Impact of Climate Change in the Indian Marine Fisheries and the Potential Adaptation Options

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Introduction

Marine capture fisheries have very important roles for food supply, food security and income generation in India. About one million people work directly in this sector, producing 3 million t annually. The value of fish catch at production level is about USD 2.8 billion (CMFRI, 2007) and India earns USD 1.6 billion by exporting fish and fishery products. The country has a fishing fleet consisting of 58,911 mechanized craft, 75,591 motorized craft and 104,270 non-motorized craft (CMFRI, 2006). Due to overfishing, unregulated fishing, habitat destruction and pollution, production from marine fisheries is stagnant in the last ten years. Being open access to a large extent, there is intense competition among the stakeholders with varied interests to share the limited resources in the coastal waters. Fishing remains coastal, restricted mostly to waters within 100 m depth, and deep sea and oceanic fishing is not progressing as expected. It was realized about ten years ago that the scope for increasing fish catch from the coastal waters is limited (Devaraj and Vivekanandan, 1999). Climate change is projected to exacerbate this situation and act as a depensatory factor on fish populations. Warming of water has potential impact on fish diversity, distribution, abundance and phenology, which will have, in turn, effects on the ecosystem structure and function. Acidification of water will have effects on calciferous animals. Increased incidence of extreme events such as storms, floods and drought will affect the safety and efficiency of fishing operations, flow of rivers, area covered by wetlands and water availability and will have severe impacts on fisheries. Sea level rise will have effects on the coastal profile and livelihoods of communities. The potential outcome for fisheries may be decrease in production and value of fisheries, and decline in the economic returns from fishing operations.

The relevance of active regional and international participation and collaboration to exchange information and ideas is being felt now as never before. For this, action plans at regional level need to be taken by (a) strengthening regional organizations and place climate change agenda as a priority; (b) addressing transboundary resource use; and (c) evolving common platforms and sharing the best practices. Action plan at international level also need to be taken by (a) linking with mitigation activities; (b) enhancing co-operation and partnerships; and (c) applying international fishery agreements. It is necessary to develop knowledge base for climate change and marine fisheries, adopt Code of Conduct for Responsible Fisheries and increase awareness on the impacts of climate change.

Impact of climate change on climatic and oceanographic parameters

There is now a widely-held consensus among scientists and policy-makers that human activities are increasing the levels of carbon dioxide and other 'greenhouse' gases in the atmosphere, leading to a rise in temperature. This links in turn to changes in seawater temperature, varying with latitude and topography, and to thermal expansion and melting of ice caps and sea level rise. The world's oceans that are affected by changes in precipitation, wind and currents, themselves the result of geographical differences in temperature and humidity of the atmosphere. Thus, important oceanic weather systems such as the El Niño Southern Oscillation (ENSO) and the Indian Ocean monsoon will be affected by global warming.

There is now ample evidence of the impacts of global climate change on marine environments. Organisms, however, do not respond to approximated global averages. Regional changes are more relevant in the context of ecological response to climate change. Hence, global-scale climate models may be unable to simulate observed changes in temperature and rainfall or the intensification of coastal upwelling in many areas, but regional-scale models may be able to do this (Clark, 2006).

Analyzing the data set on sea surface temperature (SST) obtained from International Comprehensive Ocean – Atmosphere Data Set (ICOADS) (ESRL PSD www.cdc.noaa.gov) and 9-km resolution monthly SST obtained from AVHRR satellite data (provided by the NOAA/NASA at http://podaac.jpl.nasa.gov/), Vivekanandan *et al.* (2009a) showed warming of sea surface along the entire Indian coast (Fig. 1). They found that the SST increased 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. For instance, the annual average SST, which ranged between 27.7° C and 28.0° C during 1961-1976 increased to 28.7° C-29.0° C during 1997-2005 between 9°N, 76°E and 11°N, 77°E (southwest coast). The warmer surface waters (29.0° C-29.2° C) expanded to a very large coastal area (between 8°N, 72°E and 14°N, 75.5°E) in the 45 year period. The cooler waters (25.2° C-25.5° C) in 23°N, 68°E (off Saurashtra in the northwest coast) during 1961-1976 disappeared completely in the later years. Similar pattern of warming was evident in the Bay of Bengal too. Based on the trajectory suggested by HadCM3 for SRES A2 scenario, Vivekanandan *et al.* (2009b) predicted that the annual average sea surface temperature in the Indian seas would increase by 2.0°C to 3.5°C by 2099.

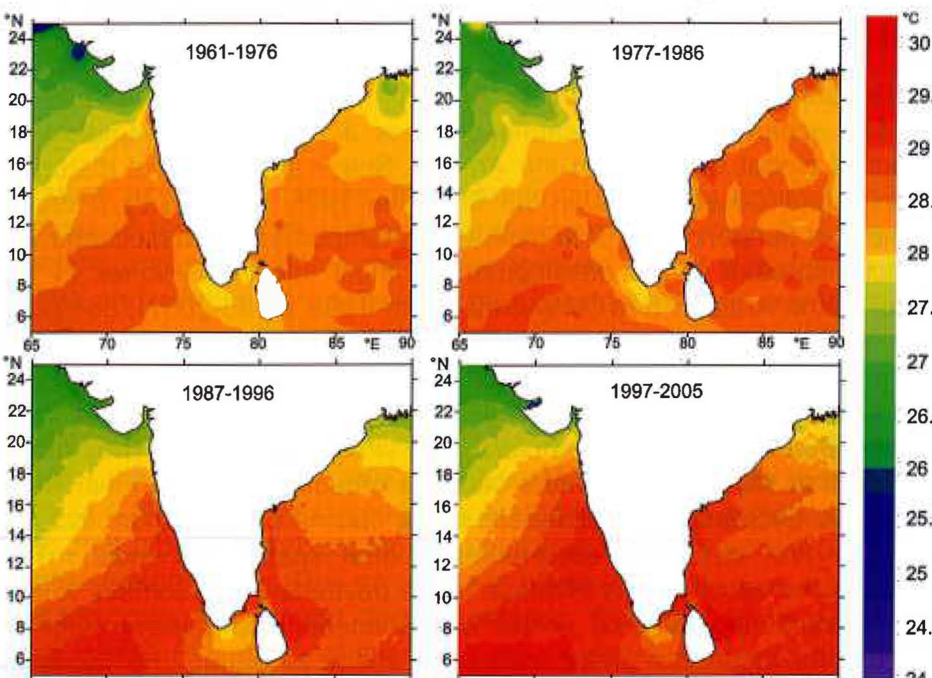

Fig. 1. Warming of sea surface along Indian coast

To understand the temporal changes in the climatic and oceanographic variables off Kerala (southwest coast of India), Vivekanandan *et al.* (2009c) gathered monthly average data on sea surface temperature (SST), relative humidity (RH), total cloudiness (TC), zonal wind (U), meridional wind (V), scalar wind (W), Multivariate El-Nino Southern Oscillation Index (MEI), Southern Oscillation Index (SOI), Coastal Upwelling Index (CUI) and chlorophyll concentration (chl-*a*). They found that the SST showed peaks at an interval of about ten years (1969-70, 1980, 1987-88, 1997-98, 2007) during 1961-2007, and the decadal number of SST anomalous (+ 1 or – 1 deviation from the 47-year mean) months increased. For example, only 16% of the months were SST anomalous during 1961-1970, but 44% during 2001-2007. The meridional wind speed (V) increased in the last ten years. They further made the following conclusions on the climatic and oceanographic parameters off Kerala: (i) For some parameters, the anomalies of some of the variables are increasing, and for others, the annual trend is changing. (ii) The annual CUI and chl-*a* concentration increased during 1999-2008. (iii) If the changing annual trend and anomalies affect the well-defined seasonal oceanographic settings, it is possible that the biological processes may be affected in the future.

Response of the ocean to human-induced changes is different between ocean basins. Prasannakumar *et al.* (2009) showed that the impact of global warming on the Arabian Sea is the cause of disruption of the natural decadal cycle in the SST after 1995, followed by a secular increase in temperature. This increase in temperature is associated with a 5-fold increase in the development of most intense cyclones (> 100 kmph) in the Arabian Sea (May-June) after 1995 (1995-2007), compared to the previous 25 years (1970-1994). Concurrent with these events, there are progressively warmer winters, decreased monsoon rainfall, both occurring over India and an increase in the phytoplankton biomass in the Arabian Sea during fall and winter, all of which are linked. They further showed that the warmer winters cause a reduction in the annual wheat yield while decreased rainfall results in the decline of vegetation, increase in aridity and increased occurrence of heat spells over India. They attributed the synchronous increase in the phytoplankton biomass to iron-fertilization during fall and winter by enhanced dust-delivery from the surrounding landmass under increased aridity. Further, the increased phytoplankton biomass is tightly coupled to the higher fish (oil sardine) catch in the eastern and western Arabian Sea after 1995.

Sea level rise in the Indian seas

Inter-governmental Panel on Climate Change has projected that the global annual seawater temperature and sea level would rise by 0.8 to 2.5°C and 8 to 25 cm, respectively by 2050 (IPCC, 2007). The historic sea level rise for Cochin (southwest coast) is estimated to have been 2 cm in the last one century (Emery and Aubrey, 1989; Das and Radhakrishna, 1993). However, the rate of increase is accelerating, and it is projected that it may rise at the rate of 5 mm per year in the coming decades. Considering this, it is possible that the sea level may rise by 25 to 30 cm in 50 years (Dinesh Kumar, 2000). An increase in mean sea level will affect waves, currents and bottom pressure in the near shore region. In general, an increase in mean water depth will be accompanied by an increase in mean wave height, resulting in a more severe wave attack on the coast and a greater wave induced littoral drift. The erosion due to sea level rise for the region is estimated to be 7125 m^3 per year, implying an erosion rate of 0.3×10^6 m^3 per year, which could be attributed to the effects of wave attack. Using the extreme conditions of wave height and sea level rise, future erosion potential is expected to increase by 15.3% by the year 2100 (Dineshkumar, 2000). Besides destruction through increased rates of erosion, the sea level rise situations also increase the risk of flooding (Nicholls *et al.,* 1999).

Impact on marine fish

Many tropical fish stocks, for instance, are already exposed to high extremes of temperature tolerance, and hence, some may face regional extinction, and some others may move towards higher latitudes. Coastal habitats and resources are likely to be impacted through sea level rise, warming sea temperatures, extremes of nutrient enrichment (eutrophication) and invasive species. Most fish species have a narrow range of optimum temperatures related to their basic metabolism and availability of food organisms. Being poikilotherms, even a difference of 1°C in seawater may affect their distribution and life processes. At shorter time scales of a few years, increasing temperature may have negative impacts on the physiology of fish because oxygen transport to tissues will be limited at higher temperatures. This constraint in physiology will result in changes in distributions, recruitment and abundance. Changes in timing of life history events (phenological changes) 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. At intermediate time scales of a few years to a decade, the changes in distributions, recruitment and abundance of many species will be acute at the extremes of species ranges. Changes in abundance will alter the species composition and result in changes in the structure and functions of the ecosystems. At long time scales of multi-decades, changes in the net primary production and its transfer to higher trophic levels are possible. Most models show decreasing primary production with changes of phytoplankton composition to smaller forms, although with high regional variability.

The tropical fisheries are characterized by several fast growing (von Bertalanffy's annual growth coefficient: 0.5 to 1.0) and multiple spawning species. Low levels of spawning take place throughout the year for most of the species, however, there are one or two distinct spawning peaks in a year. The eggs of most of the species are pelagic, directly exposed to the higher temperature and currents. As temperature increases, the development duration of eggs decrease, while the size of emerging larvae decreases (Vidal *et al.*, 2002). In the warmer years, the adults may grow faster, but there will be a point where growth rates would start to decrease as metabolic costs continue to increase. In the case of the squid *Loliolus noctiluca* (Jackson and Moltschaniwskyj, 2001), it has been found that the average life-span will decrease as a function of increased growth rate, and the individuals will mature younger at a smaller size. This will in turn reduce the absolute fecundity, as smaller individuals produce lesser number of eggs. The scale of these organism-level changes on the recruitment, biomass and fishery may depend on the environmental variables and food availability in different regions.

Generally, the more mobile species should be able to adjust their ranges over time, but less mobile and sedentary species may not. Depending on the species, the area it occupies may expand, shrink or be relocated. This will induce increases, decreases and shifts in the distribution of marine fish, with some areas benefiting while others lose. From the recent investigations carried out by Indian Council of Agricultural Research, the following responses to climate change by different marine species are discernible in the Indian seas: (i) Changes in species composition of phytoplankton at higher temperature; (ii) Extension of distributional boundary of small pelagics; (iii) extension of depth of occurrence; and (iv) phenological changes. Some evidences for the responses are given below:

Changes in species composition of phytoplankton and the potential impact at higher trophic levels

Laboratory experiments on seven species of phytoplankton at lower (24°C) and higher (29°C) seawater temperatures showed that at higher temperature, the rate of multiplication was faster and cell density was higher for all the seven species (Jasper *et al.*, 2009). However, the decay set-in earlier and the cycle was completed earlier at higher temperature. For instance, the maximum cell density of *Chaetoceros calcitrans* was 510×10^3 cells per ml on Day 7 after initiation of culture at 24°C, but the maximum cell density was 650×10^3 cells per ml at 29°C on Day 6. All the microalgae died on Day 12 at 24°C, but on Day 10 at 29°C. The species composition within the culture period was different between the two temperatures. For example, on Day 9, *Chlorella salina* contributed 22% to the total population at 24°C, but only 12% at 29°C. This study indicates the potential response in the growth rate, species composition and longevity by phytoplankton to higher temperature. Other factors such as light, current and nutrient availability will also affect the amount and composition of phytoplankton. The availability of phytoplankton influences the food availability up through the various trophic levels. The transport and abundance of zooplankton, the main consumers of phytoplankton, must synchronize with the phytoplankton bloom, or the zooplankton cannot survive, thus depriving food for organisms at higher trophic levels. In nature, the phytoplankton blooms, and the occurrence and abundance of zooplankton are always well timed. For instance, along the southwest coast of India, the herbivorous *Temora* spp. have been recognized as opportunistic species following pulses of diatom blooms. Swarms are observed in recently upwelled waters during southwest monsoon. This is followed by abundance of carnivores mainly *Euchaeta* spp. and *Candacia* spp. In the fading phase, the small carnivores such as *Oithona* and *Oncaea* dominate, supplemented by smaller herbivores such as Paracalanidae, and larger Eucalanidae (Stephen, 2008). Any potential mismatch would offset the food web. Synchrony between timing and abundance of peak zooplankton determines the larval recruitment as well as the abundance of some adult fishes like the Indian mackerel.

Zooplankton, especially the copepods, are regarded to act as sentinels to the marine biogeochemical cycles. Interannual changes in species assemblages often reflect an integrated response of the ecosystem to hydrometerological forcing. They are considered suitable to indicate the impact of the climate change because (1) they are not commercially exploited. (2) Since short lived, they do not contain persistent forms of previous years and exhibit imminent coupling between environmental changes and plankton dynamics. (3) Being free drifters, they can expand and contract geographical distribution according to their affinity to the environmental properties. During 1998 to 2005, a decrease in the abundance of copepods was observed during SW monsoon in the Arabian

Sea (Stephen, 2008). Significant changes in the community structure of copepods in active upwelling waters along the southwest coast were also observed.

Extension of distributional boundary of small pelagics

The oil sardine (*Sardinella longiceps*) and the Indian mackerel (*Rastrelliger kanagurta*) are tropical coastal and small pelagic fishes, forming massive fisheries (21% of marine fish catch during 2006: 0.6 million tonnes valued at about 150 million US$) in India. They are governed by the vagaries of ocean climatic conditions, and have high population doubling time of 15 to 24 months. They are cheap source of protein, and form a staple, sustenance and nutritional food for millions of coastal people. These small pelagics, especially the oil sardine, were known for their restricted 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 29°C. Until 1985, almost the entire catch was from the Malabar upwelling zone and the catch was either very low or there was no catch from latitudes north of 14°N (Fig. 2). In the last two decades, however, the catches from latitude 14°N - 20 °N are increasing, contributing about 15% to the all-India oil sardine catch during 2006. A positive correlation was found between the oil sardine catch and SST (Vivekanandan *et al.*, 2009a). 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 and Indian mackerel to extend their distributional range to northern latitudes. It is also found that the catches from the Malabar upwelling zone has not decreased indicating the distributional "extension" and not distributional "shift". The Indian mackerel are also found to extend the distribution to the northern latitudes of the Indian seas in a similar way.

Considering the catch as a surrogate of distribution and abundance, it is found that the two most dominant fish are able to find temperature to their preference especially in the northern latitudes in recent years, thereby establishing fisheries in the extended coastal areas. Assuming further extension of warmer SST tongue in the future, it is expected that the distribution may extend further north of latitude 20°N. However, if the SST in the Malabar upwelling zone increases beyond the physiological optimum of the fish, it is possible that the populations may be driven away from the southern latitudes in the future.

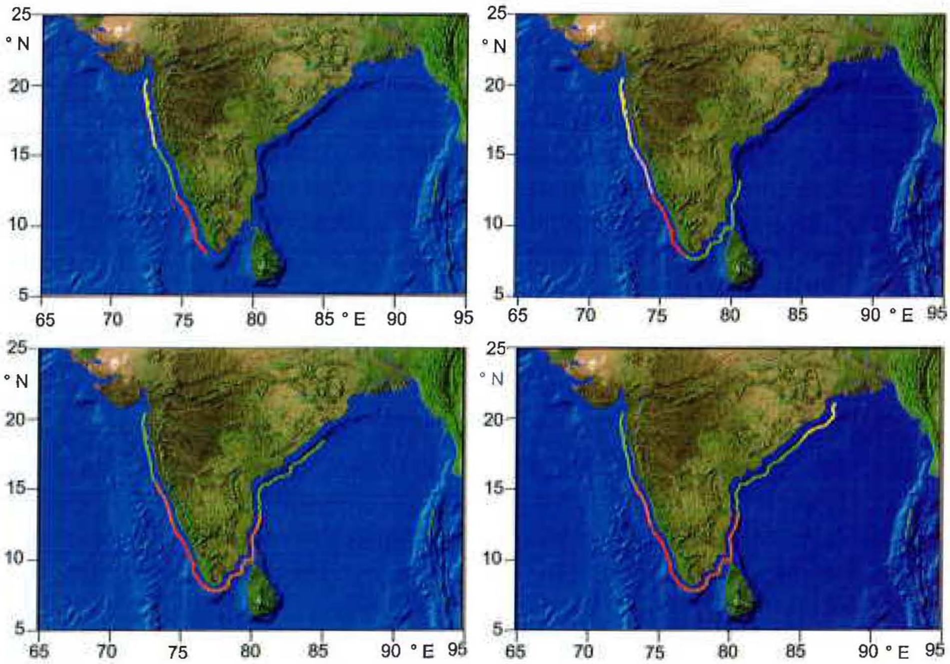

Fig. 2. Extension of distribution boundary for small pelagics

Extension of depth of occurrence of Indian mackerel

The Indian mackerel, *Rastrelliger kanagurta*, in addition to extension of northern boundary, are found to descend to deeper waters in the last two decades (CMFRI, 2008). The fish normally occupy surface and subsurface waters. During 1985-89, only 2% of mackerel catch was from bottom trawlers, and the rest of the catch was contributed by pelagic gear such as drift gillnet. During 2003-2007, it is estimated that 15% of mackerel catch is contributed by bottom trawlers along the Indian coast. The Indian trawlers operate at a depth ranging from 20 m to 80 m by employing high opening trawlnets. In the last 25 years, the specifications of trawlnet such as mouth opening, headrope length, otter board and mesh size have not been modified, and hence the increase in the contribution of trawlers to the mackerel catch is not gear-related. As the subsurface waters are also warming up, it appears that the mackerel, being a tropical fish, have extended their vertical boundary to deeper waters.

Phenological changes in threadfin breams

Fish have strong temperature preferences to spawning. The process of spawning is known to be triggered by pivotal temperatures. The annually recurring life cycle events such as timing of spawning can provide particularly important indicators of climate change. Though sparsely investigated, phenological changes such as seasonal shift in spawning season of fish are now evident in the Indian seas.

The threadfin breams, *Nemipterus japonicus* and *N. mesoprion*, are distributed along the entire Indian coast at depths ranging from 10 to 100 m. They are short-lived (longevity: about 3 years), fast growing, highly fecund and medium-sized fishes (maximum length: 35 cm). Data on the number of female spawners collected every month off Chennai (southeast coast of India) from 1981 to 2004 indicated wide monthly fluctuations. However, a trend in the shifting of spawning season from warmer (April-September; mean SST: 29.0°C-29.5°C) to relatively cooler months (October-March; mean SST: 27.5°C- 28.0°C) was discernible (Vivekanandan and Rajagopalan, 2009). Whereas 35.3% of the spawners of *N. japonicus* occurred in warm months during 1981-1985, the number of spawners gradually reduced and only 5.0% of the spawners occurred in the same season during 2000 - 2004. During 1981-1985, it was observed that 64.7% of the spawners occurred during October-March, whereas as high as 95.0% of the spawners occurred during the same season in 2000 - 2004. A similar trend was observed in *N. mesoprion* too. The percent occurrence of spawners of the two species linearly decreased with increasing temperature during April-September, but increased with increasing temperature during October-March over the time scale. It appears that SST between 28 and 29°C may the optimum and when the SST exceeds 29°C, the fish are adapted to shift the spawning activity to seasons when the temperature is around the preferred optima.

These changes may have impact on nature and value of fisheries (Perry *et al.*, 2005). If small-sized, low value fish species with rapid turnover of generations are able to cope up with changing climate, they may replace large-sized high value species, which are already showing declining trend due to fishing and other non-climatic factors (Vivekanandan *et al.*, 2005). Such distributional changes would lead to novel mixes of organisms in a region, leaving species to adjust to new prey, predators, parasites, diseases and competitors (Kennedy *et al.*, 2002), and result in considerable changes in ecosystem structure and function.

Currently, it is difficult to find out how much of catch fluctuation is due to changes in fish distribution and phenology. A time series analysis on stock biomass of different species along the Indian coasts does not exist. Long-term records of the abundance for most species are limited to historical commercial landings. Moreover, availability of time series data on climatic and oceanographic parameters and fish catches in India may be too short to detect displacements of stocks or changes in productivity. Moreover, these records are often influenced by economic factors such as the relative price paid for different types of fish, and changes in fishing methods or fishing effort. For instance, introduction of mechanized craft in the 1960s, motorized craft, high opening trawlnet, minitrawl and ringseine in the 1980s, and large trawlers for multiday fishing in the 1990s substantially increased the fish catch along the Indian coast. These non-climatic factors often obscure climate related trends in fish abundance. Perhaps a de-trending analysis for removing the impact of non-climatic factors may help arrive at conclusions on the impact of climate change on marine fisheries.

The effects of changed fish migrations and distribution caused by climate variability and climate change are likely to be most difficult to deal with for highly migratory species, such as tuna. Climate plays a large role in determining short-term, seasonal and multi-year patterns of variability in the location and productivity of these optimal tuna habitat zones. It is not clear whether the spurt in yellowfin tuna fishery in the Bay of Bengal and eastern Arabian Sea in the last five years is due to climate driven changes in the migration route of the fish.

Vulnerability of corals in the Indian seas

Coral reefs are the most diverse marine habitat, which support an estimated one million species globally. They are highly sensitive to climatic influences and are among the most sensitive of all ecosystems to temperature changes, exhibiting the phenomenon known as coral bleaching when stressed by higher than normal sea temperatures. Reef-building corals are highly dependent on a symbiotic relationship with microscopic algae (type of dinoflagellate known as zooxanthellae), which live within the coral tissues. The corals are dependent on the algae for nutrition and colouration. Bleaching results from the ejection of zooxanthellae by the coral polyps and/or by the loss of chlorophyll by the zooxanthellae themselves. Corals usually recover from bleaching, but die in extreme cases.

In the Indian seas, coral reefs are found in the Gulf of Mannar, Gulf of Kachchh, Palk Bay, Andaman Sea and Lakshadweep Sea. Indian coral reefs have experienced 29 widespread bleaching events since 1989 and intense bleaching occurred in 1998 and 2002 when the SST was higher than the usual summer maxima. By using the relationship between past temperatures and bleaching events, and the predicted SST for another 100 years, Vivekanandan *et al.* (2009b) projected the vulnerability of corals in the Indian Seas. The outcome of this analysis suggests that if the projected increase in seawater temperature follows the trajectory suggested by the HadCM3 for an SRES A2 scenario, reefs should soon start to decline in terms of coral cover and appearance. The number of decadal low bleaching events will remain between 0 and 3 during 2000-2089, but the number of decadal catastrophic events will increase from 0 during 2000-2009 to 8 during 2080-2089.

Given the implication that reefs will not be able to sustain catastrophic events more than three times a decade, reef building corals are likely to disappear as dominant organisms on coral reefs between 2020 and 2040 and the reefs are likely to become remnant between 2030 and 2040 in the Lakshadweep sea and between 2050 and 2060 in other regions in the Indian seas. These projections on coral reef vulnerability have taken into consideration only the warming of seawater. Other factors such as increasing acidity of seawater would affect formation of exoskeleton of the reefs, and scientists are of the opinion that if the acidification continues as it is now, all the coral reefs would be dead within 50 years. Given their central importance in the marine ecosystem, the loss of coral reefs is likely to have several ramifications.

Options for fisheries sector for adaptation

Options for adaptation are limited, but they do exist. The impact of climate change depends on the magnitude of change, and on the sensitivity of particular species or ecosystems (Brander, 2008).

Develop knowledge base for climate change and marine fisheries

As the ability to sustain fisheries will rest on a mechanistic understanding of the interactions between global change events and localized disturbances, it is important to recognize the regional responses to climate change. Hence, considerable effort should be made for gathering historical climatic and oceanographic data in addition to monitoring these key parameters to suit climate change research. It is also important to recognize the importance of the changes in these parameters as drivers of change in marine communities including fish. Initiating a commitment on long-term environmental and ecological monitoring programmes is important as such data cannot be collected retrospectively. In India, spatial marine fish catch and effort data are available for the last four decades. However, a synergy between the climatic and oceanographic data and fisheries data does exist. Projections on climate change impact on fish populations have not been performed so far. Such projections need to be developed as the first step for future analytical and empirical models, and for planning better management adaptations.

Adopt Code of Conduct for Responsible Fisheries

Fish populations are facing the familiar problems of overfishing, pollution and habitat degradation. In India, fisheries still remain, to a large extent, an open access. Seasonal closure of mechanized fishing for 45 to 60 days is perhaps the only regulatory measure that is being followed at present. Though the fish catch has not reduced conspicuously, it is stagnant for the last one decade and there are indications of decline of several fish stocks. Fishing and climate change are strongly interrelated pressures on fish production and must be addressed jointly. Reducing fishing mortality in the majority of fisheries, which are currently fully exploited or overexploited, is the principal means of reducing the impacts of climate change (Brander, 2007). Reduction of fishing effort (i) maximizes sustainable yields, (ii) helps adaptation of fish stocks and marine ecosystems to climate impacts, and (iii) reduces greenhouse gas emission by fishing boats (Brander, 2008). About 1.2% of global oil consumption is used in fisheries, and it is found that fish catching is the main contributor to global warming in the fish production chain (Thrane, 2006). Hence, dealing effectively with the old familiar problems of overfishing may facilitate mitigation of climate change impacts on fisheries (Brander, 2008), and adapt Code of Conduct for Responsible Fisheries and Integrated Ecosystem-based Fisheries Management (FAO, 2007). In countries like India, the primary mechanisms for managing large-scale commercial fisheries such as total allowable catch (TAC) or total allowable effort (TAE), which are applied through a proportional allocation system, do not exist. Hence, it is relatively difficult for managers to accommodate for changes in stock abundance and it is a challenge to fully comply with the CCRF. The challenge becomes severe considering the high level of poverty prevalent in the coastal communities involved in traditional fishing methods, and the lack of suitable alternate income generating options for them. These factors make these communities highly vulnerable to future changes, as their capacity to accommodate change is very limited. Effort to reduce dependence on fishing by these vulnerable communities is essential.

Increase awareness on the impacts of climate change

Being a signatory to the United Nations Framework Convention on Climate Change (UNFCCC), India has submitted the first National

Communication to the UNFCCC in 2004. The second National Communication is under preparation for submission in 2011. National climate change response strategies are under preparation on a sectoral basis. Specific policy document with reference to the implications of climate change for fisheries needs to be developed for India. This document should take into account all relevant social, economic and environmental policies and actions including education, training and public awareness related to climate change. Effort is also required in respect of raising awareness of the impact, vulnerability, adaptation and mitigation related to climate change among the decision makers, managers, fishermen and other stakeholders in the fishing sector.

Strategies for evolving adaptive mechanisms

In the context of climate change, the primary challenge to the fisheries and aquaculture sector will be to ensure food supply, enhance nutritional security, improve livelihood and economic output, and ensure ecosystem safety. These objectives call for identifying and addressing the concerns arising out of climate change; evolve adaptive mechanisms and implement action across all stakeholders at national, regional and international levels (Allision *et al.*, 2004; Handisyde *et al.*, 2005; WorldFish Center, 2007; FAO, 2008). In response to shifting fish population and species, the industry may have to respond with the right types of craft and gear combinations, on-board processing equipments etc. Governments should consider establishing Weather Watch Groups and decision support systems on a regional basis. Allocating research funds to analyze the impacts and establishing institutional mechanisms to enable the sector are also important.

For the fisheries and aquaculture sector, climate change notwithstanding, there are several issues to be addressed. Strategies to promote sustainability and improve the supplies should be in place before the threat of climate change assumes greater proportion. While the fisheries sector may strive to mitigate climate change by reducing CO_2 emission especially by fishing boats, it could contribute to reduce the impact by following effective adaptation measures by providing fiscal incentives for reducing the sector's carbon footprint, and for following other mitigation and adaptation options.

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