



Research Paper

Impact of Climate Change in Fish Biology

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Abstract: Climate refers to the long-term average pattern of weather conditions in a particular area, while climate change denotes persistent changes in climatic conditions resulting from natural and anthropogenic factors. Climate change can substantially affect inland fisheries by altering water temperature, dissolved oxygen, salinity, pH, water availability, biodiversity and productivity, thereby influencing fish growth, reproduction, survival and food security. In marine

ecosystems, climate change affects species habitats, distributions and biological characteristics, leading many fish species to shift towards higher latitudes and modify their horizontal and vertical movements in response to changing environmental conditions.

Keywords: Aquatic ecosystems, Biodiversity, Climate change, Environmental change, Fish biology.

Introduction:

Climate is defined as the average weather conditions, characterized by long-term statistics for the meteorological elements in a given area. While climate change (CC) is described as the change in the climate of an area as a result of anthropogenic and natural disorders such as the depletion of the ozone layer and greenhouse effects. There for the twentieth century experienced the strongest warming trend of the last millennium with average temperatures rising by about 0.6°C. However, future temperature rises are

likely to exceed this with a predicted rise of between 0.1 and 2°C per decade CC affects species and ecosystem composition and function both directly increases in temperature and changes in precipitation water temperature and sea level and indirectly (changes the intensity and frequency of wildfires). The species in both terrestrial and marine ecosystems are vulnerable to climate changes and die out in their present areas and colonize new sites. At a changing climate in the future, there will be disruption of natural communities and extinction of species (Muluneh, 2021).

Causes of Climate change

Climate change may result from factors such as changes in solar emission, long-term changes in the earth's orbital elements (eccentricity, obliquity of the ecliptic, the procession of the equinoxes), natural processes and human forcing on a planet. Though CC is due to alteration in external forcing (natural factors or human activities) future projections consider the influence

of only anthropogenic increases in greenhouse gases and other human related factors. Climate is defined as the average weather conditions, characterized by long term statistics for the meteorological elements in a given area. While climate change (CC) is described as the change in the climate of an area as a result of anthropogenic and natural disorders such as the depletion of the ozone layer and greenhouse effects (Muluneh, 2021).

Agriculture accounts for about 15% of total global greenhouse-gas emissions, mainly in the form of methane and nitrous oxide. The livestock sector is one of the largest contributors to greenhouse-gas emissions. Estimates indicate it produces roughly 8–10.8% of global emissions, but assessments based on full lifecycle analysis suggest it may account for up to 18%. Major sources of emissions from livestock include enteric fermentation, nitrous oxide release, the use of fossil fuels, liming, organic waste and the production of fertilizers. The use of nitrogen-based chemical fertilizers further adds to greenhouse-gas emissions. However, improved crop-production practices offer significant mitigation potential. With better management, nitrogen fertilizer use can be reduced by nearly 38%. Such practices also decrease input energy requirements by around 11% while increasing yields by 33%, ultimately lowering greenhouse-gas emissions by about 20% (Malhi *et al.*, 2021).

Natural Processes Affecting Earth's Temperature

The Sun is the primary source of energy for the Earth. Variations in solar radiation, changes in the Earth's orbit, volcanic eruptions, atmospheric greenhouse gases, aerosols and land-cover changes can alter the Earth's energy balance and influence its climate.

Orbital forcing refers to long-term variations in the Earth's orbit, axial tilt and orientation around the Sun. These changes affect the distribution of solar energy received by the Earth. Volcanic eruptions can also influence temperature by releasing sulphur dioxide (SO₂), which forms sulphate aerosols in the atmosphere. These aerosols reflect sunlight and may cause temporary cooling (Mohanty *et al.*, 2010).

Greenhouse gases (GHGs) absorb and re-emit infrared radiation, contributing to the greenhouse effect. Major GHGs include Water vapour (H₂O), Carbon dioxide (CO₂), Methane (CH₄), Nitrous oxide (N₂O) and Ozone (O₃). Human-made gases, such as Chlorofluorocarbons (CFCs), also contribute to atmospheric warming.

Carbon dioxide (CO₂) is particularly important because its atmospheric concentration has increased mainly due to fossil-fuel combustion, industrial activities and deforestation. Increased CO₂ strengthens the greenhouse effect and contributes to long-term global warming. Therefore, both natural processes and human activities influence the Earth's climate system.

The largest contribution to this warming is believed to be from the increase in atmospheric concentration of GHGs, such as CO₂, methane (CH₄) and nitrogen dioxide NO₂. GHGs act like a thermal blanket around the planet and are responsible for allowing life on Earth to exist the exponential increase in the

emission of GHGs since the industrial revolution has resulted in atmospheric concentrations of these gases that are unprecedented in the last 0.8 million years. For example, atmospheric CO₂ concentrations increased from 278 ppm in the middle of the eighteenth century to around the current level of 400 ppm. The (Intergovernmental Panel on Climate Change) IPCC has also concluded that it is extremely likely that humans have been the dominant cause of the observed warming since the mid-twentieth century, through the association of GHG emissions with gas and oil combustion, deforestation and intensive agriculture. Only one percent of the additional heat caused by anthropogenic climate change is retained in the atmosphere, whilst 93 percent has been absorbed by the global ocean. The remaining three to four percent is absorbed by the melting of ice and snow. The ocean's heat buffer is thus enormous and any small change in the balance of heat between ocean and atmosphere would have huge impacts on global air temperature in addition to its thermal capacity, the ocean has also sequestered about 25 percent of the CO₂ released as a result of anthropogenic activities (Le Quere *et al.*, 2018). playing a crucial role in the regulation of the Earth's climate (Hartmann *et al.*, 2013).

Climate Change Impacts on Inland Fisheries

Climate change has wide-ranging effects on inland fisheries, influencing fish distribution, breeding and spawning, growth, thermal tolerance, stress physiology, species invasions, aquatic productivity and habitat quality. Changes in water availability, sedimentation, aquatic weeds and salinity can further affect fish populations and fisheries-dependent communities. These impacts extend from the cellular and physiological levels to entire ecosystems, with important implications for biodiversity, productivity,

sustainability and food security (Das *et al.*, 2019; Karmakar *et al.*, 2018).

Changes in Temperature, Rainfall and Extreme Events

India has experienced an increase of about 0.4°C in surface air temperature over the past century. Although no significant long-term trend has been observed in all-India monsoon rainfall, substantial regional variations have occurred. Increasing rainfall has been reported along the west coast, northern Andhra Pradesh and north-western India, while decreasing trends have occurred in eastern Madhya Pradesh, north-eastern India and parts of Gujarat and Kerala. Changes in droughts and severe storms can further affect inland water bodies, fish habitats and fish production (Vivekananda and Das, 2010).

Effects of Different Factors on Fish Biology

Water temperature Anthropogenic forcing has made a substantial contribution to the upper ocean warming (above 700 m) that has been observed since the 1960s (Cheng *et al.*, 2017). with the surface waters warming by an average of 0.7° C per century globally from 1900 to 2016 (Huang *et al.*, 2015). Ocean temperature trends over this period vary in different regions but are positive over most of the globes, although the warming is more prominent in the Northern Hemisphere, especially the North Atlantic. The upper ocean (0 m to 700 m) accounts for about 64 percent of the additional anthropogenic energy accumulated in oceans and seas. Upper ocean warming is expected to continue in the twenty-first century, especially in the tropical and Northern Hemisphere subtropical regions, whereas in deep waters the warming is expected to be more pronounced in the Southern Ocean. The trend in sea surface temperature already exceeds the range in natural seasonal variability in the subtropical areas and in the Arctic

(Henson *et al.*, 2017). Best estimates of mean ocean warming in the top 100 m by the end of the twenty-first century are about 0.6°C to 2.0°C and about 0.3°C to 0.6°C at a depth of about 1000 m compared to the 1986 to 2005 average.

Temperature strongly influences fish metabolism, oxygen consumption, growth and thermal tolerance. Rising temperatures can increase metabolic demands and physiological stress, potentially reducing growth and survival when thermal limits are exceeded. Temperature also affects embryonic and larval development, spawning, gonadal maturation, fecundity and recruitment. Excessive temperatures may reduce hatching success, increase embryo mortality and cause developmental abnormalities (Afzal *et al.*, 2025).

Dissolved oxygen (DO) Dissolved oxygen (DO) is a critical environmental factor that regulates various aspects of fish biology. Variations in DO levels, particularly under hypoxic conditions, can adversely affect swimming performance, feeding, respiration, metabolism, growth, reproduction, immunity, stress responses and behaviour. Low DO levels can reduce feeding activity and aerobic metabolism, leading to reduced growth and alterations in energy allocation. Hypoxia may also impair gonadal development, fertilisation, hatching and larval survival, while prolonged oxygen deficiency can increase physiological stress and susceptibility to disease. Therefore, maintaining adequate DO levels is essential for the normal physiological functioning, growth, reproduction and survival of fish (Ali *et al.*, 2022).

Salinity Salinity is an important environmental factor that influences fish growth, metabolism, feeding, digestion, osmoregulation and immunity. Stated that increased salinity reduced growth performance, feed utilisation and the activities of digestive enzymes such as protease, lipase and α -amylase in Nile

tilapia (*Oreochromis niloticus*). Salinity stress also altered haematological and biochemical parameters and suppressed innate immune responses, including lysozyme activity, respiratory burst and phagocytic activity. Furthermore, structural changes in the gills, liver and intestine indicated that elevated salinity can adversely affect the physiological condition and overall health of fish (Monier *et al.*, 2025).

Euryhaline species are organisms that can tolerate a wide range of salinities. Examples: Mummichog (*Fundulus heteroclitus*): It can survive in freshwater, brackish water and seawater. European Eel (*Anguilla anguilla*): This fish can move between freshwater and marine environments during its life cycle. Atlantic Salmon (*Salmo salar*): Known to migrate between freshwater (where they spawn) and the ocean. Stenohaline species are those organisms that can only survive within a narrow range of salinity. Examples: Goldfish (*Carassius auratus*): A freshwater fish that cannot survive in high-salinity environments. Open-ocean fishes (e.g., Marlin, Tuna): Marine species adapted to consistent ocean salinities and are not typically found in areas with fluctuating salinity like estuaries (Marium *et al.*, 2023).

Impacts on Distribution and Habitats

Climate change can alter the geographical distribution and habitat preferences of fish. Many species shift towards higher latitudes or modify their horizontal and vertical movements in response to unsuitable environmental conditions (Pal and Sarkar, 2021). Changes in Himalayan glaciers may also influence the seasonal flow of major rivers such as the Indus, Ganga and Brahmaputra, potentially affecting water availability, aquatic habitats and fisheries (Vivekananda and Das, 2010).

Distribution Temperature changes can cause fish species to shift their distribution as they search for environments that match their thermal tolerance. This section explores how different fish species respond to temperature fluctuations, highlighting the complex interactions between temperature and fish biology (Vivekananda and Das, 2010).

Effect of dissolve oxygen on fish biology Reproduction and development

Dissolved oxygen levels play a critical role in fish reproduction and larval development. Adequate oxygen availability is essential for successful spawning, egg development, and survival of fish larvae. Oxygen-deprived conditions can reduce hatching success, developmental abnormalities, and increased mortality rates among fish embryos and larvae. Fish species exhibit preferences for specific dissolved oxygen ranges, selecting habitats that provide optimal oxygen conditions for survival and physiological needs (Marium *et al.*, 2023).

Performance and behaviour

The influence of dissolved oxygen levels on fish behaviour and movement patterns is examined in this section. It discusses how Fish may alter their swimming speed, foraging behaviour and habitat selection in response to variations in oxygen availability (Marium *et al.*, 2023).

Effect of pH on fish biology:

Influence the physiology and behaviour

Altered pH levels can influence the interactions between fish and other organisms. Changes in pH can affect the physiology and behaviour of prey species, predator-prey relationships and symbiotic associations. Disrupted interactions can cascade ecosystem dynamics. pH is a crucial environmental factor that influences the physiological processes and overall health of fish. Fluctuations in pH levels can have significant effects on fish

populations. The optimal pH range for most freshwater fish species typically falls between 6.5 and 9.0, allowing for maximum growth and reproduction.

Water quality in ponds for aquaculture. pH levels ranging from 6.5 to 9.0 are optimal for most freshwater fish species. This pH range provides favourable conditions for their growth and reproduction, contributing to healthy populations (Marium *et al.*, 2023).

Conclusions:

Climate change due to several anthropogenic activities is the most significant concern of our society. In aquaculture front, though it is more prominent in oceans and seas, inland fisheries as indicated in several studies is also severely affected by this phenomenon. It is known that the two environmental factors, viz., photoperiod and temperature play a crucial role in enhancing maturation and spawning in fish. A sudden and marked change in the temperature and day length will, therefore, interfere with the various physiological and cellular processes including gonadal recrudescence and subsequent spawning. Thus, climate change reduces the hatching period with decreased availability of quality seeds. As is common across climate change science, there is significant knowledge on the biophysical impacts of climate change on aquatic ecosystems, but much less insight on how these impacts will be mediated by the socio-economic context of fisheries and how adaptation measures can be taken up. Climate change is predicted to have a wide range of impacts on fisheries and aquaculture and those who depend on them.

Reference:

Muluneh, M. G. (2021) Impact of climate change on biodiversity and food security: a global perspective. a review article. Agriculture and Food Security, 101, 1-25.

- Malhi, G. S., Kaur, M. and Kaushik, P. (2021) Impact of Climate Change on Agriculture and Its Mitigation Strategies: A Review. *Sustainability*, 13, 3, 1318.
- Mohanty, B., Mohanty, S., Sahoo, J. and Sharma, A. (2010). Climate change: impacts on fisheries and aquaculture. *Climate change and variability*, 119, 978-53.
- Le Quere, C., Andrew, R. M., Friedlingstein, P., Sitch, S., Pongratz, J., Manning, A. C., Korsbakken, J. I. et al. (2018) Global carbon budget 2017. *Earth System Science Data*, 10, 1, 405-448.
- Hartmann, D. L., Klein Tank, A. M. G., Rusticucci, M., Alexander, L. V., Bronnimann, S., Charabi, Y., Dentener, F. J. et al., (2013) Observations: atmosphere and surface. In T. F. Stocker, D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P. M. Midgley, eds. *Climate change: The physical science basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, 159–254.
- Das, B. K., Sarkar, U. K. and Roy, K. (2019) Global climate change and inland open water fisheries in India: Impact and adaptations, 81-82.
- Karmakar, S., Purkait, S., Das, A., Samanta, R. and Kumar, K. (2018) Climate change and inland fisheries: impact and mitigation strategies. *Journal of Experimental Zoology, India*, 21: 329-335.
- Vivekanandan, E. and Das M. K. (2010) Climate change - Impact and mitigation In: Ayyappan S. (ed.). *Handbook of Fisheries and Aquaculture*, 1st Edn., Directorate of Information and Publications of Agriculture, Indian Council of Agricultural Research, New Delhi, pp 794-821.
- Cheng, L., Trenberth, K.E., Fasullo, J., Boyer, T., Abraham, J. and Zhu, J. (2017) Improved estimates of ocean heat content from 1960 to 2015. *Science Advances*, 3, 3, 454-455.
- Huang, B., Banzon, V. F., Freeman, E., Lawrimore, J., Liu, W., Peterson, T. C., Smith, T. M., Thorne, P. W., Woodruff, S. D. and Zhang H. M. (2015) Extended Reconstructed Sea Surface Temperature Version 4 Part I: Upgrades and intercomparisons. *Journal of Climate*, 28, 911–930.
- Henson, S. A., Beaulieu, C., Ilyina, T., John, J. G., Long, M., Seferian, R., Tjiputra, J. and Sarmiento, J. L. (2017) Rapid emergence of climate change in environmental drivers of marine ecosystems. *Nature Communications*, 8, 14682.
- Afzal, R., Fatima, S. A., Azam, F., Ghazal, F., Anoosh, S., et al., (2025) Aquatic ecosystem and fish: A review on alterations of climate change impact on *Labeo rohita* physiology. *Aquatic*, 3, 3.
- Ali, B., Anuska and Mishra, A. (2022) Effects of dissolved oxygen concentration on freshwater fish: A review. *International Journal of Fisheries and Aquatic Studies*, 10, 4, 113–127.
- Monier, M. N., Shady, S. H. H., Grana, Y. S., Abd El-Ghaffar, H. A., Samir, F., El-Werwary, S. O. M., Ahmed, A. A. and Abdel-Tawwab, M. (2025) Fish Physiology and Biochemistry, 51, 200.
- Marium, A., Chatha, A. M. M., Naz, S., Khan, M. F., Safdar, W., Ashraf, S. (2023) Effect of Temperature, pH, Salinity and Dissolved Oxygen on Fishes. *Journal of Zoology and Systematics*, 1, 2, 1–12.
- Pal, S. and Sarkar, J. (2021) Change in the Hydro-climate variables and impact on Indian Fisheries Sector. *Food and scientific Reports*, 2, 11,36-38.