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Impact and Adaptation Options For Indian Marine Fisheries To Climate Change

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Introduction

With global warming, the waters of oceans are also warming up though there are considerable variations in different geographical regions and at different times. Warming has been more intense in surface waters, and there are evidences for deep water warming too. The world's oceans are also affected by changes in precipitation, wind and currents, which are 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 Indian Ocean monsoon will be affected by global warming. Other direct effects of warming on aquatic systems include changes in precipitation, evaporation, river flows, groundwater, lakes and sea levels (see Prasannakumar et al., 2009). These changes have altered the energy balance in the atmosphere, resulting in a warming effect.

Marine ecosystems are not in a steady state, but are affected by the environment, which varies on many spatial and temporal scales. Changes in temperature are related to alterations in oceanic circulation patterns that are affected by changes in the direction and speed of the winds that drive ocean currents and mix surface waters with deeper nutrient rich waters (Kennedy et al., 2002). These processes in turn affect the distribution and abundance of plankton, which are food for small fish.

Besides, the rising acidity levels in the seas as a result of the climate change have negative effect on coral reefs and calcium-bearing organisms. Global warming and the consequent changes in climatic patterns will have strong impact on fisheries with far-reaching consequences for food and livelihood security of a sizeable section of the population. The Food and Agriculture Organization (FAO) has pointed out that the responses of capture fisheries to climate change are fundamentally different from other food production systems (FAO, 2008). Unlike most terrestrial animals that constitute the livestock sector, aquatic animal species used for human consumption are poikilothermic, meaning their body temperatures vary according to ambient temperatures. Any change in habitat temperatures significantly influence their metabolism, growth rate, productivity, seasonal reproduction, and susceptibility to diseases and toxins, the report points out. This is likely to result in significant changes in fisheries' production in world oceans. The magnitude of impact would vary in different regions. For communities that heavily rely on fisheries, any decrease in the availability of fish will pose serious problems.

In the last six decades, marine fish production in India has increased from 0.5 million tonnes (m t) in 1950 to 3.9 m t in 2012. This trend is different from that of global decadal growth rate, which consistently decreased from the year 1970. However, there are several sustainability concerns that demand immediate as well as long-term solutions. Overcapacity of fishing fleet, overexploitation, pollution and habitat degradation are some of the factors that need to be addressed to sustain marine fisheries.

Long-term climate change will affect the ocean environment and its capacity to sustain fishery stocks and is likely to exacerbate the stress on marine fish stocks. The extent to which it will affect fisheries, in different regions and species, is however not yet clear. Productivity might increase or decrease significantly. Ecosystem boundaries may be displaced and species composition may change remarkably. Fisheries infrastructures may have to be displaced, at high cost. Fisheries lacking mobility (e.g. small-scale traditional fisheries) might suffer the most.

Impact on marine fish

Marine ecosystems are not in a steady state, but are affected by the environment, which varies on many spatial and temporal scales. Fish populations respond to the variation in different ways. As examples, during short term weather changes such as storms, fish may take refuge from rough conditions through minor changes in distribution. Interannual or El Niño scale changes in the ocean environment may result in changes in the distribution patterns of migratory fishes and can affect reproduction and recruitment in other species. Decadal and longer scale variations may have other impacts, potentially including cyclic changes in the production level of marine ecosystems in ways that may favor one species or group over another.

Temperature is one way we measure ocean variability, but temperature is also an indicator of more complex ocean processes. Changes in temperature are related to alterations in oceanic circulation patterns that are affected by changes in the direction and speed of the winds that drive ocean currents and mix surface waters with deeper nutrient rich waters. These processes in turn affect the abundance and variety of plankton which are food for small fish. The biological responses to those ocean processes are complex and not well understood.

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^{o}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.

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 (Vivekanandan, 2011): (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.

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. We have to find answers to several questions. What will be the influence of rising seawater temperature on the bombay duck, whose northern boundary is landlocked? The sex of sea turtles is critically determined by the soil temperature at which the embryo develops. Temperature above 28^{o} C produces only females. How the turtles would adopt to this crisis? Will there be species succession of phytoplankton with the domination of temperature tolerant species? Is the massive intrusion of pufferfish and medusae into the Indian coastal waters in recent years a fall out of climate change?

Future Research

Evolving models to understand impacts of climate change

In India, marine fish catch and effort data are available for the last five decades. However, a synergy between climatic and oceanographic data and fisheries data does not 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.

Biswas et al (2005) developed a method for forecasting of fish catch of the major fishing areas in the world oceans under higher temperatures. This method predicts the tendency (increase or decrease) for fish catch, with quantitative predictor's power, if the temperature is known. This method has been applied to the Indian Ocean to assess the climate-change impact on fish catch. Based on the temperatures predicted using the CLIMate-BiospheRE model for the years 2000–2100, a decrease of fish catch in the Indian Ocean, with the confidence of the predictor's power at ≥ 90%, has been predicted.

Cheung et al (2008, 2010) developed a new computer model that predicts what might happen under different climate scenarios to the distribution of commercially important species. Using a model that tracked a range of habitat conditions, including water temperature and depth from sea ice, to predict which habitats would be most impacted by climate change, they found that around 50 species of commercial fishes living near or at the poles will go extinct within the next 4 decades. Those species that can will try migrating toward the Arctic and Southern oceans or end up trapped in closed seas. While fisheries species in colder waters succumb to climate change, those living in tropical waters will be stresses by overfishing.

Mass-balance models – Ecopath, Ecosim and Ecospace

Many climate change impacts on individual populations will have cascading effects throughout the ecological communities in an ecosystem. The broad ecological impact of climate change can be estimated using the whole food web trophodynamic modelling suite Ecopath with Ecosim and Ecospace. This modelling tool has three complimentary modules (www.ecopath.org): (1) Ecopath is a static mass-continuity description, or accounting, of trophic flows i2n any given ecosystem and time period using biomass as a currency. It is a food web model in which all species in the system are aggregated into functional groups whose biomasses, production rates, consumption rates, physiological efficiencies, and diet compositions are estimated and specified, and includes flows to and from fisheries. (2) Ecosim uses information in Ecopath dynamically so that temporal changes in mortality or other physiological rates can be specified to simulate impacts of changes in fisheries exploitation or environmental changes, or both simultaneously. Ecosim allows physiological rates to be changed with climate change. (3) Ecospace enables the expression of Ecosim in a spatially-explicit form for the spatial exploration of biological impacts of an environmental or fisheries change. Ecospace can be used to explore impacts of changes in the distribution of biomasses of each functional group based on how they interact with each other spatially.

There are four approaches that are fruitful for characterising climate change impacts using the Ecopath with Ecosim modelling approach (Richardson and Okey, 2006): (1) constructing and balancing future Ecopath models using estimated biomasses and physiological rates for a future scenario, information from climate envelope and other biophysical models, and comparing the projected to the present day system; (2) producing a time series of fitting error terms that represent non-fisheries impacts (e.g. environmental change) for comparison to integrated ocean climate indicators; (3) forecasting change using Ecosim based on estimated responses of functional groups to particular scenarios of change; and (4) explicitly integrating functional response models within the Ecopath with Ecosim modeling approach.

However, Ecopath has not been extensively used for understanding the impact of climate change as it is not directly connected to hydrodynamic models.

Adaptation options for fisheries

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). 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 addressing the concerns arising out of climate change, and evolve adaptive mechanisms and implement action across all stakeholders at national, regional and international levels (Table 1; Allison et al., 2004; Handisyde et al., 2005; Leary et al., 2006; World Fish Center, 2006; FAO, 2008). In response to shifting fish population and species, the 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. Action plans at regional level need to be taken by

- strengthening regional organisations and place climate change agenda as a priority;
- addressing transboundary resource use; and
- evolving common platforms and sharing the best practices.

Action plans at international level also need to be taken by

- linking with mitigation activities;
- enhancing co-operation and partnerships; and
- applying international fishery agreements.

Table 1. Options for adaptation with climate change in fisheries and aquaculture (after Allison et al., 2004; Handisyde et al., 2005; FAO, 2008)

Concerns	Adaptive mechanisms
Uncertainties in fish availability and supply	i) Develop knowledge base for climate change and fisheries and aquaculture; ii) Predict medium and long term probabilistic production iii) Assess the adaptation capacity, resilience and vulnerability of marine production systems; iv) Adjust fishing fleet and infrastructure capacity; v) Consider the synergistic interactions between climate change and other issues such as overfishing and pollution
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; iv) consider gender and equity issues
Complexities of climate change interactions into governance of frameworks to meet food security	i) Recognition of climate-related processes, and their interaction with others; ii) Action plans at national level based on (a) Code of Conduct for Responsible Fisheries, (b) Integrated ecosystem approach to fisheries and aquaculture management plans, (c) framework for expansion of aquaculture, (d) linkage among cross-sectoral policy frameworks such as insurance, agriculture, rural development and trade iii) Action plans at regional level by (a) strengthening regional organizations and place climate change agenda as a priority, (b) addressing transboundary recourse use, (c) evolving common platforms and sharing the best practices iv) Action plans at international level by (a) linking with mitigation activities (b) enhancing co-operation and partnerships, (c) applying international fishery agreements

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 and aquaculture need to be reviewed and further developed 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 on infrastructure, such as construction of fishing harbour, should consider climate change; 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 areas; v) Incentive for reducing the sector's carbon footprint and other mitigation and adaptation options

Adopt Code of Conduct for Responsible Fisheries

Fishing and climate change are strongly interrelated pressures on fish production and must be addressed jointly. Moderately-fished stocks are likely to be more resilient to climate change impacts than heavily-fished ones. 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, some of the most effective actions which we can tackle climate impacts are to deal with the familiar problems such as overfishing (Brander 2008), and adapt Code of Conduct for Responsible Fisheries and Integrated Ecosystem-based Fisheries Management (FAO, 2007). In India, mechanisms for managing large-scale commercial fisheries such as total allowable catch (TAC) or total allowable effort (TAE) do not exist. Hence, it is a challenge to fully comply with the CCRF. The challenge becomes severe considering the poverty prevalent among 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 climate change, as their capacity to adapt is very limited. Effort to reduce dependence on fishing by these vulnerable communities is essential. It is essential to adopt Ecosystem-based Fisheries Management by integrating fisheries management into coastal areas management.

Understanding the Indigenous Technical Knowledge

Fishing communities have often developed adaptation and coping strategies to deal with fluctuating environmental conditions. Greater understanding of how communities cope with and adapt to fisheries with extreme natural variations would assist in developing adaptation strategies for climate change. Fishermen in India are generally able to track seasonal and spatial variations in fish stock availability and relate it to climatic and oceanographic variabilities. They are able to detect some of the variables such as speed and direction of wind and current, watermass movement and upwelling, and make short-term predictions on fish distribution, spawning and abundance. This knowledge enables them to switch their fishing activities with respect to species exploited, location of fishing grounds and gear used. Gaining an insight into this and advantageously use their ITK to evolve coping mechanism will be useful.

Develop knowledge-base for climate change and marine fisheries

Considerable effort should be made for gathering historic 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 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. These programmes should develop fisheries models and lead into risk assessment of future fish stock variations and likelihood of resource collapses; and evolving sectoral and food security plans.

Climate change risk assessments

It is important to conduct climate change risk assessments estimate the cost of adaptation of fisheries sector under different climate scenarios. The current and future risks and mechanisms within communities may be identified. The communities should be engaged together with governmental and non-governmental agencies in preparedness planning.

In India, 458 (of the total 2132) coastal fishing villages with a population of one million are located within 100 m from the high tide line (CMFRI, 2009). Risk reduction initiatives such as early warning systems, disaster recovery programmes and reducing risk exposure by enhancing coastal defences are in place. Along the east coast where storms and floods are relatively regular, the governments take preparative action and organize sufficiently to relocate the people temporarily and to restore key services and economic functions. Fishermen receive up-to-date weather forecasts and weather warnings through television, radio and print media, thereby reducing the number of vessels caught at sea by cyclones. Along 400 km of Kerala's 590 km coastline, coast protection structures such as sea walls and gyrones are in place. However, coastal communities often complain incursion of sea through the open, undefended coast. Cost- effective engineering solutions for conservation of erodable shorelines to prevent damage to properties and human life need to be put in place. Risk reduction plans concerning coastal and flood defences should be linked with disaster management.

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. Resilience of fishing communities needs to be enhanced by supporting existing adaptive livelihood strategies. The relative risk of climate change also needs to be understood in the context of impacts on other hazards such as poverty, food insecurity, epidemic diseases, inequity and intrasectoral conflicts.

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 cannot do much to mitigate climate change, it could contribute to reduce the impact by following effective adaptation measures.

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