

Impact of climate change and technologies

for climate resilient inland open water fisheries

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Climate change adversely impacts aquatic ecology and fisheries especially in the developing countries including India. This results in loss of fish diversity leading to habitat degradation which impacts income and livelihood, making the dependent fishers vulnerable. Hence, assessment of vulnerability is essential to develop appropriate adaptation and mitigation strategies. Application of vulnerability framework suggested low adaptive capacity of the fishers in the states of West Bengal, Assam and Kerala suggesting the need for adopting appropriate adaptation strategies. The identified potential climate resilient management strategies, viz. climate resilient pen system, cage culture, climate resilient culture-based fisheries, temporary pre-summer enclosure, deep pool refuge, autumn stocking, submerged branch pile refuge and floating aquatic macrophyte refuge-based fishery can be adopted by wetland fishers to cope up with adverse impact of climatic variability and associated stressors. As per the study, fish species, viz. Labeo bata, Systomus sarana, Channa punctata, Anabas testudineus, Clarias magur, Heteropneustes fossilis, Cirrhinus mrigala, Puntius sophore were identified as climate smart. Technological advances in climatic change and importance of climate resilient inland fisheries in India have been discussed and potential adaptation strategies for food and nutritional security have been suggested.

Keywords: Adaptation, Climate change, Inland open waters, Vulnerability

CLIMATIC variability and its consequences have intensified across the world during the last few decades impacting livelihood and nutritional security of people especially in developing countries. The global surface temperature has increased faster since 1970 than in any other 50 years period over at least the last 2000 years (IPCC 2021). In the last two decades of the 21st century (2001–20), the rise in global surface temperature was +0.99°C. While just within one decade (2011–22), the current global surface temperature has risen to +1.09°C. Therefore, at global level the focus has been given to develop technologies and climate resilient adaptation strategies for sustainable food and nutritional security.

Climate change can alter the water temperature, water levels and flow, and it will exert substantial impact

on aquatic ecology and fisheries. The impact of climate change alongside the anthropogenic factors and other stressors render inland open water ecosystems vulnerable, leaving the income and livelihood of millions of fishers at stake. Climate data analysis revealed a warming trend along major river basins, declining rainfall and shifting seasonality of rainfall occurrence. The available literature showed an increase of 0.99°C in the minimum water temperature in the upper stretch of river Ganga and 0.5–1.4°C in the aquaculture farms of West Bengal located in lower Ganga basin.

ICAR-Central Inland Fisheries Research Institute has been conducting research on climate change and inland open water fisheries under the network project on National Innovations on Climate Resilient Agriculture (NICRA).

Significant research pertaining to impact of changing climate on fish diversity and breeding phenology, assessment of the tolerance level of species, development of wetland vulnerability assessment framework, ecosystem and social vulnerability, carbon dynamics and methanogenic, and methanotrophic microbiota in different categories of wetlands, heatwave impact on aquatic ecology and development of climate resilient adaptation strategies etc. have been carried out.

Climate change impact

Loss of aquatic biodiversity is a major consequence of climate change and anthropogenic stressors are affecting sustainability of fisheries. In the wetlands of West Bengal, the population of fishes like Pabda, Boal, Sarputi, Aar, Betta and Eelshas declined in last 15 years. The

fish diversity declined to the tune of 22.85–54% in the last two decades in the studied wetland. The spawning of Indian major carps in hatcheries of eastern region of India has been extended, due to climate variability. The studies on snow trout from lesser Himalayas revealed stabilization of breeding phenology and the species is adapting to changing climate in the region. The study on breeding phenology of revealed that the changing climate pose a negligible threat on reproduction of *Channa punctata*, *Puntius sophore*, *Amblypharyngodon mola*, *Nandus nandus*, *Johnius coitor* in the near future in Ganga basin. In the case of *Gudusia chapra*, fishing by small mesh nets appeared to be a bigger threat than climate change.

Water stress affects fish physiology, viz. growth and reproduction and thereby fish production. The persistent stress compromises the immune system of fish and leads to disease outbreak and crop loss. The occurrence of droughts is becoming common due to reduced rainfall and delayed monsoon. The drought is associated with reduced water level and area, cessation of fish seed production and farming, reduced dissolved oxygen level, increased salinity, occurrence of algal bloom, ammonia toxicity, and fish disease outbreak, associated mortalities and economic loss. Heat Waves (HWs) influence the environment parameters and biotic community especially primary producers in the aquatic ecosystems

of lower Ganga basin, India. They impact the feeding behaviour of commercially important fishes.

Coastal wetlands are threatened due to extreme weather events like storm surges and sea level rise. The occurrence of a tropical cyclone Aila in South 24 Parganas, West Bengal caused considerable salt water intrusion into coastal lowlands and consequently increased the salinity of water. This made these lands unsuitable for agriculture and thus were converted to brackish aquaculture site for farming of highly valued fish species such as seabass and mullets as an alternate livelihood option. Due to repeated extreme climatic events (i.e. Amphan in 2020, Yass in 2021), large number of river bheries were destroyed, leaving fish stocks to adjacent rivers and canals. Due to irregular climate events and lack of alternative income generating activities, primary fishers have been forced to search for alternative livelihood options causing migration.

Vulnerability assessment

Assessment of vulnerability is essential to develop appropriate adaptation and mitigation strategies. Multiple methods are available to assess the vulnerability of wetland ecosystem and fisheries. Stakeholder perception based approach is one such method which overcomes the absence of time series data. Our findings showed that out of the 14 districts of West Bengal, five districts were highly vulnerable

which could be attributed to low adaptive capacity of the fishers. The institute has also developed a hybrid method of index-based vulnerability comprising two types of indicators, viz. climate indicators and stakeholder perceived vulnerability indicators based on a study conducted in 15 wetlands of West Bengal.

Climate resilient inland fisheries management

As stated by FAO, inland fisheries are reinforced by a complex interaction of physical, chemical and biological factors which have to be regulated to increase the fishery output and sustainable fishing. Apart from aquaculture, inland fisheries encompasses diverse farming operations such as culture-based fisheries in reservoirs and wetlands, enclosure culture techniques like cage culture, and pen culture.

Climate resilient culture-based fisheries (CRCBF): The adoption of CBF will result in significant increase in fish production, especially in aquatic habitats that are limited in terms of natural recruitment (e.g. small seasonal reservoirs, wetlands). The fish seed stocking should be based on effective water area and small indigenous climate smart fishes may be promoted for stocking along with Indian major carps. Stocking of plankton feeders in wetlands with plankton bloom/ algal biomass is a viable option to utilize the excess food base in



Climate resilient fish



CIFRI GI model cage installed in a wetland and fish seed stocking

the system and to keep the water quality at desired levels. Grass carp can be stocked as biological control strategy of macrophytes in wetlands as it feeds heavily on macrophytes. The removal of *Eichhornia* sp. and its management is suggested for better utilization of the water resource. Nutrient management may be prioritized to avoid eutrophication and excess carbon can be converted to fish biomass especially in sewage fed wetlands through customized CBF practices.

Cage culture: Cage culture utilizes the existing water resources effectively so that more production per unit area could be achieved. Cages are being used to produce different fin fish and shell fish species in fresh, brackish and marine ecosystems. Cages in inland waters can be used for both table fish production and fish seed raising for stocking in open waters. The cages have high strength, flexible net material, provision to withstand wind action, flood and can be used for culturing resilient

indigenous fish species. Stocking of climate resilient fish species must be encouraged in cages to adapt to changing climate.

Pen culture: The institute has successfully demonstrated climate resilient pen systems in wetlands of West Bengal, Assam and Kerala for farming of fish and conservation of SIFs. The climate resilient pen system (CRPS) has HDPE net material of high strength, provision to withstand flood, wind action and is used for culturing climate smart species. The clam relaying and rack culture were devised and demonstrated in Vembanad lake to increase production of black clams (*Villorita cyprinoides*) in the context of decline in clam harvests. The annual growth rate of clams was 14.23 mm/year and 47.98 g/year as per length and weight, respectively. An average production of approximately 2 tonnes was obtained from the pen.

Other adaptation strategies: Indigenous adaptation strategies were identified and documented from wetlands, viz. temporary pre-

summer enclosure, submerged branch pile refuge, autumn stocking, deep pool refuge and floating aquatic macrophyte refuge fishery. These can serve as refuge during summer and help in maintaining base stocks in the wetlands for recruitment in the following monsoon season. The study elaborated the climate smart nature of these indigenous strategies, emphasized the optimization of these strategies for large-scale adoption by the fishers.

Exploring climate smart freshwater fish species

A total of 66 common fish species of the Gangetic floodplain wetlands were studied to identify climate smart species based on their biological characteristics. Depending on key features, they were enlisted into 5 categories, viz. climate smart species, resilient species, moderately resilient species, moderately sensitive species and sensitive species. As per the study, fish species like *Labeo bata*, *Systemus sarana*, *Cirrhinus mrigala*, *Anabas*



National campaign on Climate Resilient Inland fisheries at freshwater and coastal wetlands

Table 1. Biological features of selected climate smart freshwater fishes

Species	Feeding habit	Trophic level	Fecundity	IUCN status	Vulnerability	Optimum temperature	Doubling time	Breeding season	Optimum pH range	Accessory respiratory organ
<i>Anabas testudineus</i>	Carnivorous	3.0 ±0.4	39687–86108	LC	12	22–30°C	15 months	June–July		Present
<i>Channa punctata</i>	Carnivorous	3.8 ±0.70	2300–29600	LC	18	22–28°C	1.4–4.4 years	April–October		Present
<i>Clarias magur</i>	Carnivorous	3.4 ±0.5	2,340–13400	EN	25		15 months	May–July		Present
<i>Heteropneustes fossilis</i>	Omnivorous	3.6 ±0.3	4200–15750	LC	17	21–25°C	1.4–4.4 years	June–September	6.0–8.0	Present
<i>Labeo bata</i>	Herbivorous		192785	LC	23		15 months	July–August		Absent
<i>Systemus sarana</i>	Omnivorous	2.9 ±0.2	65485	LC	31	22–30°C	1.4–4.4 years	April–July	6.5–8.5	Absent
<i>Puntius sophore</i>	Omnivorous	2.6 ±0.1	6106–6942	LC	11	22–30°C	15 months	April–July	8.0–8.5	Absent

testudineus, *Channa punctata*, *Clarias magur*, *Heteropneustes fossilis* and *Puntius sophore* can be considered as climate smart species due to wide extend of food acceptance, multiple trophic level habitat, high fecundity rate, wide range of thermal tolerance level, low doubling time, prolonged breeding period, and presence of accessory respiratory organ in some species which help them to survive in low dissolved oxygen.

SUMMARY

Climate resilient management strategies such as CRPS, cage culture, CRCBF, temporary pre-summer enclosure, deep pool refuge, autumn stocking, submerged branch pile refuge and floating aquatic macrophyte refuge-based fishery have the potential to cope

up with adverse impacts of climate change. Application of vulnerability framework suggested low adaptive capacity of the fishers indicating the need for appropriate adaptation and mitigation strategies. The fish species identified as climate resilient from Ganga basin using multiple approaches can be included in fish farming practices for increased profitability and adaptability. The research outputs and data generated will serve as baseline to understand the climate change and associated impacts on inland fisheries and to develop mitigation and adaptation strategies. The stakeholders must be included in decision making process especially in the context of climatic variability and participatory management. The expansion of identified climate resilient

adaptation strategies in potential resources and mass awareness programs to sensitize the fishers about the climate change are the need of the hour. CRPS may be used efficiently for conservation of Small Indigenous Fishes (SIFs) of wetlands. There is also a need to intensify efforts for increasing climate literacy among all stakeholders as well as farmers for sustainable climate smart fisheries. National campaigns for awareness creation and capacity building of stakeholders have to be prioritised to have effective climate resilient inland fisheries.

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Jai Kisan, Jai Vigyan

- A total of ₹788.33 crores have been sanctioned for opening six new agricultural colleges for eastern India under Central Agricultural University, Imphal, and a new Central Agricultural University in Meghalaya.
- For the establishment of two new agricultural research institutes in Asom and Jharkhand, a sum ₹100 crores is allocated.
- First academic session of the Rani Lakshmi Bai Central Agricultural University has been allocated for four new agricultural colleges in Ditiya and Jhansi.
- An Memorandum of Understanding was signed for transforming the Rajendra Central Agricultural University, Pusa, Samstipur, Bihar. A proposal of ₹400 crores is submitted in EFC.
- Post-Graduate Institute of Horticulture is being established in Amritsar, Punjab.
- Foundation stone of the Indian Institute of Agricultural Biotechnology is laid at Ranchi for promoting agricultural biotechnology.