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Sustainability of fisheries and aquaculture in context of emerging climate change issues

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Abstract
At present the global milieu is extremely susceptible to the effects of climate change typically the fisheries sector owing to its economics, diets and social dependencies on fisheries and climate change is exerting an extra pressure over the many folds (fishing pressure, loss of habitat, pollution, disturbance and introduced species) and the fish stocks all over the world have already experienced the adversities. Besides, temperature rise, amplified irregularities in the rainfall pattern and frequency and harshness of life-threatening occurrences, upsurges of precipitation, tremendous flooding and salinity intrusions may have an undesirable impact on aquatic biota as well as fish. The utmost imperative effects of climate change in fisheries sector are – destruction of habitat, alteration of habitat conditions, disease outburst, obstacle in migration routes, hindrance in reproduction and finally reduced production. In Bangladesh climate changes also distresses the Sundarbans, the world largest mangrove forest, occasioning the damage of nursery ground of many marine fish species and also eradicate them. This will certainly bring about the loss in rural household income, distress our food security and level of poverty by uplifting adversity on fisheries production, unemployment and cut-off the supply of dietary nutrition, exerting extreme hazard to the existence of many species, imbalance in ecosystems, rise in mortality rates which may threaten the viability of the fisheries production henceforth and the financial feasibility of fisheries production systems. For sure that climate change has already created a strong demand of adapting accessible technologies and generating new ones to withstand the fisheries sector. In addition, Government also needs to emphasize on research and development of new technologies to lessen the impacts of climate change and sustain the fisheries sector as well.

Keywords: adaptation, aquaculture, climate change, fisheries, food security, rural poor, economic, ecosystem, mitigation

1. Introduction
The global climate is shifting and it is probable to alteration additional over upcoming spans due to growing concentrations of 'greenhouse gases' in the earth's atmosphere triggered mostly by human actions and human persuaded climate change intimidates ecosystems and human health on a global scale. This will upshot in larger deviations in weather arrangements, a greater incidence of extreme weather happenings such as inundations, droughts and tropical storms, and ongoing escalations in average temperatures and sea-levels [1]. The recently-published Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC), 2007 states evidently that climate change is paying to the global encumbrance of ailment and untimely deaths [14]. Since health is the principal goal of sustainable growth and contains physical, social and psychological comfort, it is vital that the health influences of climate change be assumed and precisely addressed. In spite of the contemporary strides towards accomplishing supportable expansion, Bangladesh's potential to sustain its expansion is confronted with substantial tasks postured by climate change [2]. It is consequently of extreme significance to comprehend its susceptibility in terms of population and sectors at jeopardy and its potential for adaptation to climate change. Despite the current strides towards accomplishing sustainable development, Bangladesh's likely to sustain its expansion is confronted with noteworthy encounters posed by climate change [2]. As Bangladesh is home to one the world's largest delta arrangements, two-thirds of the country is fewer than five metres above sea level and climatically, one of the world's most susceptible countries with numerous natural adversities for instance cyclones cause loss of life and impairment to infrastructure, economic possessions, and livings. It is therefore of supreme significance to cognize its susceptibility in terms of population and sectors at jeopardy and its prospective for adaptation

to climate change (Fig. 2). Consistent with the Third Assessment Report of IPCC, South Asia is the utmost susceptible constituency of the world to climate change influences [17]. The international community likewise identifies that Bangladesh statuses great in the list of extreme susceptible countries on earth. Bangladesh's high susceptibility to climate change is owing to a number of hydro-geological and socio-economic factors. Fisheries of this world's prevalent Delta with Semi-enclosed tropical basin are recognized by the nature of the waterbodies of the country (Fig. 1). Production in 2014- 2015 fiscal year was reported to be of 3.54 million metric ton of fish were produced in the country of them 16.78% of fish was produced from the sea, Whereas 55.15% from the inland culture sector and 35.53% from the inland capture fisheries sector[8]. As stated by the fisheries statistical year book published by FRSS, DoF this sub-sector of agriculture contributes ±5% in GDP. Fish is the source of 60% animal nutritional protein of the country population demand and this sector is a source of employ and revenue for a large sector of the population [8]. The purpose of the present study was to discover the effect of climatic change of existing time frame side by side find out the tentative solution with proper observation and suggestion.

2. Approaches and Methodology

The general approach for the current synthesis was to highlight the results available in literature on the actual situation about the real impact of climate change and vulnerability to climate change and their negative impacts in environmental resources, such as, water and air quality, temperature increase, poverty, natural disasters and other subjects, especially the effect on fisheries sector, its adaptation and vulnerability to climate change for Bangladesh as well as global and presented these results in summary form. In order to achieve the objective of the study, the study was carried out by employing a general review of literature on climate change, focusing on its effects in Bangladesh fisheries and aquaculture sector, and the results of specific research recently conducted and the general methodology deals with a number of steps: a. collecting existing literature on climate change issues for fisheries and aquaculture sector, available both nationally and internationally, to the extent possible; b. digging into existing literature to find out and collate key findings therein (taking into consideration methodological rigor that had been applied to reach a conclusion); and c. briefly highlighting on the ground adaptation practices as reported in literature. Outcome of the paper could be used as an important tool for actions in environmental/ ecological and fisheries sector conservation and management in context of climate change by the government of Bangladesh.

3. Results and Discussion

The role of fisheries and livestock sub-sector is very decisive for the economic growth of agriculture-based Bangladesh. Fish and livestock deliver daily protein and milk dietary necessities of the population, thus singing a vital part, providing nutrition and health. Slightly drop in production in this sector will upshot in a loss in rural domiciliary income, and a rise in unemployment in the rural parts. In susceptibility study of 132 national economies to possible climate change influences on their capture fisheries using an indicator-based tactic originate Bangladesh and three others in the most vulnerable group among the tropical Asian countries. The study found that this susceptibility was because of the collective consequence of forecast warming, the comparative prominence of fisheries to nationwide economies and diets, and inadequate societal capacity to acclimatize to potential influences and opportunities. This section of the paper concisely pronounces the concerns around how climate change could directly affect the fisheries sector, subsequent impacts and economic losses.

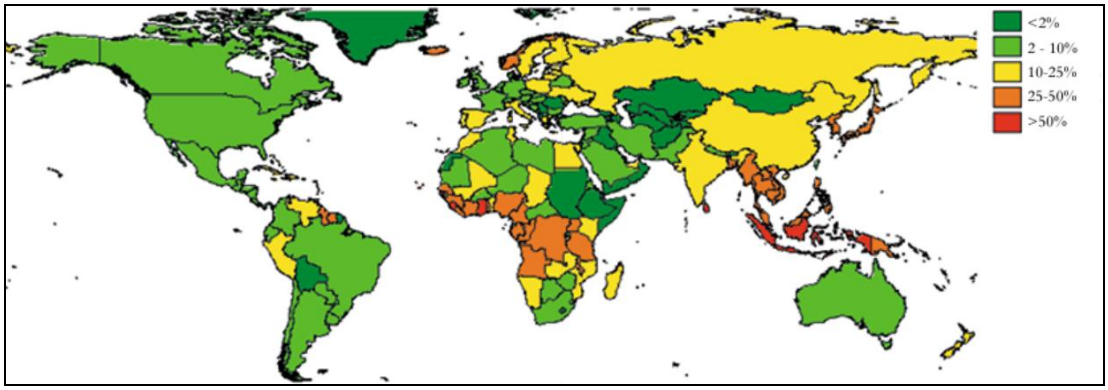


Fig 1: National average of fish protein as a percentage of total animal protein consumed (Handisyde *et al.* 2006)

Fig 2: Threatened deltas of the world owing to climate change (Ericson *et. al*., 2006)

3.1 Emerging Climate Change Issues

Consistent with IPCC [13], the succeeding fluctuations in climate trends, variability and extreme procedures are added significant and its insinuation to fisheries sector is very severe:

- Average water temperature rise
- Sea level rise
- The annual mean rainfall has been increasing
- Decadal rain anomalies will exceed
- Serious and recurring floods will occur
- Increased concentration of Cyclones originating from the Bay of Bengal
- Increased Frequency of monsoon depressions and cyclone formation in the Bay of Bengal
- Penetration of Salt water from the Bay of Bengal is to inland along tributary channels during the dry season.
- Undesirable impact on aquatic biota as well as fish.

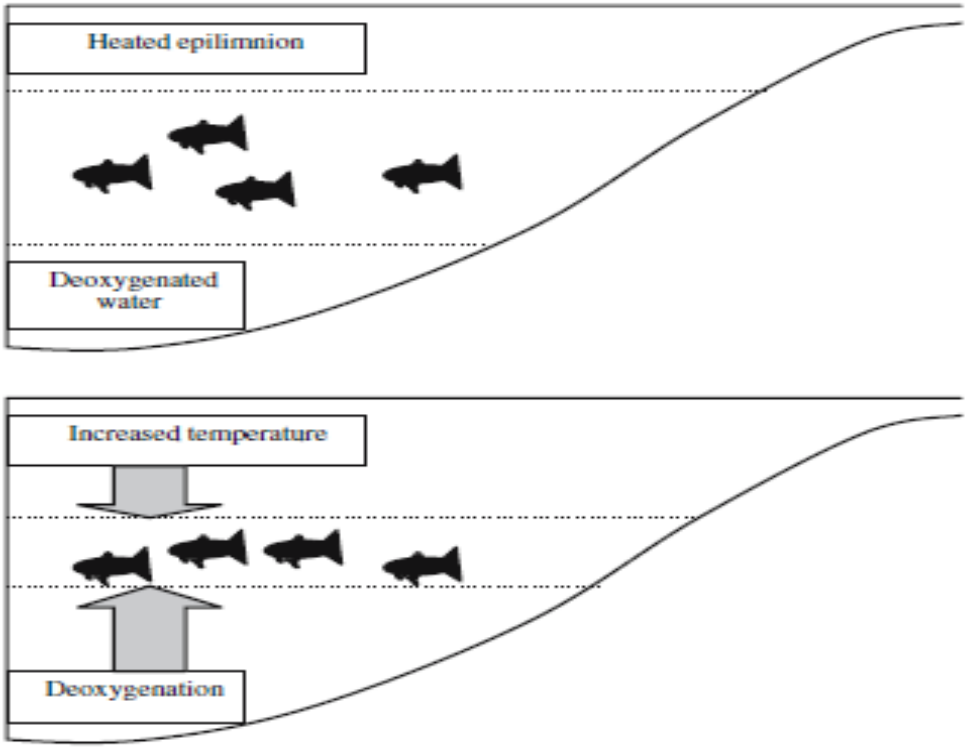


Fig 3: Due to species-specific temperature and oxygen requirements, climate change may restrict pelagic habitat availability for many species. Increased solar radiation will thicken the epilimnion, and increased fish metabolism will result in decreased concentrations of dissolved oxygen (Potential impacts of global climate change on freshwater fisheries (Ashley *et. al.*, 2006).

3.2 Specific impacts

3.2.1 Effects on Reproduction and Growth of Fish

- Inconsistent and uneven rainfall in addition to temperature change will upset the readiness, maturity and gonad development of fishes in breeding period.
- Higher water temperature may convey changes in Physiology and sex ratios of fished species, Alteration scheduling of spawning, migrations, and/or peak profusion, Variations in timing and levels of productivity across marine and freshwater systems, Escalation in profusion of invasive species, diseases and algal blooms.
- Deviations in timing and levels of productivity through marine and freshwater systems and
- Decline in production of target species in marine and fresh water systems.

3.2.2 Effects on Species Arrangement, Richness and Dissemination

Intensification in salinity and change in water quality can initiate a modification in species arrangement and dissemination especially in coastal areas. Clear modification in seasonal richness of separate fish encounters a modification in fish culture performs in the exaggerated parts. Intensification of adversity happenings will damage culture firms more often.

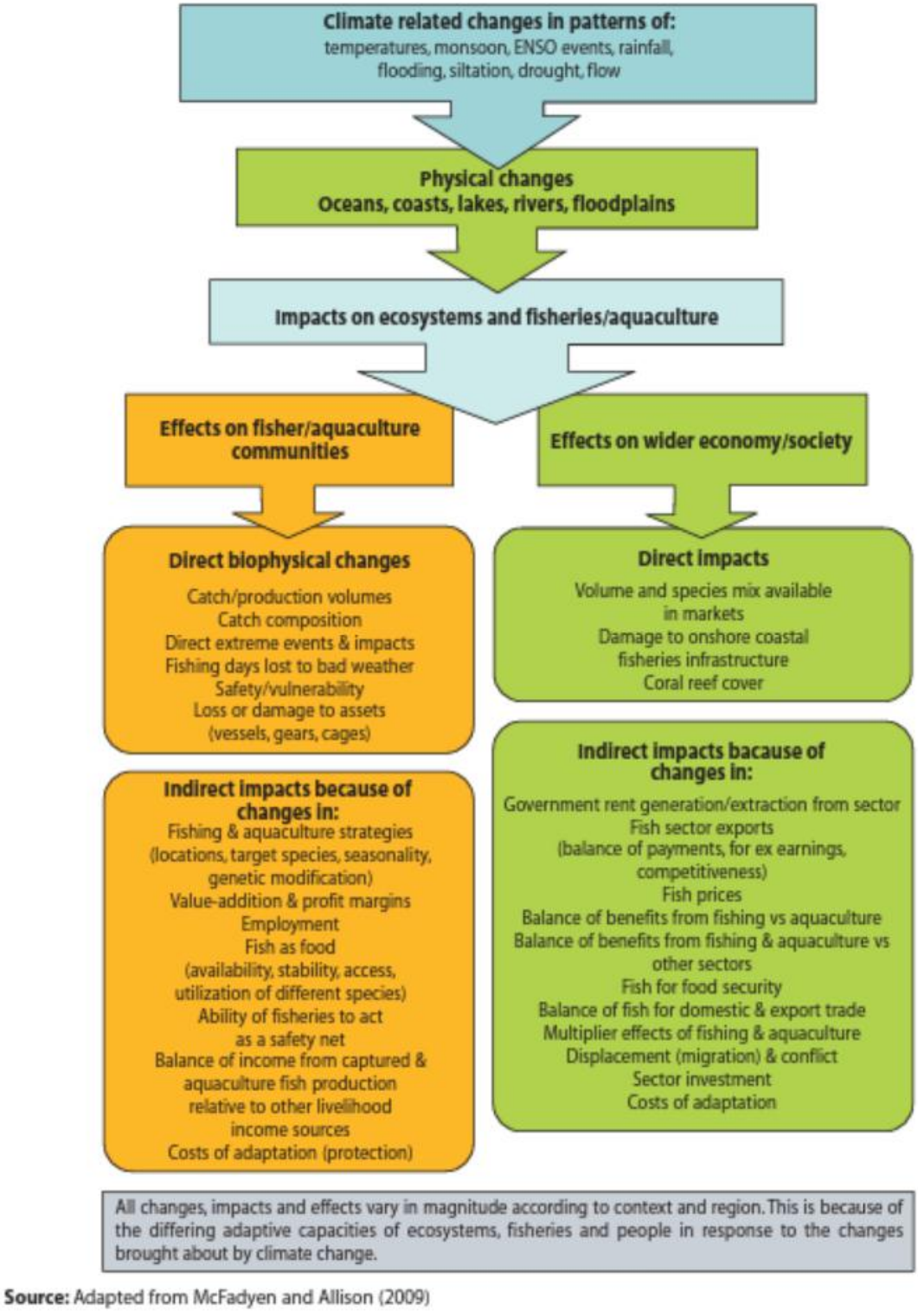


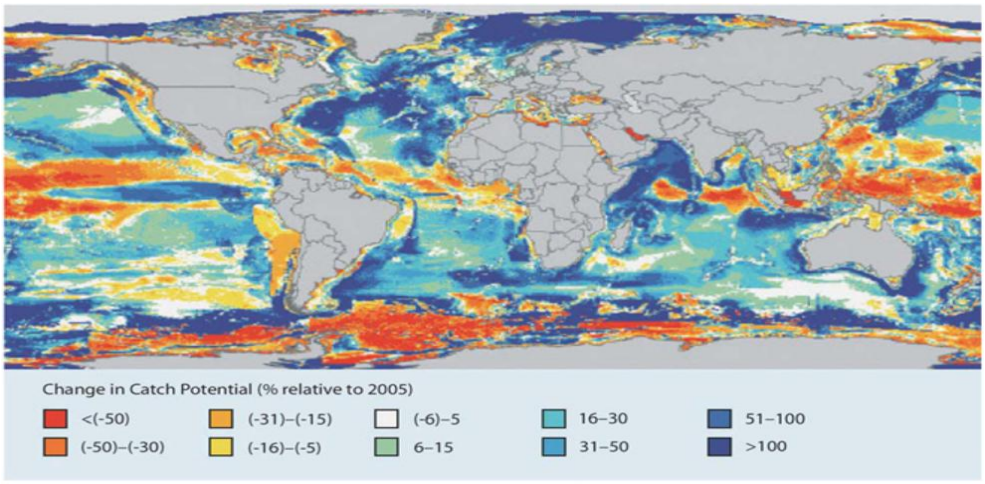
Fig 4: Overall Climate change implications for fisheries, communities and national economies

3.2.3 Effects on Habitat Quality and Migration Routes

- Proliferation in flooding and erosion can consequence in natural habitats being devastated.
- Alteration in habitat quality will abolish breeding sites.
- Fluctuations in water levels of wetland and in dry water flows in rivers leading to abridged productivity subsequent change in migration shape.
- Transformation in migratory routes of imperative species: Migratory routes of species may modification like Tuna and *Catadromous Hilsha and Bagda chingri*. Improved production of pelagic fish owing to upwelling which may results in negative change in food chain. Alteration in the position of the fishing grounds will similarly arise.

3.2.4 Short-Term Effects of Climate Change on Fish Harvests

In the short term, the direct effects of climate change would happen consequently of deviations in species abundance. Variations in species abundance may have an assortment of direct and indirect economic and social belongings (Fig. 5). We may abridge possible effects of climate change on fish harvests as follows:



Source: Cheung *et al.* 2009a

Fig 5: Changes in catch potential % relative to 2005.

- Climate abundance. Climate change is liable to lessen the abundance of some species while increasing the abundance of others.
- Changes in harvests. As the richness of a species changes, fishermen will catch added or scarcer fish either.
- Changes in fishing and processing employ. Changes in harvests disturb employment chances in fish harvesting and processing.
- Changes in prices. Fisheries markets are extremely subtle to supply. Changes in harvests tend to have conflicting possessions on prices. Because variations in climate are prospective to increase harvests of some species while dropping harvests of other species, it is dubious that the comparative extent of the change in total or wholesale value, as well as other economic effects, would be as prodigious as the comparative magnitude of the change in value for distinct species.

3.2.5 Effects on Seed production
Seasonality of fish seed production is a very significant dimension of aquaculture since production of fish seeds and its demands are capricious for diverse sort of grow-out growers in Bangladesh. Diverse commercially imperative species have dissimilar seasons of seed production and obtainability that impacts aquaculture production. Climate change will affect the obtainability of seasonal production of seed and impede aquaculture.

3.2.6 Other Impacts
Increased temperature upturns the metabolic action of fishes. Increased temperature also raises the evapotranspiration of water, which diminishes the surface and volume of water in the fish pond. Fishes face hypoxic ailment, recurrent incidence of which will cause the decrease of the growth rate and reproductive yield of culture species. Higher productions of aquatic macrophytes can diminution the productivity of water; decrease the fish habitat and oxygen supply which will produce the anoxic circumstance for fishes. This will leads to fish loss (Fig. 3).

3.3 Impact of Climate Changes on Commercially most Important Species
Tropical fishes have high critical thermal stability and an aptitude to regulate to increasing temperatures. Rather than having remarkably high metabolic rates and energy demands, tropical fish held at their optimum temperatures have metabolic rates similar to those of temperate fishes [23]. It appears conceivable that tropical fish will not suffer the effects of climate change as much as temperate or polar fishes. Nevertheless tropical fishes can presently undergo these temperatures [18]; a slight (1–28C) escalation in regional temperatures may cause the daily temperature maxima to surpass these limits, predominantly for populations that presently occur in thermally marginal habitats [21].

3.3.1 Hilsa (*Tenualosa ilisha*)
Hilsa (*Tenualosa ilisha*) is the national fish of Bangladesh. It accounts for 13-14 percent (valued at around Tk 6,000 million, 1.3 % of GDP) of the over-all fish production of Bangladesh [10]. Around 2% of the complete population of the country is directly or indirectly tied up with Hilsa fishing. The global Hilsa catch is stated to be 75% from Bangladesh water, 15% from Myanmar, 5% from India and 5% from other countries such as Thailand and Iran [29]. The migratory routes as well as spawning grounds of Hilsa are troubled, displaced or even devastated. Throughout the last two decades hilsa production from inland waters dropped around 20 percent, while marine water yield improved threefold [29]. Major Hilsa catch has progressively shifted from inland to marine waters. Contemporary studies disclose that the obtainability of hilsa is progressively decreasing in the Padma and Meghna river catchment areas. Hilsa fish climb for spawning migration from sea into estuaries. It has been found that the major spawning areas have been shifted to the lower estuarine regions of Hatia, Sandwip and Bhola. High turbidity, increased flooding, added tidal deed and fluctuations of salinity etc. have enhanced the variation of migration arrangements of spawning, growth and its production. Hilsa fecundity ranges from 1.5 to 2.0 million eggs for fish ranging in length from 35 to 50 cm. Hilsa fecundity is lessening in diverse parts because of climate change and the deteriorating fecundity impacting significantly on Hilsa production. Attributable to shifting of the spawning ground at the lower zone, the survival rate of juvenile Hilsa is extremely affected [26].

3.3.2 Tilapia and Carps
Because of higher temperature, fertilized eggs might be annulled 11 times from an individual tilapia brood stock in the year of 2008; conversely, in the year of 2009 it was only 7

times [26]. Water could be exchanged by the ground water to lessen the temperature; yet abrupt cool shock of groundwater can condense the hatching rate of tilapia eggs. As Indian major and Chinese carps are the notable providers to the aquaculture production in Bangladesh, reliance on hatchery based seed production of these species significantly affected by the rising temperature and its steady period. Common carp seed production is befallen naturally and majority of seed production happened in the pond based system which could be affected adversely with higher temperature in winter [19]. Contemporary work on common carp and rohu (*Labeo rohita*), imperative eurythermal aquaculture species on the Indian subcontinent, showed improved tolerance to raised temperatures succeeding acclimation to water temperatures of 30°C and 35°C [5]. This recommends that there may be physiological modifications to an innovative climate by eurythermal species in low latitudes. Yet, for fish presently living in marginal habitats, the effects of global warming would be comparable to those anticipated for temperate systems because tropical fish display comparable physiological symptoms when exposed to higher temperatures. Common carp and rohu had improved oxygen ingestion rates at temperatures of 30ºC and 35ºC [5], which advise that higher temperatures and a fixed ration would consequence in declined growth rates. The importance of this for aquaculture systems is that it would take longer for the fish to reach a harvestable size or it would necessitate more food to grow them to the harvestable size in the equal extent of time. Assumed their effects on growth, sub-lethal temperature proliferations could lessen productivity of natural and artificial aquatic systems by slackening distinct growth rates.

3.3.3 Penaeid Shrimp
Penaeid shrimp breed and progress in brackish water. Sea level rise and subsequent fluctuations to the river estuary can trigger changes in fish habitat and breeding ground. Sea level escalation would turn this edge backward, altering the natural habitat of the prawn population. Overall rise in surface water temperature would also put shrimps into heat associated stress. It is found that, if the temperature crosses a threshold of 32˚C, the small shrimp fries would display very high rates of mortality. Warmer water might perform advantageous for algal bloom – the concluding having damaging effects on growth of shrimps. Flooding triggered by sea level rise can inundate shrimp ponds and extinguish this forthcoming foreign exchange earner. It can also affect the dry fish industry.

3.3.4 Bombay Duck, Pomfret and Indian Salmon
Additional vital fisheries based on the populations of Bombay duck, pomfret and Indian salmon, having extensive variety of habitats may be affected by the increased temperature with reproductive physiology.

3.4 Sub-Sector wise lmpact
3.4.1 The Sundarbans
The Sundarban mangrove forest that positioned in the Gangetic delta (Ganges-Brahmaputra-Meghna) of India and Bangladesh is the prevalent single chunk of incessant mangrove forest in the world. Above 120 species of fish are normally caught by commercial fishermen in the Sundarbans area. This world's biggest mangrove can be smeared out by a 1- metre rise in sea level [24]. The Sunderban correspondingly have been playing a very significant role as a defensive wall in contradiction of the devastating cyclones and tidal surges by deflecting and reducing energy. The mangrove similarly supports offshore and deep sea fisheries by playing a noteworthy part as nursery ground for many deep sea fishes and shrimps including the *P. Monodon*, which is the foremost species of the industrial bottom trawl fishery of Bangladesh. Forfeiture of the Sundarbans would be ruinous a forfeiture of heritage, of biodiversity, of fisheries resources, of life and livings and of a very high productive ecosystem and Sea level rise may abolish the marine fish nursery ground.

3.4.2 St. Martin's Island
Sea level rise can decline obtainability of light for corals and thus their development. It can extinguish St. Martin's island, the only vastly productive coral island of Bangladesh. Temperature rise will cause Bleaching and mass mortality of corals. When temperatures pass the threshold for thermal tolerance, corals will be disappeared. Total collapse of ecosystem and extensive extinction of associated species, which will affect fisheries, tourism, and increased susceptibility of coastal areas will also be observed.

3.4.3 Effects on Aquaculture
Alteration in temperature will effect on aquaculture by increasing threat of disease outburst may cause economical losses in coastal areas (Fig. 7). It is now acknowledged that climate change would raise the magnitude of monsoon flooding. Consequently, the probable threat to culture fisheries would also rise under climate change [9]. Shrimp farms outside embankments generate earthen mini-polders, locally recognized as ghers, to yield shrimp in confinement. It is now a days an immense business in the coastal districts of Cox's Bazar, Satkhira, Khulna and Bagerhat. High tides would positively threaten these ghers both inside and outside embankments [24]. On the other hand, salinity ingress in new extents to the north of existing shrimp growing zones would enable shrimp business [4]. Overall increase in surface water temperature would also put shrimps into heat associated stress. It is found that, if the temperature crosses a threshold of 32˚C, the small shrimp fries would show very high rates of mortality [24]. In April the temperature is now relatively high. Climate change can, consequently, place this lucrative business into ambiguity.

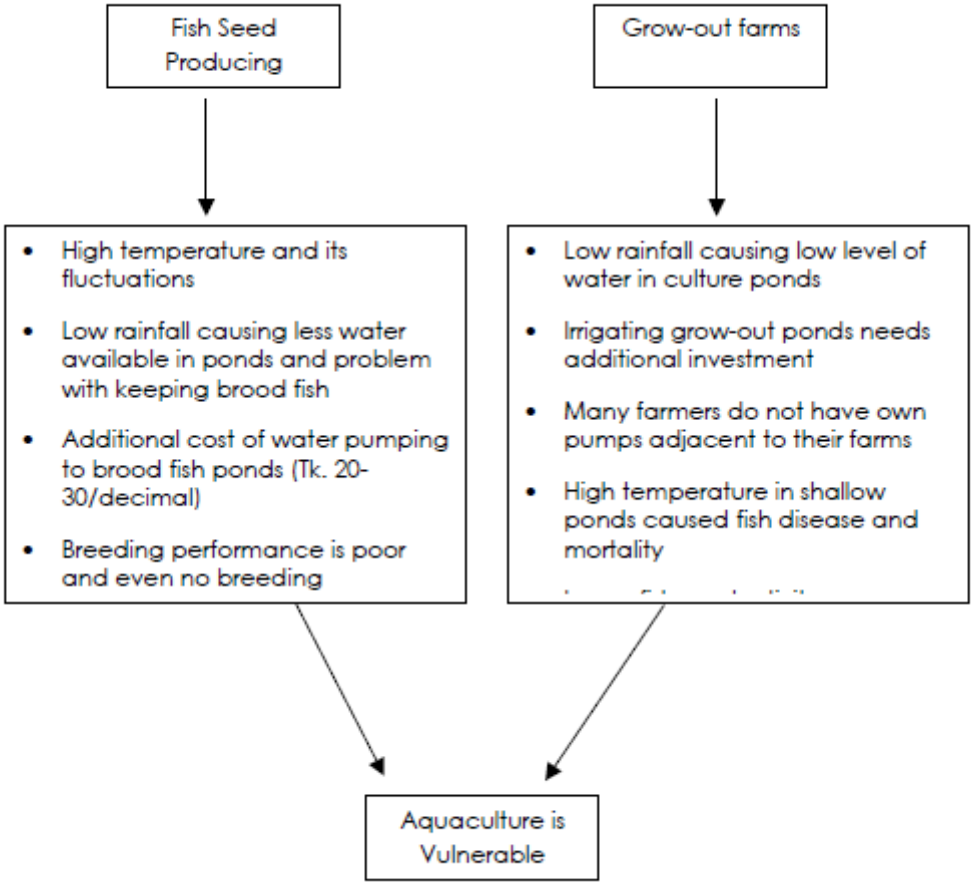


Fig 6: Impacts of higher temperature and low rainfall on aquaculture (Mustafa and Sharmin, 2010)

3.4.4 Effect on Open Water Fisheries Resources

Fish is a poikilothermic animal that cannot control their body temperature through physiological procedure and this is regulated by environmental procedure. Fish physiology like growth, reproduction and action are directly predisposed by the alteration of temperature. With rising environmental temperature, the physiological action of the fishes also increases. Rise of physiological activity raises the oxygen demand. Nevertheless the solubility of the oxygen in water contrariwise associated to temperature and salinity. Hence, dissolved oxygen availability in water will reduced, resulting as the reduction of growth and reproduction success of fishes and stopping them from dealing as successfully with the other environmental fluctuations. Increased temperature and declined level of dissolved oxygen might cause detrimental consequence for pond fish culture in Bangladesh. There are two reasons underlying this effect. Initially, increased temperature raises the metabolic action of fishes. Secondly, increase in temperature raises the evapotranspiration of water, which diminishes the surface and volume of water in the fish pond. So, in pond culture system, critically low oxygen concentrations will occur in the instant when all aquatic organisms use the dissolved oxygen for respiration and the occurrence of least dissolved oxygen concentration happens just before sunrise. As a consequence, fishes face hypoxic condition, recurrent incidence of which will cause the decrease of the growth rate and reproductive output of culture species. In 2013-2014, culture fisheries contributed 28.07% of total fish production of Bangladesh. It is assumed that if the global climate change cannot be controlled, its contrary impact will be reflected on our aquaculture yield.

Temperature incretion may equally embolden the growth of aquatic macrophyte and rise of 2-3°C could cause a 300-500% incretion of aquatic macrophyte [18]. Progressive production of aquatic macrophytes can decay the productivity of water; reduce the fish habitat and oxygen supply which will yield the anoxic disorder for fishes. This can convey almost fish kill. Open water of Bangladesh might aspect this problem.

Due to modification in rainfall, added droughts or floods, and scarcer likely wet/dry seasons, there will be reduced events for farming, fishing and aquaculture as portion of rural living arrangements, impairment to productive belongings (fish ponds, rice fields, etc.) and homes; and condensed skill to approach seasonal livelihood arrangements.

3.4.5 Impact on Marine Fisheries

Climate change impacts on marine fisheries resources Modification of marine ecosystems because of climate change has both direct and indirect effects on fish their reproduction, migration and survival.

3.4.5.1 Effect on Coastal Fisheries

Coastal infrastructure and fishing actions: Due to sea level rise and amplified regularity of storms, there will be vacillations in coastal profile, forfeiture of harbours and homes. Livelihood will be significantly affected for coastal fisher populations due to scarcer days at sea and increased risk of accidents as well as damages to aquaculture installations (shrimp hatchery). Costs of adaptation will rise and may make fishing less profitable.

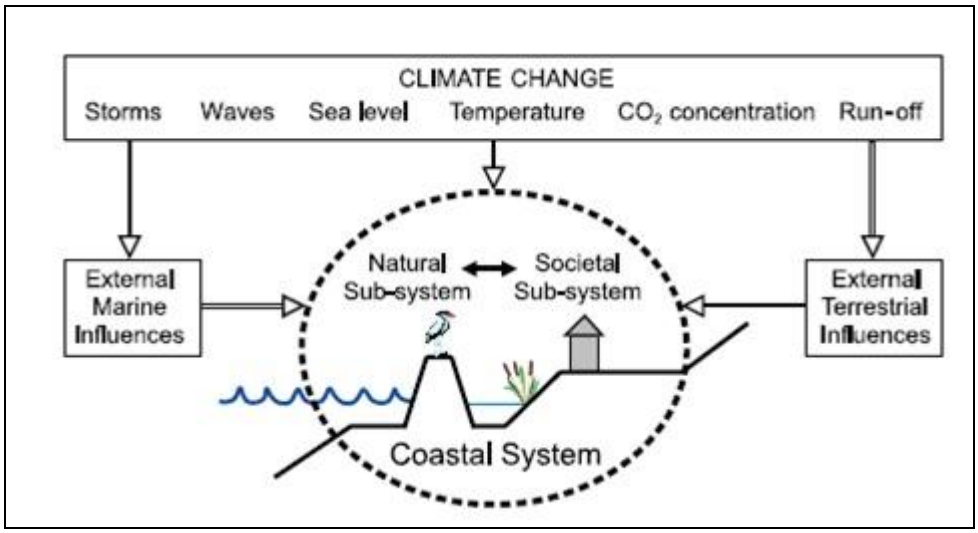


Fig 7: Climate change and the coastal system (*Source*: Nicholls *et al*, 2007)

3.4.5.2 Effects on Wetlands

Subsidence and salinization; increased acquaintance to extreme weather irreversible sea level rises will submerge coastal wetlands, distressing their ecology. Resulting as, vanishing of coastal wetlands, displacement and extinction of local and migratory species. This is affecting coastal infrastructure, fisheries, and agriculture.

3.4.5.3 Effect on Bay of Bengal Fisheries Resources and Bangladesh EEZ

Average tropical sea surface temperature is projected to rise by 50-80% of the average atmospheric change over the same retro [26]. Increased temperature may disturb the dispersal shape of some fish species where some of them may be migrate to the upper latitude for cooler domicile. Atmospheric CO_2 concentration is assumed to be enhanced from 380 ppm to 540-979 ppm by the close of the century [7] and this will cause the average ocean pH to drop by 0.4-0.5 related to pre industrial period [27]. Fish embryos and larvae are further subtle to pH alteration than juvenile and adults [28]. Eggs of the pelagic fishes might be more vulnerable to pH change. Increased level of dissolved CO_2 also diminishes the pH of animal tissue [29] and it might distress the marine fish physiology. Global heating may cause variations in the regional climate of the Bay of Bengal and can cause rise in the existence of forceful tropical cyclone and surge [24]. There is certain indication that local incidences of tropical cyclones topmost concentration may be increased by 5% to 10% and rainfall rates may be rise by 20% to 30% [17].

It is forecasted that Bangladesh is expected to face added cyclone and concentration and precipitation is also extraordinary. Tropical cyclones repeatedly cause a provisional deterioration in the profusion of some fishes due to damage of critical habitat of food for certain species [24] and also increase the disruption regime for fish communal. Cyclone Sidr and Aila affected the coastal fishery and fishing ground.

3.5 Overall impact (Fig. 4)

3.5.1 Sea Surface Temperature

Biophysical effects of Changes in sea surface temperature (Fig. 6) for fisheries and aquaculture will be

- Less dissolved oxygen which will consequently lead in increased aeration price, lessening in stocking concentrations of aquaculture.
- Increased occurrence of disease and parasites will affect changing vulnerability of some stocks to disease in fisheries sector and Aquatic diseases may become more easily conveyed through aquaculture or fish outlines and movements (especially during CC adaptation actions) in aquaculture sector.
- Alteration in the position and area of apt assortment for precise species will employ effects on increased productivity of some fisheries/species with longer growing seasons and lesser natural mortality in winter; improved metabolic and growth rates, alteration in fishing acts to follow fish, probable species loss and transformed species arrangement will hinder fisheries sector,
- Insinuations of improved primary productivity will affect the likely assistances for fisheries but conceivably offset by altered species arrangement; increased detrimental algal blooms and conceivably offset by eutrophication/dissolved oxygen jeopardy.
- Variations in timing and success of migrations, spawning and highest abundance, as well as alteration in sex proportions have insinuations on possible forfeiture of species or change in arrangement in capture fisheries and potential for mitigation through culture-based or improved fisheries with influences on seed obtainability and likely opportunities from hatchery produced larvae for aquaculture.
- Destruction to coral reefs that assist as breeding habitats and might aid defend the coast from wave act will consequence condensed recruitment of fishery species with degraded wave impairment to infrastructure or flooding from storm surges and degraded wave damage on cage and line culture with influences on coastal pond infrastructure; flooding from rainstorm surges will affect aquaculture.

3.5.2 Rising Sea Level

Consequential impact of Changes in rising sea level for fisheries and aquaculture will be

- Loss of land will bring about loss of freshwater fisheries and lessening of area obtainable for aquaculture with changes in species richness.
- Variations to estuary systems will cause damage of nursery grounds for coastal fisheries and dispersal and configuration of fish stocks and aquaculture seed.
- Saline water invasion will display severe influence on

freshwater capture fisheries in alteration of species composition and freshwater obtainability for aquaculture which will consequently decrease and produce chance to alteration to brackishwater species and enhanced chances for mariculture.

- Varying coastal ecosystems for instance mudflats and mangrove forests. Conversely, abridged recruitment and stocks for broodstock and seed for aquaculture, degenerated exposure to waves and storm surges and risk that inland/delta aquaculture will convert inundated because of salinity intrusion.

3.5.3 Ocean Acidification

Ocean acidification have unembellished inferences for fisheries and aquaculture and the subsequent impact of this Change will be abridged volume of the ocean to buffer when the amount of acidity change quicker than shells and skeleton upsetting formation and disbanding of calcium carbonate will abolish fisheries resources with its inferences on variations in species development, reproduction and behaviour.

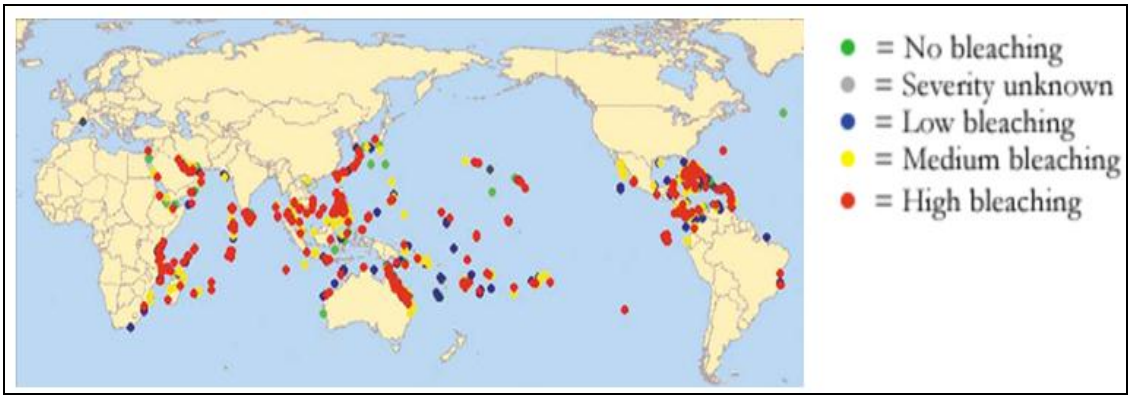


Fig 8: Probable coral bleaching due to climate change (UNEP, 2008)

3.5.4 Precipitation and Water Availability

Biophysical effects of fluctuations in rainfall (Fig. 6) and water convenience for fisheries and aquaculture will be

- Variations in fish migration, recruitment forms, and recruitment success with its implications for fisheries are transformed abundance and arrangement of wild stock, where food webs will also obstructed and influences on seed obtainability for aquaculture will also disclose.
- Temperature/dry period variations and water shortage will lead transformed and abridged freshwater deliveries with greater risk of drought and increased struggle/conflict with other water users (exclusively for sustaining river flows). Water quality variations because of population burdens, abridged flow or increased urban/agricultural releases and lesser water obtainability for aquaculture will outcome lesser water quality triggering added disease; augmented struggle/conflict with other water users; influences on traditional systems, e.g. rice-fish farming; higher charges of upholding pond water levels; abridged production volume with stock losses and alteration of culture species and culture systems (including some possible chances).
- Variations in lake and river levels and the complete magnitude and movement shapes of surface water will infer severe consequence on fisheries with variations in food webs and species arrangement and reduced biodiversity in all inland aquatic environments will cause transformed dispersal, configuration and richness of fish stocks; fishers enforced to migrate further and pay added exertion because of habitat and nursing grounds alteration.
- Abrupt, high rainfall leads to speedy overflow which cause indigenous flooding in deltas, coastal areas. Quickly altering water levels/flow rates in rivers, inundating of low lying plains/ floodplains and glacial lake upsurges will display inferences in fisheries through submerging, particularly flash flooding with effects to housing/communities; relocation of subsequent flooding which produce foremost problematic in high reliant on freshwater fisheries e.g. Hilsa fisheries in Bangladesh; turbidity and changing water quality with consequential result on fish stocks; fishing gears damage or loss will also be the concerns. Flooding in areas where there is no preparation will cause aquaculture ponds flooding and interrupt/damage cage aquaculture and escape of stock.
- Variations in salinity, temperatures, turbidity will affect increased stress and disease; and also has influences on seaweed culture (e.g. "Ice" disease).

3.5.5 Higher Inland Water Temperatures

Higher inland water temperatures will disturb

- Potential for improved primary productivity with greater fishery production, while, Eutrophication and weed/fouling development will obstruct aquaculture.
- Increased stratification and abridged mixing of water in lakes, dropping primary productivity and eventually food supplies for fish species will cause drops in fish biomass and alteration in food webs and species arrangement and dissolved oxygen complications and influences of "turnover" will also disturb cage culture.
- Abridged water quality, particularly in terms of dissolved oxygen as oxygen carrying volume of water deteriorations will condense development and disturbs stocking densities/production. Conceivable decreases in feeding rates and growth, higher capital costs for aeration equipment or deeper ponds and augmented aeration functioning charges will also be consequences of this.
- Metabolic rates will rise which will lead possible harm of species and modification of species arrangement for capture fisheries. Conversely, numerous species in tropical countries previously exist at the superior end of their temperature acceptances and consequently may not be able to acclimatize to even higher temperatures. And likely assistances for aquaculture, particularly intensive and semi-intensive pond systems such as raised metabolic rates increased feeding rates and growth; only if water quality, dissolved oxygen levels, and food supply are sufficient. Probable harmful impacts on hatchery and

nursery rearing operations will be added costs to alleviate.
- Variations in the variety and richness of pathogens, predators and opponents and alien species introduction will modify capture fisheries stocks and species arrangement. And new diseases/forms of epidemiology and perhaps deteriorated losses to disease (and so higher functional costs) which may entail variations of culture species.
- Variations in timing and success of migrations, spawning and peak abundance will employ effects on normal populations that in sequence have influence on aquaculture and probable loss of species or modification in arrangement for inland capture fisheries such as species fluctuating with temperature; affected migration timings forms; altered gonadal improvement/ maturation/sex ratios with altering spawning periods. And influences on wild seed obtainability for aquaculture with alteration in spawning habitats/ spawning time will affect development of hatchery brood fish.

3.5.6 Increase in Frequency and/or Intensity of Storms
The most plausible and sever influence of increased frequency and/or concentration of storms will be
- Huge waves and storm surges will result inland inundating from intense rainfall and salinity variations will distress wild fish recruitment and stocks, greater the direct jeopardy to fishers and damage of fishing gears which cause escalation in capital costs for moorings jetties, etc. that can endure storms. Improved insurance costs, and infrastructure impairment or loss of aquaculture amenities will lead mortality loss of aquaculture stock; biosecurity from runaways; overview of disease or predators into aquaculture facilities throughout inundating incidents with extrême alternances in culture environnent will cause increase in capital costs in design cage moorings, pond walls, improved insurance costs and lesser water quality and obtainability for aquaculture;
- Salinity variations will affect the damage of cultured stock; amplified production costs; loss of chance as production is inadequate.
- Variations in lake water levels and river streams will cause abridged wild fish stocks; exaggerated competition for fishing areas and additional migration by fisher community. And cage actions in rivers/water bodies will also be affected.

3.6 Adaptation and Mitigation
Constructing adaptations in the sectors with the intention of endure deleterious influences as well as to exploit on any chances; and mitigating the likely influence of these sectors to Climate change.
- Mitigation through enhancement or formation of dry season refuges for floodplains; creating habitats; engineer water management for the housing of fisheries or incorporation of refuges in water management systems.
- Aquaculture expansion may be an adaptation choice or another form of livelihood, e.g. rice farmers.
- Necessitates upturn dialogue with other sectors not to block migration, withstand flows in rivers, and preserve connectivity. Likelihood of mitigation through fishery improvement of cage operations in rivers/waterbodies which are adversely affected.
- Defense in contradiction of pond inundating, developed crafts and gears, substitute aquaculture system, new fishing skills, mechanization of boats and fishing, advance of alternate fish species aquaculture system, endowment of alternate living for susceptible fishermen.
- As direct fundamental connections between climate change drivers (versus other drivers) and variations to the systems will be tough (and costly) to conclude,
- Vigorous managing approaches and policy will be desirable, self-sufficiently of the driver of modification.
- Good governance is indispensable for operative governance
- Supporting science-based policymaking methods that are responsive and responsible to all stakeholders;
- Consolidation key organizations such as fisheries administrations, fisher co-operatives, pertinent civil society organizations, research institutes
- Empowering native government agencies to make precise policy choices based on distinguished native essentials;
- Recognizing and determining obstinate incentives, which are counter-productive to good governance;
- Undertaking shapes of corruption and support that may bring about decision-making based on short-term conferred welfares;
- Safeguarding cross-sectoral alliance is made conceivable (e.g. Developing multi sector decision-making bodies);
- Confirming fisheries and aquaculture deliberations are redirected in crucial expansion policies such as national development approaches and poverty reduction strategy papers; eliminating interdepartmental rivalry for power and properties);
- Integrating joined governance tactics, such as integrated coastal management (ICM) and the ecosystem approach to fisheries (EAF) management in policy objectives can support in creation significant added sectoral links.
- EAF, for example, can be associated to ecosystem based adaptation for instance the use of coastal ecosystems for coastline fortification that can also endow to fisheries habitat management, biodiversity defense and the tourism sector [15].
- Implementing the ecosystem approach to aquaculture which highlights the incorporation of other sectors, specifically the probable of integrated aquaculture-agriculture [22].
- Communities themselves must be strengthened through endowment of amenities for instance insurance and weather notices to lessen risk, sustenance for participatory natural reserve management and sustainability of fishing actions.
- Furthermore, Government also needs to accentuate on research and development of new skills to diminish the influences of climate change and withstand the fisheries and aquaculture sector too.

4. Conclusion
Climate change is one of the utmost vital concerns to tackle this generation and perhaps any generation in history. In end, water resources and hydrology of Bangladesh are extremely delicate to current climate inconsistency and Bangladesh is one of the top 10 nations that are regularly susceptible to climate change and by the end of the century, Bangladesh may be buckle down vanish under the waves. Inside Bangladesh, climate erraticism has two major dimensions – temporal and spatial. Both are extremely noteworthy. There are numerous essentials of susceptibility in fisheries and aquaculture sector allied to existing climate inconsistency.

Under climate change, observed climate inconsistency will rise extreme climate circumstances producing floods, droughts and salinity intrusion will befall added recurrently and with higher concentration instigating higher salinity, choking up of small rivers, water logging, embankment breaching and overtopping, cyclonic storm surges, riverbank erosion which may collapse or entirely harm the fisheries and aquaculture sector and cause a great socio-economic damage to the country. Consequently, it is very crucial that the country has to device adaptation procedures so as to decrease its existing inconsistency, change and loss. The government and non-governmental organizations have a vital part to play in mitigation and adaptation in milieu of climate change.

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