ISSN 2321–340X

Journal of Aquatic Biology & Fisheries | Vol. 5 | 2017 | pp. 7-17

CLIMATE CHANGE, FISHERIES AND COASTAL ECOSYSTEMS IN INDIA

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Abstract: India, with an extensive coastal line of 7,500 km and an Exclusive Economic Zone of 2.02 million sq km harbours rich diversity of coastal and marine biodiversity. The aquatic resources biodiverse coastal and marine habitats provide significant contributions to food and nutritional security and economic and social development of the country. Main evidences for climate change in coastal and marine habitats of India include sea level change, increased exposure to natural calamities, increase in ocean temperature, ocean acidification and impacts on fisheries and biodiversity. The major adaptive strategies evolved centers around providing awareness to the coastal population, training on alternate livelihoods in order to negate the risks and ill effects of climate change, and vulnerability assessment at micro levels. There is also a need for flood mapping, flood forecasting, development of hydrological framework and downscaled climate change projection modelling coupled with strengthening coastal protection methods with the participation of local communities. These adaptation methods would become effective only through mainstreaming biodiversity into climate change strategies and by integrating climate change risk in the state level disaster management policies.

Keywords: Climate change, Ocean acidification, Resident time, Sea Surface Temperature, Adaptation, Mitigation

INTRODUCTION

Surrounded by the Indian Ocean, the Arabian Sea and the Bay of Bengal, India has a coastline of above 7,500 km, spanning nine maritime mainland States and two Union Territories (UTs). The Exclusive Economic Zone (EEZ) extends to 2.02 million sq km and the continental shelf area to 0.18 million sq km. The Indian coasts support about 20 per cent of the total 1.2 billion human population. Indian coastal ecosystems are represented primarily by mud flats, sandy beaches, estuaries, creeks, mangroves, coral reefs, marshes, lagoons, seagrass beds, and sandy and rocky beaches extend to 42,808 sq km. These ecosystems are highly productive and provide significant contributions to food and nutritional security and economic and social development from fisheries and aquaculture, marine and coastal tourism, shipping, mining, energy, and ecosystem services such as carbon sequestration, water filtration, atmospheric and temperature regulation, protection from erosion and extreme weather events. However, these systems are increasingly under pressure due to unsustainable development practices, destruction of habitats, pollution, over exploitation of resources, presence of invasive alien species and climate change. The fisheries sector are vital providing employment to over 6 million people and accounts for 1.07% of India's total GDP. Marine fish landings in India is 3.63 million tonnes during the year 2016, it contributes to over 30,000 crores of Indian rupees towards export earnings of the country annually (FRAD, CMFRI, 2017).

Coastal systems are particularly sensitive to three key drivers related to climate change: sea level, ocean temperature and ocean acidity. While the impacts of sea level changes can be revealed only though long-time data analysis and modelling, short term changes in distribution and abundance of species in the coastal water can be easily quantified by precise scientific investigations. On the other hand, for many other coastal changes, the impacts of climate change are difficult to comprehend as other anthropogenic interventions such as land-use change, coastal development and pollution are much effervescent in these areas. The projected implications of climate change on coastal and marine ecosystems (IPCC, 2013) may vary considerably at the local scale and therefore demanding regional assessments.

In the recent past the concept of blue economy is gaining more visibility and importance within the framework of the post-2015 Sustainable Development Goals (SDGs), in particular, Goal 2 (end hunger, achieve food security and improved nutrition, and promote sustainable agriculture) and Goal 14 (conserve and sustainably use the oceans, seas and marine resources for sustainable development). Healthy marine and coastal ecosystems provide many valuable services - from food security, resources for economic growth and recreation alongside tourism and coastline protection. They are also recognized as crucial reservoirs of biodiversity at a time when the loss of species on both land and in the sea is an increasing cause for concern. Moreover, in states like Kerala, the health of the coastal and marine ecosystems are intricately related to the health of other ecosystems such as forests, rivers, backwaters, estuaries and mangroves.

The population and assets exposed to coastal risks as well as human pressures on coastal ecosystems will increase significantly in the coming decades due to population growth, economic development and urbanization (IPCC, 2013). Therefore, adaption and mitigation strategies specially oriented towards coastal zones of the State, with more proactive responses based on technological, policy related, financial and institutional support is mandatory, taking into account national strategies and action plans.

The economy of developing countries depends primarily upon climate sensitive sectors such as agriculture, fisheries and forestry, and therefore a holistic analysis of climate vagaries and its implications on economy is highly warranted in order to achieve sustainable development. The impacts of climate change on critical ecosystems and livelihood activities and on critical biological resources, especially those which are vulnerable due to other prevailing anthropogenic interventions, are discussed in this paper, especially in the context of India.

IMPACTS

In India the ecological problems of the coastal zone are unique due to the high density of population, loss of land due to coastal erosion, mining of beach sand for industrial purposes, drastic morphological and shoreline changes due to shore structures like harbour breakwaters, destruction and reclamation of wetland including mangroves, saline intrusion into the water table, decreasing fish catch, development related degradation of the environment and violation of the provisions of Coastal Regulation Zone (CRZ). The existing issues will be further exacerbated in the scenario of climate change driven pressures.

Shore line and coastal wetlands

The potential impacts of climate change are reflected on shorelines, estuaries, coastal wetlands and ecosystems bordering ocean, and the impacts in Indian coast may be due to several key drivers including increase in sea level change, alterations in precipitation patterns and subsequent delivery of freshwater, nutrients, and sediment, increased sea surface temperature, increase in ocean acidity alterations in circulation patterns and increased levels of atmospheric carbon dioxide. Estuarine productivity could change in response to alteration in the timing and amount of freshwater, nutrients, and sediment delivery. The coastal areas, especially the low lying areas such as Kuttanad in Kerala state, may experience adverse impacts such as submergence, coastal flooding and coastal erosion due to relative sea level rise. This will further impact the water security and food production in the coastal habitats. The highly productive ecosystems along Indian coast, including mangroves and sea weed ecosystems would also be impacted by the climate change.

The sea level rise recorded in Indian seas during 1970-2010 was more than 8cm (Unnikrishnan and Shankar, 2007) and the projection for 2050 and 2100 are more than 20 to 40 and 50 to 70 cm respectively. Under the influence of climate change, beaches, sand dunes and cliffs currently eroding will continue to do so under increasing sea level. The human settlements (especially those of the fisher folks), transportation and tourism infrastructure at or near the coast is vulnerable to more frequent flooding, rising sea levels and possible increase in the magnitude and frequency of tropical storms and other natural calamities due to climate change. Main threats could be salinity ingress in water bodies and inundation of low lying areas, with resultant loss of fertile agricultural lands in coastal areas. However, aquatic biodiversity like fisheries resources may provide opportunity for adaptive livelihood measures for food security in the coastal areas.

Some marine ecosystems, such as mangroves, salt marshes and seaweed ecosystems, beyond having high biodiversity values and providing breeding grounds and nurseries for fisheries, can also play a key role in mitigating global climate change through their ability to store carbon. These blue carbon ecosystems are being degraded at a very high level in Kerala state and the current stretch of mangrove forests in India is only 663.09 ha (Anon., 2012) as against 70,000 ha reported by Blasco (1975) in earlier period, and climate change- related changes would seriously hamper their sustainability. Climate change assessment report documents that sea level rise along the Indian coast would submerge the mangroves as well as increase the salinity of the wetland and this would favour mangrove plants that tolerate higher salinity (Anon., 2010).

Analysing the data on Sea Surface Temperature (SST) obtained from International Comprehensive Ocean – Atmosphere Data Set (ICOADS) (www.cdc.noaa.gov) and 9-km resolution monthly SST obtained from Advanced Very High Resolution Radiometers (AVHRR) satellite data (provided by the NOAA/NASA at http://podaac.jpl.nasa.gov/), it has been found that the SST increased in the Indian seas, by 0.2°C along the northwest (NW), southwest (SW) and northeast (NE) coasts, and by 0.3°C along the southeast (SE) coast during the 45 year period from 1961 to 2005 (Vivekanandan, 2013). Global surface temperature change for the end of the current century is likely to exceed 1.5°C- 2°C for various scenarios (IPCC, 2013). The SST showed peaks at an interval of about ten years (1969-70, 1980, 1987-88, 1997-98) during 1961- 2005, and the decadal number of SST anomalous (+ 1 or – 1 deviation from the 45-year mean) months increased. Off Kerala, for example, only 16% of the months were SST anomalous during 1961-1970, but 44% during 2001-2005 (Vivekanandan *et al.*, 2009), while the predictions for 2050 consider it as more than 1.5°C and for 2100 as 2.0-2.5°C.

Coastal freshwater wetlands may be vulnerable to saltwater intrusion with rising sea-levels, but in most river deltas local subsidence for non-climatic reasons will be more important (Syvitski *et al.*, 2009). Humans have been the primary drivers of changes in coastal aquifers, lagoons, estuaries, deltas and wetlands and are expected to further exacerbate human pressures on coastal ecosystems resulting from excess nutrient input, changes in run-off and reduced sediment delivery (IPCC, 2013). A large portion of the population along the coastline is dependent on climate-dependent activities such as fisheries and agriculture. In Kuttanad region of Kerala the farmers have been practicing below sea level farming for several decades, using salt-resistant strains of paddy. However, frequent exposure to flooding may lead to ecological changes in the agricultural fields.

The impact of the rising sea levels would be variable depending upon the characteristics of the coast such as geomorphology and slope and the variability of marine processes such as waves and tides along the coast. Mapping of coastal landforms, slopes, and the recent changes that occur, therefore assumes greater significance in understanding the coastal response to sea-level rise (Anonymous, 2012). Although these potential impacts of climate change and variability will vary from region to region, in-depth studies are needed to surmise the potential impacts on coastal and marine ecosystems of Kerala.

Ocean Acidification

Ocean acidification is the ongoing decrease in the pH of the Earth's oceans, caused by their uptake of anthropogenic carbon dioxide from the atmosphere and it is expected to have negative impacts on other calcified marine organisms such as dinoflagellates, corals, molluscs and larval echinoderms, while impacts on non-calcified species are unclear (Branch, *et al.*, 2013). On the other hand on rocky shores, warming and acidification are expected to lead to range shifts and changes in biodiversity but beaches may erode and coastal ecosystems such as mangroves will decline, unless they receive sufficient fresh sediment to keep pace or they can move inland (Kintisch, 2013).

Coral reefs are the most diverse, biologically complex and economically important marine ecosystems on earth. The reef building scleractinian corals are currently facing multiple stresses caused by shifts in the marine environment associated with global warming, ocean acidification, sedimentation, pollution and eutrophication. Coral reefs in the Indian Ocean have experienced rapid and large-scale changes, which likely began in the early 1980s due to strong temperature anomalies, and the 1997–1998 El Niño Southern Oscillation (ENSO) event, which elevated SSTs of tropical oceans by more than 3°C, triggered massive coral bleaching in the east and west coast of India and in Lakshadweep (Arthur, 2000). By using the relationship between past temperatures and bleaching events, and the predicted SST for another 100 years, Vivekanandan *et al.* (2009) predicted that reefs should soon start to decline in terms of coral cover and appearance. Southwest coast of India, which is not a coral reef habitat, harbours about 13 species of scleractinians (Jasmine *et al.*, 2009) and therefore detailed monitoring is required even for such habitats.

Fisheries

Fisheries play an important role in food supply, food security and livelihood security of thousands of fishermen and associated fish supply chains living in coastal areas. The impacts of climate change on coastal and marine ecosystems are summarized in Fig. 1.

Temperature is known to affect fish distribution and migration; the combined effects of changes in distribution, abundance and physiology may reduce the body size of marine fishes, particularly in the tropics and intermediate latitudes (Cheung *et al.*, 2013). Growth rate of fish increases with increasing temperature within the optimal temperature window. It is likely that the food utilization parameters may be operating at an elevated level in fishes at higher temperatures, demanding higher food supply to attain faster growth rate. Fishes may change their phenology of reproductive activity to adapt to elevated temperatures for spawning and larval survival. At population level, temperature and other factors related to climate change may strongly influence

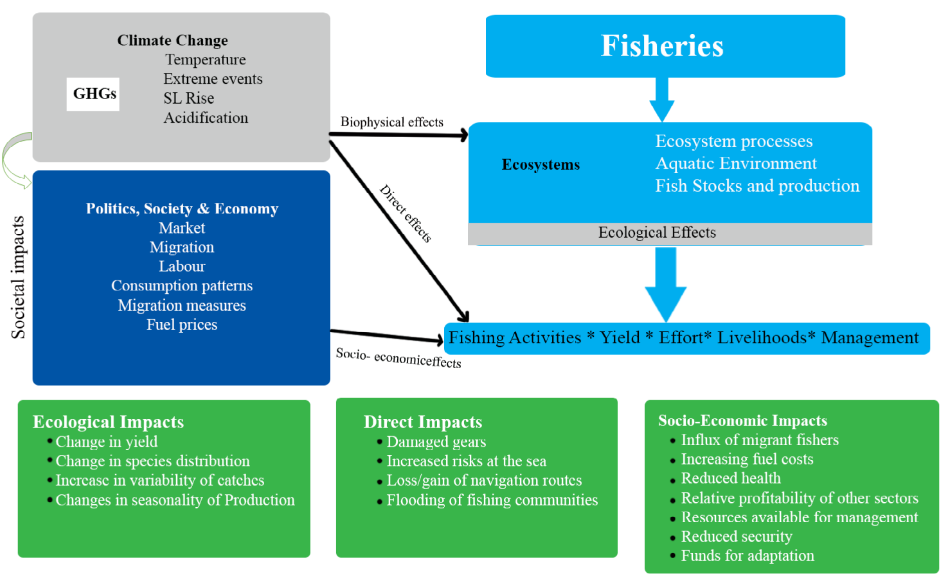

Fig. 1. Impacts of climate change in marine fisheries

distribution and abundance, evidences for which are accumulating in Indian seas; extension of distributional boundary of small pelagics, extension of depth of occurrence, and phenological changes were recorded from Indian waters (Vivekanandan, 2013).

The major pelagic species that represent major portion of marine fish landings in India are the oil sardine *Sardinella longiceps* and the Indian mackerel (*Rastrelliger kanagurta*). The oil sardine is restricted in distribution between latitude 8°N and 14°N and longitude 75°E and 77°E (Malabar upwelling zone along the southwest coast of India) where the annual average sea surface temperature ranges from 27 to 29oC. While almost the entire catch of oil sardine was from the Malabar upwelling zone till 1985, their landings from latitude 14°N - 20°N are consistently increasing in the last few decades (Vivekanandan *et al.*, 2009). The surface waters of the Indian seas are warming by 0.04°C per decade, and the warmer tongue (27-28.5°C) of the surface waters is expanding to latitudes north of 14°N, enabling the oil sardine to extend their distributional range to northern latitudes (Anon., 2010). The studies done by the Central Marine Fisheries Research Institute (CMFRI) showed that elevated SST, favourable wind (and perhaps current) and increasing CUI have induced higher chlorophyll-a concentration during southwest monsoon, which has resulted in increasing the recruitment and catches of oil sardine during post southwest monsoon season along the Kerala coast (Vivekanandan *et al.*, 2009). Prasannakumar e*t al.* (2009) recorded increase in phytoplankton biomass and oil sardine in the last two decades in the Arabian Sea.

The Indian mackerel commonly found in the Indian and West Pacific Oceans, and their surrounding seas; in India they are abundantly found along the southwest coast. Recent reports indicate that this fish, in addition to extension of northern boundaries, are found to descend to deeper waters in the last few decades. The mackerel populations normally occupying surface and sub-surface waters, have now started moving down the water column and are often caught in large numbers in bottom trawl nets operated by large mechanised boats at about 50 to 100 m depth (Vivekanandan *et al.*, 2009).

According to Mohamed *et al.* (2013) the increase in catch of puffer fish *Lagacephalus inermis* biomass along Kerala coast in the recent decades may be related to the decline of predators. The examples recorded from Kerala coast shows that differential physiological effects of temperature on individual species are key to understanding and projecting climate-induced changes in species interactions and in community composition (Portner and Farrell, 2008). Further, habitat destruction, pollution, energy production, mining, and aquaculture are all affecting marine ecosystems and may exacerbate the effects of climate change.

Marine turtles

Marine turtles occupy a wide range of marine habitats and many aspects of their life history have been demonstrated to be closely tied to climatic variables such as ambient temperature and storminess and therefore could be used as indicators of climate change. Out of the four species of sea turtles that are recorded from Kerala coast, the olive ridley turtle (*Lepidochelys olivacea*) is the most common species and many of their nesting beaches are in bad shape due to coastal erosion and other anthropogenic activities. Interestingly the eggs of these turtles incubated at temperatures of 31 to 32°C will produce only females; eggs incubated at 28°C or less will produce solely males; and incubation temperatures of 29 to 30°C will produce a mixed sex clutch (Carl *et al.*, 1994). As the hatching success also varies by beach and year, due to changing environmental conditions the impact of climate change on the nesting and hatching of olive ridley turtles remains to be documented.

Jellyfish

Jelly fishes are cnidarian animals that form a major element of marine biodiversity and play a key role in the food web of marine ecosystems. The jellyfish blooms or the unprecedented increase in the population of jellyfish, recorded more frequently in the last decade, can result direct negative effects on human enterprise; specifically, they interfere with tourism by stinging swimmers, fishing by clogging nets, aquaculture by killing fish in cages and power plants by clogging cooling-water intake screens. They also have indirect effects on fisheries by feeding on zooplankton and ichthyoplankton, and, therefore, are predators and potential competitors of fish. Ironically, many human activities and the resultant environmental perturbations such as eutrophication, over fishing (especially removal of predators), climate change and creation of more artificial structures in the coastal waters (which provide more substratum for the jellyfish larvae to settle and multiply) may contribute to increases in jellyfish populations in coastal waters. Recent concerns that jellyfish populations are increasing have stimulated speculation about possible causes including climate change, eutrophication, over fishing and invasions. From Indian waters there are scanty reports on jellyfish population and in either role in coastal ecosystem or consequential increase in heavily exploited regime, while a significant decrease in mean trophic index of the landed fish species has been reported. Biju Kumar (2012) recorded jellyfish blooms along Kerala coast, mass mortalities of jellyfish and their deposition in beaches and the impact of blooming on fishing operations. However, the factors (including climate change) that trigger jellyfish blooms remain to be investigated. The recent incidences of jellyfish blooms resulted in the loss of many fishing days along Kerala coast as the trawl nets are clogged with jelly fish (Fig. 2) (Biju Kumar and Riyas, Unpublished data)

Eutrophication

Eutrophication of coastal marine waters is globally considered to be a serious environmental problem and changes in run-off and river flows explain major of the variability in land-sea fluxes of nutrients. Human activities, especially increased nutrient loads that set in motion a cascading chain of events related to eutrophication, accelerate development of hypoxia (lower oxygen concentration) in many areas of the world's coastal ocean. As a result, the symptoms of eutrophication, such as noxious and harmful algal blooms, reduced water quality, loss of habitat and natural resources, and severity of hypoxia and its extent in estuaries and coastal waters will increase. Global climate changes will likely result in higher water temperatures, stronger stratification, and increased inflows of freshwater and nutrients to coastal waters in many areas of the globe (Rabalais *et al.*, 2009). Occurrence, increase in frequency, intensity and spatial coverage of harmful algal blooms during the past decade in the EEZ of India indicated a sharp increase, with the frequent contribution of toxic species such as *Alexandrium* spp., *Gymnodinium* spp., *Dinophysis* spp., *Coolia monotis*, *Prorocentrum lima* and *Pseudonitzschia* spp. (Padmakumar *et al.*, 2012). The frequency of occurrence of algal blooms in Kerala coast was found to be more during September to October period and blooms of the dinoflagellate *Noctiluca scintillans* (Fig. 3) is more frequent along the coast.

Fig. 2. Trawl nets operated along Kollam coast of Kerala clogged with jellyfish *Crambionella orsini*

Fig. 3. Blooms of *Noctiluca scintillans* along Kerala coast (Blooms in red colour or in lighter shade).

ADAPTATION AND MITIGATION

Climate change involves complex interactions between climatic, environmental, economic, political, institutional, social, and technological processes. It cannot be addressed or comprehended in isolation of broader societal goals (such as equity or sustainable development), or other existing or probable future sources of stress.

Climate adaptation refers the terms "adaptation" and "mitigation" are two important terms that are fundamental in the climate change debate. The IPCC defined adaptation as adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderate harm or exploits beneficial opportunities. Adaptation is also defined as an understanding of how individuals, groups and natural systems can prepare for and respond to changes in climate or their environment and is crucial to reducing vulnerability to climate change.

'Mitigation', in the context of climate change, is a human intervention to reduce the sources or enhance the sinks of greenhouse gases (GHGs). Because mitigation is intended to reduce the harmful effects of climate change, it is part of a broader policy framework that also includes adaptation to climate impacts. In short, while mitigation tackles the causes of climate change, adaptation tackles the effects of the phenomenon. The potential to adjust in order to minimize negative impact and maximize any benefits from changes in climate is known as adaptive capacity. A successful adaptation can reduce vulnerability by building on and strengthening existing coping strategies.

In the coastal front, awareness of the fisher folk to climate change is low and they are not adapted for the changes in the environment. Of late the unpredictability in weather patterns coupled with decline in resources put the traditional fishermen in chaos. There is a need to involve the coastal communities in disaster preparedness, planning and mitigation process. Further, they should also be given training in alternate livelihoods in order to negate the risks and ill effects of climate change. Some of the key priorities for the state are discussed below.

First of all the bottleneck for any successful adaptation and mitigation strategy is the absence of baseline timescale data on the status and dynamics of coastal ecosystems. Microlevel studies are required to develop models to assess and predict the impact of climate change in various coastal ecosystems and to assess erosion prone areas in the coast with the Digital Elevation model. Further, vulnerability assessment should also be done at microlevels. There is also a need for flood mapping, flood forecasting, developing hydrological framework and downscaled climate change projections modeling.

At present the local communities in Kerala coast are least adapted for facing the climate vagaries. Considering the fact that the coastal zone is the population dense area in the state, with lot of developmental activities in progress, there is an urgent need for strengthening coastal protection methods with the participation of local communities, especially by promoting coastal bioshields wherever ecologically feasible. Further, a techno-legal regime for construction of disaster resilient housing and public infrastructure and construction of multipurpose flood shelters in the coastal areas are required in vulnerable areas, besides improving measures for flash flood management.

The adaptation methods would become effective only through integrating climate change risk in the state's disaster management policy. There is also a need for setting up an integrated training and capacity building protocol. Energy audit should be done to identify how to reduce the use of fuel for routine fishing operations, followed by energy efficiency programmes to implement these savings.

It is also imperative to study the impact of global warming on the biodiversity of coastal and marine ecosystems with special emphasis on flagship species that sustain the economy. Further, there is also a need to assess the impact of climate change on inland and coastal aquaculture, and the spread of the invasive species in the context of changing thermal regimes in water bodies. Infrastructure facilities should also be created for the developing an early warning systems in coastal areas for the fishermen to face natural calamities.

Ecosystem restoration is another area where original research is at its infancy in India. In Kerala scenario restoration of mangrove ecosystems is one of the priority areas to be considered for sustainable management. Coastal wetland restoration and sustainable management is yet another priority for both biodiversity conservation and for ensuring ecosystem services.

The United Nation's Food and Agriculture Organization (FAO) formally declared the Kuttanad below sea-level farming system as Globally Important Agricultural Heritage Systems (GIAHS) and the farmers of Kuttanad have developed and mastered the spectacular technique of below sea-level cultivation over 150 year ago. They made this system unique as it contributes remarkably well to the conservation of biodiversity and ecosystem services, including several livelihood services for local communities (Swaminathan, 2013). The global focus on the Kuttanad unique system of farming will be reinforced by the setting up of proposed international-level institute for below sea-level farming in Kuttanad. The traditional method of integrated farming system practiced in Kuttanad, with salt and flood tolerant rice varieties at below sea level would serve as a model to plan adaptation strategies elsewhere.

Integrated coastal area development programme covers activities of improvement of socio-economic conditions of fisherfolks in coastal areas. Adaptation measures for the communities reliant on fisheries for food and income should also consider options such as education, entrepreneurial training, and training in tourism and aquaculture to prevent potential deterioration of social conditions in fisher communities associated with climate change. Value-adding to current catches and improved market access through eco-certification and other mechanisms should also support fisheries adaptation. The fish processing sector in Kerala is managed predominantly by the women workforce and the efficiency and productivity are likely to be improved by ensuring that the rights and responsibilities of women are recognized in their employment conditions and their sustainable income is ensured.

In the marine fisheries sector there is a need to develop a database on the impact of climate change and marine fisheries. Projections should be made on the biodiversity changes in marine ecosystem under the influence of climate change through appropriate modelling studies. Capture fisheries also faces multiple pressures as a result of overfishing, habitat modification and pollution. To build resilience to the effects of climate change and derive sustainable benefits, fisheries and aquaculture managers needs to adopt and adhere to best practices such as those described in the FAO Code of Conduct for Responsible Fisheries. These practices need to be integrated more effectively with the management of river basins, watersheds and coastal zones partnerships and collaboration are of prime importance in addressing the complex and cross-cutting challenges of climate change.

By focusing on herbivorous species aquaculture can provide nutritious food with a low carbon footprint. Farming of sea weeds facilitates carbon sequestration and assists bioremediation. Reducing Emissions from Deforestation and Forest Degradation (REDD) is an effort to create a financial value for the carbon stored in forests, offering incentives for developing countries to reduce emissions from forested lands and invest in low-carbon paths to sustainable development. "REDD+" goes beyond deforestation and forest degradation, and includes the role of conservation, sustainable management of forests and enhancement of forest carbon stocks. Accordingly mitigation solutions require innovative approaches such as the recent inclusion of mangrove conservation as eligible for REDD funding which demonstrates the potential for catchment forest protection under REDD.

Ecosystem approaches to fisheries (EAF) and to aquaculture (EAA) that embed precautionary approach applications within integrated management (IM) across all sectors have the potential to increase ecosystem and community resilience and provide valuable frameworks for dealing with climate change. This requires effective public, private and NGO partnerships, integrating research and management across the sectors. Marine protected areas (MPAs) and other forms of spatial management are important tools for restoring and sustaining the health of marine biodiversity. They need to be effectively managed to enhance ecosystem resilience under future climate conditions. This can be achieved by preventing and mitigating stressors such as overfishing, pollution and invasive species, as well as establishing and expanding MPAs to maintain ecosystem diversity and resilience, support fisheries management and to maintain connectivity among sites. Policies could encourage diversification of activities and income generation to enhance social resilience in the face of uncertainty and variability, particularly for vulnerable coastal and fisher communities (WWF, 2013).

Climate change may have positive impacts on certain species and their associated fisheries. Changes in sea surface temperature, for example, may limit the possible range of some species but may expand the optimal range available to others. This could result in new fishing opportunities. For example, commercially valuable species may enter new areas and become available for harvest. Some areas may also become more productive, which may increase fisheries yield, but increased productivity may also lead to an increase in low oxygen events that may impact negatively on some resources. Fishers are considered opportunistic and respond to environmental change by adapting their fishing areas, target species and strategies where the management framework supports such adaptation (WWF, 2013).

As with coastal ecosystems, natural freshwater ecosystems provide vital water regulation services and can play a role in adaptation to water scarcity as well as flooding. Actions to reduce degradation of watersheds, through reduced deforestation, afforestation, and soil conservation can lower vulnerability to drought and the maintenance and restoration of water regulating services of wetlands are important for flood control. The need of the hour is to integrate conventional and modern watershed management practices in order to make adaptation a practical reality at the grass roots.

Ecosystem-based Adaptation (EbA) is an important approach for achieving multiple benefits in the context of sustainable development. EbA been defined by the CBD as "the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change". This definition clearly identifies a strong link between biodiversity, ecosystem services, climate change adaptation and societal resilience. In order to achieve sustainable development, a synergy between biodiversity and ecosystem conservation, socio-economic benefits and climate change adaptation is necessary. In addition to protection from climate change impacts, EbA also provides many other benefits to communities, for example through the maintenance and enhancement of ecosystem services crucial for livelihoods and human well-being, such as clean water and food. Appropriately designed ecosystem management initiatives can also contribute to climate change mitigation by reducing emissions from ecosystem loss and degradation, and enhancing carbon sequestration.

ALIGNMENT OF WORK TO NAPCC/ SAPCC

International efforts to address climate change began with the adoption of the United Nations Framework Convention on Climate Change (IPCC) in 1992. The fifth assessment of the IPCC (IPCC, 2013) provides the latest understanding on the science, impacts, vulnerabilities, adaptation and mitigation of climate change. India released its National Action Plan on Climate Change (NAPCC) on 30th June 2008 to outline its strategy to meet the challenge of climate change. The National Action Plan advocates a strategy that promotes, firstly, the adaptation to climate change and secondly, further enhancement of the ecological sustainability of India's development path. India's NAPCC envisages India's efforts being led through 8 Missions, 2 of which are focus on 'Mitigation' (National Solar Mission and National Mission for Enhanced Energy Efficiency) and 5 on 'Adaptation' (National Mission for Sustainable Habitat, National Water Mission, National Mission for Sustaining the Himalayan Ecosystem, National Mission for a Green India, and National Mission for Sustainable Agriculture).

In 2009 the Indian Network for Climate Change Assessment (INCCA) involving 120 research institutions was launched by Government of India, which has been conceptualized as a Network-based Scientific Programme designed to: (i) assess the drivers and implications of climate change through scientific research, (ii) prepare climate change assessments once every two years (GHG estimations and impacts of climate change, associated vulnerabilities and adaptation), (iii) develop decision support systems, and (iv) build capacity towards management of climate change related risks and opportunities. Action on the national missions proposed under the NAPCC has already been on way in the guidance of the respective Ministries of

Government of India. NAPCC envisages State Action Plan on Climate Change (SAPCC) for translating national policy into action, especially at local levels. In line with NAPCC, SAPCC can help states address climate change issues and SAPCC was prepared under the overarching NAPCC. The state level action plans in India, in general, have failed to develop specific action plans related to costal and marine ecosystems. Effectiveness of local scale adaptation projects is enhanced through decentralization of project management and delivery. Capacity building and climate change mainstreaming are widely advocated as tools to support effective climate change adaptation. However, the ability of a project to achieve increased capacity and climate change mainstreaming is not widely explored.

RESEARCH, AWARENESS AND EDUCATION

In order to enable informed decisions on the appropriate mitigation and adaptation strategies, there is a growing need to strengthen the wealth of climate data and information and transform the knowledge into action. Further, a fundamental restructuring of the way energy, land, water and biological resources are managed is needed to achieve a cost-effective transition to low-carbon economy and society. Research and innovation will play an important role in defining cost-effective decarbonisation pathways, developing alternative technological and socio-economic solutions for decision-makers and for the society as a whole, while informing them on related risks and costs, besides planning suitable adaptation and mitigation programmes.

India's Indian Network for Climate Change Assessment (NAPCC) envisages National Mission on Strategic Knowledge for Climate Change as one of the missions with the objective of vulnerability assessment, research and observation, data management implemented through Department of Science and Technology. Considering that climate change is a relatively new challenge, the focus of the conservation action plan should be on generating awareness and building capacity and this should be done across all levels of the Government and external stakeholders involved in the different sectors. This strong drive towards building capacity will result in empowering people and organizations to be able to address, manage and respond to climate change concerns. Information, Education and Communication (IEC) technologies should be better utilized for the purpose. Climate change should also be included as a topic in academic curricula in education.

There is a need to involve stakeholders, particularly coastal community, in a more proactive way in the climate action plan implementation. This involvement will relate to (i) promoting much greater climate change awareness within community, (ii) identifying problematic issues relevant to climate change, (iii) support in monitoring of climate-induced problems and (iv) ensuring greater accountability to the people on climate change issues. Stakeholder involvement will be an effective tool with stakeholders, who play an important part in bringing out the solutions.

Climate change is an inter-disciplinary subject that cuts across physics, chemistry, biology, earth sciences, economics, technology development, etc. Therefore, multiple data sets are required even to simulate the current situations by different models. So, current data on observations on climate, natural ecosystems, soils, water from different sources, agricultural productivity and inputs and socio-economic parameters amongst others are continuously required. In this context, it is essential to have accessibility to databases at micro levels prepared with various agencies and to continuously monitoring the impacts. Further, there is also a need capacity building to co-ordinate world class climate change research in India. In tropics large number of people depend on marine biodiversity for their livelihood and nutritional security, while their capacity to adapt to climate change impacts remain minimal due to economic and social constraints (Cheung and Pauly, 2016). This warrants specific local studies on the impacts of climate change and ocean acidification on biodiversity, with a focus on impacts of resource depletion on the livelihood and adaptation of local fishers. According to Cheung and Pauly (2016) there is a greater need to understand the impacts of multiple stressors (climatic and non-climatic) and their interactions on local fisheries with appropriate modelling studies.From the foregoing it is clear that the nature, scale and magnitude of the climate change impacts is likely to be of high significance in India as the economy is dependent on climate sensitive sectors such as agriculture, fisheries and tourism. In terms of assessing the climate change implications for the state, the government has to adopt a dual approach, i.e., top-down approach through the downscaling of global models as well as a bottom-up approach through collecting empirical evidences of climate change at a grassroots level. A multidisciplinary, integrated and co-ordinated convergence approach should be adopted in implementing the action plans, especially in meeting the targets set for the United National Sustainable Development Goals.

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