Climate Change and its Effect on Aquatic Ecosystem

Binal Rajeshbhai Khalasi[1]*, Chonyo Shinglai[1], Prabhutva Chaturvedi[2]*, Sheethal K.U [1], Narendra Kumar Maurya[1] and Shiwam Dubey[1]

[1]*College of Fisheries, Karnataka Veterinary, Animal and Fisheries Sciences, University, Mangaluru -575002*
[2]*College of Fisheries Science, Chaudhary Charan Singh Haryana Agricultural University, CCSHAU, Hisar - 125004*

Corresponding Author
Binal Rajeshbhai Khalasi
Email: binalkhalasi1920@gmail.com
Prabhutva Chaturvedi
Email: chaturvediprabhutva@gmail.com

OPEN ACCESS

Keywords

Climate change, Aquatic ecosystem, Species diversity, Productivity, Biodiversity, Conservation

How to cite this article:

Khalasi, B. R., Shinglai, C., Chaturvedi, P., Sheethal, K. U., Maurya, N. K. and Dubey, S. 2025. Climate Change and its Effect on Aquatic Ecosystem. *Vigyan Varta* 6 (6): 84-90.

ABSTRACT

Climate change is widely recognized as one of the most significant and multifaceted challenges facing the world today. It refers to alterations in climate patterns that may occur over brief periods or span across centuries, resulting from both natural processes and human-induced activities. These changes are now increasingly affecting how ecosystems respond and adapt. Aquatic life and freshwater ecosystems are particularly vulnerable, facing multiple pressures linked to changing climatic conditions. Variations in rainfall and surface runoff significantly affect both the quantity and quality of aquatic habitats, indirectly altering ecosystem productivity and species diversity. Aquatic species and the ecological balance of water-based environments are at considerable risk. Warmer water temperatures can disrupt the normal biological processes of aquatic species, affecting their growth, reproduction, feeding patterns, distribution, and overall population dynamics. This growing threat highlights the importance of conserving biodiversity, which provides essential resilience and protection against environmental disturbances.

INTRODUCTION

Climate refers to the average and long-term atmospheric patterns observed in a particular geographic region, incorporating key elements such as temperature, moisture levels, rainfall, and wind speed. In contrast, weather represents short-lived atmospheric conditions that may change from day to day or week to week. Climate, however, is understood over extended durations—often spanning years, decades, centuries, or even millennia. In recent years, both naturally occurring variations and increasing human activities, particularly the emission of greenhouse gases and land-use changes, have significantly altered climatic patterns worldwide. These changes are not only evident at the global level but also manifest regionally and locally, creating a wide range of environmental shifts. One of the most concerning outcomes of this evolving climate scenario is its direct impact on living organisms. Species at different stages of their life cycles are experiencing physiological, behavioral, and morphological disruptions as they attempt to adapt to changing environmental conditions. These responses may include altered breeding cycles, migration patterns, and feeding behaviors. In aquatic systems, especially in freshwater and marine environments, climate change has further complicated the biological dynamics that govern fish growth, reproduction, and survival. These disruptions ultimately threaten the productivity and long-term sustainability of global fisheries, which are vital for food security, livelihoods, and ecosystem balance. Therefore, understanding and addressing the implications of climate change on biodiversity and fisheries is essential for maintaining ecological integrity and ensuring the resilience of aquatic ecosystems.

According to Baillie *et al*. (2004), human-induced modifications to natural environments significantly affect global biodiversity. Natural fluctuations in climate already contribute to ongoing shifts in biodiversity, but the added pressure of human-induced climate change has intensified the rate at which species are being lost. This modern climate shift, largely fueled by industrial activity, deforestation, and pollution, compounds existing environmental stresses caused by human actions. Since water covers nearly 70% of the Earth's surface, aquatic ecosystems are particularly vulnerable to climate-related changes. Rising temperatures, even at slight levels, can have widespread effects—such as changing the direction and strength of ocean currents. These changes, in turn, influence the distribution, productivity, and stability of aquatic life. Aquatic ecosystems are generally divided into two main types: marine ecosystems, which include oceans and seas with high salinity, and freshwater ecosystems, which consist of rivers, lakes, streams, and wetlands with low salt concentrations.

"Climate variability" refers to fluctuations in temperature, wind patterns, and hydrological cycles that occur over periods ranging from years to decades. In contrast, "climate change" refers to more extended shifts in average climate conditions over much longer periods. It is crucial to differentiate between natural climate variability, natural climate change, and human-induced climate alterations. However, pinpointing the exact causes of specific observed effects is a challenging task (IPCC, 2003). The physical and chemical environment experiences natural changes on various timescales—daily, seasonally, or over longer durations such as the 18.6-year nodal tide cycle, which is tied to the Earth's orbital movements. Climate change has the potential to affect the frequency and severity of extreme weather events, such as floods, droughts, heatwaves, and hurricanes. While directly

linking any specific extreme event to human-driven climate change is complex, the likelihood of such events occurring more frequently can be predicted (IPCC, 2003). There is a high probability (greater than 90% chance) that hot extremes, heatwaves, and heavy rainfall events will continue to increase in frequency.

Causes of climate change

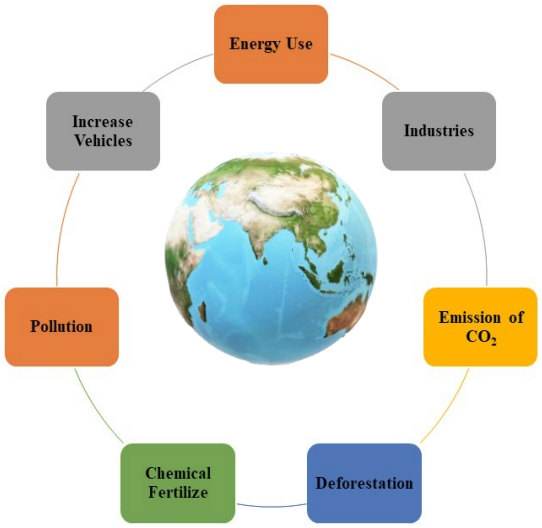

Fig. Causes of climate change

Climate change and the hydrologic cycle

The warming of the climate has significant implications for the hydrological cycle. Changes in precipitation patterns, temperatures, and other climate factors, along with the thawing of ice and snow, are influencing the quantity, quality, and seasonal timing of water resources. As a result, shifts in aquatic ecosystems are inevitable. Climate change is already causing the warming and thawing of permafrost in northern regions and accelerating the reduction of glaciers in mountainous areas, impacting water availability in downstream areas. Moreover, the melting of Arctic Sea ice has the potential to disrupt or slow the global ocean circulation system, which plays a critical role in marine ecosystems.

Alterations in the hydrological cycle will have a major impact on freshwater ecosystems, making it difficult to predict outcomes accurately. As temperatures rise, both evaporation from water bodies and plant transpiration will increase, thereby amplifying the water cycle. This will directly affect lake ecosystems by causing temperature increases and changes in water movement. Additionally, shifts in precipitation will significantly alter the flow patterns of rivers and wetlands, intensifying the effects of human water use in developed river basins.

Impact of climate change on fish production and ecosystem

Fisheries and aquaculture depend heavily on the complex relationships between various factors, including the Earth's climate and oceanic conditions. As a result, changes in air and sea surface temperatures, rainfall, sea levels, ocean acidity, and wind patterns can have signifi cant negative impacts on these industries. Climate change is increasingly affecting communities and livelihoods that depend on fisheries and aquaculture, highlighting the need for adaptation and mitigation strategies that focus on human welfare. In particular, tropical regions are witnessing severe consequences of climate change, impacting both the ecosystems and communities that rely on them.

Marine Ecosystems

Climate change has a profound impact on marine fish production, disrupting various aspects of the ocean environment. Shifts in climatic conditions are leading to rising temperatures, the melting of polar ice, rising sea levels, changes in ocean currents, and increasing acidification of seawater. Over the coming decades, it is expected that the temperature in the Indian Ocean will rise by 1–3°C. The first group to be significantly affected by these changes will be plankton,

which forms the base of the marine food web. As plankton populations decline, other marine species, including corals, fish, and seabirds, will also face severe challenges. Ocean acidification, in particular, could hinder marine organisms such as oysters, shrimps, and corals from producing their protective shells through the process of calcification. This disruption within the marine food web could trigger cascading effects that compromise the health and balance of marine ecosystems. Marine species may respond to climate change in various ways, such as altering their physiology, phenology, distribution ranges, and ecological interactions (e.g., Perry *et al*. 2005, Cheung *et al*. 2009). These biological changes directly influence the distribution and productivity of marine fisheries. Simulation models that consider the primary biological reactions to changes in climate and ocean conditions have been used to predict these shifts (Cheung *et al*., 2010).

Freshwater systems

Freshwater ecosystems are particularly vulnerable to climate change, with factors such as lake size, depth, and trophic state influencing their level of susceptibility. Research by Field and colleagues highlights that cold-water species tend to suffer negative effects, while warm-water species experience more favorable conditions. Climate change is causing significant shifts in the size and distribution of freshwater lakes, with some lakes vanishing entirely due to changes in precipitation, evaporation, and runoff patterns. Although warmer temperatures are expected to boost fish production in the long term, changes in the composition of prey species could undermine these potential increases. In the short term, mismatches in the timing of biological events are expected to reduce fish production. The ability of freshwater species to migrate is essential for their survival and adaptation to the impacts of climate change.

Climate Changes Effects on Capture and Culture Fisheries

Climate change is significantly affecting the production, ecology, and biodiversity of aquatic ecosystems, resulting in shifts in species composition in catches, reduced production and yields (especially noticeable in tropical areas), increased fluctuations in yields, and higher incidences of diseases, coral bleaching, calcification problems, and distribution changes. These environmental shifts are also having profound effects on the socioeconomic conditions of the fisheries and aquaculture industries globally, contributing to higher levels of poverty and food insecurity in communities that rely on fish and fishery products. Moreover, these changes pose significant challenges for governance and management within the sector. Climate change exerts both direct and indirect effects on fish stocks. Direct effects impact fish physiology and behavior, influencing growth, reproduction, mortality, and distribution. Indirect effects, on the other hand, modify the productivity, structure, and composition of marine ecosystems, which are vital for providing food for fish.

The Effects of Climate Change on Aquaculture

Recently, there has been increasing attention on how climate change affects the sustainability of aquaculture. This growing interest stems from the sector's crucial role in ensuring global food security, nutrition, and providing livelihoods. The effects of climate change on aquaculture are expected to vary based on several factors, including geographic location, economic status, regions, production methods, and the species being farmed. Moreover, the effects on aquaculture producers are likely to differ depending on the specific environmental conditions of their

farming systems, whether they are freshwater, brackish, or marine environments.

The impacts of climate change on aquaculture production are anticipated to occur through both direct and indirect pathways. Direct effects include changes in the physical and physiological characteristics of finfish and shellfish populations within aquaculture systems. Indirect effects, on the other hand, may arise from shifts in primary and secondary productivity, as well as alterations in the structure of ecosystems. Additionally, climate change could affect the availability of essential inputs and the prices of products, such as fishmeal and fish oil, along with other goods and services required by fishers and aquaculture operators.

Effects on Aquatic Birds and Mammals

With a growing understanding of the important role climate plays in influencing the population dynamics of waterfowl and aquatic wildlife, it is highly likely that rapid and ongoing climate changes will lead to significant fluctuations in native species. The responses of aquatic birds and mammals at the population and community levels are likely to be influenced by a combination of direct and indirect effects. These may include changes in the severity of winters, variations in the distribution and depth of seasonal snow and ice, shifts in the timing and peaks of lake, pond, and wetland productivity, alterations in predator-prey relationships, changes in parasite-host interactions, and variations in habitat quality and distribution. furthermore, changes in the frequency, intensity, and distribution of fires are also expected to affect these species.

Shallow Arctic lakes and ponds that do not have a thermocline are expected to experience a range of direct and indirect effects due to rising temperatures. As summer temperatures increase, they are likely to surpass the preferred physiological ranges of algae, plankton, and benthic invertebrates, leading to substantial shifts in their diversity and abundance over time. These changes at lower trophic levels will probably result in earlier or reduced seasonal peaks in the abundance of essential food sources. As a result, these shifts may create mismatches between the timing of resource availability and the breeding schedules of higher-level consumers. This disruption could negatively impact the reproductive success of species such as waterfowl, which rely on these resources during their breeding periods.

Many shorebird species, such as sandpipers, plovers, snipe, godwits, and curlews, rely on the water levels and stability of shallow wetlands for their survival. For example, several North American shorebird species breed in the Arctic, with ten species commonly found in the outer Mackenzie Delta (Gratto-Trevor, 1994 and 1997). These birds depend on invertebrates as their primary food source during the breeding season, and the hatchlings, in particular, rely heavily on mosquitoes and chironomids, which are the preferred food for growing young birds.

Adaptation and mitigation measures to reduce the effects of climate change

Efforts to manage and reduce the impacts of climate change require both adaptation and mitigation strategies. Adaptation focuses on reducing the vulnerability of ecosystems and communities to climate change by modifying policies, practices, and infrastructure. On the other hand, mitigation seeks to lower or prevent greenhouse gas emissions through actions like adopting renewable energy sources, improving energy efficiency, and promoting sustainable land use and forestry practices. A combined approach of both adaptation and mitigation is crucial for

effectively tackling the challenges that climate change presents.

The long-term effects of climate change on fisheries could be significant, though they remain highly uncertain. What can be stated with a high level of confidence is that the future of fisheries will largely depend on the progress made in reducing current fishing practices and addressing other human-driven impacts. In an optimistic scenario, excessive fishing would be reduced, and other anthropogenic pressures would be lessened, which would allow the effects of climate change to affect more resilient ecosystems. In contrast, a pessimistic scenario would see continued overfishing of major capture fisheries, leading to further degradation of marine ecosystems. In this case, the added stress of climate change would be even more damaging, as it would be impacting already stressed ecosystems with fish populations that are lower and therefore less able to recover.

Recommendations to enhance the management of fisheries in response to climate change

- The ecosystem-based approach should be holistic, efficient, well-integrated, straightforward, and continuously evaluated to guarantee the successful management of coastal areas, fisheries, and aquaculture.
- Environmentally sustainable aquaculture and fishing practices should be adopted, with energy-efficient methods implemented in both sectors.
- Climate-resilient aquaculture should be incorporated alongside other sectors.
- Overfishing and excessive fishing capacity should be prevented by implementing systems that reduce subsidies.
- Risk assessments must be precise and thorough at the local level.
- It is advisable to investigate the carbon sequestration processes occurring in aquatic ecosystems.

Steps for sustaining the fish production and economy against climate change

A significant knowledge gap exists between fisheries and aquaculture management and climate change, which must be practically addressed. To evaluate the risks that climate change poses to coastal populations, it is essential to enhance both human and institutional capacities and implement effective adaptation and mitigation strategies. Properly managed fisheries and aquaculture have the potential to foster a thriving and sustainable ecosystem. The responsible use of coastal and watershed areas should be treated as a shared responsibility across various sectors to support the development of such ecosystems. Furthermore, actively involving youth in all policy and decision-making processes concerning aquaculture and fisheries—at both national and continental levels—should be formally established, recognizing that young people are the foundation of our society.

CONCLUSIONS

Climate change is expected to bring about substantial changes to hydrological patterns, including variations in runoff, water levels, the presence and duration of ice on rivers and lakes, as well as alterations in thermal conditions. These changes are likely to significantly influence key ecological and chemical processes such as carbon cycling and broader biogeochemical dynamics. In turn, this will affect aquatic biodiversity, the resilience and adaptability of aquatic organisms, and the structure and function of food webs, ultimately influencing primary and secondary productivity within these ecosystems. Additionally, shifts in the distribution, range, and the quality and availability of habitats for

aquatic mammals and waterfowl are anticipated. One particularly concerning consequence is the accelerated thawing of permafrost, which is expected to increase the influx of nutrients, sediments, and carbon into freshwater systems. These changes may have both beneficial and detrimental effects on freshwater chemistry, altering ecosystem functioning and the suitability of habitats for numerous aquatic species, including mammals and birds that rely on these environments.

REFERENCE

Barange, M., & Perry, R. I. (2009). Physical and ecological impacts of climate change relevant to marine and inland capture fisheries and aquaculture. In *Climate change implications for fisheries and aquaculture: Overview of current scientific knowledge* (FAO Fisheries and Aquaculture Technical Paper No. 530, pp. 7–106). FAO.

Brander, K. (2010). Impacts of climate change on fisheries. *Journal of Marine Systems, 79*(3–4), 389–402. https://doi.org/10.1016/j.jmarsys.2008.12.015

Cheung, W. W. L., Lam, V. W. Y., & Pauly, D. (2008). Dynamic bioclimate envelope model to predict climate-induced changes in distribution of marine fishes and invertebrates. In W. W. L. Cheung, V. W. Y. Lam, & D. Pauly (Eds.), *Modelling present and climate-shifted distributions of marine fishes and invertebrates* (Fisheries Centre Research Reports, Vol. 16, pp. 5–50). University of British Columbia.

Cheung, W. W. L., Lam, V. W. Y., Sarmiento, J. L., Kelly, K., Watson, R., Zeller, D., & Pauly, D. (2010). Large-scale redistribution of maximum fisheries catch potential in the global ocean under climate change. *Global Change Biology, 16*(1), 24–35. https://doi.org/10.1111/j.1365-2486.2009.01995.x

Gratto-Trevor, C. L. (1994). Potential effect of global climate change on shorebirds in the Mackenzie Delta Lowlands. In S. J. Cohen (Ed.), *Mackenzie Basin Impact Study (MBIS) Interim Report #2*. Environment Canada.

Gratto-Trevor, C. L. (1997). Climate change: Proposed effects on shorebird habitat, prey, and numbers in the outer Mackenzie Delta. In S. J. Cohen (Ed.), *Mackenzie Basin Impact Study (MBIS) Final Report*. Environment Canada.

Intergovernmental Panel on Climate Change (IPCC). (2003). *The IPCC workshop on the detection and attribution of the effects of climate change* (81 pp.).

Intergovernmental Panel on Climate Change (IPCC). (2007). *Climate change 2007: The physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (996 pp.).

Lam, V. W. Y., Cheung, W. W. L., Swartz, W., & Sumaila, U. R. (2012). Climate change impacts on fisheries in West Africa: Implications for economic, food and nutritional security. *African Journal of Marine Science, 34*(1), 103–117. https://doi.org/10.2989/1814232X.2012.673294

Perry, A. L., Low, P. J., Ellis, J. R., & Reynolds, J. D. (2005). Climate change and distribution shifts in marine fishes. *Nature, 308*, 1912–1915. https://doi.org/10.1038/nature03059

Prakash, S. (2021). Impact of climate change on aquatic ecosystem and its biodiversity: An overview. *International Journal of Biological Innovations, 3*(2). https://doi.org/10.46505/IJBI.2021.3205