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Pesticide Pollution and Decline of Fish Biodiversity: A Regional Case Study of Meerut

*Tanya and Neeru Singh

Department of Zoology, Keral Verma Subharti College of Science,
Swami Vivekanand Subharti University, Meerut, UP, India

*Corresponding Author's email: tanyachaudhary30062002@gmail.com

Agricultural intensification in western Uttar Pradesh has significantly increased pesticide usage, leading to growing concerns about contamination of freshwater ecosystems. Meerut district, characterized by intensive cultivation of sugarcane, wheat, paddy, and vegetables, has witnessed substantial agrochemical application over the past decades. Runoff and leaching of pesticides into canals, rivers, and ponds have contributed to deteriorating water quality and declining fish biodiversity. This article critically examines the relationship between pesticide pollution and fish diversity loss in Meerut, exploring ecological mechanisms, species vulnerability, and socio-economic implications. The study highlights the urgent need for integrated pest and water resource management strategies to safeguard aquatic biodiversity.

Introduction

Freshwater ecosystems in India support a rich diversity of fish species that provide ecological services, nutritional security, and livelihood support. However, these systems are increasingly threatened by anthropogenic activities, particularly pesticide contamination arising from modern agriculture. Meerut district, situated in the fertile Gangetic plains, is one of the agriculturally productive regions of Uttar Pradesh. High-yield crop production relies heavily on chemical pesticides including organophosphates, carbamates, pyrethroids, and herbicides. While these compounds protect crops from pests, their unintended entry into aquatic systems poses serious risks to non-target organisms, especially fish. Recent ecological observations indicate a reduction in native fish populations and a shift toward pollution-tolerant species. This regional case highlights how pesticide pollution is emerging as a critical driver of biodiversity decline in freshwater habitats of Meerut.

Agricultural Practices and Pesticide Usage in Meerut

The agricultural landscape of Meerut is dominated by sugarcane and cereal cropping systems that require repeated pesticide application. Farmers often apply insecticides to control borers, aphids, and leafhoppers, along with herbicides for weed management. During monsoon seasons and irrigation cycles, surface runoff carries pesticide residues into the Ganga canal network and associated water bodies. In addition, seepage through soil leads to contamination of groundwater and connected aquatic systems. Many small ponds and village tanks located near agricultural fields serve as collection points for agrochemical residues. These stagnant water bodies often show visible ecological stress, including algal blooms, fish mortality events, and reduced species diversity.

Mechanisms of Pesticide Toxicity in Fish

Pesticides affect fish through multiple physiological and biochemical pathways. Acute toxicity can cause immediate mortality, while chronic exposure results in sub-lethal effects that impair survival and reproduction. Organophosphate and carbamate insecticides inhibit

acetylcholinesterase activity, disrupting nervous system function. Affected fish exhibit erratic swimming behavior, respiratory distress, and reduced feeding efficiency. Pyrethroids interfere with sodium channel regulation in nerve cells, leading to neurotoxicity even at low concentrations. Herbicides may alter endocrine function and impair reproductive cycles.

Chronic pesticide exposure can result in:

- Reduced growth rates
- Suppressed immune response
- Increased susceptibility to pathogens
- Reproductive failure and decreased fecundity
- Developmental deformities in larvae

These impacts collectively reduce recruitment success and long-term population stability.

Impact on Fish Biodiversity in Meerut

Field observations and regional reports suggest a noticeable decline in indigenous species such as *Labeo rohita*, *Catla catla*, *Cirrhinus mrigala*, and various small indigenous fishes. Sensitive species that require clean, oxygen-rich water are particularly vulnerable to chemical contamination. In contrast, hardy and pollution-tolerant species tend to dominate contaminated habitats. This leads to ecological homogenization, where species richness decreases and community structure becomes simplified. Loss of smaller indigenous species is particularly concerning, as they play vital roles in nutrient cycling, food web stability, and as prey for larger predatory fish and birds. Over time, repeated pesticide influx reduces ecological resilience, making aquatic ecosystems more susceptible to additional stressors such as climate variability and eutrophication.

Bioaccumulation and Human Health Concerns

Many pesticides are lipophilic and accumulate in fish tissues through bioaccumulation and biomagnification. Predatory fish may accumulate higher concentrations over time. Consumption of contaminated fish poses potential health risks to local communities, including neurological, endocrine, and carcinogenic effects depending on the pesticide type. Thus, pesticide pollution is not only an ecological issue but also a public health concern, particularly in regions where fish constitute a significant dietary protein source.

Climate Change and Synergistic Effects

Rising temperatures associated with climate change may intensify pesticide toxicity. Higher water temperatures increase fish metabolic rates, potentially enhancing chemical uptake and physiological stress. Reduced water flow during drought periods can concentrate pesticide residues, increasing exposure levels. The combined stress of chemical contamination and environmental fluctuations accelerates biodiversity decline.

Management and Mitigation Strategies

Addressing pesticide-induced biodiversity loss requires coordinated intervention at multiple levels:

Integrated Pest Management (IPM): Promotion of biological control agents, crop rotation, and reduced chemical dependence.

Buffer Zones: Establishment of vegetative buffer strips around water bodies to reduce runoff.

Water Quality Monitoring: Regular assessment of pesticide residues and ecological indicators in canals and ponds.

Farmer Awareness Programs: Education on safe pesticide application rates and timing to minimize environmental leakage.

Policy Enforcement: Strengthening regulation on banned or highly toxic pesticides and ensuring compliance.

Aquatic Biodiversity Surveys: Periodic scientific assessment of fish species composition using ecological indices to detect early warning signals.

Conclusion

The decline of fish biodiversity in Meerut is closely linked to pesticide pollution arising from intensive agricultural practices. While pesticides contribute to crop productivity, their uncontrolled use threatens freshwater ecosystems and associated socio-economic systems. The case of Meerut underscores the urgent need for sustainable agricultural practices that balance productivity with environmental conservation. Integrating scientific research, regulatory enforcement, and community participation will be essential to restore and protect aquatic biodiversity. Protecting fish diversity is not only about conserving species; it is about maintaining ecological balance, ensuring food security, and safeguarding public health for future generations.

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