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Research Article

Adaptation and Mitigation Strategies of Climate Change Impact in Freshwater Aquaculture in some states of India

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Abstract: We surveyed the fish farmers of five states, viz. Andhra Pradesh, Karnataka, Gujarat, Odisha and West Bengal of India for adaptation and mitigation strategies of climate change impact in freshwater aquaculture. In monsoon period especially when the cyclone occurred, overall 9% fish farmers responded regarding fish migration from one pond to another pond. Sometimes entire stocks washed out due to heavy floods. Overall 23% farmers responded about water quality deterioration and contamination due to unforeseen weather conditions mostly during rainy and summer seasons. Disease incidences during the winter seasons especially Argulus infestation was reported by 42% respondent. About 37% farmers in Andhra Pradesh, West Bengal and Odisha expressed that farming systems were damaged and lost all the fishes because of extreme events like flood, cyclone etc. They also reported that all operational cost increased every time in re-construction of ponds due to floods. The farmers tried to mitigate some of the problems encountered due to climate change. Overall, 43% of farmers are pumping freshwater to cool down the temperature of fish culture ponds. Some farmers applied oxygen tablets during higher summer. When there is low rain fall, 60% farmers maintain water level by pumping in water from their bore well. While 75% farmers never experienced any disease problem, 25% reported such incidence, among them 50% apply lime in case of appearance of disease symptoms. In case of drought, 25% of the farmers reported that they have made early harvest, irrespective of the fish growth, others never stock the ponds. In case of flood, 48% of farmers used to prevent fish escape by using mesh like structures in pond bunds to prevent fish escape, while 16% pump out water using their pumps.

Keywords: Adaptation; Mitigation; Climate Change; Aquaculture

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Introduction

Aquaculture is shaping up into a global venture and it is considered as the fastest growing food producing sector in the world to feed the ever-growing population. Freshwater aquaculture is the principal component for catering the increasing demand for fish particularly in India. Fish is considered as a cheap and safe source of protein which provides essential nutrition for 3 billion people and at least 50% of animal protein and minerals to 400 million people from the developing and under-developed countries in the world. Also, it gives livelihood option to about 520 million people in the globe. With a total fish production of 9.33 million metric tones (mmt) in 2010, India has become the third largest fish producer in the world. Of the total, about 49.72% (4.64 mmt) is contributed by freshwater aquaculture and India is second to China in freshwater aquaculture production. This much important food producing sector is really in the threat of global warming and climate change. Climate change is a change in the statistical distribution of weather over periods of time that range from decades to millions of years. It is now widely accepted that climate change is no longer simply a potential threat, it is unavoidable; a consequence of 200 years of excessive greenhouse gas (GHG) emissions from fossil fuel combustion in energy generation, transport and industry, deforestation and intensive agriculture is realized. Climate change is an additional pressure on the freshwater aquaculture and the impacts of climate change on freshwater aquaculture are more complex than those on terrestrial agriculture because it holds poikilothermic animals, which is highly sensitive to various kind of biotic and abiotic stress that directly affect the growth, reproduction, physiology and behavior of fishes. Climate changes affect the aquaculture directly by influencing fish stocks or indirectly alter the primary and secondary productivity, structure, and composition of the ecosystems, or by influencing fish prices or the cost of fish meal, fish oil and other goods and services required by fishers and fish farmers. In the present study, we conducted survey among fish farmers in different states of India about their views on adaptation and mitigation strategies for climate change impact in freshwater aquaculture.

Materials and Methods

A study about fish farmers' perceptions of possible impact of climate change on freshwater aquaculture was done through some structured questionnaire and personal interview. For, adaptation and mitigation strategies, we have surveyed the fish farmers of some states, viz. Andhra Pradesh, Karnataka, Gujarat, Odisha and West Bengal in India.

The fish production in Andhra Pradesh was 19.64 lakh tones (2015-16) and the state holds 1st rank in aquaculture production. We conducted a survey among fifty respondents through random sampling procedure in the Krishna Godavari Delta of Krishna, Guntur and West Godavari districts of Andhra Pradesh. Karnataka has 5.93 lakh ha inland water resources. The state stands in 8th position with respect to inland fish production in the country with 1.69 lakh MT (2015-16). Fifty respondents were interviewed in Bellari and Bangalore of Karnataka in this study.

Gujarat ranked first in marine fish production but rank 15th in inland fish production during year 2013-14. The freshwater aquaculture activities in Gujarat mostly carried out in village ponds (6860 nos. with 0.22 lakh ha.) and small reservoirs (1547 nos. with 0.92 lakh ha). We conducted a survey among fifty respondents through random sampling procedure in three districts of Middle Gujarat as Anand, Kheda and Vadodara.

Odisha is one of the important maritime states of India having plenty of freshwater resources (6.72 lakh ha) and has got excellent scope for freshwater aquaculture development. The freshwater aquaculture activities in Odisha mostly carried out in tanks and ponds (1.21 lakh ha) with production level of 2.31 lakh MT. We conducted a survey among sixty respondents through random sampling procedure in Puri, Cuttack, Khurdha and Keonjhargarh districts of Odisha.

West Bengal is one of the maritime states in the Country bestowed with immense freshwater fisheries resources (Pond/tanks: 2.88 lakh ha, Beel & Boar: 0.42 lakh ha, Reservoirs: 0.28 lakh ha, Canal: 0.80 lakh ha and Sewage fed fishery; 0.04 lakh ha) spread over the State considered to provide the massive scope for development of aquaculture. West Bengal is the pioneer and leader in production of fish seed in India. It contributes approximately 37-40% of the total seed production in the country. During 2015-16, 17521 million fish seed have been produced. During 2015-16, the state has produced 16.71 lakh ton fish of which 14.93 lakh ton (21-23% country) was from Inland. We conducted a survey among fifty respondents through random sampling procedure in Purba Midnapur, south and north 24 Paraganas. Overall, 260 respondents in the five states of India were interviewed in this study and the surveyed respondents selected through random procedure.

Results and Discussion

Almost 60 to 90 percent of the farmers perceive about the increased water temperature in summer months in the fish pond **(Table 1)**. They have perceived about decreased cool days/increased hot days. The 90 percent respondent in Andhra Pradesh and West Bengal are in the opinion that temperature increased to beyond optimum levels in the fish pond in summer months which causes high mortality due to stratification. About 14 to 35% of the farmers responded that water availability reduce during culture period particularly in summer month. They perceive that pond productivity decreases because of decreased water availability. The water scarcity is due to less rainfall in these areas. The farmers in Gujarat responded that insufficient water availability in the village ponds those are not connected to village drainage or canal. In Andhra Pradesh, the farmers responded that most of the hatcheries are closed in Krishna delta due to lack of water availability and is shifted to Godavari basins.

As freshwater availability is crucial for securing a sustainable, lower carbon future, there is a critical connection between water management and climate policies. Under a rapidly changing climate, it is more important than ever to estimate the degree of

Table 1: Farmers perception for possible impact of climate change on freshwater aquaculture.

Possible Impacts	States (respond %)					
	Andhra Pradesh (N=50)	West Bengal (N=50)	Odisha (N=60)	Gujarat (N=50)	Karnataka (N=50)	Overall (N=260)
Increased water temperature in summer months	90	90	70	70	60	66
Reduced water availability during culture period	14	30	25	35	20	25
Water quality deterioration	30	25	14	25	20	23
Migration of fish from one pond to other ponds during flood	10	10	8	-----	----	9
Increased disease outbreaks	43	46	16	46	60	42
Reduced survival due to heat stress	10	10	5	15	20	12
Damage to farming system and loss of crops due to extreme events like flood, cyclone etc	46	43	23	---	---	37
More disease incidence (Prevalence)	40	40	15	15	25	27
Loss of farm soil productivity	----	-----	------	----	27	---

future water security. This is a challenging task as it depends on many different variables: the degree of warming and its consequent effects on hydrological resources, the water demand by different sectors, and the possible ameliorations or deteriorations of the effects due to climate change adaptation and mitigation strategies. Koutroulis et al. (2018) reported about a simple and transparent conceptual framework to assess the European vulnerability to freshwater stress under the present hydro-climatic and socioeconomic conditions, in comparison to projections of future vulnerability for different degrees of global warming (1.5°C, 2°C and 4°C), under the high-rate warming scenario (RCP8.5). According to these authors different levels of adaptation to climate change were considered in the framework, by employing various relevant pathways of socioeconomic development.

Most of the fry production of Nile tilapia is done in the wet season in northern Thailand, as cold spells and drought conditions disrupt hatchery production and reduce fish farm demand in the dry season because of climate change (Uppanunchai et al., 2015). In the wet season, some hatcheries are also impacted by floods and for this; a couple of strategies was suggested by these authors that should help make hatchery operations more climate change resilient.

Climate change is expected to amplify existing threats within catchments, alongside causing novel shifts in the hydrological, thermal and biotic components of freshwater ecosystems. The ability of species and communities to adapt to climate change, together with the availability of in-stream refugia and options for species to move across natural and artificial barriers, will become increasingly important as time progresses (Markovic et al., 2017).

Almost 20-30% of the farmer's respondent about water quality deterioration, mainly due to unforeseen weather conditions mostly during rainy and summer seasons. Farmers felt that poor water quality was due to no drying of ponds which is due to non-availability of enough water to refill the ponds from the canal once it is emptied, which, in turn, is due to less rain fall.

About 5 to 20% of the farmers responded about the IMC mortality because of higher temperature and humidity in summer months. They also experienced mortality of IMC because of low dissolved oxygen problem during the rainfall at hot summer days. About 8 to 10% of farmers reported about the migration of fish from one pond to other ponds during cyclone or heavy floods. This mitigation mainly happens in the ponds having no bundh or fence with net or directly connected with canal or with low lying areas like rice field. However, Karnataka and Gujarat farmers have not reported this incidence of fish migration.

Almost 23 to 46% farmers responded that high temperature and heavy cyclone like *HUD HUD* (Particularly in Andhra Pradesh and Odisha) damaged most of the ponds and lost all the fishes due to mortality. All operational cost increased every time in re-construction of ponds due to floods. However, such incidents have not been reported by the farmers of Gujarat and Karnataka.

About 15 to 40% farmers perceived that higher disease incidence occurred during the winter seasons. The farmers experienced the incidence of *Argulus* infestation, particularly for IMC's, almost throughout the year. Most of the cases, farmers apply lime in case of appearance of disease symptoms.

About 27% of the farmers feel that soil salinity development in their farm in Bellari district of Karnataka. This incidence is due to reduced rainfall, which in turn, is due to climate change. However, farmers of other states have not experienced this. Attaher et al. (2009) concluded that sea level rise, soil and water degradation, undiversified crop-pattern, yield reduction, pests and disease severity, and irrigation and drainage management were the main key factors that increased vulnerability of the agriculture sector in Nile Delta.

The farmers tried to mitigate some of the problems of climate change in aquaculture practices. 60 to 100% of farmers pump freshwater to cool down the temperature of fish culture ponds **(Table 2)**. Andhra Pradesh and West Bengal farmers use this practice. In these states, farmers exchange water to maintain the good water quality. This helps to cool down the temperature. The farmers of Andhra Pradesh also planted coconut trees along the bunds of fish ponds to avoid heat in summer months.

Table 2: Farmers perception for mitigation practices to counteract climate change impact in freshwater aquaculture of some states in India.

Mitigation Practices	**States (respond %)**					
	Andhra Pradesh (N=50)	**West Bengal (N=50)**	**Odisha (N=60)**	**Gujarat (N=50)**	**Karnataka (N=50)**	**Overall (N=260)**
Freshwater pumping to cool down the temperature of the ponds	70	84	15	30	23	44
Use of oxygen tablets	46	43	35	40	15	36
Under low rainfall use of bore well water	80	70	60	43	46	60
Early harvesting because of drought	---	20	40	-----	15	25
Use of mesh like structures in pond bunds to prevent fish escape in case of flood	53	80	42	40	23	48
Pumping out water using pumps in case of flood	4	6	8	5	7	6
In early drying of ponds, stocking of advanced fingerlings for faster growth	80	70	50	15	15	46
The ponds used for seed rearing during monsoon are used for fodder during summer	----	-----	------	----	15	----
Use of different fish species other than Indian major carps	----	-----	------	----	15	---

In summer season, the oxygen deficiency problem occurs particularly in the mid-noon. To increase the DO content of the water, 15 to 46% farmers use oxygen tablet in the pond. When there is low rainfall, 43 to 80% farmers maintain water level by pumping in water from their bore well or canal.

In case of drought, 15 to 40% of the farmers responded that they have made early harvest, irrespective of the fish growth. However, in Andhra Pradesh and Gujarat farmers did not report about early harvesting of fish. 15 to 80% farmers have reported to stocking advance fingerlings for faster growth in early drying ponds. In fact, West Bengal and Andhra Pradesh farmers stocks advance fingerlings for getting faster growth. 15% farmers in Bellary district, Karnataka have reported to cultivation of fodder grass (which requires less irrigation) for their livestock during non-availability of sufficient amount of water for aquaculture. The ponds used for seed rearing during monsoon are used for fodder during summer.

In case of flood, 23 to 80% of farmers used to prevent fish escape either by using netting arrangement at inlet and outlet of the pond or by using mesh like structures in pond bunds to prevent fish escape. 4 to 8% of farmers pump out excess flood water using pumps. In case of small ponds, farmers do this practice to remove excess water as the ponds do not have any outlet to remove the water.

Almost 15% farmers have started culture of different fish species to combat climate change effect particularly in Karnataka as the farmers are experiencing mortality of carps due to DO problem during rainfall at higher temperature and humid days, they are opting for poly culture of *Pangassius* and pacu (major component) with small portion of carps, since these species are not so sensitive to high temperature and low dissolved oxygen like IMCs. The benefits of *Pangassius* culture as said by the farmers is that it requires water only for six months compared to 1 year for carps and also it can be grown with 1-2 feet of water compared to carps which requires 3-4 feet of water depth in addition to the higher production of *Pangassius* compared to carps per hectare. However, the culture of *Pangassius* is now widely being practiced in Andhra Pradesh particularly because of higher production. Few farmers have started culturing of *Litopenaeus vannamei* in their ponds as they are experiencing the development of salinity in soil due to scarcity of rain.

Paerl (2016) suggested that cyanobacteria's long evolutionary history has enabled them to adapt to geochemical and climatic changes, and more recent human and climatic modifications of aquatic ecosystems, including nutrient over-enrichment, hydrologic modifications, and global warming. Harmful (toxic, hypoxia-generating, food web altering) cyanobacterial bloom (CyanoHAB) genera are controlled by the synergistic effects of nutrient (nitrogen and phosphorus) supplies, light, temperature, water residence/flushing times, and biotic interactions. Accordingly, mitigation strategies are focused on manipulating these dynamic factors. Strategies based on physical, chemical (algaecide) and biological manipulations can be effective in reducing CyanoHABs. However, these strategies should invariably be accompanied by nutrient (both nitrogen and phosphorus in most cases) input reductions to ensure long-term success and sustainability. While the applicability and feasibility of various controls and management approaches is focused on freshwater ecosystems, they will also be applicable to estuarine and coastal ecosystems. In order to ensure long-term control of CyanoHABs, these strategies should be adaptive to climatic variability and change, because nutrient-CyanoHAB thresholds will likely be altered in a climatically more-extreme world (Paerl, 2016).

Table 3: Adaptive capacity to face climate change.

Issues	Andhra Pradesh (N=50)		West Bengal (N=50)		Odisha (N=60)		Gujarat (N=50)		Karnataka (N=50)		Overall (N=260)	
	Yes (%)	No (%)	Yes (%)	No (%)	Yes (%)	No (%)	Yes (%)	No (%)	Yes (%)	No (%)	Yes (%)	No (%)
Support through Insurance schemes	--	--	--		--		--		--		--	--
Institutional support in adaptation planning	20		20		20		15		15		18	
Existence of risk communication network	90		90		78		70		70		80	
Farmers' association role in increasing the resilience	10		10		5		8		8		8	

None of the farmers has the insurance for their farm; it is noticed that few are not aware of this. For adaptive capacity, 15 to 20% farmers are obtained institutional support, mainly from the different training and awareness programs of the ICAR- CIFA, different Krishi Vigyan Kendras (KVKs) and state fisheries department **(Table 3)**. Never the less, 70 to 90% farmers get the risk-oriented information through a communication network. However, only 8-10 percent farmers are involved in the farmers' association regarding the climate resilience aquaculture. Medany et al. (2007) concluded that designing adaptation strategy for agriculture sector should consider the simple and low cost adaptation measures, which may be inspired from traditional knowledge, and meet local conditions and compatible with sustainable development requirements.

According to Intergovernmental Panel on Climate Change (IPCC) and Food and Agriculture Organization (FAO), climate change may result in global warming, sea level rise, changes of ocean productivity, freshwater shortage, and more frequent extreme climate events. Consequently, climate change may affect aquaculture to various extents depending on climatic zones, geographical areas, rearing systems, and species farmed. There are two major challenges for aquaculture caused by climate change. First, the current fish, adapted to the prevailing environmental conditions, may be suboptimal under future conditions. Fish species are often poikilothermic and, therefore, may be particularly vulnerable to temperature changes. This will make low sensitivity to temperature more important for fish than for livestock and other terrestrial species. Second, climate change may facilitate outbreaks of existing and new pathogens or parasites. To cope with the challenges above, three major adaptive strategies are identified. First, general 'robustness' will become a key trait in aquaculture, whereby fish will be less vulnerable to current and new diseases while at the same time thriving in a wider range of temperatures. Second, aquaculture activities, such as input power, transport, and feed production contribute to greenhouse gas emissions. Selection for feed efficiency as well as defining a breeding goal that minimizes greenhouse gas emissions will reduce impacts of aquaculture on climate change. Finally, the limited adoption of breeding programs in aquaculture is a major concern. This implies inefficient use of resources for feed, water, and land. Consequently, the carbon footprint per kg fish produced is greater than when fish from breeding programs would be more heavily used. Aquaculture should use genetically improved and robust organisms not suffering from inbreeding depression. This will require using fish from well-managed selective breeding programs with proper inbreeding control and breeding goals (Sae-Lim et al., 2017).

Creating opportunities for the aquatic acidification, community and the aquaculture industry to work together should help to speed up the adaptation process and enable the aquaculture industry to rapidly adapt by using better-informed decisions to; a) optimize the water chemistry conditions within intensive aquaculture to suit the species, and/or b) select traits within the species to suit intensive aquaculture conditions. This will help address the environmental, economic and social impacts of this developing sector towards a sustainable intensification of production, enhancing food security and its resilience to climate change. Equally, this cross-discipline interaction should also improve our capability to predict and mitigate the consequences of the changing chemistry for natural ecosystems in a future "high" CO_2 world (Ellis et al., 2017).

Conclusion

From the above discussion, it is clear that climate change has a strong impact on aquaculture. Different strategies are being used by the fish farmers and by doing so, they are getting benefit. The strategies are location specific. Among the three main problems, viz., drought, flood and temperature rising, drought is very much dangerous as without sufficient rainfall, the culture of freshwater aquaculture practices will be difficult. In this regard, more research is required by which 'per drop more crops' can be achieved.

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