Climate Change and Indian Agriculture: Challenges and Adaptation Strategies

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Hazards in the Wake of Climate Change Induced Extreme Weather Events and Their Impact on Indian Fisheries

20

Abstract

Climate change, whether driven by natural or human forcing, can lead to changes in the likelihood of the occurrence or strength of extreme weather and climate events or both. In recent past, the increased occurrence of extreme climatic events has caused enormous damage to fisheries sector particularly to the tropical coastal countries such as India. The vagaries of climate are reflected in many forms, such as changes in temperature and rainfall pattern, which consequently lead to increased frequency of extreme events such as floods, cyclones, heat anomalies and unpredictable monsoons. These are further exacerbated by the activities such as anthropogenic enrichment of the coastal environment through coastal aquaculture farming, ballast water discharge, tourism, damming and so on. Further, the climate change impacts are also expected to intensify in the years ahead. Some of the resilient strategies, such as hazard mapping, spatial planning, participatory planning and capacity building, are the need of the hour for mitigating these hazards caused due to climate change induced extreme weather events and their impact on Indian fisheries.

Keywords: Environment, Ocean, Cyclones, Floods, Fishery.

I. Introduction

Climate change impact crisis is an important world-wide environmental emergency which has far-fetched significant implication in agriculture sector including fisheries (Srinivasarao *et al.,* 2019). Frequent floods, droughts, ocean acidification and rising sea levels, all due to climate changes pose a challenge as a whole, and the available reports suggest that the developing countries including India are more vulnerable since it is causing a huge impact on all dimensions of the society. Further, the climate change impacts are also expected to intensify in the years ahead.

Events such as floods, droughts, cyclones, tsunamis, etc. are the extreme weather scenarios that fishers, fish farmers and coastal population, in general, are confronting as the impacts of climate change, with increased intensity and frequency. It is important to initiate necessary steps and precautions to face the worsening impacts, which can be part of the adaptation strategy for mitigating them.

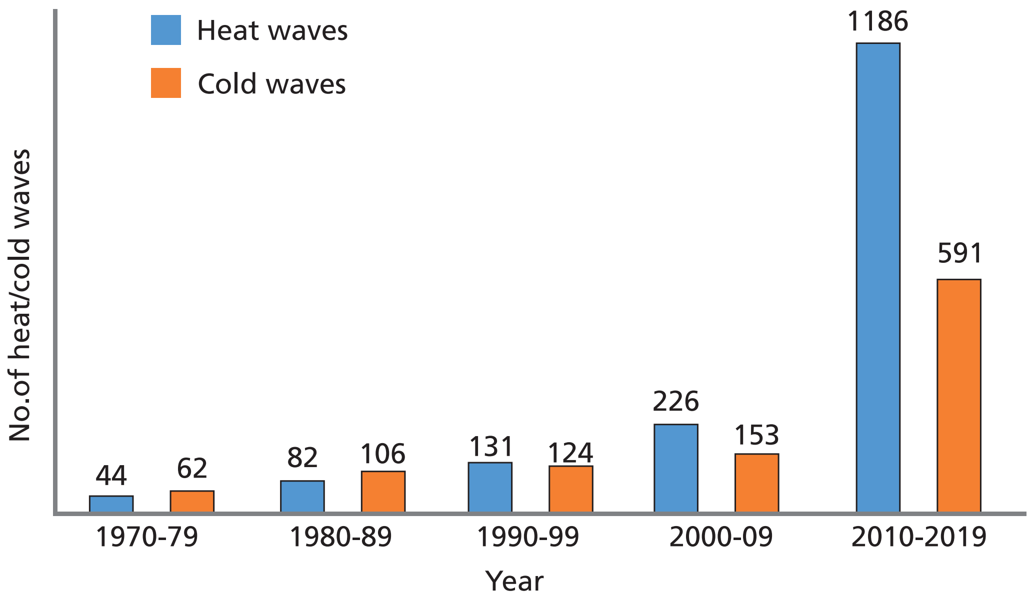
The increasing frequency and intensity of extreme weather events lead to intense coastal vulnerability and consequent severe socio-economic impacts. The crisis is a multi-faceted challenge for developing countries such as India demanding holistic approaches to reinvigorate the diminishing resilience of the poor and vulnerable sections of the coastal population.

With the changes in surface temperature of sea water, there are observed changes in the patterns of rainfall, evaporation, onset and duration of seasons and frequency of extreme events. This indicates that climate change is posing significant environmental challenge requiring an efficient disaster management at present. With the past experiences over the extreme events due to climate change, we can develop better strategies for risk management and adaptation. These strategies are to be supported with scientific information on climate trends in order to reduce the rising human, economic and financial losses due to extreme weather events triggered by abnormal climate variabilities.

II. Decadal Trends Related to Extreme Weather Events in India

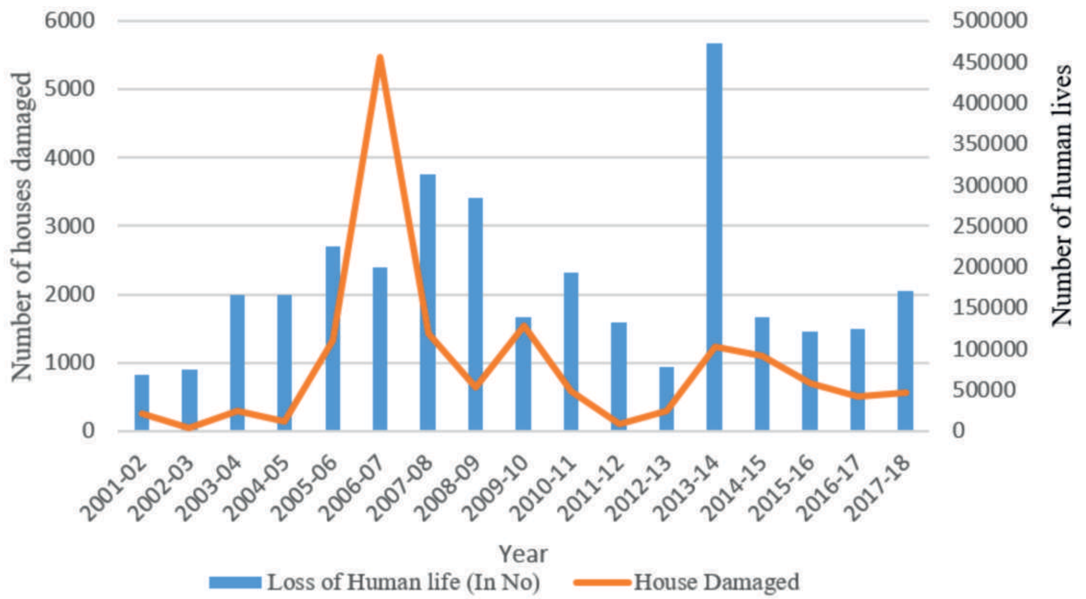
In India, there is an increasing trend of heat waves which is associated with the global warming (Perkins *et al*., 2012). The current decade has experienced more than double the number of heatwaves compared to the previous decade (Fig.1).

A similar situation is prevailing in case of cold waves also. These two weather extremes are influenced by the changes in ENSO phases (*El Nino* and *La Nina*). In the northern Indian Ocean region, there is a serious influence of Indian Ocean Dipole (IOD) events also which is having a cascading effect on the fishery in the region (Prathibha *et al*., 2018). Extreme events, such as tropical cyclones, heat waves, cold waves, droughts, floods, *etc*., have the potential to cause human loss, injury and huge economic losses to the



Source: Indian Metrological Department, Ministry of Earth Sciences

Fig. 1: Number of Heat Waves & Cold Waves Recorded in India

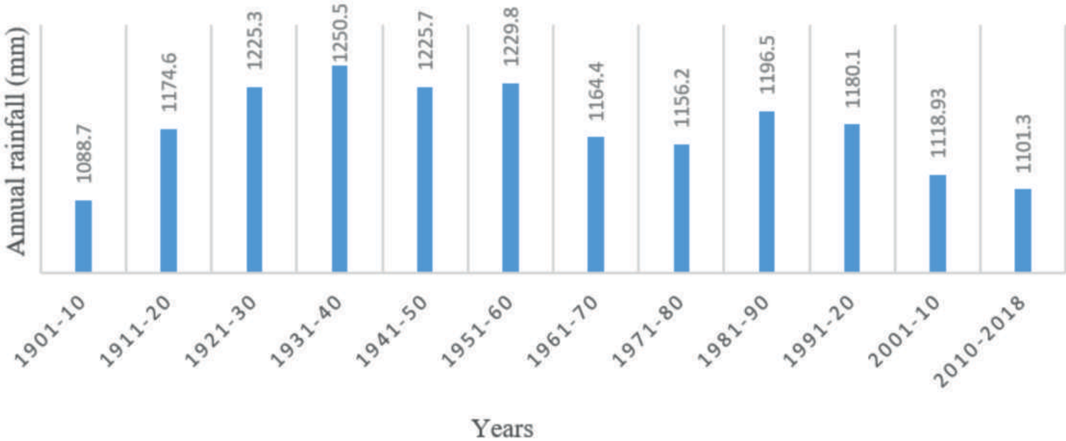


Source: Envistat, 2019

Fig. 2: Year-Wise Damage due to Extreme Events in India

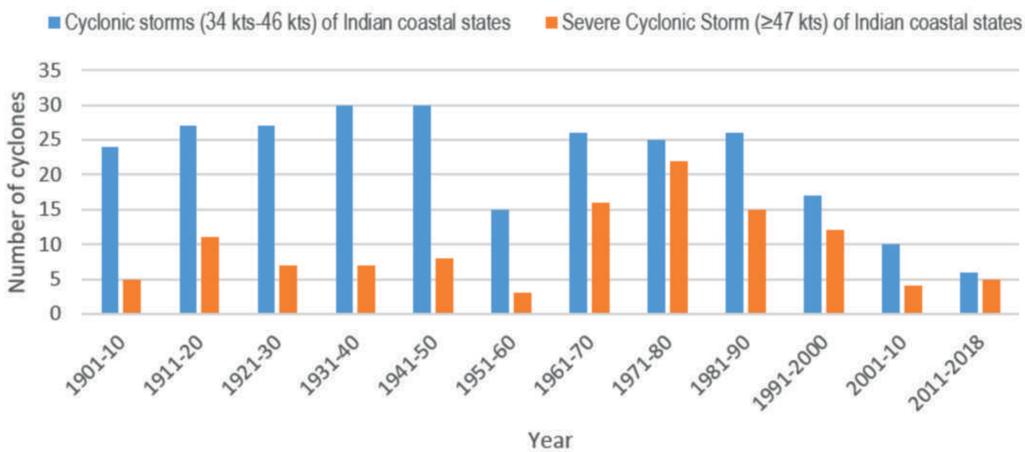
country (Fig.2). Large proportion of the global population is affected by the natural disasters and these numbers are fluctuating every year. Some of these disasters are very difficult to predict (Ray-Bennett and Nibedita, 2018).

Fluctuation in rainfall alters the hydrological cycle and the pattern of basic stream flow. This will call for a review of reservoir design and management practices in India. The patterns of annual rainfall in India have been irregular and inconsistent in the past decades (Fig.3). The fluctuating rainfall pattern with a declining trend in recent decades threatens the biodiversity and fishery production of our country (Kumar *et al*., 2010). It was observed that there had been many cyclones in the Bay of Bengal compared to the Arabian Sea. Though the number of cyclones is on marginal decline in recent years, their intensifications are high compared to earlier decades (Fig.4).



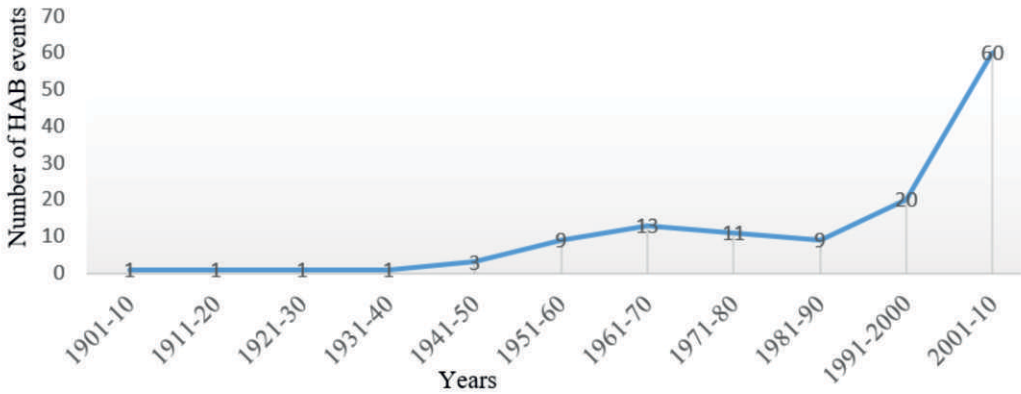
Source: Indian Metrological Department, Ministry of Earth science

Fig.3: Decadal Averages of Annual Rainfall in India (mm)



Source: Envistat, 2019

Fig. 4: Cyclones Occurrence in Indian Coastal Waters



Source: Padmakumar et al., 2012

Fig.5: Harmful Algal Bloom (HAB) events in Coastal Waters of India

The increasing frequency of occurrence of harmful algal blooms (HABs) in Indian coastal waters is a serious issue as the greater is the number of the HABs observed, more is the severity in deterioration effect on the quality of Indian coastal waters and fisheries (Padmakumar *et al.*, 2012).

III. Complexities in Extreme Events

Extreme events, in nature, can be defined as the occurrence of those calamities which are spontaneous, unpredictable and uncontrollable within the short time of its evolution or any such hazardous happenings which threaten the existence of livelihoods depending directly or indirectly on different coastal ecosystems and their provision of goods and services. For example, it can be flooding of rivers in north eastern hilly areas during monsoon, cyclones along Odisha coast or landslides in Western Ghats during south west monsoon season and so on. Complexities in extreme events, associated with weather elements or effect of anomalies of different meteorological parameters (*eg*. solar radiation, sea surface temperature, precipitation, *etc*.), can be described as natural calamities which bring forth scalable disaster after their occurrence threatening the very existence of life and human settlements. For example, there can be heavy loss of life and damages to coastal structures due to Tsunami or destruction of roadways and communication facilities soon after landslides/floods *etc*. Any such event's origin and occurrence regionally associated with climate change has produced serious impacts on fish and fisheries also. It also causes serious damage and loss to different stakeholders associated with fisheries and aquaculture (Zacharia *et al*., 2016).

III.1 Extreme Floods

Floods during the monsoon season in Indian sub-continent are considered to be among the unpredictable extreme events which hamper the food fish production both from capture fisheries and through commercial aquaculture practices. In general, the south-west monsoon season, along the south-west coast of India (Kerala and Karnataka coast), is one of the two rainy seasons which receives maximum rainfall. This season, in particular, receives heavy rainfall which causes floods in the tropical rivers of Kerala and Karnataka. Subsequently, the multi-purpose dams and reservoirs constructed in these states, are also flooded during the season immediately after heavy showers during the mid-monsoon. Heavy rainfall, followed by flooding in rivers along with the anomalies in monsoon winds over the coastal seas, causes severe impacts on marine fish production. The changes in breeding patterns of different pelagic and estuarine fishes (as flooding alters the environment, habitat and living conditions and monsoon winds alter the micro-climate at regional levels), delayed or reduced recruitment of different fish resources, etc., are some of the after-effects of extreme flood occurrences.

Extreme floods also bring in huge loads of nutrient-rich sediments to the coastal waters which through upwelling reach the surface waters. This sediment loading in the sea has differential effects on fish production, sometimes detrimental even. The delta formation with sediment loads, along the east coast of India in Bay of Bengal, is also having significant role in influencing the coastal fish production. The rivers' discharge during heavy monsoon and the ensuing floods observed in major rivers such as Godavari, Krishna, Ganges, *etc*., contribute to vagaries in fish production. However, altered and increased flooding along with increased pollutant loads from the mainland reaching though flood water and sediment make the environmental conditions at sea unfavourable for fish growth and production (Gibson *et al*., 2002).

III.2 Unpredictable Monsoons

Monsoon winds influence the agro-climate of Indian sub-continent significantly. Monsoon winds enter in the Indian subcontinent along the southwest coast of India and bring in rains all along the western part of Western Ghats. These heavy showers over Kerala and Karnataka are important for the productivity of coastal and inland water bodies (Shafeeque *et al*., 2019). The direct dependence of fishes on rainfall is that the onset of monsoon rainfall along with favouring temperature induces fishes to spawn and reproduce naturally. Increased rainfall and changing water currents in sea also favour primary and secondary food sources' growth such as that of phyto and zoo plankton. Plankton blooming also is boosted by upwelling phenomenon. Upwelling episodes along with the mud bank formation in sea, during peak monsoon season, high rate of plankton multiplication followed by increase in shrimp and fish reproduction. Mud bank formation in sea along the Kerala coast is due to the sediment discharge by rivers draining into the sea during the rainy season. Increased river flows and sediments draining into coastal waters get accumulated and form colloids in the column and bottom, relatively at lower depths (15-20 m) which form the nutrients' source. Upwelling brings these nutrients from colloidal mass in deeper waters to the surface. Where rainfall is high, it triggers plankton blooming offering primary food source to coastal pelagic resources. In reality, any alterations in monsoon wind patterns negatively influence the fish production. Similar is the case in other coastal areas also. Anomalies in rainfall pattern directly influence the primary producers' biomass and thus fishes also, as they occupy all other trophic levels linked to the first trophic level. Late arrival of monsoon winds influences the brooders to spawn asynchronously or to reabsorb the gonadal contents in their body itself. It also results in larval mortalities due to lesser abundance of food-planktons and other live fish food organisms in water, relatively higher water temperature, *etc*. All these reduce the recruitment intensity and thus fish production. Altered and uncertain rainfall patterns thus reduce the fish production dramatically.

III.3 Intense Heatwaves

There has been a tremendous rise in the intense heatwave events affecting the human comfort globally. It is the abnormally high temperatures, more than the normal maximum temperature that occurs between March and June usually in North-Western parts of India, adversely affecting the folks as they cause physiological stress, sometimes resulting in death (NDMP, 2016). The re-curving tropical cyclones before the onset of the heatwaves could change the direction of the winds and cut-off moisture to the inland regions leading to heatwaves (De *et al*., 1998). The abnormally high temperature anomalies have been recorded over south India and coastal eastern India (Ratnam *et al*., 2016). The climatology on sea level anomaly in northern Indian Ocean indicate an anomalous low-pressure area along the east coast of India indicating the moisture driven winds blowing out of India and transported to the cyclonic anomalies in the west Pacific. The transport of the moisture out of the Indian coast causes the reduction in precipitation along the east coast of India (Ratnam *et al*., 2016).

IV. Impacts on Fisheries

Fisheries and aquaculture are among the critical sectors as they are dependent on nature to variable extent. The vagaries of climate are reflected in many forms, such as changes in temperature and rainfall pattern, which consequently lead to increased frequency of extreme events such as floods, cyclones, heat anomalies and unpredictable monsoons. These are further exacerbated by the activities such as anthropogenic enrichment of the coastal environment through coastal aquaculture farming, ballast water discharge, tourism, *etc*. Changing land use cover, reservoir storage and agricultural and industrial operations in the vicinities are altering the functions of natural habitats such as brackish water wetlands as seen in the case of Kerala floods.

The scale of impacts can be seen in various perspectives as discussed below.

IV.1 Food Production

The Fani cyclone, 2018 caused a severe impact on shrimp production of Odisha. It not only affected the aquaculture farms but also the seafood processing units due to power failure, incurring a loss of around Rs.30-400 crores (Krishna Kumar, 2019).

Floods in Kerala have cascading effect on fish farming ventures in sheltered areas of the coast that are used for pen and cage fish farming in the state. Many times, the ready to harvest crops of Pearl Spot, Sea Bass and Red Snapper are lost in the usual floods occurring ahead of the Onam season when they would have fetched maximum profit due to festival peak sales. A total loss of Rs.4 crores in the year 2018 was estimated for Ernakulum and Thrissur districts of Kerala (Kumar, 2018).

IV.2 Abundance of Competitors

Fish, being a poikilothermic organism (Bowden *et al*., 2007), will be more severely affected than other homoeothermic animals and ultimately the production scenario would alter to the detriment due to extreme events in nature. For Instance, rising temperature in the Arabian Sea has extended the distribution of Indian oil sardine up to the north-western zone, but its spread can have severe impact on the Bombay duck having restricted distribution in the North-west coast of India (Rohit *et al*., 2018). It will not only enhance the competition for food and space but also outpace those species in competition whose distribution is restricted to specific environmental parameters; for instance, tidal oscillations in the case of Bombay duck.

IV.3 Impact on the Oceanic Food Webs

Marine heatwave happens when the ocean temperature is much warmer than usual for the time of year which may be due to heating of the surface water by excess sunlight or warm water being brought via ocean currents. In 2015, New Zealand experienced its longest and mostintense marine heatwave on record and it brought down the abundance of valuable tropical species like kingfish and snapper (Oliver *et al*., 2017). In the aquaculture industry, it resulted in disease outbreaks in oyster farms, disruptions to salmon farming and death of abalones along the coast (Oliver *et al*., 2017).

Extreme marine heatwave lingered over the Shark Bay World Heritage area of western Australia in 2011, seagrass and kelp forests damaged in mass (Arias-Ortiz *et al*., 2018). Some kelp species became regionally extinct over hundreds of kilometres. This loss was not only a direct effect of the heat, but also was due to herbivorous fish migrating along with the warm water and foraging over the kelp. The kelps were also being replaced with seaweeds turfs, thus having severe impact on the kelp ecosystem (Arias-Ortiz *et al*., 2018).

IV.4 Critical Ecosystem

Strong storms, in terms of severity, are in increasing frequency and are influencing the mangrove productivity and health (Stocker *et al.,* 2013). Activity, such as defoliating the canopy, uprooting trees, etc at the seaward margins are observed (Doyle *et al*., 1995). Changing rainfall patterns (Gilman *et al*., 2008),

Table 1: Various Extreme Events Reported from India

Extreme event		Effect	Impact	Reference
Cyclone	Fani (2019)	6416 traditional fishing boats, 8828 nets, 2524 fish ponds, 157 aquaculture ponds covering an area of 77 ha, 3 fishing harbours, 6 fish landing centres, 5 fish farms were damaged in Odisha.	The economic losses including damages to aquaculture and infrastructure were INR 158.35 crore (USD 23 million) amounting to 5% of the total damage and loss in the sector.	Jain and Malladi., 2019
	Titli (2018)	About 80% i.e. 4,200 units including mechanised boats, traditional boats and nets were damaged in Srikakulam, Andhra Pradesh	Coastal villages of state were deserted under the impact of migration for livelihood.	Babu, 2018
	Ockhi (2017)	Many fishers were found dead or missing, numbering 143 & 218 in Kerala and Tamilnadu, respectively.	Loss of lives, livelihood, resources and infrastructure affecting socio economically.	Roshan, 2019
	Phailin (2013)	Affected 1.3 million people in 18,374 villages; damaged 8 423 boats; and killed more than 50 people in Odisha.		Singh and Jeffries, 2013
Harmful Algal blooms	HABs (2012)	Visible discolouration of the waters, foam production, fish or invertebrate mortality or toxicity to humans.	Human fatality: In 1981, Paralytic Shellfish poisoning (PSP) resulted in death of 3 persons and hospitalization of 85 people due to consumption of affected mussel *Meretrix casta* in Tamilnadu. Massive fish kill: An unusual nauseating smell emanating from the coastal waters was recorded from Kollam to Vizhinjam in the southwest coast of India.	Padmakumar *et al.*, 2012
Extreme event		Effect	Impact	Reference
Unpredictable Monsoons		Salinity changes in several water bodies such as coastal ponds, wetlands, Estuaries, etc., limits the time of fish culture for small and marginal farmers. Heavy rainfalls lead to fish escape, entrance of predatory and weed fishes from the nearby water resources into the ponds affecting ecologically socially and economically.	While too little rainfall during the monsoon can cause dire conditions for farmers on land, too much rainfall and overly strong winds can make coastal waters unsafe, preventing fishermen throughout South Asia from heading to sea to catch the fish they depend on for income.	Gouda *et al.*, 2017
Heat waves		Significant effect on the marine ecosystem with changes to seagrass/algae and coral habitats, as well as fish kills and northern extension of the range of some tropical species	Major impact on high value fish species such as tuna	Menard *et al.*,2007

abnormal precipitation and increase in evaporation have indirect effects, such as incremental increase in soil salinity and low survival of seedlings, reduced productivity and growth rates, and thus a heavy loss to mangrove ecosystem (Duke *et al*., 1998). Coral reefs are among the critical ecosystems supporting fisheries, as well as, guarding our coastline against severe wave action and erosion. With extreme temperatures and solar irradiance, global warming and the resultant climate change, enhanced frequency of floods and abnormal rainfalls are directly or indirectly contributing to sea-level rise that is detrimental for already stressed coral reefs. Changed weather patterns, such as altered *El Niño* and *La Niña* events, are already affecting coral reefs. In 1998, the highest of the tropical sea surface temperatures (SSTs) recorded in the last 50 years, as a result of El Niño phenomenon, was recorded (Wilkinson *et al*., 1999) and the coral reefs suffered the most extensive and severe mass bleaching episodes, resulting in obliteration of 16 per cent of the world's coral reefs and 50 percent of those in the Indian Ocean (Wilkinson *et al*., 1999).

IV.5 Socioeconomic Sustainability

The fishing community suffers greatly due to the loss of infrastructure such as boats, nets and other fishing equipment, during events such as cyclone and flood. Mental trauma and grievances take time to heal and subside and get prepared to venture again into the sea. The women of the community, who used to sell fish or work as casual labourers, also go without jobs. Thus, both men and women of the fishing community are unable to earn a living (Singh *et al.,* 2018). Migration to other states for petty jobs is also visible from the cyclone affected areas of the country (Babu, 2018).

V. Towards Resilient Pathways

Climate change resilience mainly has two aspects - one is mitigation of greenhouse gas (GHG) emissions and the other is adaptation to impacts of climate change on different eco-systems and their services. Recently, climate change has emerged as a global environmental challenge. In 1992, with the adoption of United Nations Framework Convention to Climate Change (UNFCCC), different steps were taken to address the effect of climate change. India is a party to UNFCCC and the Government of India gives significant importance to climate change issues. Disaggregated impacts of climate change affect the fisheries sector. The 73rd and 74th Amendment Acts, 1992, of the Constitution of India have given immense power to local governments at rural and urban levels, respectively, which reflect the commitment of Indian Government in the direction of mitigation of climate change.

V.1 Dimensions of Exposure and Resilience Pathways

To build resilience to the effects of climate change and to derive sustainable benefits, fisheries managers, as a top priority, need to adopt and adhere to best practices such as those described in the FAO Code of Conduct for Responsible Fisheries and the EAF/EAA. Progress in this direction would be an important contribution to maintaining biodiversity, preserving the resilience of human and aquatic systems to climate change, and improving our capacity to anticipate and adapt to inevitable climate induced changes in aquatic ecosystems and the related fisheries production systems.

V.2 Hazard Mapping

A hazard mapping is intended for highlighting the areas that are already affected by different hazards and those vulnerable to specified hazards. They are typically created in relevance to natural hazards, such as earthquakes, volcanoes, landslides, flooding and tsunamis. For vulnerability assessment, three vulnerability factors are used which are exposure, sensitivity and adaptive capacity. Exposure refers to people, property, systems, *etc*. present in hazard zones that are thereby subject to potential impacts of climate change. Sensitivity means responsiveness of a system to climate hazards. Adaptive capacity refers to the ability of a system to adjust to the impacts like those of climate change. For preparing communities and people to meet the challenges arising out of such changes, information specific to a state or even district is needed because such impacts of climate change are not uniform. In order to meet this need, a national level climate vulnerability assessment map needs to be developed.

V.3 Community based Experiences

Community-based experiences can be combined in comparison to individual strategies across multiple setting aiming at the wellbeing of the society. Based on their knowledge, experiences and availability of local resources including the social capital, community based vulnerability reduction and disaster management strategies can be formulated through wider development planning and debates.

V.4 Spatial Planning

At a different scale, traditional policy and management planning and tools will have to be “climate proofed”, by using GIS tools spatially and temporally – *eg*. Protected areas and closed seasons. At the regional level, agreements among countries sharing transboundary stocks will also need to be adjusted as shifts in stock distribution and changes in productivity occur. Fishing vessels of all sizes may be rendered more stable to allow for fishing farther away from the coastal area. Fish aggregating devices may be used to lure fish back within the traditional fishing areas.

V.5 Participatory Planning and Capacity Building

Participatory planning is done by taking all the stakeholders in consideration for any management. For the extensive community engagement careful consideration of local culture, values, and belief systems is important as they play a major role in understanding future climate impacts. Capacity-building is about enhancing the ability of individuals, organizations and institutions in developing countries and in countries with economies in transition to identify, plan and implement ways to mitigate and adapt to climate change.

V.6 Building Vertical and Horizontal Governance

A multilevel governance framework calls for the narrowing or closing of the policy "gaps" between levels of government *via* the adoption of tools for vertical and horizontal governance. The vertical dimension of multilevel governance recognises that national governments cannot effectively implement national climate strategies without working closely with regional and local governments as agents of change. The horizontal dimension of multilevel governance is also associated with improving coordination across national line ministries to implement crosscutting programmes, such as those required in many climate change policies. Whereas the multilevel governance approach recognises that local governmental authority has to act in areas of its jurisdiction with the close coordination of all link departments, institutions and local people for developing climate resilient strategies to mitigate the losses from the unpredictable and unavoidable extreme events and for the sustainability of the fisheries resources.

VI. Conclusion

Extreme events in recent years are drawing the increased attention to the science seeking to understand their causes as some extremes especially droughts, heat waves, cyclones and heavy precipitation events are becoming more frequent annually. Since natural variability is playing a substantial role in individual events, there is a need for a science-based evidence to assess how climate change has affected the strength and likelihood of individual extreme events. In order to find the resilient pathways to mitigate the overburdening impact of extreme events fueled by the impact of climate change there is need for strengthening local co-management plans, involving fishers in data collection and analysis, developing complementary livelihood strategies and addressing the broad socio-economic rights of communities. Participation in community-level vulnerability assessments enhances understanding, builds capacity, generates knowledge for management, and allows communities to identify locally appropriate adaptation strategies for climate change.

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