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



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

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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 संबंद समजून घेवप हो हया अभ्यासाचो उद्देश आशिल्लो. निदर्शक प्रजाती मूल्य (IndVal) आनी हिल संख्या विश्लेषण वापरून सूक्ष्म अधिवासांशी आशिल्लो संबंद आनी ऋतुमानानुसार दिसपी कल हांचे विश्लेषण केले. निष्कर्षावरून 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 प्रजातींचे वितरण आनी विपुलता हांचेर लक्षणीय परिणाम जाता. निष्कर्षावरून बेबकांचो अधिवास आनी ऋतुमान हांचेकडेन घट्ट संबंद आसा, हें दिसून येता. गोंयच्या हया वैशिष्ट्यपूर्ण परिसंस्थे खातीर संवर्धन धोरणां तयार करपाक हो अभ्यास उपेगी थारता.

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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.

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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

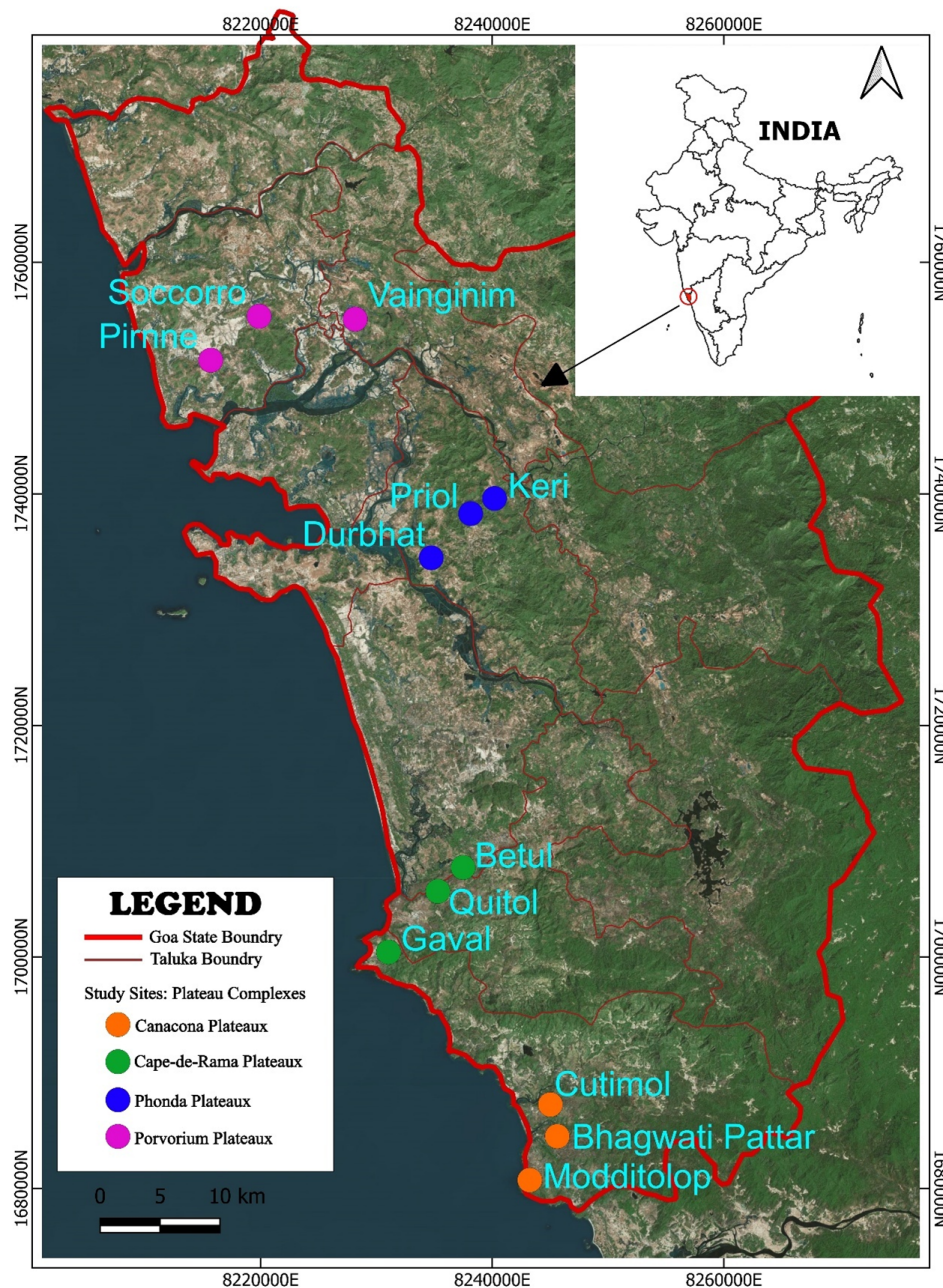


Image 1. Map of Goa with study sites within the colour-coded plateaux marked.

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 q_0 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 marmoratus* | 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													
<i>Duttaphrynus melanostictus</i>	7.17	Peripheral vegetation	LC	↑se	+		+	+		+	+	+	+
Family: Dicroglossidae													
<i>Euphlyctis cyanophlyctis</i> *#	43.6	Ephemeral pools	LC	Stable	+					+	+	+	+
<i>Hoplobatrachus tigerinus</i> #	16.4	Exposed rock	LC	Stable	+	+		+		+	+	+	+
<i>Minervarya cepfi</i> *	38.8	Exposed rock	LC	↓se	+			+	+	+	+		
<i>Minervarya gomantaki</i> *	44.8	Ephemeral vegetation	LC	↓se	+					+	+	+	+
<i>Minervarya syhadrensis</i>	14.3	Ephemeral vegetation	LC	↓se		+	+			+	+	+	+
<i>Phrynoderma cf. konkani</i> *	3.6	Ephemeral pools	NE	-						-		-	-
<i>Sphaerotheca dobsoni</i> *	10.9	Exposed rock	LC	↓se	+		+			+	+	+	+
Family: Microhylidae													
<i>Microhyla ornata</i>	30.3	Ephemeral vegetation	LC	Stable	+	+	+	+		+	+	+	+
<i>Uperodon marmoratus</i> *	3.39	Peripheral vegetation	LC	↓se	+					+	+	+	+
Family: Ranidae													
<i>Hydrophylax bahuvistara</i>	7.86	Shrubs and bushes	LC	↓se	+					+	+	+	+
Family: Ranixalidae													
<i>Indirana salelkari</i> *	11	Peripheral vegetation	VU	↓se	+					+	+		
Family: Rhacophoridae													
<i>Polypedates maculatus</i>	13.9	Ephemeral vegetation	LC	Unknown	+		+	+		+	+	+	+
<i>Pseudophilautus amboli</i> *	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 marmoratus* 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 q_0 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 q_1 value is an indicator of effective species diversity and measures the exponential of Shannon entropy. Here, it was evaluated that q_1 was highest in shrubland patches of 8.4, while lowest in the runoff channel and ephemeral pool with q_1 of 2.4 for both. The Hill numbers q_2 and q_3 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

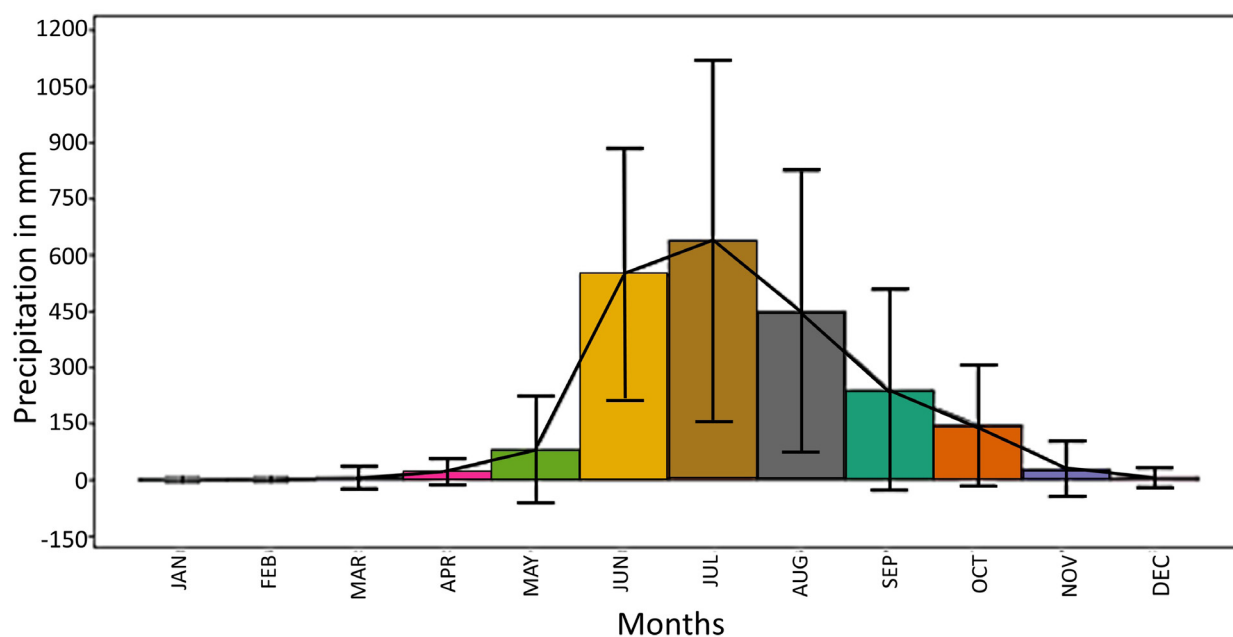


Image 4. Annual precipitation trend for study sites with cumulative average from 1981–2023.

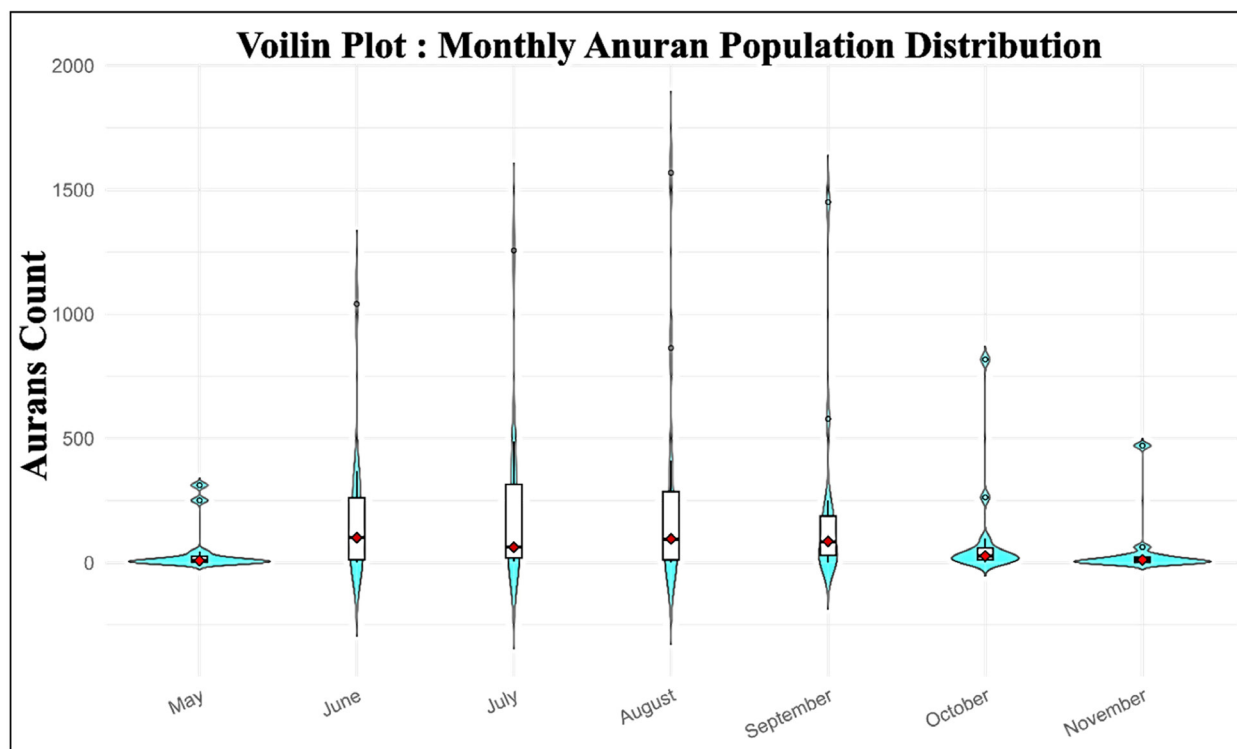


Image 5. Violin plot showing a monthly trend of anuran encounter cumulative of all study sites.

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.

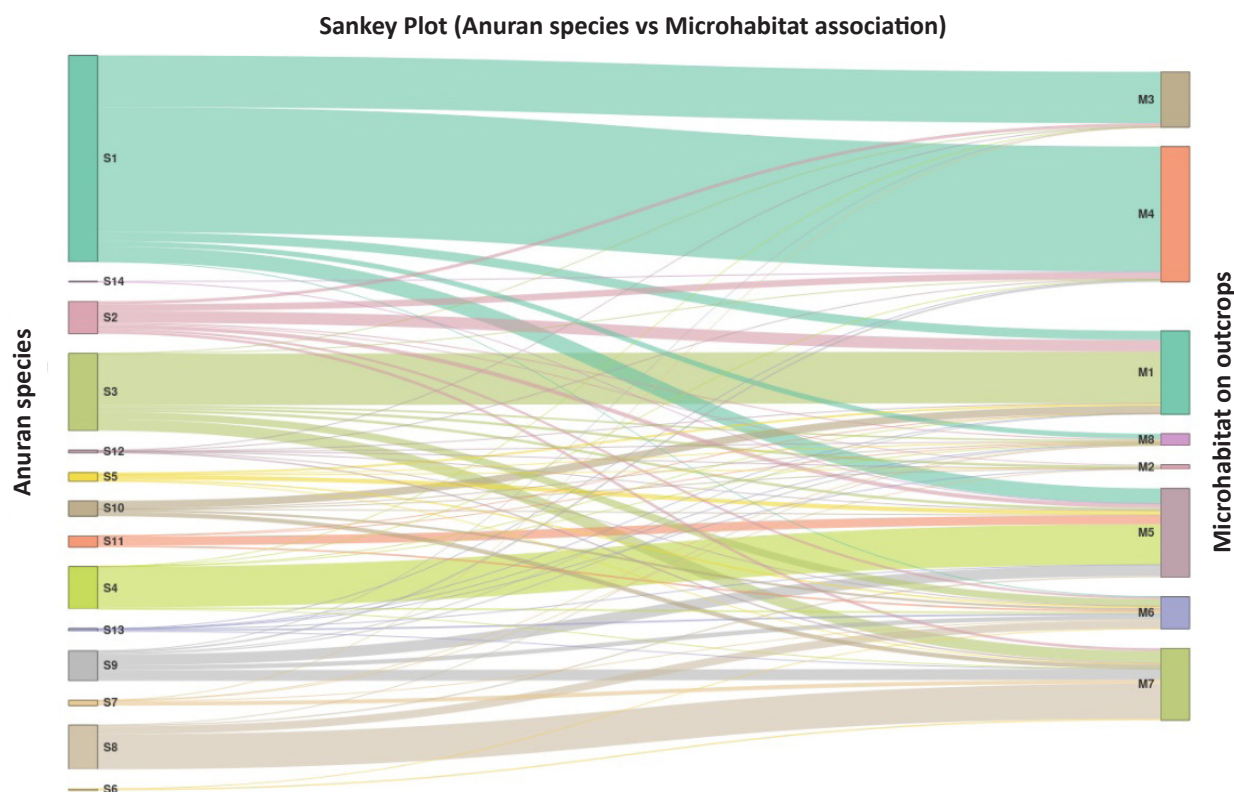


Image 6. Sankey plot visualising association of anuran species with respective microhabitats: S1—*Euphlyctis cyanophlyctis* | S2—*Hoplobatrachus tigerinus* | S3—*Minervarya cepfi* | S4—*Minervarya gomantaki* | S5—*Polypedates maculatus* | S6—*Uperodon mormoratus* | S7—*Indirana salelkari* | S8—*Pseudophilautus 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.

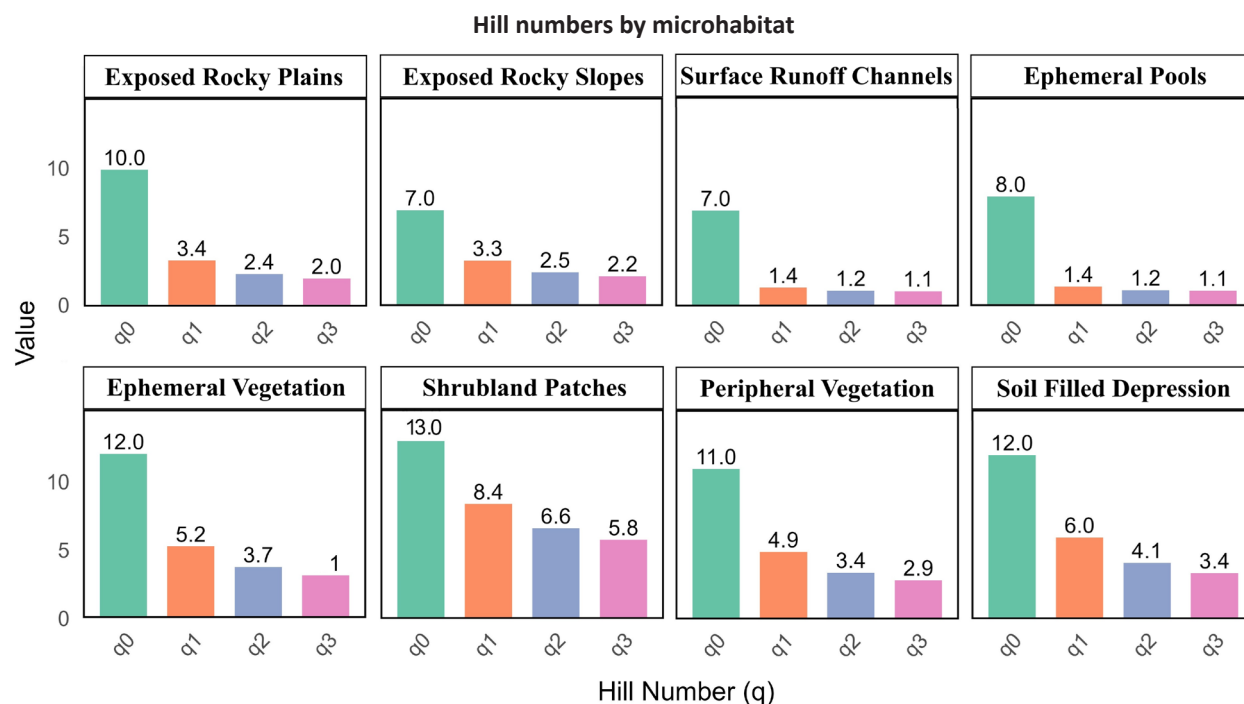


Image 7. Alpha diversity; Hill numbers (q_0 – q_3) for eight microhabitats on Goa lateritic outcrops.

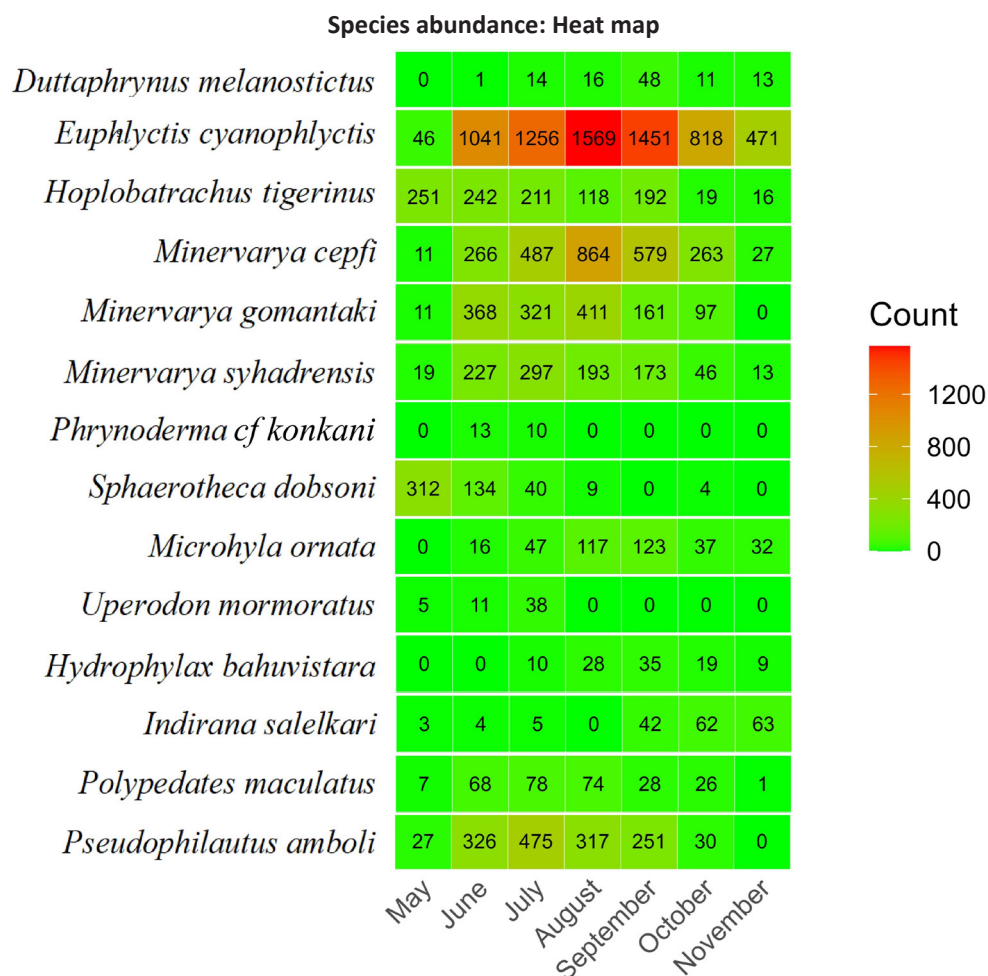


Image 8. Heatmap showing anuran species distribution across wet months on the plateau (May–November).

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 *Phrynodermis 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). *Phrynodermis 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 dominantly 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 from 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.

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