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An Updated Review on the Role of Certain Physicochemical Parameters in Regulating Fish Diversity of Tropical Aquatic Ecosystems

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ABSTRACT

Numerous physicochemical factors found in aquatic environments have far reaching impact on fish growth and diversity. Contamination of aquatic resources has become a global environmental problem that threatens both the aquatic environment and the fishes, consequently affecting human health. Environmental stressors such as pollution, habitat loss and degradation, and climate change can also have significant negative impacts on aquatic ecosystems and can reduce the overall health and biodiversity of aquatic environments and fishes living in such environments. The present review emphasizes how crucial physicochemical factors such as temperature, pH, dissolved oxygen, nutrition levels, flow patterns, and habitat connectivity can shape fish assemblages. Predicting fish population dynamics, managing fish communities, and preserving biodiversity in the face of environmental change all depends on the better understanding of these interactions. This review also aims to give a comprehensive grasp of how these aspects affect fish diversity by synthesizing findings from other research projects. Although the physico-chemical properties of water play such a crucial role in determining the life history as well as the distribution range of fishes and their diversity, there is a lack of information regarding the suitable range of water quality parameters in which freshwater fishes can persist, as well as the role of the physico-chemical parameters affecting their assemblages. The observed adverse impacts of these pollutants along with external factors on aquatic ecosystems and fish growth and diversity emphasize the future needs for effective pollution control measures, proper waste management, and sustainable practices to protect and preserve the already deteriorating water quality and consequent decline in fish populations.

KEY WORDS: Fish Diversity, Habitat Connectivity, Physicochemical, Water Quality.,

INTRODUCTION

In aquatic habitats, fish variety plays a crucial role in biodiversity, impacting ecological balance and the overall well-being of these settings. Fish species composition and abundance are mostly determined by physicochemical factors, which also include water temperature, pH, dissolved oxygen, nutrition levels, flow regimes, and habitat connectivity. Environmental stressors such as pollution, habitat loss and degradation, and climate change can also have significant negative impacts on aquatic ecosystems and can reduce the overall health and biodiversity of aquatic environments and fishes living in such environments (Weinke & Biddanda, 2018).

Contamination and pollution of aquatic resources has become a global environmental problem that threatens both the aquatic environment, fishes and human health. The pollutants specially heavy metals and pesticides can cause severe destruction of aquatic ecosystem and induce risks for human health through consumption of contaminated fish. The presence of pollutants in aquatic habitats can vary in concentration and allotment depending on the specific location, sources of pollution, and environmental conditions (Gavrilescu et al., 2015).

The adverse impacts of these pollutants on aquatic ecosystems and human health emphasize the need for effective pollution control measures, proper waste management, and sustainable practices to protect and preserve water quality (Perkumienė et al., 2023). Some of the specified pollutants that have been extensively studied and documented include petroleum hydrocarbons (Asif et al., 2022).

According to Kasperson et al, (2022) reported that there are urgent demands for comprehensive methodological

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approaches to evaluate the actual state of these ecosystems and to monitor their rate of changes. Physical and chemical measurements commonly form the basis of monitoring, because they provide complete spectrum of information for proper water management.

This review research aims to give a comprehensive grasp of how these aspects affect fish diversity by synthesizing findings from other research projects. The research covers a variety of geographical areas and aquatic system types, providing insights into both regional variances and worldwide trends.

Although the physico-chemical properties of water play such a crucial role in determining the life history as well as the distribution range of fishes and their diversity, there is a lack of information regarding the suitable range of water quality parameters in which freshwater fishes can persist, as well as the role of the physico-chemical parameters affecting their assemblages.

The aim of this review is to analyse the role of some water parameters of inhabitant water bodies and corelate if there persists any correlation between physico-chemical parameters and fish assemblage with regard to their diversity.

As the physico-chemical parameters of aquatic bodies primarily regulate the biology and physiology of inhabitant fish species, the diversity of fishes are directly affected by mortality, growth patterns, and other several important factors related to physico-chemical aspects of aquatic system, (Kisku et al., 2017). The water quality parameters can be roughly divided into three categories, namely (1) physical (e.g., temperature and pH), (2) chemical (e.g., dissolved oxygen, total hardness, and nutrients), and (3) biological (e.g., microbes). Earlier studies on fish showed species-specific tolerance ranges of these factors, like thermal tolerance (Anttila et al., 2013; Chretien & Chapman, 2016), dissolved oxygen tolerance (Franklin, 2014), pH tolerance (Oliveira et al., 2008), nitrogen tolerance (Bowser et al.,1983; Williams & Eddy, 1986; and phosphorous tolerance (Nordvarg, 2001).Elevated freshwater pH occurs primarily due to acidified rain or snow depositions having long-lasting effects on freshwater pH. Aquatic ecosystems may also be affected by climate change-related acidification due to the increased uptake of carbon dioxide from the atmosphere, humic acid (from the degrading organic matter) can be another cause of freshwater acidification (Steinberg, 2003 and Kroupova et al., 2005).

Recently the excessively introduced nutrients from sewage discharges, agricultural wastewater, and diffuse runoff could build up the sediment. Nitrogen and phosphorus concentrations in the sediments are influenced by several hydro-chemical and hydrodynamic conditions in the water column above the sediment. Processes leading to their release to the water column from underlying sediments are numerous. The environmental variables which appear to regulate the release rate from the sediments are temperature, dissolved oxygen concentration, pH value, and redox potential (Hou et al., 2013).

The temperature of the water and its changing patterns have significant impacts on biological communities' composition as it determines the metabolic demand of individual organisms (Brown et al., 2004). The change in water temperature can be linked with thermal discharges, land-use changes, agricultural and irrigation return-flows, flow modifications, inter-basin water transfer, modification to riparian vegetation, and global warming (Roy, 2014). Warming increases metabolic rates more rapidly than ingestion rates leading to energetic inefficiency and predator starvation, affecting the higher trophic levels disproportionately. Thus, the indirect effects of warming through the food web sometimes can be greater than direct.

Physiological Effects. These impacts are stronger in freshwaters, with relatively discrete ecosystem boundaries which constrain the species potential to range shifts for tracking thermal optima.

As ectotherms, fish cannot regulate their body temperature, dependent on the external environment, so warming may directly alter physiological functions like thermal tolerance, growth, metabolism, food ingestion, and reproduction. If increases in metabolic demand are not meet by increasing food availability or strategies to maximize energy intake, populations are likely to decline or go extinct (O Gorman et al., 2016). Temperature alteration has a profound impact on the dissolved oxygen contents in water. The dissolved oxygen (DO) contents ofwater decrease with increasing temperature. Fish growth, feed utilization, and the bodys innate immunity are adversely affected by low dissolved oxygen (Abdel-Tawwab et al., 2015).

Acidification causes fundamental changes to biological and ecological processes in the aquatic ecosystem. One of the main consequences is the disruption of the chemosensory abilities of aquatic organisms. Detection of chemical cues supports a wide range of decision-making processes to exhibit their social behaviour. A low pH has been shown to interfere with predator avoidance and the detection of foraging cues (Kleinhappel et al., 2019).

Fish diversity is primarily influenced by two basic physicochemical factors: pH and water temperature. In a blackwater stream in the Southeast United States, Miranda and Hodges (2000) discovered a strong relationship between pH, temperature, and fish assemblage structure. Similar to this, Wang et al. (2019) showed that the pH levels in Erhai Lake, China, changed the biomass and distribution of aquatic vegetation, which in turn had an indirect effect on fish habitats. The role of physico-chemical parameters in fish culture and growth is a crucial aspect of aquaculture. Physico-chemical parameters such as water temperature, pH, dissolved oxygen, and turbidity significantly impact fish growth, survival, and their overall health.

Water temperature is one of the most critical physico-chemical parameters affecting fish growth and metabolism. Optimal temperature ranges vary among fish species, but most fish grow best in temperatures between 20-30°C. pH is another essential parameter, as it affects the availability of nutrients and the toxicity of certain substances. Most fish species prefer a pH range of 6.5 to 8.5. Similarly, dissolved oxygen is vital for fish respiration, and its levels can significantly affect mortality and growth of fishes. Nutrient concentrations and dissolved oxygen are essential for fish diversity and survival.

According to research conducted in the Nanak Sagar reservoir in Uttarakhand by Banothu et al. (2018), high DO levels support a wider range of fish species. Their research revealed a positive correlation between total alkalinity, pH, and DO and fish productivity. Levels of nutrients, especially phosphorus and nitrogen, are also very important. Diverse fish communities were sustained by nutrient-rich habitats, as observed by Miranda and Hodges (2000).

An earlier important observation was of Edward and Ugwumba (2010) in which they reported that there is an increase in the number of zooplankton including fish fauna during the rainy season that was linked to the influx of nutrient. All the fish fauna and phytoplankton indicated high productivity in the rainy season and decrease to dry season.

This could be the reason why some studies have reported that the fish fauna has a positive correlation to most physicochemical parameters with only negative correlation to total dissolved solids, conductivity, calcium, pH and alkalinity. The high levels of parameters like nitrates observed, usually build up during dry seasons and that are only observed during early rainy seasons. This also played a vital role in the abundance of both fish and phytoplankton. Fishes appear to be sensitive indicators of changes as they have a temperature tolerance range of 25°C to 30°C with less alkalinity of 16 to 20 ppt compared to ammonia in their natural waters. Clarias species have possessed an ability to tolerate adverse water quality and difficulty in aquaculture.

Lates niloticus are found to be less abundant in oxygen poor condition in water quality. The positive correlation of most fishes like Cladocerans with dissolved oxygen and biochemical oxygen demand can be an indication that the waters are unpolluted. Balogun et al. (2005) in Makwaye (Nigeria) made an observation that fish and phytoplankton in Mairua reservoir, indicated monthly variations in abundance which could be due to variations of physico-chemical parameters. Food condition is still considered an important factor affecting growth and reproduction of most species of fishes.

Fish variety is seriously threatened by climate change because it changes the physicochemical properties of water bodies. When comparing the macroinvertebrate populations found in streams in temperate and Mediterranean regions, Bonada et al. (2007) hypothesized that variations in water temperature and flow patterns will be exacerbated by climate change, which will have an impact on aquatic biodiversity.Technological developments like next-generation DNA sequencing have completely changed how fish diversity and ecological health are measured. The potential of environmental DNA (eDNA) for biomonitoring was emphasized by Baird and Hajibabaei (2012), opening up new avenues for tracking how environmental change affects fish populations.

Hughes et al (1987) have reported that fish quantity and distribution are impacted by aquatic ecoregions, stream typology, and environmental conditions, as this study examined. It was discovered that many ecoregions, each sustaining distinct fish communities, are shaped by regional environmental factors as climate and hydrology. Fish presence and abundance are also influenced by the stream typology, which includes substrate type and flow regime. These findings emphasize how important it is to manage and conserve fish populations while taking typological and regional variability into consideration.

In his research, Matthews (1988) offered a thorough analysis of the ecological traits of prairie streams in North America, emphasizing their importance as important study systems for ecology. The review explores how fish and macroinvertebrate communities in these distinct stream systems are affected by physicochemical parameters as temperature, nutrient levels, and flow regimes. By analyzing these patterns, the research offers valuable insights into the biological processes that shape North American prairie streams, improving our knowledge of their biodiversity and ecosystem functioning.

In his review Matthews (1988) also has presented the ecological traits of prairie streams in North America, emphasizing their importance as important study systems for ecology. The review explored how fish and macroinvertebrate communities in these distinct stream systems are affected by physicochemical parameters as temperature, nutrient levels, and flow regimes. By analyzing these patterns, the research offers valuable insights into the biological processes that shape North American prairie streams, improving our knowledge of their biodiversity and ecosystem functioning.

Using molecular data, the study of Ganasan and Hughes (1998) examined gender-biased dispersal in the goby species Pseudogobius olorum. The results showed that there was no discernible gender bias in the dispersal patterns, indicating that environmental factors like connectedness and habitat availability could have an impact on the dispersal behaviors. Predicting fish population dynamics and preserving genetic diversity depend on an understanding of these processes.Similarly, Miranda and Hodges (2000) investigated a blackwater stream in the Southeast of the United States, the influence of physicochemical parameters on fish assemblage structure was the main focus of this study, which highlighted the significance of these factors in controlling fish populations in stream ecosystems by finding strong relationships between fish diversity and environmental factors such temperature, pH, dissolved oxygen, and nutrient levels.

Later on Caissie (2006) examined the river thermal regimes and their effects on aquatic environments, emphasizing the ways in which temperature fluctuations affect fish distribution and variety. It adds significantly to the body of knowledge on physicochemical parameters and fish variety by offering a thorough examination of the variables influencing river temperatures and the ecological effects they have. Following this Leprieur et al (2008) reported the influence of fish invasions on river systems around the world, with a focus on how human activity might impede natural processes. Understanding the factors that lead to fish invasions is essential to reducing their negative effects on fish diversity and ecosystem integrity. Invasive fish species outcompete native species and change the architecture of their habitats, which modifies the physicochemical conditions.

Boix, et al (2008) worked on the parameters governing macroinvertebrate assemblages in streams with a Mediterranean climate, where physicochemical properties like nutrient levels, conductivity, and water temperature were found to have had a significant impact on the food chain involving fish diversity. The effects of siltation and changed flow patterns on the plains minnow's ability to reproduce in a riverine environment were the main focus of the work of Gido et al (2011) . The disruption of spawning habitats and the impact on fish reproductive behaviors caused by altered flow patterns and increased sedimentation underscore the significance of preserving natural flow regimes in order to sustain fish diversity.

Baird and Hajibabaei (2012) investigated the potential of next-generation DNA sequencing for biomonitoring and evaluating ecosystem health was covered in this research. Researchers can learn more about fish variety and aquatic community composition by examining environmental DNA (eDNA), which opens up new possibilities for tracking how changes in the environment affect fish populations. The combined impacts of fish stocking, habitat modification, and land use on mercury levels in fish populations in northern Minnesota were examined in this study. The findings highlighted the important of accounting for a range of stressors when assessing the health of aquatic ecosystems by demonstrating how anthropogenic activities have a substantial impact on physicochemical features and cause mercury to bioaccumulate in fish tissues, (Kratzer et al 2014).

Banothu et al (2018) evaluated the ichthyofaunal variety and limnological features of the Nanak Sagar reservoir in Uttarakhand. From August 2016 to March 2017, thirty fish species were identified through monthly sampling. Fish output was shown to be positively connected with pH, specific conductivity, total alkalinity, dissolved oxygen, and clarity in the reservoir's water, suggesting that a variety of fish communities are supported by the water quality of the reservoir. The study of Rodrigues and Leunda (2018). looked at how fish assemblage structure in a transient Mediterranean river was affected by environmental factors. Fish species composition and abundance were highly influenced by variables such water temperature, flow velocity, and substrate composition, highlighting the significance of taking local environmental circumstances into account in dynamic aquatic systems.

Fish diversity and physicochemical properties are greatly impacted by human activities, such as pollution, altered habitats, and changes in land use. The intricate interplay between anthropogenic stressors and aquatic health were highlighted by Kratzer et al. (2014), who looked at the cumulative impacts of land use, habitat modification, and fish stocking on mercury levels in fish populations in northern Minnesota.The fish fauna diversity, particularly, composition and abundance varies with months and seasons, which may be due to fluctuation of physicochemical parameters and reduction in abundance of phytoplankton, which are the primary producers. Yaseen et al, (2022) reported factors such as light intensity; food availability, dissolved oxygen, and predation affect the population composition of zooplankton including fish fauna. Later on, Wang et al (2019) looked into how pH affected the biomass and distribution of aquatic plants in China's Erhai Lake. High nitrate levels (> 1mg/l) are not good for aquatic life as recently reported by Gharti and Liping, (2023).

These studies have demonstrated the intricate relationships between physicochemical factors and biotic components in aquatic ecosystems which can affect the composition and abundance of aquatic plants, abundance of food, which in turn influence the quality of fish habitat and biodiversity.

CONCLUSION

Maintaining fish diversity is crucial for thriving aquatic ecosystems and is influenced by physicochemical factors like temperature, dissolved oxygen, pH, and nutrient levels. Anthropogenic activities, such as pollution, habitat change, and invasive species, negatively impact these conditions. Effective management requires controlling invasive species, reducing pollution, and restoring habitats. Advanced tools like eDNA and remote sensing can enhance understanding and management. Integrating ecological, hydrological, and social approaches is vital. Collaborative efforts among scientists, policymakers, and stakeholders are essential for sustainable conservation of aquatic resources, benefiting both ecosystems and human communities.

This review provides a comprehensive grasp of how these aspects affect fish diversity by synthesizing findings from other research projects. The physico-chemical properties of water play such a crucial role in determining the life history as well as the distribution range of fishes and their diversity. The observed adverse impacts of these pollutants along with external factors on aquatic ecosystems and fish growth and diversity emphasize the future needs for effective pollution control measures, proper waste management, and sustainable practices to protect and preserve the already deteriorating water quality and consequent decline in fish populations.

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