**Consequence of climate change on fisheries and aquatic system**

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**INTRODUCTION**

The Intergovernmental Panel on Climate Change1 (IPCC) has been regularly disseminating information on climate change and its political and economic ramifications since 1988. These updates provide a thorough synopsis of the generally recognised body of knowledge regarding the causes, effects, and science of climate change. This chapter presents a comprehensive overview of the impacts of climate change on aquatic systems (oceans, seas, lakes, and rivers), with a particular emphasis on their effects on aquatic food production, including fisheries and aquaculture. The information is drawn from the 5th IPCC Assessment Report (AR5) and up-to-date scientific literature. While subsequent chapters delve into more detailed information on these food production systems' climate change impacts, this chapter primarily focuses on explaining the fundamental drivers of climate change and their resulting biophysical alterations in aquatic ecosystems.

**OBSERVED CHANGES IN THE CLIMATE** **SYSTEM**

The IPCC AR5 firmly established the undeniable warming of the climate system and highlighted the unprecedented nature of many observed changes from 1950 onwards, surpassing conditions seen in earlier decades to millennia. This conclusion was drawn from rigorous data analysis, acknowledging potential uncertainties stemming from knowledge gaps and data limitations. Since the middle of the nineteenth century, the average surface temperature of the Earth has grown by more than 0.8 °C, and it is currently warming at a rate of more than 0.1 °C every decade (Hansen et al., 2010). Even though data dependability and degree of accuracy differ between continents, heat waves are increasingly often lately (Hartmann et al., 2013). The increase in the atmospheric concentration of GHGs including CO2, methane CH4, and nitrogen dioxide NO2 is thought to be the main cause of this warming. GHGs are in charge of sustaining life on Earth by acting as a heat blanket surrounding the planet (IPCC, 2014). Since the industrial revolution, GHG emissions have grown exponentially, resulting in the highest atmospheric concentrations of these gases in the past 800 000 years. For instance, atmospheric CO2 levels rose from 278 ppm in the middle of the eighteenth century to approximately 400 ppm now (Ciais et al., 2013). The IPCC AR5 also came to the conclusion that it is very likely that human activity, specifically the coupling of GHG emissions with gas and oil burning, deforestation, and intensive agriculture, is the primary driver of the warming that has been observed since the middle of the 20th century. Only 1% of the extra heat brought on by human-caused climate change is kept in the atmosphere; 93% of it has been absorbed by the world's oceans. The ocean plays a vital role in the Earth's climate regulation, absorbing the last three to four percent of heat through the melting of ice and snow, effectively acting as a vast heat buffer. Even small alterations in the heat balance between the ocean and atmosphere can substantially influence global air temperatures (Reid, 2016). Furthermore, owing to its significant thermal capacity, the ocean has sequestered approximately 25 percent of anthropogenic CO2 emissions (Le Quéré et al., 2018), further emphasizing its importance in mitigating climate change.

Climate warming significantly influences the hydrological cycle, affecting the quantity, quality, and seasonal patterns of water resources due to changes in precipitation, temperature, and climatic conditions. The melting of snow and ice further alters aquatic habitats. In high-latitude areas, permafrost is thawing, and in high-elevation regions, glaciers are receding, impacting downstream water resources (IPCC, 2014). Moreover, the melting Arctic sea ice has the potential to disrupt the global ocean conveyor belt in marine systems (Liu et al., 2017).

Fish is a crucial source of sustenance for underprivileged and vulnerable communities, serving as a major traded food item and employing many men and women. The fish trade significantly contributes to the economic growth of developing nations, aiding in foreign debt payments, government funding, and enhancing national food security through diversified diets. Climate changes, particularly on a medium (decadal) scale, have historically influenced fisheries and their management. Looking ahead, the continued warming of the atmosphere and ocean, rising sea levels, ocean acidification, and potential circulation pattern changes will impact fisheries, categorizing the effects as physical, chemical, and biological changes.

**Physical Changes**

**Water Surface Temperature Rise**: The control of the world's climate is greatly influenced by the oceans. Due to their heat capacity being around 1000 times greater than that of the atmosphere, they are able to absorb a sizeable portion of the heat that is emitted globally. Such variations in ocean temperature have the potential to alter the regional aquatic habitats' dynamics. Fish migration patterns may shift as a result of changes in ocean dynamics, and landings may decline, particularly in coastal fisheries.

**Sea Level Rise** During the 20th century, global sea levels increased by 10 to 20 cm primarily due to thermal expansion, and the Intergovernmental Panel on Climate Change projects a further rise of 9 to 88 cm by 2100. This sea level increase could impact estuarine habitats, wetlands, and submerged vegetation along coastlines, affecting species that rely on these areas for recruitment and reproduction. Additionally, rising sea levels may pose increased risks to sea ports, fishing facilities, and fish storage facilities located near the coast, as they become more vulnerable to tidal and storm inundation

**Chemical changes**

**Increasing Water Salinity**

Water salinity can alter as a result of climate change in a number of ways. Oceans near the poles have become fresher while those in the tropics have become more salinized. It is expected that anthropogenic climate change would cause an increase in the salinity of several freshwater environments. By impairing the organisms' capacity for osmoregulation, such physical alterations will have a detrimental effect on the population of both plankton and larger prey fish species. Salinity is regarded as one of the most crucial factors affecting how long species survive in estuarine ecosystems. It can either directly affect the creatures or indirectly affect them by damaging their habitat, especially their breeding and rearing grounds.

**Ocean Acidification**

The majority of anthropogenic CO2 emissions may be able to be absorbed by oceans. In water, CO2 dissolves and irreversibly changes into carbonic acid. The world's oceans are becoming much more acidic as a result of this chemical process. Ocean habitats are negatively impacted by seawater's increased acidity due to dissolved CO2. Changes in physiological functions such as decreased growth of calcified structures, otolith development, and fertilisation success are examples of direct consequences. Modifications in predator or prey abundance, impacts on biological ecosystems like coral reefs, and adjustments to nutrient recycling are examples of indirect effects.

Ocean acidification, a long-term decrease in ocean pH mainly due to the uptake of atmospheric CO2, is primarily caused by human activities and termed anthropogenic ocean acidification. Increased atmospheric CO2 concentrations lead to ocean CO2 absorption, lowering water pH, mineral saturation, and increasing pCO2 near the ocean surface. The decline in ocean surface water pH by an average of 0.1 since the industrial era began represents a 26 percent rise in acidity. Coastal waters exhibit more variable pH and higher pCO2 levels, exacerbated by lower salinity from ice melt or excessive precipitation. Regional variations in surface water acidification exist, with Arctic waters acidifying faster due to their higher CO2 absorption capacity in cold water. In the California Current, corrosive conditions events have increased in frequency and intensity. Future projections indicate widespread pH decreases, most pronounced in warmer low- and mid-latitudes, while already low Ωar waters in high latitudes and upwelling regions are expected to become aragonite unsaturated first.

**Biological Changes**

**Changes in primary productivity**

Ocean acidification has increased since the dawn of the industrial period, with the pH of the ocean's surface dropping. It is believed that the availability of enough and the right kind of food is crucial for the survival of fish larvae during the planktonic stage. Therefore, in addition to effects of changes in production, climate-induced changes in the distribution and phenology of fish larvae and their prey can also have an impact on recruitment and production of fish stocks. Increased stability of the water column has reduced mixing, deep-water nutrient upwelling, and entertainment into surface waters due to an increase in surface-water temperature and a regional decrease in wind velocity. The result has been a decline in primary production.

Primary production: The marine food web's foundational mechanism, phytoplankton production regulates the energy and food accessible to higher trophic levels and, ultimately, to fish. Global marine primary production forecasts due to climate change are questionable, with models predicting both rises and decreases of up to 20 percent by 2100 (Taucher and Oschiles, 2011). (Bopp *et al*., 2013). This is due in part to the fact that changes in light, temperature, and nutrients are integrated by primary production, but it is also a result of the lack of clarity over how sensitive tropical ocean primary production is to climate change. It is unclear specifically how El Nio episodes in the tropical Pacific will be impacted by climate change. Primary production in freshwater lakes has been observed to increase in some Arctic (**Michelutti et al., 2005)** and boreal lakes, but to decrease in Lake Tanganyika in the tropics (O’Reilly et al., 2003). In both cases the changes were attributed by the authors to climate change **(IPCC, 2014).**

**Changes in Fish Distribution**

One of the most frequently noted ecological reactions of marine species is a change in fish distribution. Fish species are thought to alter their latitudinal and depth ranges in response to environmental changes like changing water temperatures. Fish migration patterns may shift as a result of changes in ocean dynamics, and landings may decline, particularly in coastal fisheries. Since marine fisheries are a significant source of food, changes in the overall quantity or geographic distribution of fish that are accessible for catching could have an impact on food security.

**CONCLUSION**

This chapter provides background material and establishes the context for the following chapters by summarising theme information on climate change and its effects on aquatic systems. Given that aquatic systems make up more than two-thirds of the surface of the Earth, the amount of evidence currently available on the effects of climate change is very limited, and many of the ideas and presumptions are still up for debate. However, it is undeniable that oceans play a crucial part in regulating the climate as well as in absorbing heat and the increased CO2 levels brought on by our activity. According to model predictions, ocean warming, greater stratification, and rising emissions will diminish the ocean's potential to absorb CO2 in the future (Gattuso *et al*., 2015). Freshwater systems have a close relationship to climate since they can both affect atmospheric processes that are relevant to climate and serve as indicators of climate change. Due of the numerous anthropogenic impacts that freshwater systems are exposed to, the IPCC judged them to be among the most imperilled on the world. As a result of hydropower infrastructure, irrigation water consumption, and agricultural land use, water bodies are fragmented, flow regimes are changed, and floodplains and wetlands are gradually cut off from the rivers that support them. These stresses are anticipated to remain dominant as human demand for water resources increases, along with urbanisation and agricultural growth, in addition to climate change (Settele *et al*., 2014). Fishing and farming operations are likely to face impacts from both short-term events like extreme weather and medium to long-term changes such as lake levels or river flow, potentially affecting the safety and working conditions of fishers and fish farmers. Additionally, food control procedures will undergo significant adjustments to safeguard consumers from potential increases in contaminants and toxins due to alterations in water conditions.

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