Marine Fishery Development and Climate Change

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INTRODUCTION

Marine 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 3.1 million tonnes annually. The value of the marine fish landings have been estimated at Rs. 36,964 crores in 2010 and India has earned a foreign exchange of Rs. 10,000 crores through the export of 6 lakh tonnes of sea food products. The fisheries sector, presently contributes around one percent to the GDP and 4.72 percent to Agricultural GDP of our country (Sathiadhas *et al.*, 2012). 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, which has resulted in overfishing and decline in stocks of a few species. Climate change renders severity to this situation and act as a dispensatory factor on fish populations. Further, it will also have strong impact on fisheries with far-reaching consequences for food and livelihood security of a sizeable section of the population.

Concerns on global warming have been with us now for more than a decade. The global warming that is widely expected to occur over this century will not be confined to the atmosphere; the oceans would also get warmer. Over the next 50 years, sea surface temperature in the Indian seas is expected to rise by 1 to 3. The oceans are predicted to acidify, become more saline, and the sea level will rise, and currents may change. It has been recognised that it will have consequences, both benign and disadvantageous, on fisheries. Fisheries, which essentially are an advanced form of hunting, are totally dependent on what nature will or will not provide. The effects of environmental change on fisheries are likely, therefore, to be severe. Such changes are likely to affect fish migrations and habitat, augmenting fish stocks in some places and decreasing them in others, perhaps causing stocks to be displaced permanently to new habitats. Investigations are progressing to find out the possible consequences of environmental change for fisheries. Nevertheless, the effects of climate change on fish stocks and their migrations are extremely difficult to predict.

The marine fish landings of India during the year 2010 has been estimated as 3.07 million tonnes (table 1) with a decrease of about 1.31 lakh tonnes compared to the estimate for 2009. The pelagic finfishes constituted 55%, demersal fishes 26%, crustaceans 14% and molluscs 5% of the total landings. The sector-wise contributions during the year 2010 were mechanized 73%, Motorized 25% and artisanal 2%. The west coast accounted for 55 % of the total landings and east *coast* 45%.

Table 1
Profile of Marine Fisheries in India

Component	Profile
Physical Components	
Coastline length (km)	8129
Exclusive Economic Zone (million km^2)	2.02
Continental shelf area (million km^2)	0.50
Area within 50m depth (million km^2)	0.18
Human Components	
Marine fisher population (million)	4.0
Active fisher population (million)	1.5
Infrastructure Components	
Landing centres	1511
Mechanized vessels	72559
Motorized vessels	71313
Non-motorized vessels	50618
Fish Catches	
Annual landings (2010) (million t)	3.07
Potential yield (million t)	3.92

Source: CMFRI, 2010

IMPACT OF CLIMATE CHANGE ON MARINE FISH

There is now ample evidence of the impacts of global climate change on marine environments. Analysis of 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) showed warming of sea surface along the entire Indian Coast. *The SST increased* by 0.2° C along the north-west (NW), South-west (SW) and north-east (NE) coasts, and by 0.3° C along the south-east (SE) coast during the 45 year period from 1961 to 2005. For instance, the annual average SST, which ranged between 27.7 ° C *and* 28.8° 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 (south-west 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, 68° E (off Saurashtra in the north-west 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, it is predicted that the annual average sea surface temperature in the Indian seas would increase by 2 ° C to 3 ° C by 2009. The predicted trend showed that the annual average temperature is likely to increase from 28.5 ° C during 2000-09 to 31.5 ° C during 2089-99 in the Andaman, Nicobar, Lakshadweep and Gulf of Mannar; and from 27.5 ° C to 30.5 ° C in Gulf of Kutch.

Most fish species have a fairly narrow range of optimum temperatures related to their basic metabolism and availability of food organisms. Being poikilotherms, even a difference of 1° C or 0.1 unit pH in seawater may affect their distribution and life processes. 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 include increases and shifts in the distribution of marine fish, with some areas benefiting while others lose. From the recent investigations carried out by the Indian Council of Agricultural Research (ICAR) and Central Marine Fisheries Research Institute (CMFRI), the following responses to climate change by different marine fish species are discernible in the Indian seas: (i) Extension of distributional boundary (Vivekanandan *et al.* 2009); (ii) Shift in latitudinal distribution; (iii) Shift/extension of depth of occurrence (CMFRI, 2008); and (iv) phenological changes (Vivekanandan and Rajagopalan 2009). Some evidences of the responses are given below:

Extension of Distributional Boundary

The oil sardine *Sardinella longiceps* and the Indian mackerel Rastrelliger kanagurta are tropical coastal and small pelagic fish, forming massive fisheries in India (catch during 2010: 4,03,932 tonnes contributing 13.1%of the total marine landings of the country). They are governed by the vagaries of ocean climate conditions, and have high population doubling time of 15 to 24 months. They are cheap source of protein, and form a staple and nutritional food for millions of coastal people. They 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 south-west 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. In the last two decades, however, the catches from latitude 14° N to 20 ° N are increasing and a positive correlation was found between the catches and sea surface temperature (SST). The surface waters of the Indian seas are warming by 0.04 ° C per decade, and the warmer tongue (27-28° C) of the surface waters expanded to latitudes north of 14° N, enabling the oil sardine.

Shift in Latitudinal Distribution and Abundance

Catfish are one of the major resources along the southwest and southeast coasts of India (latitude: 8° N – 14° N). During 1970-2007, the catches from these coasts decreased from 35,000 tonnes to 7,800 tonnes. On the other hand, the catches from the northwest and northeast coasts (latitude: 15° N – 22° N) increased from 16,000 tonnes to 42,500 tonnes during the same period. There was a strong negative correlation between catfish catch and SST along the two southern coasts whereas the correlation between catch and SST was positive along the northern coasts.

Shift/Extension of Depth of Occurrence

The Indian mackerel, *Rastrelliger kanagurta*, the second important resource contributing 7.9% of total landings for 2010 in addition to extension of its northern boundary, is found to descend to deeper waters in the last two decades. The fish normally occupies surface and subsurface waters. During 1985-1989, 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 2003-2010, 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 20m to 80m by employing high opening trawlers. In the last 25 years, the specifications of trawlnet such as mouth opening, headrope length, otterboard 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 surface waters are also warming up, it appears that the mackerel, being a tropical fish, has extended its vertical boundary to deeper waters.

Phenological Changes

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.

The threadfin breams *Nemipterus japonicas* 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 (annual egg production around 0.2 million per adult female) and medium-sized fishes (maximum length: 35 cm). Data on the number of female spawners collected every month off Chennai (south-east coast of India) from 1981 to 2010 indicated wide monthly fluctuations. However, a trend in the shifting of spawning season from warmer (April-September) to cooler months (October-March) was discernible. Whereas 35.3% of the spawners of *N.japonicus* occurred during warm months, the number of spawners gradually reduced and only 5.0% of the spawners occurred during the same season. A similar trend was observed in *N.mesoprion* too. The present 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.

Vulnerability of Corals

Coral reefs are the most diverse marine habitat, which support an estimated one million species globally. They are highly sensitive to climate 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 (*i.e.*, 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 zooxanthallae themselves. Corals usually recover from bleaching, but die in extreme cases.

In the Indian seas, coral reefs are found in Gulf of Mannar, Gulf of Kachchh, Palk Bay, Andaman and Lakshadweep Seas. Indian coral reefs have experienced 29 widespread bleaching events since 1989 and intense bleaching occurred in 1998 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.* (2009) 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 beaching events will remain between 0 and 3 during 2000-2099, but the number of catastrophic events will increase from 0 during 2000-2009 to 10 during 2000-2099.

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 region and between 2050 and 2060 in other regions in the Indian Seas.

OPTIONS FOR FISHERIES AND AQUACULTURE SECTOR FOR ADAPTATION

Tackling Overfishing

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). Fish populations are facing the familiar problems of overfishing, pollution and habitat degradation. Food and Agriculture Organization has estimated that about 25% of all fish stocks are overexploited and 50% are fully exploited (FAO 2007). Reduction of fishing effort will benefit in relation to adaptation of fish stocks and marine ecosystems to climate impacts; and mitigation by reducing greenhouse gas emissions. Hence, some of the most effective actions which we can be taken to tackle climate impacts are to deal with the old familiar problems such as overfishing (Brander 2008) and adapt Code of Conduct for Responsible Fisheries (FAO 2007).

Cultivation of Sea Plants

Sea plants are excellent carbon sequestration agents and many of them sequester at a rate better than their terrestrial counterparts (Zon 2005). CO_2 sequestration by the common sea plants such as the red algae *Gracilaria corticata* and *G.edulis*, brown alga *Sargassum polycystum* and the green alga *Ulva lactuca* has been qualified in laboratory studies in India by Kaladharan *et al.* (2008). The seaweed *Kappaphycus alvarezii* has been collected and experiments are in progress. Initial results suggest that the seaweed has good carbon sequestration potential (CMFRI, 2010).

Cultivation of Halophytes

In coastal areas and mudflats near the sea, where the salinity does not allow farming of the usual food crops, plants that grow and flourish those conditions are advocated. One such plant is the sea asparagus, *Salicornia*. The plant grows well with maximum yields in hot climates if the seeds are sown in cool season so as to reach maturity during the hot months, (*www.hindu.com/seta/2003/09/05.htm*).

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, and improve livelihood and economic output, and 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. In response to shifting fish population and species, the fishing sector 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. The relevance of active regional and international participation and collaboration to exchange information and ideas is being felt now as never before.

CONCERNS AND ADAPTIVE MECHANISMS

Uncertainties in Fish Availability and Supply

- i) Adapt Code of Conduct for Responsible Fisheries
- ii) Develop knowledge-base for climate change impact of fisheries and aquaculture
- iii) Predict medium and long term probabilistic production
- iv) Assess the adaptation capacity, resilience and vulnerability of marine production systems
- v) Adjust fishing fleet and infrastructure capacity
- vi) Consider the synergistic interactions between climate change and other factors such as fishing

New Challenges for Risk Assessment

- i) Consider increasing frequency of extreme weather events
- ii) Consider past management practices to evolve robust adaptation systems

iii) Identify and address the vulnerability of specific communities; consider gender and equity issues.

Complexities of climate change interactions into governance frameworks to meet food security objectives

i) Recognition of climate-related processes, and their interaction with others

ii) Action plans at national/regional level based on (a) Code of Conduct for Responsible Fisheries; (b) Integrated ecosystem-based fisheries and aquaculture management plans (c) framework for expansion of aquaculture (d) linkage among cross-sectoral policy framework such as insurance, agriculture, rural development and trade

Fisheries and aquaculture may be more vulnerable in conflicts with other sectors

i) Action plans should involve not only fisheries institutions/departments, but also those for national development planning and finance

ii) Sharing and exchange of information with other sectors

iii) Existing management plans for fisheries need to be reviewed by considering climate change

Financing climate change adaptation and mitigation measures

i) Fishermen, fish farmers, processors, traders and exporters should increase self protection through financial mechanisms

ii) Improving equity and economic access such as microcredit should be linked to adaptation responses

iii) Investment of infrastructure such as construction of fishing harbor, should consider climate change issues

iv) Financial allocation in national budget for risk reduction and prevention practices such as early warning systems and disaster recovery programmes and for relocation of villages from low lying area

v) Fiscal incentive for reducing the sector's carbon footprint and other mitigation and adaptation options

vi) Full potential of existing financial mechanisms has to adapt and mitigate the issue of climate change.

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