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IMPACTS OF CLIMATE CHANGE ON SHRIMP FARMING IN INDIA

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ABSTRACT:

The purpose of this review is to explore the effects of climate change on shrimp aquaculture in India. Aquaculture sector contributes on a large scale to livelihood and food security in developing countries like India. Shrimp farming creates significant impact in socio-economic development in terms of income and employment generation. *Penaeus monodon* and *Penaeus vannamei* are two mostly preferred brackish water crustacean in India having a demand all over the world. The brackish water shrimp farming is expanded considerably during the last ten years and in 2020, area under cultivation was around 158859ha and estimated production was 747111 tons. Elements of climate change that are likely to impact shrimp farming include monsoon pattern, sea level rise, seasonal change, temperature rise, water pollution, salinity fluctuation, flooding, erratic weather etc. The negative impacts on shrimp culture due to climate change are significantly observed starting from pond preparation to harvest and postharvest management. The outcomes of climate change include inundation of shrimp farms by sea water particularly located at low lying coastal areas, hypersalination, ecological changes, disruption of farming system, displacement of fisherman communities, prevalence of pathogenic and non-pathogenic diseases, and evolution of resistant pathogen strains. The abiotic changes are more severe than the pathological consequences. Various environmental stimuli such as changes in pH, salinity, dissolved oxygen (DO), temperature and pollutants affect the growth of shrimp. The climatic variables create significant impact on the ecosystem of shrimp farms and as a result severe effects are noticed in terms of growth and production of shrimp. The abrupt changes in the environmental parameters lead to mass mortality of shrimp that causes direct economic loss to the farmers. Community-based adaptation strategies and integrated coastal zone management are needed to cope up with the effects of climate change on shrimp farming.

Keywords: Aquaculture, Socio-economic development, Climate change, Ecosystem, Prevalence of diseases.

INTRODUCTION:

Fisheries and aquaculture sector contribute around 1% to India's GDP (Gross Domestic Products). The shrimp farming which is considered as the major activity in brackish water aquaculture has reached 7.0 lakh tonnes production in 2019. Shrimp aquaculture has experienced an exponential growth in India and other countries due to its growing global demand and high economic value in terms of export earnings. India is one of the largest producer and exporter of shrimp in the world. Penaeid shrimps are the preferred crustaceans in aquaculture and vast area are invested for shrimp farming (Karuppasamy and Mathivanan, 2013) because of high demand of it all over the world. The brackish water aquaculture comprises varieties of shrimp mainly the native black tiger shrimp *Penaeus monodon* (also called bagda shrimp) and the exotic white leg shrimp *Penaeus vannamei* (*Litopenaeus vannamei*) which is native to the Pacific coast from Northern Peru to Mexico. The scientific and commercial shrimp culture in India started with *P. monodon* in 1990 because it was a huge profitable sector but outbreak of viral disease in 1995-1996 led the shrimp farming industry to huge loss.

Then the application of bio-secured closed culture technology (Panigrahi *et al.*, 2009) which followed better management practices (BMPs) revived the industry with its lost glory during the early years of last decade. In shrimp aquaculture, black tiger shrimp was the major farmed species in India till 2009, when a non-native hardy shrimp species *P. vannamei* was introduced following prescribed guidelines of Coastal Aquaculture Authority of India (CAA, 2009) during the year 2009-10 due to frequent crop failures of black tiger shrimp, caused by the fatal white spot disease. The culture of *P. vannamei* has attracted farmers due to a number of competitive advantages like faster growth rate, safe high stocking density, low salinity tolerance, temperature tolerance, utilization of low protein diet and increased potentiality of breeding, domestication, and lower number of diseases in comparison to *P. monodon* (Kapiris, 2017). Now vannamei farming is occupied by around 90% of total shrimp farming.

The impact of climate change is likely to have serious impact not only on aquaculture but also on the food security and livelihoods of major rural population of developing countries like India (IPCC, 2007). The major climatic variables including cyclone, heavy rainfall, coastal flooding, sea-level rise, high temperature and salinity create adverse effect on shrimp farming which results in lower feed intake, poor growth and development, outbreak of pathogenic and non-pathogenic diseases and mass mortality of shrimp. Heavy rainfall causes low dissolved oxygen (DO), fluctuation in pH and salinity, and prevalence of emerging diseases. High temperature of shrimp farms increases pH and salinity, decreases water availability of the farms with reduced DO concentration. Coastal flooding causes water pollution, contamination and transmission of pathogenic diseases. As a consequence the farmers have had a great economic loss and foreign exchange earning get reduced. The livelihood of small and marginal farmers and landless people are more adversely affected. The adverse environmental impacts on shrimp farming are associated with food security, poverty alleviation and overall socioeconomic development of that region and country also. So, considering the vulnerability of climate change effects on shrimp farming, sustainable shrimp culture along with community-based adaptation strategies and integrated coastal zone management are very essential.

Area, Production and Productivity

India has a coastline of 7516.6 km length (Mainland: 5422.6 km; Island Territories: 2094 km) extended from West Bengal to Gujarat. The brackish water shrimp (mainly *P. vannamei* and *P. monodon)* farming area is around 158859ha (MPEDA, 2021) which is located basically alongside the coastline of India. This is extended over 10 states and union territories viz. West Bengal, Orissa, Andhra Pradesh, Tamil Nadu, Pondicherry, Kerala, Karnataka, Goa, Maharashtra, and Gujarat (Fig 1). The estimated production of shrimp in 2020 was 747111 tons of which tiger shrimp was 35437 tons and white leg shrimp was 711674 tons (MPEDA, 2021) [Table 1]. The white leg shrimp production was progressively increased from 2009-10 to 2019-20 except in 2018-19 but the drastic change in white shrimp production was stated from 2013-14 (Fig 2). Brackish water shrimp farming have expanded considerably during the last ten years i.e. after the introduction of *P. vannamei* in India. The shrimp farms are developed in clusters in most areas and they are located along the creeks area and estuarine watercourses.

MATERIALS & METHODS:

This study is being performed on the basis of related literature review and field observation during coastal flooding and cyclones, and consultation with the farmers. Relevant information is being collected from the secondary sources which include reports of field survey and recent research papers, journals and books. Some information have also been collected by interview with the farmers having a field experience of 10 to 20 years of shrimp culture by using a structured questionnaire containing both open-ended and close-ended type questions.

SHRIMP FARMING IN INDIAN CLIMATE: RESPONSIBLE ENVIRONMENTAL FACTORS

Suitable soil bottom quality and optimal water quality of the aquacultural farms are very essential ingredients for brackish water shrimp culture. The undesirable properties of soil like accumulation of high organic matter, presence of potential acid sulphate etc. and poor water quality like highly acidic or alkaline water, enrichment of nutrient and organic matter, highly suspended solids etc. can give rise to production loss. The suitable soil and water characteristics required for shrimp culture in Indian subcontinent are given below (Mohanty, 2018)[Table 2, 3 & 4].

RESULTS AND DISCUSSION:

The elements of climate change that affect the ecosystem of shrimp farm, and life and livelihood of farmers can be described under the following heads:

1. Temperature

Temperature is considered as a significant environmental factor in aquaculture. As the shrimps are the poikilothermic animals so, any increase or decrease in temperature of their aquatic habitat will significantly affect their body metabolism and also influence the susceptibility or resistance to diseases. Several physiological processes such as respiration, immune functions, molting, and maturation are influenced by temperature. Rising temperatures can affect homeostasis in crustaceans that ultimately results in metabolic stress and disease (Dove *et al.*, 2004, 2005). Host susceptibility to pathogens is also changed by thermal ranges (Moullac & Haffner, 2000; Shields *et al.*, 2005, 2007).

P. vannamei is tropical in origin and temperature fluctuation is a serious challenge to its survival, growth, and distribution (Peng *et al.*, 2015; Cottin *et al.*, 2016). *P. vannamei* prevents external injury by cellular and humoral immunity (Iwanaga and Lee, 2005). Alkaline phosphatise (ALP) plays major role in cold stress and significantly effective against pathogens. ALP can help protect cold-stress damage in the hepatopancreas and hemolymph (Mateus *et al.*, 2017; Peng *et al.*, 2018). It is reported that temperature changes in *P. vannamei* may lead to growth arrest, stoppage of feeding, and swimming or even death in 13°C (Fan *et al.*, 2013; Huang *et al.*, 2017; Xu *et al.*, 2018). Optimal temperature required for the growth of *P. vannamei* is size-specific and it is around 28–30°C for post-larvae (Ponce-Palafox *et al.*, 1997). The optimal temperature for development of small juveniles (<5 g) is greater than 30°C and about 27°C for sub-adults (Wyban *et al.*, 1995).

2. Salinity

Salinity change in aquatic habitat alters the growth performance and physiological responses of *P. vannamei* although euryhaline species can tolerate wide range of salinity from 1 to 50% (Fry, 1971; Kinne, 1971). The higher salinity significantly reduces the growth and survival of *P. vannamei* (Ayaz *et al.*, 2015). The optimal salinity required for the growth of white leg shrimp is still controversial although few studies by Palacios *et al.* (2004) and Ogle *et al.* (1992) have focussed on the impact of salinity on survival of white shrimp. Superoxide dismutase (SOD) and catalase (CAT) are the two primary enzymes that help in radical scavenging and thereby confer protection to shrimps. Lower salinity stress in shrimp causes accumulation of radicals and enhanced activities of SOD and CAT are recorded in shrimp during this stress. If the radicals are not scavenged in time, the organisms would suffer from serious oxidative damage (Winston and Giulio, 1991). The poorest growth performance is recorded in shrimps at low salinity and this is due to energy expenditure for osmoregulation (Chen and Nan, 1994). The water content of *P. vannamei* is increased with the decrease of ambient salinity (Huang *et al.*, 2004)

3. Floods and Cyclones

The frequency of extreme weather conditions like occurrence of cyclone and flooding of cultivation lands are getting increased in recent times due to climatic change. As a consequence shrimp farming practiced near to sea coast is mostly affected. Cyclone causes severe disruption of fishing sector. "Amphan" (2020) and "Yaas" (2021) are two recent cyclones that destroyed shrimp farming sector mostly in West Bengal and partly in Orissa. Cyclone "Yaas" along with high tidal surges caused inundation of sea water along the coastal belt of Bengal (Fig 3). As a result 70 % of shrimp farmers were totally affected and estimated economic loss was around 1500 crore rupees according to "All Bengal Aqua Farmers' Welfare Association". Super cyclone "Amphan" made landfall in Sagar Island of coastal Bengal and the three coastal districts viz. Midnapore East, North and South 24 Parganas where intensive shrimp culture occurred get destroyed. Cyclone "Tauktae" (2021) caused severe damage on India's western coastal zones. Severe cyclonic storm "Fani" (2019) and "Gaja" (2018) of recent past that caused severe damage to shrimp farming sector and major economic loss to the farmers of Orissa and Tamil Nadu respectively.

4. Sea-level rise in the Indian seas

Coastal communities are vulnerable to climate related events like storms, coastal erosion and sea water intrusion, and other hydro-meteorological hazards. Shetye *et al.* (1990) studied vulnerability of regions surrounding Nagapattinam, Kochi and Paradip for a one metre rise in sea level and reported that the inundation area will be about 4.2 km^2 for a 1.0 m rise in sea level in the region surrounding Nagapattinam. A one metre sea level rise is projected to displace approximately 7.1 million people in India and about 5,764 km^2 of land area will be lost, along with 4,200 km of coastal roads (Ministry of Environment and Forests, 2004). Dasgupta *et al.* (2009) reported that approximately 30% of India's coastal zones will be subjected to inundation risk with sea level rise and intensified storm surges.

So, the impacts of climatic variables on shrimp ecosystem, production and socioeconomic development can be summarised as follows (Fig 4).

PREVALENCE OF DISEASES:

The major constrains faced by the shrimp farmers include scarcity of good quality of certified seeds, feeds & fertilizers, modern technology for farming, disease diagnosis centres, and unregulated marketing systems with intervention of middleman. Despite of high levels of shrimp culture, the shrimp farmers have been facing economic losses in recent years due to outbreak of diseases. Environmental factors are related to shrimp stress and outbreak of diseases that ultimately lead to production loss. Temperature variation can alter the shrimp's susceptibility to pathogens and as a result morbidity and mortality of shrimp are influenced by temperature range. Climatic change also imparts role in transmission and outbreak of various infectious and non-infectious emerging aquatic diseases (Table 5 & Table 6). As the aquatic pathogens are climate sensitive so, their distribution, virulence and prevalence are co-related to environmental change.

CONCLUSION:

Shrimp farming is not only a source of income but also provider of necessary nutrients to our body. It influences income among farmers, alleviates poverty through employment, and creates scope of engagement for the rural and marginal workers. India is a tropical country and there is a risk of outbreak and prevalence of diseases by varieties of virulent pathogen in shrimp farming and it is likely to be exacerbated by the climatic change. The seasonal variations observed by the farmers mainly include late monsoon, temperature variation and heavy rainfall. Heavy rainfall causes outbreak of several diseases and damage to shrimp farming infrastructure that ultimately lead to increased production cost per unit. Agricultural land resources are gradually declining and the major challenge is to ensure food security to the undernourished protein-starved population of India. Brackish water aquaculture is a climate-friendly production system. New pathogens will almost emerge as the expansion of shrimp industry continues in new locations but we have to be prepared to limit impacts and spread of disease with the advancement of new technologies with modern equipments. The environmentally sustainable shrimp culture development requires International cooperation and productive alliances of governments, industry and the community. To reduce the growing global demand of shrimp as a protein substitute it is required to study the potential risks of climate sensitive diseases, mapping of potential risks, and disease monitoring for proper health management. The pacific white leg shrimp is a species of choice at present and holds great future. It requires genetic improvement through selective breeding. Training, workshops, awareness programs regarding climate changes and their impact on shrimp farming are to be organized for the benefit of shrimp farmers' communities and other stakeholders. Climate change impacts cause serious threat to aquaculture that need to be addressed in integrated manner, and community-based adaptation strategies and integrated coastal zone management are highly needed.

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Fig 1: Main shrimp producer states of India

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Table 1: State wise area utilized and production of tiger shrimp & white leg shrimp over last three years (Source MPEDA, 2021)

Sr. No.	States		TIGER SHRIMP			WHITE LEG SHRIMP		
			2017-18	**2018-19**	**2019-20**	**2017-18**	**2018-19**	**2019-20**
1	West Bengal	AUC	51084	51455	51422	4127	5096	6072
		EP	49319	47842	27585	22191	29846	31376
2	Orissa	AUC	2624	1389	2632	8862	5102	10554.8
		EP	3887	2146	4141	37229	24123	44007
3	Andhra Pradesh	AUC	1880	1302	882	62342	50474	63678
		EP	2714	2438	1450	456300	450797	510794
4	Tamil Nadu & Pondicherry	AUC	10	58	203	8849	6989	8190
		EP	28	112	554	43622	47184	44467
5	Kerala	AUC	3144	3258	2823	52	53	234.74
		EP	1522	1675	1370	208	259	670.7
6	Karnataka	AUC	302	690	590	399	219	539.97
		EP	59	94	34	1465	918	1195.1
7	Goa	AUC	0	0	0	32	0	0
		EP	0	0	0	78	0	0
8	Maharashtra	AUC	0	0	0	1291	916	1328.31
		EP	0	0	0	6073	6567	5625.1
9	Gujarat	AUC	55	207	101	7542	6585	9608
		EP	162	595	303	55161	58764	73539
TOTAL		**AUC**	**59099**	**58359**	**58653**	**93496**	**75494**	**100206**
		EP	**57691**	**54902**	**35437**	**622327**	**618678**	**711674**

EP=Estimated Production (Tons); AUC= Area Under Cultivation (ha)

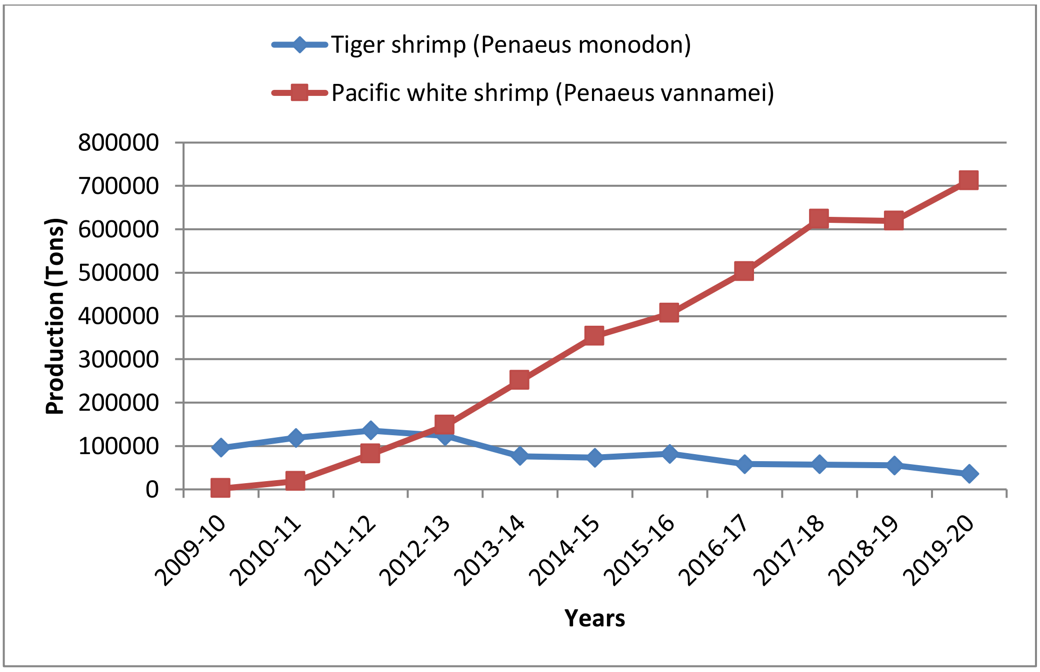

Fig 2: Shrimp production trends in India over last 11 years (Source: MPEDA, 2021)

Table 2: Suitable soil characteristics for a shrimp culture

Parameters	**Minimum**	**Maximum**	**Optimum range**
pH	6.5	9	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	04-06
Electrical Conductivity (dS/m)	NA	NA	>4

Table 3: Physical Characteristics of Water

Physical Parameters	**Shrimp farm pond water**		
	Normal	Optimum	Critical
Temperature (0C)	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 4: Chemical Characteristics of Water

Chemical Parameters	**Shrimp farm pond water**		
	Normal	Optimum	Critical
Total Alkalinity (mg CaCO3/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 0C)	0.1-0.4	Preferably Nil	>2.0
Free Ammonia (mg/l)	<0.02	Nil	>0.1
Nitrite-N (mg/l)	0.2	<0.20	>4.0
Dissolved-P (mg/l)	0.008-0.20	0.10-0.20	---
COD (mg/l)	<75	<70	>200
BOD5 (mg/l)	<20	<10	>30
H2S (mg/l)	<0.003	Nil	>0.03
Free Chlorine (mg/l)	<0.001	Nil	>0.001

Table 5: Prevalence of aquatic pathogenic diseases in shrimp due to climatic change

S.N.	**Name of the disease**	**Nature of the disease**	**Climatic factors involved**
1.	White Spot Disease (WSD)	Viral Disease (White Spot Syndrome Virus (WSSV)	Induced by changes in salinity, temperature etc.
2.	Acute Haemapoietic Necrosis Disease (AHPND)	Bacterial Disease (*Vibrio parahaemolyticus*)	Water quality is considered as a predisposing factor.
3.	Infectious Myonecrosis	Viral Disease (Totivirus)	Temperature and salinity favours disease outbreaks

Table 6: Prevalence of aquatic non-pathogenic diseases in shrimp due to climatic change

Sl. No.	**Name of the Disease**	**Climatic factors involved**
1.	Black Gill Disease (BGD)	• heavy organic load in pond bottom • presence of pollutants • low dissolved oxygen • heavy siltation
2.	Muscle Necrosis	• low dissolved oxygen • temperature and salinity shock
3.	Incomplete Molting	• low temperature
4.	Bent/Cramped Tails or Body Cramp	• mineral imbalance
5.	Loose Shell Syndrome (LSS)	• mineral deficiency • poor water quality • high soil pH • low water phosphate and low organic matter in soil
6.	Acidosis	• very low dissolved oxygen due to organic matter deposition
7.	Hypoxia	• low water pH • low soil pH

Fig 3: The effects of cyclone "Yaas" and its post effect on shrimp farming in West Bengal (Courtesy: Authors). A. Intrusion of sea water in Sunderban area of West Bengal B. Intrusion of sea water in Deshpran block of East Midnapur, West Bengal C. Mass mortality of shrimp in Namkhana Block, South 24 Parganas, West Bengal D. Mass mortality of shrimp in Sagar Block, South 24 Parganas, West Bengal

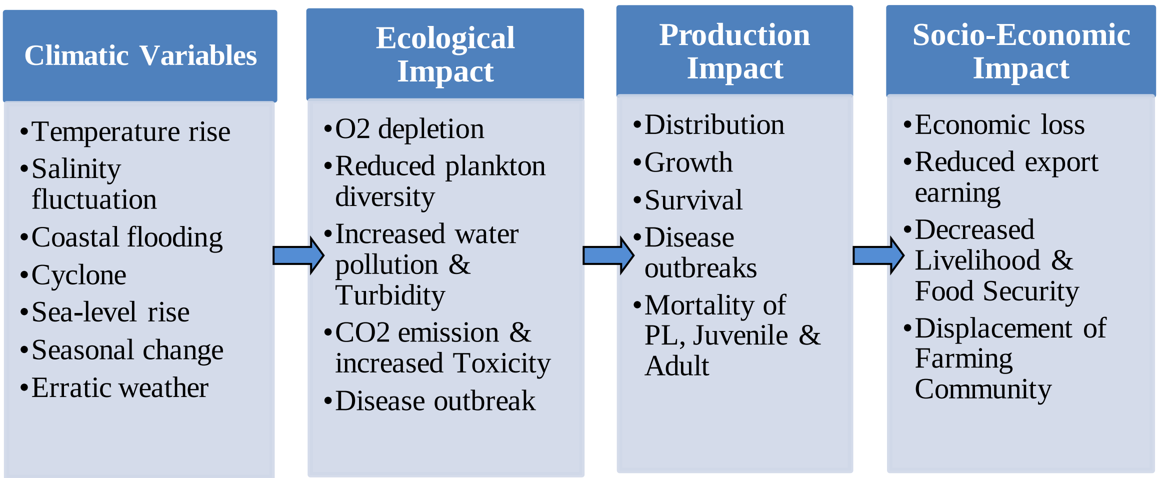

Fig 4: Effects of climatic variables on ecosystem of shrimp farms & Socio-economic development