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Faunal Assemblages and Ecological Attributes of the Ushanar Cave, Bandora, Goa, India

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ABSTRACT

Cave ecosystems, characterized by isolation and extreme environmental conditions, offer refuge to highly specialized fauna exhibiting distinct morphological and behavioral adaptations. Despite their ecological importance, Speleofaunal diversity in India remains inadequately documented. This study presents a preliminary assessment of the faunal assemblage of Ushanar Cave at Bandora village, in Ponda; a densely forested Taluka of Goa. A total of 12 faunal species were recorded through direct observations, with indirect evidences indicating the use of this cave by porcupine and leopard. Further examination of the bat guano deposits on the cave floor revealed lepidopteran wings, elytra of jewel beetle and bird skeletal remains; suggesting trophic inputs into the subterranean system from outside. Installation of snares at the cave entrance suggests anthropogenic disturbance and potential hunting activity. These findings contribute baseline data on the cave's biodiversity and highlight the need for further systematic and conservation-oriented investigations.

Keywords Speleofauna, Crepuscular, Cave ecology, Cavernicoles, Sub-troglophile.

INTRODUCTION

Caves are isolated subterranean ecosystems characterized by perpetual darkness, limited and irregular nutrient input, high humidity, and relatively stable microclimatic conditions (Biswas 2014, Mammola 2020). These extreme environmental conditions have led to the evolution of specialized biological communities known as speleofauna, which exhibit distinct morphological, physiological and behavioural adaptations such as depigmentation, eye reduction, and elongation of sensory appendages (Vandel 1965, Barr 1968, Gunn 2004, Culver and Pipan 2009, Romero 2009, Elliott 2016). At the same time, reduced predation pressure and steady microclimatic regimes facilitate the persistence of specialized faunal assemblages, particularly where organic inputs such as bat guano and detritus sustain subterranean trophic networks (Biswas and Shrotriya 2011). Due

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to their ecological isolation and environmental stability, cave ecosystems often harbor high levels of endemism and relict species, making them important natural systems for studying evolutionary processes, biogeography, and ecological adaptation (Gibert and Deharveng 2002).

Subterranean habitats are typically structured into entrance, twilight, and deep (aphotic) zones, based on light penetration and environmental gradients (Biswas 2009, Manenti *et al.* 2015, Sail *et al.* 2021). This zonation provides a functional framework for examining species distribution patterns, ecological interactions, and habitat specialization (Moldovan *et al.* 2018). Caves are increasingly recognized as natural laboratories for studying evolutionary processes such as adaptation, convergence, and speciation (Culver and Pipan 2019). Recent advances in molecular ecology and biodiversity assessments further highlight subterranean ecosystems as reservoirs of endemic and evolutionarily distinct taxa that are highly vulnerable to anthropogenic disturbance (Mammola 2019, 2020, Mammola *et al*. 2022).

Globally, speleofaunal explorations have contributed significantly to the discovery of hidden biodiversity, and has highlighted the vulnerability of subterranean ecosystems to anthropogenic disturbances; including groundwater contamination, mining, and tourism (Culver and Pipan 2014). In India, although extensive karst landscapes occur in regions such as Meghalaya, Chhattisgarh, and parts of the Western Ghats; systematic biospeleological investigations remain relatively limited. Available studies have nevertheless revealed diverse subterranean fauna, particularly arthropods and other invertebrates, many of which are endemic and poorly documented (Biswas 2009, Biswas *et al.* 2024). These findings underscore the importance of continued cave exploration and taxonomic research to better understand and conserve India's subterranean biodiversity. In Goa, systematic documentation of cave fauna is notably scarce (Sail *et al.* 2021). Addressing this gap, the present study provides a preliminary assessment of the speleofaunal diversity of Ushanar Cave, generating baseline ecological data and contributing to a broader understanding of subterranean biodiversity in the region.

MATERIALS AND METHODS

Study site

The present study was conducted in Ushanar Cave, a lateritic cave situated at 15°24′07″N, 73°57′56″E at an elevation of 61.92 m above mean sea level, on a forested hill slope in Bandora village, Ponda Taluka,

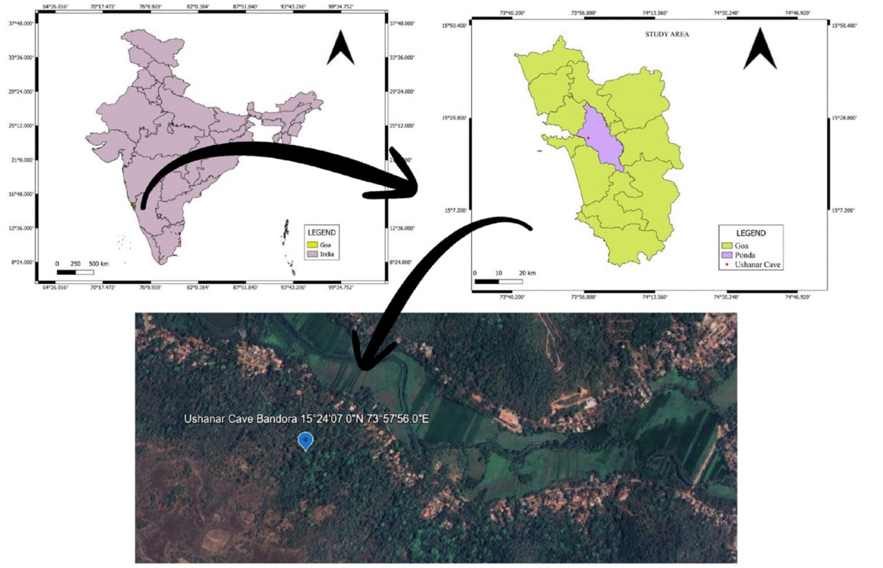

Fig 1. The location of the investigated cave in the Indian state of Goa.

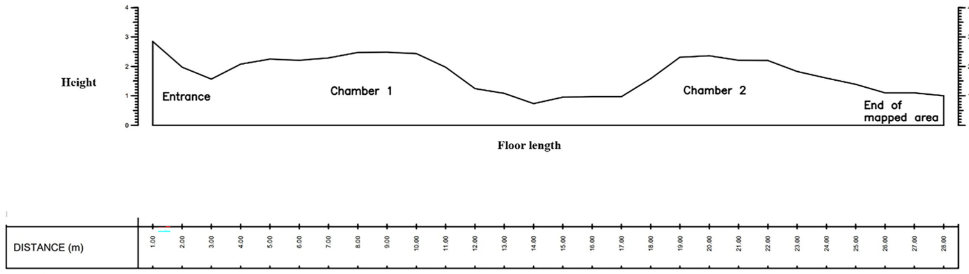

Fig. 2. Speleometric data of the Ushanar Cave, in Bandora village of Ponda Goa. After the Entrance Zone, Chamber 1 is 'Twilight Zone' and Chamber 2 is the 'Dark zone' of the cave.

Goa (Fig 1). The cave is a small, naturally formed subterranean system with an accessible floor length of approximately 28 m. The roof height ranges from 0.95 m to 2.85 m, while the floor width varies between 1.22 m and 8.82 m (Fig. 2).

Based on light penetration, the accessible portion of the cave receiving substantial natural light is the entrance zone, which further leads into two distinct chambers. The first chamber comprises the 'twilight zone', with only very faint light penetrating from the entrance. A narrow passage connects this to the pitch dark second chamber, conforming to the 'dark zone', that further extends into a narrow, water-filled passage that was inaccessible during the study, indicating the possible continuation of additional subterranean sections. Both accessible chambers were systematically surveyed to document direct sightings and indirect evidence of faunal presence (Fig. 3 & 4).

Methodology

Preliminary observations revealed that Ushanar Cave remains inundated during the monsoon season, with water flowing outward through the entrance, rendering it inaccessible. Accordingly, surveys were undertaken post-monsoon, after water levels had receded. Two exploratory surveys were conducted: the first in

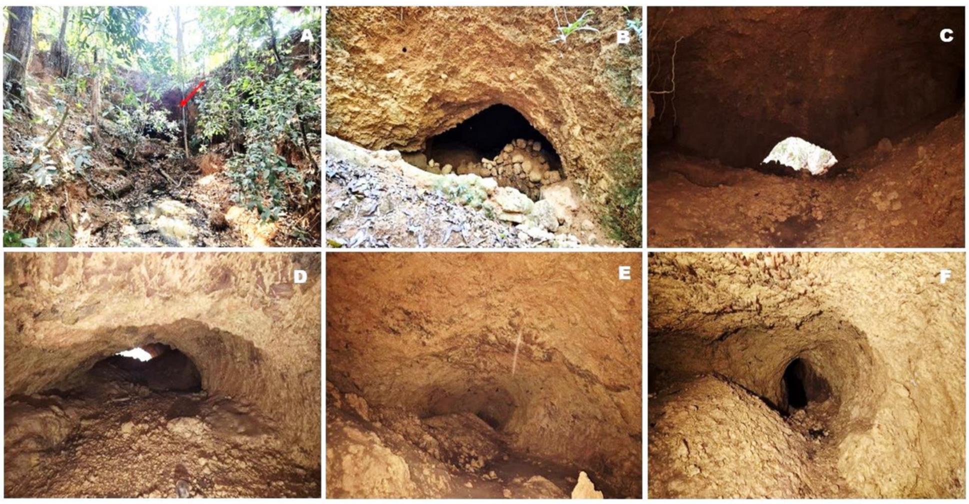

Fig 3. The Ushanar cave is located amidst dense vegetation in a hilly terrain, and can be accessed after a steep climb and descent to a low-lying lateritic cliff **(A).** The cave entrance **(B)** is wide but short in height opening into the small entrance zone, which further leads into the first chamber or twilight zone **(C).** There is a very narrow passage **(D)** between the first and second chamber, the ceiling is very low at the boundary between these two. The second chamber **(E)** is the dark zone that further continues into a narrow, water-filled constricted inaccessible passage **(F).**

August 2024 and the second in September 2025, both during evening hours (16:30–18:30 h).

Speleometric measurements; including accessible floor length, roof height, and floor width, were recorded. A scaled layout of the cave was subsequently prepared using AutoCAD software (Fig 2). Environmental parameters, including ambient temperature and relative humidity, were measured using a digital hygrometer–thermometer (HTC Model 103-CTH), sound intensity was recorded using a Fluke Sound Level Meter (Model 945), Light intensity was recorded with Fluke Light Meter (Model 941). These measurements were taken to characterize the cave microclimate during the survey period.

Faunal assessment was conducted through systematic visual surveys across accessible chambers. Observations were categorized as direct evidence (live sightings) and indirect evidence (tracks, scats, carcasses, remains, and other biological traces). All records were supported by photographic documentation.

RESULTS AND DISCUSSION

The present study provides a first account of the faunal assemblage and micro environmental conditions of Ushanar Cave, highlighting its ecological significance as a small, yet functionally dynamic subterranean ecosystem. Although limited in spatial extent, the cave supports a diverse assemblage of invertebrates and vertebrates, indicating that even relatively small lateritic caves can serve as important refugia for troglofauna.

Microclimate and habitat structuring

Microclimatic parameters were recorded at three locations along the cave gradient: the entrance, first chamber (Twilight Zone), and second chamber (Dark Zone). At the entrance, temperature measured 29.8°C, relative humidity was 87%, and mean sound intensity was 55 dB. In the first chamber, temperature slightly decreased to 29.5°C, humidity increased to 91%, and sound intensity averaged 53 dB. The second chamber recorded a temperature of 30.5°C, relative humidity of 82%, and mean sound intensity of 55 dB. Light intensity progressively diminished from the entrance towards the inner chamber, changing from 630 lux at the entrance, 18 lux in the first chamber to 0 lux in the second chamber.

Subtle variations in temperature, humidity, sound and light intensity were observed across the cave gradient. While the differences were not extreme, the progressive decline in light penetration and variation in relative humidity likely influence species distribution patterns within the cave. Microclimatic stability, particularly temperature, humidity and light are known to influence activity, distribution and aggregation structure of subterranean organisms (Mazebedi and Hesselberg 2020). The higher humidity recorded in the first chamber may explain the concentration of amphibians and certain arthropods in this zone, whereas the darker second chamber provided suitable roosting conditions for bats. Such zonation reinforces the role of environmental gradients in structuring cave communities (Biswas 1992, Pacheco *et al.* 2020).

Faunal composition and ecological interactions

Observations were categorized as direct (visual sightings of organisms *in situ*) and indirect (biological traces and remains). Specimen collection was not undertaken; however, bats encountered during the survey were temporarily handled for identification and photographic documentation.

Direct observations

A total of 12 species were recorded through direct visual surveys, comprising six invertebrates and six vertebrates.

Invertebrates

Invertebrate communities are quintessential players in energy dynamics of cave ecosystem (Mazebedi and Hesselberg 2020). The invertebrate assemblage recorded in Ushanar Cave represents a combination of detritivores, predators, and transient taxa. Six arthropod species were documented, representing the classes Insecta (1), Diplopoda (1), Arachnida (3), and Malacostraca (1). A single moth belonging to the family Geometridae was recorded from the first

Fig 4. Faunal assemblage of the Ushanar cave:- Direct evidences: **a)** Moth (Family Geometridae), **b)** Millipede (*Phyllogonostreptus nigrolabiatus*), **c)** Spider-1 (unidentified), **d)** Spider-2 (unidentified), **e)** Whip spider (*Phrynichus phipsoni*), **f)** Freshwater crab (*Ghatiana* sp.), **g)** Fungoid frog (*Hydrophylax bahuvistara*), **h)** Frog (*Indirana salelkari*), **i)** Frog *Minervarya gomantaki*, **j)** Bat (*Hipposideros lankadiva*), **k)** Bat (*Rhinolophus lepidus*), **l)** Bat (*Pipistrellus ceylonicus*); Indirect evidences: Leopard (*Panthera Pardus*), **m)** Pug imprint, **n)** Scat, **o)** Lepidopteran wings, **p)** Jewel beetle in Bat guano, **q)** Spider egg sac (unidentified), **r)** Bird feathers and bones, **s)** Moult (*Phrynichus phipsoni*), Porcupine (*Hystrix indica*)- **t)** Quill, **u)** Scat, **v)** Pugmark, **w)** Burrow, **x)** Coconut shell, **y)** Snare

chamber (Fig 4. a). The millipede *Phyllogonostreptus nigrolabiatus*, a detritivore, was observed in the first chamber, indicating the availability of decomposing organic matter, likely derived from surface inputs and bat guano (Fig 4. b). Millipedes (Diplopoda) are important detritivores in subterranean ecosystems and are frequently encountered in cave habitats due to their preference for humid, stable microclimatic conditions and availability of organic detritus. Several millipede taxa have been reported from subterranean and cave-associated habitats worldwide, particularly within orders such as Polydesmida and Spirostreptida, many of which show adaptations to low-light and high-humidity environments (Culver and Pipan 2009, Romero 2009, Abdar 2022). In India however, studies focusing specifically on cave-dwelling millipedes remain limited, with most records emerging from broader cave biodiversity surveys conducted in karst regions such as the limestone caves of Meghalaya and the Kanger Valley cave systems of Chhattisgarh (Biswas 2009, Biswas and Shrotriya 2011). These studies indicate the presence of diplopods associated with guano deposits and detrital substrates within caves, suggesting that subterranean habitats may serve as important refugia for moisture-dependent millipede species. Nevertheless, systematic exploration and taxonomic documentation of cave millipedes in India remain sparse, highlighting the need for further biospeleological investigations.

Two unidentified spider species were recorded from the cave (Fig 4. c, d). Additionally, a live individual and a moult of the whip spider *Phrynichus phipsoni* were observed across both chambers, suggesting continued occupancy (Fig 4. e, s). Previous observations from Divar Cave, Goa (Sail *et al.* 2021) report strong site fidelity in this species, with nocturnal dispersal from daytime refuges within crevices. The presence of *Phrynichus phipsoni* across both chambers suggests that the cave offers suitable microhabitats for ambush predators dependent on crevice systems and stable humidity. A freshwater crab belonging to the genus *Ghatiana* was recorded exclusively from the first chamber (Fig 4. f). Its occurrence may be associated with recent flooding prior to the survey, potentially enabling its temporary presence within the cave habitat.

Vertebrates

Vertebrate observations further highlight the ecological complexity of the cave. Three frog species were recorded from the cave. A Fungoid frog, *Hydrophylax bahuvistara* was documented from both chambers, whereas *Indirana salelkari* and *Minervarya gomantaki* were observed only in the first chamber (Fig 4. g, h, i). The distribution of frogs within the cave likely reflects microhabitat gradients and species-specific ecological preferences. After the small entrance zone, the first chamber typically corresponds to the 'twilight zone', where partial light penetration, greater airflow, and higher organic input create environmental conditions similar to the surrounding forest habitat (Culver and Pipan 2009). Species such as *Indirana salelkari* and *Minervarya gomantaki* are generally associated with moist forest floors, leaf litter, and stream margins in the Western Ghats, and may therefore use cave entrances opportunistically as temporary refuges (Biju *et al.* 2014, Garg and Biju 2021). In contrast, the presence of *Hydrophylax bahuvistara* in both chambers may be related to its semi-aquatic ecology and tolerance for persistently humid environments, especially where water seepage, drip pools, or damp substrates occur within caves. Such moist microhabitats often support abundant invertebrate prey, enabling some amphibians to extend their activity deeper into cave interiors (Romero 2009, Culver and Pipan 2009). These observations suggest that caves may function as microrefugia for amphibians, particularly in humid tropical landscapes such as the Western Ghats.

The study documented three bat species- *Hipposideros lankadiva, Rhinolophus lepidus*, and *Pipistrellus ceylonicus;* with an estimated polyspecific roosting group of about 110 individuals in the cave's second chamber or 'dark zone' (Fig 4. j, k, l). Bat colonies play a key role in nutrient flux within cave ecosystems by transporting organic matter from external environments through guano, urine, and carcasses. These nutrient inputs enrich cave sediments with nitrogen and phosphorus and support diverse microbial and invertebrate communities, often forming the basis of guano-driven food webs in otherwise energy-limited subterranean habitats (Culver and Pipan 2009, Romero 2009, Deharveng and Bedos 2012). Consequently, bat roosts can significantly enhance trophic complexity and biodiversity within cave ecosystems. Since cave ecosystems naturally lack primary productivity, the organic matter in bat guano serves as a vital nutrient source that supports the existence of cave fauna whose life cycles rely on these guano-derived nutrients (Fenolio *et al.* 2006, Deharveng and Bedos 2012, Elliott 2016). The presence and roosting habits of bats in caves of the Western Ghats, Divar cave, and other caves of Goa have been previously reported by Korad *et al.* (2007), Sail *et al.* (2021) and Borkar and Sail (2024) respectively.

Use of cave by non-obligate fauna (Indirect observations)

Evidence suggested that a Leopard (*Panthera par-*

dus) had temporarily taken shelter in the cave, as indicated by the presence of scat and pugmarks in both the chambers (Fig 4. m, n). Additionally, bird remains were observed in the second chamber (Fig 4. r), possibly brought in by the leopard. The presence of Porcupine (*Hystrix indica*) was determined by evidences such as quill, scat, imprints, burrows and gnawed coconut shells found in both the chambers of the cave (Fig 4, t, u, v, w, x). Porcupine use of caves as shelter has been reported previously from Dandak Cave, Chhattisgarh (Biswas and Shrotriya 2011). In cave ecology studies, porcupines are often regarded as occasional cave users (trogloxenes), meaning they use caves for shelter but forage outside.

Terrestrial mammals, though not obligate cave dwellers, frequently utilize caves for refuge and feeding; their excreta contribute additional nutrient inputs that support invertebrate communities and higher trophic interactions (Mane and Manchi 2018). Caves often function as important refuges for large carnivores, providing shelter, protection from climatic extremes, and secure sites for resting, breeding, and rearing young. Many carnivores including bears, hyenas, lions, leopards, and other large predators have historically used caves and rock shelters as dens or temporary resting sites. Such use has been well documented in both modern ecological studies and paleontological records, where cave deposits frequently preserve bones and other remains of large carnivores and their prey, indicating repeated occupation or denning behavior (Brain 1981, Stiner *et al.*1996). The stable microclimatic conditions and physical protection offered by caves make them particularly suitable for species that require secluded spaces for cub rearing or seasonal hibernation.

Evidence of porcupine and leopard activity indicates periodic use of the cave as shelter by terrestrial mammals. While these species are not obligate cave dwellers, their presence contributes additional organic inputs through scat, prey remains, and other biological materials. Such episodic usage may enhance nutrient heterogeneity and influence faunal dynamics. The observation of an avian carcass further suggests predator-mediated transport of surface biomass into the subterranean environment, reinforcing the cave's ecological connectivity with surrounding landscapes.

In addition to their ecological role as shelters, caves also serve as important archives of carnivore activity, preserving fossil assemblages that provide insights into past predator–prey interactions, paleoecology, and species distribution patterns (Diedrich 2013). In several regions, including parts of Asia and Europe, cave sites have yielded evidence of long-term use by large carnivores such as cave bears (*Ursus spelaeus*), hyenas (*Crocuta crocuta spelaea*), and modern large felids (Stiner *et al*. 1996, Diedrich 2013). Consequently, the study of caves is crucial not only for understanding subterranean biodiversity but also for documenting the ecological history and habitat use of large carnivores.

The dark zone had presence of numerous lepidopteran wings (Fig 4. o) and elytra of Jewel beetle (Fig 4. p), likely introduced through predation events. Similar accumulations of insect remain have been reported from other Indian caves, suggesting predator-mediated transport of surface fauna into subterranean systems (Misal and Kalawate 2023). An unidentified spider egg sac was also observed in the second chamber (Fig 4. q). Accumulations of insect wings and other 'prey remains' are commonly reported in cave environments and are often associated with predatory arthropods, bats, or other cave-dwelling predators that transport prey to sheltered microhabitats for consumption (Culver and Pipan 2009, Romero 2009). Thus, Ushanar Cave appears to function as a detritus-driven ecosystem with bats acting as keystone contributors to energy flow.

Anthropogenic implications

During the initial survey, three wire snares were observed at the entrance of the cave, suggesting the use of the cave for hunting purposes by (Fig 4. y). Similar observations of hunting around cave entrances and rock shelters have been reported from several tropical cave systems, due to the regular movement of wildlife seeking shelter or roosting space (Biswas 2009, Romero 2009). Anthropogenic disturbances may influence cave fauna by directly reducing vertebrate populations and indirectly affecting cave food webs, particularly in systems where organisms such as bats or other vertebrates contribute significantly to nutrient inputs and ecosystem functioning. In studies conducted by Kharkongor *et al.* (2024) in the Siju Caves of Meghalaya, a significant decline in faunal diversity was observed compared to findings from 1922. The likely causes include increased human disturbances such as tourism, hunting pressure, changes in agricultural practices and expanding human settlements in the surrounding areas.

Subterranean ecosystems are particularly vulnerable due to their ecological sensitivity and limited resilience to external perturbations. Hunting, habitat alteration, and increased human access can disrupt faunal assemblages, particularly bat colonies that play a foundational ecological role. The findings therefore emphasize the need for monitoring and conservation-oriented management to safeguard the cave's biodiversity. Though their ecological importance is well established, cave ecosystems remain underestimated and inadequately protected on a global scale (Ficetola *et al.* 2019).

Ecological significance and future directions

Although the study was limited to two post-monsoon surveys and non-invasive observational methods, the documentation of 12 directly observed species, along with multiple indirect evidences, demonstrates that Ushanar Cave supports a moderately diverse and functionally structured faunal community. Given seasonal flooding and possible additional inaccessible chambers, the recorded diversity likely represents only a portion of the cave's total biodiversity.

Long-term monitoring across seasons, systematic sampling of guano-associated invertebrates, and molecular identification approaches would provide deeper insights into species composition, endemism, and ecological specialization. As lateritic caves of Goa remain understudied, Ushanar Cave offers valuable baseline data and underscores the broader importance of integrating speleobiological surveys into regional biodiversity assessments.

CONCLUSION

This pilot study offers an initial account of speleofaunal diversity in Ushanar Cave, Goa, documenting 12 directly observed species alongside indirect evidence of larger vertebrates. Despite its limited extent and seasonal inundation, the cave supports a structured assemblage of invertebrates, amphibians, bats, and transient mammals. Microclimatic variation appears to shape species distribution, while bat colonies play a central role by supplying guano that underpins the detritus-based food web. Evidence of porcupine and leopard use highlights ecological connectivity with the surrounding forest, though the presence of wire snares signals emerging anthropogenic threats.

Given the short survey period, the recorded diversity likely underrepresents the cave's true biodiversity. Long-term, seasonally replicated studies with systematic sampling are needed to clarify species composition, ecological interactions, and conservation priorities. As a fragile and understudied subterranean system, Ushanar Cave warrants focused protection. Regulating access, curbing hunting, and raising local awareness are immediate priorities, alongside continued biodiversity and microclimatic monitoring. Integrating the cave into regional conservation frameworks will be critical for preserving its ecological role and maintaining landscape-level connectivity in the Western Ghats.

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