CHAPTER 31

# IMPACT OF CLIMATE CHANGE ON MARINE SECTOR

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Climate over the Earth is showing perceptible changes over both global and regional scales and the warming effects are now being felt across many parts of the world including India (Vivekanandan, 2010). Human activities are increasing the levels of carbon dioxide and other greenhouse gases in the atmosphere leading to a rise in atmospheric temperature. Since the year 1750, the level of atmospheric $CO_2$ has risen from 280 ppm to 401 ppm in 2015, and if unchecked, will be at around 560 ppm by the year 2050.

Climate change is one of the most important global environmental challenges with implications on food production including fisheries and aquaculture sector, natural ecosystems, freshwater supply, health, *etc*. Climatic scenarios generated by computer models shows that India could experience warmer and wetter conditions as a result of climate change including an increase in the frequency and intensity of heavy rains and extreme weather events (EWEs). The effects of climate change in aquatic ecosystems can be direct, through rise in sea surface temperature (SST), and associated changes in the phenology of the organisms, or indirect *i.e*., through ocean acidification, through shifts in hydrodynamics and rise in sea level. Climate change will intensify by 2050 and though climate outcomes cannot be precisely predicted, the probability towards greater impacts of climate challenge is becoming clearer.

## How does the ocean affect the climate ?

The oceans play an important role in regulating climate as its heat uptake capacity is approximately 1000 times larger than the atmosphere. The world ocean has warmed substantially since 1955 and warming account for 80% of the change in energy content of the Earth's climate system (Cochrane, 2010). These deviations from normal surface temperatures can have large-scale impacts not only on ocean processes, but also on global weather and climate.

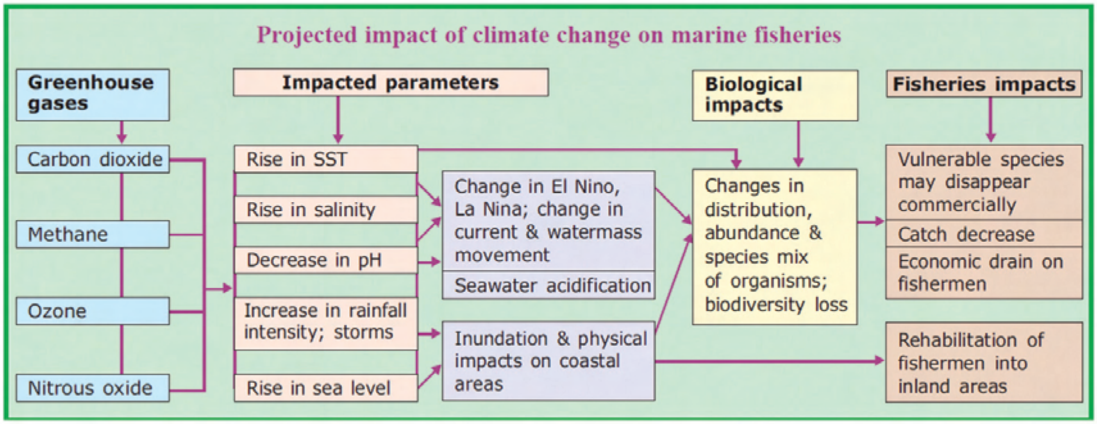
Impact on Climatic and Oceanographic Parameters

- Changes in the important oceanic weather systems such as sea surface temperature, pH, salinity, El Niño Southern Oscillation (ENSO), precipitation, sea level, frequency and intensity of cyclones and droughts are becoming evident as a result of climate change.

- El Niño-Southern Oscillation (ENSO) cycle, describes the fluctuations in temperature between the ocean and atmosphere in the east-central Equatorial Pacific.
- La Niña is the cold phase of ENSO and El Niño as the warm phase of ENSO

**Climate change impact on coastal fisheries and aquaculture**

World's Oceans are currently affected by global warming with likely impacts in changes in ocean currents and winds, precipitation, ocean acidification *etc*. which will have strong impact on fisheries with serious consequences on food and livelihood security of considerable section of the population. In India marine fisheries have very important roles in augmenting food supply, nutritional security and livelihood for millions. With the major share of marine fish catch coming from coastal and near-coastal waters, environmental change in this zone would have debilitating impact on the sector in specific and the country's food basket in general.




o Source: Vivekanandan E. CMFRI Newsletter No.112. October-December 2006

**Climate change on fishery habitat**

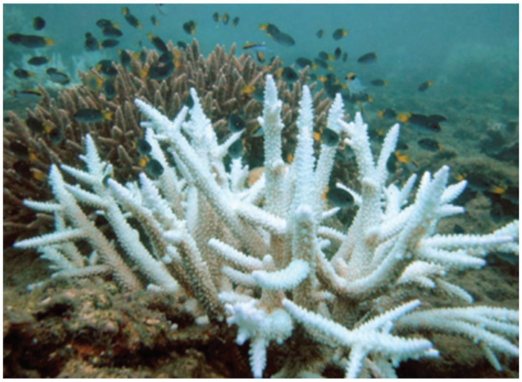
Marine ecosystems are not in a steady state, but are affected by the environment, which varies on many spatial and temporal scales. Fish populations respond to variation in different ways. Decadal variations may have unforeseen impacts, including cyclic changes in the production level of marine ecosystems that favor one species or group over another.

***Sea surface Temperature (SST) increase:*** Temperature is likely the single most important factor affecting the growth and development of aquatic organisms. Earth has been in radiative imbalance since at least the 1970s, where less energy leaves the atmosphere than enters it. Most of this extra energy (~90%) has been absorbed by the oceans (IPCC,2014). The variation of Sea surface Temperature (SST) along Indian seas during the 40 years from 1976 to 2015 revealed that SST increased by 0.602°C along the northeast India (NEI), by 0.597°C along the northwest India (NWI), by 0.690°C along the southeast India (SEI) and by 0.819°C along the southwest India (SWI). However, the rate of change in SST was highest in northwest India (0.0156/annum) followed by southwest India (0.0132/annum), southeast India (0.005/annum) and northeast India (0.001/annum) respectively. The rate of change in SST over Indian Seas revealed that west coast has more impact than in the east coast of India. Northern Indian Ocean has been identified as one of the 17 climate change hotspots among world oceans. These areas will warm faster than 90% of the world oceans. Long-term climate change is likely to impact the marine environment and its capacity to sustain fish stocks and exacerbate stress on marine fish stocks.

***Ocean acidification*:** The ongoing reduction in the pH of the Earth's oceans presents a significant challenge to the survival of marine fish. Seawater, by absorbing carbon dioxide and forming carbonic acid, is slowly dropping in pH from its natural, slightly basic state towards pH neutral conditions. The pH of the oceans has dropped to around 8.069 from a pre-industrial age state of 8.179. A total change of -0.355, to 7.824 by 2100 has been estimated by various studies.

Studies indicated an increasing trend in the annual number of instances when pH of surface waters off Kochi was less than 6. Analysis of the instances of low pH values of surface waters in three depth zones *viz*., 10m, 20m and 30m during the period 2005 to 2012 has indicated that in the year 2012, pH of surface water at 10m depth zone was low for a considerably longer period than in the previous years (CMFRI-NICRA, 2013).

***Coral bleaching*:** Warmer water temperatures can result in coral bleaching that resulting in the expulsion of the symbiotic zooxanthellae from the tissues of coral. Between 1979 and 1990, sixty major episodes of coral bleaching were recorded, and in 2016 the longest coral bleaching event on record was observed. Several studies relate bleaching events with global warming and climate change during the last few decades (Lix *et al*., 2016), and 70% of the reports of coral bleaching at that time were associated with reports of warmer than normal conditions (Glynn, 1991).



Observations on bleaching events have shown that individual species respond differently to this change in thermal environment, with higher degrees of mortality typically seen in branching corals such as *Acropora*(Mohanty *et al*., 2013). Successive bleaching events could lead to a reduction in the species richness of corals in certain global warming hotspots.

Coral reef ecosystems support a great diversity of benthic organisms, of which zoanthids, commonly found among degraded reef ecosystems, compose the dominant fauna in the rocky intertidal regions. On the Saurashtra coast, in Gujarat, studies carried out on the distribution and community structure of Zoanthids indicated higher adaptive capacity to changes in environmental and abiotic conditions in comparison to their counterparts. Coral reefs continue to suffer due to high nutrients inputs, bleaching and other anthropogenic activities, leading to shift in reef pattern towards more aggressive and rapidly growing benthic communities such as zoanthids (Kumari *et al.,* 2015).

***Sea level rise*****:** Sea level rise at long time scales is mainly due to thermal expansion and exchange of water between the other reservoirs (glaciers, ice caps, *etc.*) including through anthropogenic change in land hydrology and the atmosphere. The global average sea level rose at an average rate of 1.8 mm per year over 1961 to 2003. Additionally the rate of rise accelerated during 1993 to 2003, to 3.1mm per year. The total 20$^{th}$century rise is estimated to be 0.17 m. The movement of the saltwater/freshwater interface further inland will cause reduction and extinction of estuarine associated habitats that are common nesting and breeding grounds for a wide variety of marine fish.

Sea-level rise estimates for the Indian coast are between 1.06–1.75 mm per year, with a regional average of 1.29 mm per year, when corrected for GIA using model data (Unnikrishnan and Shankar, 2007). These estimates are consistent with the 1–2 mm per year global sea-level rise estimates reported by the IPCC. Northern Indian Ocean has been identified as one of the 17 climate change hotspots among the world oceans (Hobday *et al.*, 2008). These areas are recognised to warm faster than 90% of the oceans. These regions are expected to provide the potential for early warning and evidence of the response by natural resources to climate change. A one metre sea level rise is projected to displace approximately 7.1 million people in India and about 5,764 km2 of land area will be lost, along with 4,200 km of coastal roads (Ministry of Environment and Forests, 2004). Approximately 30% of India's coastal zones will be subjected to inundation risk with sea level rise and intensified storm surges (Dasgupta *et al.*, 2009).

***Changes in wind speed and direction*****:** As winds are generated by differences in temperature, rising surface temperatures on the earth's surface are causing winds worldwide to slow dramatically. Reductions in wind speed by 1-3% are expected over the next 50 years, and as high as 4.5% over the next 100 years.

***Changes in rainfall*****:** Changes in average precipitation, potential increase in seasonal and annual variability and extremes are likely to be the most significant drivers of climate change in aquatic systems. Analysis of historical rainfall data in the Andaman and Nicobar islands revealed that while there has been no change in the amount of rainfall received, the patterns of rainfall have changed with increase in number of extreme rainfall events.

Variations in annual rainfall intensity, dry season rainfall and the resulting growing season length are likely to create impact on shrimp/ fish farming and could lead to conflict with other agricultural, industrial and domestic users in water scarce areas.

**Impact on fish stock**

A metabolic increase of 10% corresponds to a 1°C increase in temperature, implying of seawater as low as 1°C could affect the distribution and life processes of fish. This constraint in physiology will result in changes in distributions, recruitment and abundance. Changes in timing of life history events 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.

Changes in timing of life history events are also likely to result from the warming of the Earth's waters. Many tropical fish stocks are already exposed to high extremes of temperature tolerance, and already face regional extinction, and some others may move towards higher latitudes. Shifts in spawning periods of fishes have already been observed in a number of commercially important fish stocks, such as threadfin bream (Zacharia *et al.*, 2016). Changes in distribution patterns of two key species in Indian fisheries have already been established- migration patterns of the Indian oil sardine and Indian mackerel have changed greatly over the past 50 years (Vivekanandan *et al.*, 2009).

Ocean-atmospheric coupled climate models predict changes in the ocean circulation and hypothesize that changes in the ocean circulation will stimulate phytoplankton biomass production in the nutrient depleted areas in the open ocean. The effect on atmospheric $CO_2$ is uncertain because the relationship between the enhanced primary production and air sea exchange of $CO_2$ is not understood.

Most models show decreasing primary production with changes of phytoplankton composition to smaller forms, although with high regional variability. Marked effects in plankton distribution have also been noticed concurrent to changes in sea surface temperature. These changes may affect the distribution of fish stocks that predate on plankton. Ocean acidification is believed to have negative consequences for marine denizens, particularly calcifying organisms, subjecting them to the risk of dissolution. A decline in primary productivity has also been forecast.

## Impact on fish stock availability

Evidence exists for increasing damage by extreme weather events, particularly cyclones, over time. There are various explanations for this, ranging from greater population densities to the wider effects of climate change (IPCC, 2013).

Until the mid-1980s, the restricted distribution of oil sardine ensured that the entire catch of oil sardine was obtained from the southwestern coast of India. North of 14°N, little to no oil sardine was caught previously. In the last two decades, however, the oil sardine catch from 14°N to 20°N has gradually and consistently increased, contributing 15% to the all-India oil sardine catch by 2006 (Vivekanandan *et al*., 2009). Since the catch in the Southwestern regions has not decreased in overall terms, this represents an extension of the distributional boundaries of the oil sardine.

Studies on the seasonal distribution of skipjack tuna reveal that during winter months, when sea surface temperature is lower, migration occurs towards offshore areas, and during warmer months, migration occurs towards inshore areas during warmer months. Changes in sea surface temperature due to global warming could result in changes in the seasonal distribution of certain species, and ultimately disruption in their harvest, which is usually based on indigenous knowledge (Zacharia *et al*., 2016). Changes in distributional boundaries also bear the potential to bring up delicate questions of fishing rights, especially within the context of geopolitics and exploitation of the resources found within neighbouring exclusive economic zones.

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