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Climate Change

# An overview of climate change impact in fisheries and aquaculture

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**General Note**
Article is recommended to print as color version in recycled paper. *Save Trees, Save Climate*.

## ABSTRACT
Fish can play a major role in satisfying the palates of the world's growing middle income group while also meeting the food security needs of the poorest. Already, fish represents 16 percent of all animal protein consumed globally. Coastal communities will be among the first to be impacted by changes in the oceans due to climate change. Changes in the oceans will include a rise in the sea level, which directly affects habitability of the coastline, and rising water temperature and ocean acidification, which affect productivity of local fisheries and the health of marine life and ecosystems. Small pelagic fisheries collapse to affect reduction industry (fishmeal and fish oil production) can be implemented to analyze the impact on aquaculture production that is dependent

on fishmeal and fish oil as input. Climate change also affects aquaculture production, and impacts of climate change on both capture fisheries and aquaculture and their interactions on global fish markets.

**Keywords:** Aquaculture, Climate change, Impact, Fisheries- Food security

## 1. INTRODUCTION

Fish has been an important part of the human diet in almost all countries of the world. It is highly nutritious; it can provide vital nutrients absent in typical starchy staples which dominate poor people's diets (FAO, 2005; FAO, 2007). Fish provides about 20 % of animal protein intake (Thorpe *et al*., 2006) and is one of the cheapest sources of animal proteins as far as availability and affordability is concerned. While it serves as a healthy food for the affluent world owing to the fish oils rich in polyunsaturated fatty acids (PUFAs), for the people in the other extreme of the nutrition scale, fish is a healthy food owing to its proteins, oils, vitamins and minerals and the benefits associated with the consumption of small indigenous fishes (Mohanty *et al*., 2010 a).

The main elements of climate change that could potentially impact on aquaculture production – are sea level raise in temperature rise, change in monsoonal rain patterns, extreme climatic events and water stress. The most notable and significant changes associated with climate change are the gradual rise of global mean temperature (e.g. Zwiers and Weaver, 2000) and a gradual increase in atmospheric green house gases (Brook, Sowers and Orchardo, 1996), both of which have been aptly synthesized and documented (IPCC, 2007). Impacts of climate change on aquaculture could occur directly and or indirectly and not all facets of climate change will impact on aquaculture. Aquaculture practices, as in any farming practice, are defined in space, time and size and have a fair degree of manoeuvrability.

## 2. IMPACTS

Climate change will have significant impacts on fisheries and aquaculture. At low latitudes these are likely to be largely negative for fisheries, damaging important ecosystems such as coral reefs and mangroves and causing reductions in fish stocks due to rising water temperatures and reduced primary production. This could have significant effects on food security and employment in areas dependent on fisheries that are particularly vulnerable to the impacts of climate change; these include reef fisheries, fisheries in shallow lakes or wetlands and fisheries in other enclosed or semi-enclosed bodies of water. Climate changes may affect fisheries and aquaculture directly by influencing fish stocks and the global supply of fish for consumption, or indirectly by influencing fish prices or the cost of goods and services required by fishers and fish farmers. Physical changes include sea surface temperature rise, sea level rise, changes in salinity and ocean acidification. Biological changes include changes in primary production, and fish stock distribution. These factors when combined together will have adverse impacts on the already strained resource.

### Sea level rise

Rise in sea level will be associated with global warming. Sea level increases will profoundly influence deltaic regions, increase saline water intrusion and major biotic changes. Higher sea levels may lead to salinization of groundwater, which is detrimental to freshwater fisheries, aquaculture and agriculture and limits industrial and domestic water uses. Therefore, sea level rise is very likely going to have a negative impact on fishery production (due to salt stresses on the fish stock and its habitat) and fish landing, processing and marketing facilities.

### Changes in monsoons and occurrence of climate change events

Occurrence of climate extreme change events such as floods, changes in monsoonal rain patterns (Goswami *et al*., 2006).

### Changes in ocean productivity and circulation patterns

This changes will impact on individual fisheries and other planktonic plant and animal group biomasses and changes in food webs.

### Changes in hydrological regimes in inland waters

Atmospheric warming is likely to bring about changes that could impact on aquaculture activities in both lentic and lotic waters.

**Temperature**

Temperature may influence in both ways i.e., positively or negatively. It increases the growth rate, thus it would increase the per unit area production but temperature above 30° C results in slow feeding and slow the growth rate (McCauley and Beitinger, 1992). It will enhance Net Primary Productivity (NPP) to benefit production of filter feeders. It is predicted that it may lower natural winter mortality. Rising temperatures similarly reduce levels of dissolved oxygen and increase metabolic rates of fish, leading to increases in fish deaths, declines in production or increases in feed requirements while also increasing the risk and spread of disease (FAO, 2008a).

**Increasing Water Salinity**

Climate change can cause an increase or decrease in water salinity in multiple ways. Changes in water salinity have different effects depending on the tolerance level of the organisms and the nature of their ecosystem – whether freshwater, marine or estuarine. The salinity of some freshwater ecosystems are predicted to increase as a result of anthropogenic climate change (IPCC, 2001). Such physical changes will negatively impact the population of both plankton and bigger prey fish species by affecting the organisms' ability to osmoregulate (Schallenberg et al., 2003).

**Ocean Acidification**

Oceans are believed to have the capacity to absorb most of the anthropogenic $CO_2$ emissions (Caldeira and Wickett, 2003). $CO_2$ is soluble in water and reversibly converts to carbonic acid. As a result of this chemical reaction, the world's oceans are acidifying at an alarming rate (Dupont and Thorndyke, 2009). While this has a positive impact in slowing down global warming, increased acidity as a result of dissolved $CO_2$ in seawater has negative a impact on ocean ecosystems. The impact to the ecosystem is difficult to estimate as different species at different stages of life history respond differently to different pH changes. Quantifying the effects of ocean acidification on human communities requires assessing the direct and indirect chemical impacts on valuable marine ecosystem services such as fisheries (Cooley *et al*., 2011). According to Le Quesne and Pinnegar (2011), direct effects include changes in physiological processes such as reduced growth of calcified structures, otolith development, and fertilization success. These may ultimately lead to direct impacts at the whole-organism level, including reduced growth and reproductive output, increased predation and mortality, alteration in feeding rates and behavior, reduction in immunocompetence and reduced thermal tolerance. Indirect effects include alteration in predator or pray abundance, effects on biogenic habitats such as coral reefs, and changes in nutrient recycling.

**Fishmeal and fish oil supplies**

The most obvious and most commonly discussed indirect impact of climate change on aquaculture is related to fishmeal and fish oil supplies and their concurrent usage in aquaculture. Tacon, Hasan and Subasinghe, (2006) estimated that in 2003, the aquaculture sector consumed 2.94 million tonnes of fishmeal globally (53.2 percent of global fishmeal production), considered to be equivalent to the consumption of 14.95 to 18.69 million tonnes of forage fish/trash fish/low valued fish, primarily small pelagics.

The impacts on biodiversity from alien species have mostly resulted from competition for food and space with indigenous species (e.g. Soto *et al*., 2006), alteration of habitats (e.g. Collares-Pereira and Cowx, 2004), the transmission of pathogenic organisms as well as through genetic interactions such as hybridization and introgression (Dowling and Childs, 1992; Leary, Rhymer and Araguas *et al*., 2004) and other indirect genetic effects (Waples, 1991).

**Alteration in Supporting Ecosystems**

Some important marine ecosystems such as mangroves, sea grass, coral reefs are hugely under stress due to habitat destruction by human interference, pollution etc., so climate change may add more stress into it and may completely bring the structural and behavioural change in the ecosystem. Lakshmi, A. & Ramaya, R. (2009) has reported that climate change is also expected to increase the number of extreme events such as tropical cyclones.

Consequently, any increase and/or decrease in the temperature of the habitats would have a significant influence on general metabolism and hence the rate of growth and therefore total production; reproduction; seasonality and even possibly reproductive efficacy (e.g. relative fecundity, number of spawnings (Wood and McDonald, 1997); increased susceptibility to diseases and even to toxicants (Ficke, Myrick and Hansen, 2007). Sea temperature rise in tropical and subtropical regions would result in increased rate of growth and hence in overall production. The predicted temperature rise itself will be within the optimal ranges for most species cultured in such waters (marine, brackish and/or fresh water) and therefore global warming could impact positively on the bulk of aquaculture production. Most of that production was based on feed, the major ingredients of which were fishmeal and fish oil. Feed management in salmonid culture is probably the most efficient of all aquaculture practices; however, the high degree of dependence on fishmeal and fish oil becomes a very pertinent issue under most climate change scenarios. Climate change is predicted to increase global acidification (Hughes *et al.*, 2003; IPCC, 2007).

Impact on coral formation, there is the possibility that increased acidification could impede calcareous shell formation, particularly in molluscs, an effect perhaps exacerbated by increased water temperature and thereby to have an impact on mollusc culture. Nevertheless, if coastal plankton productivity is enhanced by higher temperatures and provided that nutrients are available, there may be a positive effect on the farming of filter feeders. However, increased temperatures associated with eutrophication and harmful algal blooms (Peperzak, 2003) could enhance the occurrence of toxic tides and consequently impact production, and also increase the possibilities of human health risks through the consumption of molluscs cultured in such areas. Sea level rise over the next decades will increase salinity intrusion further upstream of rivers and consequently impact on fresh water culture practices. Adaptive measures would involve moving aquaculture practices further upstream, developing or shifting to more salinity tolerant strains of these species and/or to farming a saline tolerant species. Such shifts are going to be costly and will also impact on the socio-economic status of the communities involved.

**Changes in Primary Production**

The relationship between climate change and future ocean primary production is likely to be a key constraint on fish and fisheries production (Dulvy et al., 2010). Survival of fish larvae during the planktonic stage is thought to depend strongly on the availability of sufficient and suitable food. Therefore, in addition to effects of changes in production, climate induced changes in distribution and phenology of fish larvae and their prey can also affect recruitment and production of fish stocks (Brander, 2007). A rise in surface-water temperature coupled with a regional decrease in wind velocity has increased the stability of the water column restricting mixing and deep-water nutrient upwelling and entertainment into surface waters (O'Reilly et al., 2003). Even though there are multiple factors that affect primary production in aquatic environment, one of the main factors is surface temperature rise. O'Reilly et al. (2003) suggest that if air temperature increases by about 1.7 degrees, as predicted for the next 80 years, there will be further increases in thermal stability and reductions in productivity.

**Changes in Fish Distribution**

Change in fish distribution is among the most commonly reported ecological responses of marine species (Sumaila et al., 2011). Fish species are believed to respond to environmental changes such as warming water temperatures by shifting their latitudinal and depth ranges. Changes in ocean dynamics could lead to changes in migration patterns of fish and possibly reduce fish landings, especially in coastal fisheries.

**Carbon sequestration**

Carbon sequestration one of the major causative factors of climatic change, is the process through which agriculture and forestry practices remove atmospheric carbon dioxide, Forestation, reforestation and forest preservation are considered to be favourable practices that sequester and/or preserve carbon and all help alleviate climate change by enhancing carbon storage (Lal, 2004; Miller, 2008; Mangala De Zoysa and Makoto Inoue, 2017; Ram Asheshwar Mandal et al. 2017).

Changes in ocean currents as well as having a substantial influence on the world climate may have significant direct effects on aquaculture through changes in temperature, primary productivity and hence food availability, and distribution of disease toxic algal blooms and predators (Handisyde *et al,* 2008). The vulnerability of fishery and aquaculture to climate change is complex, reflecting a combination of all factors associated with production.

**Carbon footprints of fisheries and aquaculture**

Greenhouse gas contributions of fisheries, aquaculture and related supply chain features are small when compared with other sectors but, nevertheless can be improved, with identifiable measures already available. In many instances, climate change mitigation could be complementary to and reinforce existing efforts to improve fisheries and aquaculture sustainability (e.g. reducing fishing effort and fleet capacity in order to reduce energy consumption and carbon emissions and reducing fishmeal reliance in aquaculture) There may also be important interactions for the sector with respect to environmental services (e.g. maintaining the quality and function of coral reefs, coastal margins, inland watersheds), and potential carbon sequestration and other nutrient management options, but these will need further research and development (R & D). The sustainable use of genetic diversity, including through biotechnologies, could have particular efficiency impacts (e.g. through widening production scope of low-impact aquaculture species, aquaculture systems, or making agricultural crop materials or waste products usable for growing carnivorous aquatic species) but would need to be evaluated on wider social, ecological and political criteria.

**Adaptation and Mitigation**

Adaptation means considering in advance what changes may occur and taking those changes into account in short-term decision making and long-range planning. Adaptation is an active set of strategies and actions taken by peoples in response to, or in anticipation to the change in order to enhance or maintain their well being. Hence adaptation is a continuous stream of activities, actions, decisions and attitudes that informs decisions about all aspects of life and that reflects existing social norms and processes (Daw et al., 2009).

Mitigation in this context means reducing the rate of climate change, and is a politically difficult subject that has completely dominated public discourse on climate change. Mitigation solutions reducing the carbon footprint of Fisheries and Aquaculture will require innovative approaches. One example is the recent inclusion of Mangrove conservation as eligible for reducing emissions from deforestation and forest degradation in developing countries, which demonstrates the potential for catchment forest protection. Other approaches to explore include finding innovative but environmentally safe ways to sequester carbon in aquatic ecosystems, and developing low-carbon aquaculture production systems

**Fisheries and Aquaculture in a Changing Climate**

Fisheries and fisher folk may have the impact in a wide range of ways due to climate change. The distribution or productivity of marine and fresh water fish stocks might be affected owing to the processes such as ocean acidification, habitat damage, changes in oceanography, disruption to precipitation and freshwater availability (Daw et al., 2009). Climate change, in particular, rising temperatures, can have both direct and indirect effects on global fish production. With increased global temperature, the spatial distribution of fish stocks might change due to the migration of fishes from one region to another in search of suitable conditions.

Rising ocean temperature and ocean acidification is radically altering aquatic ecosystems. Climate change is modifying fish distribution and the productivity of marine and freshwater species. This has impacts on the sustainability of fisheries and aquaculture, on livelihoods of the communities that depend on fisheries, and on the ability of the oceans to capture and store carbon (biological pump). The effect of sea level rise means that coastal fishing communities are in the front line of climate change, while changing rainfall patterns and water use impact on inland (freshwater) fisheries and aquaculture (Harley 2006; Shyam S Salim et al. 2017).

| | Effects | Implication for fisheries and aquaculture |
|---|---|---|
| Changes in sea surface temperature | More frequent harmful algal blooms; Less dissolved oxygen; Increased incidence of disease and parasites; Altered local ecosystems with changes in competitors, Changes in plankton composition | For aquaculture, changes in infrastructure and operating costs from worsened infestations of fouling organisms, pests, nuisance species and/or predators. For capture fisheries, impacts on the abundance and species composition of fish stocks |
| | Longer growing seasons; Lower natural mortality in winter; Enhanced metabolic and growth rates. | Potential for increased production and profit, especially for aquaculture. |
| Rising sea level | Loss of land. | Reduced area available for aquaculture.<br>Loss of freshwater fisheries. |
| | Changes to estuary systems. | Shifts in species abundance, distribution and composition of fish stocks |
| | Salt water infusion into groundwater | Damage to freshwater capture fisheries.<br>Reduced freshwater availability for aquaculture and a shift to brackish water species. |
| Higher inland water temperatures | Increased stratification and reduced mixing of water in lakes,<br>reducing primary productivity and ultimately food supplies for fish species | Reductions in fish stocks. |

| | | |
|---|---|---|
| | Reduced water quality, especially in terms of dissolved oxygen;<br>Changes in the range and abundance of pathogens, predators and competitors; Invasive species introduced. | Altered culture species and possibly worsened losses to disease and possibly higher capital costs for aeration equipment or deeper ponds |
| | Changes in timing and success of migrations, spawning and peak abundance. | Potential loss of species or shift in composition for capture fisheries; Impacts on seed availability for aquaculture. |
| Changes in precipitation and water availability | Changes in fish migration and recruitment patterns. | Altered abundance and composition of wild stock.<br>Impacts on seed availability for aquaculture |
| | Lower water availability for aquaculture.<br>Altered and reduced freshwater supplies with greater risk of drought. | Higher costs of maintaining pond water levels and from stock loss.<br>Reduced production capacity.<br>Conflict with other water users |
| | Changes in lake and river levels and the overall extent and movement patterns of surface water. | Altered distribution, composition and abundance of fish stocks.<br>Fishers forced to migrate more and expend more effort. |
| Drought | Lower water quality and availability for aquaculture. Salinity changes. | Loss of wild and cultured stock.<br>Increased production costs. Loss of opportunity as production is limited. |

**Other effects**

Increased frequency of extreme weather events will affect the safety of fishers, damage homes, services and infrastructure, particularly in coastal areas (IPCC, 2007a) and will also damage many coastal ecosystems. The depletion of fishery resources is happening mainly due to anthropogenic factors such as overfishing, habitat destruction, pollution, invasive species introduction, and climate change. Fisheries and aquaculture need specific adaptation and mitigation measures like: improving the management of fisheries and aquaculture as well as the integrity and resilience of aquatic ecosystems; responding to the opportunities for and threats to food and livelihood security due to climate change impacts; and helping the fisheries and aquaculture sector reduce GHG emissions.

## 3. THE IMPLICATIONS OF CLIMATE CHANGE

The implications of climate change affect the four dimensions of food security:

1. **Availability** of aquatic foods will vary through changes in habitats, stocks and species distribution;
2. **Stability** of supply will be impacted by changes in seasonality, increased variance in ecosystem productivity and increased supply variability and risks;
3. **Access** to aquatic foods will be affected by changes in livelihoods and catching or farming opportunities; and
4. **Utilization** of aquatic products will also be impacted and, for example, some societies and communities will need to adjust to species not traditionally consumed.

Fisheries conservation in light of climate change means (1) reducing stress on the already strained fishery resources, (2) allowing fish species to adapt and settle successfully, and (3) enhancing the adaptive capacity and resilience of fisher communities. The implications of climate change for these sectors for coastal communities in general are difficult to ignore (Barange and Perry, 2010). Climate change poses significant threats to fisheries on top of many other concurrent pressures such as overfishing, habitat degradation, pollution, introduction of new species and so on (Brander, 2010). Globally, relative to the level that would support maximum sustainable yield, 20 % of targeted fishery resources are moderately exploited, 52 % are fully exploited with no further increases anticipated, 19 % are overexploited, 8 per cent are depleted and 1 % are recovering from previous depletion (FAO, 2009). Changes in biophysical characteristics of the aquatic environment and frequent occurrence of extreme events will have significant effects on the ecosystems that support fish.

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