strategies to breed while occupying different microhabitats on the outcrop. *Euphlyctis cyanophlyctis*, *Minervarya cepfi*, *Minervarya gomantaki*, *Polypedates maculatus*, *Pseudophilautus amboli*, and *Microhyla ornata* shows prolonged breeding activity with peak population in July to August when precipitation is high. *Hoplobatrachus tigerinus* and *Sphaerotheca dobsoni* appear on plateaus during pre-monsoon (May–July) showers and show early explosive breeding. *Indirana salelkari* is found to be active during late-monsoon (September–November) preferring late seasonal breeding strategy. This differential use of time by anurans acts as an important factor for temporal niche differentiation on the outcrops to maximise best utilisation of resources (Borzée et al. 2016).

Anthropogenic stress on outcrops

The present study scope is only restricted to naturally occurring microhabitats while the majority of these microhabitats are constantly altered due to anthropogenic activities. Mining, laterite stone quarrying and infrastructure development on outcrops at both domestic and commercial scale remains the biggest threat to loss of microhabitats (Thorpe & Watve 2015; Porembski et al. 2016; Jithin et al. 2025). The ephemeral pools on outcrops are altered with cemented water tank for cattle drinking and domestic use. Ephemeral vegetation like *Senecio belgaumensis*, *Utricularia* spp. and *Eriocaulon* spp. are mass exploited for ornamental and religious purposes (Ghate et al. 2023). The high demand for residential land with boom of tourism along with unplanned urbanisation in the state of Goa has forced to convert these lateritic rocky outcrops into urbanisation hubs (Sutheeshna 2021). Few lateritic outcrops of Goa due to their complex land ownership status are still retained with minimal disturbance while peripheral slopes of these outcrops are intensely exploited for cashew plantation and commercial residential projects (Nigam et al. 2024).

Conservation Status of Anurans and Outcrops

Based on the IUCN Red Data list, nine of the anuran species reported form the present study have declining population trend (Table 3). According to the IUCN habitat type, the lateritic outcrops are designated as rocky areas. While only *Minervarya cepfi* documented from the present study has been assigned to this habitat type. Other studies, along with our observation reports *Minervarya cepfi* having a strong association with exposed rocky plain microhabitats on the outcrops (Thorpe et al. 2018; Mudke et al. 2020).

Amphibians are declining worldwide, while loss of their habitat remains one of the prime contributing factors for this loss (Alford & Richards 1999; Catenazzi 2015; Luedtke et al. 2023). These habitats are declining due to their rapid land use, land cover change for human needs (Alford & Richards 1999; Catenazzi 2015; Nakazawa 2015). Outcrops can parallelly act as an alternate breeding ground for these anurans. According to the Town and Planning Survey of Goa, the status of these lateritic outcrops is of mixed nomenclature, classified mostly as wasteland, barren land, pasture land, while outcrops which show partial succession were termed as shrubland, grasslands, orchards, grazing grounds, and open natural cover. There is an urgent need for revision of this classification for the conservation of these outcrops.

REFERENCES

Alford, R.A. & S.J. Richards (1999). Global amphibian declines: a problem in applied ecology. Annual Review of Ecology and Systematics 30: 133–165. https://doi.org/10.1146/annurev.ecolsys.30.1.133

Biju, S.D. et al. (2008). Diversity and conservation status of the Western Ghats amphibians, pp. 80–82. In: Stuart, S.N. et al. (eds.). Threatened Amphibians of the World. Lynx Edicions, Barcelona.

Borzée, A. et al. (2016). Temporal and spatial differentiation in microhabitat use: implications for reproductive isolation and ecological niche specification. Integrative Zoology 11(5): 375–387. https://doi.org/10.1111/1749-4877.12200

Burrow, A. & J. Maerz (2022). How plants affect amphibian populations. Biological Reviews 97(5): 1749–1767. https://doi.org/10.1111/brv.12861

Catenazzi, A. (2015). State of the world's amphibians. Annual Review of Environment and Resources 40(1): 91–119. https://doi.org/10.1146/annurev-environ-102014-021358

Chowdhury, M.A.W. et al. (2021). Temporary water holes may benefit the breeding of the common skipper frog *Euphlyctis cyanophlyctis* (Anura: Dicroglossidae). Ecologies 2(1): 138–149. https://doi.org/10.3390/ecologies2010007

Crump, M.L. & N.J. Scott Jr. (1994). Visual encounter surveys, pp. 84–92. In: Heyer, W.R. et al. (eds.). Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonian Institution Press, Washington, DC.

Datar, M.N. & A.V. Watve (2018). Vascular plant assemblage of cliffs in northern Western Ghats, India. Journal of Threatened Taxa 10(2): 11271–11284. https://doi.org/10.11609/jott.3611.10.2.11271-11284

Dinesh, K.P. et al. (2024). Checklist of Fauna of India: Animalia: Chordata: Amphibia. Version 1.0. Zoological Survey of India. https://doi.org/10.26515/Fauna/1/2023/Chordata:Amphibia

Dinesh, K.P. et al. (2015). Systematic status of *Fejervarya* (Amphibia, Anura, Dicroglossidae) from South and SE Asia with the description of a new species from the Western Ghats of Peninsular India. Zootaxa 3999(1): 79–94. https://doi.org/10.11646/zootaxa.3999.1.5

Dufresnes, C. et al. (2022). Shedding light on taxonomic chaos: Diversity and distribution of South Asian skipper frogs (Anura, Dicroglossidae, *Euphlyctis*). Systematics and Biodiversity 20(1): 2102686. https://doi.org/10.1080/14772000.2022.2102686

Frost, D.R. (2024). Amphibian Species of the World: An Online Reference. Version 6.2 (accessed on 20.v.2025). American Museum of Natural History, New York, USA. Electronic database. https://amphibiansoftheworld.amnh.org/index.php. https://doi.org/10.5531/db.vz.0001

Gaitonde, N. & V. Giri (2014). Primitive breeding in an ancient Indian frog genus *Indirana*. Current Science 107(1): 109–112.

Garg, S. & S.D. Biju (2016). Molecular and morphological study of leaping frogs (Anura, Ranixalidae) with description of two new species. PLOS ONE 11(11): e0166326. https://doi.org/10.1371/journal.pone.0166326

Garg, S. & S.D. Biju (2017). Description of four new species of burrowing frogs in the *Fejervarya rufescens* complex (Dicroglossidae) with notes on morphological affinities of *Fejervarya* species in the Western Ghats. Zootaxa 4277(4): 451–490. https://doi.org/10.11646/zootaxa.4277.4.1

Garg, S. & S.D. Biju (2021). DNA barcoding and systematic review of minervaryan frogs (Dicroglossidae: *Minervarya*) of Peninsular India: resolution of a taxonomic conundrum with description of a new species. Asian Herpetological Research 12(4): 345–370. https://doi.org/10.16373/j.cnki.ahr.210023

Garg, S. et al. (2019). Systematic revision of *Microhyla* (Microhylidae) frogs of South Asia: a molecular, morphological, and acoustic assessment. Vertebrate Zoology 69(1): 1–71. https://doi.org/10.26049/VZ69-1-2019-01

Gawas, M. et al. (In press). Community structure and environmental determinants of amphibians in the Western Ghats watersheds of eastern Goa, India. Journal of Threatened Taxa.

Ghate, P. et al. (2023). Matvi: an eco-cultural tradition of wildflower decoration from Rajapur Tehsil, Ratnagiri District, Maharashtra, India. Journal of Ecological Society 34(1): 1–11. https://doi.org/10.54081/JES.028/03

Gururaja, K.V. (2012). Pictorial guide to frogs and toads of the Western Ghats. Gubbi Labs LLP, Gubbi, Karnataka, India, xviii + 154 pp.

Gururaja, K.V. & P. Hebbar (2016). A new species of *Euphlyctis* (Amphibia, Anura, Dicroglossidae) from the west coastal plains of India. Asian Herpetological Research 7(4): 229–241. https://doi.org/10.16373/j.cnki.ahr.160020

IUCN SSC Amphibian Specialist Group (2023). *Pseudophilautus amboli*. The IUCN Red List of Threatened Species 2023: e.T58910A3074893. https://doi.org/10.2305/IUCN.UK.2023-1.RLTS.T58910A3074893.en. Accessed on 24.viii.2026.

IUCN SSC Amphibian Specialist Group (2023). *Minervarya cepfi*. The IUCN Red List of Threatened Species 2023:

e.T121370255A121370272. https://doi.org/10.2305/IUCN.UK.2023-1.RLTS.T121370255A121370272.en. Accessed on 24.viii.2026.

Jithin, V. & R. Naniwadekar (2025). Effects of abiotic and biotic factors on tadpole occurrence and abundance in seasonal rock pools of rock outcrops, northern Western Ghats. Aquatic Ecology 59(2): 797–803. https://doi.org/10.1007/s10452-025-10195-w

Jithin, V. et al. (2023). Between a rock and a hard place: Comparing rock-dwelling animal prevalence across abandoned paddy, orchards, and rock outcrops in a biodiversity hotspot. Global Ecology and Conservation 46: e02582. https://doi.org/10.1016/j.gecco.2023.e02582

Jithin, V. et al. (2025). Orchards and paddy differentially impact rock outcrop amphibians: Insights from community- and species-level responses. Ecological Applications 35(1): e3058. https://doi.org/10.1002/eap.3058

Katwate, U. & D. Apte (2019). Amphibian diversity in two different landscapes of Konkan Region, northern Western Ghats, India. Journal of the Bombay Natural History Society 116: 9–21. https://doi.org/10.17087/jbnhs/2019/v116/115359

Komanduri, K.P.K. et al. (2023). Abundance and composition of forest-dwelling anurans in cashew plantations in a tropical semi-evergreen forest landscape. Biotropica 55(3): 594–604. https://doi.org/10.1111/btp.13210

Kulkarni, A. et al. (2022). Vanishing waters: water chemistry of temporary rock pools of the Western Ghats, India. Water Practice and Technology 17(1): 234–245. https://doi.org/10.2166/wpt.2021.107

Lekhak, M.M. & S.R. Yadav (2012). Herbaceous vegetation of threatened high altitude lateritic plateau ecosystems of Western Ghats, southwestern Maharashtra, India. Rheedea 22(1): 39–61. https://doi.org/10.22244/rheedea.2012.22.01.12

Luedtke, J.A. et al. (2023). Ongoing declines for the world's amphibians in the face of emerging threats. Nature 622(7982): 308–314. https://doi.org/10.1038/s41586-023-06578-4

Modak, N. et al. (2015). Indirana salelkari, a new species of leaping frog (Anura: Ranixalidae) from Western Ghats of Goa, India. Journal of Threatened Taxa 7(9): 7493–7509. https://doi.org/10.11609/jott.2175.7493-7509

Mudke, M. et al. (2020). Annotated list of anurans from the lateritic plateau of western India with notes on malformations. Check List 16(3): 685–698. https://doi.org/10.15560/16.3.685

Nakazawa, T. (2015). Ontogenetic niche shifts matter in community ecology: a review and future perspectives. Population Ecology 57(2): 347–354. https://doi.org/10.1007/s10144-014-0448-z

Nigam, R. et al. (2024). Evaluation of efficiency of the index of potential anthropic geomorphology at meso level: a case study of Goa State, India. The Geographical Journal 190(1): e12540. https://doi.org/10.1111/geoj.12540

Padhye, A.D. et al. (2015). *Hydrophylax bahuvistara*, a new species of fungoid frog (Amphibia: Ranidae) from peninsular India. Journal of Threatened Taxa 7(11): 7744–7760. https://doi.org/10.11609/jott.2318.7744-7760

Padhye, A. et al. (2017). *Sphaerotheca pashchima*, a new species of burrowing frog (Anura: Dicroglossidae) from western India. Journal of Threatened Taxa 9(6): 10286–10296. https://doi.org/10.11609/jott.2877.9.6.10286-10296

Porembski, S., et al. (2016). Worldwide destruction of inselbergs and related rock outcrops threatens a unique ecosystem. Biodiversity and Conservation 25(13): 2827–2830. https://doi.org/10.1007/s10531-016-1171-1

Rahangdale, S.S. & S.R. Rahangdale (2014). Plant species composition on two rock outcrops from the northern Western Ghats, Maharashtra, India. Journal of Threatened Taxa 6(4): 5593–5612. https://doi.org/10.11609/JoTT.o3616.5593-612

R Core Team (2024). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/

Rodda, G.H. et al. (2005). The predictive power of visual searching. Herpetological Review 36(3): 259–264.

Sanchez, E. et al. (2018). Phylogeny and classification of fejervaryan frogs (Anura: Dicroglossidae). Salamandra 54(2): 109–116.

Snodgrass, J.W. et al. (2000). Relationships among isolated wetland size, hydroperiod, and amphibian species richness: implications for wetland regulations. Conservation Biology 14(2): 414–419. https://doi.org/10.1046/j.1523-1739.2000.99161.x

Soni, S.P. et al. (2025). Barking up the wrong frog: global prevalence of misdirected amplexus in anuran amphibians. Biological Journal of the Linnean Society 145(1): blae062. https://doi.org/10.1093/biolinnean/blae062

Sreejith, K.A. et al. (2016). Microhabitat diversity in a lateritic hillock of northern Kerala, India. Vegetos 29(3): 100. https://doi.org/10.5958/2229-4473.2016.00074.4

Sutheeshna, B.S. (2021). Tourism, Urbanization and Spatial Reorganization: Some Reflections on Tourism Development in Goa, India, pp. 219–242. In: Jaglan, M.S. & Rajeshwari (eds.) Reflections on 21st Century Human Habitats in India: Felicitation Volume in Honour of Professor M.H. Qureshi. Springer Nature Singapore Pte Ltd., Singapore. https://doi.org/10.1007/978-981-16-3100-9_9

Thorpe, C.J. & A. Watve (2015). Lateritic Plateaus in the northern Western Ghats, India; a review of bauxite mining restoration practices. Journal of Ecological Society 28(1): 25–44. https://doi.org/10.54081/JES.024/03

Thorpe, et al. (2018). Micro-habitat distribution drives patch quality for sub-tropical rocky plateau amphibians in the northern Western Ghats, India. PLOS ONE 13(3): e0194810. https://doi.org/10.1371/journal.pone.0194810

Watve, A. (2013). Status review of rocky plateaus in the northern Western Ghats and Konkan region of Maharashtra, India with recommendations for conservation and management. Journal of Threatened Taxa 5(5): 3935–3962. https://doi.org/10.11609/JoTT.o3372.3935-62

Widdowson, M. (2009). Evolution of laterite in Goa, pp. 35–68. In: Mascarenhas, A. & G. Kalavampara (eds.) Natural Resources of Goa: A Geological Perspective. Geological Society of Goa, Miramar, Goa, India.

Widdowson, M. & K.G. Cox (1996). Uplift and erosional history of the Deccan Traps, India: evidence from laterites and drainage patterns of the Western Ghats and Konkan Coast. Earth and Planetary Science Letters 137(1–4): 57–69. https://doi.org/10.1016/0012-821X(95)00211-T

Yadav, O. et al. (2024). A new species of pond frog *Phrynoderma* (Anura: Dicroglossidae) from the coastal plains of Maharashtra, Western India. Journal of Asia-Pacific Biodiversity 17(4): 601–610. https://doi.org/10.1016/j.japb.2024.03.008

Journal of Threatened Taxa is indexed/abstracted in Bibliography of Systematic Mycology, Biological Abstracts, BIOSIS Previews, CAB Abstracts, EBSCO, Google Scholar, Index Copernicus, Index Fungorum, JournalSeek, National Academy of Agricultural Sciences, NewJour, OCLC WorldCat, SCOPUS, Stanford University Libraries, Virtual Library of Biology, Zoological Records.

NAAS rating (India) 5.64

Print copies of the Journal are available at cost. Write to:
The Managing Editor, JoTT,
c/o Wildlife Information Liaison Development Society,
3A2 Varadarajulu Nagar, FCI Road, Ganapathy, Coimbatore,
Tamil Nadu 641006, India
ravi@threatenedtaxa.org & ravi@zooreach.org

www.threatenedtaxa.org

OPEN ACCESS

ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

August 2026 | Vol. 18 | No. 8 | Pages: 29375–29558
Date of Publication: 26 August 2026 (Online & Print)
DOI: 10.11609/jott.2026.18.8.29375-29558

Articles

Communications

Review

Short Communications

Notes

Publisher & Host

Zoo Outreach Organisation

Threatened Taxa