Chapter 14

Climate Change Impacts on Indian Marine Fisheries and adaptation strategies

P.U. Zacharia, T.M. Najmudeen and Livi Wilson

Demersal Fisheries Division
ICAR -Central Marine Fisheries Research Institute, Kochi

The increase in greenhouse gases (GHGs) in the atmosphere has resulted in warming of climate systems or global warming. Global warming is a long-term rise in the average temperature of the earth's climate system, an aspect of climate change shown by temperature measurements and by multiple effects of the warming. The term commonly refers to the mainly human-caused observed warming since pre-industrial times and its projected continuation, though there were also much earlier periods of global warming. In the modern context the terms are commonly used interchangeably, but *global warming* more specifically relates to worldwide surface temperature increases; while *climate change* is any regional or global statistically identifiable persistent change in the state of climate which lasts for decades or longer, including warming or cooling. Many of the observed warming changes since the 1950s are unprecedented in the instrumental temperature record and in historical and paleoclimate proxy records of climate change over thousands to millions of years.

Global mean surface-temperature change from 1880 to 2017, relative to the 1951–1980 mean. The 1951–1980 mean is 14.19 °C (57.54 °F). The black line is the global annual mean, and the red line is the five-year local regression line. The blue uncertainty bars show a 95% confidence interval. In the latest IPCC report (IPCC, 2014), climate model projections indicated that the global surface temperature during the 21st century is likely to rise a further 0.3 to 1.7°C (0.5 to 3.1°F) for their lowest emissions scenario and 2.6 to 4.8°C (4.7 to 8.6°F) for the highest emissions scenario.

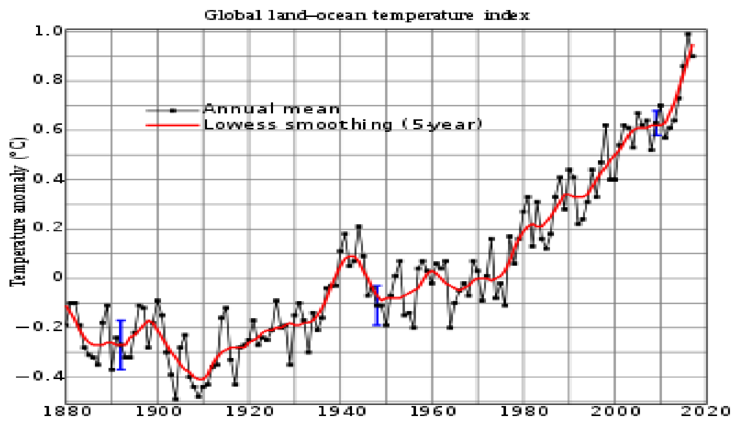

Fig. 1. Global mean surface-temperature change from 1880 to 2017, relative to the 1951–1980 mean.

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The major cause of present global warming has been attributed to anthropogenic contribution to Greenhouse effect expansion through trapping the radiating heat from atmosphere. Water vapour, carbon dioxide, Methane, Nitrous oxide and Chloroflurocarbons (CFCs) are major gases that contribute to greenhouse effect. Release of these gases to atmosphere happens through natural process such as hydrological cycles, volcanic eruptions and decomposition process or through human activities such as burning of fossil fuels, agricultural practices and industrial process.

Intergovernmental Panel on Climate Change (IPCC) through its Fifth Assessment Report emphasis that probability more than 95 % of earth's warming is through human activities during past five decades. However there are a group of scientists who claims that the climate change could be a result of natural solar process change. But the climate models that include solar irradiance could not reproduce the observed temperature trend over the past century or more without including a rise in greenhouse gases.

History of climate change

The history of climate change science began in the early 19th century when ice ages and other natural changes in paleoclimate were first suspected and the natural greenhouse effect first identified. In the late 19th century, scientists first argued that human emissions of greenhouse gases could change the climate. In the 1960s, the warming effect of carbon dioxide gas became increasingly convincing. By the 1990s, greenhouse gases were acknowledged to be deeply involved in most climate changes and human caused emissions were bringing discernible global warming. Since the 1990s, scientific research on climate change has included multiple disciplines and has expanded. Research during this period has been summarized in the Assessment Reports by the Intergovernmental Panel on Climate Change.

Evidences for climate change

IPCC states that scientific evidence for warming of climate system is unequivocal. The heat trapping nature of carbon dioxide and other gases were demonstrated in the mid of 19th century. Antropogenic activities since the mid-20th century have been attributed as cause for global warming and were observed to increase thereafter. Indications for climate change have been derived from data collected through earth-orbiting satellites. Ice cores samples from Greenland, Antartica and tropical mountain glaciers indicate earth's climate response to greenhouse gas concentrations. Paleoclimatic evidences found in tree rings, ocean sediments, coral reefs and layers of sedimentary rocks indicates that current warming is occuring around 10 times faster than average rate of ice age recovery warming (NRC, 2006). NASA is an expert in climate and Earth science. While its role is not to set climate policy or prescribe particular responses or solutions to climate change, its purview does include providing the robust scientific data needed to understand climate change and evaluating the impact of efforts to combat it.

NASA then makes this information available to the global community – the public, policy- and decision-makers and scientific and planning agencies around the world. The compelling evidences for rapid climate change as per NASA are as listed below.

- Global temperature rise since late 19th century
- Ocean warming since 1926

- Sea level rise (8 inches in last century)
- Declining Artic sea ice (extend and thickness over last several decades)
- Shrinking ice sheets (loss around 281 billion tons of ice per year at Greenland and loss around 119 billion tons at Antartica between 1993 and 2016)
- Glacial retreats (Alps, Himalayas, Andes, Rockies, Alaska and Africa)
- Decrease in snow cover (Northern hemisphere in past five decades)
- Extreme events (Increase in high temperature events, decrease in low temperature events since 1950 and increase in intense rainfall events)

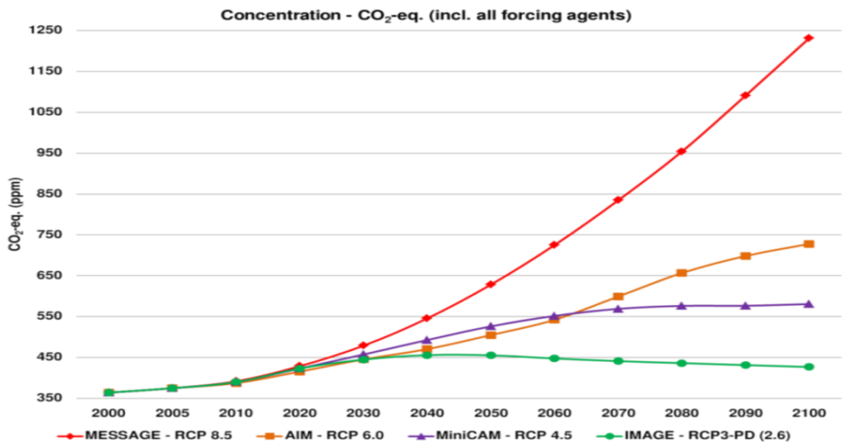

Fig. 2. Future CO_2 projections, including all forcing agents' atmospheric CO2-equivalent concentrations (in parts-per-million-by-volume (ppmv)) according to four RCPs (Representative Concentration Pathways)

The Intergovernmental Panel on Climate Change (IPCC)

IPCC was established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) in 1988 to provide the world with a clear scientific view on the current state of knowledge in climate change and its potential environmental and socio-economic impacts. 195 countries are now Members of the IPCC. IPCC reviews and assesses the most recent scientific, technical and socio-economic information produced worldwide relevant to the understanding of climate change. IPCC also prepares and publishes Special Reports, Methodology Reports, Technical papers and Supporting Material. The Nobel Peace Prize 2007 was awarded jointly to Intergovernmental Panel on Climate Change (IPCC) and Albert Arnold (Al) Gore Jr. "for their efforts to build up and disseminate greater knowledge about man-made climate change and to lay the foundations for the measures that are needed to counteract such change".

Environmental effects of global warming

The environmental effects of global warming are broad and far reaching, including: Arctic sea ice decline, sea level rise, retreat of glaciers: Global warming has led to decades of shrinking and thinning in a warm climate that has put the Arctic sea ice in a precarious position, it is now vulnerable to atmospheric anomalies. Recent projections suggest that Arctic summers could be ice-free (defined as ice extent less than 1 million square km) as early as 2025–2030. The sea level rise since 1993 has been estimated to have been on average 2.6 mm and 2.9 mm per year ± 0.4 mm. Additionally, sea level rise has accelerated from 1995 to 2015. Over the 21st century, the IPCC projects for a high emissions scenario, that global mean sea level could rise by 52–98 cm.

The major environmental consequences of global warming will lead to extreme weather, extreme events and tropical cyclones, ecosystem changes and changes in ocean properties and abrupt climate changes. On the timescale of centuries to millennia, the magnitude of global warming will be determined primarily by anthropogenic CO_2 emissions. This is due to carbon dioxide's very long lifetime in the atmosphere. Climate change could result in global, large-scale changes in natural and social systems. Examples include ocean acidification caused by increased atmospheric concentrations of carbon dioxide, and the long-term melting of ice sheets, which contributes to sea level rise.

Impact of climate change on fisheries

India is one of major fish producing countries in the world contributing over 3% of both marine and freshwater fishes to the world production with third position in capture fisheries. Fisheries and aquaculture play very important role in terms of food supply, food security and employment opportunities in India. The marine fisheries of the country are highly diverse but predominantly comprising small-scale and artisanal fishers. It is estimated that 63% of the marine catch in India originates from the western coast, with the remaining being made up by the eastern coast. The marine fisheries wealth is estimated at an annual harvestable potential of 4.412 million metric tonnes. India's freshwater resources consist of 1, 95,210 km of rivers and canals, along with 2.9 million hectares of minor and major reservoirs, 2.4 million hectares of ponds and lakes and 0.8 million hectares of flood plains and derelict water bodies. Inland fisheries contribute 13% to the total fish production of the country (FAO. 2016). Fishing is an industry of great cultural and economic significance in India, and historically, one of the fastest growing industrial sectors as well. Production of fish has increased eleven fold since independence, with total production growing from 0.75 million tonnes to 9.6 million tonnes. Indian seafood exports reached an all-time high to the tune of 10, 51,243 metric tonnes and 5.52 billion USD in 2014-15. Marine product exports, crossed all previous records in quantity, rupee value and US$ terms.

Climate change will intensify by 2050 and though climate outcomes cannot be precisely predicted, the probability towards greater impacts of climate challenge is becoming clearer. Climate change is one of the most important global environmental challenges with implications on food production including fisheries and aquaculture sector, natural ecosystems, freshwater supply, health, etc. Climatic scenarios generated by computer models shows that India could experience warmer and wetter conditions as a result of climate change including an increase in the frequency and intensity of heavy rains and extreme weather events (EWEs). The effects of climate change in aquatic ecosystems can be direct, through rise in sea surface temperature (SST), and associated changes in the phenology of the organisms, or indirect *i.e*., through ocean acidification, through shifts in hydrodynamics and rise in sea level.

Sea Surface Temperature (SST) is likely the single most important factor in among the environmental variables affecting the growth and development of aquatic organisms. The rate of change in SST over Indian Seas revealed that west coast has more impact than in the east coast of India. Northern Indian Ocean has been identified as one of the 17 climate change hotspots among world oceans. These areas will warm faster than 90% of the world oceans. Long-term climate change is likely to impact the marine environment and its capacity to sustain fish stocks and exacerbate stress on marine fish stocks.

The ongoing reduction in the pH of the Earth’s oceans presents a significant challenge to the survival of marine fish. Seawater, by absorbing carbon dioxide and forming carbonic acid, is slowly dropping in pH from its natural, slightly basic state towards pH neutral conditions. Studies indicated an increasing trend in the annual number of instances when pH of surface waters off Kochi was less than 6. armer water temperatures can result in coral bleaching that resulting in the expulsion of the symbiotic zooxanthellae from the tissues of coral. Between 1979 and 1990, sixty major episodes of coral bleaching were recorded, and in 2016 the longest coral bleaching event on record was observed. Several studies relate bleaching events with global warming and climate change during the last few decades (Lix *et al*., 2016),

Sea level rise at long time scales is mainly due to thermal expansion and exchange of water between the other reservoirs (glaciers, ice caps, etc.) including through anthropogenic change in land hydrology and the atmosphere. Sea-level rise estimates for the Indian coast are between 1.06–1.75 mm per year, with a regional average of 1.29 mm per year, when corrected for GIA using model data (Unnikrishnan and Shankar, 2007). Changes in average precipitation, potential increase in seasonal and annual variability and extremes are likely to be the most significant drivers of climate change in aquatic systems. Variations in annual rainfall intensity, dry season rainfall and the resulting growing season length are likely to create impact on shrimp/ fish farming and could lead to conflict with other agricultural, industrial and domestic users in water scarce areas.

Impact on fish stock

Climate change will result in changes in distributions, recruitment and abundance of fish stocks. Changes in timing of life history events are expected with climate change. Species with short-life span and rapid turnover of generations such as plankton and small pelagic fishes are most likely to experience such changes. Changes in abundance will alter the species composition and result in changes in the structure and functions of the ecosystems. Many tropical fish stocks are already exposed to high extremes of temperature tolerance and shifts in spawning periods of fishes have already been observed in a number of commercially important fish stocks, such as threadfin bream (Zacharia *et al*., 2016).Changes in distribution patterns of two key species in Indian fisheries have already been established – migration patterns of the Indian oil sardine and Indian mackerel have changed greatly over the past 50 years (Vivekanandan *et al*., 2009). Changes in sea surface temperature due to global warming could result in changes in the seasonal distribution of certain species, and ultimately disruption in their harvest, which is usually based on indigenous knowledge (Zacharia *et al*., 2016).

Impact on aquaculture

Rapidly depleting fish stocks necessitate aquaculture as an invaluable component of the world's agricultural output, especially if sustainable consumption is to be attained. As the farmed fish species are poikilothermic, any increase or decrease of the temperature of the associated habitats of these stock animals would significantly influence metabolism and growth, and hence, output and income. Increased water temperature would increase the production of mariculture. However, these benefits will likely be superseded by adverse effects of growth at higher temperatures. At higher temperatures significant defects in growth were observed, particularly in the musculoskeletal system and internal abnormalities including bile duct hyperplasia and acute tubular necrosis. Rising temperatures will also ultimately limit the spectrum of species that can be successfully cultured.

Climate change adaptations and mitigations options for coastal fisheries and aquaculture in India

Climate change adaptation is another policy response. The adaptation may be planned, either in reaction to or anticipation of global warming, or spontaneous, i.e., without government intervention. Planned adaptation is already occurring on a limited basis. The barriers, limits, and costs of future adaptation are not fully understood. Mitigation of climate change refers to actions taken to reduce greenhouse gas emissions, or enhance the capacity of carbon sinks to absorb greenhouse gases from the atmosphere. There is a large potential for future reductions in emissions by a combination of activities, including energy conservation and increased energy efficiency; the use of low-carbon energy technologies, such as renewable energy, nuclear energy, and carbon capture and storage. Resilience options and management plans are envisaged to cope up with the implications of climate change on fresh, cold-water, brackish, inland and marine systems, as well as the resilience of infrastructure that allow stakeholders to utilize these systems. The adaptation plans targeted a multifaceted action plan, which would compose several key elements – targeted scientific, a robust coastal ecosystem, community and industry cooperation and climate sensitive technologies with reduced carbon footprints. The following are the key adaptation strategies envisionised to reduce the impact of climate change along the Indian coast.

Resilience of fish habitat

Habitat mapping and modeling: Regional or zone wise mapping and spatial representation of Indian aquatic habitat and its linkage with eco-system services is identified as a prospective adaptation option. Habitat mapping could be extended specifically for commercial as well as vulnerable species for better conservation, management and sustainable utilization of aquatic resources.. Habitat mapping coupled with regional models and continuous monitoring of habitat change provides better adaptation and management of fisheries habitat.

Mangrove mapping, conservation and restoration: India accounts for nearly 3 % of world's mangrove vegetation and carbon sequestration potential of mangroves and their sediments makes more significant in the context of climate change. Mangrove ecosystem provides a significant habitat for several aquatic species and act as breeding ground and nursery of valuable biota. Mangroves ecosystem mapping, conservation and restoration is identified as an adaptation option to enhance coastal resilience. Ecosystem productivity could be increased by improving the habitat resulting in beneficial implications on coastal fisheries.

Resilience of fish stocks

Stock modeling: To enhance the resiliency of stocks and their ability to recover from population collapses stock modeling could be done. Several research institutions are capable of carrying this out.

Vulnerability assessment along Indian coastal zones and conservation: Scientific criteria developed by CMFRI for long term vulnerability assessment of Indian marine fishes could be used to assess the species level adaptability to climate change. Species identified as highly vulnerable could be prioritized for conservation and management strategies. Conservation and fishing protocols based on species stock vulnerability could also be developed so as to enhance the sustainability.

Monitoring, Control and Surveillance (MCS): India has effective Monitoring, Control and Surveillance (MCS) mechanism in the EEZ for sustainable usage of oceanic resources. Highly vulnerable stocks identified after scientific analysis could also be brought under MCS for better conservation and adaptation for an optimum period.

Fish stock availability

Potential fishing zone could be identified for reducing scouting time and increasing fishing profitability. Activities at fishing zones could be monitored for sustainable exploitation of fisheries resources. Fish catch forecast models could be developed for Indian coast, so as to enable the fishermen folks and stakeholders to cope up with the stock shift. New technologies and fishing methods developed could be implemented in the context of climate change and stock availability. Fishermen folks, self-help groups and other stakeholders could be trained and empowered to augment marine fish production. Regulation of fishing (fleet size, mesh size, spatiotemporal closure) could be ensured for sustainable fisheries stock utilization.

Sustainable fish harvesting

Implementation of Minimum Legal Size: Catch is of serious concern in the harvesting sector which could be directly attributed to climate change and stock distribution. However, this increases the fishing pressure on vulnerable populations. Hence to bring about sustainability, minimum legal size could be implemented to reduce growth overfishing there by to reduce excess pressure on the stocks.

Green fishing protocols for carbon foot print reduction: Alternative energy usage in fishing operations could be considered. However owing to the direct contribution of fisheries sector directly to food and nutritional security to millions of populations, implementation of shift in operational techniques to reduce the C footprint need to be done only after caution.

Adaptation on coastal aquaculture

Identification of climate resilient species suitable for mariculture: After experiments on impacts of climatic parameters, stress tolerant species (Silver pompano, Cobia, etc) were identified along with development of technologies for its culture. As climate change had affected wild species distribution and catch, focus on mariculture is an adaptive option and accordingly identification of stress tolerant species is significant. Zone wise commercially valuable stress tolerant species could be identified and cultured for better adaptation.

Adaptations to integrated farming technologies: Integrated Multi Trophic Aquaculture with farming fish with seaweed and mussel was demonstrated as a successful adaptation measure. Integrated cultivation doubled the weight of seaweed yield and also enhances the fishermen income through co-farming yields as well. Paddy-fish integrated farming was successfully implemented as an adaptive measure across several states of the nation. Successful demonstration of integrated farming of paddy (pokkali) with finfishes (mullet and pearlspot) in Kerala resulted in profitability.

Regional wetland restoration and implementing scientific fish farming: Wetland restoration along with incorporation of scientific fish farming at village level was identified as a prospective climate resilient strategy. In India 5,55,557 small wetlands were detected and mapped as point features (Panigrahy Sushma et. al, 2012) Developing wetlands of size below 2 ha for fish farming could enhance the regional resilience along with village level food and nutritional security and the surplus production could be channelized to global supply chain.

Seaweed farming along Indian coasts: Seaweed farming is identified as a prospective climate resilient strategy. Large scale seaweed cultivation along Indian coastal waters aimed at carbon sequestration, reducing ocean acidification, coastal pollution abatement, co-farming of mussels, oysters and fishes, marine product development, coastal livelihood supplementation and fish feed formulation could enhance the adaptability level of coastal aquaculture.

Development of climate resilient products: Development of climate resilient products from mariculture residues is another adaptive measure. Biochar with C sequestration ability could be further utilized for aquaculture treatment applications. Biofuel production from micro and macro algae is also a significant climate resilient strategy upon which India is focusing.

Adaptation on fishing communities

Climate change preparedness of vulnerable coastal populations: The major Climate Preparedness activities (CPAs) recommended are as Increase awareness, preparedness and adaptation among fishers on climate change related threats to the livelihood through suitable scientific interactions and trainings, Strengthen supplementary avocations available across the different fishing villages to negate the risks and uncertainties of climate change, Scientifically develop location specific elevation levels for new settlement areas for coastal erosion adaptation, Train on disaster management and evacuation plans.

Strengthen basic amenities in coastal villages: As extreme climate events negatively impacts on basic needs of coastal population, alternative facilities need to be developed for easy access to food, potable water, sanitation, shelters, etc. Local infrastructure (roads, health supports, etc) could be developed for reducing climate change vulnerability. Since fishermen are forced to move out to deeper areas, protection aids must be made available even for traditional /artisanal fishers. Strengthen seawalls and bioshields (coastal forestry). Regulate unplanned coastal activities which would affect tidal amplitudes in village canals/ riparian areas.

Increase disaster preparedness: India had established early warning system and also has a very good natural disaster management system to deal with extreme climatic events Successful disaster management plans of the nation could be implemented at each coastal village to cope with even moderate climate change events. Installations of automatic weather stations and similar facilities along with awareness at village level shall enable better weather forecasting and climate change adaptations.

Development and familiarization of E-commerce technologies for fishermen communities: Though E Commerce solutions for fish products are available, gap still exists to develop multivendor platform for directly engaging various self-help groups of fishermen communities as multiple vendors. We are ambitiously working out on the concept to develop such a system for fishermen community livelihood improvement and empowerment. Such systems could be in line with the national goal of farmer income increment. The system could fetch better income as well as better marketing for the engaged fishermen communities.

Interventions towards climate resilience through NICRA Project of ICAR-CMFRI

ICAR sponsored national level network project to bring out best climate resilient agriculture practices and strategies in each related sectors and ICAR-CMFRI has been entrusted with marine fisheries sector. The climate change research task was undertaken across the total operating centres. The project could bring several major outputs and outcomes. The project enabled the formulation of scientific criteria to assess the vulnerability of marine species of the nation, which is first of its kind and pave ways for future research in this direction. Several climate resilient products development research could also be accelerated through the project. Biofuel and biochar production from aquatic vegetation such as Seaweeds and Water Hyacinth has been attained, which paves way towards exploration of new horizons of climate resilience in marine fisheries sector. Beneficial effects of biochar in fish and paddy growth could also be established through the project.

Conclusion

Climatic resilience of the marine sector could be attained and the adaptation and mitigation options explored are feasible for time bound implementation. However, more research support could bring these strategies to village level. Climate smart coastal villages could directly contribute towards food and nutritional security of millions and the research interventions in this direction could bring significant improvements. Technology development and empowerment of fishing communities could bring significant changes in the livelihoods as well as national contributions of fisheries sector. E-commerce solution being developed through the project, provides opportunities for the involvement of SHGs of fishermen communities, which could result in the attainment of national goal of farmer income improvement/ doubling. Integrated farming methods are more economically feasible and policies need to be accordingly framed to undertake aquaculture, agriculture and farm tourism as a comprehensive package rather than depending on single sector.