Impact of Climate Change on Indian Marine Fisheries*

Is climate change the next apocalypse? Even optimists agree that it is one of the most critical global challenges of today. Research shows that climate change may impact agriculture and fisheries; endanger food security; trigger sea-level rise; lead to sea ice melting and glacier retreat; aggravate natural disasters such as floods, cyclones and droughts; accelerate the erosion of coastal zones; quicken species extinction and the spread of vector-borne diseases; cause coral bleaching and decline in biodiversity.

How has climate change affected India? Can governments and communities adapt to it? Both research and action on the subject are at a nascent stage. But recent studies throw some light on the subject.

We summarize here the observations and findings of two papers, by scientists from World Wildlife Fund-India (WWF) and the Central Marine Fisheries Research Institute (CMFRI) respectively. The authors are Dr Prakash Rao and Dr E Vivekanandan, who discuss how India's marine fisheries should adapt to climate change.

Impact of climate change on climatic parameters

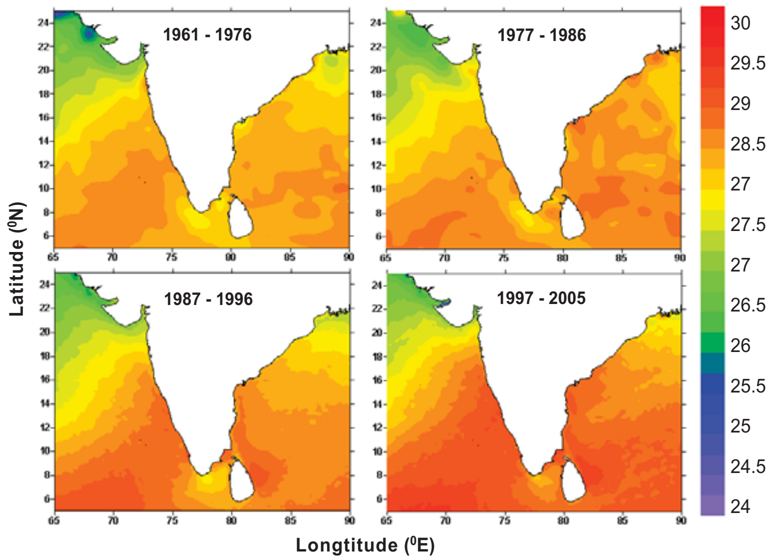
Evidence of the impact of global climate change on marine environments is ample. But it is regional rather than global climate models that are appropriate for observation and study of climate change impacts (Clark, 2006).

Analyzing data on sea surface temperature (SST) and other parameters from a variety of global sources, Vivekanandan et al. (2009a) found warming of the sea surface along the entire Indian coast. The SST increased by 0.2°C along the northwest, southwest and northeast coasts and by 0.3°C along the southeast coast during the 45-year period from 1960 to 2005. The team has predicted that the annual average SST in the Indian seas would increase by 2.0°C to 3.5°C by 2099.

Sea level rise in the Indian seas: The Inter-governmental Panel on Climate Change (IPCC) has projected that the global annual seawater temperature would rise by 0.8 to 2.5°C by 2050. The sea level would rise by 8 to 25 cm. The sea level rise for Cochin (southwest coast) during the past century is estimated at 2 cm (Emery and Aubrey, 1989; Das and Radhakrishna, 1993). But the rate of increase is accelerating. It may rise at the rate of 5 mm per year in decades to come. This will accelerate erosion and increase the risk of flooding (Nicholls et al., 1999).

Impact on marine fisheries

Production from marine capture fisheries has been stagnant during the past 10 years because of overfishing, unregulated fishing, habitat destruction and pollution; climate change may exacerbate this



Plot of SST showing warming of sea surface along the Indian coast during 1961-2005. (Source: ICOADS and AVHRR data from NOAA/NASA; the values near the vertical bar indicate SST (⁰C)

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situation. Warming of water may impact fish diversity, distribution, abundance and phenology. Acidification of water will affect calciferous animals. Storms, floods and drought will severely impair fisheries. Sea level rise will lower fish production and damage the livelihoods of communities.

Some tropical fish stocks may face regional extinction. 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. 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 result in changes in distribution, recruitment and abundance. Species with short-life span and rapid turnover 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, changes in distribution, recruitment and abundance of many species may be acute. Changes in abundance will alter the species composition.
At longer time scales of multi-decades, changes in net primary production and transfer to higher trophic levels are possible.

Investigations carried out by the Indian Council of Agricultural Research show that different Indian marine species will respond to climate change as follows:
(i) Changes in species composition of phytoplankton may occur at higher temperature; (ii) Small pelagics may extend their boundaries; (iii) Some species may be found in deeper waters as well; and (iv) Phenological changes may occur.

Changes in species composition of phytoplankton: Laboratory experiments on seven species of phytoplankton showed that some species may multiply faster at higher temperature (29°C) than at lower temperature (24°C). But they decay earlier at the higher temperature.

Small pelagics extend their boundaries: The oil sardine *Sardinella longiceps* and the Indian mackerel *Rastrelliger kanagurta* accounted for 21 percent of the marine fish catch in 2006. These small pelagics, especially the oil sardine, have been known for 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 SST ranges from 27 to 29°C.

Until 1985, almost the entire catch was from the Malabar upwelling zone, there was little or no catch from latitudes north of 14°N. During the last two decades, however, catches from latitude 14°N - 20°N are increasing. In 2006, catches in this area accounted for about 15 percent of the all-India oil sardine catch.

The higher the SST, the better the oil sardine catch (Vivekanandan et al., 2009a). The surface waters of the Indian seas are warming by 0.04°C per decade. Since the waters in latitudes north of 14°N are warming, the oil sardine and Indian mackerel are moving to northern latitudes. It is seen that catches from the Malabar upwelling zone have not gone down. Inference: The sardines are extending northward, not shifting northward. The Indian mackerel is also found to be extending northward in a similar way.

According to CMFRI, the catch of oil sardines along the coast of Tamil Nadu has gone up dramatically, with a record landing of 185 877 tonnes in 2006. The presence of the species in new areas is a bonus for coastal fishing communities. Assessing their socio-economic needs will greatly help in developing coping strategies for adaptation to climate impacts. WWF is currently documenting community perceptions and experiences in relation to the oil sardine fishery of the eastern coasts.

Indian mackerel is getting deeper: Besides exploring northern waters, the Indian mackerel *R. kanagurta* has been descending deeper as well during the last two decades (CMFRI, 2008).

The fish normally occupies surface and subsurface waters. During 1985-89, only 2 percent of the mackerel catch was from bottom trawlers, the remainder was caught by pelagic gear such as drift gillnet. During 2003-2007, however, an estimated 15 percent of the mackerel has been caught by bottom trawlers along the Indian coast.
It appears that with the warming of sub-surface waters, the mackerel has been extending deeper and downward as well.

Spawning: threadfin breams like it cool: Fish have strong temperature preferences so far as spawning goes. The timing of spawning, an annually occurring event, is an important indicator of climate change. Shifts in the 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 from 1981 to 2004 indicated wide monthly fluctuations.

However, a shift in the spawning season from warmer to relatively cooler months (from April-September to October-March) was discernible (Vivekanandan and Rajagopalan, 2009). Whereas 35.3 percent of the spawners of *N. japonicus* occurred in warm months during 1981-1985, only 5.0 percent of the spawners occurred in the same season during 2000-2004.

What about the cool months? During 1981-1985, 64.7 percent of the spawners occurred during October-March, whereas as high as 95.0 percent of the spawners occurred during the same season in 2000-2004.

A similar trend was observed in *N. mesoprion* too. The occurrence of spawners of the two species 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^{o}C may be the optimum. When the SST exceeds 29^{o}C, the fish shifts the spawning activity to seasons when the temperature is around the preferred optima.

These changes may have an impact on the 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 declining due to fishing and other non-climatic factors (Vivekanandan et al., 2005).

Such distributional changes might 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.

False Trevally populations decline in the Gulf of Mannar: As part of a WWF India-commissioned project, the Suganthi Devadason Marine Research Institute (SDMRI), Tuticorin, undertook a study in 2004 in the Gulf of Mannar region to analyze the effect of climate change on the fishery of False Trevally **(*Lactarius lactarius*)** and the reduction in the income of small - scale fishermen. The project helped identify the migratory patterns of the fish species.

False Trevally is an economically and culturally important fish in India and found near the Rameshwaram coast of south east India. The species is generally seen at depths ranging from 15 to 90 metres. But over the past few years, there has been a steady decline in the catch of this fish – both because of human disturbance and changes in ocean temperatures. Destructive fishing practices have also led to decline of the species. Result: the species has moved to other regions along the coast including the east coast of Sri Lanka.

Currently, it is difficult to find out how much of catch fluctuation is due to changes in fish distribution. A time-series analysis on stock biomass of different species along the Indian coasts does not exist. Moreover, catches are 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 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 migration and distribution caused by climate change are most difficult to deal with for highly migratory species, such as tuna. 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.

Coral reefs may become remnants: 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. 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. They believe that the coral cover of reefs may soon start declining. 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. 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 take into consideration only the warming of seawater. Other factors such as increasing acidity of seawater are not considered. If acidification continues in future as it does now, all 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.

Impacts of climate change on coastal systems

Coastal India (with over 8 000 km of coastline) is a productive and ecologically diverse landscape. Climate change may aggravate the impact of injurious large-scale development and reduce the productivity of marine ecosystems.

The Fourth Assessment Report of the IPCC (2007b) has suggested that climate change is likely to significantly impact coastal India. Some possible impacts:

- *More hot days. More heat waves. More death from heat strokes in recent years;*
- *Intrusion of saline water into groundwater in coastal aquifer; and*
- *Decline in precipitation, droughts in most delta regions of India and drying of wetlands.*

Worldwide, WWF studies have brought out some important underlying impacts of climate change on marine ecosystems – such as a rise in SST, decreasing marine pH, shifting ocean currents, release of methane hydrates and rising sea level.

India is vulnerable to major climate changes because of a long coastline on the east and west and the Himalayan mountain range in the north. WWF- India has been working in some of India's most critical ecosystems and landscape. Its studies seek to probe climate impacts in the Sundarbans, the coastal regions of south India and in the Himalayas, and focus mainly on impacts and adaptation; mitigation; and policy interventions.

Sundarbans: The Sundarbans is part of the world's largest delta (80 000 sq. km) formed from sediments deposited by three great rivers, the Ganges, Brahmaputra and Meghna. It consists of 102 low-lying islands in the Bay of Bengal and forms one of the world's richest mangrove ecosystems (34 mangrove species). Faunal diversity is significant too, with a strong tiger population. The combination of terrestrial, freshwater and marine flora and fauna makes this one of the most diverse and productive ecosystems in the country.

The Sundarbans is now under severe stress due to sea level rise and associated problems. A population of four million in the Indian Sundarbans is severely stressed. Mangroves are under threat, so are endangered species like tigers and turtles. An effective coping mechanism to reduce the vulnerability of the region is essential.

WWF- India is documenting local community knowledge and climate perceptions through an initiative known as 'Climate Witness'. It was launched because of the strong indicators of climate change from various scientific studies. WWF-India hopes that this initiative will make the authorities integrate climate change concerns into development planning through a bottom-up approach.

Characteristics of the initiative:

- *Stakeholders at different levels will help develop a model intervention;*
- *A homogeneous geographical area will be identified to validate the model; and*
- *Local concerns on climate change will be integrated into development planning.*

Islands selected for the 'Climate Witness' initiative studies are mostly in the southwestern corner of Sundarbans (except Chhoto Mollakhali and Bali islands situated in the northeastern part of the delta).

Local communities in these sites were more concerned by weather phenomena (such as monsoon delays in recent years), than by rising temperatures. Local residents reported very high frequency of thunder and lightning during storms in last 10-15 years. In their opinion depression and cyclonic storms occurred more frequently than earlier. Delayed monsoons and untimely rain impaired agricultural productivity leading to loss of crops and increased pest attacks.

Community interactions and adaptation responses

The WWF- India has been studying the coping capacities of communities – particularly in those islands where landmass has been lost over the past few decades. Community knowledge is being classified on environmental impacts like soil erosion, loss of landmass, damage of coastal embankments, siltation, unsustainable livelihood practices, population pressure, storms and cyclones, effect of tidal waves, etc.

Farmers and fishermen (both depend on the ecosystem) form a major part of the work force of these islands. Since industry isn't developed, livelihood options are limited. Nearly 61.85 percent of the respondents surveyed were farmers or fishermen. Nearly 10 percent were full-time fishers. A majority of the inhabitants were vulnerable to climate-related adversities.

In response to climate change, village communities have been taking short-term actions such as:

- *Shifting the farming time because of shifting of monsoon season;*
- *Diversifying into different weather-resistant crops;*
- *Constructing and renovating ponds and canals for rain water harvesting and use in winter cultivation;*
- *Constructing mud-barrages around the islands to protect them from saline water intrusion; and*
- *Reforesting of mangroves on the mud barrage.*

WWF- India says that in communities dependent on ecosystems, different stakeholders must come together to address climate change and environment security. They could develop site-specific measures at the local level, evolve a consensus for national strategies, and support inter-governmental processes.

The stakeholders would include the very poor; farmers and fishers; local, state and national bodies; urban consumers; business and industry; groups concerned with coastal zone regulation; scientists and academics.

When stakeholders at different levels are brought together on a common platform, climate change concerns can be better integrated into development planning. Resource centers and local knowledge networks can raise awareness and strengthen action. Some other institutional processes can also be established.

How can fisheries adapt?

Options for adaptation are limited, but 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: Considerable effort should be made to collect historical climatic and oceanographic data – in addition to monitoring these key parameters. Long-term environmental and ecological monitoring programmes are 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 is needed. 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.

Adapt the Code of Conduct for Responsible Fisheries (CCRF): Fish populations are facing the familiar problems of overfishing, pollution and habitat degradation. 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).

Some of the most effective actions which we can take to tackle climate impacts are to deal with the old familiar problems such as overfishing (Brander, 2008), and adapt the CCRF and Integrated Ecosystem-based Fisheries Management (FAO, 2007).

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. A specific policy document on 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 to raise awareness of the impact, vulnerability, adaptation and mitigation related to climate change among all stakeholders.

Strategies for evolving adaptive mechanisms: In the context of climate change, the primary challenge to the fisheries and aquaculture sectors will be to ensure food supply, enhance nutritional security, improve livelihoods and economic output and ensure ecosystem safety. These objectives call for identifying and addressing the concerns arising out of climate change and evolving adaptive mechanisms and implementing action across all stakeholders at national, regional and international levels (Allision et al., 2004; Handisyde et al., 2005; WorldFish Center, 2007; FAO, 2008).

Strategies to promote sustainability and improve 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 emissions, especially by fishing boats, it could reduce impact by following effective adaptation measures. There should be fiscal incentives for reducing the sector's carbon footprint, and for following other mitigation and adaptation options.

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