



Original Research Paper

Artificial Intelligence Analysis of Environmental DNA for Freshwater Fish Monitoring

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Key Words

Abstract

Environmental DNA,
Freshwater fish,
Artificial intelligence,
Biodiversity monitoring,
Aquatic ecosystem,
Fish conservation,
Ecological assessment.

Introduction: Freshwater habitats contain fish communities that help maintain ecological balance, biodiversity, and sustainable use of the water resources. Nevertheless, various threats to the environment, including habitat destruction, pollution, climate change, and human activities, pose difficulties in efficient fish monitoring in freshwater habitats. Traditional fish monitoring techniques usually involve fish sampling and can be difficult to detect rare fish populations while disturbing aquatic creatures. **Materials and Methods:** In this study, an artificial intelligence-based environmental DNA (eDNA) technique for monitoring fish in freshwater habitats is presented. The suggested method uses DNA traces found in water for non-invasive identification of fish species and implements AI-based ecological analysis for biodiversity, species distribution, and habitat variation analysis. **Results and Discussion:** An integration of eDNA analysis and the use of artificial intelligence technology enhances biodiversity assessment of freshwaters by facilitating efficient fish community identification and changes in their ecology. Interpretation of complicated biological data through AI-aided analysis enables the establishment of the connection between the environment and the presence of fish communities. Such an approach eliminates the necessity of conducting resource-intensive surveys and provides useful information for further conservation and aquatic ecosystem management. **Conclusion:** AI-aided eDNA analysis is a promising way of implementing sustainable monitoring of fish communities in freshwater ecosystems.

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Introduction

Fish communities are diverse and essential in freshwater ecosystems because of their role in maintaining ecological balance, being an excellent source of food, and sustaining the environment. The differences between fish diversity and distribution depend on changes in water quality, habitat conditions, climatic factors, and anthropogenic influence (Teena, P P, & K Geethanjali, 2026). Nevertheless, the presence of various risks such as contamination, habitat destruction, invasive species, and overfishing requires more efficient biodiversity monitoring strategies.

Traditionally used techniques of fish community monitoring, which include field studies, net sampling, and visual observations, supply useful ecological data but are time-consuming and can cause disturbances to aquatic organisms.

Environmental DNA (eDNA) has become one of the most efficient tools for assessing biodiversity in freshwater through the identification of fish species via traces of DNA present in water from skin cells, mucus, scales, and other biological waste (Gowmugi et al., 2026). Despite the rapid and non-destructive nature of eDNA analysis, interpretation of complex ecological data becomes a difficult task due to environmental conditions and interactions between species.

Application of artificial intelligence (AI)-based analysis will help interpret ecologically

complex information in terms of eDNA observations and environmental information. Integration of AI and eDNA allows the use of a sustainable tool for fish assessment, species evaluation, and conservation in freshwater.

The purpose of this research paper is to conduct an analysis of the role of AI-assisted environmental DNA assessment in freshwater fish monitoring. The major contributions of this study are as follows:

- Assessment of environmental DNA as a non-invasive technique for freshwater fish biodiversity monitoring.
- Analysis of the use of AI techniques in understanding information derived from eDNA.
- Evaluation of the contribution of the integration of eDNA and AI in the conservation of freshwater ecosystems.

This research paper is presented as follows: Section II highlights the background of fish monitoring using freshwater eDNA analysis and AI. Section III will discuss the methodology followed to collect the eDNA samples and conduct AI analysis. Section IV will give details of the results obtained from the above-mentioned process.

Review of Literature

Conventional freshwater fish surveillance techniques offer valuable data on species variety, population condition, and state of the ecosystem. Yet, sampling methods are highly labor-intensive

and can be complicated for the long-term monitoring of large aquatic ecosystems. Modern research emphasizes the necessity to utilize non-invasive methods, which will not disturb aquatic organisms and increase the effectiveness of biodiversity analysis (Wasik and Pattinson 2024; Palarimath 2025).

Environmental DNA (eDNA) has proven to be an efficient technique used for monitoring the freshwater ecosystems through revealing genetic materials of aquatic organisms in the surrounding water. Species identification is possible without the need for capturing them and helps in monitoring the biodiversity of the freshwater ecosystem, distribution of species, and ecological changes (Chang et al. 2025; Wang et al. 2026). Nevertheless, environmental factors and the complexity of aquatic conditions can affect the efficiency of eDNA detection, requiring enhanced analysis techniques (Mushtaq et al. 2026).

AI techniques have become increasingly important in aquatic biodiversity studies in facilitating the analysis of biological data, species identification, and ecological pattern identification. AI-enabled environmental DNA analysis and image-based methods have shown promise in helping achieve more accurate non-invasive monitoring of aquatic ecosystems (Yang et al. 2024). AI can assist biodiversity evaluation by managing complicated ecological data and increasing the accuracy of species-level analysis (Miller et al. 2025).

Despite the fact that eDNA-based methods have made considerable improvements in monitoring the biodiversity of freshwater

ecosystems, difficulties still exist regarding the analysis of big biological data and interpretation of ecological differences. Most of the research done to date concentrates on the detection and molecular analysis of species, but the use of AI to analyze the DNA of freshwater fishes has not been widely considered (Xue 2024).

Materials and Methods

Freshwater Ecosystem Sampling and Environmental DNA Collection

The research involves using freshwater environments like rivers, lakes, and wetlands for monitoring the variety of fishes found within such environments. Water samples are obtained from specific locations that represent varied environmental conditions. The environmental factors, which include water temperature, pH, dissolved oxygen, among others, are taken into account as their impact on the pattern of fish distribution is being studied. Water samples are filtered to extract environmental DNA from freshwater fish through biological matter.

Environmental DNA-Based Fish Diversity Assessment

Environmental DNA samples that have been collected are then analyzed to determine the type of freshwater fishes that exist within the ecosystem. The information that is obtained from the process is then cross-checked against available reference data to determine the types of species that exist within the habitat.

Artificial Intelligence-Assisted Ecological Analysis Framework

Analysis of the eDNA data obtained is done through artificial intelligence-based approaches

that aim at analyzing the patterns of biodiversity variations among different species. The AI-based approach is aimed at analyzing the relationship between the presence of different fish communities and the environment. The entire

process involves freshwater habitat observation, collection of eDNA samples, species identification, AI-assisted biodiversity analysis, and conservation evaluation.

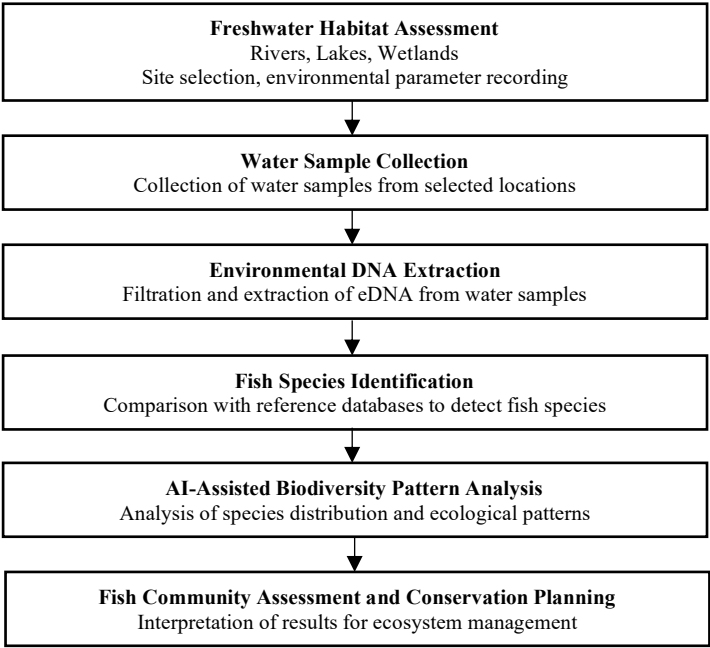


Figure 1: Artificial Intelligence-Assisted Environmental DNA Workflow for Freshwater.

Figure 1 shows that the integrated technique is sustainable for monitoring fish communities in freshwater since it integrates non-invasive biological sampling with intelligent ecological analysis. Contrary to the use of direct capture techniques in surveys, the technique minimizes the disturbance of aquatic animals.

Results and Discussion

Environmental DNA-Based Detection of Freshwater Fish Diversity

This study on fish species is useful because it does not involve any form of physical harm to the fishes in order to gain information about their community structure. The analysis shows the existence of fish species in the selected aquatic habitats. Variation in the fish species is dependent on various factors such as habitat conditions and seasons.

Table 1: Environmental DNA-Based Assessment of Freshwater Fish Species

Fish Species	Detection Frequency (%)	Habitat Preference	Ecological Importance
Species A	92	River and shallow water regions	High
Species B	78	Vegetated freshwater zones	Moderate
Species C	65	Deep water habitats	High
Species D	54	Seasonal wetland regions	Moderate



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Table 1 findings demonstrate that the use of environmental DNA for monitoring can help in the assessment of freshwater biodiversity, since it enables the detection of species that would go undetected using traditional sampling methods.

AI-Assisted Interpretation of Fish Community Patterns

The application of AI analysis in the study of eDNA leads to the identification of the connection between the presence of species and environmental conditions. This analysis contributes to the detection of biodiversity trends that have been affected by habitat quality and seasonality. This will assist in the analysis of freshwater ecosystems and will provide valuable information for conservation purposes.

The use of eDNA and AI technologies allows for continuous and non-invasive monitoring of fish populations. It allows for less reliance on extensive field studies and enhances the assessment of biodiversity.

Implications for Freshwater Conservation

These results show that AI-assisted eDNA monitoring could be used as an effective method for sustainable management of freshwater ecosystems. As this technique provides early information on the presence of certain organisms, biodiversity changes, and environmental condition changes, this technique could help make conservation decisions and protect endangered fish species from becoming extinct.

Nevertheless, one should take into account the variability in the environment, DNA persistence, and habitat complexity while interpreting the obtained results. In the future, it would be possible to combine AI-assisted eDNA monitoring and ecological observation when managing freshwater biodiversity.

Conclusion

This paper underscores the utility of the AI-assisted analysis of environmental DNA as a method for monitoring freshwater fish species. The combination of eDNA detection with ecological analysis using AI will help to identify fish communities without invasive methods, as well as the changes associated with their habitat. This is an important method for freshwater conservation.

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