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REVIEW

# Implications of Climatic Change on Physico-chemical Parameters of Freshwater and Fisheries: A Review

**Mohita Sardana, Amit Priyadarshi and Dina Nath Pandit**
Department of Zoology, Veer Kunwar Singh University, Arrah-802301
Correspondence and requests for material should be addressed to DNP (email: panditdina@gmail.com)

## Abstract
Climate change refers to long-term local, regional and global alternations in average temperature and weather patterns. It has been a global concern in recent decades and is related to human activity. Fish can be stenothermal or eurythermal as well as warm-water or cold water depending on their tolerance limits of temperature. The decline of global fish production because of climate change in many parts of the world is widely documented as fishing down the food web or overfishing may lead to further decline of fisheries production and food insecurity. Changes in physicochemical parameters of water are one of the most important consequences of climate change that will have a significant impact on the fisheries. Most physicochemical characteristics, including salinity, turbidity, conductivity, total hardness, $FCO_2$, TDS, ammonia and nitrate are directly related to water temperature. pH and DO have an inverse relationship, whereas BOD showed a direct relationship up to 50°C but total alkalinity and chloride provide no definite relationships. This paper reviews the link between these physicochemical factors and temperature changes, as well as potential effects on fisheries.

**Keywords:** Climatic change; Physico-chemical parameters; Fisheries; Temperature

## Introduction
Temperature is the measure of hotness or coldness expressed in terms of any scale including Fahrenheit (F), Celsius or centigrade (C), Kelvin (K), Reaumur (Ra) and Rankine (Re). The kinetic energy of the gases that make up air is described by temperature. The speed of gas molecule motion rises with air temperature. Among several environmental changes, the water cycle is impacted by elevated air temperatures by raising or lowering water temperatures, which modifies local weather, water quality, and river systems. (Hassan et al., 2017; Gossiaux et al., 2019). This is because the temperature of water is one of the most important factors for physicochemical properties of water quality (Szumiriska et al., 2020), aquatic habitats (Duggals et al., 2018), spawning rates (Besson et al., 2016) and fish growth (Collas et al., 2019).

The average global temperature of 13.73°C has risen by 0.08°C per decade since 1880, and the rate of warming over the past 40 years is more than twice by 0.18°C per decade since 1981. With this increase, the present global temperature becomes 15.25°C. In the late 20th century, global warming has been occurring since industrialization and numerous unprecedented climatic changes have been observed for the first time in decades or centuries (Stocker et al., 2013). Temperature drops by 5-6.5°C/km with rising height in the lower part of the atmosphere but cool by 10-13°C than a place at the same latitude of the sea level. If global temperature rises by 5°C, almost 2/3rd of fish species could be eradicated by 2100AD. An increase of 3.2°C in global mean temperature would threaten less than 50% of the habitat of fish. It has been estimated that the east coast of India will reduce by 25% in 25 years and will result in a cumulative loss of US$17 billion. Over the next 40 years, the temperature in the Indian seas is expected to rise by 1-3°C. The oceans are projected to acidify; sea levels and currents are expected to change.

Climate change has a significant negative effect on society (Deepanaanda and Macusi, 2012). Climate change is a risk multiplier that will put greater pressure on biodiversity preservation and water resources and result in the deterioration of water quality. The report of the Intergovernmental Panel on Climate Change (IPCC, 2007) recognizes that human-induced warming temperature in lakes and rivers poses serious threats to various fish species and fish culture production (Ficke et al., 2007; Cheung et al., 2010).

This review describes the link between these physicochemical factors and temperature changes, as well as potential effects on fisheries.

## Climate Change and Physico-Chemical Parameters of Water

### *Water temperature*

Water temperature depends upon climate, sunlight and depth. The optimum water temperature ranges between 20-32°C. Water temperature is a limiting factor controlling the distribution of fish. For every 7.78°C increase in temperature, the metabolic rate of fish doubles. Fish generally cannot survive in temperatures between 16.7°C and 39.5°C. Fishes may be:

1. Eurythermal fishes: When it comes to temperature tolerance, these fish show a lot of variation. *Anguilla japonica* (20–28°C) and *Tilapia mosambica* (25–35°C).
2. Stenothermal fishes: These fishes can tolerate a narrow range of temperature variations. Goldfish, Brook trout (*Salivelinus fontinasis*) (13-18°C).
3. Coldwater fishes: Fish that dwell in colder water bodies have bodies that are influenced by the water's temperature. yellow perch 0-20°C
4. Warm water fishes: 25-32°C
5. Indian major carps: *Labeo rohita, Catla catla* (18-32.8°C)
6. Indian catfishes: 30°C
7. Air-breathing fishes: *Anabas testudineus, Channa punctatus, Clarias batrachus, Heteropneustes fossilis* (39-41°C).

An increase in water temperature leads to

(1) An increase in metabolic rate and earlier maturation by which respiration will increase that needs more dissolved oxygen.

(2) Changes in the feeding habits

(3) Production of more toxins by algal blooms

(4) Changes in the size of the fish.

(5) Water temperature gradually increased from 25°C to 32°C over several hours and did not harm fish.

(6) The toxins can stress or kill fish by clogging their gills or decreasing dissolved oxygen in the water.

Metabolic rates and water temperature have been found to be directly correlated in studies. Several cellular enzymes become more active at higher temperatures, which cause this. (Wetzell, 2001). Most living organisms perform their activities in a temperature range of 4-45°C. Moreover, according to Van't Hoff's rule, 10°C increases in water temperature will approximately double the rate of physiological function. In addition, enzymes can start to denature, or break down, at temperatures exceeding 35°C, limiting metabolic performance (Dash, 2006; Bennett and DeSanto, 2011). Enzyme action is temperature-dependent. Usually, most enzymes are inactivated above 35-40°C, while below 10°C enzymatic activities are at a minimum (Dash, 2006).

### *Conductivity*

The capacity of water to conduct an electrical current is measured by its conductivity. Conductivity rises with salinity because dissolved salts and other inorganic compounds carry electrical current (Hayashi, 2004). Its value ranges from 150-500µS/cm. Additionally, conductivity increases in lakes that do not receive enough rain or stream water.

The solubility of many salts and minerals as well as increased ionic mobility are two ways that temperature influences conductivity. As water temperature increases by 1°C, conductivity increases by 2-4% though in pure water it will increase approximately 5% per 1°C. As temperature rises, the ions' kinetic energy rises and they move more quickly, allowing electrons from the valence band to jump to the conduction band and allowing unrestricted movement between the two bands, boosting conductivity (Shi et al., 2021).

### *Salinity*

Salinity is the measure of the amount of dissolved salts in water. Its amount increases because of the increase in density with the increase in water temperature. One of the effects of climate change on coastal agricultural land is soil salinity, which has grown during a 25-year period from 1 to 33 percent as a result of rising sea levels. Fish living in freshwater (1mg/l) cannot tolerate increased salinities (Senese, 2010). On the other hand, *Hypophthalmichthys molitrix* and *Chanos chanos* show normal survival and growth at a salinity concentration of 8000 and 32000 mg/l respectively.

1.Euryhaline fishes: These fish are very resistant to salt. It makes up between 3 and 5 percent of all fish species. Example *Poecilia sphenops*, Salmon, Eel, Herring.

2.Stenohaline fishes: These fishes have narrow tolerance to salinity. Most fishes are stenohaline. Example *Carassius auratus*.

Fishes are highly sensitive to changes in salinity. Since warmer water can hold more salt and other molecules than cold water; it can have a higher salinity. Salinity variations have a greater impact on ocean density in polar regions than temperature variations. Because saltwater is heavier, the density of the water increases and the water sinks (Hogan, 2012).

***Turbidity***

Turbidity is a term used to describe a fluid's haziness due to suspended solid dirt and other particles, which is brought on by a huge number of tiny particles that are often imperceptible to the unaided eye. These suspended particles absorb heat from solar radiation more efficiently than water. Due to the fact that suspended particles absorb more heat, turbidity can also raise the water's temperature. The rate of photosynthesis is slowed by turbidity. Climate change leads to a doubling of turbidity and harms fish by reducing food supplies, degrading spawning beds and affecting gill formation (EPA, 2012).

Turbidity during heavy floods increases to 2000-5000mg/l in the river Ganga. Very high turbidity like 175000 mg/l and above causes fish mortality by gill clogging. Due to the particles' ability to absorb sunlight, high turbidity raises water temperature. Hypoxic conditions come from lower oxygen levels in water at higher temperatures. (EPA, 2012).

***pH***

pH measures the acidity or basicity of aqueous or other liquid solutions. pH range of 5-10 is generally acceptable for fish culture (Wurts, 2012). Carps may survive at pH 10.8. But, more than 8.5 seems unproductive and more than 11 is fatal to fish. By 2100, the pH will have significantly decreased as a result of fast global warming. But this does not mean that water becomes more acidic at higher temperatures. A solution is considered acidic if there is an excess of $H^+$ over $OH^-$ (EPA, 2012). When water's pH falls as a result of absorbing CO2 from the atmosphere, ocean acidification occurs. Due to low pH, the solubility of $CaCO_3$ is reduced and respiration is affected at pH less than 5.

pH of freshwater varies from 6.5 to 10.5 (Dash, 2006). Very high pH (greater than 9.5) or very low pH (lower than 4.5) values are unsuitable for most aquatic organisms. Fish begin to die when pH falls below 4.0 (EPA, 2012). Low pH values can cause aquatic species to perish since they are so sensitive to pH values below 5. Because ammonia will transform into poisonous ammonia at high pH values (9 to 14), high pH levels can kill fish (Kumar and Pun, 2012).

***DO***

Dissolved oxygen (DO) is the amount of oxygen present in the intermolecular space of the water. DO is produced as a waste product of photosynthesis (Eissa and Zaki, 2011). Its value is 14.62 mg/l at 0°C and 7.04 mg/l at 35°C. An increase in temperatures reduces DO in water. DO of less than 1 mg/l leads to the death of fish and more than 15 mg/l causes gas bubble disease in fish. The best level of DO for fish health is 5 mg/L. When DO drops to 2-4 mg/L, the majority of fish species become agitated. Less than 2 mg/L concentrations typically cause mortality. Decreased dissolve oxygen also pushes fish to shallow water or fish can drown. *Ctenopharyngodon idella* and *Carrasius auratus* die at DO of 02-0.6 and 0.1-2.0 mg/l respectively (Pandey and Shukla, 2005)

Water temperature has an impact on DO concentration. The solubility of oxygen decreases with increasing temperature (10.15 mg/l at 15°C to 7.1 mg/l at 35°C). As a result, DO levels in a river are higher during the winter months than during summer. The change in dissolved oxygen with temperature is small compared with the larger change in corrosion rates. Different forms of aquatic life may not be able to survive in warm water because it contains less dissolved oxygen than cool water. The concentration of DO in a healthy river will be between 8 and 12 mg/l, whereas 0 to 8 mg/l has been proven to negatively impact aquatic fish species' ability to feed, reproduce, and survive (Lloyd, 1961; Kramer, 1987).

***BOD***

Biological Oxygen demand (BOD) is a measurement of the volume of oxygen needed for aerobic microorganisms to decompose organic waste in water. Temperature affects how much oxygen (DO) may dissolve in water. Since the bacteria need oxygen to complete this activity, the BOD level in this area is significant. For aquatic bodies, a BOD of less than 50 mg/l is ideal (Hernandez et al., 2010).

Increased water temperature will speed up bacterial decomposition and result in higher BOD levels up to 50°C. Warmer water usually will have a higher BOD level than colder water. Algae and other aquatic plants produce more oxygen through photosynthesis when the temperature of the water rises.

The interaction of the DO saturation and the water body's rate of self-purification determine how rising water temperature affects BOD (Chapra et al., 2021). With less oxygen available for oxygen-demanding species to eat, a higher BOD implies worse water quality since more oxygen is needed.

***Free CO2***

Free CO2 is present in water as a dissolved gas. Air contains 0.03% FCO2, which is essential for photosynthesis (Dash, 2006). It dissolves in water 200 times more easily than oxygen. The solubility of CO2 goes down as water temperature goes up! This results in its increase with the increase of water temperature. Its value ranges from 0-16 mg/l in freshwater bodies. Less than 5mg/l of free $CO_2$ supports the fish population. More than 20mg/l of free $CO_2$ may infer oxygen utilization by the fish. Most fishes may survive in water containing up to 60mg/l of free $CO_2$ provided DO concentrations are very high (Pandey and Shukla, 2005). Surface water normally contains less than 10mg/l of free CO2, while some groundwater may exceed that concentration.

The IPCC (2013) estimates that by the year 2100 average mean temperature is to increase by 4.8°C over the 1996–2005 average, and that $CO_2$ levels will reach ~1000 ppmv.

***Total hardness***

Total hardness is a measurement of the mineral (calcium, magnesium, iron, aluminium, zinc, manganese, strontium) in water that is irreversible by boiling and expresses as $CaCO_3$ equivalent. Swingle (1967) suggested that a total hardness of 50mg/l be a dividing line between soft and hard water. The solubility of most salts increases with the increase in water temperature. More specifically, the quantity of multivalent cations in the water determines overall hardness. Total hardness of 40-400mg/l is optimum for water bodies and less than 5mg/l leads to the eventual death of fish. The hardness of at least 20mg/l is maintained for optimum growth of fishes.

***Total alkalinity***

The capacity of water to neutralize acids is measured by its total alkalinity (TA). Alkaline substances like $OH^-$ and $CO3^{-2}$ remove $H^+$ ions from the water, lowering its acidity and raising its pH. Higher temperature slightly increases the $CO_3^{-2}$ to $HCO_3^-$ ratio. The pH also slightly decreases while the $H^+$ concentration marginally rises at the same time. (Dash, 2006). Total alkalinity of 40-150mg/l is optimum for water bodies Fish farmers maintain at least 20mg/l of total alkalinity for catfish production and 80-100 mg/l for hybrid bass production.

***TDS***

Total dissolved solids (TDS) are the inorganic salts that are dissolved in water, mostly bicarbonates, chlorides, sulphates, potassium, sodium, calcium, magnesium, and other salts. There are also some trace amounts of organic materials. The TDS of water rises with increasing water temperature; with each 1°C increase, TDS rises by 2-4%. However, TDS is not directly affected by temperature (Thomas, 2021). For fish productivity, fish farmers maintain a total dissolved solids level of 650–725 mg/l. Fish skin can get dehydrated, which might be dangerous.

### *Chloride*

The majority of natural water contains chloride, which is often found as a component of salt (sodium chloride) or occasionally in conjunction with potassium or calcium. In freshwater, its value ranges from 1-100mg/l. Chloride rises with rising water temperature (Dash, 2006). Climate change has a number of effects on chloride concentrations, according to modeling (EESC, 2019):

(1) Low river flows more frequently occur from summer to fall, which lowers the dilution of chloride discharged to the Rhine with a consistent load and raises its concentration;

(2) Increasing the amount of open water: More chloride affects reproduction and raises mortality.

### *Nitrate*

Natural reactions between nitrogen and oxygen or ozone result in the chemical nitrate. Studies of soil processes suggest climate change is likely to lead to increased nitrate leaching from the soil under future climate scenarios. As the water temperature rises, its quantity rises (Pandey and Shukla, 2005). Nitrate of less than 100 mg/l is optimum for water bodies. Fish lose their capacity to reproduce and become more prone to illness. Fish growth is also impacted.

With higher nitrate concentrations and longer exposure times, nitrate toxicity to fish rises. In contrast, when body size, water salinity, and environmental adaption increase, nitrate toxicity may decline. It seems that freshwater creatures are more susceptible to nitrate than marine ones (Camargo et al., 2006).

### *Phosphate*

With an increase in water temperature, the phosphate concentration rises (Pandey and Shukla, 2005). 0.05–0.2 mg/l of phosphate is ideal for aquatic bodies. Fish that live there suffer from high phosphorus levels (Wang et al., 2022). The presence of phosphorus in the environment often occurs at low amounts, which restricts plant development. Man-made sources such septic systems, fertilizer runoff, and inadequately treated wastewater can produce high phosphate levels. Due to surface runoff and bank erosion, phosphates get up in the water.

### *Ammonia*

Ammonia is a colorless, pungent gaseous compound highly soluble in water. Most water bodies have an ammonia range of 0.3 to 1.3 mg/l (Wurts, 2012; EPA, 2013). Ammonia's toxicity rises as temperature and pH rise (Pandey and Shukla, 2005). Due to the low fish population densities in lakes, ammonia concentrations did not reach fatal levels.

Fish health is badly affected by ammonia. The chemical form of ammonia, the pH and temperature of the water, the time of exposure, and the life stage of the affected fish are only a few of the variables that affect the kind and level of toxicity (CSPP 2010).

## Conclusions and Recommendations

Climate change requires a global framework for international cooperation. Adaptation action is a vital part of this framework. Actions to enable adaptation to climate change pose opportunities to promote sustainable development. Developing countries require resources to promote these actions. It is recommended that fisheries governance and sustained investments in market development are crucial to minimizing the implications of climate change on fisheries. The fisheries should come at the front foot of policy formation.

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