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Impact of climate change: A curse to the shrimp farming in India

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ABSTRACT

Aquaculture has been spanning one of the fastest-growing animal food-producing sectors across the globe. Humans and fish have been inextricably linked for millennia, not only because fish is an important source of animal protein, providing many millions of livelihood means and food security, but also from an evolutionary view point. In 2008, aquaculture accounted for 46 percent of the global food-fish supply, and per capita supply from aquaculture increased from 0.7 kg in 1970 to 7.8 kg in 2008, an average annual growth rate of 6.6 percent (FAO 2010). In developing countries, the sector contributes significantly to livelihoods and food security, especially in the Asia-Pacific region.

Keywords: *Shrimp farming in India, Climate change, Aquaculture.*

1. INTRODUCTION

Aquaculture has been spanning one of the fastest-growing animal food-producing sectors across the globe. Humans and fish have been inextricably linked for millennia, not only because fish is an important source of animal protein, providing many millions of livelihood means and food security, but also from an evolutionary view point. In 2008, aquaculture accounted for 46 percent of the global food-fish supply, and per capita supply from aquaculture increased from 0.7 kg in 1970 to 7.8 kg in 2008, an average annual growth rate of 6.6 percent (FAO 2010). In developing countries, the sector contributes significantly to livelihoods and food security, especially in the Asia-Pacific region

Over the years, agriculture in India has evolved from a substance and backyard activity to that of a technology-driven commercial and profitable venture. India is now second in world aquaculture production next to China. The estimated brackish water area suitable for undertaking shrimp farming in India is around 11.91 lakhs ha spread over 10 states and union territories viz, West Bengal, Odisha, Andhra Pradesh, Tamil Nadu, Pondicherry, Kerala, Karnataka, Goa, Maharashtra, and Gujarat. Of this around 1.2 lakhs ha are under shrimp farming now and hence lot of scope exists for entrepreneurs to venture into this field of activity. The success of commercial aquaculture in India is attributed to the availability of vast untapped surface water resources, standardization of many new productions and associated techniques of input and output subsystems, an extension of technology and practical knowledge to the farmers.

Map 1: Main Producer States of India

2. WHY SHRIMP FARMING?

Since, more than last two decades, the unprecedented growth of shrimp farming has been lucratively enhancing the Standard of Living Index (SLI) of coastal people. In India and Bangladesh, white leg shrimp (Litopenaeus vannamei, formerly Penaeus vannamei), is commercially known as "white gold", because of it's higher economic and export value. Litopenaeus vannamei species introduced and culture practice has been carried out in many coastal districts of Odisha last few years. Presently it is dominated 90 percent of total shrimp culture. The Litopenaeus vannamei exhibits faster growth rate and its culture period is significantly reduced compared to Penaeus monodon (Tiger Shrimp), thus the Litopenaeus vannamei has been established as an alternative to Penaeus monodon to shrimp farming in several districts. It has been acting as a catalyst facilitating well-being ranking of coastal people. However, the production of "white gold" under shrimp alternate rice and shrimp-only farming systems in coastal India has been accompanied by recent concerns over climate change. Effects of climate change curbing the shrimp productions have created havoc among the farmers. It is observed that different climatic variables including coastal flooding, cyclone, sea-level rise, salinity, drought, rainfall, and sea surface temperature have had adverse effects on shrimp culture as well as socio-economic conditions of farming households. There is also overwhelming evidence that changes in climatic variables have detrimental effects on the ecosystem of shrimp farms, and thus, severe effects on survival, growth, and production of shrimp.

3. PURPOSE

This paper aims to investigate shrimp farming process and its scope strengthening high-income generations of farmers in India and determine the vulnerability of shrimp farming income to climate change events.

4. METHODOLOGY

This paper is completely a review paper based on secondary information collecting from different sources.

5. FACTORS RESPONSIBLE FOR SHRIMP FARMING IN INDIA

Shrimp farming in brackish water holds the top-notch sheering cost-effectively lucrative and a hastily growing industry. Production of shrimp in ponds is often limited by the soil and water quality degradation. Disease outbreak in shrimp culture system is related to the environment factors such as deterioration of soil and water quality and sedimentation. The soil and water management and control of soil and water quality are therefore key factors for regulating the success in brackish water shrimp culture. Therefore, it is pertinent to know the pre-requisites which constitute the pivotal roles to carry on shrimp farming in India for a better economic perspective growth.

5.1 Soil Quality

The soil is the most important component in a culture system. The quality of soil should be ascertained for pH, permeability, bearing capacity and heavy metal content. Soil with low pH of below 5 and acid-sulfate soils should be avoided. Similarly, soils with high concentrations of heavy metal also should be avoided. The soil characteristics suitable for a shrimp culture frame given below:

Table No. 1: Characteristics of Soil

Parameters	Minimum	Maximum	Optimum range
pH	6.5	9.0	6.5-7.5
Organic Carbon (%)	0.5	2.5	1.5-2.0
Calcium Carbonate (%)	NA	NA	>5.0
Available Nitrogen (mg/100g)	25	75	50-70
Available Phosphorus (mg/100g)	3	6	4-6
Electrical Conductivity (dS/m)	NA	NA	>4

Generally, clayey loam soils are preferred. Sandy soils are seepage prone and will lead to problems of salinization of adjoining land and water resources. Further, maintenance of a farm in the sandy area needs high capital and operational costs. Hence, sandy areas should be avoided. The best site is the one, which involves lesser capital investment for constructing fully drainable ponds.

5.2 Water Quality

Availability of good quality water in required quantities is one of the most important prerequisites for sustainable aquaculture. While locating the farm site, careful study should be made on the source of water, the quantity of water available during different seasons and the quality of water. The optimal levels of various water quality (Physical and Chemical) parameters required for the best growth and survival of cultured shrimps are presented below:

Table No. 2: Physical Characteristics of Water

Physical Parameters	Shrimp farm pond water		
	Normal	Optimum	Critical
Temperature (^{0}C)	17-33	28-32	<14
pH	7.0-9.0	7.5-8.5	<6.0 (Daily fluctuation 0.5) & >11
Salinity (ppt)	7.5-34	15-25	<5 and >40 (Daily fluctuation 5 ppt)
Transparency (cm)	25-40	30-40	<20 and >60
TSS (ppm)	<100	NA	NA

Table No. 3: Chemical Characteristics of Water

Chemical Parameters	Shrimp farm pond water		
	Normal	Optimum	Critical
Total Alkalinity (mg C_aCO_3/l)	50-200	100-200	<20
DO (mg/l)	4.0-7.0	5.0-7.0	<3.0
Total Ammonia-N (mg/l) (at pH 8.2 & T 29 ^{0}C)	0.1-0.4	Preferably Nil	>2.0
Free Ammonia (mg/l)	<0.02	Nil	>0.1
Nitrite-N (mg/l)	0.20	<0.20	>4.0
Dissolved-P (mg/l)	0.008-0.20	0.10-0.20	---
COD (mg/l)	<75	<70	>200
BOD_5 (mg/l)	<20	<10	>30
H_2S (mg/l)	<0.003	Nil	>0.03
Free Chlorine (mg/l)	<0.001	Nil	>0.001

5.3 Site Elevation

Since drying of the pond bottom and proper water exchange form integral part of the technology of shrimp farming, ponds that are drainable by gravity are essential for a successful venture. Hence, the elevation of the site from the lowest low water level of the supplying creek should be given due consideration while selecting the site. A minimum elevation of 0.45 to 0.6 m is essential to ensure proper drainage.

5.4 Hydro-meteorological Parameters

The hydro-meteorological data of the proposed area is very important to develop the design of the farm. The most important data required are rainfall, tidal fluctuation, wind direction and velocity, flood levels, frequency and time of occurrence of natural calamities such as storm, cyclone, hail storm etc. Construction of farms in cyclone-prone areas should be avoided.

5.5 Infrastructure Facilities

The infrastructure facilities like roads, electricity, proximity to hatcheries, ice plants, processing plants should be considered while choosing the site for a shrimp farm since these play very crucial roles in the economics of culture operations.

Pic 1: Shrimp Farming in India

6. SHRIMP FARMING: A BLESSING TO COASTAL INDIA

i. Wind-fall gains: As compared to other agricultural activities shrimp farming provides a huge profit to the farmers due to its high cost and more productions. It is also seen that the profit amount becomes more than 2-3 times to their investment.

ii. Less time consuming: Shrimp farming takes maximum 90-120 days for its cultivation. As a result, the farmers would able to repay their loan amount with low interest during the short span of time.

iii. Farm insurance: The availability of farm insurance by the Government provides some sort of confidence and hope within the farmers' mind that in case of any mishap the lost amount will be recovered either partially or fully depending upon the insurance policies.

iv. Work force generation: As noticed, shrimp farming in coastal India covering a wider range, it engages huge manpower. It has also been noticed that the inter-state/intra-state migrations among coastal people are almost all at a stagnant level.

v. Credit facilities by the investors/financers: It attracts farmers to pursue such culture with a very low amount of money. Though it requires huge investment, all things are available on credit by the investors/financers.

vi. Venturing new investors: Apart from the farmers, it also has magnetism towards new investors especially, capturing the attention of the youth as they desire more profits within the lesser time frame.

vii. Wide- spread Market Avenue: As prawn is very attractive as well as a fascinated dish in India and out sides so it covers wide markets for selling.

viii. Accessibility to international market: Shrimp farming has a high economic and export value. It facilitates exporters and investors to access the arena of the international market.

ix. Enhancing purchasing power of the people: As discussed earlier, shrimp farming has come up with enhancing the Standard of Living Index (SLI) of the coastal people especially, to the middle class and lower-middle-class people so as their purchasing power. Nowadays they are in a position to access the better ups for their lives.

x. Establishing new industries: Shrimp farming has come up with establishing new industries i.e, hatcheries for seeds, Ice factories, shrimp processing plants, shrimp feed producing industries, chemical (shrimp drugs) industries, net producing industries etc.

xi. Technology: Accessibility to new technologies for the ruralises as the use of solar energy for water pumping, pond aeration, and light etc.

xii. Opening up opportunities for researchers/scientists: The shrimp farming is purely based on Hydro-meteorological parameters. So it requires in-depth and intensive research among the researchers/scientists on various aspects of disease control, water and soil treatment, better seeds formation, better feed, and nutrition etc.

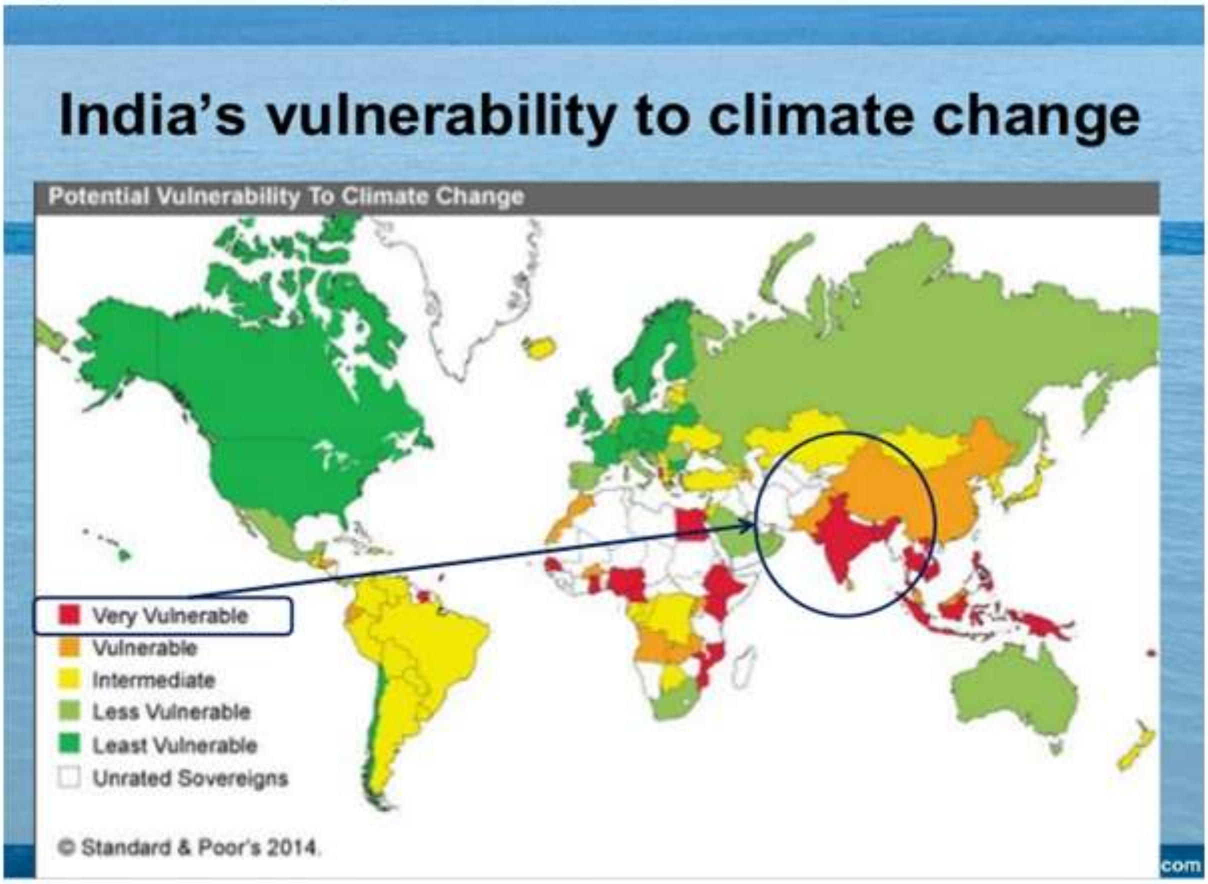
7. WHAT IS CLIMATE CHANGE?

The United Nations Framework Convention on Climate Change (UNFCCC) defines it as a change of climate that is attributed directly or indirectly to human activity, altering the composition of the global atmosphere. Human activity includes the pollution that arises from industrial activity and other sources that produce greenhouse gases. These gases, such as carbon dioxide, have the ability to absorb the spectrum of infrared light and contribute to the warming of our atmosphere. Once produced, these gases can remain trapped in the atmosphere for tens or hundreds of years.

8. CLIMATE CHANGE SCENARIOS

The 2010 INCCA Assessment30 provides an assessment of the impact of climate change in the 2030s on four key sectors of the Indian economy, namely Agriculture, Water, Natural Ecosystems & Biodiversity and Health in four climate-sensitive regions of India, namely the Himalayan region, the Western Ghats, the Coastal Area and the North-East Region. Climate change impacts of highest relevance in coastal areas are with respect to sea level rise and changes in the occurrence and frequency of storms and storm surges. India's coastal zones can be divided into the Gujarat region, west coast, eastern coastal plains, and the islands. There is the difference between the east coast and the west coast. Fast flowing rivers in the largely mountainous west coast form estuaries and backwaters while deltas are predominant in the broad and flat plains of the east coast. The temperature in the coastal regions exceeds 30°C and has high levels of humidity receiving rainfall from both the northeast and southwest monsoons.

The climate change scenarios have been derived from a regional climate change model PRECIS (a version of HadRM3 developed by the Hadley Centre, UK) with a resolution of 50km x 50km and forced by a greenhouse gas (GHG) emission scenario emanating from A1B IPCC SRES (Special Report on Emission Scenario; IPCC, 2000)31. The 2030s is the average of the period between 2021 to 2050. All the changes in the 2030s are with respect to the average of the period 1961 to 1990s, also referred to as the 1970s or the baseline. With respect to surface temperatures, the model predicts32 §An annual mean surface temperature rise by the end of this century, ranging from 3°C to 5°C (under A2 scenario) and 2.5°C to 4°C (under B2 scenario), with the warming more pronounced in the northern parts of India. §A20 per cent rise in all India summer monsoon rainfall and a further rise in rainfall is projected over all states except Punjab, Rajasthan and Tamil Nadu, which show a slight decrease.



Map 2: India's Vulnerability to Climate Change

9. FACTORS INFLUENCING CLIMATE CHANGE

9.1 Carbon Dioxide

Produced primarily through the burning of fossil fuels (oil, natural gas, and coal), solid waste, and trees and wood products. Deforestation and soil degradation add carbon dioxide to the atmosphere, while forest regrowth takes it out of the atmosphere. Carbon dioxide's lifetime in the atmosphere cannot be represented with a single value because the gas is not destroyed over time, but instead moves among different parts of the ocean-atmosphere–land system. Some of the excess carbon dioxide is absorbed by natural processes, but some remains in the atmosphere for thousands of years, due to the slow process by which carbon is transferred to ocean sediments.

9.2 Methane

Emitted during the production and transport of oil, coal and natural gas. Methane emissions also result from livestock and agricultural practices and from the anaerobic decay of organic waste in municipal solid waste landfills. Its average lifetime in the atmosphere is 12.4 years.

9.3 Nitrous Oxide

Emitted during agricultural and industrial activities, as well as during combustion of fossil fuels and solid waste. Its lifetime in the atmosphere stands at 121 years.

9.4 Fluorinated Gases

A group of gases that contain fluorine, including hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride, among other chemicals. These gases are emitted from a variety of industrial processes and commercial and household uses and do not occur naturally. Sometimes used as substitutes for ozone-depleting substances such as chlorofluorocarbons (CFCs).

10. IMPACTS OF CLIMATE CHANGE ON SHRIMP FARMING

All identified climatic variables have severe effects on the ecosystem of shrimp farms. Shrimp is highly sensitive to ecological conditions and changes in ecosystem have profound impacts on their survival, growth, and production (Fig. 1). The following sections describe how different climatic variables have effects on ecological conditions of shrimp farms and consequences on production.

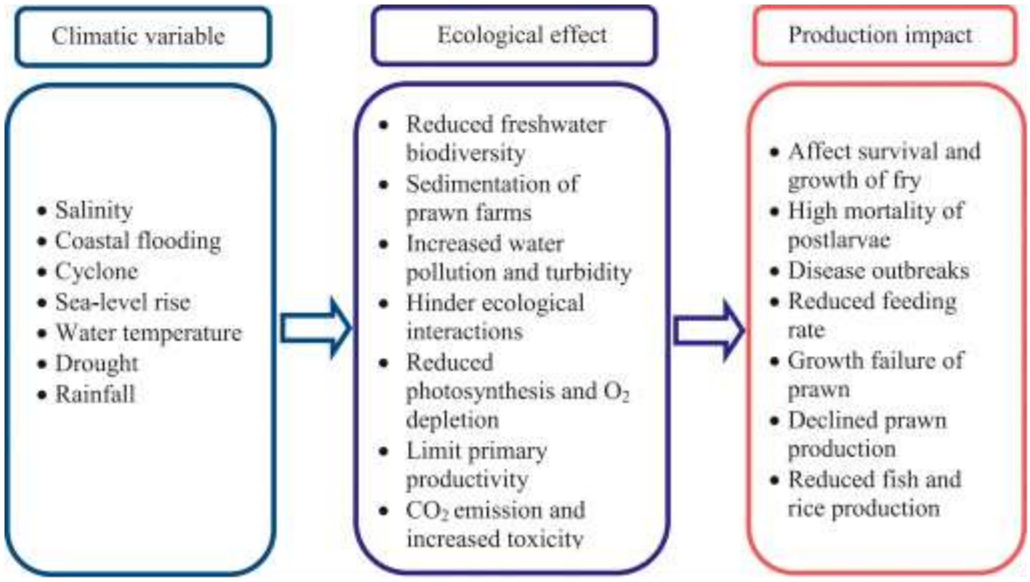


Fig. 1 Effects of climatic variables on ecological conditions of shrimp farms

10.1 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 favour one species or group over another.

10.1.1 Sea Surface Temperature (SST) increase: Temperature is likely the single most important factor in among the environmental variables 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.

10.1.2 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.

10.1.3 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).

10.1.4 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 5 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 3.1 mm per year. The total 20thcentury 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.

10.1.5 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.

10.1.6 Changes in rainfall: Changes in average precipitation, the 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 the increase in the number of extreme rainfall events (Velmurugan et al., 2015)

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

10.2 Impact on fish stock

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

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.

10.3 Impact on the harvesting sector

Climatic changes that affect distribution also affect the fishing methods used to harvest affected fish stocks. In the Bay of Bengal, rising sea surface temperatures have caused fisher folk to increase the depth at which nets are cast. Studies have shown an increase in recruitment and catch of oil sardine and Indian mackerel during the post southwest monsoon season as a result of increased temperatures (Zacharia et al., 2016).

Change in wind direction and speed adversely affect yellowfin tuna fishery of the southeastern coast of India. The north to south winds during October-January is favorable for tuna fishery with tuna moving along with wind and current from offshore deeper waters to near shore shallower waters. In Mumbai, studies of sea surface temperature against catch per unit effort in hour revealed a mild positive correlation between the two parameters, indicating that with rising temperatures, greater amounts of energy must be spent to harvest a particular quantity of fish (CMFRI-NICRA, 2016).

A potential impact of climate change is the increase in the frequency of extreme weather events and the associated damage to the fishing sector. Cyclones of sufficient strength may damage equipment and fishing facilities, as well as cause disruptions in fishing operations.

Life cycle assessments (LCA) performed on the fishing industry has shown the majority of emissions originating from the fishing sector are generated during the actual harvesting phase, followed by the processing phase (CMFRI-NICRA, 2014).

10.4 Impact on fishing communities

Erosion due sea level rise and abnormal weather events present a significant risk for vulnerable coastal communities. In some coastal areas of Asia, a 30 cm rise in sea level can result in 45 m of landward erosion. The east coast of India is considered more vulnerable due to its flat terrain and the numerous deltas. Estimates show that the inundation area will be about 4.2 km2 for a 1.0 m rise in sea level in the region surrounding Nagapattinam (Shetye et al., 1990).

Areas with a large number of creeks and backwaters are likely to be at a higher risk of inundation, due to the easier influx of water into vulnerable areas. Recent studies indicated that a net decrease in coastal area was suffered due to erosion. While the total area lost is a small fraction of the total Indian coastal area, it represents a significant loss of income and livelihood for the affected communities.

Cyclonic weather events such as the recent cyclone Vardha in Chennai also wreak havoc on fishing communities, in multiple ways – by preventing fisher folk from carrying out fishing operations as well as causing infrastructural damage to key equipment utilized in the practice of the craft.

The group most likely to be affected by the effects of climate change on fisheries is the small-scale fisheries sector, comprising artisanal and subsistence fishers. Low and irregular income derived from fishing activities will result in low flexibility and poor adaptability to the economic effects of climate change. Damage to the sector's ability to contribute to the output of the fisheries sector will also be a likely result. Aid and assistance programs to mitigate these effects will likely be necessary but at the same time, will place a strain on the ability of governmental institutes to provide an economic buffer for this sector.

10.5 Impact on market and trade

An increase in market costs of commonly consumed fish stocks is to be expected as a result of climate change. Shifts to more sustainable fuels, while necessary, will also contribute to these increases.

Due to shifts in the distribution of fish stocks, commercial fisheries will also be severely impacted. Climate change is expected to change future fisheries production patterns, either by shifting production as species move to new habitats or as a result of changes in net marine primary production (Brander, 2007). The effects of climate change on the output and reliability of aquaculture practices, however, present a significant hurdle to the food security of states dependent on aquaculture. Ensuring that fisheries are efficiently governed and that aquaculture continues to grow in a sustainable manner will be the main constraints to the sustainability of global fish production (Merino et al., 2012).

10.6 Potential positive impacts

A small number of potentially positive effects of climate change exist. Warmer temperatures may lead to quicker growth and earlier maturity, which, in certain situations, may be beneficial. Silver pompano fingerlings were found to grow at a greater pace at slightly higher temperatures, though once the temperature exceeded the optimal maximum, abnormalities in growth were noticed (CMFRI-NICRA, 2016). Elevated temperatures of coastal waters also could lead to beneficial impacts with respect to growth rate and feed conversion efficiency (Lehtonen, 1996), and increased production.

A survey by ICAR-Central Institute of Brackishwater Aquaculture (CIBA) revealed that around 829 ha of seawater inundated areas in the Andaman & Nicobar Islands after 2004 tsunami are now suitable for brackishwater aquaculture (Pillai and Muralidhar, 2006) after the lands became completely saline. These lands cannot be used for agricultural crops and brackishwater aquaculture is the only option for the livelihood of farmers and provides employment opportunities and nutritional security.

Certain species, such as oil sardine and mackerel, have undergone range extensions over the past few decades in response to the warming waters of the Indian Ocean (Vivekanandan et al., 2009). This is distinct from a distributional shift, which could cause disruptions in traditional fishing practices and knowledge. Range extensions, on the other hand, allow the usage of a particular stock in a greater number of areas. For stocks capable of being utilized at sustainable levels, this is unlikely to be detrimental.

11. POLICY MEASURES

On account of policy measures, the followings are priority areas for development of the sector.

i. To implement an ecosystem approach to aquaculture (EAA) as a global strategy,

ii. To enhance the use of suitable inland water bodies through culture-based fisheries and appropriate stock enhancement mechanism,

iii. Considering extreme vulnerability to the effects of climate change on shrimp farming, it is proposed that community-based adaptation strategies and integrated coastal zone management are needed to cope with the challenges,

iv. Aquaculture Insurance, an adaptive measure that will help limit bankruptcies in aquaculture businesses as a result of losses caused by climatic events is to encourage aquaculture participants to take insurance against damage to stock and property from extreme climatic events,

v. Research and technology transfer, relevant research is required for aquaculture to adapt to climate change and countries and regions need to streamline work on issues such as new diseases and preventive treatments, aquatic animal physiology, the search for new and better-adapted species, better feeds and feeding practices that are more ecosystem friendly. Technology transfer mechanisms must reach farmers, especially small farmers. It is in this context that application of better management practices into small-scale farming practices needs to be integrated into EAA strategies,

vi. To secure National Calamity Contingency Fund (NCCF) for shrimp farmers to compensate the losses due to extreme weather events,

vii. To improve early warning systems on cyclones and floods.

viii. To strengthen coastal systems against storm surge and sea level rise by planting tree barriers,

ix. To build the capacity of farmers through training and initiation of Climate field school,

x. Encouraging women’s participation in future adaptation measures.

12. CONCLUSION

The impacts of climate change on the east coast of India is highly vulnerable to extreme weather events, including cyclones, floods, in addition to likely changes in temperature, sea-level rise and change in monsoon patterns. Habitat change was induced due to variability in climatic as well as oceanographic parameters. Technologies to adapt to climate change are to be developed and demonstrated directly to shrimp farmers communities. Brackish water aquaculture is a climate-friendly production system for enhancing fish production, providing employment opportunities and nutritional security. There is a need to forecast the likely effects of climate change on the shrimp farming sector and to develop strategies to assist farmers and rural communities to adapt to the upcoming changes. Integrated farming methods developed need to be sensitized across the nation with support from the government. A large number of shrimp farmers communities and other stakeholders are to be empowered to cope-up with climate change through training, workshops, awareness programs, etc. Measures need to be taken care of to reduce the vulnerability and improve the adaptive capacity of the shrimp farmers.

