

CHAPTER 2

Environmental Impacts of Fish Farming

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Abstract: Sustainable aquaculture promises to provide more productive, climate smart and environmentally responsible farming practices with reduced impacts on global environment. Fish farming, or aquaculture, can have both positive and negative effects on the aquatic environment. Negative impacts include chemical, genetic and nutrient pollution, eutrophication, habitat destruction. Proper management and environment friendly fish farming practices will result in mitigating effects of fish farming in aqueous environment

Keywords: Fish farming, Sustainable aquaculture, Aquatic environment, Pollution, Microplastics

Introduction

Aquaculture plays a major role in providing sufficient food, nutrition and livelihood for the growing world population. In 2022, global aquaculture production reached 130.9 million tonnes, valued at USD 312.8 billion, 59 percent of global fisheries and aquaculture production. Inland aquaculture contributed 62.6

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percent of farmed aquatic animals, marine and coastal aquaculture 37.4 percent. For the first time, aquaculture surpassed capture fisheries in aquatic animal production with 94.4 million tonnes, representing 51 percent of the world total and a record 57 percent of the production destined for human consumption. Aquatic animal production is expected to increase by 10 percent by 2032, driven by aquaculture expansion and capture fisheries recovery. It will reach 205 million tonnes – 111 million tonnes from aquaculture and 94 million tonnes from fisheries. Sustainable aquaculture promises to provide more productive, climate smart and environmentally responsible farming practices to feed the expected 9.7 billion world population by 2050 with reduced impacts on global environment. Fish farming, or aquaculture, can have both positive and negative effects on the aquatic environment. While it can help reduce pressure on wild fish populations and provide a sustainable food source, Production of culture fish will reduce the price of captured fish and provide more labour to local fisherman finally positive effect on conservation of wild fish population. Fish farming positively impact biodiversity by enhancing depleted stocks and natural production (Diana, 2009). It can also lead to pollution, habitat degradation, and other ecological problems if not managed properly. (FAO. 2024)

Nutrient Pollution and Eutrophication

One of the most important sources of pollution due to high nutrient and organic matter enrichment is feed wastage which in turn depends on type of fish cultured and feed used. The culture method used also plays a significant role in this disposal as cage method generates more wastage than in pond and raceway culture. Feed input will also release C, N and P in to the environment. Majority of organic matter from feed is accumulated in the sediment. Thicker deposit makes the recycling and mineralization of nutrients difficult due to the presence of anaerobic condition and absence of benthic reworks. Another important concern are feed additives like vitamins, pigments added to improved colouration of farmed fishes and therapeutants used to treat diseases. Antifouling agents used in cage farming possess another threat to environment. The impact due to organic and nutrient pollution is more in sediment than in water. Benthic organisms are adversely affected due to increase in SOD, release of toxic gases and oxygen deficit conditions. This condition changes flora and fauna of entire area particularly benthos. These impacts are usually localized and resolve gradually with the cessation of farming activities. Increase in BOD and nutrients lower the dissolved oxygen content in the farm area. (R.S.S Wu,1999)

Water quality of fish farms depends on interactions of physical, chemical and biological factors. The deterioration of water quality results from natural and artificial sources. The natural sources include wastes from solid and dissolved wastes from fish metabolism, waste food from intensive and semi-intensive farming only becomes harmful if they are released in excess. The artificial source include man-made chemicals which is used in the fish farm to treat diseases, anti- fouling agents, water treatment, feed additives, manures. Nutrients, organic matter and toxic pollutants released in to environment due to farming activities directly and indirectly affects the health of the ecosystem. Disturbance created by this organic matter decrease the amount of oxygen supply to burrowing forms and increase BOD. Enrichment of nutrients leads to Eutrophication which promote Harmful Algal blooms causing depletion of oxygen and releases toxins as in the case of redtide which results in mortality of farmed fish (Holmer et al, 2007)

Chemical Pollution

The growth of fish farming during the current decades also witnessed the use of various chemicals to increase fish growth, manage weeds, weed fishes, predators and aquatic insects, disinfectants and also usage of antibiotics and pesticides for the treatment of fish diseases. Introduction of these chemicals to aqueous environment adversely affect the health of ecosystem. Tetracyclines and fluoroquinolones are major antibiotics used in treating fish diseases. Misuse of antibiotics and pesticides to treat bacterial, fungal, viral and protozoan diseases leads to the development of antibiotic resistant microorganisms and alternation of fish symbiotic microbiota. These chemicals finally enter higher trophic levels producing physiological implications in human beings. Lack of expertise and knowledge of effective dosage make the condition worse. Proper and recommended usage of environment friendly chemicals will alleviate the problem. (Salma et al,2022, Bojarski et al, 2020, Iyiola et al,2023, Kim et. al., 2017)

Habitat Destruction

Conversion of mangroves to fish farms is another impact to environment due to growing demand in fish farming. Mangroves are ecotones with fluctuating environmental parameters are not ideal for fish farming due to high organic content, poor drainage and highly acidic condition. Mangroves provide sustainability of local population by providing food, fodder and protection from coastal erosion and cyclones. They provide nursery grounds for shrimp. These ecological services provided by mangroves make them more susceptible to environmental degradation. Clearing of mangrove forests for farming activities increase foreign exchange and employment opportunities to local population but the loss to nature is irreplaceable. Removal of vegetation affect both abiotic and biotic factors. This will alter the sediment quality and affect benthic communities. Mangroves play an important role in climate change mitigation by carbon sequestration. Deforestation of Mangrove results in exposure of this sediment C to oxygen due to microbial activity and final emission of GHG like methane and carbondioxide which contribute to global warming and climate change. (Malik et al,2017, Ahmed et al 2018, Granek et al,2008)

Genetic Pollution

The success of Pisciculture depends on good quality seeds and brood stocks. Genetically improved varieties with high FCR, disease resistance and adaptable to fluctuating environmental factors are preferred in modern farms. Natural calamities (flood, storm), transportation and equipment failure result in escape of this genetically improved species to natural habitat. This will replace the native species and act as a triggering factor in extinction of endemic species. Accidental or deliberative release of farmed species negatively impact the wild population at ecological and genetic levels. The genetic impacts include direct and indirect interactions. The direct effect involves reproductive interactions like hybridization with indigenous species will negatively alter the population structure and diversity of native species. Indirect interactions are ecological leading to competition, habitat destruction and introduction of parasites and disease causing pathogens to aqueous environment. Increased loss of biodiversity will impact character, abundance and vitality of species. Proper implementation of policies and monitoring will effectively reduce the escape of farmed species and finally mitigate their environmental impact. (Peeler et al, 2004, Lorenzen et al,2012, Bentsen et al,2005, Kolavani,2025)

Overfishing of Wild Populations

Carnivorous fish culture uses fish meal, fish oil and trash fish as feed ingredients which increases nutrient and flavour of farmed fish. About 90% of wild-caught fish are used for fish meal production. Wild fish populations are overexploited for obtaining this by products. Indirect environmental impact involves depriving food for higher trophic levels which include fishes, birds and mammals. This decreases the diversity of these piscivorous animals. Direct environmental impact is pollution produced by intensive farming method which uses fish meal and oil as feed ingredient. It also creates more pressure and dependence on capture fisheries. The situation become worse when environmentally contaminated feed is used as it is transferred in to higher consumers Trash fish based feed is highly perishable and leads to water pollution. Increased risk of diseases, fishing pressure on non commercial species, reduction in juveniles and more demand on trash fish species are main consequences.(Bedolfe,2015, Huntington et al , 2009))

Microplastics and Pharmaceutical Residues

One of the emerging challenges to the aquaculture practice is the detection of microplastics in all sources of water like surface water, ground water and waste water (Pashaei et al., 2022). Plastics of various sizes have been detected in aquafeed and facilities. Plastic particles less than 1 mm are considered as microplastics (MPs) (Imhof et al., 2013). Plastics within the millimetre to sub-millimetre size are include under the term MPs (GESAMP, 2015). According to Ferrando (2021), polyethylene (PE) polymer is the most prevalent in the global environment, followedby polypropylene (PP), polyvinylchloride (PVC), polyurethane, polyethylene terephthalate (PET), polystyrene (PS) and others and can exist in different forms ranging from plastic resins (powder) to microbeads and macropolymers. In aquaculture MPs mainly come from different sources like fish gears, dilapidated or weathered of fish culture facilities, fishmeal, and culture water, wastewater from treatment plants, personal protective equipment, and feedstuff etc. (Cole et al., 2011; Hanachi et al., 2019; Murphy et al., 2016; Thiele et al., 2021). MPs have a significant impact on wild and domestic fish stocks. Main outcome of MPs uptake include obstruction cum mechanical damage of the digestive system, resulting to starvation and consequent puncture of the stomach and intestine, of which can cause death in severe cases (Farrell & Nelson, 2013; Kühn et al., 2015, pp. 75–116; Seltenrich, 2015; Sharma & Chatterjee, 2017). Microplastics are emerging as a great threat to aquatic ecosystem. Regulation on the use of single-use plastic, finding alternative protein sources for fish meal, waste water recycling, biodegradation of plastics, following 3R's are some of the ways to control this alarming condition (Iheanacho et al., 2023).

Innovations For Environment Friendly Aquaculture

Recirculating Aquaculture Systems (RAS) and Environmental Control

A self-reliant aquaculture system in which water is recycled is called Recirculating Aquaculture System(RAS)(Holan et al 2020).Unlike the traditional method RAS rears fish in indoor tanks with a controlled conditions and an adaptive strategy to meet climate change(Narsale et al., 2024,Cheruiyot et at.,2023, Føreet al.,2018, Wang et al.,2021) RAS removes waste products like ammonium, CO₂ from the water and the purified water after saturation with oxygen is returned to the tank (Piedrahita et al., 1996). This can be performed in any place including urban areas. Water quality is maintained by different methods like physical, chemical biological filtration and U V sterilization as the disinfection process. To ensure the quality of the recycled water, different parameters are checked and oxygenation and aeration are done. Fishes which are robust, disease resistant, fast growing are selected for RAS farming. Tilapia, Carp and catfish are some of the examples of such fishes (Jham lal et al.,2024). The initial investment and operating cost depends on the type of fish, size of operation and location. Largest operating expense is feed (Jham Lal et al., 2024). For aquaculture's intensive fish production and water conservation, recirculating aquaculture systems are a useful and pertinent technology (Aji., 2012).

Integrated Multi-Trophic Aquaculture (IMTA)

Productivity and profitability within short time have commercialised the pond aquaculture. But heavy feed application and waste accumulation together with high stock causes waste accumulation and bottom soil contamination, which in turn negatively affect the farming. (Pawar et al.,2020). Mixed culture cultivation at all possible trophic levels will enhance the efficiency of ecosystem productivity in eco-friendly manner is called Integrated Multi-Trophic Aquaculture (Shinde, et. al., 2024; Chopin,2010). IMTA system has already evolved in fresh, brackish and marine water with sustainable approaches by many countries (Azhar & Memis,2023). This technique uses extractive species along with fed species; thus, this blend will improve the management, economic stability and environmental sustainability through bio mitigation.

A successful IMTA operation necessitates careful selection, arrangement and placing of various components in a farm. Species selection and design of the system should be properly planned to reduce the recovery of waste products. Adequate planning for removing large organic particles of by deposit feeders and suspended particles by filter feeders must be done. Seaweeds also to be include to remove inorganic dissolved nutrients from water (Sukhdhane., 2018). World need to explore the area of IMTA.

Data-Driven and Machine Learning Applications

Global aquaculture has been developed strikingly over the years, still the processes depend upon labour intensive traditional methods. Environmental impacts and low production efficiency are still posing problems to this industry (Dinakaran et al,2023). By automating and applying smart technologies in water monitoring, feeding, fish behaviour etc may help to revive these practices in a modern way. Auto ML is such a IoT used to observe and analyse fish behaviour (O'Donncha et al.,2021). Initial cost of application such new methods are high and challenges like dta quality, integration and scalability are to be properly addressed before completely depending upon IoT (De Villa Delfino et al., 2024)

Conclusion

Aquaculture was introduced as an ecofriendly source of employment and income for the unprivileged segment of the society and those residing in water-surrounded places. Society considers economic growth aspect when discussing the benefits and draw backs. In-depth research is urgently needed to comprehend these detrimental effects and practise sustainable fish farming

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