Impact of Climate Change on Fish Farming Practices

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ABSTRACT

Climate change is a significant danger to the stability and productivity of the aquaculture system worldwide. Since fish cultivation becomes an important important component of global food security, the region must be suitable for increasing environmental challenges such as rising temperatures, sea acidification, shifting rain patterns and spreading diseases and spreading diseases and harmful algal blooms. This review explains the versatile effects of climate change on fish cultivation practices, exposing physical stress on aquatic organisms, availability of water and quality disruption and increased risk of pathogen's outbreak. In addition, it emphasizes the importance of species and livelihood diversification, climate-flexible farming strategies, and carbon emission mitigation to protect the economic and ecological viability of aquaculture. Permanent adaptation and technological progress are necessary to ensure that these adverse effects can continue to compete and ensure that the rapidly changing climate can continue to contribute to food security and rural livelihood.

INTRODUCTION

Aquaculture has become a major industry in food production over the last 20 years, accounting for 82.1 million tons (46%) of the 179 million tons of fish produced worldwide. According to FAO 2020, 53% of fish production is expected to come from aquaculture by 2030. In the face of population increase and climate change, the issue is to ensure sustainable growth to fulfill rising demand (Maulu *et al.* 2021). Water quality is already declining globally due to droughts, harsh weather, and climate variability. In order to improve aquaculture's sustainability and resilience against biological and physical effects, this study looks at climate-smart alternatives.

Climate Change Factor	Impacts on Aquaculture & Fisheries	Adaptation / Mitigation Strategies
Rising Temperature	Heat stress, reduced survival of cold-water species, increased HABs, pathogen spread, higher costs	Climate-flexible species, improved management, technological innovation
Ocean Acidification	Weakens shells, alters physiology & markets, affects seaweed production	R&D, selective breeding, carbon mitigation
Rainfall & Water Availability	Longer dry seasons, droughts, water scarcity for farming & communities	Integrated water management, GIS-based monitoring, efficient use
Diseases & HABs	More outbreaks, higher mortality, hypoxia, organ damage, losses in shellfish & finfish	Biosecurity, diversification, nutrient management, early warning systems
Economic Impacts	Changed distribution, catch composition, reduced revenues, ENSO-driven shocks (e.g., $8.2B loss in Peru)	Diversification , insurance, policy support, sustainable harvest practices
Livelihood Diversification	Increased resilience, income stability, reduced vulnerability to climate shocks	Integration with agriculture, non-aqua ventures, policy support, R&D

Rising Temperature

The growth and development of aquatic organisms are significantly impacted by temperature (Ngoan *et al,* 2018). Fish are extremely vulnerable to climate-induced warming because they are poikilothermic. Cold-water species including salmon, cod, and halibut may experience higher mortality rates from thermal stress as a result of a predicted 1.5°C rise. Immunity, metabolism, nutrition, development, and general physiology are all impacted by prolonged stress. Additionally, warming causes toxic algal blooms, changes the nitrogen cycle, and decreases the oceans' ability to absorb carbon, which increases expenses and decreases production. Although there are still unanswered questions, warming may help warm-water species like prawns, oysters, and tilapia as well as prolong growing seasons in temperate and Arctic regions. While these changes present social and economic opportunities, they also endanger the sustainability of the ecosystem.

Ocean acidification

Even though the data are far more few than those on temperature changes, a rise in ocean salinity may be a sensitive but Climate processes like evaporation, precipitation, and glacier melt are indirectly predicted by the oceans. They lower pH and accelerate ocean acidification by absorbing almost half of CO_2 emissions from fossil fuels and cement since industrialization (Hu *et al.,* 2022). Predictions are challenging because, whereas the chemical reactions of CO_2 in saltwater are well recognized, the biological effects are still unclear. Acidification weakens calcified skeletons in marine animals via lowering calcium carbonate saturation. Additionally, it may change commercial features, species physiology, and consumer preferences. Depending on how well a species absorbs inorganic carbon, seaweed output can vary.

Rising dependency on fish farming for food security

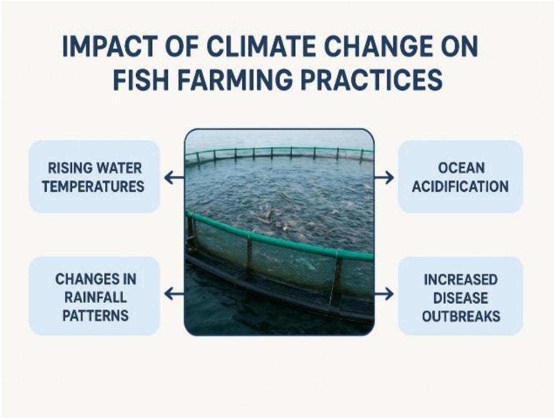
A major global concern is the production of sustainable food, since agriculture is responsible for 25% of greenhouse gas emissions, 75% of deforestation, and 70% of freshwater consumption. Fish raised for food have much smaller carbon, land, and water footprints than meat from the wild. While expanded aquaculture reduces some pressures, it exacerbates eutrophication and acidification by shifting the effects on crop-based feeds, fishmeal, energy, and land for water quality. Improved environmental performance evaluations assist the sustainable growth of bivalve systems, recirculating aquaculture, and marine finfish.

Introduction to climate change and its global environmental effects

Food security, livelihoods, and economic growth are all bolstered by marine fisheries (FAO, 2022). However, the physiology, reproduction, and dependent populations of species are all impacted by climate change, which exacerbates overfishing, pollution, and habitat loss through rising temperatures and changed biogeochemistry. By using fuel and power, fishermen also release greenhouse gases into the atmosphere, contributing to sea level rise and ocean acidification. Beyond their effects on the atmosphere, these pollutants pose a hazard to marine ecosystems. To protect marine resources and maintain sustainability, carbon emissions must be reduced and efficient mitigation techniques must be put in place.

Livelihood and species diversification

Diversification provides farmers with more revenue streams and increases their resilience to climate change. In areas where aquaculture may be declining, aquaculture systems should interact with agriculture or other industries to increase revenue (Maulu *et al.*, 2021). Promoting non-aquaculture endeavors among families and fish farmers increases financial securit. Policies that effectively promote sustainability, efficiency, and equity are crucial. Diversity in species and systems promotes ecological, social, and economic stability while enhancing resilience to climate-related disasters (Sinha, 2023). Increasing species farming through technology and domestication provides adaptation, but it also necessitates risk assessment, biosecurity planning, and R&D expenditure.



Changes in Rainfall Patterns and Water Availability

Climate change has caused mid-latitude regions to become wetter and tropical and subtropical regions to become drier. In addition to changing rainfall patterns, rising global temperatures also lengthen dry seasons, shorten rainy seasons, and exacerbate extreme weather events. Water resources for drinking, industry, and ecosystems are at risk due to decreased rainfall and extended drought. El Niño has caused droughts in parts of Indonesia like Pangkep, Barru, and Soppeng, extending dry seasons and reducing water supplies (Nuryadin *et al.,* 2024). Geographical considerations limit water, a vital resource for human survival, both spatially and temporally. Precipitation, the main source of surface water, is shaped by the global water cycle, which climate change disrupts. Since water is essential for daily needs—drinking, cooking, bathing, and cleaning—its scarcity directly impacts communities. Without reliable access, both urban and rural populations face shortages, crises, and severe challenges to meeting basic demands.

Diseases and Harmful Algal Blooms

Fish and shellfish are more susceptible to bacterial, viral, parasitic, and fungal infections as a result of rising temperatures, which also raises the danger of aquaculture diseases. Frequent outbreaks and financial losses result from heat stress's enhancement of pathogen proliferation, virulence, and transmission. While some cold-water diseases may decrease in salmon farming, warm-water diseases like sea lice may get worse. Additionally, eutrophication and nutrient loading exacerbate harmful algal blooms (HABs), which result in hypoxia, acidification, organ damage, and fish death. The sustainability of aquaculture and coastal ecosystems are at risk due to these combined pressures.

Economic impacts on fisheries

Fishing economics are predicted to be impacted by climate change, which will modify the quantity, quality, and distribution of marine species throughout exclusive economic zones. Changes in catch value, expenses, incomes, firm profits, discount rates, and economic rent are a few examples of potential effects. Although they don't last as long as climate change, ENSO occurrences serve as an example of these effects. Chilean and Peruvian pelagic landings fell 50% during the 1997–1998 El Niño, which resulted in a US$8.2 billion decline in fishmeal export prices and significant employment and income losses. Mackerel landings in Southeast Asia also indicated short-term economic benefits, and Icelandic fisheries also benefited. However, catch composition is important; in the Celtic Sea, increased captures of smaller, low-value species resulted in lower overall revenues. Peru's pelagic losses during El Niño also caused over US$26 million in income decline across the Southern Hemisphere.

CONCLUSION

Aquaculture and fisheries are at serious risk from climate change due to increased temperatures, acidity of the ocean, changes in rainfall patterns, and disease outbreaks. Fish physiology, water availability, and ecological balance are all impacted by these effects, which lower production efficiency and financial returns. The long-term viability of some warm-water species is still in jeopardy. Climate-smart behaviors, carbon emission reduction, and livelihood diversification are essential adaptation tactics. Innovation in technology, better governance, and ecosystem-based management are necessary to guarantee that aquaculture will continue to sustain livelihoods and food security in the face of climate change.

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