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Diversity of Amphibians in India, a review

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Abstract

India has a large amphibian population and is one of the 17 most biodiverse countries in the world. As delicate bioindicators, amphibians are vital to maintaining ecological harmony in their dual roles as predators and prey. With a focus on endemic species and biodiversity hotspots, this review paper provides an overview of frogs in India, including their richness, distribution, and conservation status. The ecological systems in India rely heavily on amphibians. Much is still unknown, despite the fact that diversity documentation has come a long way. Preserving India's amphibian heritage requires vigilant habitat protection and regular revisions to scientific evaluations.

Keywords*:* amphibian population, bio indicators, ecological harmony, biodiversity hotspots

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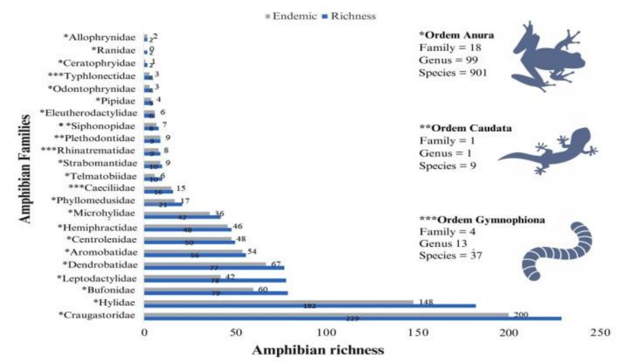
Introduction

The first terrestrial vertebrates were the amphibian class, which descended from lobe-finned fish approximately 365 million years ago during the Devonian Period (carol,2009).But during the Carboniferous Period, when air-breathing terrestrial insects were simultaneously evolving (nel, 2019),It provided amphibians with prey, allowing them to fully take over the ground (Lane, 1945; Stanley, 2009). Even yet, a portion of their life cycle stays in the water, which helped them adapt to both aquatic and terrestrial environments. As a result, these group of animals was given the name Amphibia, which is derived from the Greek words amphi = both and bios = life.The group of cold-blooded creatures known as amphibians includes salamanders, frogs, toads, caecilians, and newts.They are classified into three living taxonomic orders based on phylogeny: order Anura, which includes frogs and toads; order Gymnophiona, which includes caecilians; and order Caudata, which includes newts and salamanders.Salamanders typically live in meadows, tiny bodies of water, forest leaf litter, or damp ground beneath rocks, whereas caecilians are mostly aquatic, semi-aquatic, or fossorial (Gower and Wilkinson, 2005; Hegde and Deuti, 2007). However, because they live in aquatic and semi-aquatic environments, marshes, terrestrials, forest leaf litter, burrows, bushes, and trees some of which are really arboreal in nature auroran species are the most cosmopolitan in terms of their distribution and habitats. According to Zhou *et al*. (2008) and Simon *et al*. (2011), amphibians are regarded as "ecological indicators" since they are the first to be impacted by changes in the air, water, and land environments.

Global Diversity: There are 8,617 amphibian species worldwide, which can be divided into 75 families and three orders (Frost, 2023).With 7,586 species, the order Anura (frogs) has more than 88% of these species, compared to 810 species in the order Caudata (salamanders) and 221 species in the order Gymnophiona (caecilians).

https://blog.pensoft.net/2020/05/25/a-new-critically-endangered-frog-named-after-the-man-from-the-floodplain-full-of-frogs/

Diversity in India: Over 90% of India's amphibian fauna is Anura, which has 411 species and dominates the country's amphibian variety. This order has remarkable ecological breadth by flourishing in a wide variety of environments, ranging from deep rainforests to urban settings, from high-altitude alpine meadows to desert scrublands. The group's taxonomic complexity and the undiscovered cryptic diversity within genera like Raorchestes, Micrixalus, and Nyctibatrachus are demonstrated by the quick speed of new species discovery, which has increased by more than 150% since 2009.Tylototriton verrucosus and T. himalayanus are the only two salamander species known to exist in India (Dinesh *et al*., 2024). They are both members of the Salamandridae family. These montane salamanders live in the foothills of the Himalayas in chilly, high-elevation environments. They have gotten a lot of conservation attention, including legal protection and captive breeding initiatives, despite having a small worldwide distribution. With India at the easternmost point of their global range, their rarity highlights the distinctive patterns of salamander distribution.With forty-one species, the order Gymnophiona is the second most diverse amphibian order in India. These elusive and little-known burrowing caecilians are mostly found in the biodiversity hotspots of the Indo-Burma and Western Ghats. Usually only seen during monsoon seasons, they inhabit ecological niches in leaf litter, wet soils, and under rocks. They are of disproportionate evolutionary importance even though they only make up around 9% of India's anuran species. Important Gondwanan legacy maintained underground are highlighted by the finding of a whole new caecilian family (Chikilidae) in northeastern India. Dia is home to about 5.3% of the world's amphibian variety (454 out of 8,617 recognized species), however many species are poorly understood either identified decades ago without a contemporary taxonomic revision, or solely from their original sites. According to genetic research, India's amphibians exhibit cryptic diversity, suggesting that the true species richness may be much greater. Furthermore, 32% of Indian amphibians have not yet been evaluated by the IUCN, and 22% of them are still categorized as Data Deficient, making it more difficult to determine conservation priorities (Vijay Ramesh *et al*, 2020).



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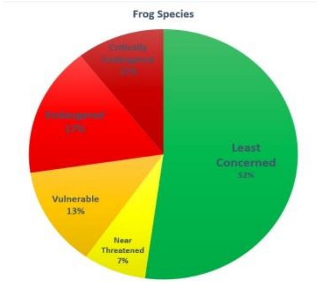
Diversity in States: Adult anurans are remarkably ecologically versatile, inhabiting aquatic, terrestrial, sub-terrestrial, and arboreal habitats, but tadpole stages are primarily aquatic. Nevertheless, bush frogs (genus Raorchestes, family Rhacophoridae) deviate from this pattern by means of direct development, whereby embryos develop fully inside the egg and hatch as tiny adults (froglets), avoiding the stage of free swimming tadpoles (Elinson & del Pino, 2012; Fang *et al*., 2021). Bush frogs do not require an aquatic larval phase thanks to their reproductive technique, which allows them to flourish in terrestrial and arboreal settings (Yang & Li, 1978;

Madhava Meegaskumbura *et al*., 2015). The life cycle of salamanders (order Caudata) is more typical among amphibians. According to Elinson and del Pino (2012), their eggs develop into gill-bearing, free-swimming larvae (tadpoles), which then transform into terrestrial or semi-aquatic adults. It is noteworthy that a large number of salamander species demonstrate parental care. To protect developing embryos until they hatch, females or males frequently coil around their egg clutches, which are placed beneath logs, in streamside nests, or within terrestrial burrows (Biology Educare, 2023; Notes on Zoology, 2018). The reproductive tactics of the limbless Gymnophiona (caecilians) vary, yet they all show parental investment. Many oviparous species' females coil around their eggs to protect them after laying them on damp soil or close to water (Kouete *et al*., 2023; Wilkinson *et al*., 2013). In certain species that undergo direct development, hatchlings become miniature adults and participate in maternal skin-feeding, a type of caregiving in which the mother stays coiled around the larvae while the larvae consume lipid-rich skin secretions (Wilkinson *et al*., 2013; Kouete *et al*., 2023). According to Kouete *et al*. (2023) and Notes on Zoology (2018), certain Ethiopian caecilians are also viviparous, meaning that their larvae develop inside and are born as fully grown juveniles.



https://gonefroggin.com/2018/03/19/world-frog-day/

Ecological Significance: Amphibians are particularly sensitive to changes in their environment since they breathe in part via their skin. Because of this, ecologists can better understand how ecosystems function and use them as a trustworthy indicator of pollution, climate change, and environmental toxicity (Olson and Saenz, 2013). They also play an important role in controlling the insect population through predation (Bowatte *et al*., 2013; Khatiwada *et al*., 2016). Amphibians serve as prey for higher trophic levels in an ecosystem (Poulin *et al*., 2001).Amphibians are excellent bioindicators because they are extremely sensitive to changes in their environment because they breathe in part through their skin (Cunningham *et al*., 2013; Olson & Saenz, 2013). In addition to facilitating gas exchange, their permeable integument makes it easy for chemical contaminants to enter. Both skin and larval gills absorb synthetic chemicals, such as pesticides, herbicides, heavy metals, and road deicers, which build up in tissues and cause decreased survival, decreased body mass, and a sharp rise in developmental abnormalities (Belluardo *et al*., 2021; Orton *et al*., 2010; Olson & Saenz, 2013). They are susceptible to disruptions in both domains due to their dual life cycle, which starts in water as larvae and ends with a terrestrial or semi-terrestrial adult stage (Cunningham *et al*., 2013). It has been demonstrated that sub-lethal stresses including exposure to contaminants affect immunity, disrupt hormone signaling, decrease metabolism, and change skin microbiomes, making people more vulnerable to infections like Batrachochytrium dendrobatidis (Fisher *et al*., 2009). Their dual life cycle, which begins in water as larvae and culminates in a terrestrial or semi-terrestrial adult form, makes them vulnerable to disturbances in both domains (Cunningham *et al*., 2013). Sub-lethal stressors, such as exposure to pollutants, have been shown to alter skin microbiomes, impair immunity, interfere with hormone signaling, and lower metabolism, leaving people more susceptible to infections like Batrachochytrium dendrobatidis (Fisher *et al*., 2009). Additionally, higher trophic levels depend on amphibians for their prey biomass. While terrestrial adults eat insects to help maintain the balance of invertebrate groups, aquatic tadpoles eat algae to help with nitrogen cycling and water quality. Fish, birds, reptiles, and mammals are among the predators that rely on amphibians for their diet. Ecosystems may become unstable as a result of subsequent losses in predator populations or the expansion of pest insects brought on by cascading trophic effects caused by declines in amphibian abundance (Wilkinson *et al*., 2018; Paine, 1966).

Human Significance: A reliable environmental indicator for biomonitoring ecosystems is amphibians (Zhou *et al*., 2008; Simon *et al*., 2011). Insect vectors are decreased and people are protected from a range of vector-borne diseases by amphibians, which act as a natural insect controller. According to Bowatte *et al*. (2013) and Khatiwada *et al*. (2016), they also assist the ecology by deterring crop pest populations. The frog, which is considered a culinary delight in many parts of the country and the world, can help with food security if it is bred and raised under controlled conditions outside of the environment (Saikia and Sinha, 2022). Not to mention, they might supply pharmaceuticals that promote medical research (Saikia and Sinha, 2022).

Protected species as Per WPA (2022): Prior to the WPA's 2022 modification, three dicroglossid frogs Euphlyctis hexadactylus, Hoplobatrachus crassus, and Hoplobatrachus tigerinus were granted limited protection under the Schedule-IV category of the WPA (1972). 37 amphibian species are currently protected under Schedule I and Schedule II, albeit, due to the most recent revision to the WPA (2022). The Purple Frog (Nasikabatrachus spp.) and rare salamanders like Tylototriton verrucosus and T. himalayanus are among the critically endangered species that are best protected by Schedule I (Dinesh *et al*., 2024). Schedule II includes dicroglossid frogs such as the Malabar tree toad (Pedostibes tuberculosus), Euphlyctis cyanophlyctis, and H. tigerinus (Indian bullfrog), which are deemed to be at reduced risk but still require conservation measures (Dinesh *et al*., 2024). This is a historic expansion of legal protections to previously disregarded amphibians, many of which remain underregulated under the old WPA framework despite playing important ecological functions. A firmer statutory foundation for amphibian protection in India is provided by the amended Act, which strengthens restrictions on hunting, trading, and habitat disturbance by adding these species to Schedules I and II.

Species under CITES: Appendix II: CITES. Two additional salamander species, however, have just been added and are described below.

1) Lesson, 1834: Euphlyctis hexadactylus 2) (Daudin, Previous lists only included Euphlyctis hexadactylus and Hoplobatrachus tigerinus.)1802) Tigerinus Hoplobatrachus

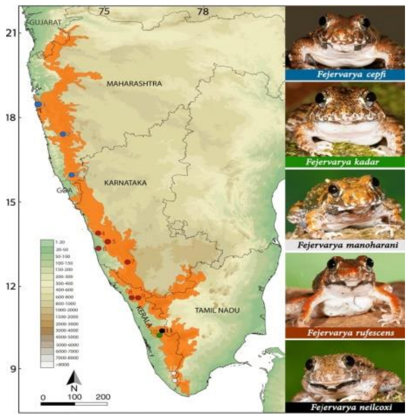
3) Anderson (1871) and Khatiwada, Wang, Ghimire, Vasudevan, Paudel, and Jiang (2015), Tylototriton Himalayanus

Invasive alien species: There have been significant ecological effects since the Indian bullfrog (Hoplobatrachus tigerinus) was brought to the Andaman Islands in the early 2000s. Although their adults are ferocious hunters of tiny vertebrates and invertebrates, their tadpoles have shown an equally concerning ability to endanger native amphibian larvae. In controlled mesocosm trials, Mohanty and Measey (2019) found that within three weeks, bullfrog tadpoles ate all of the coexisting larvae of two endemic Andaman species, Microhyla chakrapanii and Kaloula ghoshi, with 83% of the larvae being eliminated in the first week alone. These findings point to an effective carnivorous predation approach that provides H. tigerinus larvae with a notable competitive advantage over native species that do not have evolved protections. When combined with invasive larvae, several native larval species did not undergo metamorphosis, according to dietary studies of bullfrog tadpoles; yet, the growth and survival of the tadpoles remained unaltered. Remarkably, intense cannibalism was observed even in single-species bullfrog treatments: only roughly three individuals out of every 30 tadpoles survived, indicating intra-species hostility and substantial mortality from overcrowding. In addition to preying on larvae, adult bullfrogs can also be dangerous. Adult bullfrogs hunt on a variety of endemic wildlife, such as Andaman endemic frogs, blind snakes (Typhlops oatesii), emerald geckos (Phelsuma andamanensis), skinks, and even small rodents and chicks, according to field research and gut-content investigations. This suggests possible trophic cascade effects at several ecosystem levels. In addition to direct predation, dietary overlap study between H. tigerinus and two native genera (Limnonectes and Fejervarya) showed notable overlaps with the former, indicating possible competition for prey resources. Even in cases where predation does not occur, this rivalry may lead to food scarcity, which would put more stress on local amphibian populations. These problems are made worse by H. tigerinus's quick geographic spread. Since its first introduction, the species has spread to six of the eight inhabited islands, and if precautions are not taken, it is predicted to soon expand to the Nicobar Islands. Strong anthropogenic facilitators, like the transportation of fish fry, have expanded its range in addition to contaminating the aquaculture trade and purposefully releasing it for human consumption. Mohanty *et al*. and other experts support strict biosecurity measures, including as screening at island ports and swift elimination operations of fledgling populations in South and Little Andaman, in light of these serious ecological repercussions. These tactics are further supported by modeling efforts, which demonstrate how effective they are at preventing further spread.

Gap areas: Obtaining complete DNA sequence data for all known Indian frogs is essential since many frog species complexes are cryptic, displaying little physical changes despite significant genetic divergence. Molecular phylogenetic studies, such as those examining Micryletta aishani in Northeast India (3.5–5.9% divergence in 16S rRNA; turn0search1), reveal the depth of hidden diversity in poorly sampled regions. Similar cryptic lineages have been uncovered in the Western Ghats: at least 14 distinct lineages in Indirana and 5 in Walkerana have been delineated solely through genetic data, despite morphological ambiguity (turn0search10). These examples underscore the necessity of DNA-based approaches to resolve evolutionary relationships, clarify taxonomy, and guide conservation priorities (Biju & Bossuyt, 2003; turn0search0). In addition, with little to no modern sampling or genetic data (turn0search13, turn0search14), many Indian amphibian species like Ichthyophis khumhzi (2009) and Clinotarsus alticola (1882) are only known from their type localities, which were frequently described more than 60 years ago. This limited documentation hinders our understanding of their distribution, population trends, and ecological requirements. In the absence of genetic vouchers or documented populations outside of their type sites, these species remain vulnerable, particularly to the effects of habitat alteration and climate change. Despite being a part of the Indo-Burma and Eastern Himalaya biodiversity hotspots, Northeast India is still under-documented. Although checklists list about 147 species in the region (turn0search4), there are only a few molecular studies, such as those on Hoplobatrachus litoralis (470 bp Cytb; first record from Mizoram; ca. 19% interspecific divergence; turn0search0) and the discovery of Micryletta aishani (turn0search1). A few integrative taxonomic studies on soil caecilians (e.g., Eutyphoeus in Meghalaya & Mizoram) have used DNA barcode (COI) sequences to identify at least 19 out of 28 reported species, revealing previously undiscovered cryptic diversity (turn0search6). These findings demonstrate the potential and scarcity of molecular surveys in this biogeographically complex region. The documenting of natural history and breeding biology is another significant need. Most species lack fundamental reproductive data, especially cryptic taxa in inaccessible forest canopies or high-altitude streams, with the exception of Polypedates teraiensis, whose breeding schedule, foam-nesting behavior, and larval development (~58 days to froglet) are the subject of extensive research (turn0search12). For example, there is virtually little peer-reviewed literature on the reproductive ecology of recently found Northeast species like Xenophrys apatani and Amolops siju (turn0search2). Similarly, although being known for direct development, endemic Western Ghats species such as Raorchestes nerostagona still lack comprehensive data on breeding phenology and larval ecology (turn0search16).

Background of Amphibian Checklist for India: The systematic documentation of India's amphibians began at the end of the 20th century with the work of Das & Dutta (1998) and Dutta (1997). Soon after, Daniels (2001), Chanda (2002), and Daniels (2005) developed checklists for amphibians, and Dinesh *et al*. (2009a, 2009b, 2010, 2011, 2012, 2013, 2015, 2017, 2019, 2020, and 2021) steadily advanced the work.

In recent years, classical taxonomy has been supplemented with more phylogenetic analysis of DNA investigations. Thus, the entire categorization system and higher-level taxonomical treatments were made simpler by Frost *et al*. (2006). Phylogenetic studies and classical taxonomy were combined to create many of the molecular level classifications that adhered to the ICZN norms. Although many international amphibian researchers, including those who use the Amphibian Species of the World (ASW) global database, did not fully adhere to this classification scheme, Dubois *et al*. (2021) presented a novel classification scheme a few years ago that relies on phylogenetic analyses with a few attempts at an integrative taxonomy approach (Frost, 2023).Lesson, 1834's Phrynoderma hexadactylum; Karaavali Phrynoderma Kerala and Priti, Naik, Seshadri, Singal, Vidisha, Ravikanth, and Gururaja (2016); Four Phrynoderma aloysii species Joshy, Alam, Kurabayashi, Sumida, and Kuramoto (2009) According to research by Dinesh *et al*. (2020), Channakeshavamurthy, Dinesh, Deepak, Ghosh, and Deuti (2021) discuss the condition under the genus Phrynoderma. Lesson, 1834's Phrynoderma hexadactylum; Karaavali Phrynoderma Kerala and Priti, Naik, Seshadri, Singal, Vidisha, Ravikanth, and Gururaja (2016); Four Phrynoderma aloysii species Joshy, Alam, Kurabayashi, Sumida, and Kuramoto (2009) According to research by Dinesh *et al*. (2020), Channakeshavamurthy, Dinesh, Deepak, Ghosh, and Deuti (2021) discuss the condition under the genus Phrynoderma.



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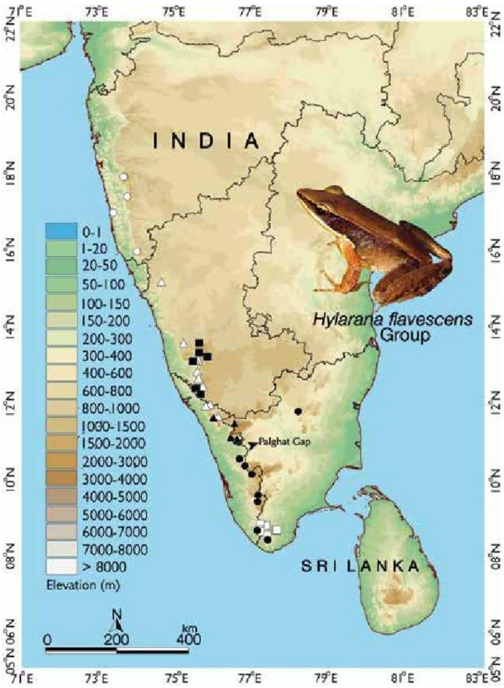

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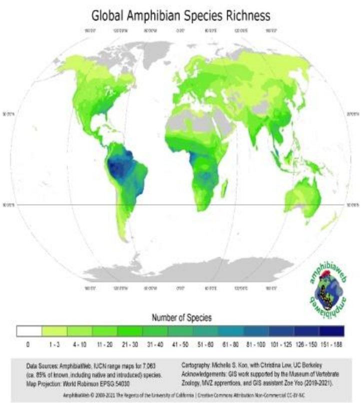

https://amphibiaweb.org/declines/

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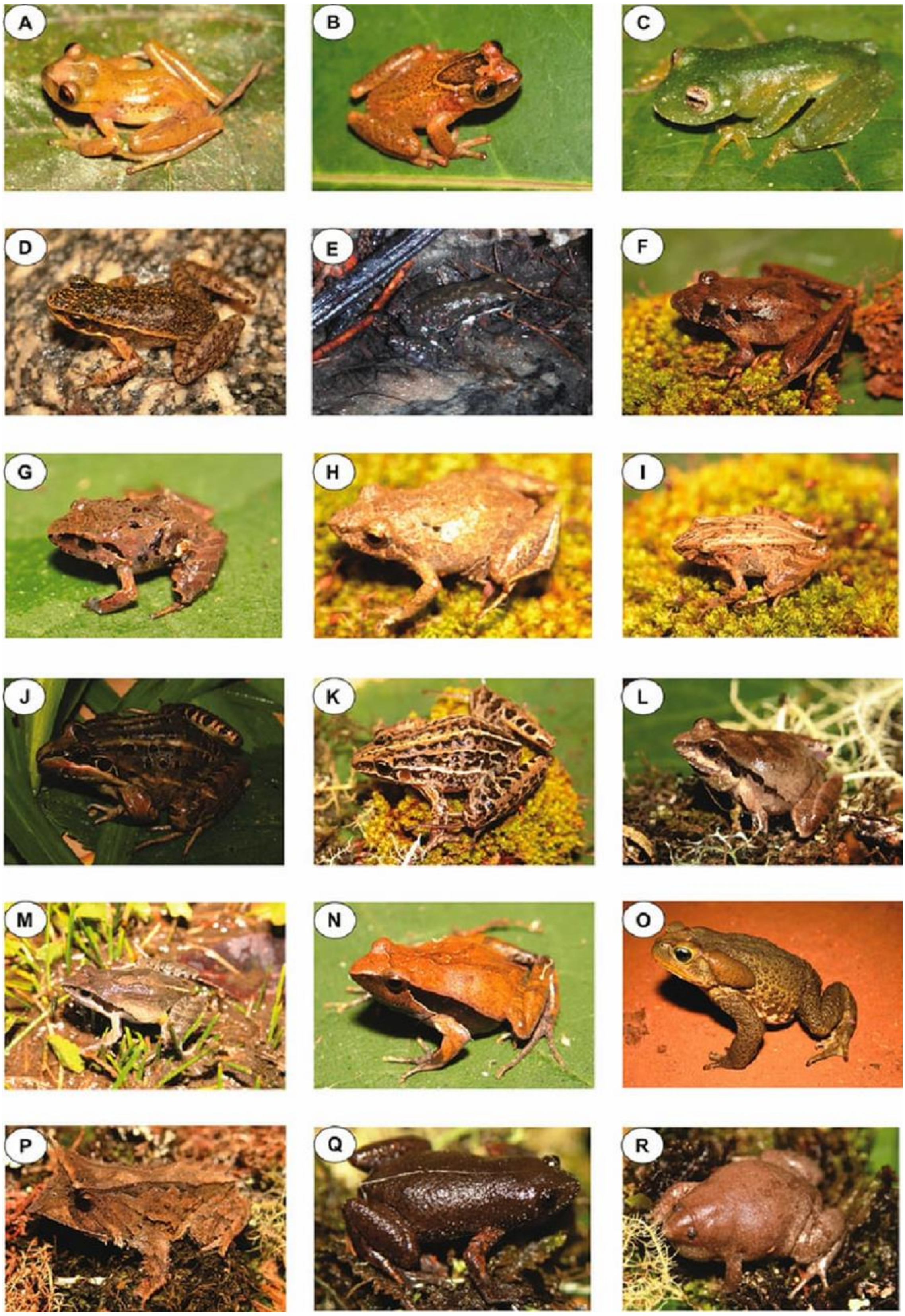

https://www.researchgate.net/figure/Some-species-of-amphibians-from-the-Serra-da-Bocaina-National-Park-A-Fritziana-sp_fig2_262188718
Figure1. Some species of amphibians from the Serra da Bocaina National Park: (A) Aplastodiscus albosignatus ; (B); A. callipygius (C) A. perviridis; (D) A. arildae; (E) Bokermannohyla ahenea ; (F) B. circumdata ; (G) Dendropsophus elegans (H) D. microps ; (I) D. minutus ; (J) Hypsiboas bandeirantes ; (K) Scinax sp. (aff. duartei); (L) Scinax hayii ; (M) Scinax sp. (aff. obtriangulatus); (N) S. atratus ; (O) S. eurydice ; (P) S. flavoguttatus; (Q) S. squalirostris ; (R) Trachycephalus imitatrix

https://www.researchgate.net/figure/Current-and-potential-distribution-in-the-Philippines-of-from-left-to-right-the-Asiatic_fig5_331589713
Fig. 2 Photographs in life of (a) the American bullfrog, (b) the Asiatic painted toad, (c) the cane toad, (d) the Chinese bullfrog, (e) the green paddy frog, and (f) the greenhouse frog

Conclusion

Over 8,200 species of amphibians, including frogs, salamanders, newts, and caecilians, make up the foundation of biodiversity worldwide and each occupy important ecological niches. As secondary consumers, they help regulate insect populations and facilitate the cycling of nutrients in both terrestrial and aquatic environments. They are sensitive bioindicators that can detect early environmental stressors, such as pollution and habitat fragmentation, thanks to their porous skin and biphasic life cycles. Almost 41% of the species under study are in danger of going extinct because of habitat loss, pollution, invasive species, UV radiation, new illnesses like chytrid fungus, and overexploitation, despite the ecological significance of amphibian variety. Populations have been decimated by chytridiomycosis, which has led to local extinctions and cascade ecological repercussions like human disease outbreaks when frogs are unable to regulate mosquito larvae. One of the most diverse collections of amphibian life in the world may be found in India; it is a living tapestry made of ecological complexity, evolutionary guidance, and astounding regional variance. India's amphibian fauna, which stretches from the foggy foothills of the Himalayas to the biodiverse Western Ghats, the tropical rainforests of the Northeast, and the isolated Andaman-Nicobar archipelago, is a striking example of both continuing speciation and the survival of old lineages. Their tale is one of ecological protectors, evolutionary wonders, and pressing conservation needs a tribute to the living heritage found beneath monsoon skies. Ancient geological divisions and a variety of microclimates are mostly responsible for this richness. Isolated mountains, islands, and wooded valleys served as breeding grounds for new species as India moved northward from Gondwanaland. Hundreds of unique species, frequently located only on a few hills or watersheds, can be discovered in the Western Ghats alone. Our knowledge of frog diversity has changed, and in recent decades, the number of recognized species has doubled thanks to the discovery of numerous cryptic species by modern research techniques, particularly genetic sequencing, acoustic monitoring, and focused field surveys. Ultimately, protecting India's amphibians is a decision to maintain the entire range of life on this planet. Every species is an example of the inventiveness and tenacity of nature, whether it is a small dancing frog or a subterranean purple frog. By preserving them, we safeguard not only their future but also the natural base that supports all of us. We can guarantee that India's chorus of croaks will continue to reverberate under monsoon skies for many generations to come by stepping up scientific research, extending habitat protection, encouraging public participation, and integrating amphibian conservation into national objectives.

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