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Impact of climate change on fisheries and aquaculture and vice versa

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Abstract
The wild population of commercially important freshwater prawns (*M. rosenbergii, M. malcolmsonii* and *M. gangeticum*) of India have been declined over the period of time due to overexploitation, habitat degradation and pollution. Moreover, these endemic species have been replaced with L. vennamei in prawn farming industry which may further lead to the extinction of these valuable species. The current biological study of these three species will help researchers and academicians to understand their life history and other biological details which in turn will help in their sustainable management and conservation

Keywords: Aquaculture, global warming, water stress, temperature tolerance, disease, biodiversity.

Introduction
Human's relentless pursuit of material comfort and 'luxurious life' has engendered an irreversible harm to the environment – statements such as these abound environmental magazines, newspapers and the rest of the media. Hardly a day passes without us having to hear such words as "catastrophe", "natural disaster", "crisis", etc. in the media. We hear of calving of ice bergs in Greenland and flash floods in the American Southwest and Australia. We also hear apocalyptic predictions made by scientists, environmentalists and even the laymen about the coastal cities getting inundated by the sea. In a country like India where seventy percent of the population is dependent on agriculture and allied sectors, it is imperative that the effects of such drastic changes in environment are studied. Also, it is equally important that we rely more on scientifically proven facts about global climate changes rather than mere conjectures and exaggerations. It is known that climate change is affecting agriculture in many ways. A lot of studies have been carried out by agriculturalists, scientists and economists on the adverse effects of climate change. In India, agriculture and allied activities constitute the single largest component of Gross Domestic Product (GDP) contributing nearly 25% of the total. The tremendous importance of this sector to the Indian economy can be ganged by the fact that it provides employment to two-thirds of the total workforce. The share of agricultural products in exports is also substantial, with agriculture accounting for 15% of export earnings. Agricultural growth also has a direct impact not only on poverty eradication, but also in employment generation. Further, Indian agriculture is fundamentally dependent on weather/monsoon season/rain for higher productivity. The proof of this has been the increasing trend in agricultural production, owing to good monsoons over the last few years.

The above facts emphasize the need not only to study in detail the climate change vulnerability of fisheries & aquaculture but also the methods of improving the adaptive capacity of agriculture to climate variability and extremes.

Climate Change
Evidence is gathering that human activities are responsible for climate change. This climate change could have a huge impact on our lives. Here are some grim aspects of climate change. Sea levels are expected to rise by at least 40 cm by 2100, inundating vast areas, including some of the most densely populated cities. A Global temperature has risen by 0.6^0C in the last 130 years. The rise in global temperatures lead to huge impact on a wide range of climate related factor. Levels of carbon dioxide, methane and nitrous oxide gases are rising, mainly as a result of human activities. Carbon dioxide is being dumped in the atmosphere at an alarming

rate. Since the industrial revolution, humans have been pumping out huge quantities of carbon dioxide, raising carbon dioxide concentrations by 30%. The burning of fossil fuels is partly responsible for its huge increase. U.S, China, Russia, Japan and India are the leading emitters of carbon dioxide @ 5.9, 4.7, 1.7, 1.3, and 1.1 CO_2 emissions (in billion tonnes) respectively.

Table 1: Predicted effects of Climate change on agriculture/aquaculture in India over the next 50 years.

Climatic Element	Expected Change By 2050	Confidence In Prediction	Effect on Agriculture/ Aquaculure
Co_2	Increase From 360 Ppm To 450-600 Ppm	Very High	• Good for Crops Increased Photosynthesis • Reduced Water Use
Sea Level Rise	Rise By 10-15 Cm	Very High	• Loss of Land Coastal Erosion • Flooding • Salinazation of Ground Water
Temperature	Rise By 1-2ºc Increased Frequency of Heat Waves	High	• Faster, Shorter Earlier Growing Seasons • Heat Stress Risk • Increased Evapotranspiration
Precipitation	Seasonal Changes By +- 10%	Low	• Impacts on Drought • Risks Soil Workability • Water Logging
Storminess	Increased Wind Speeds, Especially in North. More Intense Rainfall Events	Very Low	• Lodging • Soil Erosion • Reduced Infiltration of Rainfall

Source: FAO publication, 2004a, 2005.

Present Scenario in global Aquaculture

Fish is the main source of animal protein for a billion people worldwide. It is estimated that more than 200 million people are dependant on fisheries activity worldwide, most of them in developing countries. Fish provides an important source of cash income for many poor households and is a widely traded food commodity. In addition to stimulating local market economies fish can be an important source of foreign exchange. An average annual growth rate of 8.9%, makes it the fastest growing food production sector. Today, aquaculture provides around half of the fish for human consumption.

This document addresses the potential impacts of climatic change on the aquaculture sector and to a lesser extent the contribution of aquaculture to climate change. In order to achieve these objectives, the status of this subsector in relation to the total food fish supply, recent changes therein and other related aspects are analysed with a view to addressing potential adaptations and mitigation. Currently, the proportionate contribution of aquaculture to food fish consumption approximates 45 percent; this is also reflected in the increasing contribution of aquaculture to total fisheries figures recorded in the gross domestic product (GDP) of some of the main producing countries. Considering human population growth and stagnation in the growth of capture fisheries, it is expected that the supply of food fish from aquaculture will be required to increase even further to meet future demand for fish. It is seen that aquaculture is predominant in tropical and subtropical climatic regions and geographically in the Asian region. The main elements of climate change that could potentially impact on aquaculture production - such as sea level and temperature rise, change in monsoonal rain patterns and extreme climatic events and water stress.

Impacts of climate change on aquaculture

Impacts of climate change on aquaculture could occur directly and or indirectly and not all facets of climate change will impact on aquaculture. All cultured aquatic animal species for human consumption are poikilothermic. Consequently, any increase and/or decrease of 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 spawning) increased susceptibility to diseases and even to toxicants. The lower and upper lethal temperature and the optimal temperature range for fish species differ widely (Table). Therefore, climate change induced temperature variations are bound to have an impact on spatial distribution of species specific aquaculture activities. Those elements of climatic change that are likely to impact on aquaculture, based on the International Panel for Climate Change, IPCC forecast (2007) [3] can be summarized as follows:

- Global warming: There is agreement that our planet will heat by 1.1 °C this century and the increase could be up to 3°C.
- Sea level rise: rise in sea level will be associated with global warming. The IPCC has estimated that oceans will rise ten cm to 100 cm over this century, thermal expansion contributing 10 to 43 cm to the rise and melting glaciers contributing 23 cm. Sea level increases will profoundly influence deltaic regions, increase saline water intrusion and bring about major biotic changes.
- Ocean productivity and changes in circulation patterns: major changes in ocean productivity and circulation patterns are predicted; the most impacted being the North Atlantic and Indian oceans (Goswami *et al.*, 2006). These changes will impact on individual fisheries and other planktonic plant and animal group biomasses and result in changes in food webs.
- Changes in monsoons and occurrence of extreme climatic events: frequency of occurrence of extreme climatic events such as floods, changes in monsoonal rain patterns (Goswami *et al.*, 2006) and storminess in general.
- Water stress: IPCC (2007) [3] estimates that by 2020 between 75 and 250 million people in Africa are expected to be under water stress and freshwater availability in Central, South, East and South East Asia, particularly in larger river basins is projected to decrease. South America and Europe are better placed.

Table 1: Temperature tolerances of selected, cultured species of different climatic distribution.

Species	Lower	Higher	Optimal range (ºC)	Remarks
Redbelly tilapia (*Tilapia zillii*)	7	42	28.8-31.4	Tropical
Guinean tilapia (*Tilapia guineensis*)	14	34	18-32	Tropical
European eel (*Anguilla Anguilla*)	0	39	22-23	Subtropical
Channel catfish (*Ictalurus punctatus*)	0	14	20-25	Subtropical
Arctic charr (*Salvelinus alpines*)	0	19.7	06-15	Temperate/Polar
Rainbow trout (*Oncorhynchus mykiss*)	0	27	09-14	Temperate/Polar
Atlantic salmon (*Salmo salar*)	-0.5	25	13-17	Temperate/Polar
Indian major carps (IMC's)	15	37	19-35	Subtropical

Source: Baroudy, *et al.* (1994) [1], Das, *et al.* (2004) [5], Becker, *et al*. 1999 [2], FAO publication, 2004a [8].

Impact on Inland aquaculture

The great bulk of aquaculture in the tropical and subtropical regions is finfish culture. The dominant form of inland finfish aquaculture is in ponds, the size of pond ranges from a few hundred square meters to a few hectares. The main factors that contribute to determining pond water temperature are solar radiation, air temperature, wind velocity, humidity, water turbidity and pond morphometry. The predicted increase in air temperature will cause an increase in vaporization and cloud cover (IPCC, 2007) [3] and thereby reduce solar radiation reaching the ponds in ponds in tropical and semi tropical regions. However, the scenario may be slightly different in pond aquaculture in temperate regions; such activity on a global scale is small and confined primarily to the salmonid species and to a lesser extent, carps. The most popularly cultured salmonids in freshwater are rainbow (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta*); these have a very narrow optimal range of temperature and a relatively low upper lethal limit. The air temperature increase could be reflected in temperature increases in aquaculture ponds impacting productivity and in extreme cases, causing mortality. Higher inland water temperatures Increases stratification and reduces mixing of water in lakes, there by reducing primary productivity and ultimately food supplies for fish species. It is considered two indirect impacts that climate change may have on aquaculture *vis-à-vis* possible influences on price fluctuations of capture fishery produce and impacts on the availability of fish meal and fish oil. The major stocks that contribute to the reduction industry are the Peruvian anchovy, capelin, sandeel, and sardines. Although the emphasis has been on how to reduce fish meal and fish oil usage in feeds for cultured aquatic organisms, over the last few years new problems are surfacing (Das *et al*., 2004) [8]. Soybean meal and corn meal are often used in feeds for cultured aquatic organisms and rice bran in tropical semi-intensive aquaculture. Although more research is needed to address the impact of climate change on aquaculture production and productivity and on biology of fishes with regard to physico-chemical properties of water, and to investigate the detailed nutrient load, soil and water nutrient quality of different aquaculture systems and their impact on climate change in Indian aquaculture context. (Sharma K. *et al*., 2010) [11].

Impacts on diseases

An increase in the incidence of disease outbreaks in corals and marine mammals, together with the incidence of new diseases has been reported (Harvell *et al.,* 1999). Coral bleaching was linked to the high El Niño temperatures in 1997 to 1998. It is not difficult to predict a general impact of water warming on the spread of diseases such as bacterial diseases in aquaculture because in most cases, the incidence and persistence of these diseases are related to fish stress. Increased water temperatures usually stress the fish and facilitate various diseases process. Very recently it has been reported that ocean acidification could impact on the immune response of mussels, specifically shown for the blue mussel, *Mytilus edulis*, a popular aquaculture species. It has been suggested that the impacts are brought through changes in the physiological condition and functionality of haemocytes which in turn are caused by calcium carbonate shell dissolution. Examples of disease related catastrophes in the aquaculture industry include the spread of the white spot disease in shrimp farming in India and other countries (Sharma k, *et al.*, 2010) [11], the issue must be made a priority for aquaculture considering relevant biosecurity measures as a main adaptation.

Impacts on biodiversity

In the wake of the global climatic change induced phenomena, would impact adversely on disease transmission as well as on biodiversity. The balance of evidence suggests that global climate change will not enhance impacts on biodiversity through aquaculture *per se.* However, in view of the changes in temperature regimes and so forth, particularly in the temperate region, the possibilities of diseases occurring amongst filter feeding Mollusca and fish, for example, could be higher. The decline of coral reefs, from bleaching, weakening of coral skeletons and reduced accretion of reefs are estimated to be as high as 60 per cent by year 2030 (Dalvi, R. S *et al*., 2009) [4].

Potential impacts of aquaculture on climate change

Aquaculture, on a global scale becomes a significant contributor to the human food basket. The aquaculture sector has experienced very strong growth over the last two decades, making it the fastest growing primary production industry (FAO, 2004b) [9]. Foremost among these has been the use of fish meal and fish oil, obtained through reduction processes of raw material supposedly suitable for direct human consumption. Another target has been that of mangrove clearing during the shrimp farming boom. In the past, mangrove clearing was a major issue with respect to shrimp farming but the practice no longer takes place. In fact, it has been estimated that less than five percent of mangrove areas have been lost due to shrimp farming, most losses occurring due to population pressures and clearing for agriculture, urban development, logging and fuel. Consequently, an attempt is made below to outline the positive contributions of aquaculture towards the global problem of climate change.

Carbon emissions, viz. Greenhouse gases, in one form or the other, driven by anthropogenic activities, are a root cause of climate change (IPCC, 2007) [3] and all mitigating measures revolve around reducing the carbon emissions. It is therefore relevant to consider the degree of carbon emissions of the various animal food production sectors with a view to gauging the degree to which aquaculture contributes to this primary cause. The United States Environmental Protection Agency (EPA) recognised 14 major sources responsible for methane emissions in the USA and ranked enteric fermentation and manure management from animal husbandry as the third and fifth highest emitters respectively. Domesticated livestock, the ruminant animals (cattle, buffalo, sheep, goats, etc.) produce significant amounts of methane in the rumen in the normal course of food digestion, through microbial fermentation, that is discharged in the atmosphere. Equally, the solid waste produced manure needs to be managed and this process results in the emission of significant amounts of methane. It has been suggested that the world's livestock accounts for 18 percent of greenhouse gases emitted, more than all transport modes put together, and most of this is contributed by 1.5 billion cattle. Overall, the livestock sector is estimated to account for 37 percent of all human-induced methane emissions. The global warming potential (GWP) of methane is estimated to be 23 times that of carbon dioxide. Farmed aquatic organisms do not emit methane and therefore are not direct contributors to the causative problems. Surprisingly and unfortunately this has not been taken into account, particularly by those who tend to advocate the view that aquaculture is polluting and non-sustainable.

Carbon sequestration

Carbon sequestration 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. One of the major causative factors of climatic change, if not the major causative factor, is the accumulation of green house gases in the atmosphere, irrespective of the source(s) of emission (IPCC, 2007) [3]. Of all aquaculture commodities, the environmental cost of shrimp aquaculture is the highest. Shrimp aquaculture is economically very important to a number of tropical regions in Asia and South America. Because it needs constant aeration and water exchange, in general shrimp culture consumes a lot of energy compared to most other cultured commodities. Furthermore, shrimp culture is essentially destined for export markets and consequently needs a high level of processing, which is relatively costly in terms of energy. Moreover, the rapid turnover in seaweed culture, approximately three months per crop (in the tropics) with yields of over 2500 tonnes per ha, far exceeds the potential carbon sequestration that could be obtained through other agricultural activity for a comparable area.

Adaptive measures

It is suggested that successes in aquaculture depend on relevant institutional policy and planning changes or adaptations. In terms of institutional and policy measures the following are priority areas for development of the sector is to be taken into account:

- To implement an Ecosystem Approach to Aquaculture (EAA) as a global strategy;
- to prioritize and enhance mariculture and specially non-fed aquaculture (filter feeders, algae);
- To enhance the use of suitable inland water bodies through culture-based fisheries and appropriate stock enhancement practices.
- Farm management practices and breeding season could be modified to minimize the effect of climate change on aquaculture productivity.
- development of remediation strategies of soil and water of aquaculture ponds
- Improved training and general education of populations dependent on agriculture.
- Identification of the present vulnerabilities of aquaculture systems.
- Food programs and other social security programs to provide insurance of culture ponds against supply changes or any natural calamity.
- Transportation, distribution and market integration to provide the infrastructure to supply food during crop short falls.

Conclusion

Fisheries and aquaculture needs to be blended into national climate change adaptation strategies. Without careful planning, aquatic ecosystems, fisheries and aquaculture can potentially suffer as a result of adaptation measures applied by other sectors, such as increased use of dams and hydropower in catchments with high rainfall, construction of artificial coastal defenses or marine wind farms. Mitigation solutions are not at all well-known and require in innovative approaches such as the recent inclusion of mangrove conservation. The Ecosystem Approach to Aquaculture (EAA) aims to integrate aquaculture within the wider ecosystem as with any system approach to management; EAA encompasses a complete range of stakeholders, their influences, and other interlinked processes. In addition to the above improvements, it is imperative that the developed countries and the rapidly developing countries formulate strategies to curb greenhouse gas emissions. Developing countries like India should also look at adopting new energy-saving technologies and planting of more trees. The emphasis should also be laid on increasing the use of renewable energy sources like solar and wind. The above facts emphasize the need not only to study in detail the climate change vulnerability of fisheries & aquaculture but also the methods of improving the adaptive capacity of aquaculture to climate variability and extremes.

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