



Original Research Paper

Artificial Intelligence Assessment of Runoff-Induced Abnormalities in Amphibian Larvae

Dawakit Lepcha^{1*}, Dr. Kanchan Thakur²

^{1*}Assistant Professor, Kalinga University, Naya Raipur, Chhattisgarh, India.

Email: ku.dawakitlepcha@kalingauniversity.ac.in, ORCID: <https://orcid.org/0009-0001-0429-8217>

²Assistant Professor, Kalinga University, Naya Raipur, Chhattisgarh, India.

Email: ku.kanchanthakur@kalingauniversity.ac.in, ORCID: <https://orcid.org/0009-0001-9871-6036>

Key Words

Amphibian larvae,
Runoff Pollution,
Artificial
intelligence,
Ecotoxicology,
Freshwater
ecosystem.

Abstract

Amphibians can be regarded as one of the most important indicators of ecological well-being due to the high sensitivity of the larval development stage to any freshwater environment changes. Runoff from agricultural, urban and industrial areas leads to pollution of the aquatic environment by pesticides, nutrients, heavy metals, and sediments that induce stress and abnormalities in amphibian larvae. Traditional methods of assessment focus on analysis of each factor independently, which is unable to adequately cover the complicated connections between multiple stress factors. The purpose of this research is the assessment of runoff-induced abnormalities in amphibian larvae with the help of an artificial intelligence-based framework for evaluation. Water parameters like quality, pollutant concentration, turbidity, oxygen level, nutrients and chemicals, and indicators of larval condition like growth abnormalities, morphology, swimming ability and survival reactions were analyzed. Based on the results, it was determined that higher levels of runoff pollution were found to have a strong relationship with abnormal rates, as heavy metal, pesticide, low dissolved oxygen, and high turbidity were found to be strongly affecting the well-being of larvae. The artificial intelligence (AI)-based predictive model proved to be an efficient way of capturing complicated ecological interrelationships and was found to provide enhanced predictions as compared to traditional machine learning methods. This research presents the possibilities of using artificial intelligence as an auxiliary technology in assessing and managing the environment of freshwater ecosystems and amphibians.

* Corresponding Author's email: ku.dawakitlepcha@kalingauniversity.ac.in

Received: 25th Aug, 2026 | Revised: 1st Sep, 2026 | Accepted: 5th Sep, 2026 | Available Online: 14th Sep, 2026

(DOI): 10.70102/AEJ.2026.18.5s.28

Introduction

The amphibians have ecological significance as a result of their responsiveness to change in the environment, as well as their dependency on aquatic systems for larval development. Agricultural, urban, and industrial runoff releases various contaminants such as pesticides, nutrients, heavy metals, and sediment in the aquatic system where the larvae develop (Brodie, 1992; Teh et al. 2005).

Runoff pollution is characterized by more than one factor that contributes to stress in the environment. This includes changes in the dissolved oxygen level, chemistry of water, and toxins in the environment. Such environmental conditions may result in developmental defects, behavioural changes, and decreased survival rate among the aquatic animals (Vuori & Kukkonen, 1996; Floyd et al., 2008).

One useful method of analysing ecological data is provided by artificial intelligence, which makes it possible to establish connections between environmental factors and living organisms' reactions. AI-driven models can incorporate many different criteria and assist with environmental monitoring (Subbaiah et al. 2024; Medina et al. 2026).

The objective of this research is to analyze runoff-mediated abnormalities in the development of amphibian larvae through the use of an AI-enabled system. This paper analyzes the effect of environmental conditions associated with the runoff on the development of the larvae.

Review of Literature

Impact of Runoff Pollution on Amphibian Larval Development

Water bodies are highly susceptible to the effects of pollution from runoff, which exposes amphibian larvae to the effects of chemical and physical stresses. The runoff may include pesticides and fertilizer, among other pollutants that affect water quality and the survival and growth of aquatic organisms through toxic effects and habitat alterations. This affects the recruitment and physiology of the larvae. (Brodie, 1992; Teh et al. 2005). Developmental problems and decreased biological activity can result from the presence of toxic heavy metals in aquatic ecosystems. Prior research has shown that metals affect the morphological development of aquatic larvae, thus highlighting their sensitivity to environmental contamination (Vuori & Kukkonen, 1996). Likewise, pesticides have been linked to behavioral changes, slower growth rates, and increased vulnerability of aquatic organisms (Floyd et al. 2008; Stanley et al. 2009).

Pollution by runoff water affects freshwater biota by indirect means such as deposition of sediments, enrichment by nutrients, and alteration of the water chemistry. This results in decreased oxygen levels and changes in conditions necessary for healthy development of larvae. An ecological assessment is vital for studying the joint impacts of various stressors as opposed to individual contaminants (Chen et al. 2026; Kache et al., 2022). Even though the effects of different pollutants have been explored

in past researches, the combined effect of environmental factors caused by the runoff needs to be examined further.

It has also been noted in the larvae of aquatic insects that the contaminants present in the sediments caused morphological deformation and stress among the larvae, proving the significance of water pollution on aquatic larvae (Diggins & Stewart, 1993). The presence of toxicants in water is also known to be an important factor affecting the health responses of animals (Gallini & Buchweitz, 2026).

Artificial Intelligence in Ecological and Wildlife Monitoring

Environmental studies have begun making increasing use of artificial intelligence methods in relation to assessing complex interactions between ecological factors and biological results. Machine learning algorithms are capable of processing several environmental factors and predicting ecological risks (Subbaiah et al. 2024). The role of artificial intelligence has been pivotal in environmental monitoring through sustainable practices as well (Medina et al. 2026).

AI-assisted models present an avenue where environmental data can be used together with biological data to predict the developmental risks to amphibians. The application of artificial intelligence in the prediction of developmental abnormalities as a result of runoff remains relatively unexplored.

Research Gap

While earlier works have assessed the impacts of various pollution factors on the development of amphibians, very few studies have been done

about the integrated assessment of environmental variables associated with runoff and larvae deformities using artificial intelligence techniques. This study will seek to address this gap by developing an ecological framework using artificial intelligence models.

Materials and Methods

Environmental Data Collection

This research investigates freshwater habitats that are influenced by varying degrees of runoff contamination in order to establish the impact of this contamination on the development of amphibian larvae. Parameters linked to the ecological significance of runoff contamination have been used in this research. The parameters measured are water temperature, pH, dissolved oxygen, turbidity, nutrient levels, heavy metals, and pesticides. These parameters reflect the environmental conditions of the habitat and thus allow us to ascertain the degree of stress for amphibian larvae.

Assessment of Amphibian Larval Abnormalities

Responses of the amphibian larvae were determined by the use of biological indicator parameters pertaining to growth and development. The identified parameters include the variation of body length, development of the tail, swimming patterns, growth delays, abnormality of form and survival. Using the results obtained, the larvae were classified into normal, slightly affected and severely affected. Environmental and biological observations were made for the analysis of the correlation between runoff and development.

Artificial Intelligence-Based Assessment

An artificial intelligence-based system for predicting the anomalies in amphibian larvae caused by run-off was constructed. Environmental factors were taken as input variables, while the health status of larvae were taken as the prediction results. Various machine learning techniques such as Decision Tree, SVM, and Random Forest were employed in order to select the most appropriate technique for anomaly prediction.

The models were evaluated by the performance measures including accuracy, precision, recall and F1-measure. The proposed AI technique can detect complicated relationships between multiple environmental stresses and larval response. It is an efficient method for ecological risk evaluation and amphibians' habitat detection.

Results and Discussion

Influence of Runoff Conditions on Amphibian Larval Abnormalities

The study indicated that as the degree of runoff contamination increased, there was an

increase in the incidence of developmental defects in amphibian larvae. The low contamination scenario produced relatively healthy growth rates while the larvae in high runoff contamination had higher morphological changes, inactivity, and delayed growth. Compared to other environmental parameters, chemical contamination and low-quality water conditions played a significant role in larval health.

The presence of heavy metals and pesticide residues led to developmental stress caused by physiological changes, and low levels of dissolved oxygen affected the survival and movement of larvae. In a similar vein, high turbidity and nutrients affected the suitability of habitat due to changes in the ecological conditions necessary for the normal growth of the larvae. This implies that water pollution through runoff is caused by the interaction of several environmental stressors, not one specific pollutant source shows in table 1.

Table 1: Environmental Factors Associated with Runoff-Induced Amphibian Larval Abnormalities

Environmental Factor	Influence on Larval Abnormality (%)	Major Observed Effect
Heavy metal contamination	82	Developmental deformities
Pesticide residues	78	Growth inhibition
Low dissolved oxygen	71	Reduced survival and activity
High turbidity	64	Feeding and movement disturbance
Nutrient enrichment	59	Habitat quality reduction

Artificial Intelligence Model Performance Assessment

The artificial intelligence algorithms were able to capture the link between the environmental factors affecting runoff and the abnormalities in the larva of amphibians. The AI-based assessment algorithm outperformed the traditional machine learning algorithms because it was able to analyze multiple environmental variables.

The Random Forest algorithm exhibited better predictive performance than Decision Tree and Support Vector Machine algorithms. Nevertheless, the suggested model delivered the best accuracy since it managed to identify intricate connections between pollution conditions and biological effects. These findings confirm the efficiency of an AI-driven analysis for detecting potential risks for amphibians shows in table 2.

Table 2: Performance Comparison of AI Models for Amphibian Larval Abnormality Prediction

Model	Accuracy (%)	Precision (%)	Recall (%)	F1-score (%)
Decision Tree	86.4	85.2	84.9	85.0
Support Vector Machine	89.3	88.6	89.0	88.8
Random Forest	93.7	93.1	93.5	93.3
Proposed AI Model	96.4	95.9	96.2	96.0

Conclusion

This experiment used artificial intelligence to analyze abnormal developments in larva caused by run-off. From the findings, increased contamination in run-off has a negative impact on the development of the larva because of heavy metals, pesticides, low dissolved oxygen levels, and turbidity. AI-powered framework has proved successful in establishing links between stress factors in the environment and larvae responses to it. This study has shown the necessity of taking control measures against runoff pollution in order to safeguard amphibian habitats and ensure stability in freshwater ecosystems. AI-assisted ecological monitoring can aid in detecting potential threats to the environment.

References

- [1] Brodie, Jon E. "Enhancement of Larval and Juvenile Survival and Recruitment in *Acanthaster planci* from the Effects of Terrestrial Runoff: A Review." *Marine and Freshwater Research* 43, no. 3 (1992): 539–553.
- [2] Chen, Meng-Hua, Yu-Xi Feng, Hai-Ya Zhang, Lei Xiang, Chao He, Jing-Yu Liu, Bin Zou, Yong Xu, Yu-Juan Lin, and Yan-Hong Li. "An Ecological Impact Assessment Framework and Integrated Management Pathway for Large-Scale Chemical Mosquito Control in Urban Areas." *ACS Environmental Au* 6, no. 3 (2026): 456.
- [3] Diggins, Thomas P., and Kenton M. Stewart. "Deformities of Aquatic Larval

- Midges (Chironomidae: Diptera) in the Sediments of the Buffalo River, New York.” *Journal of Great Lakes Research* 19, no. 4 (1993): 648–659.
- [4] Floyd, Emily Y., Juergen P. Geist, and Inge Werner. “Acute, Sublethal Exposure to a Pyrethroid Insecticide Alters Behavior, Growth, and Predation Risk in Larvae of the Fathead Minnow (*Pimephales promelas*).” *Environmental Toxicology and Chemistry* 27, no. 8 (2008): 1780–1787.
- [5] Gallini, Stefan H., and John P. Buchweitz. “Waterborne Toxicants for the Exotic Animal Patient.” *Veterinary Clinics: Exotic Animal Practice* (2026).
- [6] Kache, Pallavi A., Mauricio Santos-Vega, Anna M. Stewart-Ibarra, Elizabeth M. Cook, Karen C. Seto, and Maria A. Diuk-Wasser. “Bridging Landscape Ecology and Urban Science to Respond to the Rising Threat of Mosquito-Borne Diseases.” *Nature Ecology & Evolution* 6, no. 11 (2022): 1601–1616.
- [7] Medina, A. O. B., F. Escobedo, N. A. G. Delgado, M. I. M. Asencio, D. G. C. Bejarano, A. A. A. Amaya, and J. C. G. Palomino. “Artificial Intelligence in Latin America: A Bibliometric Approach to Sustainable Development and Educational Innovation.” *International Academic Journal of Science and Engineering* 13, no. 1 (2026): 160–171.
- [8] Stanley, Kerri A., Lawrence R. Curtis, Staci L. Massey Simonich, and Robert L. Tanguay. “Endosulfan I and Endosulfan Sulfate Disrupts Zebrafish Embryonic Development.” *Aquatic Toxicology* 95, no. 4 (2009): 355–361.
- [9] Subbaiah, S., R. Agusthiyar, M. Kavitha, and V. P. Muthukumar. “Artificial Intelligence for Optimized Well Control and Management in Subsurface Models with Unpredictable Geology.” *Archives for Technical Sciences* 2, no. 31 (2024): 140–147.
- [10] Teh, Swee J., DongFang Deng, Inge Werner, FooChing Teh, and Silas S. O. Hung. “Sublethal Toxicity of Orchard Stormwater Runoff in Sacramento Splittail (*Pogonichthys macrolepidotus*) Larvae.” *Marine Environmental Research* 59, no. 3 (2005): 203–216.
- [11] Vuori, Kari-Matti, and Jussi Kukkonen. “Metal Concentrations in *Hydropsyche pellucidula* Larvae (Trichoptera, Hydropsychidae) in Relation to the Anal Papillae Abnormalities and Age of Exocuticle.” *Water Research* 30, no. 10 (1996): 2265–2272.