AQUATIC ECOSYSTEM
HEALTH & MANAGEMENT SOCIETY

MICHIGAN STATE UNIVERSITY PRESS

Effect of extreme climatic events on fish seed production in Lower Brahmaputra Valley, Assam, India: Constraint analysis and adaptive strategies

Birendra Kumar Bhattacharjya[1*], Anil Kumar Yadav[1], Dipesh Debnath[1], Bhaskar Jyoti Saud[1], Vinod Kumar Verma[1], Sona Yengkokpam[1], Uttam Kumar Sarkar[2] and Basanta Kumar Das[2]

[1]*ICAR-Central Inland Fisheries Research Institute, Regional Centre, Guwahati-781006, Assam, India*
[2]*ICAR-Central Inland Fisheries Research Institute, Barrackpore, Kolkata–700120, West Bengal, India*
**Corresponding author: bkbhattacharjya@gmail.com*

The climate of Brahmaputra valley (located in the North-eastern Indian state of Assam) witnesses considerable changes with sub-tropical rain-storm atmosphere and has four well-defined seasons (monsoon, post-monsoon, winter and pre-monsoon) in a year. The state is experiencing extreme climatic events like erratic rainfall patterns (causing abnormally high floods) and drought-like situations in recent years, which adversely affects fish seed production thereby affecting pond aquaculture and fisheries enhancements in open-waters of the region. The present paper describes the major constraints faced by fish seed producers of the region because of extreme climatic events (abnormally high floods and prolonged dry spells) based on field studies in 27 fish seed production farms (randomly selected) located in three districts of Lower Brahmaputra Valley Zone of Assam, India. Primary data on different aspects of constraints faced by the fish seed producers because of extreme climatic events were collected and analysed. Rank Based Quotient values were calculated, based on ranks given by the fish seed producers for each constraint to prioritize them. Dominant constraint related to abnormally high floods faced by the fish seed producers was 'loss of brood stock' (Rank based quotient=99.1) whereas the least important constraint was 'entry of weeds/macrophytes' during floods (Rank Based Quotient=25.5). Constraints related to drought-like situations ranged from the least important ones like 'low milt production of male brood fishes' that had the lowest value (12.5) to the over-arching constraint of 'inadequate water depth in fish ponds' during pre-monsoon and prolonged dry spells (Rank Based Quotient=100.0). Adaptive strategies developed by fish seed producers of the study region to overcome the major constraints have been outlined in the paper. The need for developing improved risk management at macro-level through appropriate policy support to fish seed producers in the fish-deficit region and suggested policy support measures for ensuring sustainability are discussed.

Keywords: adaptive strategies, climate change, dry spells, floods, fish seed production, Rank Based Quotient

Aquatic Ecosystem Health & Management, 24(3): 39–46, 2021. Copyright © 2021 Aquatic Ecosystem Health & Management Society.
ISSN: 1463-4988 print / 1539-4077 online. DOI: 10.14321/aehm.024.03.06

Introduction

The adverse impacts of climate change have been unequivocally accepted by the global community. According to Agence France-Presse (AFP), the climate is changing at unprecedented rates (AFP, 2016). February 2016 was determined as the warmest February since modern records began by the National Oceanic and Atmospheric Administration (NOAA), with an average temperature of 1.21°C above that for the 20th century. World Meteorological Organization (WMO) also confirmed that carbon dioxide levels in the atmosphere during 2014 had risen to 397.7 ppm, which was 143% higher than that prior to 1750, which is considered as the beginning of the industrial era (AFP, 2016).

India has been one of the major developing countries which advocate for preparedness for likely consequences of climate change. The climate of the Indian state of Assam - located in the North-Eastern (NE) region of the country - is influenced by the existence of the Himalayan range in the north and the sub-Himalayan ranges in the south and east. The region witnesses sub-tropical rain-storm atmosphere and has four well-defined seasons viz., monsoon (June-September), post-monsoon (October-November), winter (December-February) and pre-monsoon (March-May). Significant changes have been observed in the climatic regimes of Brahmaputra valley of NE India during the last few decades resulting in changed nature of water induced hazards in the entire agriculture sector including fisheries. Annual mean maximum temperatures and annual mean temperatures in the NE region is increasing at the rate of +0.11°C and 0.04°C per decade, respectively (Das, 2004). The fragile geomorphology of the Brahmaputra basin located in the eastern Himalayan region is affected by extreme precipitation events like rain storms and cloud bursts causing widespread landslides and soil erosions and siltation. On the other hand, drought-like situations experienced in some years (2001-02, 2005-06 and 2008-09) have also affected fishery productivity considerably in the Brahmaputra valley (Das, 2009; Pathak et al., 2010; Deka et al., 2011). Previous studies discussed climate change impacts on inland fisheries in Indian rivers and their plains (Vass et al., 2009; Das et al., 2013; Sarkar et al., 2018), including those of NE region of India (Debnath et al., 2015; Bhattacharjya et al., 2017); (Saud et al., 2012). There are a few studies that assessed the impact of climate change on breeding and fish seed production as well as vulnerability in India (Dey et al., 2007; Das et al., 2011; Sharma et al., 2014; Sarkar et al., 2019). However, available literature indicates that no studies have been conducted to assess the constraints faced by the fish seed producers in the country due to extreme climatic events and to document their adaptive strategies.

The fisheries sub-sector is important for

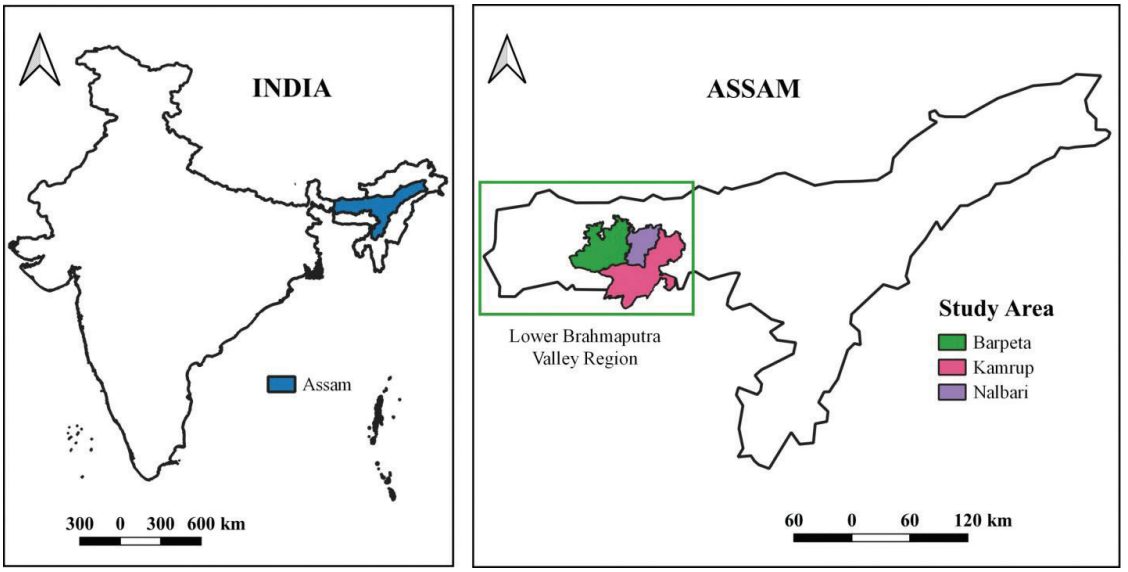

Figure 1. Map showing the study area in Northeastern India.

ensuring livelihood and nutritional security in the North-eastern Indian state of Assam, where reportedly over 90% people consume fish (Das et al., 2017, 2018; Yadav et al., 2020). Fish production of Assam state has increased from 294 thousand metric tonnes (MT) during 2015-16 to 373 thousand MT during 2019-20 with 26.9% growth. Fish seed production of the state has also increased from 5678 million fry during 2015-16 to 9519 million fry during 2019-20, registering 67.7% growth (Anon., 2020). Quality fish seed is one of the main inputs for pond aquaculture as well as for fisheries enhancements in open-water bodies like floodplain wetlands and reservoirs in the state. Against this background, the present study was conducted with a view to identify major constraints faced by fish seed producers of the region because of abnormally high floods and prolonged dry spells as well as to document adaptive strategies developed by them to overcome the major constraints.

Materials and methods

The study was conducted in three districts of Lower Brahmaputra Valley Zone of Assam, India viz., Kamrup, Nalbari and Barpeta (Fig. 1) during 2014-15. Field surveys were conducted in 27 fish seed production farms selected randomly. Data were collected through personal interviews with the selected fish seed farmers by using a pre-tested semi-structured interview schedule. The fish seed producers were asked to list out constraints faced by them related to fish production during flash floods and prolonged dry spells and rank them as per their economic importance.

The constraints reported by the fish seed producers were ranked by applying the preferential ranking technique. The data was quantified and rank based quotient (RBQ) calculated following Sabarathnam and Vennila (1996) as per the following formula.

$$\text{R.B.Q.} = \frac{\Sigma f_i(n+1-i)*100}{N*n}$$

where, f_i is the number of fish seed producers reporting a particular problem under ith rank, N is number of fish seed producers and n is number of problems identified.

Preferential ranking technique (unlike simple ranking technique) takes into consideration the average affected area as well as percentage of economic loss caused by each constraint as perceived by the respondents; this helps in prioritisation of the listed constraints based on the overall magnitude value (Sabarathnam and Vennila, 1996). Further, the adaptive strategies developed by the fish seed producers to overcome floods and prolonged dry spells were documented based on personal interviews and field observations.

Results and discussion

The impact of climate change is being felt the world over in recent years and it is concerned not only with the increase or decrease in minimum/maximum or average temperatures or with increase in emission of greenhouse gases, but also with the random behaviour of the climatic parameters such as rainfall and dry spells. Summer monsoon rainfall in the North-eastern India was found to be decreasing significantly @ 11 mm per decade during the last century (Das, 2004; Mirza et al., 1998). Even though monsoon rainfall is trendless and random in nature, pre-monsoon rainfall was more than expected in recent years leading to flash floods that are more intense and frequent in this part of the country. Decadal departures in summer monsoon rainfalls are found above and below the long-time average alternatively for three consecutive decades (Mall et al., 2006).

Fish seed is recognized as one of the critical inputs for pond culture and fish stock enhancement in open water bodies. Carp form the mainstay of freshwater aquaculture practices in India contributing over 85% of the total aquaculture production. The three Indian major carps viz., Catla (*Labeo catla*), Rohu (*L. rohita*) and Mrigal (*Cirrhinus mrigala*) contributes to bulk of inland aquaculture fish production in the country whereas the three domesticated exotic carps such as Silver Carp (*Hypophthalmichthys molitrix*), Grass Carp (*Ctenopharyngodon idella*) and Common Carp (*Cyprinus carpio*) form the second important group (Anon., 2011). These cultivable major carps generally do not breed in confined waters except common carp. They generally breed in riverine conditions during the monsoon season. The first

success in inducing *L. rohita, C. mrigala, C. reba, L. bata and Systomus sarana* to breed by injecting them with carp pituitary extract in India was reported in 1957 (Chaudhury and Alikunhi, 1957). Several synthetic inducing drugs containing GnRH-analog and dopamine antagonist have been formulated; these are gaining popularity day by day owing to their promising results (Anon, 2011). Generally, carp seed is classified into three different categories viz., spawn, fry and fingerling. The term spawn is applicable to hatchlings up to 8 mm size i.e. till yolk sac absorption. The fry stage itself can be distinguished into two sub-stages such as early fry stage (8 - 25 mm size) and advanced fry stage (26 - 40 mm size). Fingerling stage refers to those in the size range of 40 - 150 mm size (early fingerling: 40-100 mm; advanced fingerling: 101 - 150 mm). The rearing of spawn to early fry stage above 20 mm size (one crop cycle) usually takes 15 days which can be reduced to 10-12 days under intensive nursery rearing practices (Thomas et al., 2003).

Proper analysis of constraints faced by the fish seed producers due to climate anomaly is essential for taking appropriate mitigation measures by all stakeholders (including, fisheries officials and policy makers) so that production of fish seed of the region is commensurate with its requirement. In the present study, we tried to identify the major constraints faced by fish seed producers of the study region and then rank them according to their economic importance as perceived by the respondents. Constraint analysis through preferential ranking technique in the present study delineated as many as eight constraints in both flash floods and prolonged dry spell situations in the study region (Tables 1 and 2). 'Loss of brood stock during flash floods' (RBQ 99.1, Rank I) was identified as the most important constraint adversely affecting fish seed production considerably in the study area (Table 3). Heavy downpours and subsequent floods during pre-monsoon and monsoon seasons have been adversely affecting fisheries and aquaculture activities in the North-eastern Indian state of Assam. Fish seed producers reported that loss of reared brood stock fish from fish seed farms during floods has been a regular phenomenon in the study area, which is due to natural and anthropogenic factors including extreme climate change events like occasional abnormally high rainfall. It was difficult to protect fish seed produced from being washed away by sudden/ flash floods or abnormally high floods, and hence 'loss of fry' (RBQ 82.9, Rank II) was listed as the second most important constraint. Flood brings with it loads of silt to the pond that adversely affect the pond ecosystem in terms of decreasing natural productivity and depth of the pond. Naturally, 'siltation' was identified as the third most important constraint with RBQ value of 65.7. Nursery rearing of spawn takes place in smaller nursery ponds for 12-15 days, while fry rearing takes normally 30-60 days. Hence, chances of 'loss of spawn' (Rank IV) are lower compared to 'loss of fry'. The remaining constraints such as 'damage to the fish ponds and degradation of habitat' (RBQ 49.1), 'entry of disease-causing organisms' (RBQ 38.9), 'entry of weed/ macrophytes' (RBQ 25.5) and 'entry of unwanted aquatic animals' (RBQ 27.8) were of less economic importance during a flash flood situation.

On the other hand, prolonged dry spells, heat waves or drought-like situations in the region causes significant economic loss to the fisheries sector through its adverse effects on fish maturation and breeding. All the fish seed producers interviewed during the study felt that delayed monsoon and deficit rainfall during the pre-monsoon months during the last few years (2007 onwards) adversely affected their fish seed production. Hence, 'inadequate water depth in fish ponds' (RBQ 100.0) was the first and foremost constraint faced by the fish seed farmers (Table 4). All the major carps are seasonal riverine spawners, spawning during the south-west monsoon (Thomas et al., 2003). Apparently, reproductive physiology of carps and their spawning is significantly influenced by rainfall. The second most important constraint identified by the farmers was 'delayed maturation of brood fish/ release of ova & milt' (RBQ 81.0) as a consequence of low precipitation during the crucial gonadal development stages. Induced breeding of fish (through hormonal injections and synthetic inducing drugs) has revolutionized fish seed production in India, the principle of which works best when properly matured brood fishes are selected for induced breeding (Anon., 2011). The present situation is such that proper maturation of brood fish often does not take place due to deficit rainfall and inadequate water depth in brood stock ponds during the pre-monsoon season. If such

Table 1. Major constraints identified by fish seed producers of the study region during flash floods and their rank frequency table.

Problem identified	Ranks								Total
	1	2	3	4	5	6	7	8	
Loss of brood stock	25	2	0	0	0	0	0	0	27
Loss of fry	0	18	8	1	0	0	0	0	27
Loss of spawn	0	0	11	6	7	2	1	0	27
Siltation	2	7	5	5	3	1	3	1	27
Damage to fish ponds & habitat degradation	0	0	0	9	8	9	1	0	27
Invasion of disease causing organism	0	0	1	3	7	5	9	2	27
Entry of weeds/ macrophytes	0	0	1	2	0	5	5	14	27
Entry of unwanted aquatic animals	0	0	1	1	2	5	8	10	27

Table 2. Major constraints identified by fish seed producers of the study region during prolonged dry spells and their rank frequency table.

Problem identified	Ranks								Total
	1	2	3	4	5	6	7	8	
Reduced hatching rate	0	4	5	5	6	3	4	0	27
Reduced response to induced breeding	0	6	10	4	2	1	4	0	27
Reduced fertilization rate	0	0	3	7	3	7	7	0	27
Increased mortality of hatchlings	0	0	0	8	9	7	3	0	27
Reduced survival rate of spawn	0	0	0	3	7	9	8	0	27
Low milt production of male brood	0	0	0	0	0	0	0	27	27
Inadequate water depth in fish ponds	27	0	0	0	0	0	0	0	27
Delayed maturation of brood fish/ release of ova and milt	0	17	9	0	0	0	1	0	27

Table 3. Frequency distribution of RBQ of constraints identified during flash flood situations by the fish seed producers of the study region.

Problem	RBQ	Rank
Loss of brood stock	99.1	I
Loss of fry	82.9	II
Loss of spawn	61.1	IV
Siltation	65.7	III
Damage to fish ponds & habitat degradation	49.1	V
Invasion of disease causing organisms	38.9	VI
Entry of weeds/ macrophytes	25.5	VII
Entry of unwanted aquatic animals	27.8	VIII

brood-fishes are selected for induced breeding, 'reduced response to induced breeding' (RBQ 65.3, Rank III) is expected to occur. 'Reduced hatching rate' (RBQ 57.4), 'increased mortality of hatchlings' (RBQ 47.7) and 'reduced fertilization rate' (RBQ 46.3) were identified as the 4th, 5th and 6th significant constraints respectively, which are indirectly related to prolonged dry spells during

Table 4. Frequency distribution of RBQ of constraints identified during prolonged dry spell situations by fish seed producers of the study region.

Problem	RBQ	Rank
Reduced hatching rate	57.4	IV
Reduced response to induced breeding	65.3	III
Reduced fertilization rate	46.3	VI
Increased mortality of hatchlings	47.7	V
Reduced survival rate of spawn	39.8	VII
Low milt production of male brood-fish	12.5	VIII
Inadequate water depth in fish ponds	100.0	I
Delayed maturation of brood fish/ release of ova & milt	81.0	II

the pre-monsoon and early monsoon (March - June) months. 'Reduced survival rate of spawn' (RBQ 39.8) and 'low milt production of male brood-fish' (RBQ 12.5) were identified as other constraints in fish seed production in the study region. Both of these situations are related to poor brood stock development, which in turn is influenced by prolonged dry spells during the pre-monsoon and early monsoon months. Das et al. (2011) reported that most of the fish hatcheries in the neighbouring Indian state of West Bengal were affected by drought condition created by alteration of the climate variables (temperature and rainfall). Among the attributes affecting seed production in West Bengal, 20% of the hatcheries were affected by high temperature, 12% were affected by water scarcity and 68% were affected by cumulative effect of high temperature and water scarcity (Das et al., 2011).

The present study showed that the major constraints faced by fish seed producers of the study region during prolonged dry spells have adversely affected their fish seed production. Climate change (e.g. increasing weather variability and frequency of extreme events) particularly threatens livelihood and food security of small-scale farmers, since it is already having direct impacts on agricultural production and productivity (Malo et al., 2012). Probability of flood and drought-like situations is uncertain in the study region leading to increased vulnerability of fish seed producers therein especially for the small-scale fish seed producers. Introduction of improved risk management practices like fish brood stock insurance can provide protection to the fish seed producers. Policy intervention should also be made on watershed management programme to prevent drought-like situations. Watershed management programme yield multiple benefits such as sustainable production, resource conservation, groundwater recharge, drought moderation, etc. (Brooks et al., 1991). This approach will be helpful for the fish seed producers to grow brood fishes and advanced fish fingerlings/ yearlings round the year without shortage of water in their ponds. Adoption of scientific fish seed production practices (with matching investments) and climate resilient breeding practices (such as those mentioned above) will not only enhance fish seed production but also generate additional income and employment opportunities for rural people in the region.

Fish seed producers of the study region have been using certain adaptive strategies to overcome the major constraints faced by them. As part of this strategy, exotic Grass Carp (*C. idella*) is induced bred during the pre-monsoon season in place of the Indian major carps (*L. catla*, *L. rohita*, *C. mrigala*) that reportedly do not respond well to induced breeding during dry-spell periods (as reported by 64% of respondents). One new strategy to overcome this situation is induced breeding of alternative fish species like minor carps (*L. gonius*, *L. bata*) during dry-spell months, which appear to be climate resilient in respect of induced spawning. Adaptation options practiced by 90% of the fish seed farmers of the neighbouring Indian state of West Bengal were diversification to culture alternate fish species like *Pangasius* sp., *Puntius javanicus*, *Piractus brachypomus* (paku) and cross breeding of the Indian major carps in 55% of the fish seed farms (Das et al., 2011). Fish seed producers of the study region reportedly compensated for the water

loss during dry-spell periods by pumping ground water into the fish ponds (45% respondents). In order to prevent loss of fish stocks during abnormally high floods the fish seed producers either raised the height of pond dykes by 0.5-1.0 m with earth/ nets (35% respondents) or adopted a low-cost ITK-based green-fencing technique (by planting *Ipomoea aquatica*) on the pond dykes.

Communities exposed to hazards would normally adapt to survive. Meanwhile, adaptation could involve anticipating adverse effects, taking relevant actions to prevent and reduce potential damage and exploring opportunities that may arise. Adaptation strategies could include processes by which strategies to moderate, cope with and take advantage of the consequences of events are enhanced, developed and implemented (OECD, 2006). However, adaptation strategies may vary across populations of locations and adaptation strategies could be anticipatory, reactive, private, public, autonomous and planned (IPCC TAR, 2001). The individualistic adaptation approach would contribute to a heterogeneous climate change impact response structure, mobilization for proactive public adaptation strategies using policy and management tools and promoting sustainable community-based adaptation strategies would be necessary (Oyebola et al., 2021).

Conclusions

The present study revealed that fish seed producers of the study region are facing a number of constraints and challenges related to fish seed production due to extreme climate change events like flash floods and prolonged dry spells. Successful resolution of these constraints is expected to enhance their fish seed production, which in turn will lead to enhanced fish production from pond aquaculture and fisheries enhancements in open waters of the region. Adaptive strategies developed by fish seed producers of the study region to overcome the major constraints (especially the ITK-based low-cost options) need to be documented, validated and popularized both at regional and national levels. Policy makers should be sensitized about the need for improved risk management at macro-level through appropriate policy support to the fish seed producers to overcome the constraints faced by them in the fish-deficit region.

Acknowledgements

Funding support received for the study under NICRA project through ICAR-CRIDA, Hyderabad is duly acknowledged. We are thankful to the Director and PI, NICRA project, ICAR-CIFRI, Barrackpore for providing facilities and encouragement. Thanks are also due to the fish seed producers of the study region for helping us in carrying out the study.

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