Chapter 9
Climate Change a Great Threat to Fisheries

Muhammad Younis Laghari, Abdul Ghaffar, and Muhammad Mubeen

Abstract For billions of people all around the world, fish is a major source of aquatic animal protein, essential vitamins, fatty acids, and starchy diet. Around 520 million fishers and fish farmers worldwide, mostly in developing countries, depend upon fishing and aquaculture. Climate change influences fish stocks directly and has great impacts on fisheries and aquaculture. There might be unpredictable and surprisingly various impacts of climate change on fishes, which effect in a wide range. Ocean acidification, coral bleaching, and altered river flows are the processes which affect the marine and freshwater ecosystem. Fishes are not only threatened by extreme weather but at the same time these are vulnerable to sea-level rise as well. Meanwhile, the social and economic context of fisheries will be disrupted by impacts on security, migration, transport, and markets. Because of overexploiting natural resources there is a significant decline in fisheries production. In recent years, the fisheries sector has been confronting with numerous challenges (including natural and anthropogenic) such as natural disasters, climate change, industrialization, environmental pollution, and overfishing. Temperature is one of the major factors that cause the physical changes in the aquatic environment such as fluctuation in oxygen in the ecosystem, development of algal blooms, and enhancing the frequency and intensity of disease outbreaks. In Asia and Africa, many regions are dominated by the fishery sector and some regions have greater poverty where fisheries-related livelihood prevails. It is a matter of great concern and needs the utmost attention of policymakers and world aquaculture fisheries authorities to take the matter seriously. Hence, to cope with global climate change and save fisheries resources as well as to increase aquaculture production, a consistent policy is desired in order to find out remedial measures.

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9.1 Introduction

Fisheries is one of the vulnerable sectors that is facing widespread and often profound changes for decades. The freshwater, as well as marine water, have been affected by many factors, such as anthropogenic activities and alteration in River flows, coral bleaching, and ocean acidification. Overall, not only fish or aquaculture production is disturbed but fishing communities are vulnerable to such climate change as rise in sea level, and their livelihoods are threatened by extreme weather and storms, etc. On the other hand, due to markets, transport, migration, and security reasons, fisheries will be disturbed in the context of socioeconomic policy. Inland fishery is also at great risk and is a big threat not only to the livelihood of the poorest populations of the world but for food supply too (Smith et al. 2010).

There are millions of people who are dependent on fisheries and aquaculture for their livelihoods throughout the world. At present, it is estimated that about 42 million people work full or part-time as fishers and fish farmers, mainly in Asia. It is expected that by the year 2100, there will be a significant (25%) impact on the inland aquatic ecosystem of Africa, at the same time aquatic culture also will be affected simultaneously.

Through scientific investigation, it has been proved that increases in greenhouse gas emissions have caused global warming. The greenhouse gas emissions have not been recorded as highest at any time since last 650,000 years as it is nowadays (IPCC 2014). The scientific approaches have revealed that globally average increase in air temperature and rise in sea level. While, widespread melting of ice and snow is expected. Sea level is rising due to climate change and causing the salinity increase in rivers and deltaic regions. Hence, this also will have a great impact on fish farming.

9.2 Factors (Related to Climate Change) Affecting Fisheries

Climate change is rapidly proceeding that will have serious impacts on humans, wildlife, aquatic life, and habitat. The present scenario of heat-trapping might lead to a shift in local, regional, and national climate levels. Hence, it will not only disturb the natural processes but will also significantly destroy the ecosystems. That ecosystem degradation certainly will disturb our sustainable natural resources including aquatic and terrestrial. Fishes need a long-term iterative process to adapt

to climate change. Habitat loss, water pollution, and diseases are the major threats. The speedy development and expansion of industrial technology is another threat that causes contamination of many freshwater ecosystems (Mashkoor et al. 2013; Ghaffar et al. 2014). The industrial and agricultural processes continuously release wastes into natural water sources and have adverse effects on aquatic biota (Witeska et al. 2014; Shakeel et al. 2017; Amin et al. 2017; Zia et al. 2017; Saud et al. 2017). Management of these wastes is crucial in order to minimize their adverse effects on aquatic ecosystems (Ghaffar et al. 2016). The major challenging factors for their existence are shifts in local climate (temperature and precipitation). The recent years global warming has been accelerated, even it might be rapid in the next century if the current rate of greenhouse gas emissions is not controlled. As a result, most species will adapt to the evolutionary changes (Abbas et al. 2017; Adnan et al. 2017; Awais et al. 2017; Fahad et al. 2017; Rasool et al. 2017).

The major factor of climate change is temperature that is root cause of all other factors affecting the fisheries sector through various aspects.

9.2.1 Temperature

The proper weather record keeping started in the year 1880, since then, the highest earth's surface temperature was recorded in 2019 and it is the largest temperature anomaly of any month. Detailed illustration of temperature can be seen in Fig. 9.1. The global average temperature had increased 0.2 °C per decade up to the year 1970s and average record in 1990 is 1.4 °C (IPCC 2007). It is predicted that the temperature might rise up to 5.8 °C in the year 2100 (WMO 2018). That rise will directly impact the production by affecting all the responsible factors. In these major factors, oxygen, sea level, toxic algal blooms, prevalence of pests, diseases, and predators are included. Based on these factors temperature might influence

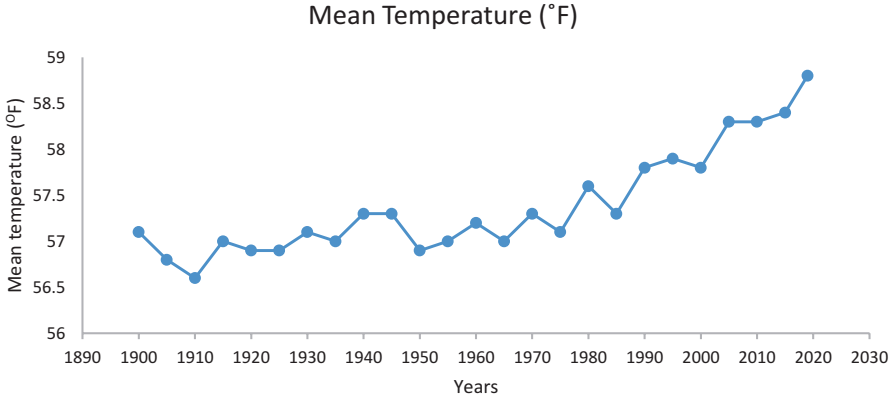

Fig. 9.1 Mean temperature trend from 1900 to 2019

positively or negatively. In general, the increase in temperature boosts up the growth that may increase per unit area production. But, fish stop feeding at above 30 °C temperature and slow down the growth rate (Renee et al. 2019; Eoin et al. 2016).

9.2.2 *Oxygen Fluctuation*

Oxygen is one of the most important requirements of any living organism. In general, it has been noted that temperature has a direct relationship with the oxygen contents in water. Hence, climate change is the main cause of deoxygenating in the open oceans. The first impact of oxygen fluctuation is on the food chain that plays a primary role in the existence of any living organism. In further, due to stratification on the ocean, the produces are also greatly affected due to the lowest oxygen supply at the bottom level. Hence, such vertical oxygen supply would affect the physical as well as biogeochemical process too. While such changes will also have a great impact on the living style of any aquatic organism. All the physiological processes including respiration, reproduction, digestion, and many others are greatly influenced by the oxygen contents (Tran-Duy et al. 2012; Mohsen et al. 2015). Overall, all these changes ultimately have loss or threat to the fish and cause a decrease in production. A bioindicator fish species, the eelpout (*Zoarces viviparous*), used for environmental monitoring has been decreasing and its growth performance has been affected at North and Baltic Seas. Lakani et al. (2013) showed that mean fish weight was not affected by oxygen levels during the first 2 weeks in large size fish, but after that until the end of the study, fish showed significant differences in mean weight (Fig. 9.2).

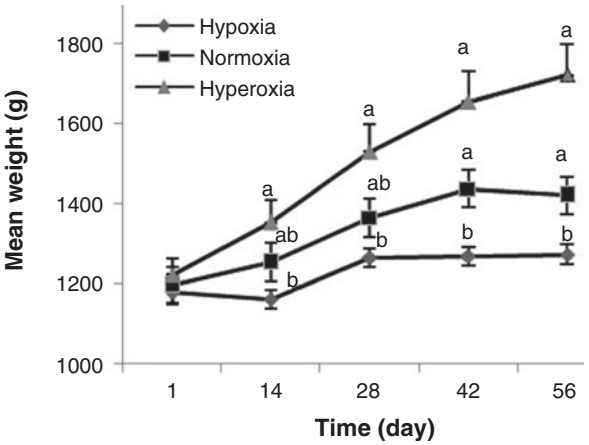

Fig. 9.2 Mean weight of *H. huso* during 8 weeks rearing under different oxygen levels. A significant difference was shown by different letter as determined by ANOVA and Tukey's test at $P \leq 0.05$. [source: Lakani et al. 2013]

9.2.3 Net Primary Productivity (NPP)

The production system of any water body is regulated by the Net Primary Production (NPP). There is a negative as well as positive impact of the climate change in any ecosystem. It will boost up the production of filter feeders by enhancing the NPP and may lower winter mortality. But, there is a huge negative effect of it; as toxins will be released in the water by boosting the algal blooms and dissolved oxygen in the ecosystem will be decreased. That might increase infestation of nuisance species and fouling organisms. Hence, such situation might increase the fish kill. Commonly the water productivity is dependent on planktons, especially the phytoplankton. The phytoplankton population directly depends on the availability of nutrients and light in the water. The atmosphere, ocean mixing, clouds, and the solar cycle are directly effecting both the light and nutrients in the water. It has been recorded that NPP has been altered since the last two decades because of changes in ocean surface temperature, atmospheric iron deposition, and wind (Khan et al. 2018; Hashmi et al. 2018). As we know that temperature plays an important role in thermal stratification, as a result it affects the nutrients in the water and exchange of gases. Finally, it will alter the primary productivity that brings a serious change in the food chain and food web. Hence, that altered food availability might result in alteration of species assemblages because of changes in food availability, species-specific differences in thermal tolerances, disease susceptibility, and shifts in the competitive advantage of species. Due to all these factors, the nutrient supply to upper productivity of the Atlantic and the Pacific oceans is declining.

9.2.4 Ecosystems Alteration

The ecosystem plays a vital role in survival and normal life routine of living organisms of any habitat. Alteration in the ecosystem affects all life activities of an organism from birth to death. The mangroves, seagrass, and coral reefs are considered as basic ecosystems of the marine. These ecosystems are under great threat due to anthropological activities and climate change has added more stress to them. Both factors have brought a complete structural and behavioral change to the ecosystem. The process of the ecosystem is climate-dependent and the influenced process will affect the ecological communities as well as individual species. Recently the concern of many species extinction goes to climate change (Pounds et al. 2006; Amin et al. 2018; Awais et al. 2018; Afzal et al. 2018; Fahad et al. 2018). Climate change might enhance the extreme events and would have rapid changes in any ecosystem in the future. Brander (2007) has briefed the situation as ***"The resilience of species and systems is being compromised by concurrent pressures, including fishing, loss of genetic diversity, habitat destruction, pollution, introduced and invasive species, and pathogens."*** He also added that the pH of ocean water is decreasing due to rise in CO_2 and its consequences are still hidden.

9.2.5 Food Availability

The human population is growing rapidly throughout the globe accompanied by increasing food fish demand. The major source of animal protein is fish for the billions of people all around the world. Fish provides the essential vitamins and fatty acids along with protein complements. About 520 million people, including their dependents, rely on fishing and aquaculture. Majority of them are from developing countries.

There is not only development in modern technology for comfort and luxury life but the food habits also have been changed throughout the world for last few years. Where everyone is demanding food safety and best quality. There are no so far days, when our consumer will demand labeled farmed food, with detailed environmental conditions as greenhouse gas (GHG) emissions per unit of produce, in the market. Hence, based on the consumer consciousness it might be predicted that aquaculture also will meet these aspirations in the future. About 100% mollusks and 70% of finfish are considered minimum emitting GHG. Hence, the aquaculture sector will ensure such demand and increase the fish supply as the most GHG-friendly food source. However, the model change in seafood consumption will be required to achieve it. People get an advantage through fishing during seasonal stock availability when food production and income generation fall down. Fishing communities are dependent on inland fisheries resources that are particularly vulnerable to climate change. Aquaculture is thought to be one of the fast growing food production sectors that have expanded at an average annual rate of 8.9% since 1970. The fishing only could not fulfill the market demand of increasing human population because of overexploiting and climate change. Because, the production of natural sources has been decreasing significantly day by day. Therefore, for the significant nutritional and economic benefits from available land and resources, integrated aquaculture is the best choice. Where as, fish raising in a rice field or using agricultural waste, to fertile the pond, are the best choice of natural resources utilization.

9.2.6 Predation

The temperature and water current leads distribution in fish stock that would cause loss in some area and benefiting other. Only the higher valued fishes are focused in research in this aspect while the potential impact of mass movement of noncommercial or wild species has not been investigated which directly or indirectly has an impact on the fisheries production. We are well aware of the role of such wild species in the food chain. Whenever there is migration of fish due to said factors then the fish predation is effective in two ways. First, when large fishes (mostly carnivores) move to the place of habituating small fishes then those fishes invade them for their food. Secondly, whenever the movement of small fishes to the habitat of large ones then also they become the food of the dominant fishes. Overall the

climate change create these circumstances of mass movement where there is a significant impact of predation on fish production. Such type of challenges is significantly observed between climatic regions, especially in the deltaic region, which are mostly impacted by the sea-level rise. Most of the fish habit is to move in schooling; therefore, serious research must be paid to cope with external shock.

9.2.7 Mass Movement

There is a strong correlation between temperature on fish migration. The physiology and behavior of fish are also affected by climate change. The fish is a poikilothermic animal and its distribution is controlled by the water temperature because fish cannot maintain its body temperature according to the surrounding degree of hotness/coldness. Hence, for its survival the fish always move to the suitable temperature side from the high temperate water region. It has been reported through the research investigation that fish which normally thrive in the tropics are quickly migrating in an effort to discover cooler seas (Sarah 2019). Such migration of fish reveals that in search of better food and better oxygenated habitat, it moves to the Polar Regions. Hence, due to climate change and marine migration at such speed it might be predicted that a substantial amount of fish species will have evacuated the tropics till the year 2050. Such type of forced migration might have a dangerous effect on the ecosystems, especially the oceans. Such type of migration of temperate to polar region also will have a great impact on the sustainability of that habitat fishes. Rapid dispersal abilities have been found in most of the invasive species because they have a wide range of tolerance and survival in a range of environment. In the present situation of fast climate change, it might be predicted that our oceans will be fully 3 °C warmer globally, in the next 50 years. Such impact of climate change on the marine ecosystem and fish migration would vanish the species from the water once roamed. As there are many records of the history of the planet for such extinction of the species.

Cleaner seas (2019) reported that ***"Once bounding with infinite amounts of underwater life, a small fishing town in the state of Virginia was proudly known as the flounder capital of the world, in recent years however the flounder have struggled with rising sea temperatures and have relocated to cooler waters closer to New York and New Jersey."*** Hence, ocean's ecological stability is affected by the altering producer's chain reaction due to climate change.

9.2.8 Diseases Distribution

In aquaculture, where temperature plays a positive role in sense of fish growth there is also an increasing opportunity for bacterial growth, algal blooms, and parasitic development in the ecosystem. Hence, all these might cause various diseases in the

fishes. Hence, change in climate that alters the temperature of water could cause slow growth due to above consequences and ultimately causes a decrease in production.

9.2.9 Rise in Ocean Level

Generally, over a long period the mean sea level rises but due to climate change the patterns have been changed and sea level rise earlier. This type of change might cause the fish stock distribution and their migration pattern. While, sea level rise alters the mangroves ecosystem that ultimately affects the fish life. On other hand, the brackish water increase at the coastal side has an impact on the freshwater fishes. Most of the fishes exist at 0–300 m layer all around the world and that layer of the ocean is warming sharply. It is a great concern regarding the prediction of mean sea-level rise may be up to 90 cm in twenty first century. As a result the coastal ecosystem will be destroyed, which is considered most important for the survival of many species. Because the coastal ecosystem is rich in mangroves and marshes and this is not only the shelter for fishes but also provides enough seed supply to aquaculture.

Hence, such significant change in the ocean and climate change may produce various factors including ocean current, temperature, distribution of algae blooms (toxic), predators, and primary productivity will have direct effects on aquaculture and its productivity (Handisyde 2008).

Rise in sea level will increase the salinity in the groundwater that will not only affect the freshwater fishery but agriculture too. At the same time, that saline groundwater will limit domestic as well as industrial consumption. Therefore, it is important to prepare broader policy according to climate change. However, that increasing saline water would lead to develop saline water aquaculture. Where some high-value species including shrimps and crabs culture will be benefited along with the negative consequences of sea rise. Hence, new policies and opportunities will lead the public to get an advantage in such circumstances. Therefore, the fish farmers/fisherman must be trained that how aquaculture can play an important role in diversifying livelihoods in such situations.

9.3 Impacts on Culture

Aquaculture might be affected directly or indirectly through various factors due to climate change. Such factors include fish stock, fish supply, fish consumption, and cost of supply and fish farmers' services.

Rise in sea level will increase saline water intrusion and will reduce the water inflow in the deltaic region will have a significant impact on the tropical aquaculture system. Hence, due to extreme weather conditions inland cage culture, pen culture,

and other types of culture could be affected due to increasing upwelling deoxygenated water in the reservoir. As the reproductive cycles of species are dependent of the monsoon season and rain pattern that would affect indirectly on the aquaculture system. Becasue of the seed production and grow out cycle of the species. Especially, the great impact might be observed in the species whose seeds are collected naturally, because of their nature of spawn such as mollusks. While upper tolerance temperature limit of some species, emergent of no pathogen organism and many unknown diseases would make the culture system vulnerable to high temperature. Same time the temperature affects trash fish production, by disturbing the food chain, which in turn has an impact on some culture species, especially the carnivores. While, the basic supply of fishmeal and fish oil, for the preparation of fish feed, also considered to be one of the issues affected by climate change. Hence, all these factors affect the aquaculture practices in the climatic region.

There is a limited research on the climate change impact on aquaculture or vice versa. Overall extreme rains or alteration in monsoon in recent years, more warming post-monsoon, lower number of rainy days, annual mean temperature increase, increase in hot days' frequency, and consequent droughts have a major impact on the aquaculture. Hence, to cope with climate change in such situation, the aquaculture practices must consider the adaptive and mitigate measures. As aquaculture is considered as the backbone in many developing countries, socioeconomic and modern technology must be adopted to address the potential climate change. Hence, small-scale farming, intensive culture, integrated aquaculture system, and recirculatory farming system must be promoted in order to maximize per unit area production at environment-friendly system.

9.4 Impacts on Economics and Community

Climate change varies from region to region. Therefore, the regional productivity and specific species resources may be varied regionally. Ultimately the climate change will impact the effort per unit catch that will lead to go further for harvest. Likewise, it will require much more effort and higher cost. Allison et al. (2009) has reported that out of 132 nations the central, western Africa, and some in Asia have the most vulnerable capture fisheries due to potential climate change impacts. Hence, decrease in harvest capacity in natural water resources has an impact on fisheries production that reduces the access to the market. In such circumstances, the local economies adapt to new conditions in terms of labor and capital mobility that is said to be an indirect economic impact. Aquaculture is growing fast at an annual rate of 8.7% and is thought to be rapidly developing food producing sector of the world. Because of high nutritional value and quality, the aquatic food contributes about 20% per capita animal protein for around 2.8 billion people all over the globe, most of them belong to developing country. Generally, the aquatic environments, freshwater, marine, or brackish water, respond to climate change equally as

atmospheric environment. The aquaculture practices represent mostly undefined sources of greenhouse gases (GHGs).

9.5 Conclusion

Fish is a basic source of essential nutrition and income to outpace population growth around the world. It provides a major contribution or might provide livelihood where other food and employment resources are limited. Fisheries and Aquaculture continue to be the fastest growing animal food producing sectors but along with climate change the poor illiterate fisherman/fish farmers are another challenge to adopt changes and have a great impact on the fish resources. In general, the change in temperature, water ecosystem, and precipitation are a major threat to the fisheries. Due to climate change, the storms become frequent and extreme and result in the destruction of infrastructure, affects the livelihood, imperiling habitats and stocks. In such situations, high-level research is required to suggest the best plan and coping strategies to improve the adaptability of the fisher community. Still, the fisheries sector is growing fast in food production sector. Per capita supply from the aquaculture sector increased from 0.7 kg in 1970 to 7.8 kg in 2006. Aquaculture is gradually drawing attention internationally for potential impact of climate change. In the Asian region, there is great poverty and aquaculture-related livelihood prevailing that needs great concern. If we plan properly to challenge the climate change the fishes have property to adapt to climate change as integrating aquaculture and agriculture (Hydroponic, Aquaponic, Recirculatory Aquaculture, Biofloc system, In Raceway Pond System). This type of culture system can help farmers cope with drought while boosting profits and household nutrition. Further, the management system should go forward to seek to maximize yield to increasing adaptive capacity. Therefore, the world aquaculture authorities and policymaker should pay attention to this serious matter. Hence, to cope with climate change the policymakers along with researchers/scientists must prepare policy based on the current scenario and find out the remedial measures.

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