3.6 Intensification vs sustainability in aquaculture

In India, over 1.4 billion people are significantly affected by environmental issues arising from agricultural intensification, which impacts both terrestrial and aquatic ecosystems. Inland aquatic resources have declined over recent decades due to landscape destruction, water pollution, and the over-exploitation of fish stocks, leading to a marked depletion in biodiversity. Intensive aquaculture contributes to this lack of sustainability through nutrient enrichment, soil leaching, and groundwater salinization. A critical concern is the widespread use of antibacterial medicines; the discharge of antibiotics into the environment-often via wastewater-facilitates the development of selective drug resistance in bacteria. Exposure to sub-lethal levels of these compounds allows bacteria to evolve resistance, making future infections increasingly difficult to treat with standard clinical medicines (Pillay, 1994).

Marine pollution, driven by eutrophication and the sedimentation of organic matter, acts as a significant pollutant source, causing harmful environmental impacts as large amounts of nutrients sink to the benthos (Dawood and Koshio, 2020). Intensification results in habitat destruction and compromised water quality due to the accumulation of metabolic waste and uneaten feed, which ultimately stresses the cultured organisms. The environmental footprint varies across systems; extensive systems have minimal impact, whereas intensive operations generate substantial waste depending on stocking density, feed inputs, and waste treatment efficiency (Maulu et al., 2021). Common detrimental practices include the release of dissolved nutrients, feces, and carcasses into water bodies containing aquaculture cages. Consequently, pathogens such as *Aeromonas salmonicida*, *Vibrio* sp., and motile aeromonads have developed significant resistance. Furthermore, fish larvae and fingerlings are highly vulnerable to pesticides and heavy metal pollution, which primarily damage the gill, kidney, and liver tissues (De Kinkelin and Michel, 1992).

Globally, sustainable aquaculture has become a revitalizing economic force for rural communities. To achieve long-term viability, there is an increasing emphasis on eco-labeling and the adoption of ecosystem-based approaches (FAO 2009a, b; Davenport et al., 2018). While some chemicals used in aquaculture, such as certain parasiticides, break down quickly, others like organotin and antibiotics-including oxytetracycline and flumequine-can significantly alter bacterial ecology and sedimentation processes (Shah et al., 2018). The residual effects of hormones used for induced spawning and growth stimulation also pose potential health hazards to humans. Ecologically, the most severe impacts include the loss of biodiversity and the destruction of mangroves, which serve as vital breeding grounds. Globally, shrimp pond construction has led to the loss of approximately 3.7 million acres of mangroves; in some Asian nations, this accounts for 27% to 50% of total mangrove area (Pillay, 1994). In contrast, the removal of mangroves for shrimp farming is less common in India, where strategies focus on integrated and responsible farming practices to address sustainability (Ninawe, 1999).

4 Risks/ Hazards in Aquaculture

4.1 Issues and concerns

Aquaculture plays a critical role in global food production, and its sustainable development is a key focus for international bodies like the United Nations (UN) and the Food and Agriculture Organization (FAO). The concept of sustainability, as defined by the World Commission on Environment and Development (WCED), emphasizes meeting current needs without compromising the ability of future generations to meet their own. This necessitates adopting practices that ensure long-term productivity, minimize environmental impacts-such as waste and pollution-and contribute to economic growth across related sectors like agriculture and forestry. Historically, the FAO has recognized that responsible management is essential for securing future food supplies and maintaining healthy ecosystems. FAO declarations provide the foundation for policies aimed at ensuring the long-term viability of aquatic food systems by minimizing waste and pollution in adherence with the broader sectors of agriculture, fisheries, and forestry (FAO, 1988).

Risk analysis in aquaculture involves identifying potential hazards with the capacity to cause economic loss or introduce harmful pathogens into the aquatic environment, which impacts genetic diversity, ecological integrity, and food safety. These hazards can have a broad impact on the environment and human health, often leading to