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Chapter

Effect of Climate Change on Aquatic Ecosystem and Production of Fisheries

Satarupa Ghosh, Snigdha Chatterjee, Ghora Shiva Prasad and Prasanna Pal

Abstract

The exploitation of nature for decades due to several anthropogenic activities has changed the climatic conditions worldwide. The environment has been polluted with an increase of greenhouse gases. The major consequences are global warming, cyclone, an increase in sea level, etc. It has a clear negative impact on the natural environment including aquatic ones. As a result, production of fish in the aquaculture system and marine system is greatly affected. Marine ecosystems like coral reefs are also destroyed. Decreased fish production has also affected the livelihood and economic condition of the fish farmers. So, corrective measures should be taken to reduce the climate changes for minimizing its effects on fish production. Using more eco-friendly substances, planting more trees, and preserving our nature are some steps to be taken. Awareness should also be generated among the common people.

Keywords: aquatic environment, economy, climate change, fish production, global warming

1. Introduction

For the last few decades, climate change, food security and their complex interaction have become a global issue [1]. With the rapid increase in human population, we have destroyed our nature and polluted the environment. The level of greenhouse gases in the atmosphere is increasing day by day. Consequently, we are facing the threats of global warming and other climatic changes like cyclone, drought, flood, etc. Change in the climatic conditions may be limited to a specific region or may occur across the whole earth. But, it is affecting all the ecosystems including the aquatic ones. Aquatic organisms are very vulnerable to climate change because the average temperature of both air and water are changing simultaneously. Climate change in the aquatic system mainly occurs through sea level and temperature rise, change in monsoon patterns, extreme weather events and water stress having both direct and indirect impacts on aquatic animals including fish stocks. It directly acts upon the physiological behavior and growth pattern of organisms, subsequently decrease reproductive capacity and finally cause mortality. Indirectly it may alter the productivity, structure, function and composition of aquatic ecosystems. All these effects finally result in decreased fish production. It disturbs the economic

condition of fish farmers and hamper their normal livelihood by huge economic losses. In this chapter, we will discuss how climate change affects the production of fish and the lives of fish farmers and how it could be mitigated through proper actions.

2. Causes of climate change

The factors that can cause a change in the atmospheric system or climatic regime are called "climate forcing" or "forcing mechanisms." So, forcing mechanisms can be of two types, i.e., internal forcing mechanism and external forcing mechanisms. Internal forcing mechanisms are natural processes in the climatic system like thermohaline circulation, etc. External forcing mechanisms can also be of two types- anthropogenic mechanisms including greenhouse gas emission and the emission of several other pollutants and natural mechanisms like changes in solar output, volcanic eruptions, etc. All these mechanisms are responsible for the change of climate. But overwhelming evidence exists that anthropogenic activities are the major reason behind this dreadful condition. These are described below.

- Fossil fuel burning: Fossil fuel burning is one of the most important sources of climate change. As fossil fuels contain carbon for many years, they can release back CO_2 into the air. This is one of the direct causes of carbon emission in the air, which can cause all sorts of environmental problems including global warming.

- Livestock farming: Through livestock farming, methane (CH_4) gas is emitted into the atmosphere. As we know, CH_4 is a greenhouse gas, so capable of trapping a huge amount of heat from the sun. In that way, they can contribute to global warming in broad sense.

- Aerosols: Aerosols also represent a big problem for the climate today. Aerosols are a very small naturally occurring particle in the atmosphere. Previously the number of aerosols in the atmosphere was very less, but now the level is increasing.

- Use of fertilizers: Use of fertilizers in both agricultural and aquacultural farmland can increase the availability of food source greatly to us. To meet up the growing demand for food, the use of fertilizers have increased rapidly. Fertilizer contains a huge amount of nitrous oxide, which is responsible for a steady increase in the earth's surface temperature.

3. Changes on aquatic ecosystem due to climate change

3.1 Temperature

All the aquatic organisms including fish and aquatic invertebrates are poikilothermic in nature and the body temperature of those organisms changes with environmental temperature. So, they are very much sensitive to the change in the temperature in their external environment where they live. When the external environmental temperature goes beyond the tolerance limit of these organisms, they will go for migration to the place where their internal system allows them to regain their internal homeostasis. This procedure is termed as behavioral

thermoregulation [2]. This will result in rapid migration to the cooler zones of the water body [3]. This migration allows the shifting of the aquatic animals from shallow coastal waters and semi-enclosed areas into deeper cooler waters [4]. In spite of the negative impacts of these phenomenons like coral reef destruction and increased ocean acidification, it would have some conservative approach. This phenomenon of migration can alone reduce the maximum catch potential of the tropics by 40% [4].

As the major consequences of climate change, especially increased temperature strongly affects the recruitment process [5]. Some stocks may become intolerance to the sustainable fishing effort because they experience them as overfishing due to the side effects of temperature enhancement [6]. Temperature enhancement of water, where fish live, will slow down their growth and maximum size as the temperature would increase their metabolic rate [2].

Local extinction of fish species would be noticed, among freshwater and diadromous species especially [7]. Because of the higher potential for migration, terrestrial species show a higher rate (15–37%) of overall migration than marine species [8].

The increased temperature would bring a deadly impact on reef fisheries by inducing bleaching of the coral reef [7].

3.2 Primary productivity

The levels of light and temperature determine the availability of nutrients in the water body, which in turn affects the primary productivity. Due to climate variability, reduced precipitation would lead to reduced run-off from land, which caused the starvation of wetland and mangrove and damage local fisheries. In some other places, due to increased precipitation from extreme weather events like flooding, nutrient level in the water body tremendously increased causing eutrophication and washout fertilizer causing harmful algal blooms into the water bodies, known as red tides [2, 9]. Most of the small scale fisheries locate at the lower latitude, where climate change hit the most and decline the primary productivity [10] of the fisheries sector.

4. Impact of climate change on fish production and ecosystem

4.1 Aquaculture system

Fisheries and aquaculture are largely dependent on the interactions among the various factors like the earth's climate and ocean environment. So, changing the pattern of air and sea-surface temperatures, rainfall, sea level, ocean acidity and wind-pattern will adversely affect the fisheries and aquaculture [3].

4.1.1 Marine system

Marine fish production is largely disrupted by climate change. With the change in the climatic conditions, several changes are observed in the ocean including a rise in temperature, melting of polar ice, rising sea level, change in ocean current system and acidification of seawater. Over the coming decades, the temperature of the Indian seas is going to increase by 1–3°C [11]. The species that is going to be affected first due to these conditions is plankton. It forms the basis of the food chain in the marine ecosystem. Other species including corals, fishes, sea birds will be affected simultaneously. Due to increased ocean acidification, marine organisms like oysters,

shrimps and corals would unable to form their outer covering or shell through the process of calcification. Thus, the entire marine food web get affected because of the formation of cracks in the marine food chain.

4.1.2 Freshwater systems

The vulnerability of the freshwater ecosystems against climate change is very high. The size, depth and trophic status of the lake determine the vulnerability of this system against climate change. According to Field and coworkers [12], the negative impact was observed on the cold-water species and positive impact on the warm-water species. Due to acute effects of climate change, alteration of shapes and distribution is seen in the freshwater lake system and in some cases, they might be disappeared. These are the attributes of the dynamics change in precipitation, evaporation and run-off [13]. Climate change promotes long-term increases in fish-production by inducing the enhancement of the production rate of invertebrate prey logarithmically with increasing temperature. The increasing rates are 2–4 times for each 10°C increase in temperature [14]. But on the other hand, climate change will result in a change in prey-species composition. This change may cause antagonistic effects on the long-term enhancement of fish production [14]. In short-time, climate change will cause a decrease in fish-production because of timing mismatch [14]. The ability of the movement of the freshwater species is vital in determining the resistance of those species to withstand climate change [13].

4.2 Coral reef

The coral reef is an important source of income for many developing countries [15]. Coral provides habitat for more than half of all marine species. But now coral reefs of the ecosystem are in great danger. The main reasons are increasing temperature, acidity, etc.

Climate change-related impact on the coral reef can be based on three different time-scales.

- Years: Coral bleaching which increased in recent years and results in degradation of reefs.
- A few decades: Acidification increased and carbonate structures degenerate.
- Multi-decades: Weakened the structural integrity of the reefs which causes large scale composition shifts.

The coral reef is one of the most resistant ecosystems and too resilient to recover from weak chronic as well as acute stresses [16]. But according to Hughes and coworkers [17], the reef ecosystem is not able to sustain against chronic plus acute stress.

Increasing acidity causes decreasing the pH of the ocean, which results in decreased aragonite saturation that can disrupt the calcification of coral [18]. Enhanced acidity of the world's ocean is very much important and represents a long-term threat to coral reefs but the impact growth of the corals on the increasing acidity is unknown [15]. The saturation level of aragonite in deep cold water corals are 90–150 m [19]. The impact of the acidification is badly seen in these deep- cold-water corals.

If corals are decreased due to adverse impacts from climatic change, it causes a negative impact on the reef fish- biodiversity [20]. According to Grandcourt and

Cesar [21], coastal fisheries are badly affected by the warming of the climate and bleaching events. It can be concluded that coral reef destruction causes a long-term impact on the animals which depends on these reefs for their food and habitat.

4.3 Global marine biodiversity

Climate change acts as an important determinant of the distribution of biodiversity in past and future aspect [22–26]. Environmental factors reflect strong influences upon species richness of aquatic organisms [27]. Ocean warming can cause change to the marine species especially in their latitudinal range [28–30] and depth range [31]. At a larger scale, such changes can lead to local extinction and invasions and shifting to their bio-geographic pattern [28]. As a result, a huge shift in species richness can occur which is regarded as the main cause of disruption of marine biodiversity and ecosystem [2, 32, 33]. The climate in the aquatic environment can affect biodiversity, community structure and ecosystem function [34–37].

5. Economical crisis of the fish farmers due to climate change

Change in the aquatic environment has a direct impact on the lives of the fish farmers. Due to disturbed fish production, farmers face economic losses. Besides global warming, cyclone is another problem that affects the lives of the farmers. Cyclone combined with a flood and heavy rainfall creates a major problem every year for the farmers especially in the coastal states of India. It is a matter of great concern that the frequency of intense tropical cyclones has increased in the Indian ocean [38]. The factors such as warm sea temperature, high humidity and instability of atmosphere are responsible for intensifying the cyclone [39]. As a consequence of global warming, the temperature of the Indian Ocean has also increased promoting devastating cyclones. In May 2019, a cyclone named Fani hit Andhra Pradesh, Odisha and West Bengal. It caused damage to the coastal land, boats, jetties and the shelters of the fishermen and five lakh houses were destroyed in 14 districts [40]. In Odisha only, the losses were estimated to be 12,000 crores. Regarding the seafood sector, the production of shrimp was declined by 60–70% [41]. Most recently, in May 2020, cyclone Amphan hit eastern India specifically West Bengal and alos Bangladesh. This was the first super cyclone in Bay of Bengal since 1999 super cyclone that hit Odisha took the life of more than 9000 people [42]. Amphan affected the coastal areas of West Bengal including East Midnapur, North 24 Parganas, South 24 Parganas, Kolkata, Hoogly and Howrah. According to Chief Minister of West Bengal, the death toll was more than 86 and the state suffered a damage of 1 lakh crore rupees (15.38 Billion USD) [43]. Specially, the Sundarban areas were highly devastated, millions of homes were damaged breached embankments led to flood in villages. It takes years for the local residents as well as fishermen to recover from these situations. They do not have shelter to stay, do not have a boat for fishing and no money to pay back the loans that ultimately affects their psychological health sometimes leading to suicidal tendencies.

6. Adaptation and mitigation measures to reduce the effects of climate change

Consideration of future climate changes in advance and making them a part of short-term decision making is known as adaptation. This includes using more eco-friendly substances, planting more trees and preserving our nature as much as

possible. On another hand, preventing the chances of climate change, before it has occurred, reducing the effects of climate change in case of occurrence is known as mitigation. Reducing the carbon footprint and related activities should be a major step. The level of environmental pollution should be decreased as soon as possible before it becomes too late to act. Some strategies that we should follow immediately are discussed below.

Adaptation of forest conservation measures: Forest plays an important role in maintaining equilibrium in our ecosystem. We should conserve and prevent the destruction of forest land through afforestation as well as reforestation and prohibit the use of forestland for nonforest purposes to meet the livelihood of local people.

Inclusion of climate-study in the school-level educational system: If we want to generate awareness in the young generation by the introduction of climate-related study along with traditional educational system with the help of governmental initiatives. This will help to grow the consciousness among the young generation from very beginning which will significantly broaden this culture at the local, state and national levels.

Slowing down of population growth: Population growth is becoming a burden especially in the case of a developing country like India. It has become a major obstruction in achieving social and economic development. So, in order to fight against climate change, population pressure over the area need to be reduced by reversing down the population growth curve in developing countries.

Integration of climate issue with economic planning: Climate protection-related policies and programs should be incorporated into the local, state and national levels in order to encourage the integration of climate issues with economic planning and management.

7. Recommendation for better management of fisheries against climate changes

- The ecosystem approach should be comprehensive, sound, integrated, compact and revised to make complete management of sand oceans of coasts, fisheries and aquaculture.
- Environmental friendly aquaculture and fishing practices to be undertaken.
- Fuel-efficient aquaculture and fishing practices to be undertaken.
- Integration of climate-proof aquaculture with other sectors.
- Over-fishing and excess fishing capacity should be eliminated through the implementation of reduced subsidy systems.
- Risk assessments should be proper and accurate at the local level.
- Exploration of the carbon sequestration process by aquatic ecosystems.

8. Steps for sustaining the fish production and economy against climate change

There is a crucial knowledge gap between fisheries, aquaculture management and climate change that need to be filled practically. In order to assess the risk of

climate change to coastal communities, human and institutional capacity building should be strengthened and proper adaptation and mitigation measures should be implemented. Therefore, well managed fisheries and aquaculture could give birth to a healthy and productive ecosystem. Careful use of coastal areas and catchment areas should be cross-sectoral responsibility to encourage the building process of a healthy and productive ecosystem. Moreover, youth engagement in each and every policy and decision-making process related to aquaculture and fisheries both at continental and national levels should be institutionalized efficiently as youth are the backbone of our society.

9. Positive effects of climate change on the aquatic environment

- **Slowed down the winter death rate of aquatic organisms:** Water temperature is one of the most crucial factors in determining the survival of aquatic animals. Many years ago, especially before the drastic climate change, winters were too cold to maintain the minimum metabolic rate of the aquatic organisms and the consequent death rate has increased rapidly. As a result of climate change, the average temperature of the water body increased so rapidly that winter has now become bearable considerably. So, the number of death due to winter temperature –falling has decreased.

- **Reduction of the fuel cost of the aquatic environment:** As a result of climate change, heat energy becomes available and affordable at a cheaper rate. So, the demand for fuel in the aquatic environment has decreased and the consequent cost of fuel has also become cut down.

- **Growth in aquaculture production:** Some thermophilic organisms living in the aquatic environment demand high temperature for maintaining their metabolic rate at an optimum level. The excess heat which is introduced as a result of climate change meets the demand of those aquatic organisms. So, in that way, climate change benefited the overall aquacultural yield.

10. Conclusion

Climate change is a major threat to both aquatic and terrestrial ecosystems. In present days, a random population explosion increases fossil fuel burning, industrialization, deforestation, and profit-oriented capitalism, which can, in turn, create synergistic effects on climate change. Aquaculture sector is much impacted by temperature increase in water and air, sea level rise, and associated water intrusion as affected by global warming and climate change. This change in the aquatic environment or a decrease in fish production is directly affecting the economic sustainability of fish farmers. Thus, this situation can be corrected if necessary actions will be taken in reducing environmental pollution as soon as possible. Researchers, economists, policymakers, and farmers should act together to fight economic instability and maintain harmony with nature. One thing we should remember that we should protect nature if we want to protect ourselves from the coming threats.

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