Nexus of Climate Change with Fish Production and Its Implications on Livelihood and Nutritional Security

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Abstract

Fish being one of the major sources of protein and essential nutrients plays a crucial role in ensuring the nation's food security and also generates livelihood opportunities for a significant portion of the populace especially poor resource-limited marginal fishers often belonging to the vulnerable communities. Availability of an ideal aquatic environment is the limiting factor that regulates the outcomes from the sector as a result a changing climate poses serious multifaceted threats—both direct and indirect to this enterprise. Adaptation to these changes is required for both impact assessment and employing policies to minimize the impact. The impact of climate change on the socio-economics of the fishers is going to be area-specific and therefore specialized adaptation strategies and need-based capacity building are going to prove more fruitful rather than a generalized one, which accentuates the requirements of literature that provides an idea about the nature of changes, their possible impacts, and finally adapting strategies. This chapter highlights the impacts of the changes in climate on both the ecological and socio-economical aspects of fisheries and aquaculture and also directs towards possible adapting strategies that could be beneficial for policy making.

Keywords

Socio-economics · Policy · Livelihoods · Climate change

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1 Introduction

Fisheries and aquaculture have a huge impact on the Indian economy as well as on food security, nutritional security, employment generation, etc. The fisheries sector received a huge boon in the form of the blue revolution and witnessed a humongous growth in terms of production especially the move from marine-centered fisheries to inland-based fisheries as the contribution of the latter grew from a 36% in the 1980s to 70% in the recent times due to prioritization of culture-based fishery over capture-based fishery in the recent past. The fisheries sector is the primary source of livelihood for 20 million fishers in the nation and contributes approximately a staggering 1.75 trillion to the nation's economy. Aquaculture products being one of the major exporting goods in the country, fisheries also play a crucial role as it earns the nation an approximate amount of Rs. Forty-seven thousand crores in foreign currencies. Keeping these in mind it needs to be ensured that along with the expansion of this sector in the form of resource utilization and production enhancement, the preservation of resources to make sure prolonged sustained availability of these natural resources is also required.

While the emphasis is on enhanced fish production by adapting latest technologies and utilization of resources to their full potential the preservation of the aquatic ecosystem and prevention of degradation of the environment take a backseat. One of the major factors impacting the environment is climate change and since the fisheries and aquaculture depend largely on the availability of suitable habitats for the aquatic organisms, any derogatory changes in these habitats will have an impact on the health and availability of these fishes and ultimately impact on spawning season, migration pattern, survival, and mortality, selection of species to be firmed, etc. Primarily climate change will lead to frequent climatic events, increase in the water level, coastal and inland flooding, erratic drought patterns, altered salinity, and changes in riverbed level due to sedimentation which will eventually result in lower available water area ultimately causing habitat loss and degradation of aquatic ecosystems and would hamper fisheries practices. According to IPCC climate change will also change the pattern of disease outbreaks and may also change the susceptibility of the fishes towards various disease-causing agents. Recording the observable impacts of the changing weather patterns on the aquatic organisms is going to be crucial in adapting to these changes and taking mitigating measures.

2 Impact on Aquatic Ecosystems

Changes in the climate are being observed in rising water and atmospheric temperature, and changes in weather patterns especially in terms of precipitation are causing floods and drought which are eventually impacting aquatic habitats. Rising surface water temperature may result in lesser dissolved oxygen level, increased occurrence of disease and parasites, altering food web due to changes in competitor composition, may favor certain predators and invasive species to flourish in this altered

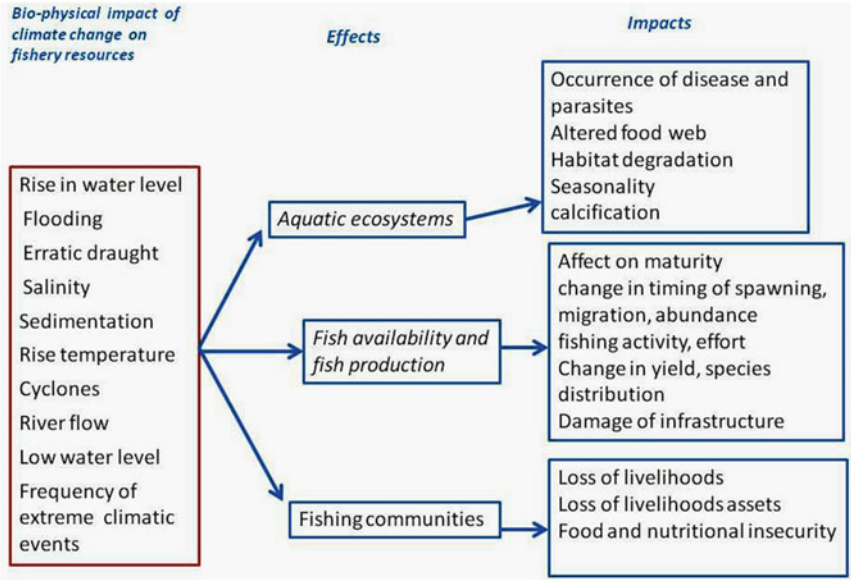

Fig. 1 Climate change impacts pathways in fisheries and aquaculture

environment, changes in plankton composition, etc. Higher inland water temperature will result in more stratification and less mixing of water due to changes in a temperature gradient, altered primary production hampering natural food supply for fish species, a shift in the ideal place and potential range for a particular species, etc. In higher altitude regions rising temperature will cause the melting of glaciers causing floods whereas in drier regions rivers and aquatic bodies may face scarcity of water due to erratic patterns of rainfall eventually leading to habitat loss. These ecosystem changes are likely to be reflected in the aquatic organisms and some of which can already be observed. Climate change impacts pathways in fisheries and aquaculture is depicted in Fig. 1.

3 Impact on Fish Availability and Fish Production

Changing rainfall as well as temperature is likely to affect the period of maturity; gonadal development in breeding seasons also causes transformation in physiology and sex ratio of fish species, change in spawning timing, migration, abundance, level of productivity, etc. The shift in the availability of fishes in a certain location, e.g., due to rising temperature in the upper stretches of Ganga, fish species which were earlier not captured in the upper stretch but the middle, can now be seen in the upper stretches as well. Increased acidity makes it difficult for zooplankton to form their shells through the process of calcification, which is likely to affect various aquatic food webs. Inland fishery is mostly dependent on rivers, riverine systems, and

wetlands. Changes in hydrologic systems due to altered precipitation leading to changes in magnitude and frequency of flood would result in additional severe low flow due to improved evaporation and also change in peak stream from spring to winter season. The major river systems impacted by climate change are likely to be the Himalayan glacier-supported rivers like the Ganga, Brahmaputra, Indus, etc. which sustain the majority of fisheries activities of the nation. Also, the rivers originating from the mid-plateau of India like Narmada, Tapti, Mahanadi, Mahi, etc. will either face severe drought or excessive flood conditions. Precipitation along with the rate of downstream discharge regulates the water availability in the wetlands. Changes in river flow and water availability in the riparian zone would leave an impact on the overall fish production in these resources.

4 Impact on Fisheries and Aquaculture

Climate change is impacting fisheries through an all-encompassing varied range of pathways. The ecological and socio-economic impacts can have both direct and indirect impacts. The rising temperature and sea level directly influence the ecosystem, aquatic environment, fish stock, and productivity thereby affecting fishing activity, effort, livelihood, and management. The ecological factors will result in a change in production and productivity, species allocation, the unpredictability of catches, seasonal change in production, etc. The direct impact would be observed in damaged facilities and infrastructure, damaged crafts and gears, flood situations, and all of these have consequence effects on fisher folk communities, etc. Impact on socio-economics would result in migration of fishers in search of other jobs, poor health conditions, reduced social and economical security, limited resources for managing, fewer funds for an operation, etc.

5 Impact on Inland Fisheries

Inland fisheries have a substantial role both in livelihood generation and food security. Most of the countries involved in Inland fishery are developing countries where a section of the population depends on inland fisheries for income generation through small-scale fishery. Also, inland fisheries perform a crucial function in terms of food security in developing countries viz. India and Bangladesh where consumption of freshwater fishes as a part of the daily diet has been practiced throughout the ages. Worldwide the freshwater ecosystems supporting inland fisheries activities are subjected to various anthropogenic stressors like over-extraction of water whether for agricultural or industrial purposes, overutilization of resources, the inclusion of exotic species, contamination, habitat degradation, growing population pressure, etc. The impacts of climate change in combination with these already existing stressors will have severe effects on inland fisheries. Freshwater ecosystems are more susceptible to climate variability due to their low buffering capacity (Perry 2011). Water temperature, water flow, availability, etc. are physiological impacts on the ecological

units that are sustaining inland fisheries. Freshwater fish species and many of the taxa they interact with are poikilotherms, i.e., thermal conformers and require specific temperature ranges that may differ between species and even life stages and are therefore affected by changes in water temperature at many levels including sub-organism, individual, population, species, community, and ecosystem levels (Brett 1970; Harrod 2016; Harrod et al. 2018; Souchon and Tissot 2012). Different species occupy distinct niches based on their food habit that is spread across different stratification layer within the aquatic habitat; any imbalance in these systems would result in the availability of these species. Among the anthropogenic stressors, the primary ones are river regulation, dam construction, water abstraction, etc. which cause degradation and fragmentation of habitat, loss of sensitive species, and population connectivity. Climate change affects catchment hydrodynamics through the change in the pattern of precipitation which affects discharge patterns and influences the availability of water for fisheries, physico-chemical parameters, etc. (De Wit and Stankiewicz 2006).

6 Impact on Biodiversity

Climate change may cause a reduction in the profusion of certain species while facilitating the growth of certain other species. Changes in species abundance will result in a change in harvesting patterns. On a larger scale, this may drive certain species towards extinction. Also, the incidence of invasion may become more random and certain alien species may become abundant in ecosystems that were otherwise not suitable for them. Changes in the top predators depend on prey availability. In case of an altered abundance of certain prey species, it will result in a lower encounter of prey densities by the predator. In a study conducted by Vass et al. (2009), it has been observed that the predator-to-prey ratio has decreased in the middle and lower parts of the river Ganga from 1:4.2 to 1:1.4 and 1:2.3 to 1:0.9, respectively, in the last four decade. Altered prey–predator relationships would disrupt the food chain and alter the availability of fish.

7 Impact on Fishing Communities

Indigenous communities who mostly depend on the fisheries and other agricultural practices for livelihood especially in the coastal and surrounding regions are likely to be hugely impacted as a rising sea level would leave them landless and also changing weather pattern leading to frequent cyclonic storms along with loss of mangrove covers not only causes destruction of their houses, properties, and livestock but also an influx of sea water in their ponds and freshwater bodies and agricultural lands leaves them unsuitable for fishing and farming thereby eliminating their sources of livelihood which ultimately forces them to move to towns and cities in search of jobs giving rise to climate refugees, an example of which can already be observed in the deltaic Sundarbans where rural landholders and pond owners were forced to move to

towns and cities in the aftermath of the recent cyclonic storms like Ayla, Bulbul, and Amphan, and the dangers imposed by such unplanned migration were observed in the course of the nation-wide lockdown due to the Covid-19 pandemic where migrants could not sustain their daily lives in the absence of their livelihood giving the situation an apocalyptic appearance. In the case of communities living in various areas of the mainland, they exclusively rely on traditional knowledge and indigenous practices. In changing climatic conditions leading to reproductive and behavioral changes in the aquatic organisms these people are likely to face serious constraints in terms of fisheries and therefore are expected to face loss of livelihood eventually crippling them with poverty and malnutrition.

7.1 Loss of Livelihood

Fish Seed collection is one of the major livelihood options of the fishermen community in Sundarbans. But, due to the impact of climate change, particularly for fluctuation in surface water salinity, and sea-level rise the availability of commercially important shellfish and finfish has reduced, and it is now directly impacting their major livelihood option.

In Sundarbans, people are involved in fish culture in the adjoining ponds of their houses for consumption purposes and also for earning. But, due to climatic hazards, like changes in rainfall patterns or for prolonging dry spells the ponds are dried up and the aquaculture activities often hamper and the food and nutritional security comes under question.

Capturing/harvesting fish from the water channels, canals, paddy fields, and creeks is often hampered due to floods or prolonged dry spells. The creeks, channels, and canals are overflowing or dried up and the fishermen's community loses their earnings.

7.2 Impact on Food and Nutritional Insecurity

"Adequate access of food to all people at all times for an active, healthy life" is food security (Gross et al. 2000). People should have availability and access to safe and quality drinking water and also nutrition-rich food to meet their daily dietetic requirements. But, due to climate change, some islands are almost disappearing, some are sinking, agricultural land is shrinking, and many people are displaced from their land. Due to the ingress of sea water in some places, people do not have even physical access to safe drinking water. Moreover, due to extreme climate event Aila in 2009, in Indian Sundarbans, the salt water ingress has destroyed the natural habitat of many nutrition-rich Small Indigenous Fishes (SIFs) like Kholisa, *Nandos,* Akash Tangra (*Mystus vittatus*), Pabda (*Ompok pabda*), etc. and that has caused a drastic reduction of the population of such fishes in the freshwater bodies in Sundarbans (Sinha et al. 2014). Small Indigenous Fishes are traditionally an integral part of the household diet of Indian Sundarbans. These small fishes are rich in vitamins and

minerals. Women of the fisher folk community are solely responsible for the household food and nutritional security because they collect food, prepare food, purchase food, grow food, and store food. Due to climate change, the decline in SIFs in natural water bodies ultimately has led to nutritional insecurity of the local populace of Sundarbans, as fish is the only source of protein, minerals, and vitamins to the fishermen community. Moreover, due to land erosion, and an increase in soil and water salinity, kitchen gardening is also not clicking. So, people of the fisher folk community have to think of alternate strategies to feed their children. They are compelled to work hard or overtime to earn money.

8 Vulnerability and Resilience

Vulnerability and resilience have come to be known as two key concepts in the climate change scenario. Vulnerability is defined as the susceptibility of groups or individuals due to climate changes. Vulnerability is influenced by key factors like external environmental threats, internal factors like socio-economic disposition, governance, geographical distribution, food security, conflict, quality of health, etc.; according to the Intergovernmental Panel on Climate Change vulnerability is defined as ". . .a function of the character, magnitude, and rate of climatic variation to which a system is exposed, its sensitivity, and its adaptive capacity" (McCarthy et al. 2001: p. 995). Allison et al. (2005) described vulnerability (V) as a function of potential impact (PI) which is the total impact without taking any planned adaptation into account and adaptive capacity (AC) which is the ability of systems to adapt to changing climate, i.e., $V = f(\text{PI, AC})$, where PI is determined by exposure (E) and sensitivity (S) and E is the degree to which fisheries systems are exposed to climate change; and S is the degree to which economy reliant on fisheries is sensitive to changes.

Resilience depends on vulnerability and adaptive capacity. In fisheries-like sectors where management involves both social-ecological systems resilience has gained acceptability. Resilience focuses on the capacity of the system to defy change and also involves the importance of disturbance, reform, and restoration. Social economical resilience includes social learning, information, awareness, leadership, social networks, linkages, and institutions for navigating disturbance, adapting to change, and managing the resilience of a system to remain in a desirable state (Folke 2006).

9 Adaptation and Mitigation of the Impacts of Climate Change

Ideally controlling the emission of greenhouse gases and other damaging practices that accelerate global warming therefore climate change should have been the priority to lower the chances of worsening the situation than it already is; unfortunately, it seems to be a matter of conflict among the decision-makers at an

international level, thus making it nearly impossible to achieve the climate goals in its due time. Hence the next course of action is going to be making adjustments and adapting to the changing environment. Detailed and systematic analysis of the presently available data is going to be crucial in assessing the observed changes and predicting the expected changes in the future and therefore recruiting strategies to address the challenges.

Adaptation involves multifaceted adjustments by people to sustain their well-being which includes ecological, social, and economic areas, either in the face of an already observed change or in anticipation of one that is predicted to take place soon. Therefore adaptation can be either in terms of bringing changes in fisheries management practices or through building adaptive capacity (Daw et al. 2009). Therefore adaptation can be defined as ongoing changes involving actions, decision making, planning strategies, and attitudes towards capitalizing and alleviating the unfavorable effects of climate change.

10 Adaptation in Fisheries Management

The role of management in fisheries is mostly limited to achieving the highest production through sustainable practices that involve static management plans that do not generally incorporate environmental processes. In the face of a changing climate introducing somehow flexible management practices that are specific to the requirement at the moment is going to be crucial. Therefore adopting the ecosystem approach to fisheries (EAF) (FAO 2007), which involves an ecosystem-integrated and participatory approach, is going to prove more beneficial. The act of strategizing adaptive management practices, making policies following those decisions, developing new technologies, and proper implementation of these newly adapted tools and strategies is going to be crucial at the institutional level. At the same time involvement of smaller organizations like district or block level fishery officials, fishers cooperatives, panchayat members, and even individuals is imperative in ensuring successful adaptation of these practices through area-based micro-management and needs to be equally valued to ensure that policies enforced by larger institutions are equally effective at the local level and are adaptable by the local communities.

11 Building Adaptive Capacity

The consequences of climate change are unprecedented; hence the fishers especially rural, marginal fishers who are likely to be otherwise less sensitized would probably find it difficult to make the necessary adjustments that are being made in the face of such changes. To address this issue capacity building is going to be of utmost importance. Capacity-building programs that are directed towards enabling them for making any adjustments when necessary and allocating adequate funds for the same would prove to be beneficial in this scenario. Also, the institutional framework

needs to be built keeping in mind the need for shifting focus towards adapting flexible resilient fishery practices in place of the static production centric one. The resource-poor fishers are already troubled with various constraints be it socio-economical, health, etc. that leave them more vulnerable to adversities brought upon by the changing climate. Therefore any capacity-building work done with the aim of their general well-being would ultimately be beneficial in empowering them with adaptive abilities.

12 Adaptation in Aquaculture Practices

Adapting from the categories provided by Tompkins and Adger (2004), Smit et al. (2000), and Daw et al. (2009) provided certain adaptation strategies for aquaculture involving both public and private involvements that can be either anticipatory or reactive based on the kind of impact a certain change asserts on fisheries. Adaptations in aquaculture practices need to be made as per the circumstances are faced. In case of reduced productivity accessing higher-value markets by the traders and increasing fishing efforts by fishers can be beneficial. In case of increased variability in yield introducing insurance schemes would benefit the smaller farmers whereas the application of integrated adapting measures in terms of fishing practices can help secure the amount of yield. In case of change in the distribution of fisheries research predicting the availability of fish stock would prove to be beneficial, especially for riverine fisheries. In case of reduced profitability through fisheries reducing the cost to increase efficiency is required and alternate livelihood opportunities need to be considered when cost reduction cannot be implemented or the workforce needs to be reduced. Also in more severe cases leaving the fishery altogether for other livelihoods has to be advised. As the coastal, riparian, and the communities of the floodplain wetlands are more vulnerable to the changing climate reactive and anticipatory adaptations are required. Early warning systems and educating the common populace about the coming dangers help to mitigate the adversities to some extent. Improving infrastructure to secure landing sites or equipment would reduce loss. Post-disaster responses like quick disaster response and rehabilitation would save potential live loss, and assisted migration when necessary would ensure minimal damage in terms of overcrowding and acquiring unhealthy living situations. Diversification of markets and products and also dispersal of information on the trends and anticipation in terms of market shock would help to avert the economic shocks and would also help fishers to reach international markets and achieve a fair price for their produce (FAO 2007). While generalized adaptation measures are introduced Morton (2007) argues that it would be difficult to predict the impacts of climate change and therefore come up with a model for adaptation to these changes, especially for small and marginal farmers. Hence location and context-specific adaptation strategies would prove to be more beneficial. Eriksen et al. (2005) encourage diversifying cropping systems and also the use of wild foods.

13 Gender Aspect to Vulnerability and Adaptive Capacity

Earlier studies have revealed that access to basics is essential for adaptive capacity depending on various socio-economic variables like age, class, gender, etc. (Cutter 1995; Denton 2004; Enarson 2002). Consequently, climate change also has gender-specific propositions (Dankelman 2002). There are defined gender roles in social, cultural, and household life that affect the vulnerability and adaptive capacity of women to climate change. According to Davison (1988), women in developing countries are involved in natural resource-based activities like agriculture compared to salaried jobs and since these resources are directly dependent on climatic conditions women are likely to be affected through different mechanisms like water availability, availability of fuelwood, vegetation, health issues, etc. Women are seen to be the worse sufferers of any natural disaster whether in terms of more death or post-event recovery which can be attributed to the additional burden of caregiving to children and the elderly compared to men who return to their pre-disaster roles. The vulnerability of women is amplified by unequal access and right over resources, discrimination in property rights, etc. Like other agricultural practices, women's involvement in fisheries is also affected by similar constraints. Though the involvement of women in large-scale fish capture is less observed, women are more involved in catching fish especially SIFs for household consumption which is crucial for household nutritional security thus in case of altered fish availability due to climate change it is going to add to the burden of hunger and malnutrition. The role of gender in influencing adaptive capacity is critical and thus capacity-building policies implemented without considering gender add the gender dimension of vulnerability (Denton 2004). It can be also observed that proactive capacity building rather than reactive disaster management would be beneficial in ensuring gender equality (Mirza 2003).

The fisherwomen perceived that in any governmental program they are generally ignored, and no input facilities are provided to them even after heavy climatic shock. Domination of individuals or a particular group often causes an equilibrium in distributing inputs. In inland open water fisheries there is no insurance policy for the fishermen's communities. Due to a lack of financial inclusion, the fishermen's community cannot access insurance facilities due to damages in natural calamities. Even they cannot access institutional credit facilities after smash-up events. Male members generally migrate for a job and the fisherwomen stay behind and become more vulnerable to criminal attacks or sexual violence. The health and hygiene of fisherwomen are often forfeited at the cost of their family responsibilities.

14 Mitigation

Though emission from fisheries especially inland fisheries is not generally significant, however opportunities to reduce emissions if possible need to be explored. The use of fossil fuel in vessels, emission of GHGs while production of fish feeds, and emissions due to trade are the major contributors to this sector. Improving the

efficiency of fishing vessels to ensure lesser use of fuels or sustainable practices in feed production or fisheries management or encouraging local consumption or use of bulk sea freight for transport of aquaculture products in place of using air freights may help reduce overall emission. Long-term goals may include increasing mangrove cover, research on climate-resilient species, etc.

15 Conclusion

Climate change will impact the weather systems and therefore it will affect weather patterns, the occurrence of climatic events that would ultimately impact fisheries resources, and therefore fisheries practices and all the associated areas. Adaptation strategies that have been devised to combat climate change sometimes cannot be implemented properly due to a lack of political will. It can be argued that the adaptation that involves large-scale investment or major action is more likely to be implemented when triggered by an extreme event. It can also be noted that adaptation operates differently at different spatial and socio-economical levels and therefore the feasibility of a certain adaptation plan needs to be assessed separately for each condition. For management practices, comprehensive and ecosystem-integrated approaches are to be encouraged. Vulnerability and risk assessment needs to be conducted at the local level. The threat to food security needs to be assessed beforehand, and availability of the required nutrition needs to be ensured to avert the impact of hunger and malnutrition and the consequential morbidities on the society. Water demand is likely to increase in the coming years due to uncertainty involving water availability and growing population pressure, increased need for irrigation in agriculture, etc. which will lead to water stress. To deal with it integrated water resource management practices and different measures for different resources need to be implemented. Reforms in institutional, market infrastructure, and fisheries governance to adjust and adapt to the changing environment are required. Finally, extensive research and development of technologies, both to assess and adapt to the ongoing changes, seem to be the best choice of defense.

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