

Impact of Aquaculture on Environment

**Rajalaxmi Dalabehera¹,
Suvankar Rout¹,
Subhransu Mohapatra^{2*} and
Pralipta Priyanjali Panda³**

¹Ph.D. Scholar, Department of
Aquaculture, Central Agricultural
University, Lembucherra, Tripura,
India, 799210

²Young Professional II, NSPAAD,
College of Fisheries, OUAT,
Rangailunda, Berhampur, Odisha,
India, 760007

³Assistant Fisheries Officer,
FARD, Govt. of Odisha, India



*Corresponding Author
Subhransu Mohapatra *

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INTRODUCTION

Fish and fisheries play an important role in socio-economic development by providing high-quality animal protein, generating employment, reducing poverty, and contributing to foreign exchange earnings. With the rapid growth of the global population, climate change, limited land and freshwater resources, and the decline of wild fish stocks, concerns about future food security have increased. In this context, aquaculture has emerged as a vital and rapidly expanding sector that can provide an alternative and sustainable source of aquatic protein. Although it significantly contributes to food security and economic development, aquaculture has been widely criticised for its environmental impacts. Issues such as nutrient pollution, habitat degradation, chemical use, and disease outbreaks have raised concerns about its long-term sustainability. For example, uneaten feed and fish waste release organic matter, nitrogen (NH_x, NO_x), and phosphorus into surrounding waters, potentially affecting water quality, particularly in areas with low water exchange (Mpeza *et al.*, 2013). In addition, pollution from urban and agricultural sources can negatively affect aquaculture production and fish health (Saad *et al.*, 2020).

1. Destruction of Natural Ecosystems

One of the most significant environmental impacts of aquaculture is the destruction of natural habitats, particularly mangrove forests, to construct aquaculture farms. Mangroves serve as critical nurseries for fish and other aquatic species, protect coasts from erosion, stabilise sediments, and store carbon (Saad *et al.*, 2020).

Between 1980 and 2000, global mangrove cover decreased from 19.8 million hectares to less than 15 million hectares, with aquaculture identified as a major contributor to deforestation in countries such as Thailand, Indonesia, Ecuador, Madagascar, and the Philippines (Mpeza *et al.*, 2013). The destruction of these ecosystems reduces biodiversity and diminishes the ecological services that sustain both wild fisheries and local communities.

2. Soil and Water Impacts

2.1 Salinization and Soil Degradation

Abandoned aquaculture farms often leave behind hypersaline, acidified, and eroded soils, rendering them unsuitable for agriculture for long periods. Treatments with lime and other chemicals can further alter soil properties, exacerbating degradation (Ni *et al.*, 2018).

2.2 Water Pollution

Intensive aquaculture generates large amounts of waste, including uneaten feed, faeces, and dead organisms, which can pollute freshwater and marine systems. Studies suggest that a farm producing three tons of freshwater fish may generate waste equivalent to that of 240 people (Saad *et al.*, 2020). Effluents can increase turbidity, organic load, and chemical oxygen demand (COD), impacting both aquaculture and nearby human water supplies.

2.3 Nutrient Loading and Eutrophication

Excess feed and waste discharge release high levels of nitrogen, phosphorus, and carbon into surrounding waters, causing eutrophication. Only 20–50% of nitrogen supplied in feed is retained in biomass, with the remainder entering the water column or sediments (Hu *et al.*, 2018). This can trigger harmful algal blooms, benthic mortality, oxygen depletion, and pathogen proliferation.

3. Biological and Ecological Impacts

3.1 Introduction of Exotic Species

Aquaculture often introduces non-native species, which can outcompete local species,

spread pathogens, and alter natural ecosystems. For example, sea lice from farmed salmon have been shown to infect wild populations, potentially leading to collapse of wild population (Hu *et al.*, 2018).

3.2 Loss of Genetic Diversity

Escapes of fish from aquaculture farms can interbreed with wild populations, leading to hybridization, loss of local adaptation, and genetic pollution of broodstock. This threatens the genetic integrity of native fish populations.

3.3 Bycatch and Wildlife Mortality

Collection of wild juveniles for stocking causes substantial bycatch. In some regions, thousands of seeds of finfish are destroyed for each kilogram of shrimp seed collected, significantly affecting biodiversity (Ni *et al.*, 2018).

4. Disease, Chemicals, and Aquaculture Pollution

Aquaculture requires the use of therapeutics, antibiotics, antifoulants, and disinfectants to control disease and improve production. Improper use or excessive application of these chemicals can:

- Persist in water, soil, and sediments
- Affect non-target species
- Promote antibiotic resistance, which can transfer to human pathogens
- Cause toxic accumulation in aquaculture products (Hu *et al.*, 2018; Ni *et al.*, 2018)

Intensive systems, combined with high stocking densities, exacerbate the need for chemical inputs, increasing the risk of environmental contamination.

6. Hydrological and Landscape Changes

Construction of aquaculture ponds and farms alters natural hydrological patterns, modifies landscapes, and may disrupt local ecosystems and weather patterns. Pumping large volumes of groundwater for fish farms can lower water tables, reduce availability for local communities, and lead to salinization of agricultural land (Mpeza *et al.*, 2013).

7. Causes of Environmental Adversities in Aquaculture

Key drivers of environmental impacts include:

- Lack of technical knowledge and training among farmers
- Use of low-quality or low-cost feeds, leading to excess waste
- High stocking densities
- Disease outbreaks and misuse of chemicals
- Absence of proper drainage and wastewater treatment
- Over-reliance on wild-caught juveniles
- Escape of farmed species and predation management

Addressing these factors through education, best management practices, and adherence to international standards such as HACCP, FAO Codes, and BAP (Best Aquaculture Practices) is essential to mitigate environmental impacts. In socio-economic development by providing high-quality animal protein, generating employment, reducing poverty, and contributing to foreign exchange earnings. With the rapid growth of the global population, climate change, limited land and freshwater resources, and the decline of wild fish stocks, concerns about future food security have increased. In this context, aquaculture has emerged as a vital and rapidly expanding sector that can provide an alternative and sustainable source of aquatic protein.

8. Management Measures to Mitigate Environmental Impacts of Aquaculture

Ensuring sustainable aquaculture requires the implementation of effective management measures at multiple levels to minimize environmental and social impacts. Practical strategies can be applied at the farm level as well as through broader planning, policy, and regulatory frameworks (Soto *et al.*, 2008).

8.1 Farm-Level Measures

8.1.1 Environmental Impact Assessment (EIA)

EIA is a critical tool for evaluating potential environmental and socio-economic impacts of

aquaculture projects, particularly large-scale operations. It can serve as:

- A decision-making tool to determine project feasibility
- An assessment of environmental and socio-economic risks
- A basis for developing environmental management and monitoring plans

EIA should include regular monitoring of water and sediment quality, key habitats, and sensitive species. It is particularly important to involve stakeholders and use scientifically sound information to guide sustainable practices (Soto *et al.*, 2008).

8.1.2 Better Management Practices (BMPs)

BMPs are practical, cost-effective measures to reduce negative environmental impacts and are often voluntary but highly effective when combined with government oversight. Key BMP strategies include:

- Site selection and pond design: Avoid ecologically sensitive areas such as mangroves and wetlands
- Optimized feeds and feeding strategies: Improve feed conversion ratios (FCRs) to reduce nutrient and organic matter discharge
- Effluent management and nutrient recycling: Treat Pond wastewater, reuse nutrient-rich residues, and integrate green infrastructure
- Containment and escape prevention: Secure nets and emergency protocols to prevent farmed species from escaping into the wild
- Disease and aquatic animal health management: Implement quarantine, vaccination, and biosecurity measures to limit disease spread and reduce chemical usage
- Water conservation and pond fallowing: Rotate sites and periodically fallow ponds to restore ecosystem balance

8.1.3 Feed and Nutrient Management

Efficient feed management reduces nutrient pollution and improves profitability. Practices

include using high-quality feed, minimizing overfeeding, and optimizing FCR. For filter feeders such as molluscs, proper feeding enhances nutrient uptake while reducing waste.

8.1.4 Wastewater and Sediment Treatment

Excess nutrients in effluents can be reused or treated using on-farm or community-scale infrastructure. Measures include:

- On-site treatment systems and sediment traps
- Recycling of nutrient-rich residues
- Site rotation and fallowing to allow natural ecosystem recovery
- Enhancement of natural treatment systems, such as constructed wetlands, to assimilate nutrients

CONCLUSION

Aquaculture is essential for food security and socio-economic development, but it can cause serious environmental impacts, including habitat loss, nutrient pollution, chemical contamination, and biodiversity decline. Sustainable aquaculture is achievable through responsible farm practices, such as optimized feeding, waste management, disease control, and containment, along with regulatory oversight and environmental monitoring. By balancing production with ecological protection and social well-being, aquaculture can continue to provide protein and

livelihoods without compromising the health of aquatic ecosystems for future generations.

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