

# Local perceptions of and adaptation to climate variability and change: the case of shrimp farming communities in the coastal region of Bangladesh

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**Abstract** Shrimp aquaculture is the predominant farming practice in the southwest coastal region of Bangladesh and has been under increased pressure from environmental and climatic changes. To date, most of the studies examining farmer’s vulnerability and adaption to climate change have been agriculture-focused with little attention to the impacts on other livelihood systems. Based on a case study approach our study presents: i) how local people perceive climate change and whether it corresponds to meteorological records, ii) what climate change impacts people consider significant, and iii) what strategies the shrimp farmers employ to ameliorate perceived risks. This study was conducted using local climate data, focus groups and household survey in Mongla sub-district. This study shows that local people are aware of the changes in hydro-climatic parameters. Their accounts of climate change mostly diverge from the scientific evidence when long-term climate trends are considered, but on short-term variability, the correlation between scientific evidence and local perceptions is high. Repeated adverse impacts caused by climate stressors on livelihood activities shape people’s climate risk perceptions. In relation to perceived risks, farmers have made adjustments in their aquaculture practices. Yet, the level of responses clearly lags behind the extent to which concerns about climate disturbances are expressed. This is partly due to farmers’ efforts for managing transformation from agricultural livelihood system to aquaculture-based livelihood systems and partly associated with other social factors. This case study recommends governmental support for the shrimp aquaculture sector to facilitate the process of adaptation to changes in the hydro-climatic environment.

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## 1 Introduction

The fourth assessment report (AR4) of the Intergovernmental Panel on Climate Change (IPCC) indicates that the low-lying coastal areas in many Asian countries are facing increasing challenges to a range of stresses and shocks. Although social-ecological systems have evolved over the centuries through coping with and adapting to these pressures, today increased pressure mainly associated with climate and environmental change poses a threat to the resilience of the ecosystems as well as human societies in many coastal areas (Parry et al. 2007; UNEP 2006). This is particularly relevant for coastal communities in Bangladesh who have encountered extreme vulnerability to hydro-climatic hazards (Hedger 2011). These coastal communities, especially those in the southwest coastal region of Bangladesh are amongst the most vulnerable in the country, mostly due to their frequent exposure to tropical cyclones with tidal surge and hydro-climatically driven changes in environment and natural resource base on which they depend for their livelihoods and wellbeing. While exposure to these physical hazards has serious implications for both human and natural systems, other socio-economic factors including poverty, inequality, poor infrastructure and inadequate government capacity often exacerbate this risk situation. The southwest coastal region of Bangladesh, therefore, presents a unique opportunity to explore how rural households and farmers who are faced with hydro-climatic risks manage their economic production systems and livelihoods.

According to the fifth assessment report (AR5) of the IPCC, there is significant evidence that climate is changing (Cubasch et al. 2013). However, the direction of this change in different parts of the world is uncertain (Cubasch et al. 2013). Whilst knowledge of past changes in climate has advanced over the last few decades, specific local outcomes of changes in climate are still fraught with uncertainty. This motivates researchers and practitioners to investigate local perceptions of climate change from the people who are directly affected. A number of studies suggest that the ways local people understand climate variability, uncertainty and change provide a foundation for adaptation measures at a local level (Arbuckle et al. 2013; Blennow and Persson 2009; Boissière et al. 2013; Thomas et al. 2007; West et al. 2008). Therefore, this cognitive aspect of adaptation is drawing increasing attention by researchers investigating local adjustments to changes in environmental and climatic conditions. This paper responds to the need for such detailed understandings at the local level and adds to the theoretical frameworks for such investigation by considering the interaction between local and wider knowledge.

In the context of a broader study on climate change adaptation processes in the southwest coastal region in Bangladesh, we examine how local people perceive hydro-climatic change and how they have adjusted their livelihoods to adapt to this change. In doing so, we first document how local people experience and describe changes in hydro-climatic characteristics and compare their narratives with local meteorological data for the past few decades. Second, focusing on aquaculture farmers we identify the kinds of impacts that they consider significant. Finally, we investigate the strategies that these farmers employ in aquaculture practices to adapt to climate change and identify associated constraints. In examining how local people perceive climate change, this study enhances our understanding of vulnerability of shrimp farming communities to cope with changes in hydro-climatic environment, and provides important insight that can be useful in developing future climate change adaptation policies and strategies.

## 2 Background

### 2.1 Hydro-climatic features in the study area

The coastal zone of Bangladesh is the lowest land mass of the country characterized by a large network of river systems discharging huge amount of fresh water, heavily laden with sediments, into the Bay of Bengal. The coastal area encompasses three distinct regions: inactive deltaic area in the southwest where Sundarbans—the world largest mangrove forest - are located, the very active delta in the central part and the narrow strip in the southeast. The western coastal zone lies at 0.8 to 4 m above the mean sea level (Iftekhhar and Islam 2004).

Bangladesh has generally a sub-tropical monsoon climate marked by wide seasonal variations in rainfall, moderately warm temperature and high humidity (Rashid 1991). There are four prominent seasons in a year, winter (December-February), pre-monsoon (March-May), monsoon (June-September) and post-monsoon (October- November). Temperature records over the period between 1989 and 2008 show that winter temperature in the study area ranges between 12 and 32 °C. Temperature typically reaches the maximum in April, with the maximum pre-monsoon summer temperature observed to fluctuate from a minimum of 32 °C to a maximum of 37 °C.

During 1991–2008, the study area received annual rainfall ranging from 1230 to 2800 mm. The seasonal distribution of the rainfall was concentrated during monsoon period (June-September), accounting for 71 % of the total precipitation. About 15 % of the total rain fell during the summer months (March-May), 12 % in the autumn (October-November) and a small proportion (2 %) during the winter.

The coastal regions of Bangladesh are vulnerable to tropical cyclones, striking generally in early summer (April–May) or late rainy season (October – November). Almost every year cyclone lashes the country's coasts, and a severe cyclone, on an average, hits every 3 years (MOEF 2009). The low-lying coastal areas are also affected by salinity intrusion from the Bay of Bengal. Salinity intrusion falls to lowest level during monsoon (June – September), and from December onwards the salinity level as well as the salinity affected area starts rising and reaches to the highest in March – April. Salinity has affected about 1 million ha of arable land in the coastal and off-shore areas (SRDI, 2010).

### 2.2 Shrimp aquaculture in the coastal region

Bangladesh has 710 km of coastline, estuaries of numerous rivers and low-lying tidal flood plains and therefore, provides enormous opportunities for brackish water shrimp aquaculture (USAID 2006; Alam et al. 2005). Having this suitable aquatic environment, commercial shrimp farming has undergone rapid expansion in the southwest coast districts, mostly attributable to higher economic return and expanding global demand (USAID 2006; Afroz and Alam 2013; Swapan and Gavin 2011). In 1980, approximately 20,000 ha of land were being used for shrimp farming (Metcalf 2003). By 2010, this figure rose to 245,000 ha, representing a 1125 % increase in area under cultured shrimp over the last 30 years (Belton et al. 2011).

It is estimated that approximately 1.2 million people are directly dependent on shrimp production (USAID 2006; BFRI 2011). In several costal districts, such as Khulna, Bagerhat, Shatkhira and Cox's Bazar; shrimp farming has become the key economic activity (Afroz and Alam 2013).

### 3 Methodology

#### 3.1 Study area

This research was carried out in Mongla Upazila (sub-district), in the southwest coastal zone of Bangladesh (Fig. 3). The region accounts for 80 % of shrimp production in the country (Alam et al. 2005; Belton et al. 2011). Mongla Upazila covers an area of 1461 km<sup>2</sup> and is divided into six unions (union is the smallest administrative unit and consists of several villages). The total population of the Mongla sub-district in 2011 was 150,139 (MOHFW 2012). Mongla and Pasur are the two main rivers in this subdistrict.

The Pasur River, the largest river in this region, flows from north to south and finally falls into the Bay of Bengal. Interlinked with this river, salinity front has encroached inland and penetrated into domestic ponds, groundwater and agricultural land through various small rivers, canals and water inlets.

The livelihoods of this area are dominated by shrimp aquaculture, fishing and agriculture. In relatively upland areas where soil and water salinity is low, slightly salt-tolerant rain-fed rice is cultivated during the month of July to September. Other activities include crab fattening, petty trade, migrant worker, wage labourer and collection of fuelwood and honey from nearby Sundarbans.

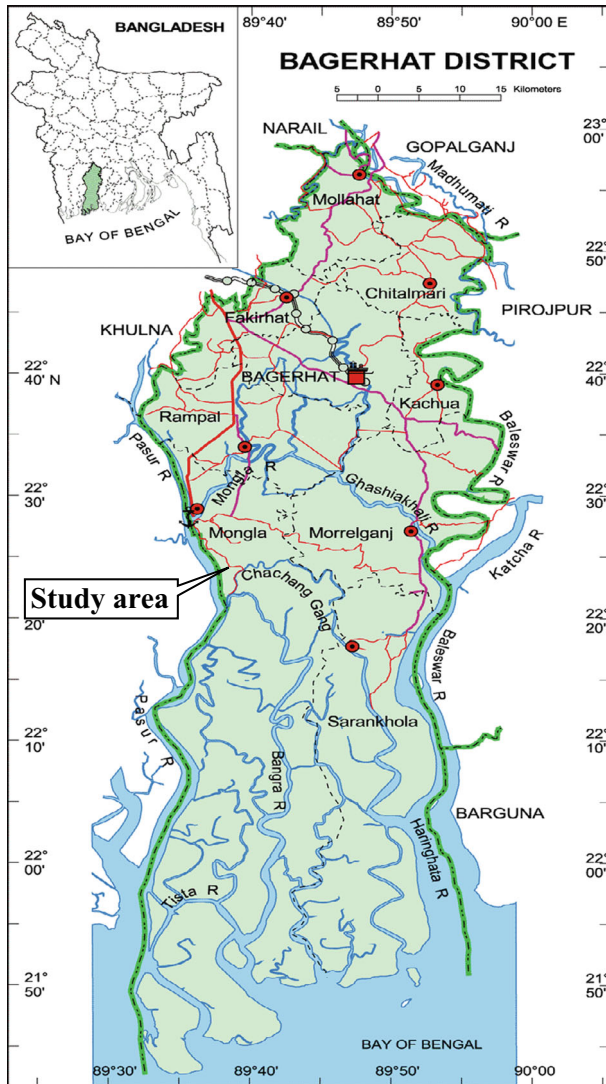
All the 14 villages of Chila Union (Fig. 1) were selected for this study in consultation with NGOs involved in climate change action research. According to Chila Union Council's report, its population was 19,150 in 2011.

#### 3.2 Data collection and analysis

This research is based on information collected for a broader study, investigating (1) adaptive capacity of the rural households in the coastal region of Bangladesh, (2) local people's perception of changing climate parameters around them, (3) coping and adaptation strategies to these climate parameters, and (4) the role of policies, institutions and practices in facilitating local adaptation to climate variability, extreme event and change. Fieldwork for this research took place between September 2012 and January 2013.

This study used a face-to-face household survey using semi-structured questionnaires with the members from statistically selected sample of households ( $n=372$ ). Sample size was calculated at the 95 % confidence interval and  $\pm 5$  % level of precision (Sampling and Surveying Handbook 2002). This was used to assemble information on household's livelihood assets, source of income, farming practices, perception of climate risks, coping and adaptation strategies.

Having acquired information on livelihoods and climate issues of the community through survey, focus group discussion was used for eliciting detailed information on specific issues. With the participation of members representing a cross-section of community including both genders and different livelihood groups, a total of twenty focus groups each with 5–8 members were engaged in a wider range of exercises such as hazard mapping, seasonal calendar making, and developing historical timeline. Each exercise was followed by a learning and discussion session where issues related to a specific exercise were discussed in detail. Generally broader socio-economic and environmental questions were introduced to the discussion at the beginning, and this was continued in follow-up questions relating to climate risks and management.



**Fig. 1** Map showing the location of the study area in Bagerhat District (Source: Banglapedia)

Based on their responses, we elicited local understanding of climatic disturbances and change of today, their impacts on livelihoods and household’s response strategies.

Due to the fact that shrimp aquaculture is the pre-dominant livelihood in the case study region, a face-to-face field survey was also carried out with the members from shrimp farming households only (n=30), which was a subset of the larger survey sample. These were selected with the advice from local leaders so that they represented a cross-section of shrimp farming community. This was sought to elicit the important socio-economic and environmental aspects relating to shrimp farming as well as farmer’s account of climate risks and other stressors affecting shrimp farming and specific actions that shrimp farmers take as responses. The

survey data complemented the related information gathered through discussions in groups and that enabled triangulation of findings.

We accessed monthly precipitation, and maximum and minimum temperature data from the Mongla meteorological station. Local temperature and rainfall data spanning the period of about two decades were graphed to visualize the climatic environment that the people in Mongla have recently been exposed to. The mean of the total length of observation and 5-year running mean were used to evaluate the extent to which local perception of climate change correlates with recent climate variability. Given the shorter period of records obtained from Mongla station, observed trends are more representative of short-term variability than long-term climate change. In order to get scientifically tested evidence of changes in climate in the study area, we, therefore, relied on findings of published literatures where researchers have analysed long-term (>50 years) temperature and rainfall data of the adjacent meteorological stations.

The time series of cyclone data used here comes from Water Resources Planning Organization of Bangladesh (WARPO) web site (WARPO [undated](#)) for the period 1960–1991 and for 1992–2013, we relied on the Emergency Events Database (EM-DAT) of the Centre for Research on the Epidemiology of Disasters (CRED), Belgium (EMDAT [2013](#)). A decadal frequency (an aggregate of 10 years) of major tropical cyclones over Bangladeshi coast was analysed to understand historical variability and change in tropical cyclone. This long-term trend in cyclone disturbances was then compared with communities' perception about the changing patterns of this extreme event.

Both qualitative and quantitative techniques were utilized for analysis of data. Basic descriptive statistics combined with qualitative information collected through qualitative techniques were used to describe the patterns in the data and their interpretations.

## 4 Results

### 4.1 Local perceptions of changes in climate

Respondents in the study area described changes in climate by describing their personal experiences of changes in seasons, weather pattern and sea level rise. Respondents related the changes in long-term patterns in climate to increased extreme weather events, variability in weather and climate parameters, and impacts on their local physical environments. When the directional changes were indicated by the participants in focus group discussions, this information was coded (Table 1).

The respondents described their observed changes in patterns of seasonality in many ways, of which the most common changes experienced included warmer summer characterised by more intense heat, drier winter with decreasing rainfall and shorter monsoon season with decreasing trend in total rain in this season.

Changes to cyclonic storms were described by the respondents, relating to increased occurrence of tropical cyclones with strong wind and high storm surge resulting in extensive inundation of the coastal area.

Some respondents observed the high tidal water reaching areas along the coasts, estuaries and coastal rivers which were previously above the normal high tide level. This change is quite evident to respondents who live outside the embankment and behind the shore as they experience the high tide now reaches their homes causing land erosion of homesteads.

**Table 1** Local perceptions of climate change

	Local experience of changes	
Climate variables	Temperature	<ul style="list-style-type: none"> <li>• Summer hotter than before</li> <li>• Increase in warmer days</li> <li>• Increase in frequency of abnormally hot days/ heat waves</li> </ul>
	Rainfall	<ul style="list-style-type: none"> <li>• Decrease in total rainfall in rainy season</li> <li>• Number of annual rainy days decreased</li> </ul>
Climatic phenomenon	Monsoon	<ul style="list-style-type: none"> <li>• Shorter rainy season</li> <li>• Late onset of rainy season</li> </ul>
	Tropical cyclones	<ul style="list-style-type: none"> <li>• Increase in tropical cyclonic activities</li> <li>• Increase in height of storm surge and wind velocity.</li> <li>• Increase in area being flooded by cyclonic storm surges</li> </ul>
Impacts on physical environment	Seas level rise	<ul style="list-style-type: none"> <li>• More area being inundated during high tide</li> <li>• More area being intruded by salinity</li> <li>• Increase in level of salinity during summer.</li> </ul>

Respondents were less likely to perceive it as a manifestation of sea level rise due to global warming. They predominantly attributed this change to increased sediment and siltation of rivers, and restricted river flows due to embankment built for shrimp farming. Very few participants mentioned sea level rise as the cause of increasing high water.

Increasing salinity intrusion from the Bay of Bengal is a well-known phenomenon in this part of the county. As expected all the respondents reported the increase of salinity encroachment as well as the level of salinity during dry season. While forming attribution for the increasing saltwater intrusion, most of the respondents described it as a result of cyclonic storm-induced coastal flood, prolonged brackish water shrimp cultivation, freshwater withdrawal from upstream rivers and low seasonal rainfall.

#### 4.2 Comparison between local accounts of climate change and meteorological information

Respondents' descriptions regarding their experiences of changes in climatic characteristics were evaluated to ascertain the degree of correlation of people's perception of changing climate with scientific evidence of observed hydro-meteorological trends of the study region.

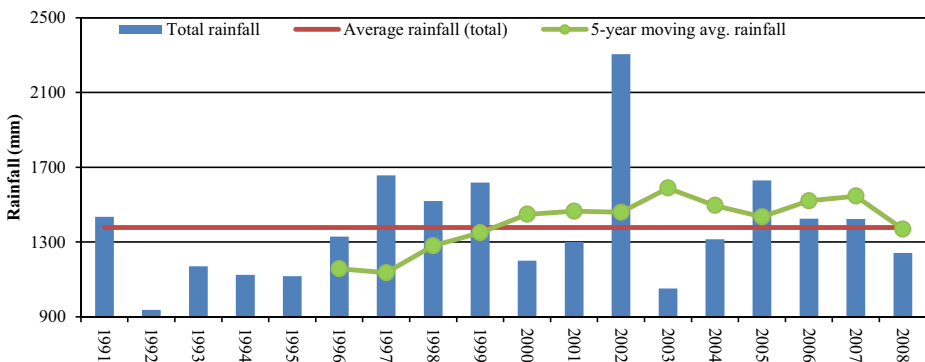
As reported by the Climate Change Cell of the Department of Environment, there were increasing linear trends in seasonal and annual mean temperature for the period between 1980 and 2007 for all the 34 stations in Bangladesh (Climate Change Climate Change 2009). The Climate Cell reports the rising trends in annual and seasonal mean maximum temperatures of the country that have been observed since 1970s or 1980s depending on the region in question. From May through September, the warmer trends are statistically significant since 1980. As mean temperature has increased strongly since 1980, it is very likely that the respondents would have experienced hot temperature extremes in summer and monsoon seasons in higher frequency. Thus, there is a strong correlation between the respondents' perceptions of increase in warm weather and actual temperature records.

The ways in which respondents reported they had experienced changes in rainfall were: decrease in monsoon rainfall and the number of rainy days annually. To verify their claims, respondents' perceptions of changes in precipitation were compared with rainfall data from a local meteorological station. The seasonal rainfall time series for 18-years (1991–2008) does not show any statistically significant changes over this time period (Fig. 2). However, Climate Change Cell study shows, at regional scale over the period of 1981–2001, monsoon rainfalls appeared to have decreased in the central and southern part of the country but increased in the northern part (Bogra, Mymensingh and sylhet areas) compared to the reference period of 1960 to 1980. However, some other studies do not support the claim of decreasing rainfall in southwestern part of the country during monsoon season (Shahid 2009; Mondal et al. 2013).

To the next level, analysis aimed to investigate rainfall anomalies from the Mongla station's 1991 to 2008 mean and 5-year running average. Figure 2 shows that during the 18-year period, no convincing pattern in monsoon rainfall anomalies could be noted in Mongla in comparison to the 1991–2008 mean. However, the 5-year moving average of monsoon rainfall shows that except 2002 and 2005, the trend of below average rainfall has persisted since 2000, supporting respondents' perception of decline in monsoon rainfall.

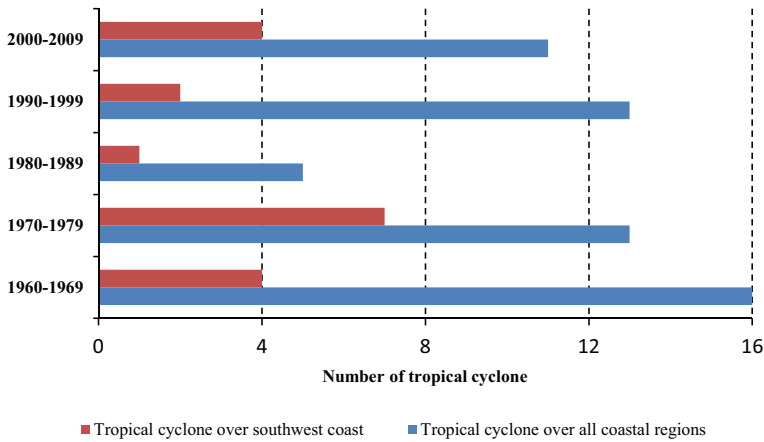
The personal experience of late occurrence of rainy season may be due to the decline in the number of rainy days in the month of June, the first month of rainy monsoon. Unfortunately, monthly rainfall records for Mongla station instead of daily or 10-day rainfall data did not allow of testing whether the numbers of rainfall events have decreased in June. However it is revealed from the monthly trend analysis of the rainfall data from the adjacent meteorological station (Khulna) that the rainfall in June has decreased significantly (Mondal et al. 2013).

The decadal frequency (an aggregate of 10 years) of major cyclonic storms striking over coastal regions of Bangladesh during 1960–2009 (Fig. 3) shows that there is a decreasing trend in frequency of total major cyclonic storms landfalling over Bangladeshi coasts during the three decades, and the rate of decadal decrease was 19 % during 1960s to 1970. Between the 1970s and 1980s the rate of decrease was 62 % and in the following decade, the trend reversed toward increased cyclones at the same rate (62 % per decade). There has been a small decrease in frequency of total major cyclones in the first decade of the twenty first century from the previous decade. Although interdecadal variations are observed in the past 50 years, overall there is no significant trend in frequency of cyclonic disturbances crossing over Bangladeshi coast (Wasimi 2010; Tyagi et al. 2009).



**Fig. 2** Annual departure of monsoon rainfall from the 1991–2008 mean in Mongla





**Fig. 3** Decadal frequency of cyclonic storm over southwest coast and all the coastal regions of Bangladesh during 1960–2009 (Data source: Water Resources Planning Organization (WARPO) of Bangladesh for the period 1960–1991, and from the Emergency Events Database (EM-DAT) of the Centre for Research on the Epidemiology of Disasters (CRED), Belgium for 1992–2013)

Residents' accounts of tropical cyclone becoming more frequent and more intense with increased storm surge height and more spatial inundation may be because of occurrence of two severe cyclones in the study area in the recent past (2007 and 2009). From 1970 to 2011, 18 major storm surges struck the southwest coastal areas, of which 6 were severe cyclonic storms. Within 5 years prior to the survey, the respondents experienced two severe storms.

Respondents' observation concerning the salinity intrusion into non-saline area and the rising level of salinity in soil and water was consistent with the soil survey and water quality monitoring records where observed changes in both soil salinity class and level of salinity towards increasing trend have been reported (SRDI 2010; Rahman et al. 2011). With respect to change observed by the respondents to expansion of area inundated due to rising high tide water level has been confirmed by some recent studies in southwest coastal region (World 2010; Mondal et al. 2013).

### 4.3 Perception of risk concerning climate change and its impacts

While attempting to understand the respondents' perceptions of major risks associated with climate variability and change, the participants in group discussions identified some of the disturbances which can be explicitly attributed to climatic factors while the others are related to the impacts of climate change entwined with non-climatic factors such as salinity intrusion. The livelihood in the study area is predominantly based on aquaculture dominated by shrimp culture. Because of this particular farming activity, the respondents were found to attach significance to those risks that they experienced as the significant contributors to the crisis in shrimp farming (Table 2).

Most of the respondents identified increased heat in summer months with increase in frequency of unusually warm days as a risk because it causes human and animal health problems, damages aquaculture production and increases salinity of various natural water sources from which drinking water is obtained by the local residents. Respondents noted that

**Table 2** Local perceptions of risk of climate change

Perceived changes in climate	Key impacts
Increase in summer temperature	<ul style="list-style-type: none"> <li>• Public/animal health problem</li> <li>• Disease outbreak/mortality in shrimp farm</li> <li>• Increase in salinity due to high evaporation</li> </ul>
Late onset of rainy season	<ul style="list-style-type: none"> <li>• Stoking of freshwater fish delayed</li> </ul>
Decline in seasonal rainfall	<ul style="list-style-type: none"> <li>• Increase in salinity</li> </ul>
Increase in cyclonic activities	<ul style="list-style-type: none"> <li>• Injuries and loss of lives</li> <li>• Loss of crop, fishstock, livestock and poultries</li> <li>• Damage to public and private infrastructure</li> <li>• Contamination of drinking water sources</li> <li>• Impacts on livelihood activities</li> </ul>
High tide rising	<ul style="list-style-type: none"> <li>• Salt-line moves to inland</li> <li>• Land erosion</li> </ul>

the exposure to the stress of heat and high salinity resulted in retarded growth and mortality of shrimp.

Late onset of monsoon rainy season marked by erratic rainfall pattern at the beginning of the season was viewed as a risk as it affects farm production cycle. After harvesting shrimp and euryhaline fish species which are cultivated during high salinity period, shrimp farmer expects monsoon rain to flush the salt from the shrimp pond at the end of this production cycle. People contend that the onset of rainy season now occurs later in the season, causing delay in stocking freshwater fish.

All participants were concerned about the vulnerability of shrimp farm to cyclone accompanied by storm surge due to ineffective coastal embankment or lack of flood control structures. When the cyclone hits the area with increased height of storm surge, the surge water breaches the earthen embankment encircling the pond and inundates the shrimp pond, allowing shrimps to escape to floodplain and water courses.

Salt-water intrusion is a major concern in the shrimp farming regions because it has degraded coastal ecosystems by causing soil degradation, deforestation, destruction of homestead vegetation, loss of coastal vegetation and decline in agro-biodiversity (Rahman et al. 2011; Paul and Vogl 2011). With increasing salinity in surface and ground water, access to fresh water becomes scarcer and that, in turn, affects economic and household activities.

In Mongla area, people living in the proximity to estuary or river and outside the coastal embankment are exposed to rising high tide causing soil erosion and salinity intrusion. However, high tide rise is not perceived as a major risk especially by the people living in areas protected by coastal embankment.

#### 4.4 Shrimp farmer's adaptation to climate disturbances and change

In Chila shrimp farmers have adapted to flood by investing in farm infrastructure (Table 3). Of the respondents surveyed, the majority (47 %) reported that they had increased the embankment height around the shrimp pond in order to prevent fish from escaping during inundation

**Table 3** Adaptation measures implemented by shrimp farmers in the study area

Changes in shrimp farming practices*	Respondents ( $n=30$ ) Number of sample (Percentage of $n$ )
Increased embankment height	14 (47)
Digging pond inside fish farm	6 (20)
Liming	3 (10)
Use medicine	2 (7)
Placing net around shrimp field	1 (3)
No response measures implemented	14 (47)

\*Respondents employed more than one type of adaptive measures

caused by intense rain in short duration or tidal flood. In order to make this intervention more effective, 3 % of the respondents placed net around the shrimp gher so that shrimp farm could sustain destructive flooding.

Farmers perceived that there was increase in number of summer days with intense heat elevating the level of salt concentration in the shrimp pond through accelerated evaporation from shallow pond. Understanding the relationship between the exposure to the stress of heat and high salinity in shrimp pond and retarded growth and mortality of shrimp, 20 % of the respondents dug deep ponds inside the shrimp fields so that shrimps could take refuge from heat stress during summer season.

Aside from specific responses to climate events, some farmers have adopted other new techniques to maintain healthy aquaculture environment in shrimp ponds which can be adversely affected by high temperature and intense rainfall. Data suggest that there were significant number of respondents (47 %) who did not implement any measures against climate or non-climate hazards affecting shrimp cultivation (Table 3).

In attempting to understand the reason, respondents were asked whether they were worried about the climate impacts and the reasons for inactions. As expected, most participants were concerned about the climate disturbances and change but they could not afford to take adaptation measures.

## 5 Discussions

The long-term rise in temperature reported in a number of scientific reports closely conforms to the belief held by most respondents. Similar correlation has been found between the local observations and meteorological records about changes in high tidal water level and salinity. Respondents also reported experiencing climate change in terms of changes in rainfall, cyclonic activities, storm height and wind speed but these are not substantiated by scientific evidence. However, when compared with aforementioned trends based on short-term record, local perceptions show strong correlation with meteorological records. In taking a closer look at the local accounts of climate change, we find that based on personal observation, lay people are likely to detect changes in hydro-climatic conditions when the change is large and that happens in a short period of time. This may also reflect the difficulties in detecting trends by personal experience within random natural variability of condition that can be expected for both stable and changing climates (Weber 2010).

In line with previous studies we have found that recent memory of climate event could affect local people's belief in direction of change. For example, respondents' inaccurate judgement about changes in cyclonic activities could be linked to two recent cyclones that were both very intense and destructive occurring in short interval (2007 and 2009). This is consistent with a study among the Papuan population in Indonesia, where Boissière et al. (2013) reported that people's belief in increased frequency of flood was associated with two recent floods in the study area, reflecting a correlation between local interpretation of climatic trend and recent climate events.

In the study area the most frequently mentioned climatic characteristics causing risk to life and livelihoods are associated with climate extreme events notably intense heat and increased cyclonic activities; changes in pattern in rainfall characterised by late onset of rainy season and decline in seasonal rainfall; and the impacts of climate change on physical environments such as rising tidal water level and salinity intrusion. It appears that the adverse impacts of climate events on aquaculture play an important role in shaping people's risk perception of climate change although they affect other spheres of life too. The underlying reason of this association is understandable; aquaculture dominates the rural economy in the southwest coastal region and this farming practice is very much sensitive to changes in hydro-climatic conditions. When the required hydro-climate conditions exceed the normal range, farmers experience adverse impacts on fish production. Whether this altered condition is a short-term variability or a long-term change, it appears to local farmers as indicative of climate change. Weber (2010) argues that the repeated personal experiences of hazardous weather events with adverse consequences lead to physical evidence of climate change in individual's perception, and that, in turn, results in concern about climate change, i.e., perceptions of its riskiness.

This risk perception of individual, group or society plays an important role in giving early warning to indicate that some risk management actions are in order and motivate people to execute that action (Weber 2010). The results of this study show that there are several modifications to on-going aquaculture farming practices being undertaken in light of climate variability and changes perceived to have occurred. Most of these response measures are kind of infusing traditional knowledge into current farming practices, providing new ways to deal with growing changes in climatic and environmental parameters. Although use of local knowledge is evident, but it did not trigger large scale adaption in the aquaculture practices nor did it bring about specialized adaptation options. This may be related to the fact that unlike agriculture, shrimp culture is not a historically well-established farming practice and therefore, local knowledge about the adaptive measures to climate disturbances may not be rich enough to help identify potential adaptation options.

The study shows that the participants who took adaptation action, their activities were not solely directed to address climate hazards; rather farmers embedded adaptation into main-stream risk management process of shrimp farming. This is due to the fact that shrimp farmers' vulnerability to climate hazards is also linked to non-climatic stresses. Yet, local autonomous response measures to specific stresses appeared to be focused more on short-term strategies than on long-term changes in practices. From this study it appears that many of the farmer's adaptive efforts in managing risks and reducing vulnerability were effective only when the changes to hydro-climatic variables were within the specific range, and thus, these responses are unlikely to be able to cope with extreme events.

Aquaculture farming systems in the coastal regions have evolved by way of unguided transformation from long-established agriculture-based production system and this transformation is still underway. Faced with increasing salinity intrusion, local people in the study area

are shifting their existing production system to a fundamentally new system and that results in reconfiguration of the linked social-economic system. While managing this transition to aquaculture-based farming systems, people faced increased pressure to take steps to respond to climatic disturbances. However, in this zone of proneness to disaster that results in out-right livelihood failures, many of community members cannot afford to allocate extra resources in their farming practices in order to ameliorate the potential threat from climate disturbances in spite of their awareness of climate risks. This calls for governmental policy interventions through integrating adaptation issues into aquaculture development program in the coastal area.

## 6 Conclusion

This study examines the climate change perceptions of the rural communities and their adaptive measures to manage climate risks in aquaculture, the mainstay in the southwest coastal region in Bangladesh. The results of the study show that local accounts of climate change mostly diverge from the scientific evidence when long-term climate trend is considered, but on short-term variability, the correlation between scientific and local accounts is high.

People in southwest coastal districts perceive that they have experienced increasing effects of hydro-climatic variability and change. Over the years, repeated experience of negative consequences resulting from climate events on livelihood activities, principally on shrimp aquaculture, shape people's climate risk perceptions. In relation to these perceived risks, farmers have made adjustments in their aquaculture practices, demonstrating the linkage between risk perception and related responses. However, the level of responses among the farmers in our case study and diversity of responses clearly lag behind the extent to which they demonstrate their concerns about climate disturbances. This slow process of adaptation is partly because farmers' efforts for managing transformation from agricultural livelihood system to aquaculture-based livelihood systems and partly associated with other social factors such as poverty, education and cultural values. Given that the adjustment in farming practices is occurring among only a few aquaculture farmers, the farming community needs governmental supports to make their livelihoods resilient to climate variability and change.

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