RESEARCH PAPER

Amphibians as Bioindicators: Role in Ecosystem Monitoring

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ABSTRACT

Amphibians are widely recognized as sensitive bioindicators of environmental change due to their permeable integument, biphasic life history, and ecological roles across aquatic–terrestrial interfaces. Their unique physiological and ecological characteristics make them highly responsive to environmental stressors such as pollution, climate change, and habitat degradation. This review synthesizes current knowledge on the role of amphibians in ecosystem monitoring, integrating classical ecological approaches with emerging molecular tools such as DNA barcoding and environmental DNA (eDNA). Key mechanisms underlying amphibian sensitivity, quantitative monitoring methods, and major environmental threats are discussed. Special emphasis is given to the Indian context, including field observations from Rajanagaram Mandal, Andhra Pradesh. The review highlights the importance of integrating traditional and molecular approaches for accurate biodiversity assessment and emphasizes the role of amphibians as early warning indicators of ecosystem health.

Keywords : Amphibians,Bioindicators,Ecosystem Monitoring, Environmental Change,DNA Barcoding,eDNA,India,Rajanagaram, Conservation.

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INTRODUCTION

Bioindicators are organisms used to assess the condition of the environment and detect changes in ecosystem health. Amphibians, including frogs, toads, and salamanders, are among the most effective bioindicators due to their high sensitivity to environmental changes. Over recent decades, global amphibian populations have experienced significant declines, making them important subjects for ecological monitoring.

Amphibians occupy both aquatic and terrestrial habitats during their life cycle, enabling them to reflect environmental conditions across ecosystem boundaries. Their permeable skin and dependence on moisture further increase their vulnerability to pollutants and climatic fluctuations. These characteristics make amphibians ideal organisms for monitoring environmental disturbances and assessing ecosystem integrity.

2. Mechanistic Basis for Indicator Value

2.1 Permeable Skin

Amphibians possess thin, moist, and highly permeable skin that allows direct absorption of water and dissolved substances. This makes them highly susceptible to environmental pollutants such as pesticides, heavy metals, and industrial chemicals.

2.2 Biphasic Life Cycle

The amphibian life cycle includes aquatic larval stages and terrestrial adult stages. This dual habitat utilization enables them to act as indicators of both aquatic and terrestrial environmental conditions.

2.3 Sensitivity to Environmental Changes

Amphibians are highly sensitive to variations in temperature, humidity, and rainfall. Even minor environmental changes can significantly affect their survival, reproduction, and distribution.

2.4 Ecological Role

Amphibians function as both predators and prey in food webs. Changes in their populations can influence broader ecosystem dynamics.

3. Environmental Stressors Affecting Amphibians

3.1 Pollution

Agricultural runoff, industrial waste, and urban pollutants can cause developmental abnormalities, reduced survival rates, and population decline in amphibians.

3.2 Climate Change

Changes in temperature and precipitation patterns affect breeding cycles, habitat availability, and species distribution.

3.3 Habitat Destruction

Deforestation, wetland drainage, and urbanization lead to habitat loss and fragmentation, significantly impacting amphibian populations.

3.4 Chemical Contamination

Endocrine-disrupting chemicals interfere with hormonal systems, affecting growth, development, and reproduction.

Table 1. Major Environmental Stressors and Their Effects on Amphibians

Environmental Stressor	Source	Effects on Amphibians	Indicator Response
Water Pollution	Agricultural runoff, industrial waste, sewage	Developmental deformities, reduced survival, impaired growth	Increased abnormalities, reduced larval survival
Pesticides	Crop fields, agrochemicals	Endocrine disruption, reproductive failure	Decline in population, altered breeding patterns
Climate Change	Temperature rise, altered rainfall	Shift in breeding season, habitat loss	Changes in phenology, distribution shifts
Habitat Destruction	Deforestation, urbanization, wetland drainage	Loss of breeding sites, fragmentation	Reduced species richness, local extinctions
Chemical Contaminants	Heavy metals, industrial chemicals	Toxicity, immune suppression	Increased mortality, disease susceptibility
Pathogens (e.g., fungi, viruses)	Chytrid fungus, ranavirus	Mass mortality, population collapse	Sudden decline in populations
UV Radiation	Ozone depletion	DNA damage in embryos, reduced hatching success	Increased egg mortality, developmental defects

4. Indicators and Quantitative Metrics

- Species richness and diversity
- Population abundance
- Developmental abnormalities
- Reproductive success
- Behavioral changes such as calling activity

5. Methods of Amphibian Monitoring

5.1 Visual Encounter Surveys (VES)

Systematic searches of habitats to record amphibian presence and abundance.

5.2 Acoustic Monitoring

Use of frog calls to identify species and estimate population size during breeding seasons.

5.3 Pitfall Traps and Drift Fences

Used to capture ground-dwelling amphibians and monitor population trends.

5.4 Larval Sampling

Sampling tadpoles to assess reproductive success and water quality.

6. Molecular Tools in Monitoring

6.1 DNA Barcoding

DNA barcoding uses genetic markers such as COI and 16S rRNA for accurate species identification, especially for cryptic species.

6.2 Environmental DNA (eDNA)

eDNA allows detection of species from environmental samples such as water, improving monitoring efficiency and accuracy.

7. Indian Context

India is a biodiversity hotspot for amphibians, particularly in the Western Ghats and Northeast regions. However, amphibian populations are threatened by agricultural expansion, pesticide use, habitat loss, and climate change.

Field observations from Rajanagaram Mandal (East Godavari District, Andhra Pradesh) revealed that amphibian occurrence was higher in roadside microhabitats such as temporary puddles, drainage channels, and agricultural margins compared to large water bodies. Several species were encountered in disturbed habitats, indicating a degree of tolerance to anthropogenic environments; however, species richness declined in areas with intensive pesticide use. These observations highlight the importance of small, often overlooked microhabitats in supporting amphibian diversity and emphasize their value in localized ecosystem monitoring.

8. Limitations of Amphibians as Bioindicators

- Natural population fluctuations
- Seasonal variability
- Difficulty in species identification
- Requirement of long-term monitoring

9. Future Directions

Future research should focus on integrating ecological monitoring with molecular tools such as DNA barcoding and eDNA. Long-term monitoring programs and improved conservation strategies are essential for effective ecosystem management.

10. Conclusion

Amphibians are highly effective bioindicators that provide valuable insights into ecosystem health. Their sensitivity to environmental changes makes them early warning systems for ecological disturbances. Conservation of amphibians is essential not only for biodiversity preservation but also for maintaining ecological balance and environmental sustainability.

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