Climate Change And Inland Fisheries – An Overview

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Abstract
Fisheries are affected by climate change in many ways; aquatic ecosystems are being affected by changes in water temperature, water flow, and fish habitat loss. These effects vary in the context of each fishery. Climate change is modifying fish distributions and the productivity of freshwater species. Climate change is expected to lead to significant changes in the availability and trade of fish products. The geopolitical and economic consequences will be significant, especially for the countries most dependent on the sector. The biggest decreases in maximum catch potential can be expected in the tropics, mostly in the South Pacific regions. The impacts of climate change on fresh water systems has impacts on the sustainability of fisheries, on the livelihoods of the communities that depend on fisheries, and on the ability of the fresh water to capture and store carbon. The effect of sea level rise means that coastal fishing communities are significantly impacted by climate change, while changing rainfall patterns and water use impact on inland freshwater fisheries. Increased risks of floods, diseases, parasites and harmful algal blooms are climate change impacts on fisheries which can lead to losses of production and infrastructure. With this scenario, in the present review we aimed to describe and delineate on the potential impacts of climate change on Inland fisheries and its economic implications.

Keywords: Inland fisheries, Aquaculture, Climate Change, Growth, Health, Physiology

INTRODUCTION

Climate change is one of the most important global environmental challenges of 21st century. India has reasons to be concerned about climate change. Nearly 700 million rural populations directly depend on climate-sensitive sectors (agriculture, forests, and fisheries) and natural resources (such as freshwater, mangroves, coastal zones, grasslands, and biodiversity). Any adverse impact on water availability due to recession of glaciers, decrease in rainfall and increased flooding in certain areas would threaten food security, cause further degradation of natural ecosystems and its resident species that sustain the livelihood of rural households. Occurrence of sea-level rise and increased extreme events will adversely impact the coastal eco-system and the dependent population. The impacts are already being felt in India (Sarkar and Das, 2021).

The significance of animal and fisheries sector for food security of the fast-growing nation like India is enormous. These sectors play a critical role in the socio-economic development and welfare of India's rural population, not only as a source of nutrient-rich food but also provide family income and generate gainful employment particularly among the landless, small, and marginal farmers (Murthy and Behere, 2021).

India is bestowed with vast and varied inland open-waters *viz.* lakes, reservoirs, wetland, rivers, and estuaries, the traditional sources of fisheries, supporting many landless poor fishers (Figure 1). In recent times, however, fish production from these resources has declined steadily due to increased man centric interventions. The resultant impact has been an erosion of livelihood base for the traditional fishers, who depend exclusively on these resources for their livelihood and nutritional security. Of concern is the fact that the impact of climate change is already perceptible in these inland aquatic ecosystems and on fisheries, increasing pressure on all livelihoods and food supplies. Though living resources are self-renewable, more so are the aquatic living organisms, especially fish, provided they can be utilized rationally on a sustainable basis maintaining harmony with the aquatic environment (Kelkar and Arthur, 2022).

Figure 1: Showing Inland fisheries practice

With this background, in the current review we aimed to describe and delineate on the potential impacts of climate change on Inland fisheries and its economic implications.

IMPORTANCE OF FISHERIES IN INDIA

Inland fisheries play a significant role in the economy of India. Though often overlooked, the following points would provide a glimpse of the economic importance of the sector. Fisheries sector in India provides nutritious food, has high potential for rural development, domestic nutritional security, employment generation, as well as export earnings. India occupies third position in fisheries production. The Fishery sector has shown a steady growth in India and hence it is called the sunrise sector. Indian share in global fish production is 4.36% with 9.92% in Inland and 2.28% in marine. Its contribution to the National GDP is 1.07%, and to National Agriculture and allied activities is 5.84 %. The Export potential is 18% of the agricultural exports. The sector provides direct and indirect engagement to 14 million people. India relies on fisheries for around 13.5% of its national animal protein intake and the average per capita fish protein consumption is 0.51 kg/capita/yr. But the contribution of fish to the total animal protein consumption for the non-vegetarian population is much higher than the overall Indian average (Dey *et al.,* 2007). Thus, any potential direct or indirect effects of climate change will have immense implication on regional food security especially in the eastern Indo-Gangetic states of India. It is therefore imperative to think of the vulnerability and adaptation strategies of the sector in dealing with the impacts of climate change.

ROLE OF CLIMATE CHANGE ON PHYSIOLOGY OF FISH

Investigation of global climate change is apprehensive with improbability at each level of observation. Combustion of fossil fuel is mainly responsible for the changing climate (Perera, 2018). About 80% of the world's power is produced from fossil fuels (Weblink). The benefits of such power use are obvious, but fossil fuel combustion is the main reason for producing greenhouse gases that increase global climate. The global surface temperature is increased by 0.85 (0.65 to 1.06°C) over the period from 1880 to 2012, as indicated by a linear trend. The prediction showed that the global mean surface temperature change for the period 2016–2035 relative to 1986–2005 is predicted to be in the range of 0.3°C - 0.7°C (Hijioka *et al.,* 2014).

Freshwater fish species are ectothermic that body temperature is influenced by the surrounding environment (Gillooly *et al.,* 2017). Therefore, increasing temperature can alter the physiological functions (thermal tolerance, growth, metabolism, food consumption, reproductive success, etc.) of the fish body to maintain homeostasis with the environment (Volkoff and Ronnestad, 2020). Physiological and molecular mechanisms mediating plasticity at different time scales can be important in modulating the effect of temperature on individual fish and thereby render populations more resilient to climate change– up to a point (Little *et al.,* 2020). Nonetheless, the capacity for plasticity varies between species and populations within species. For example, tropical fish are thought to be particularly vulnerable to fresh water warming because some species are living at temperatures close to their thermal maxima (Campos *et al.,* 2021), and show a limited capacity for acclimation of critical thermal maxima (Vinagre *et al.,* 2016). Polar cod have a reduced capacity for acclimation of mitochondrial function to warmer temperatures than a temperate population of Atlantic cod that had recently radiated to polar regions (Little *et al.,* 2020), maybe because the variable climates experienced by Atlantic cod select for reversible acclimation.

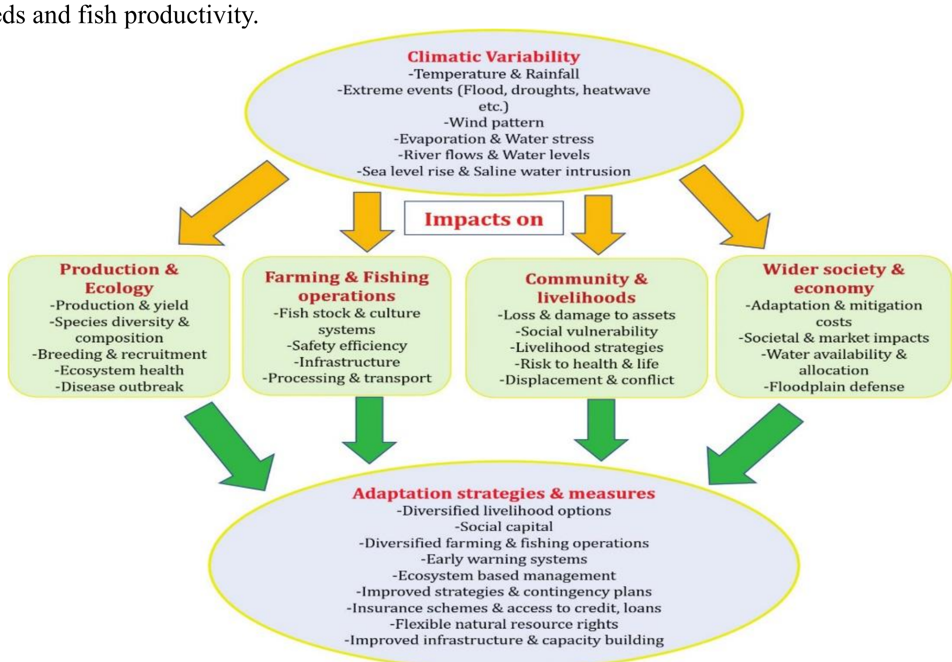
Warm-acclimated Arctic cod (acclimated to 6.5°C) showed an increase in the critical maximum temperature for loss of equilibrium and in the optimal temperature for metabolic scope. Nonetheless, at this high acclimation temperature cardiovascular performance started to decline, and 50% of fish were unable to recover from maximal swimming episodes, so that the ecological benefits of warm acclimation are questionable (Drost *et al.,* 2021). Different populations of brook trout (*Salvelinus fontinalis*) and mosquitofish (*Gambusia holbrooki*) had different capacities for reversible acclimation, possibly because of different climates experienced by populations, and genetic drift, respectively (Fost, 2017).

The challenge for fisheries now lies in determining the capacity for plasticity in different target species and populations within species. Understanding these physiological responses combined with projections of future water temperature changes will be invaluable to predict the vulnerability of populations to climate change – by direct effects on the physiology of individuals and through trophic cascades – and thereby the sustainability of the fishery. Conceivably, the changes in the surrounding environmental conditions profoundly impact the energy utilisation and disrupt fish physiology. In recent years, clear signs of modification and degradation of ecosystems, over-exploitation of commercially important inland capture fish stocks have become discernible. These factors threaten the long-term sustainability of inland fisheries and its contribution to the food basket of the country. The potential inland fish production is estimated at over 5.0 million tonnes annually and capture fisheries contribute more than 30% from the inland open waters. Fisheries plays a major role as the prime producer of fish. Rivers are the primary sources of precious germplasm and breeding ground for many fish species. However, over the years, the fish yield from the different rivers systems of India is showing a declining trend. Considering the current environmental status of the inland aquatic resources, substantial increase in fish production from rivers is unlikely (Panikkar *et al.,* 2022). However, the reservoirs and floodplain lakes in the country offer considerable opportunity for enhancing fish production.

CLINICAL CHANGE AND IMPACT ON INLAND FISHERIES IN INDIA

Changes in key climate variables, namely temperature, precipitation, and humidity may have significant long-term implications for water quality and quantity of water. River systems of the Brahmaputra, the Ganga, and the Indus, which benefit from melting snow in the lean season, are likely to be particularly affected by the decrease in snow cover. A decline in the total run-off for all the river basins, except Narmada and Tapti, is projected in India (Shrivastava *et al.,* 2019). A decline in run-off by more than two-thirds is also anticipated for the Sabarmati and Luni basins. Rivers differ a great deal in the amount of water they carry depending upon the precipitation in their catchments and other sources of water (e.g., snow melt), as well as factors that determine runoff, infiltration, and evaporation. Flow is an important factor determining the physical structure of a river and thus maintaining in-stream habitats. For wetlands adjoining rivers the hydrological processes in the watershed, and the rate of downstream discharge, determine the depth, duration, and frequency of inundation of the floodplain, which periodically becomes a part of the river. The area of floodplain immediately adjacent to, and influenced by the river is often distinguished as the riparian zone. The riparian zone and the floodplain are important riverine habitats; they form a critical link between terrestrial and aquatic ecosystems. River flows determine the nature and strength of a river's interaction with its floodplain, and consequently the diversity of habitats and biotic communities. Any human activity that directly or indirectly impinges upon the flows has an impact on fishery resources. Due to sea level rise, the freshwater sources near the coastal regions will suffer salt intrusion (Klassen and Allen, 2017).

Fisheries ecosystems and fishing-based livelihoods depend upon a range of climate-related variability, from changing patterns and abundance of fish stocks, through changes in aquatic ecosystem structure and productivity, to extreme weather events, floods and droughts (Karmakar *et al.,* 2018). Threats are arising to food and livelihood security of millions of people subsisting on aquatic ecosystem due to direct changes (physical and physiological) on the organisms due to various factors mainly, global warming as well as socio-economic pressures on natural ecosystems (Mbow *et al.,* 2020). In the short term, climate change is anticipated to impact inland fisheries by incremental changes in water temperature, nutrient levels and lower dry season water levels as illustrated in Figure 1. A decline in dry-season flow rates in several South Asian and African river basins, resulted in reduced fish yields. However, in the long-term, more significant changes in river flows are anticipated as glaciers melt, which will result in reduced capacity to sustain regular and controlled water flows (Nie *et al.,* 2021). For riverine fisheries, downstream impacts from adaptations in other livelihood sectors are a concern. In particular, the effects of reduced flows and floodplains on seasonal spawning and conflicts exist between agricultural needs and fish productivity.



Courtesy: Sarkar and Das, 2021

Figure 1: Climate change and impact on inland fisheries

IMPACT OF GROWTH OF FISH

Water temperature strongly affects metabolism, consumption, growth fish behaviour, habitat selection, spawning, foraging, and predator-prey interaction. Growth rate potential provides a good measure of habitat quality (Lea *et al.,* 2018), and effectively incorporates biotic and abiotic characteristics of the environment in a metric that directly relates to the fitness of fish (Stewart, 2019). Temperature changes will have an impact on the suitability of fish species for a given location. In temperate areas increasing temperatures could bring the advantages of faster growth rates and longer growing seasons. Investigations were conducted by Das et al., at Central Inland Fisheries Research Institute (CIFRI) to assess the impact of unit rise in temperature on the growth of Indian Major Carp, *Labeo rohita* fingerlings reared simulating temperature rise in tropical countries in seven thermostatic aquarium for five weeks at water temperature of 29ºC, 30ºC, 31ºC, 32ºC, 33ºC, 34ºC and 35ºC. Fish reared at 34ºC water temperature exhibited a significantly ($p<0.05$) faster growth (SGR-2.36 % body weight per day) than those at other temperatures (Das *et al.,* 2013).
The change in growth rates were insignificant between 29ºC, 30ºC, 31ºC and 32ºC treatment groups but growth rates significantly increased in the temperatures ranging from 32ºC to 34ºC and thereafter it decreased. Carp reared at 34ºC grew significantly faster (18.38 cg in a day) than those at 29-33ºC and 35ºC. It would take average 54-55 days for a carp to double in weight at 30ºC to 33ºC and 35ºC, but at 34 ºC it would take only 35-36 days. A linear growth model of *Labeo rohita* fingerlings growth has been developed using the data generated. This simple growth model provides a reliable projection of growth (SGR %) with unit rise of temperature within the range of 29º to 34ºC (Das *et al.,* 2013).

IMPACT ON FISH HEALTH

Fluctuating temperature very often disturb the homeostasis of fish and subject them to physiological stress and shift in habitat or mortality. In the climate warming scenario fishes will be subjected to the hazard of rapid temperature changes. It is more so in the tropical waters where daily variations in water temperature and thermocline in deep water bodies will assume significance. It is essential to understand that these temperatures change though sublethal, can place a stress of considerable magnitude on the homeostatic mechanism of fishes at the primary, secondary, and tertiary level (Reid *et al.,* 2022).

SURVIVABILITY INLAND FISHERIES TO CLIMATE CHANGE

For sustainability of the inland fisheries sector, climate change notwithstanding, there are several issues to be addressed. Strategies to promote sustainability and improve the supplies should be in place before the threat of climate change assumes greater proportion. While the fisheries sector cannot do much to mitigate climate change, it could contribute to reduce the impact by following effective adaptation measures. Options for adaptation are limited, but they do exist. The impact of climate change depends on the magnitude of change, and on the sensitivity of species or ecosystems (Carozza *et al.,* 2019).
In the context of climate change, the primary challenge to the fisheries sector will be to ensure food supply, enhance nutritional security, improve livelihood and economic output, and ensure ecosystem safety. These objectives call for addressing the concerns arising out of climate change, and evolve adaptive mechanisms and implement action across all stakeholders at national, regional, and international levels (Rasul and Sharma, 2016). Though, the international Climate Convention-related meetings continue to focus on mitigation of greenhouse gas emissions as a global public good but it is heartening to see a visible shift at present in the global discussions towards adaptation as a local public good.

ADAPTATION ACTIONS IN INLAND FISHERIES

A wide range of adaptations is possible, which may be carried out in response to impacts once they have occurred or in anticipation of future effects. To increase the resilience of aquatic resources ecosystems and fisheries production systems, and aquatic resource dependent communities, the ecosystem approaches to fisheries (EAF) should be adopted (Dutta *et al.,* 2020). In general, steps must be taken, as part of long-term integrated management planning for extreme events on fisheries and allied infrastructure and dependent communities are likely to be more efficient. However, it should be noted that extreme protective measures could themselves have negative social and economic impacts. Hence, they should be commensurate with risk. There is thus a need for integrated assessment of different changes impacting water resources and environment at multiple spatial scales instead of separate assessments focusing merely on climate change or, for that matter, on hydropower development, irrigation, land use changes and so forth.
Throughout their history people have responded to changes, first and foremost, in the spatial context of their social and environmental conditions. However, as the different sectors are threatened differently by climate risks, they are responding differently to the climate change impacts. For example, negative impacts on aquatic ecosystems and fisheries can be further aggravated by human adaptation to changes in climate. A specific example is the demand of water for irrigation by farmers. For adaptation to the increased demand for irrigation water the supply side option will aim at increasing supply. Increasing the water source for irrigation is expensive and has the potential environmental impacts. The demand side options on the other hand aim at reducing demand. They include increasing irrigation efficiency through improved technology and higher prices for water, and changes in cropping pattern by switching to crops that require less or even no irrigation. So a variety of options are available; influences on the aquatic ecosystem and fisheries sector would depend on the details of such choices. The demand side options in most cases would appear to be better choices for those interested in conserving the aquatic ecosystem and fisheries (Some *et al.,* 2022).

FUTURE PERSPECTIVES

To improve the capabilities to project the implications of climate change for inland fisheries in India, key biophysical, social and economic knowledge gaps need to be addressed. First, there is a level of uncertainty regarding the physical and biogeochemical changes anticipated in the Indian waters. Large number of experts has opined that Global Climate Models such as those used by the IPCC perform poorly at regional and sub-regional scales, and there is a need to improve such models, and their coupling with the dynamics of inland freshwaters. Second, we need to understand better the transfer of primary productivity to fish and fisheries and the potential impacts of climate change on the productivity of a range of inland ecosystems. There is insufficient understanding of the links between projected climate change, environmental responses, fish stock and aquatic ecosystem responses, Third, we must improve our understanding with regard to evolutionary adaptation and behavioural responses to changed climatic conditions, and the indirect effects on the interactions between species in inland food webs. Fourth, Understanding the response and adaptation capacity of fishing and fishers to the physical and biological changes. At present few, studies have specifically looked at the socio-economics of the Indian fisheries sector in relation to climate change. Exploring the synergistic dual exposure of inland aquatic ecosystems to climate change and other anthropogenic activity appears essential for effective adaptation and mitigation options to be developed. Addressing these knowledge gaps will clearly require both interdisciplinary and within-discipline studies (Sharma *et al.,* 2014).

It is felt that the certain areas require appropriate intervention of research programmes. A lack of appropriate methodology and limited availability of appropriate data for vulnerability assessment to identify priority areas for action. Improving parameterisation of 'risk exposure' to climate change *viz.,* projected changes in precipitation, storm, and flood frequencies (based on historic observations), and sea level rise. Improving parameterisation of sensitivity and adaptive capacity using regional demographic data to refine some of the indices of sensitivity and adaptive capacity currently calculated at national level. Gaps in scientific knowledge should not delay climate change mitigation and adaptation policy actions. Thus, it is important to develop adaptation policies for the inland fisheries sector, which could be updated and adapted as new knowledge emerges. There are various 'no-regret' policies which have large co-benefits for other ecosystem services (Sharma *et al.,* 2014).

There is a consensus among scientists that human impacts on inland aquatic ecosystems through overfishing, habitat destruction, pollution, etc. reduce adaptive capacity of the ecosystems and organisms to climate and other environmental changes. Fishing threatens some of the unassessed stocks, particularly species that are vulnerable to exploitation such as carps and hilsa. Recovery of depleted fisheries stocks depends largely upon reducing fishing effort to allow existing year classes to survive to maturity. By rebuilding over-exploited fish populations and ecosystems, and improving habitat quality for inland organisms, society and the fishing industry would gain from more productive fish stocks, higher biodiversity and higher resilience and adaptive capacity to climate change. Improving education and communication within the inland fisheries industry and with other stake holders about climate change could be important for effective implementation of climate change mitigation and adaptation policies. Such measures would allow the fisheries industry to develop capacity and to respond effectively to threats or opportunities posed by climate change (Sharma *et al.,* 2014).

The most feasible ways to build adaptive capacity at the local level in India are essentially the same as those needed for example in livelihood diversification and, more generally, in poverty reduction and sustainable development. Enhancing climate change adaptation should therefore build on these initiatives, and integrate climate change needs with the routine policies, measures and activities which are undertaken by the government and different stakeholders as a part of the sustainable development priorities of India thereby contributing to climate goals at little or no cost (Sharma *et al.,* 2014).

CONCLUSIONS

The biophysical effects of climate change on aquatic ecosystems are well understood, as is typical of climate change science, but little is known about how these effects will be mediated by the socioeconomic context of fisheries and how adaptation measures can be implemented. Numerous effects of climate change are anticipated on fisheries and the people who depend on them. Our impression from this review of the literature in areas related to climate change is that the future vulnerability of livelihoods in fishing communities will be at least as vulnerable to changes in the human context of fisheries (supply, demand, technology, and the capacity to manage collective resources) as to ecological or direct impacts of climate change.

It is well known that photoperiod and temperature, two environmental factors, are crucial for promoting fish maturation and spawning. Therefore, various physiological and cellular processes, such as gonadal recrudescence and subsequent spawning, will be affected by a sudden and noticeable change in temperature and day length. Thus, climate change reduces the hatching period with decreased availability of quality seeds. Besides, climate change leaves several adverse effects on spawning and feeding migration, availability of natural foods and ultimately invites several pathogenic organisms. All these together pull the production to negative side- a great concern to all. Thus, further attention is needed for mitigation and possible advance adaptation techniques to combat the changing climatic conditions.

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