



Original Research Paper

Impact Of Agricultural Runoff And Water Pollution On Freshwater Fish Diversity Health And Trophic Interactions In Riverine Systems

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Key Words	Abstract
Agricultural runoff, Water pollution, Freshwater fish, Biodiversity, Trophic interactions, Ecosystem health, Conservation.	Agricultural water runoffs and water pollution are significant causes of degradation in the freshwater ecosystem; they impact the fish diversity, health, as well as the trophic interactions within the river system. High manufacturing of nutrients through the application of fertilizers, pesticides, and livestock waste causes the chemistry of water to be changed, causing eutrophication, hypoxia, and deposits of toxic materials. The alterations also destroy fish habitats, decrease species abundance, and increase tolerance to pollution, leading to diversity community and population transitions. Physiologically, the fish subjected to the pollutant have their gill and liver systems compromised, are affected by oxidative stress, slow growth, and poor reproduction systems, and their habitats aid the onset of diseases and eventual depletion with time. There are also influences on the trophic interactions as a result of shifts in prey abundance and toxin accumulation, which will have influences on how the organisms eat, predator-prey relationships, and the overall stability of the food chain. Endemic and sensitive species that reside in the rivers where there is a lot of agricultural and industrial effluent have been found to be decreasing in their numbers. There must be riparian buffer zones, reduced input, reduced pesticide use, reduced effluent, and community participation to be incorporated into conservation to achieve the best mitigation strategies. Habitat rehabilitation and policy implementation play a vital role in protecting the freshwater ecosystems. This paper discusses the effects of farm runoff and the pollution of water from a number of case studies. The paper will focus on the cascading effects of farm runoff and water pollution to the fish populations in the freshwater ecosystem.

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Introduction

Agricultural pollution of water and runoff are one of the most spread anthropogenic forms of stressors that are threatening freshwater ecosystems (Asghari, 2019; Mishra et al., 2023). Agricultural landscapes contribute to rivers, streams and lakes with undesirable nutrients, chemicals and organic matter through fertilisers, pesticides, herbicides and livestock excrements. This inflow alters the water quality, increases the turbidity and decreases the amount of dissolved oxygen and supports the growth of harmful algae, all of which, along with the other factors, renders the water, hostile to aquatic life (Polazzo et al., 2022; Matkarimov et al., 2025).

The fishes that are found in the fresh water are a significant component of these ecosystems, which aid in the balancing of nutrients, regulation of the population of prey and offer livelihoods to the locals through fisheries (Kapoor & Vasudevan, 2025; Pathak et al., 2026). Diversity and population health of the fish is a delicate indicator of ecosystem health: even small changes in the water quality can lead to a change in ecosystems in terms of species structure, reproductive success and even the growth rates (Lee et al., 2023; Sidibe et al., 2026). Pollutants may also affect fish physiology, increase their susceptibility to disease, disrupt feeding and reproductive behaviours, and disrupt ecological interactions within aquatic food webs.

The study will be focusing on the impact of agricultural drainage and water pollution to the freshwater fish diversity, health, and trophic structure of the riverine systems. The aim of the study will be to describe how the processes of

influencing pollutants on fish communities and ecological processes are explained, including studies of the quality of water and fish populations, along with the interactions of ecological processes. These types of relationships are fundamental in order to inform sustainable management practices, to inform conservation interventions, to respond to the freshening waves of biodiversity cascades in the context of human action.

Key Contributions

- Illuminates the impacts of farm runoff and pollution of waters on the health and diversity of freshwater fish.
- Stated how pollutants interfere with trophic relationships and stability of the entire ecosystem in a general way.
- Offers information on conservation to be applied in managing riverine systems on a sustainable basis.

Introduction Section I examines the problem of agricultural runoff and water pollution in freshwater habitats, with emphasis on the effects they have on fish diversity, physiology, and interactions. It discusses the role that freshwater fish play in the ecosystem, serving as an indicator of its health, as well as the goals of the research, which form the foundation for all following sections discussing pollution sources, effects, and solutions.

Sources and Effects of Agricultural Runoff

The substantial source of water pollution in the river systems is agricultural runoff. It happens when the soil, fertilizers, pesticides and livestock

waste deposited on farmland is washed away by rainfall or irrigation into water bodies. Primary pollutants in the runoff are excessive nutrients (In the form of nitrogen and phosphorus), chemical pesticides and herbicides, sediments and pathogenic microorganisms.

The abundance of nutrients encourages eutrophication that causes thick algal growths that decrease dissolved oxygen and hinder the effectiveness of fish survival. Pesticides and herbicides may be poisonous to fish, leading to behavioral alteration, stunted growth and death (Jargal et al., 2022). Runoff leads to sediment deposition, which enhances turbidity, changes the penetration of light and growth of aquatic vegetation, and indirectly impacts the fish habitat and food supply. Livestock waste contributes organic matter that increase biochemical oxygen

demand (BOD), which leads to hypoxia that is fatal to most of the sensitive fish species (Rimada & Mrinh, 2026; Hahshmi et al., 2024).

The impact of farm runoff on freshwater fish population is complex. The richness of the species tends to decline as the tolerant species ascend, while the sensitive species either decline or become extinct. The density of populations and age distribution are also influenced as there is less recruitment and lopsided sex ratios between the polluted habitats. The effects of poor spawning conditions, reduced egg viability and deviations during juvenile development of fish could be reduced fish reproductive success. All those cumulative impacts lead to a lack of ecosystem balance and decreasing the overall resilience of freshwater communities.

Table 1: Major Pollutants from Agricultural Runoff and Their Effects on Freshwater Fish

Pollutant Type	Source	Water Quality Impact	Fish Impact
Nitrogen & Phosphorus	Fertilizers	Eutrophication, low DO	Reduced diversity, hypoxia stress
Pesticides/Herbicides	Crop protection agents	Toxicity, chemical stress	Behavioral changes, mortality
Sediments	Soil erosion	Turbidity, habitat smothering	Reduced foraging efficiency, habitat loss
Organic matter	Livestock waste	High BOD, low oxygen	Disease susceptibility, reduced growth
Pathogens	Animal waste	Contamination, waterborne pathogens	Disease outbreaks, mortality

Table 1 provides an overview of major pollutants in agricultural runoff, such as nutrients, pesticides, sediments, organic materials, and pathogens. This table also demonstrates the source of each pollutant, its effect on water quality, and the impact that the

effects have on freshwater fish species. This table shows how the pollutants mentioned lead to issues such as eutrophication, hypoxia, chemical stress, habitat destruction, and disease outbreaks.

Water Pollution and Freshwater Fish Diversity

One of the primary contributors to the decrease in the freshwater fish diversity is water pollution. Industrial effluent, agricultural effluent, and urban effluents bring heavy metals, chemical pollution, and too much nutrients into rivers, changing conditions of habitats and making the spawning and feeding grounds less suitable. Pollution that begins in sediments and water include mercury, lead, and persistent organic compounds, which affect sensitive species of fish more than the tolerant ones. Such changes lead to a transformation in the composition of species and, over time, causes sensitive endemic species to decline in population or disappearance with pollution-tolerant generalists taking over.

Pollution has an impact on fish reproduction and survival as well. The pollutants may affect

the quality of gametes, cause developmental defects in the embryos, and minimise the survival rates in juveniles. There are alterations in water chemistry which add to reproductive stress including changes in pH and decreases in dissolved oxygen. Loss of aquatic vegetation and silt, habitat degradation, reduces refuge and feeding areas and additionally affect health of the population.

There are case studies of the river systems in India of clear correlations between water pollution and fish species richness. Another case in point, the rivers into which agricultural and urban effluents are high experience a decrease in endemic carp species, whereas generalist catfish and tilapia become highly abundant. These tendencies imply that the quality of water has a profound effect on the organization of a community and biodiversity.

Table 2: Observed Impacts of Water Pollution on Freshwater Fish Diversity

River / Location	Dominant Pollutants	Species Richness Change	Sensitive Species Affected	Tolerant Species Dominant
Ganga, India	Nutrients, pesticides	-35%	Labeo rohita, Cirrhinus mrigala	Clarias batrachus, Oreochromis niloticus
Yamuna, India	Heavy metals, organic waste	-42%	Puntius sophore, Barilius barna	Channa striata, Mystus spp.
Godavari, India	Industrial effluents, pesticides	-28%	Catla catla, Cirrhinus cirrhosus	Tilapia spp., Wallago attu

Table 2 gives a summary of the effects of water pollution on freshwater fish diversity in certain rivers. The major pollutants involved, alterations in species richness, species affected by pollution, and dominant species in polluted

environments are shown in table 2. It illustrates how high levels of nutrients, chemicals, and organic pollutants affect fish diversity and cause an imbalance in river ecosystems.

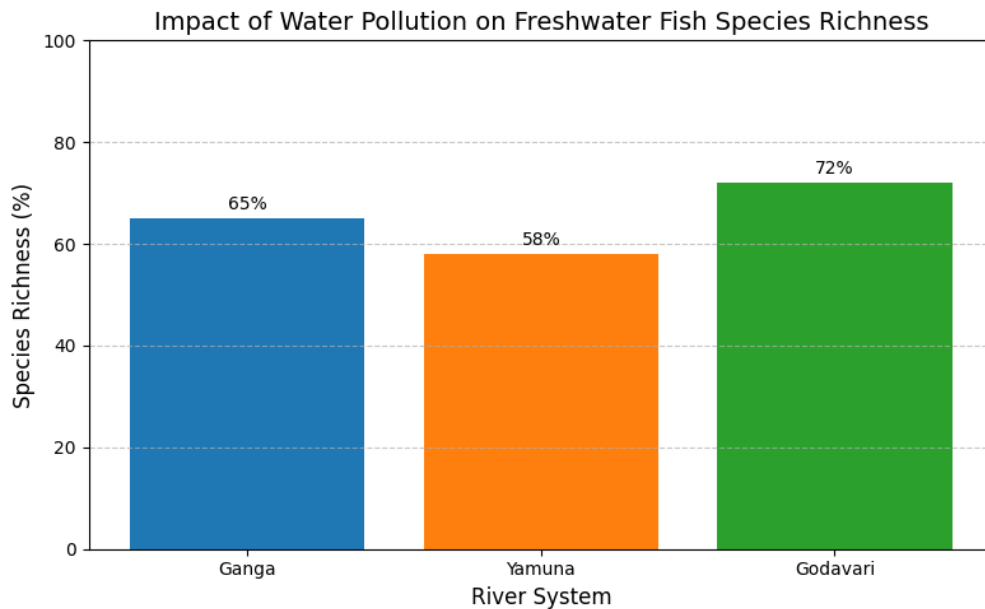


Figure 1: Impact of Water Pollution on Freshwater Fish Species Richness

The percentage of fish species that still remain in Ganga, Yamuna and Godavari rivers is indicated in figure 1. The richness of the species is lower when there is higher pollution with Yamuna at 58, Ganga at 65 and Godavari at 72. This figure shows that there is an inverse relationship between pollution and biodiversity of freshwater fish.

Health Impact on Freshwater Fish

Agricultural runoffs and water contamination may expose freshwater fish to severe health damages due to their exposure to agricultural pollution. Physiological effects comprise gill and liver damage, oxidative stress, and malfunctioning osmoregulation, which diminishes the capacity of fish to sustain metabolic and ionic equilibrium. Lead and mercury are heavy metals, which are stored in the tissues resulting in chronic toxicity and pesticides and herbicides destroy the endocrine system, which affects growth and reproduction.

Pathogens spread through waterborne water and organic matter which is generated by runoff are some of the factors that lead to disease outbreaks such as bacterial, viral and parasitic diseases. Fisheries in contaminated waters are usually characterized by impaired growth, decreased immunity and reproductive output. These health losses are more serious cases on sensitive species, which can suffer the local extirpation or decline in population. Juvenile fish are especially susceptible, exposing them to development issues and high mortality rates.

Long-term impacts due to pollutant exposure will alter the population structure, reduce genetic variation, and affect the health status of the inhabitants of the freshwater ecosystem. Higher trophic levels could also be affected by bioaccumulation of toxins that are flowing down the food chain. It is crucial to learn about these health impacts for understanding and evaluating the ecosystem's integrity.

Table 3: Physiological and Health Effects of Water Pollution on Freshwater Fish

Pollutant Type	Physiological Impact	Health Consequence	Affected Species Examples
Heavy metals (Hg, Pb)	Gill and liver damage, oxidative stress	Chronic toxicity, reduced growth	Labeo rohita, Cirrhinus mrigala
Pesticides/Herbicides	Endocrine disruption	Impaired reproduction, developmental abnormalities	Catla catla, Cirrhinus cirrhosus
Nutrient-induced eutrophication	Hypoxia stress	Increased mortality, behavioural stress	Puntius sophore, Barilius barna
Organic matter & pathogens	Elevated BOD, waterborne pathogens	Disease outbreaks, lowered immunity	Clarias batrachus, Mystus spp.

Table 3 provides a summary of physiological and health impacts of various water contaminants on fresh water fish. It places special focus on how the presence of toxic elements like heavy metals, pesticides, oxygen deprivation caused by excessive nutrients and organic compounds lead to damage to tissues, oxidative stress, disruption in the endocrine system, and makes one vulnerable to sickness. Fish species that get affected due to these forms of pollution, which are also listed in the table, indicate the relation between water pollution and declining fish health.

Trophic Interactions and Food Web Disruption

The freshwater food web is highly compromised by water pollution and agricultural runoff. The overpowering nutrients and pollution from chemicals result in a decrease in the number of invertebrates, which are the primary food for several fish species. This forces the fish to feed differently and to compete for resources, hence compromising predator-prey interactions. With accumulation of toxic compounds in the bodies of prey species, there is an impact on the

predators of fish and birds higher up the food chain. This results in reproductive dysfunction and increased rates of death. The nutrient enrichment leads to algal proliferation, thus creation of low oxygen zones that exclude sensitive species and favor opportunist species. The alterations are widespread throughout the ecosystem, hence compromising the integrity of the ecosystem. The disruption of the interactions among the trophic levels through pollution leads to changes in the flow of energy and population structure and exposes the population to anthropogenic stress.

Mitigation and Conservation Strategies

A combination of management practices, policy implementation and community participation is required to overcome the effects of agricultural run off and water pollution on freshwater fish (Ulkilan et al., 2024; Xu et al., 2025). Best management practices (BTM) could play a great role in mitigating the pollutants that find their way into the river systems e.g., the establishment of riparian buffer zone, controlled application of fertilizers and pesticides, and the

setting up of wetlands to filter runoff can greatly reduce the amount of nutrient and chemical loads entering the river. Wastewater treatment regulations, effluent limit and monitoring schemes are important issues which can help to sustain water quality (Asghari, 2019). The further destruction of freshwater habitats is prevented by planning and implementing land-use sustainability programs, as well as environmental regulations. It is also important to have community involvement. Local stakeholders will be able to take up conservation efforts, check the sources of pollution, and also encourage the farmers to adopt sustainable agriculture techniques. The citizen science initiatives and environmental education initiatives enable local communities to take an active role in conserving riverine ecosystems to achieve long-term stewardship. The restoration actions, such as the rehabilitation of the habitat, introduction of threatened species, and conservation of ecological corridors, help in restoring biodiversity and ecological processes (Ogidi & Akpan, 2022). The combination of both strategies reduces the effects of the pollutants, enhances fish health, and sustains trophic interactions, which come together to make the freshwater ecosystems resilient to support a diverse group of aquatic life (Hussain & Taimooz, 2024; Dineshkumar, 2025).

Conclusion

The present research paper demonstrates that the influence of agricultural water pollution and runoffs is profound for fish populations in rivers, impacting not only the biodiversity, but also fish physiology and trophic interactions within

freshwater ecosystems. As stated, a noticeable decline in species numbers can be seen; moreover, according to statistics, there is even a 42% reduction in the species abundance in heavily polluted rivers, showing how vulnerable endemics and other pollution-sensitive species are. It is physiologically justified by oxidative stress, negative impact on reproduction, and susceptibility to diseases caused by contamination, as well as a change in the feeding habits because of hypoxia due to nutrients. A comparative analysis among the Ganga, Yamuna, and Godavari rivers indicates that the level of pollution negatively relates to species richness, highlighting the paramount importance of water quality in maintaining ecological stability. Riparian buffers, agrochemical application control, effluent treatment, and habitat restoration, active community effort can mitigate pollutant loadings, aid recovery of vulnerable species, and can recover trophic integrity. The results have highlighted the importance of implementing an integrated approach in the management of freshwater biodiversity through a combination of policy implementation and enforcement, sustainable agriculture, and conservation practices. The priority of future studies will be to monitor the dynamics of the pollutants in the long term, determine the cumulative and synergistic impact on fish populations, and model ecosystem behavior in various management situations. Also, the adaptive management and conservation outcomes can be enhanced by exploring bioindicator species and implementing early-warning systems. All these measures will

increase the resilience of freshwater ecosystems, protect biodiversity, and guarantee provision of ecological services that have an important role in human and environmental well-being.

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