Research in
ISSN : P-2409-0603, E-2409-9325
AGRICULTURE, LIVESTOCK and FISHERIES
An Open Access Peer Reviewed Journal

Open Access
Research Article

Res. Agric. Livest. Fish.
Vol. 3, No. 1, April 2016: 227-239

IMPACTS OF CLIMATE CHANGE ON SHRIMP FARMING IN THE SOUTH-WEST COASTAL REGION OF BANGLADESH

Md. Adibul Islam[1], Md. Shariful Islam[2]* and Md. Abdul Wahab[3]

[1]Assistant Superintendent of Police, Bangladesh Police, Ministry of Home Affairs, Bangladesh; [2]*Scientific Officer, Bangladesh Fisheries Research Institute, Freshwater Sub-Station, Chanchra, Jessore-7402, Bangladesh; Department of Fisheries Management, Faculty of Fisheries, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh

***Corresponding author:** Md. Shariful Islam, E-mail: bausharif@yahoo.com

ARTICLE INFO

Received
12.04.2016

Accepted
26.04.2016

Online
30 April 2016

Key words
Climate change, Shrimp farming, Aquaculture, Adaptation measures

ABSTRACT

The inhabitants of south west region of Bangladesh are prone to floods, cyclones, salinity intrusion and droughts, and the incidence of these hazards is rising. Recently two cyclones (known as *Aila* and *Sidr*) hit the southwest region of Bangladesh. Considering the above in view, research had been conducted for understanding the impacts and adaptation measures through sustainable coastal resources management in the cyclone affected greater Khulna areas. The present study was carried out (from January to June, 2011) to understand impacts of climate change on the shrimp farming, hatchery and nursery operations in the selected upazilas (Paikgacha and Shyamnagar). The study was conducted both primary and secondary data sources. To collect primary data different methods had been adopted which were informal interview, a pre-formulated questionnaire survey and Focused Group Discussion (FGD). In the study areas, about 80-90% people are involved with shrimp farming with 10-15 years experience. About 60% shrimp farmers thought that the weather has changed abruptly within the last 5 years. The study showed that the first and foremost factor is high temperature (49.5%). Majority (43.21%) encountered that temperature hampered the farm operation while lower growth (54%), low production (19%), loss of crops (13%), less water (4%), mortality (4%), and diseases (4%) occurred due to less rainfall or no rain. From the study, farmers (80%) reported susceptibility of shrimp to diseases in body deformation, spots or lesions on skins while 13.33% mentioned fry susceptibility to diseases. Some time oriented and need based adaptations in shrimp farming are now most concern. Government and other stakeholders should come forward to execute research for adaptations.

To cite this article: Islam MA, MI Shariful and MA Wahab, 2016. Impacts of climate change on shrimp farming in the South-West coastal region of Bangladesh. Res. Agric. Livest. Fish., 3 (1): 227-239.

INTRODUCTION

Bangladesh is among the countries with large number of people vulnerable to the potential impacts of climate change. The extensive coastal floodplains in the lower Ganges-Brahmaputra delta are important for natural fisheries, shrimp farming, agriculture, and other natural resources including the Sundarbans mangrove forest. The livelihoods of over 20 million people are based largely on the biodiversity of this region. However, the inhabitants are already prone to floods, cyclones, salinity intrusion, and seasonal drought, and the incidence of these hazards is rising. These natural calamities have been stressful to the already vulnerable livelihood strategies of many poor people: fish catches are declining, and demand for labour has fallen resulting in rural to urban migration. According to the International Climate Change Strategy and Action Plan 2008, climate change will exacerbate many current problems and natural hazards due to increasingly frequent and severe tropical cyclones leading to more damage, heavier and more erratic rainfall, resulting in higher river flows, river bank erosion, and sedimentation, melting of the Himalayan glaciers, lower and more erratic rainfall, and sea level rises.

Recently two cyclones (known as *Aila* and *Sidr*) hit the south-west region of the country. These natural events have brought about remarkable environmental and social changes in this region. Agriculture sector in general and fisheries in particular has been severely affected by these catastrophes. During the last decade, erratic precipitation patterns and an increasing number of cyclones and heat waves have been observed (Ahmed 2012, Thomas 2013 and Sarwar 2013). Between 2000 and 2010, the southwestern coastal zone of Bangladesh experienced two mega cyclones which caused enormous economic, infrastructural, agricultural, and human losses (Penning-Rowsell 2012). Sea level rise is already observed in coastal Bangladesh (Huq *et al.,* 2012). Estimations and projections shows that 97.1 percent of coastal areas and over 35 million people of coastal Bangladesh are vulnerable and exposed to multiple climate change hazards such as tropical cyclones, storm surges, coastal flooding, salinity intrusion associated with global warming and sea level rises (Shamsuddoha 2013, Sarwar 2013 and Ahmed 2013). This area is also ecologically rich because of the combination of coastal mangrove forests, tidal estuaries, productive agricultural lands, and economic activities such as shrimp farming, crab harvesting and crab fattening. However, storm surges and coastal flooding are putting serious pressure on agricultural production and are causing reduced productivity (Agrawala 2003 and Mallick 2012). Coupled with low socio-economic conditions of the area, the impacts of climatic events like cyclones, storm surges, and tidal flooding eventually negatively affect coastal fishing communities with regard to their livelihood, income opportunities, education, and food security (World Bank 2000 and Rimi 2013). Emerging shrimp farms and newly developed crab farms have recently been constructed in coastal Bangladesh and this is inducing increasing saline water intrusion inland. This is attributed to climatic events such as tidal processes, storm surges, coastal erosion and tropical cyclones (Mirza 2011 and Haque 2014). Climate change is significantly contributing to increased salinity intrusion in coastal Bangladesh which in turn is destroying biodiversity, loss of agricultural jobs, reduction in agricultural production and mounting food and human insecurity in the area in cascading and consequential orders over different time horizons. The vulnerability of coastal socio-ecological system (SES) is an indication of exposure to climatic stresses, sensitivity to harm, and lack of capacity to cope and adapt (Rahman 2013 and Jongman 2014). Considering the above in view, the present study has been done in the Southwest region of Bangladesh. The main objectives of this work are to understand the impacts of climate change on shrimp farming in the south-west region as well as evaluate the impacts of cyclones (*Sidr* and *Aila*) on the inland and coastal fisheries, coastal aquaculture, and the livelihood of the fishing communities, and those people who were directly and indirectly involved with shrimp farming, crab fattening, fish drying and other fisheries related activities in south-west region.

MATERIAL AND METHODS

Study period and area

As part of the research, preliminary facts finding research was carried out through a survey for one year from January to December 2010. Then the study was conducted from January to June, 2011 in the selected areas. The study was conducted in two upazilas from two districts in the south-west region of Bangladesh (Fig. 1). The selected study areas were Shyamnagar upazila under Satkhira district (22°19.8' N, 89°6.2' E) and

Paikgacha upazila, Khulna (22°5833´N, 89°3333´E). A number of shrimp farms, gher and shrimp processing plants exist in the selected areas. Besides, the shrimp farming sector in these areas are highly vulnerable due to climate change.

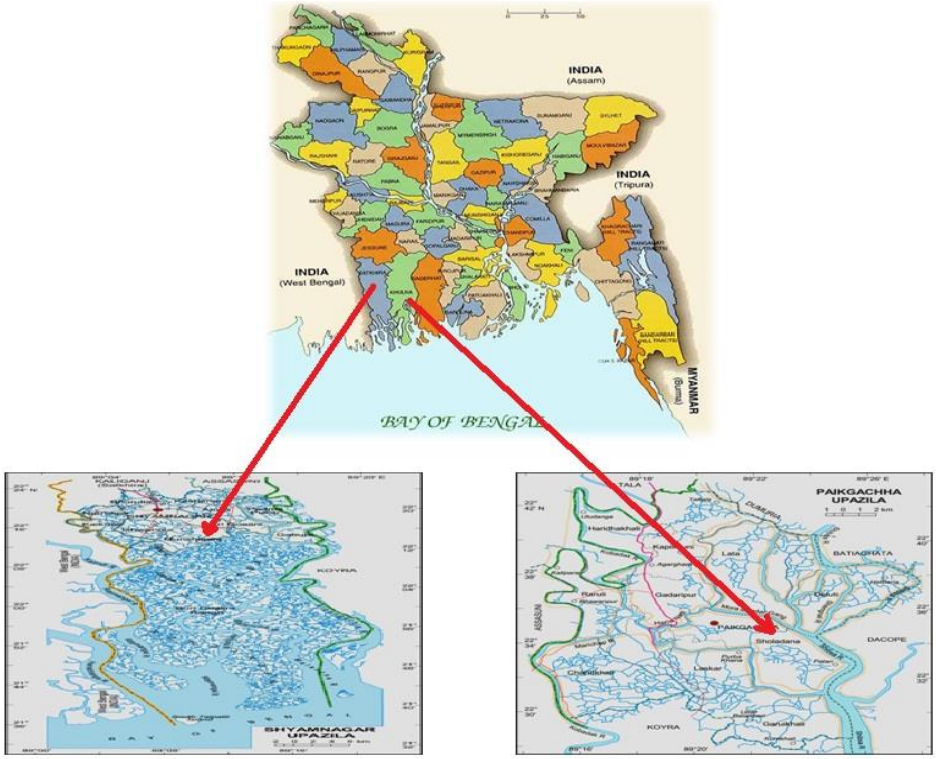

Figure 1. (*Left*) Map showing the study area in area in Shyamnagar upazila under Satkhira district and (*Right*) Paikgacha upazila under Khulna district.

The inland and coastal area shrimp farmers have experienced more or less similar climate change extremes though there was a difference in the order of priority. The climate change impacts identified on priority were seasonal changes, heavy rains, floods and cyclone in inland shrimp farming area and high temperature, floods, un-seasonal rain fall, low temperature, cyclone and low tidal amplitude in coastal shrimp farming areas. The seasonal changes were mainly temperature variations and delay in monsoon. The water inundation in ponds is due to heavy rainfall caused by both floods and cyclone. Cyclones are not a problem as they are not very frequently occurring event. However, if cyclone occurs with heavy rainfall, then the economic loss was hundred per cent. Floods and seasonal changes are under extreme risk category whereas heavy rain and cyclone are under high risk category in inland area. High temperature, floods and low rainfall were under high risk category while less cyclone, low tidal movement and low temperature were under medium risk category in coastal area (Muralidhar *et al.* 2012).

Data Collection and Analysis

The target groups were the aqua - farmers and villagers who are directly or indirectly involved with the shrimp farming, crab, fattening and fish drying. The other major target groups were the fishermen who are dependent on the inland wetland capture fisheries and inshore coastal fisheries. Different types of data were collected using different methods. The extensive visits to the affected areas, meeting with the fishermen, fish farmers, fish traders and other stakeholders of the government and non-government organizations, and interviewing with a pre-tested questionnaire as well as arranging Focus Group Discussion (FGD) meeting. Local elites and informed people like the teachers, community leaders and NGO workers were interviewed. Both men and women from different economic classes of people took part in the interview and other information gathering processes.

The design of the present study involved some necessary steps which are presented below (Figure 2)

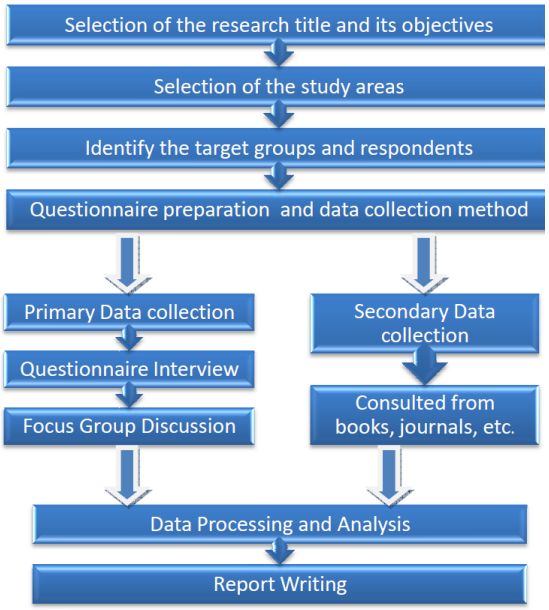

Figure 2. Schematic diagram of methodology followed in the present study

Table 1. The sampling frame for conducting the study

Category of shrimp farmer	Name of the place	No. of respondents	Name of the place	No. of respondents	FGD
Individual Shrimp Farmer	Soladana Union,	5		5	
Group Shrimp Farmer	Paikgaccha Upazila	10	Munshiganj Thana, Shyamnagr	10	5
Lessee Shrimp Farmer		5	Upazila	5	
Total		**20**		**20**	**5**

(Source: Field survey, 2011)

The average farm size varied among individual (2.28 ha), group (4.59 ha), and outside lessee (19.56 ha). After collecting, data were sorted, edited and encoded. All the collected data were summarized and scrutinized carefully and entered into Microsoft Excel-2007. All the collected information were accumulated and statistically analyzed by MS- Excel-2007 and presented, tabular and graphical forms.

RESULTS AND DISCUSSION

Area, population and no. of shrimp gher of the selected region

Paikgacha is a upazila of 411.19 sq km with a population of 2,25,085. It is situated at the side of Shibsha River. There are about 3,736 shrimp gher in Paikgaccha upazila which occupies an area of about 16,800 hector. Another study area is the Shyamnagar upazila under Satkhira district. Shyamnagar is one of the largest upazila of Bangladesh, it has an area of about 1968.24 sq km and total population is about 2,06,004. The number of shrimp gher is 3,659 with an area of 14,669 ha (Table 2).

Table 2. Area, population and no. of shrimp Gher of the selected region

Sl. No.	District	Upazila	Total Area (sq km)	Total population	No. of Shrimp gher	Total Area of gher (ha)
01	Khulna	Soladana Paikgacha	411.19 sq km	2,25,085	3,736	16,800
02	Satkhira	Shyamnagar	1,968.24 sq km	2,06,004	3,659	14,669

Farmers involved with the shrimp farming

About 40% of the individual farmers with smaller farm size had 6-10 years of experience, while 25% of the same category had 1-5 years of experience. 35% gained 16-20 years of experience in shrimp farming. In group farming with moderate farm size, 55% groups had 6-10 years while 48% groups were found with 11-16 years of experience. Only 10% had 16-20 years of experience. In outside lessee farming with largest farm size, 67% respondents had 6-10 years experience, while only 33% had less than 5 years experience (Table 3). This indicated that group farming was splitting, and more individual farmers were moving into this entrepreneurship and had limited experience with shrimp culture.

Table 3. Involvement of the fishermen with shrimp farming

Category of Shrimp farmer	Year of experience	% of farmer involved in shrimp farming
Individual	1-5	25%
	6-10	40%
	16-20	35%
Group farmer	6-10	42%
	11-16	48%
	16-20	10%
Lessee farmer	5	33%
	6-10	67%

Occupations of the farmer

It was observed that almost 90% of the respondents under each category had shrimp farming business as the primary occupation, while the same respondents had agriculture as their secondary occupation. Some are involved with some small business and some work as day laborer (Figure 5). At present, due to climate change, a massive change has been brought in this region. Especially due to *Sidr* and *Aila*, the intrusion of salt water has reduced the rice cultivation. Now, in this region most of them are more or less involved with shrimp farming. While the study was conducted, about 80-90% people was involved with shrimp farming and the rest are occupied with some other small business and day laborer (Figure 3). Some rich farmers informed that they have other types of business and they invested money in shrimp farming from other business.

Major changes in shrimp farming over last 5 years

Farmer perception is that shrimp farming is more profitable than rice cultivation. But over 5 years, the unfavorable environmental conditions have dramatically decreased the shrimp production while shrimp farming has brought positive changes in their livelihood pattern; they are also facing some negative changes due to climate change. During the survey period, about 98% people reported that excessive temperature, salinity intrusion and the natural disasters, environmental condition have dramatically reduced per unit shrimp production. About 60% people agreed that the shrimp and rice production have decreased, 55% people reported that income also decreased and changed their livelihood pattern (Figure 4).

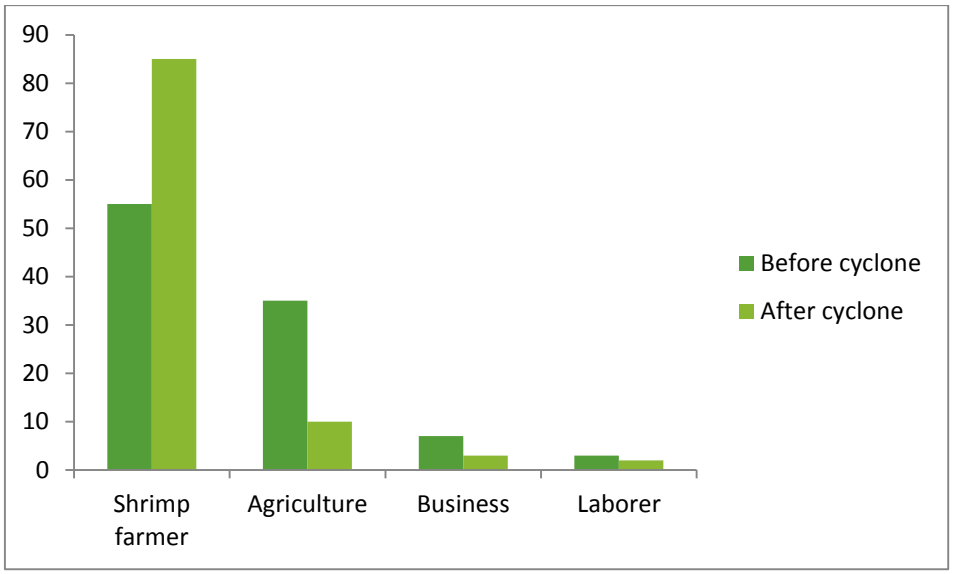

Figure 3. Percentage of different occupations before and after cyclone

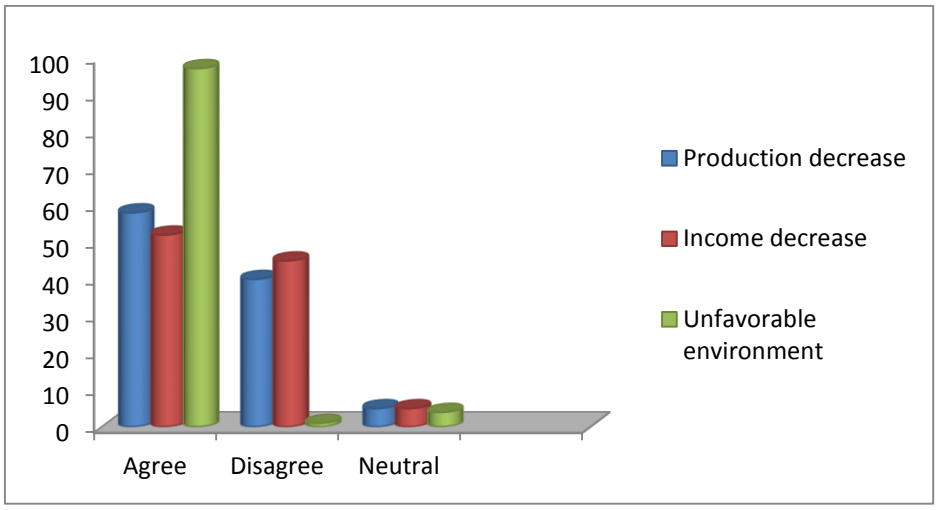

Figure 4. People's perception on impacts of cyclones

Abnormality of climate

Most of the shrimp farmers, hatchery and nursery operators encountered that the weather changed over last decade. 60% shrimp farmers, hatchery owners and nursery operators thought that the weather has changed abruptly within the last 5 years, 34% mentioned 5-10 years, and rest 5% thought more than 10 years (Table 4).

Table 4. Climate abnormality observed

Observing Year	Shrimp farmers	Hatchery owners	Nursery owners	% Average
<5	65.23	54.07	60	59.76
5 to 10	32.23	39.15	32.57	34.65
>10	2.54	6.78	7.43	5.58

Impacts of climatic factors

Several climatic factors such as less or fluctuating rainfall, prolonged drought were affected the shrimp farming and hampered the sustainable environmental conditions. The respondents mentioned that the first and foremost factor is high temperature (49.5%). The second important factor was excess rainfall (22.5%) and third important factor were salinity problem (17.5%) and shifting season (8%). Few farmers (2.55%) also mentioned prolonged drought influenced the shrimp farming (Table 5).

Table 5. Factors affecting the abundance of shrimp farming in the selected region

Factors	Munshiganj, Shyamnagr (%)	Soladana, Paikgacha (%)	% of Average
High temperature	53	46	49.5%
Excess rainfall	24	21	22.5
Salinity	13	22	17.5
Shifting season	7	9	8
Prolonged drought	3	2	2.5

In the study area, most of the farmers (49.5%) said that due to high temperature, the water level has decreased and sometimes they are facing the acid-sulfate soil problem. Besides, due to different natural calamities, the intrusion of freshwater decreased the ppt of the saline water which is a major problem for shrimp farming (Figure 5).

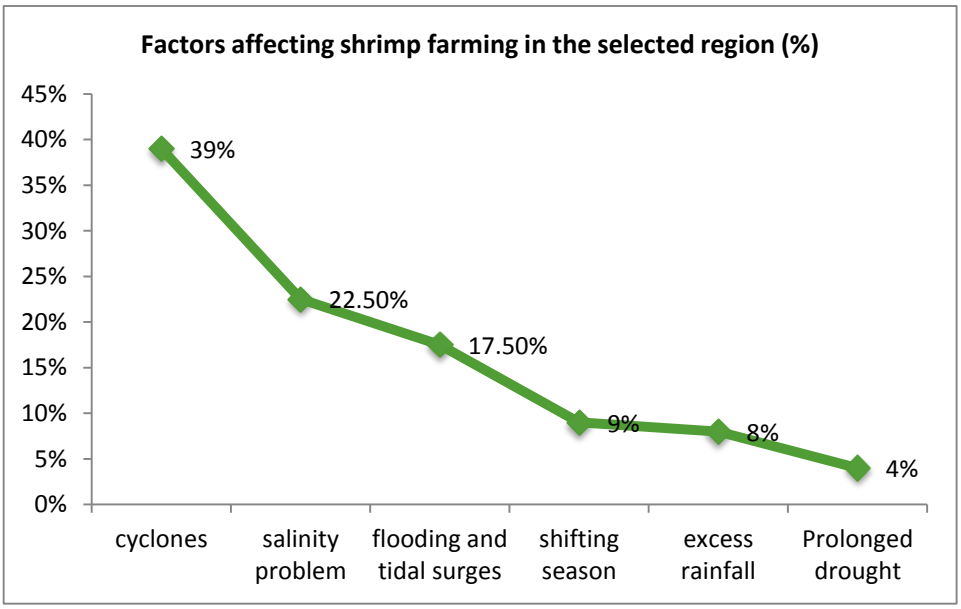

Figure 5. Factors affecting the shrimp farming in the selected region

Climatic factors such as less or fluctuating rainfall, prolonged drought were affected the shrimp farming and hampered the sustainable environmental conditions. Changes in rain fall pattern and annual variability likely to be the most significant climate parameters. Rainfall is forecasted to be turn down in Bangladesh and increase the dry months. As a result, prolonged droughts have encountered. From the present study, the respondents cited that the first and foremost factor is high temperature (49.5%). The second important factor was excess rainfall (22.5%) and third important factor were salinity problem (17.5%) and shifting season (8%). Few farmers (2.55%) also mentioned prolonged drought influenced the shrimp farming. Islam *et al.* (2008) reported that the occurrence of fluctuating rainfall/drought in this country was not new but the duration had been increasing alarmingly.

Temperature problems encountered by the shrimp farmer

It was found that 65% in Munshiganj and 60% in Soladana farm operators encountered over temperature problem and the rest fetched temperature fluctuation during the study period in South-West region (Figure 6).

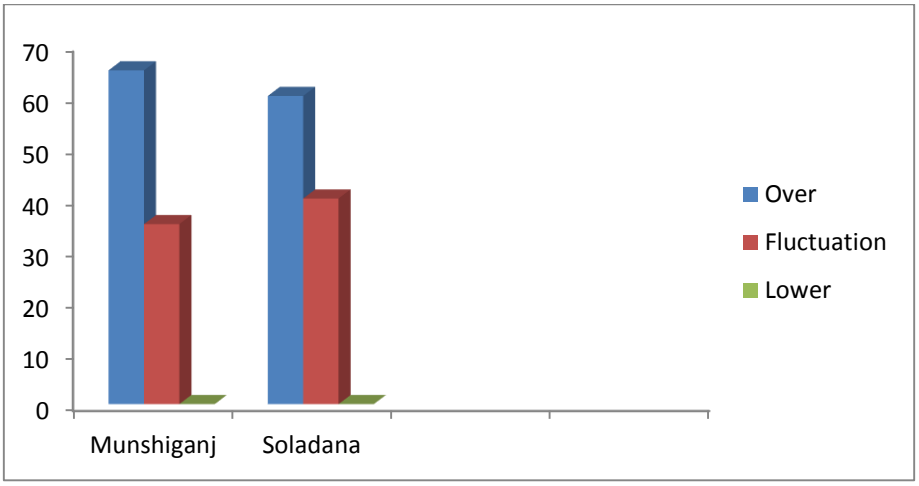

Figure 6. Temperature problem encountered by the farm operators in two study areas

Temperature fluctuation affected shrimp farm operation

About 43.21% of the shrimp farm operators mentioned that various problems occurred due to climate change such as over heat of pond water, bad water quality, diseases prevalence, insufficient water in the ponds, reduce feeding activity and lower survival and growth rate (Table 6).

Table 6. Temperature fluctuation affected shrimp farm in the study area

Type of problem	Munshiganj	Soladana	Average (%)
Over heat pond water	40.0	46.43	43.21
Lower growth	26.66	34.32	30.49
Bad water quality	13.33	6.76	10.04
Diseases prevalence	6.57	13.12	9.84
Insufficient water	5.87	0.0	2.93
Reduce feeding activity	6.23	0.0	3.11
Drying up ponds	0.0	0.0	0.0
Every day water adding	0.0	0.0	0.0

Climate change affected the survival, growth, reproduction and distribution of individuals within a species, but impacts also can have on population, communities and ecosystems. Majority (43.21%) of the farm operators, hatchery and nursery owners mentioned that various problems occurred due to climate change such as over heat of pond water, bad water quality, disease prevalence, insufficient water in the ponds, reduce feeding activity and lower growth rate resulted in the growth and survival in culture, nursery and hatchery level. Water temperature is the most important physical environmental factor controlling growth in the early stage of shrimp and often correlated with mortality of PL. More or less similar findings were noted by Handisyde *et al.* (2006), who found that increased stratification, reduced mixing of water in lakes, reducing primary productivity, reduction in fish stocks, bad water quality, reducing feeding and growth, changes in timing and success of migration, changes spawning and peak abundance of fishes were due to temperature fluctuation in lakes.

Less rain reduced shrimp farming

Most of the farm operators mentioned that they experienced insufficient rainfall during the peak culture period. Moreover, 65% and 32% respondent claimed that insufficient and fluctuating of rainfall affected their farm operation (Table 7).

Table 7. Rainfall problem encountered in shrimp farm operation in the study areas

Type of problem	Shrimp farmer	Hatchery owner's	Nursery owner's	% of Total
No rain	29.68	22	31.39	27.69
Rain fluctuation	25	32	28.61	28.53
Excess rain	45.32	46	40	43.77

No rain or less rain due to climate change created various problems like less water availability, reduce feeding activity, diseases prevalence and mass mortality of fishes happened in the region (Figure 7).

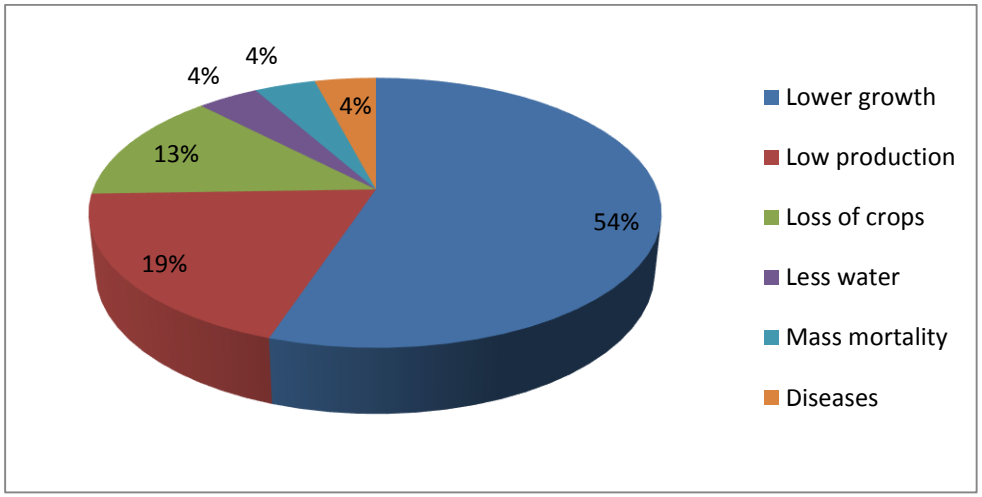

Figure 7. Hampered Less rainfall the shrimp farming in the study areas

Rainfall pattern consisted of some irregularity with yearly highest 357mm and lowest 353mm along with year to year variation. Higher temperature may stress culturable species and increase their susceptibility to disease. No rain or less rain due to climate change induced various problems like less water availability, reduced feeding activity, disease prevalence and mass mortality of shrimp. The present research findings were more or less similar to the finding of Habib (2001) which reported the body deformation, spots or lesions on skins. Prevalence of fish disease was found maximum in January due to no rainfall and minimum in warmer month showing a decreasing trend of infection with the rising the temperature. Simpson *et al.* (1983) cited that the use of acid sulfate soil present serious problems for shrimp culture as liming, sea water flushing and other management practices are required to avoid the low productivity, acidity and heavy toxicity associated with aquaculture which are dissimilar to present finding.

Deformed PL and shrimp produced due to impact of climate change

A mixed answer was obtained when the farm owners, hatchery and nursery operators asked whether they have seen any deformity of shrimp and PL. Shrimp farmers and nursery owners answered positively that they had some deformity of shrimp but majority of the hatchery owners mentioned that they did not have this problem (Figure 8).

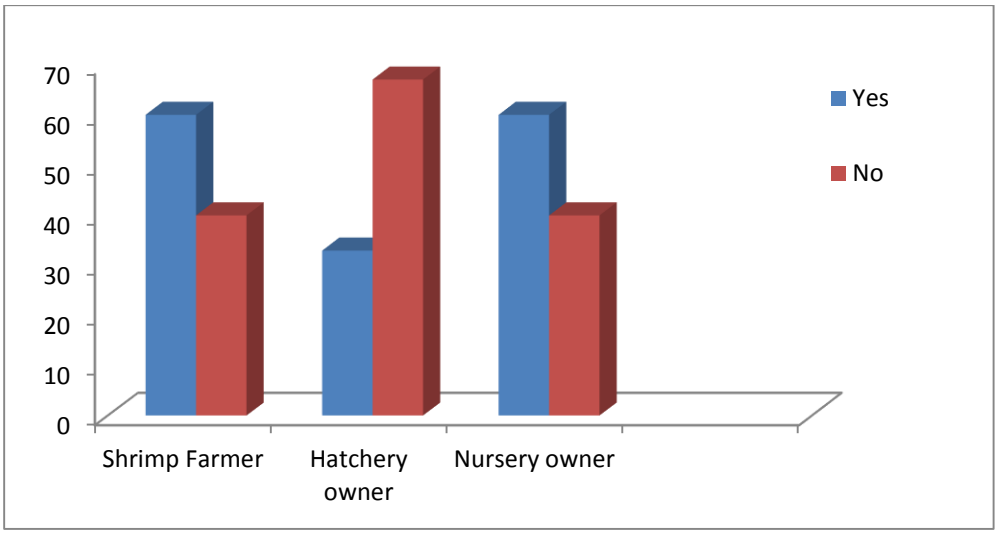

Figure 8. Shrimp farmers, hatchery and nursery operators' opinion on PLs and shrimp deformity

Shrimp susceptibility to diseases

It was observed that 80% farmers reported susceptibility of shrimp to diseases in body deformation, spots or lesions on skins while 13.33% mentioned fry susceptibility to diseases and 6.67% reported that PL could not recover from diseases (Table 8). After *Aila* and *Sidr*, the following of diseases were found in shrimp farming systems:

- White spot syndrome virus (WSSV)
- Yellow Head Virus (YHV)
- Infectious Hypodermal and Hematopoietic Necrosis (IHHNV)
- Hepatopancreatic Parvo-like virus (HPV)
- Monodon Baculovirus (MBV)

Table 8. Diseases prevalence by shrimp due to climate change

Diseases prevalence	Soladana, Paikgacha (%)	Munshiganj, Shyamnagr (%)	% Average
Fry susceptible to diseases	25	27	26
Fry cannot recover from diseases	15	14	14.5
Others (body deformation, spots etc)	60	59	59.5

Impacts of Sidr and Aila on shrimp farming

Sidr and *Aila* have brought environmental and social change in the study areas. Shrimp and crab farming were affected due to salinity intrusion in the freshwater wetlands, losses of the crafts, gears and shelters of the coastal farmers. It was observed that intrusion of salt water had made the soil unsuitable for rice cultivation. The traditional farmers of the inland wetlands have changed their profession either as day labourer or joined with the fry collectors or going to the inshore fishing with the survivors from the sea fishermen. Cyclone *Sidr* had partly damaged the soils but after *Aila,* lands are now only used for shrimp culture because of extreme salinity. Due to the shrimp culture, the poor people are the most sufferers. Their opportunity to work in the field as a laborer has been reduced. *Aila* has also destroyed most tube-wells, and lack of drinking water is a major problem in the Southwest region. The people are more or less dependent on the rain water and they reserve water during the rainy season. There has been spread of various enteric diseases because people sometime need to depend on salt water for drinking. There has been a great shortage of vegetable and freshwater fish in the local markets.

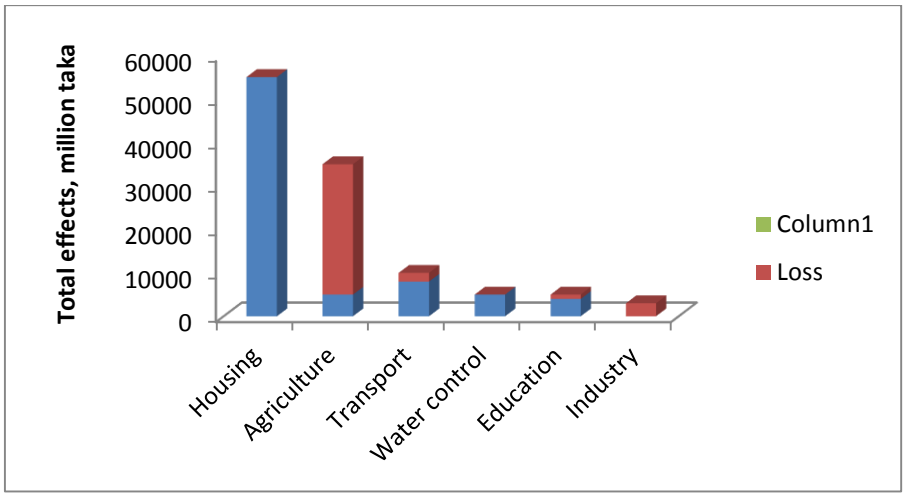

Figure 9. Damage and Losses caused by Cyclone *Sidr* in most affected Sectors

A mixed answer was obtained when fish farm owners, hatchery and nursery operators were asked whether they have encountered any deformity of shrimp and PL. In the above question, shrimp farmers and nursery owners answer positively that they had have some deformity of shrimps but majority of the hatchery owners mentioned that they did not encounter this problem. Wagner *et al.* (1997) mentioned that increase or decrease of temperature can be lethal to fish which depends on various factors such as temperature, nutritional deficiency, genetics, DO concentration and water.

Climate change had direct or indirect influence on the susceptibility to diseases by shrimp. From the present study, it was observed that 80% fishermen reported that susceptibility of shrimp to diseases in body deformation, spots or lesions on skins while 13.33% mentioned fry susceptibility to diseases and 6.67% cited that fry could not recover from diseases. Paz *et al.* (2007) mentioned that environmental degradation might cause mass mortality of fish by diseases. Rahman *et al.* (1999) mentioned that in 1995, some brood stock collected by a commercial trawler showed white spots on the carapace, indicating that white spot disease had spread to wild stocks of *P. monodon*.

CONCLUSION

In conclusion, the present study has identified that the shrimp farmers, hatchery owners and nursery owners in all two selected areas (Munshiganj, Shyamnagar upazila and Soladana, Paikgaccha upazila) are severely affected by climate change. Maximum shrimp farmer said that they are fully unknown to severity of climate change, they cannot market their crops in proper time, they face late PL availability, high price of PL etc and they become economically looser. Climate change is inevitably a challenge for fisheries and aquaculture in the region. The aquaculture production has been greatly reduced due to uncertain climate change in the southwest region of Bangladesh.

ACKNOWLEDGEMENT

The research reported here represents part of an academic research by the first author and corresponding author at the Fisheries Management Department, Bangladesh Agricultural University. We are grateful to the inhabitants of Shyamnagar upazila, Satkhira and Paikgacha upazila, Khulna for their help and cooperation during data collection there. Author acknowledges fellowship provided by the INSPIRE Climate Change Project, British Council in collaboration of Middlesex University, UK, Bangladesh Agricultural University and Independent University Bangladesh.

REFERENCES

1. M Muralidhar, M Kumaran, M Jayanthi, B Muniyandi, AG Ponniah, Udaya S, Nagothu, Patrick White and A Eknath, 2012. Case study on the impacts of climate change on shrimp farming and developing adaptation measures for small-scale shrimp farmers in Krishna District, Andhra Pradesh, India, Network of Aquaculture Centers in Asia-Pacific, 126 p
2. Ahmed F, Al-Amin AQ, Alam GM, 2012. Climate change issues: Challenges for natural resource management in Bangladesh-A way forward. International Journal of Global Warming, 4: 68-80.
3. Thomas TS, Mainuddin K, Chiang C, Rahman A, Haque A, Islam N, Sun Y, Quasem S, 2013. Agriculture and Adaptation in Bangladesh Current and Projected Impacts of Climate Change; The International Food Policy Research Institute (IFPRI): Washington, DC., USA.
4. Sarwar MG and Woodroffe CD, 2013. Rates of shoreline change along the coast of Bangladesh. Journal of Coastal Conservation, 17: 1–12.
5. Penning-Rowsell EC, Sultana P, Thompson PM, 2012. The “last resort”? Population movement in response to climate-related hazards in Bangladesh. Environmental Science & Policy, 27: 1–16.
6. Huq N, Hossain Z, Hasan R, Azad AM, 2012. “Climate Proofing” Water Resources Development Policy: The Evidence from Bangladesh. In Climate Change and the Sustainable Use of Water Resources; Leal Filho, W., Ed.; Climate Change Management; Springer: Berlin, Germany; Heidelberg, Germany, pp. 389–400.
7. Sarwar MG and Woodroffe CD, 2013. Rates of shoreline change along the coast of Bangladesh. Journal of Coastal Conservation, 17: 1–12.
8. Shamsuddoha M, Islam M, Haque MA, Rahman MF, Roberts E, Hasemann A and Roddick S, 2013. Local Perspective on Loss and Damage in the Context of Extreme Events: Insights from Cyclone-Affected Communities in Coastal Bangladesh; Center for Participatory Research and Development (CRPD): Dhaka, Bangladesh.
9. Ahmed F, Mahabubul G, Al-Amin AQ and Bin Hassan CH, 2013. The Impact of Climate Changes on Livestock Sector: Challenging Experience from Bangladesh. Asian Journal of Animal and Veterinary Advances, 8: 29–40
10. Agrawala S, Ota T, Ahmed AU, Smith J, van Aalst M, 2003. Development and Climate Change in Bangladesh: Focus on Coastal Flooding and the Sundarbans; Organisation for Economic Co-operation and Development: Paris, France.
11. Mallick BJ, Witte SM, Sarkar R, Mahboob AS, Vogt J, 2012. Local Adaptation Strategies of a Coastal Community during Cyclone Sidr and their Vulnerability Analysis for Sustainable Disaster Mitigation Planning in Bangladesh. Journal of Bangladesh Institute of Planners, 2: 158–168.
12. Rimi RH, Farzana S, Sheikh S, Abedin Z, Bhowmick AC, 2013. Climate Change Impacts on Shrimp Production at the South-West Coastal Region of Bangladesh. World Environment, 3: 116–125.
13. World Bank, 2000. Bangladesh Climate Change and Sustainable Development; The World Bank: Dhaka, Bangladesh.
14. Mirza MMQ, 2011. Climate change, flooding in South Asia and implications. Regional Environmental Change, 11: 95–107.
15. Haque AN, Dodman D, Hossain MM, 2014. Individual, communal and institutional responses to climate change by low-income households in Khulna, Bangladesh. Environment Urban.
16. Rahman A, Miah G, 2013. Causes of coastal ecosystem degradation in Bangladesh. In Proceedings of the 10th Global Congress on ICM: Lessons Learned to Address New Challenges, EMECS 2013—MEDCOAST 2013 Joint Conference, Marmaris, Turkey, 30 October–3 November 2013; Middle East Technical University: Ankara, Turkey, 2013; Volume 2, pp. 853–862.
17. Jongman B, Hochrainer-Stigler S, Feyen L, Aerts JCJH, Mechler R, Botzen WJW, Bouwer LM, Pflug G, Rojas R, Ward PJ, 2014. Increasing stress on disaster-risk finance due to large floods. Nature Climate Change, 4: 264–268.
18. IPCC (Intergovernmental Panel on climate Change), 2007. Climate Change 2001. Impacts, Adaptation, and Vulnerability Contribution of Working Group 11 the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK

19. Handisyde NT, LG Ross, MC Badjeck and EH Allision, 2006. The threat to fisheries and aquaculture from climate change. http://pubs.iclarm.net/resource_centre/ClimateChange2.pdf
20. Habib MAZ, 2001. Aeromonad infection in the fishes of small scale farmer's ponds and its control. MS Thesis. Department of Aquaculture, BAU, Mymensingh. 71p.
21. Simpson JJ, 1983. Remote Sensing and Geographical Information System: their past, present and future use in global marine fisheries, Oceanography, 30: 238-280.
22. Wagner EJ, Bosakowski and Intelman, 1997. Combined effects of temperature and high pH on mortality and the stress response of Rainbow Trout after stocking Trans Am. The Fish Society, 126: 985-998.
23. Paz S, N Bisharat E, Paz O, Kider and D Cohen, 2007. Climate change and the emergence of *Vibrio vulnificus* disease in Israel. Environmental Research, 103: 390-396.
24. Rahman M, SC Paul and PPGSN Siriwardena, 1999. Farmers training and extension: Key to health management in extensive brackish water shrimp aquaculture in Bangladesh. Workshop on Aquatic Animal Health Care in Rural Aquaculture. 27-30 September 1999, Dhaka, Bangladesh. Working Paper 27.